Pacific Fisheries Resource Conservation Council

Proceedings—Climate Change and Salmon Stocks

Vancouver, BC

Pacific Fisheries Resource
Conservation Council

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MESSAGE FROM THE CHAIRMAN

Over the last several years, we have become increasingly aware of the probable interaction of the West Coast salmon issue with that of global climate change. While much time has been spent focused on changes to fisheries management practices, this has been done largely without putting the problems into the context of the global, human-induced impacts that may render the changes pointless. It was with this thought in mind that we organized the Conference, the outcomes of which are presented in this report.

Some readers will find much of the information disconcerting, especially those who want to continue living as in the past. For others, particularly those in politics, industry, or the media who, for their own short-term benefit, want to deny the advice of the scientific community, we hope this report will serve as a wake-up call.

Scientific debate is a process that is not universally understood. However, it is a fundamental element of science. Scientists develop hypotheses as to how natural systems work. They then collect data, generate information, and develop models to test for validity. As the real world is extremely complex, the best that can be done is to try to discover the major factors that are controlling what we observe. Of course, not everyone agrees on which these facts are. As a result, several different hypotheses emerge which then compete with one another until there is a general consensus on the one that best represents reality, as we observe it. This competition sharpens the mind and drives the scientific community. Often the hypothesis that gains majority support is still attacked by a few (the skeptics) who continue to pick away at the "soft spots". This action is welcomed in science as it forces the rest of the scientific community to further refine and improve the hypothesis. Unfortunately, the lay person, intercepting this natural conflict out of context, may all too easily presume that it represents scientific uncertainty, rather than a natural scientific refinement process.

As mentioned above, once a hypothesis is developed and data collected, models are constructed. Scientific models of natural processes have been with us for hundreds of years. Their development is vital to our understanding of the natural world as they allow us, in essence, to step outside our "reality" and try to understand the forces shaping our past, present, and future. For example, most of us depend on the weather forecast each day to plan our activities. In business and government we also construct models, often designed to predict human behaviour, a notoriously fickle subject. We use this type of model to make key decisions, often with national or international consequences. However, there is a real difference between scientific models and the decision-making models: the former are open to public scrutiny and continual refinement based on facts; the latter are not. When detractors suggest that models "cannot be trusted", they are seriously underestimating the role of models in all decision-making. The real question is not whether to use models, but how to determine the best available model.

To arrive at the "best available model", it is critical to incorporate as much objective information as possible, to test models against the past, and to continually refine them. Often in nature this means trying to separate out many different influences so as to arrive at those parameters that have the greatest influence. As nature is extremely complex, with countless feedbacks, this is not an easy task. However, the skeptics mentioned above help to focus the effort. They look for the weaknesses in the predictions of the past and force those developing the models either to modify the models to better represent nature or to clarify reality. Often both occur as our understanding of the past is often in need of as much attention as our prediction of the future. This point is often not fully appreciated by lay persons, and sometimes the media, and this lack of understanding is exploited by those who deny climate change or wish to deny that human activity has anything to

do with it. As a result, scientific debate or disagreement is all too often perceived as invalidating the models.

Let me now put each of these preceding ideas into the context of the debate that swirls around the issue fundamental to this report—global climate change.

As we have reviewed the scientific reports on this issue and talked to some of the top scientists in the world working on the problem, we are struck by the unanimity of all those directly involved, both the large numbers of believers and the few "skeptics". They all believe that the "greenhouse gases" have a direct effect on the global temperature of the earth. They all agree that the concentrations of these gases are significantly above anything we have experienced in the last 200,000 years. They all admit that the combustion of fossil fuels is having a significant impact on the observed levels of carbon dioxide in the atmosphere. They all will concede that these gases will alter the average temperature of the globe in the future by at least 1°C, and most will even concede that there already are discernible effects, among which are warmer winters and nights. Finally, they all accept that there will be biological and physical changes to earth systems as a result. Differences tend to focus on the rate of change, the existence of yet-to-be-determined mitigating feedbacks, the magnitude of the resulting effects, and the consequences to life forms on earth. While these differences are important for the continued refinement of the existing models, as yet there are no indications they indicate that the fundamental hypothesis and the models that support it that lead to the prediction of global climate change are fundamentally wrong. Where there may be a major dispute is on the human input to these models, such as the predictions as to the amounts of fossil fuels we will be using in the future.

The models themselves encounter public scorn from time to time. This normally results from the change in outcome over time. What we have to remember is that this is perfectly normal. The models are complex. They incorporate many factors that are still being refined and better understood. However, what is most interesting is that, from the initial calculation made back in the late 19th century to today, no model has predicted a global cooling resulting from the changes in the greenhouse gases that we are observing today or are predicted for the future.

The skeptics have played a critical role in the refinement of these models. Their concerns with results not reflecting reality led to the inclusion of fine particulates and stratospheric ozone depletion into the models, resulting in significant improvements in predicting the present distribution of significant patterns of heating and cooling on Earth. Their continued emphasis on mitigating feedbacks from water vapour have resulted in considerably enhanced study of this area resulting, so far, in both positive and negative signals resulting in little change in the end result. Their charge that the models do not represent reality has led to the use of models to predict the global effects of major volcanic eruptions, with noticeable success proven by measured results. Thus, the finding of significant patterns of change in the global climate system that are consistent with the predictions of the models, e.g., global temperature changes, should cause us all to take grave notice of other aspects of these predictions.

On the temperature front, there have been numerous suggestions that the warming currently underway is not significant. Well, the facts we have seen do not support the skeptics in this area. The existing measurements indicate a general warming throughout the 20th century. Some argue that this has mainly occurred in the first half, but the data show that, while half of the warming occurred then, the other half has occurred since 1980. In fact, nine of the eleven hottest years in the last 150 years of direct surface measurement have occurred since 1986, and the four warmest years are 1990, 1995, 1997 and 1998, with the last one being 0.57°C above the thirty-year average from 1961 to 1990. The evidence of the uniqueness of the present is further supported by studies that have now, using proxy data, extended the record back to over 1000 years, and

indicate that we are now experiencing global warming greater than any experienced for that time. The data record produced by this work has also shown that the warming we all remember from our history lessons of the Norse explorers was not a global phenomenon, but a regional one, giving greater significance to the current situation. Finally, some argue that these surface temperature measurements and estimates are not supported by other data. We think in reality that they are. From bore hole information, through melting glaciers and disintegrating ice sheets, to balloon and satellite data, this warming trend is evident. The last to fall, the satellite data, was corrected last year for orbit decay, resulting in information that seemed to be inconsistent with the models demonstrating consistency, a fact still denied by some outside the scientific community.

We are hopeful that, with these thoughts in mind, the reader will review the new information presented in this report in a serious light. The message from the scientists is consistent. They are very concerned that we are making decisions without a clear understanding of the consequences. They are the first to admit they cannot say exactly what is going to happen. At best, they can give us a sense of what might happen. From this, we have to recognize that we are in the midst of a major experiment on the natural environment of Earth. Models predict smooth transitions; our experience has taught us that this seldom occurs. Action should be taken now, or else we condemn future generations to deal with “our” problems.

We are facing a global phenomenon which necessitates a clear-headed sense of urgency. To use the lawyer’s phrase “time is of the essence”, we are running out of time. We must not dither until the last salmon proves the thesis.

WELCOME

The Honourable John Fraser, Chairman of the Pacific Fisheries Resource Conservation Council, welcomed participants. "We're here to discuss salmon stocks," said Mr. Fraser, "so why are we discussing climate change? That requires a long answer." He referred participants to page 14 of the *Annual Report* of the PFRCC, and read the following excerpt aloud:

"There is a healthy and vigourous debate in the scientific community about what to expect from the oceans in the coming years. Some scientists have suggested that if ocean warming trends persist, sockeye may vanish from the Fraser River, which is near the southern extent of the sockeye's range. Russian scientists have analyzed long-term trends and concluded that if present trends persist, the Pacific Ocean may be capable of supporting only half the 1990s abundance of salmon by the year 2020. These sorts of suggested trends are hotly debated within the scientific community.

"The North Pacific Marine Science Organization (PICES), a treaty organization which provides a forum for ocean scientists from Canada, China, Korea, Japan, Russia and the United States, has as its main research program a study of Climate Change and Carrying Capacity of the North Pacific. This ambitious program seeks to: describe ecosystem variability in North Pacific regions; explain ocean-atmosphere interactions; conduct research into El Niño and broad-scale regime shifts; and develop a more elaborate understanding of the way salmon populations are affected.

"Fisheries scientists from throughout the Pacific Rim recently gathered at a Vancouver Conference hosted by the North Pacific Anadromous Fish Commission (NPAFC) to compare notes about El Niño and other matters related to the salmon's survival in the Pacific Ocean. The conference organizers summed up the proceedings this way:

"'There was a recognition that environmental conditions need to be explicitly accounted for in our assessment and management of fish stocks. This concept is not new and has been alluded to in the process of explaining away large discrepancies encountered with traditional fisheries models. *What is new is the relative importance given to the environment and ecosystem changes. The effects of climate change on fish production are now being given nearly equal consideration to the competing hypothesis that fish production is governed solely by an intrinsic stock recruitment relationship and fishing. Such fundamental changes in approach will require time and, above all, education, both within and outside the scientific community.'"*

"We need to recognize two things uppermost," said Fraser. "First, we depend on science to explain phenomena; science provides a key ingredient in the debate. Second, the debate itself is old and intensely political." He recalled the commitment at Rio de Janeiro to significantly reduce emissions, a commitment that was confirmed at Kyoto. Those commitments met with intense, unpleasant opposition from a small coterie of people who claim to be scientific experts, from certain organizations in Canada and the US, and from some elements of industry.

"Some of the debate has not been taken seriously, but it must be taken seriously," he said, "because the campaign against doing anything has continued full blast since 1992. And if measured against what has been accomplished, it has been successful." He then listed highlights of this campaign, including:

- US Senator Dana Rohrabacher was quoted in a book called *The Heat is On* as saying that the ozone scare has turned out be another "sky-is-falling cry from an environmental Chicken Little," and government response has been to "repress rational discussion."

- Terrance Corcoran, a former *Globe and Mail* columnist who now writes for *The National Post,* repeatedly condemns commentary from environmental and conservation groups.
- Former vice president Dan Quayle recently said, "It's not pollution that's harming the environment; it's the impurities in our air, water, and food."
- The Vancouver-based Fraser Institute recently commented that there is no scientific evidence linking CO_2 levels with global warming and therefore CO_2 should not be considered a pollutant but only a secondary indicator of air quality.
- Bob Peterson of Imperial Oil (IO) (whose views do not represent those of the entire industry, Fraser stressed) justified IO's opposition to the Kyoto treaty by questioning whether human activity is even a factor in climate change.
- A Canadian MP recently said in Parliament, "Let us pause, especially those of us who have lived in a northern environment, to give thanks to the greenhouse effect."

"This is all very well," said Fraser, "but there are appalling pieces of evidence that we can't continue to disregard. We may not know everything we need to know," he said, "but we must begin using our brains to infer from what we do know." He referred to what is happening with the environment now as "humans conducting an uncontrolled experiment whose consequences could be second only to global nuclear war," and referenced facts such as:

- the dieback of Amazon forests, much of which will be gone by 2050;
- the displacement of 13 million people worldwide in 1994 by flooding;
- scientists singling out water quality and climate change as the two biggest issues facing humanity in the next century;
- increasing heat in the oceans tipping the balance, in recent years, to more frequent and more severe El Niños;
- northern boreal forests shifting from CO_2 sinks, which they've been for 9000 years, to CO_2 sources;
- the earth's temperature increasing over the past 100 years but speeding up recently, making 11 of the last 16 years the hottest of this century; and
- average increases of 8°F in ocean temperatures, making the coast of California warmer and less productive of zooplankton, with a resulting shift northward of animal life.

At the same time, he noted, there are reasons for optimism. The province of Alberta, not noted as a leader in environmental matters, has publicly recognized that climate change is a problem. A letter to *The Financial Post* listed major corporations that are shifting policies and practices in response to climate change, including Lockheed-Martin, Boeing, Toyota, Weyerhauser, Maytag, Shell, Sunoco, United Technology, and Whirlpool. And Prime Minister Jean Chrétien recently gave the environment new prominence on the national agenda.

Yet there is still a long way to go. Some time ago, Fraser noted, the government set up 16 "tables" on climate change, each representing a different sector, with the goals of developing sectoral approaches to reducing emissions. The Industry Table has been the first to report back—by urging Ottawa to move even more slowly toward the Kyoto targets than it has already been

doing. “It would be hard to understand how it would be possible to move more slowly,” said Fraser.

“Climate change is a serious issue,” he said. We may not know everything about it yet, but we do know that there is compelling evidence of its seriousness that can’t be ignored. Fraser explained that the goal of the day’s discussions would be to move toward a better understanding of climate change, to improve publicity around the issue, and ultimately to reduce emissions.

Dr. Paul LeBlond thanked Mr. Fraser for his remarks and noted that the morning speakers would include Mr. Henry Hengeveld of Environment Canada, Dr. Brian Shuter of the University of Toronto, and Dr. Richard Beamish of Fisheries and Oceans Canada’s Nanaimo office.

MR. HENRY HENGEVELD, ENVIRONMENT CANADA

Climate Change and the Ocean Environment—Understanding the Science

Mr. Hengeveld, following on Mr. Fraser's comments, noted that another interesting article on the side of the skeptics had appeared in *The Calgary Herald* two days earlier, this one suggesting that people shouldn't trust government employees on the subject of climate change because they're being paid to push a government agenda; people shouldn't trust academics on the subject because they're pushing their own agendas; and people shouldn't trust anyone from the west coast because they're all left-wing. Thus, he said, most of the day's speakers, according to the skeptics, simply weren't to be trusted.

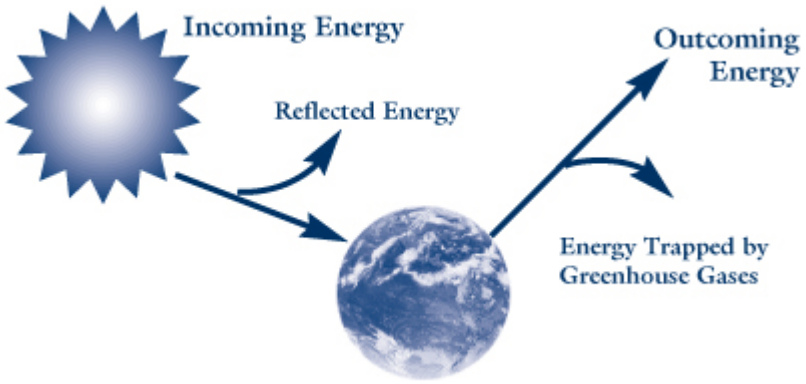
Aside from this perspective, he said, "two other viewpoints leave me uneasy." First, at this time of year, Canadians begin to think that climate change sounds pretty good and that its positive aspects shouldn't be ignored. Second is the reverse perspective of attaching every weather-related catastrophe to climate change. "It's incorrect," he said, "to link the Winnipeg flood or the Quebec ice storm to climate change." The skeptics play with the facts, he said, and we should avoid doing the same thing. Science shows that climate change is a serious issue, but we need to be cautious about either overstating or understating the problem.

Hengeveld noted that his talk would be divided into four sections:

- Background on the science of climate change
- Projections of future changes
- Implications for oceanography
- Recent developments

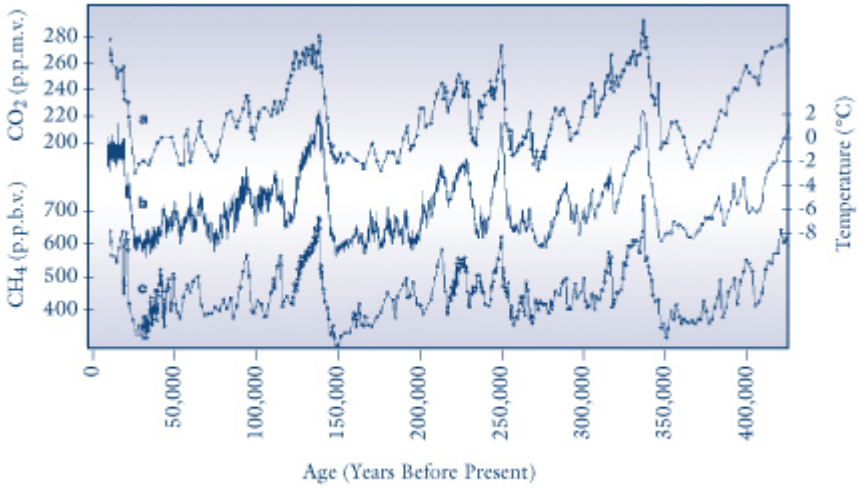
The phrase "greenhouse gases" is a misnomer, said Hengeveld, because they function less like greenhouse glass than an insulated blanket. The blanket absorbs heat radiation that would otherwise escape into space, and recycles it back into earth's system. About 70% of the sun's heat penetrates cloud cover and heats the earth's surface. Some of that heat is reflected off the earth's surface, but greenhouse gases keep it in the earth's atmosphere where it warms the earth 30% more than it otherwise would [Figure 1]. That makes it an essential part of the earth's life-support system.

Hengeveld Figure 1. The Greenhouse Effect.



Ice cores provide an excellent history lesson regarding past climate change, said Hengeveld, both by revealing information about temperature and through fossilized air bubbles, which provide archival records of air mass composition throughout time. Ice cores from Antarctica show temperatures over the last 400,000 years varying from ice age conditions to warmer periods every 100,000 years. Air samples show a correlation between changes in CO_2 levels and temperature changes, although this correlation does not prove a cause-effect relationship. There was a range in temperature of about 10°C at the South Pole. At the highest temperatures, CO_2 reached about 280-300 ppm or 0.03% of the atmosphere [Figure 2].

Hengeveld Figure 2. Past trends in temperature and greenhouse gas concentrations in Antarctica.



Source: Petit *et al*, 1999

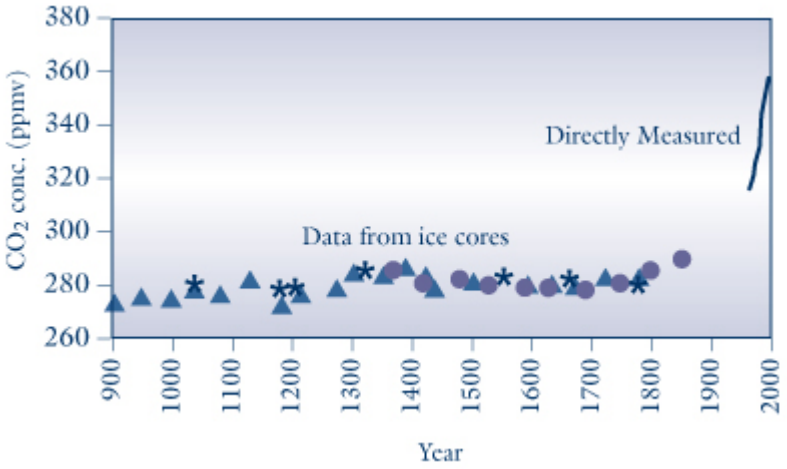
The natural greenhouse effect is caused by three groups of gases, said Hengeveld:

- Water vapour makes up 65% of the natural greenhouse effect. Human activity doesn't change this directly but does affect it through temperature change.
- CO_2 makes up about 25% of the greenhouse effect. This is the area of heaviest input of greenhouse gases from outside the system, and it is significantly affected by human activity.

- The other 10% is made up of other gases, such as methane and nitrous oxide, which are also beginning to be affected by human activity.

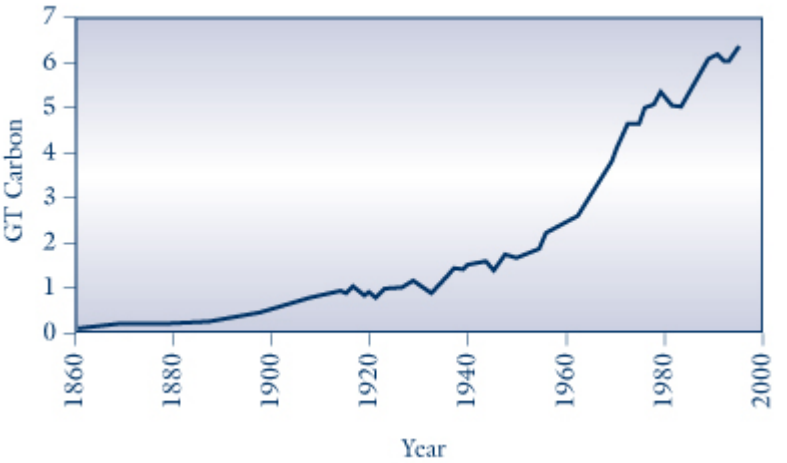
Data from ice cores in Greenland and Antarctica show CO_2 remaining relatively stable at 200 ppm in the atmosphere over the last millennium until about 200 years ago. Then it began to climb and today sits at 365 ppm—30% higher than the highest detected levels over the last 400,000 years [Figure 3]. "Calling this natural variability (as the skeptics do) is stretching the imagination," said Hengeveld.

Hengeveld Figure 3. Trends in CO_2 concentrations (past 1000 years).



There is clear evidence linking this increase in CO_2 levels to increased emissions in greenhouse gases from the burning of fossil fuels. One hundred and forty years ago, carbon emissions were still almost zero; today they are approaching 6.5 billion tonnes daily [Figure 4]. This is a bit like the national deficit, Hengeveld said, in that it's not how much of a deficit is run up in a year that's problematic; but if it's repeated year after year, it eventually amounts to a large national debt.

Hengeveld Figure 4. Global trends in fossil fuel CO_2 emissions.

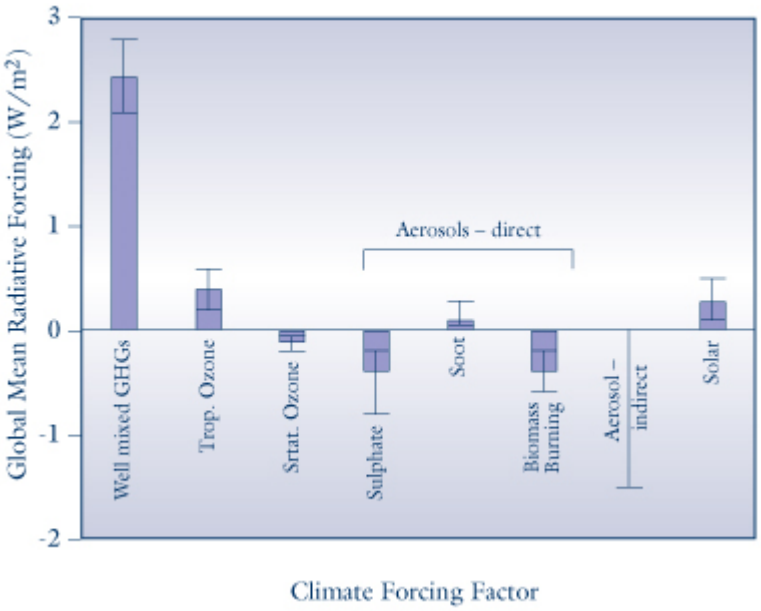


At the same time as CO_2 emissions have been increasing, methane emissions have risen by 145%, nitrous oxide by 15%, and other gases, formerly present at negligible levels, are beginning to

have significant effects. Complicating the problem, some of these gases have lifetimes of thousands of years, "so once they're released, they're up there forever."

Hengeveld turned to the effects of different kinds of gases on the climate. Well-mixed gases, such as CO_2, have caused a net increase in energy input to the climate system of about 2.5 watts per m^2 [Figure 5]. Tropospheric ozone is not well mixed and harder to assess, but has certainly increased in the Northern Hemisphere. Stratospheric ozone depletion has led to temperature reductions in some areas.

Hengeveld Figure 5. Radiative forcing.



Then there are the aerosols, which are solid and liquid particles within the atmosphere that can interfere with the flow of energy. Sulphates, for example, are highly reflective and therefore reduce the sunlight absorbed within a climate system. Sooty aerosols absorb sunlight rather than allowing it to travel through the atmosphere. Aerosols from biomass burning have a cooling influence. However, aerosol influences are regionally focused, and predominantly in the Northern Hemisphere.

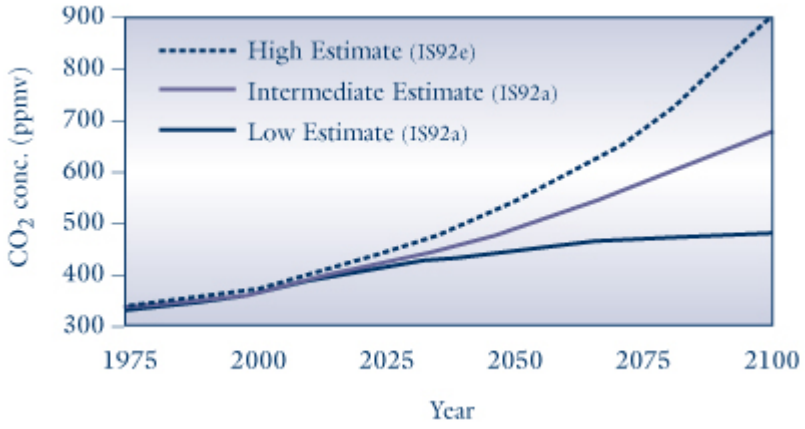
An indirect effect of aerosols is that they change the properties of clouds. Aerosol particles form the nuclei of water droplets. When the number of particles in the atmosphere increases, cloud droplets form on more particles. This makes them, on average, smaller and more luminous and causes a net cooling effect. "But our understanding of that is extremely uncertain," said Hengeveld. "The Achilles Heel of climate change is not knowing what those aerosols are doing." Part of the problem, and one of the areas on which the skeptics focus, is that all of these functions take place on microphysical levels but scientists are trying to model them on global levels. But even though this is a key concern, it is still clear that current levels of aerosols in the atmosphere should be less than that which we're seeing for greenhouse gases.

There has also been discussion regarding solar forces, he said. Over the last century there has been a warming influence from this source of 0.2 to 0.3 watts per m^2. But this is an order of magnitude less than that caused by greenhouse gases, so it is unlikely that current warming trends can be entirely attributed to it.

"That's looking at the past, but what about the future?" asked Hengeveld. Predicting the future of climate is as much an exercise in demographics as in science. Emissions are influenced by population growth, changing economies, and kinds of energy used, and we don't know what the future will hold in any of these areas.

The international community has played around with these variables and come up with a range of scenarios including low, mid-range, and high population growth, economic growth, and energy use, and has looked at how each scenario might affect CO_2 concentrations. The most conservative of these scenarios is unrealistic given current population levels, but even at this level CO_2 concentrations will approach 500 ppm by 2100. At the high end, there will be a tripling of current CO_2 concentrations in that time period [Figure 6]. "There is no best scenario because any one of them could happen," said Hengeveld, but the middle one is most often used to simulate how the climate system will respond to increased CO_2 concentrations.

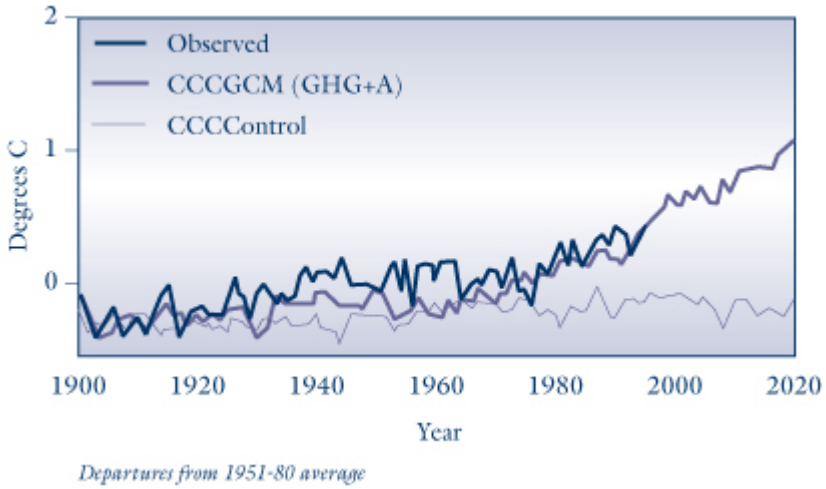
Hengeveld Figure 6. Projected CO_2 concentrations (to 2100).



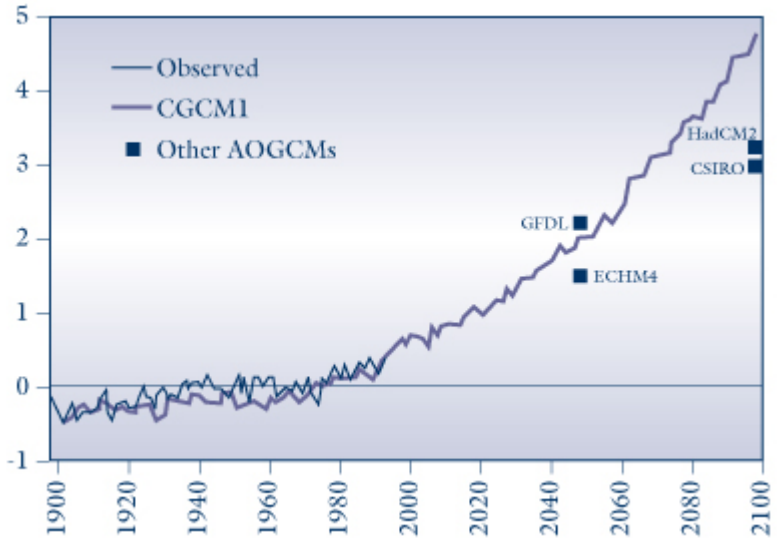
These scenarios are then applied to climate models. This is one of the primary areas where the skeptics identify problems with the science. But we have little choice but to use models, said Hengeveld. As has been pointed out, we have started an uncontrolled experiment with the environment and we can't wait for the results. So scientists use math to run simulations, which they test against observed situations and past changes. If the simulations stand up reasonably well against these comparisons, they are used as projection tools. Their use is fraught with problems, Hengeveld said, and they don't provide predictions, only projections. Therefore, they must be used with caution—but they can still be useful tools.

Scientists have observed and modeled global temperature change in line with what's happened in the past and found the models to be reasonably reliable for making predictions [Figure 7]. When those projections are extended to 2100, the Canadian model projects warming of 4.5°C with CO_2 and sulfate aerosol production as identified in the middle scenario [Figure 8]. Although other models produce different results, all of them show significant changes to the global climate.

Hengeveld Figure 7. Observed and modeled global temperature change (to 2020).



Hengeveld Figure 8. Observed and modeled global temperature change (to 2100).



The geographic pattern of these changes will be complex, said Hengeveld. Continents will warm more than oceans and high latitudes will warm more than low latitudes. By about 2050, the North Pacific is projected to warm by 1–2°C, while parts of the North Atlantic are expected to cool because of changes in ocean circulation. Changes in precipitation levels and distribution will be significant, with precipitation projected to increase in the tropical and sub-tropical Atlantic and in the Arctic, and to decrease over the American Southwest and other regions.

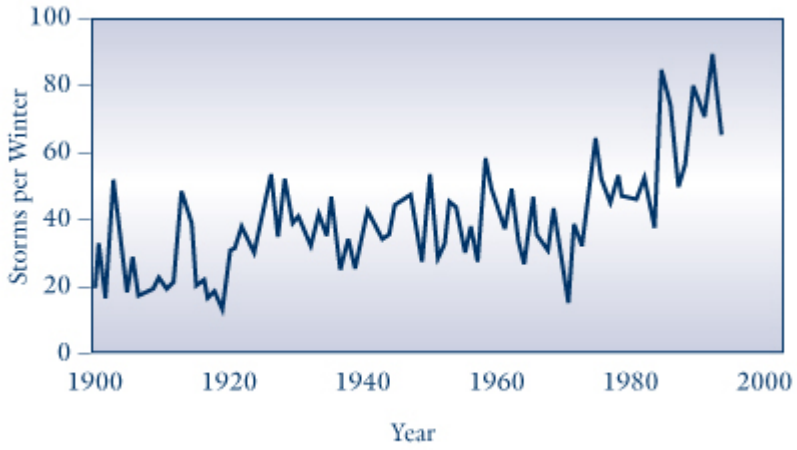
All of this will change ocean dynamics and salinity. As the climate warms, we'll see a more El Niño pattern around the world. By 2090, the Arctic could warm by as much as 20°C, resulting in removal of most of the sea ice. The tropical Pacific is projected to warm by 4–5°C, and there will be further warming in the North Pacific as well, while the North Atlantic will either not warm or could remain still cooler than today.

Much of the increase in rainfall will take place over the oceans, with little change or less rainfall over many mid- to low-latitude areas of the continents. This will affect fresh water flux into the

oceans. The key thing affecting the ocean system is thermohaline circulation. This affects both salinity and temperature, creating different densities in ocean water and driving water movement. In the North Atlantic, strong sinking areas push deep water south and allow warm surface currents to move from tropical regions to the north, creating the gulf stream effect that warms Northern Europe. Increased high-latitude fresh water flux and changed temperatures will slow down that process and temperatures in Northern Europe would warm much less than other continental areas. Although the results of six models vary widely in specifics, they all show slowdowns in the current system resulting from global warming.

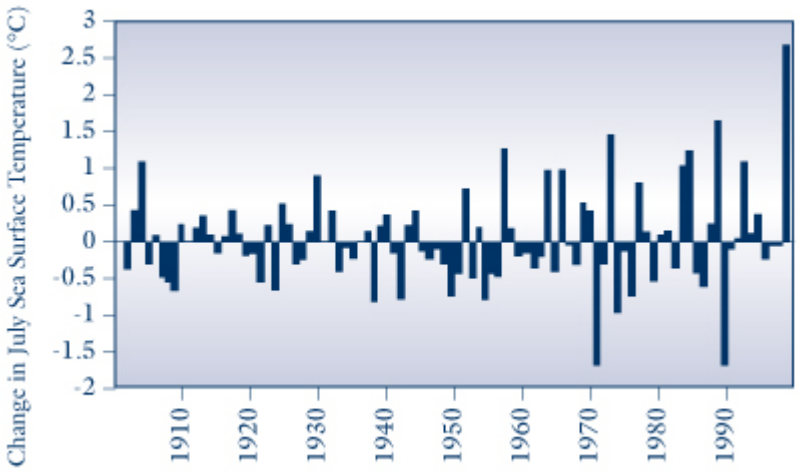
Warming will also affect surface winds and currents, which will in turn affect pressure systems [Figure 9]. But there's a lot of uncertainty as to how this will impact regional systems. Regarding El Niño, although most models have insufficient resolution to properly simulate its behaviour, a German model with an embedded high resolution tropical ocean submodel has suggested that mean temperature changes will increase the variability of El Niño and La Niña intensities, with a bias toward a greater increase in the latter [Figures 10 & 11].

Hengeveld Figure 9. Frequency of winter storms in the Northern Hemisphere.

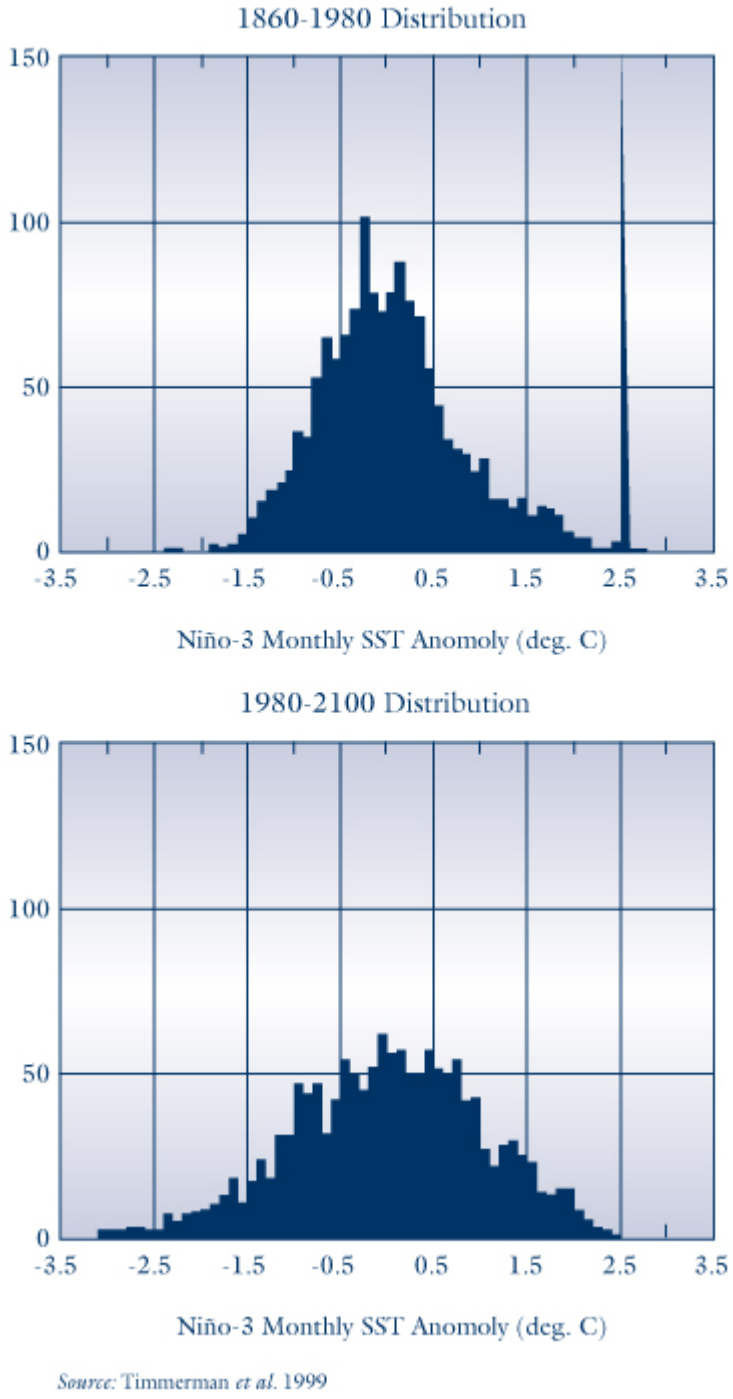


Source: Lambert, 1966

Hengeveld Figure 10. El Niño frequency and intensity in the 20th Century.



Hengeveld Figure 11. Modeled El Niño and La Niña frequencies (1860–1980 and 1980–2100).

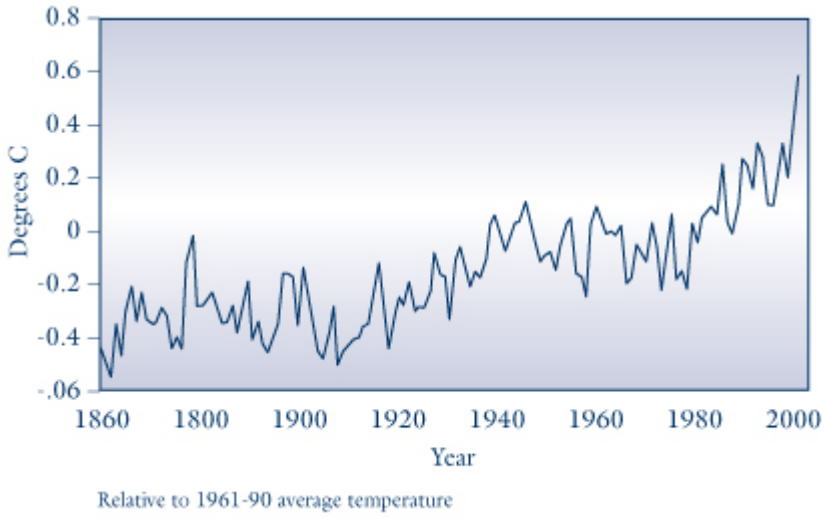


Source: Timmerman *et al.* 1999

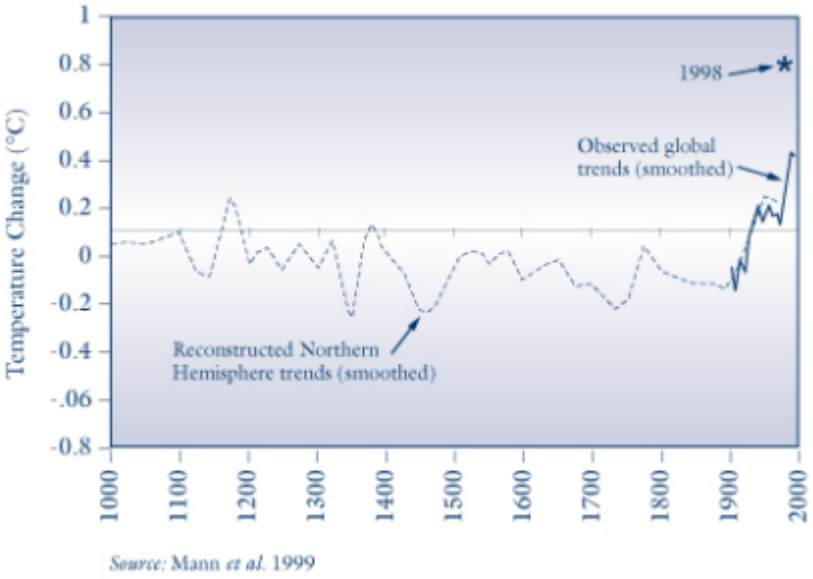
In recent developments, records show that the last decade of this century has been the hottest in record [Figures 12 & 13]. "The skeptics say this is natural variability and there is no proof that climate change is related to greenhouse gas emissions," said Hengeveld, "and to some extent they are correct." But the clincher comes in comparing indicators of past climate change with the more

recent trends. Scientists have examined tree rings, ice cores and other indicators of variations in global climate going back 1000 years and found that the changes during the last 30 years extend far beyond anything found within that long-term climate record.

Hengeveld Figure 12. Global temperature change.



Hengeveld Figure 13. Hemispheric temperature trends of the past Mllennium.



"Natural variability is undoubtedly part of the explanation but it's unlikely that it tells the whole story," said Hengeveld. Weather changes dating back to the late 1970s, such as changes in surface air temperatures and the growing intensity of winter storms, are becoming increasingly hard to attribute entirely to forces of nature.

The key points in this are:

- The basis for projecting future climate change is scientifically sound.
- The debate focuses on the magnitude and distribution of the change.

- Ocean changes will include large-scale shifts in deep and surface circulation.
- The effects of this on local ocean climates will be complex, non-linear, and regionally variable.
- Some changes may already be happening and have important implications for decision-makers today.
- Politicians are experienced in making decisions based on uncertainties and must be relied on to make good decisions now.

Discussion

A participant asked if any of the studies relate to solar weather patterns. Mr. Hengeveld said most studies show that solar intensity changes with time but don't adequately explain why. There are a number of theories, such as one about sun-spot cycles and resulting effects on the ozone, the stratosphere, and the troposphere; there are also discussions about magnetic storms and intergalactic activity. "But really what we have is a bunch of theories without any good linkages," he said.

Dr. LeBlond asked Mr. Hengeveld to summarize what kinds of changes might be expected in BC. Mr. Hengeveld said that, in general, temperature changes could be expected to be more modest on the coast than in the interior. Coastal inhabitants could anticipate snowier winters while interior dwellers should expect drier summers with resulting impacts for forest and stream systems. "But," he said, "I get uneasy about trying to answer regional questions because the models lack the resolution to produce reliable regional projections, and changes at this level are likely to be very complex."

A participant asked if there had been any attempt to look at the effect of the Kyoto Protocol and whether it would reduce the rate of CO_2 increase at all. Mr. Hengeveld said that a carbon cycle model has been used to look at this, but what it reveals is that although the Protocol, if implemented, could delay the timing of a doubling of CO_2 by a decade or two, it would not avoid it.

A participant noted Mr. Hengeveld's reference, in one overhead, to an increase in precipitation over California and wondered if that would be delivered as violent storms. Mr. Hengeveld said that although there has been a lot of debate about extreme regional weather systems, the resolution in the models is too poor to allow for predictions. The Canadian model suggests increased intensity but decreased frequency of storms, he said, and suggests the same regarding hurricanes. But not all the models show the same thing. The participant related his question specifically to agricultural effects, that more precipitation would be good but intensity could have ramifications for crop damage and insurance losses. Hengeveld said that in general, summer storms could be expected to be less frequent but more intense with more lightning, tornadoes, and hailstorms. But the duration of dry periods between these storms could increase.

DR. BRIAN SHUTER, UNIVERSITY OF TORONTO

Climate and the Life History and Zoogeography of Fish

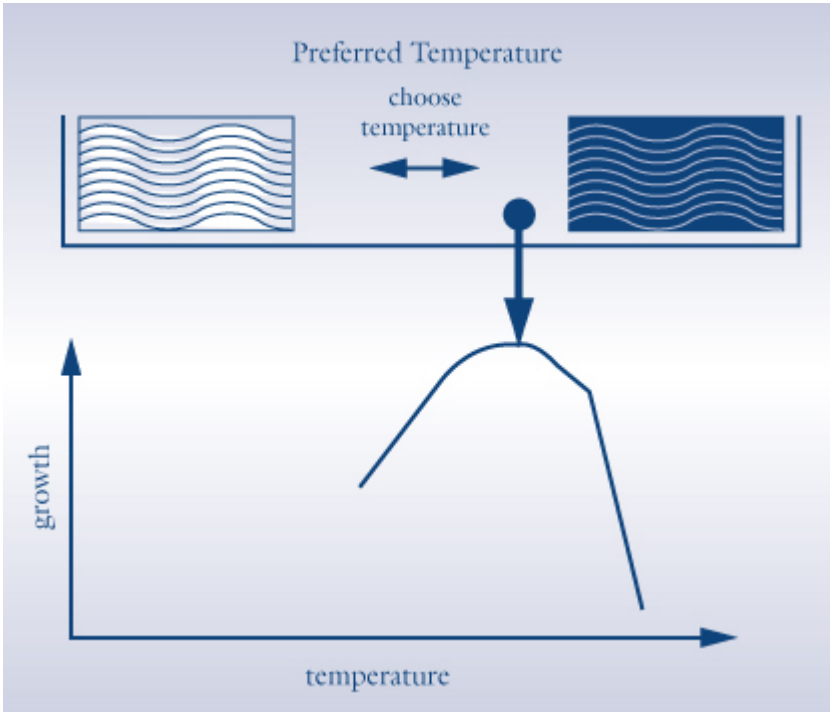
Dr. Shuter said the impact of climate change on water will result in fresh water becoming warmer with amounts of fresh water decreasing or, more rarely, increasing.

The negative consequences for fish of less water are obvious. The effects of warmer water are more complex, and will be the focus of the presentation. His experience is mainly with central Canadian species, but participants can make the relevant connections to West coast species.

Fish don't regulate their body temperatures. Body temperature depends on the temperature of the surrounding water and the rates of all the biochemical processes that support life depend on body temperature. Hence, the water temperatures fish must live in have a major impact on how fish live.

Over the past 50 years, procedures have been developed to quantify how fish modify their behaviour in relation to water temperatures. In one type of experiment, fish are placed in a long tank in which water temperature gradually changes from cold water at one end to hot water at the other. Typically, individuals from a particular species will choose to remain within a well-defined, narrow temperature range—the midpoint of which is defined as the species' preferred temperature. In another type of experiment, fish growth rates (a good indicator of health) are measured at several temperatures, under conditions of abundant food supply. Typically, individuals from a particular species will exhibit maximum growth rates within a narrow, well-defined range: growth rates decline gradually in cooler waters and decline sharply in warmer waters. Scientists have found a good correlation between the preferred temperature and the temperature range for optimal growth [Figure 1].

Shuter Figure 1. Preference experiments and performance experiments demonstrate that each fish species performs best over a narrow range of temperature.



These tests have been applied to many species, allowing scientists to categorize fish species into three groups:

- Cold-water species prefer temperatures around 12–15°C
- Cool-water species prefer temperatures around 22–24°C
- Warm-water fish prefer temperatures around 28–30°C

The preferred temperatures for salmon species are:

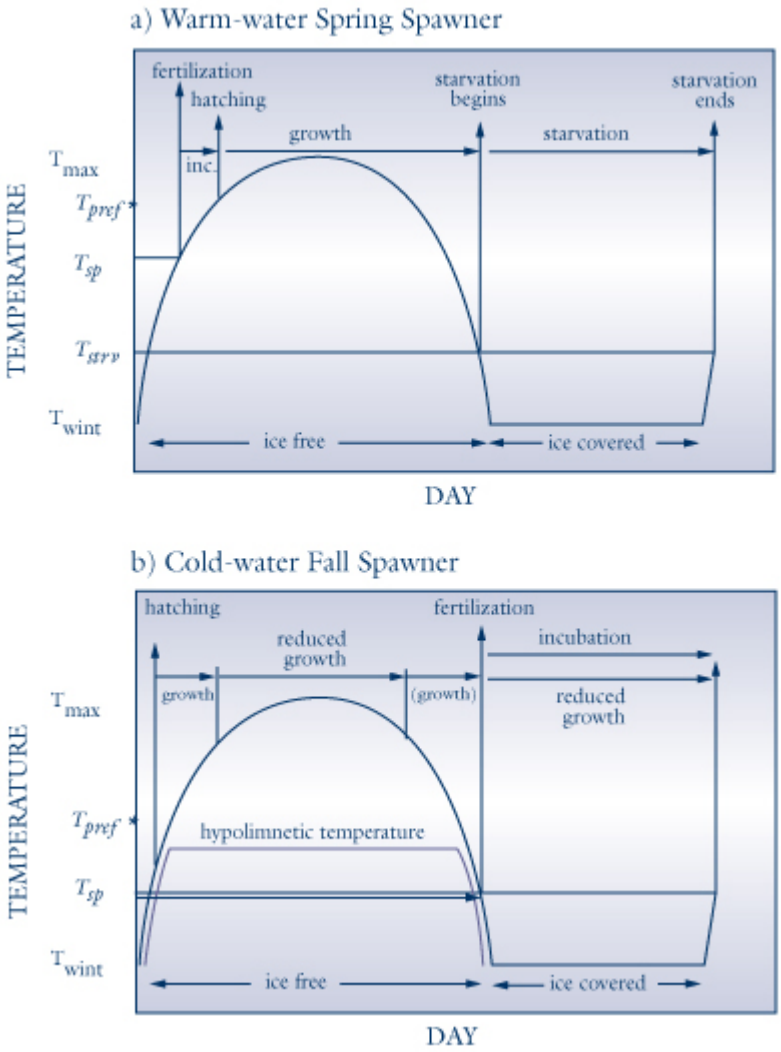
- Chinook: 11–15°C
- Chum: 10–12°C
- Coho: 12–14°C
- Pink: 11–13°C
- Sockeye: 12–15°C

All species deal more successfully with environmental challenges when they are within their preferred temperature range.

Research shows that freshwater fish living in seasonal climates adapt their life cycles to take advantage of seasons in which temperatures are optimal [Figure 2]. Warm-water fish spawn in early spring, when the water is just below their preferred temperature. The young hatch in late spring and grow during the summer, when temperatures are most suitable. Cold-water fish such as lake trout prefer spring and fall temperatures, and growth slows during summer as well as

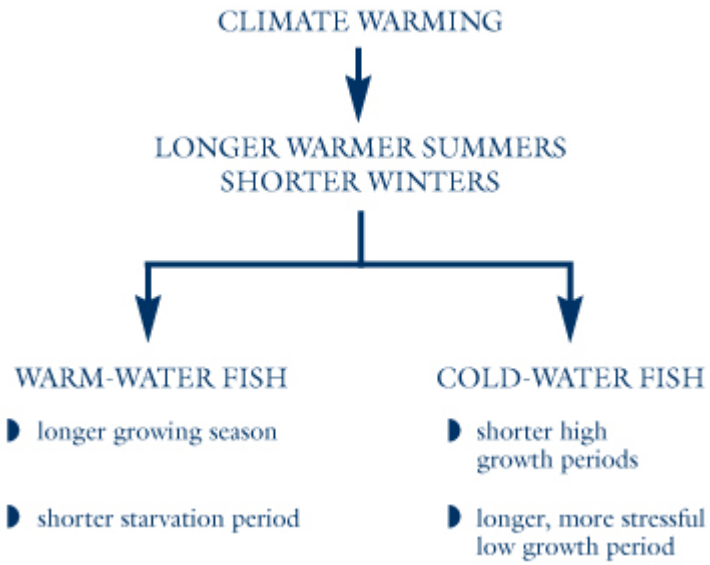
winter. They therefore spawn in the fall and the young hatch in early spring, when water temperatures are close to optimal.

Shuter Figure 2. Fish adapt their life cycles to take best advantage of the seasonal variation in temperature typical to freshwater environments.



To predict how fish species will deal with future climate changes, scientists first study how the behaviour of each species is adjusted to the seasonal temperature cycles where they live now and then determine how climate changes will affect those cycles. These data are fed into computer models which predict the consequences [Figure 3].

Shuter Figure 3. Climate Warming.



Climate studies show links between maximum summer temperatures and season lengths. In warmer climates, summers are longer and hotter and the other three seasons may be shorter. This benefits warm-water species, as they have a longer growing season and a shorter stressful period of colder water. However, the consequences for cold-water fish are negative. Their optimal growth periods in spring and fall may be shortened, and they must survive a longer stressful period of warmer summer temperatures.

To predict distribution boundaries for fish species, scientists first determine what type of climatic conditions best suit the species. These data are combined with knowledge of current climate zones to estimate the species' distribution boundaries. These estimated boundaries are compared to the actual observed boundaries. If the two match, it is safe to conclude that the existing boundaries are under climatic control and, therefore, that it is reasonable to use estimates of climate change to predict changes in the boundaries of species' distribution. In general, as global warming occurs, warm-water species are expected to expand their distributions northward, while cold-water species retreat.

Dr. Shuter and Professor J. Post of the University of Calgary conducted such an analysis on yellow perch and smallmouth bass. They concluded that with a warming in mean annual air temperatures of 4°C, the northern boundaries for both bass and perch would move several hundred kilometres northward—the Canadian distribution for both species would expand. A similar study by Dr. D. Meisner examined brook trout, a cold-water species found in northeastern North America that requires cold summer refuges. Observation of actual population boundaries showed that the most southerly groups were found at increasingly higher altitudes where they find cooler groundwater. As groundwater temperatures rise, the southern distribution boundaries of this species are expected to retreat to the north.

The expected impact of warmer water on cold-water species will be slower growth, smaller sizes, later maturity, lower population growth rates, and therefore lower sustainable rates for fishing.

Dr. Shuter concluded that a reliable evaluation of the potential impacts of climate change on a particular species of fish requires research in at least two areas:

- Comparison studies, that describe populations of interest across a broad range of climatic conditions and hence document how the animal deals with climatic differences in nature.
- Zoogeographic studies, aimed at assessing the role of climate in determining existing boundaries of the species' distribution.

Discussion

One participant asked whether factors other than water temperature might impact the health of species as population shifts occur. Dr. Shuter referred to a study examining how the introduction of smallmouth bass into a lake affected the existing lake trout population. There was evidence that the bass, which tend to feed around the shoreline, had out-competed the lake trout for shoreline minnows and forced the lake trout to rely more heavily on less productive, offshore food resources, resulting in lower growth rates and other effects on the trout population. He added that as species move northward in response to warmer conditions, they may well threaten existing species that may have been able to survive and adapt in the absence of competition from such warm-water invaders.

Paul LeBlond commented that since salmon live in fresh water as well as in the ocean, Dr. Shuter's presentation is most relevant to the freshwater stages of their life cycle. Dr. Shuter acknowledged that the implications of climate change for salmon are very complex, and made the following points:

- Salmonid life histories are shaped by existing patterns of seasonal variations in temperature (and other environmental variables) in several distinctly different aquatic environments (i.e., marine, estuarine, river, lake); climate change will impact all of these environments in different ways, so there is great potential for disrupting the behaviour of existing salmon populations.
- Recent observations of sockeye and other salmonid species in the western Canadian Arctic suggest that northward extensions of the ranges of all these populations may already be occurring.

DR. RICHARD BEAMISH, FISHERIES AND OCEANS CANADA, NANAIMO

Why a Strategy for Managing Salmon in a Changing Climate is Urgently Needed

Dr. Beamish said climate change must be taken very seriously, although it is difficult to forecast the impact on Pacific salmon. He said scientists already have difficulty predicting annual returns, and the models used to predict the impact of climate change still leave a tremendous amount of uncertainty. His presentation will focus on the impact of climate change on ecosystems and the ocean, rather than on water temperature.

He favours the Russian term "ecosystem reorganization" because it connotes the familiar qualities of dislocation and sloppiness inherent in corporate or government reorganizations. Extensive ecosystem reorganizations are occurring and they relate to climate change.

The presentation will not discuss the impact of fishing, although it is very important.

Despite currently low numbers, salmon stocks have been well-managed in the face of recent climate changes such as the El Niño and La Niña effects.

In addressing these issues, scientists have an obligation to pass on all the necessary data so that individuals can draw their own conclusions.

Referring to a graph of temperature changes from the year 1000 to the present, with projected changes to the year 2050, Dr. Beamish said he believes global warming is a serious threat. Climate change information must therefore be incorporated into all fisheries management. Noting projections for global warming and population growth, he said the resulting scenario may be apocalyptic at best.

Total catch is a good indicator of salmon abundance. The combined catch of North Pacific salmon for all nations is now at a record high. Meanwhile, the Canadian catch, which reached a historic high in 1988, is currently at a historic low. This discrepancy is explained by the different impact that climate patterns have had on Canada's Pacific waters compared to that experienced further north. These changes affect other species. For example, the Canadian catch of ground fish has fallen for natural reasons in the 1990s, from the historic high levels of the 1980s. Declines have been more severe where the impact of the cyclical lows has been combined with overfishing, notably off Oregon and Washington. Sardines have returned to British Columbia's coastal waters, after being absent since 1947. Hake are moving farther north and mackerel are arriving in BC waters for the first time. The whole ecosystem has changed in the past ten years.

The abundance of species that normally produce large numbers of seeds or babies depends on habitat, not on the number of offspring produced. The ocean is a harsh environment and very small changes can thus significantly affect the number of offspring that survive.

To assess the effects of global warming on salmon, many factors must be examined. One is the changing percentage of wild salmon versus hatchery fish. Fisheries and Oceans Canada is finalizing a new policy on wild salmon which Beamish thinks is a good start towards adjusting to the impact of climate change on salmon. If wild salmon are over-harvested, they will end up being replaced by hatchery salmon, and this may already be happening.

Many factors affect the survival of salmon in the ocean, including predators, prey, salinity and water temperature. An historical analysis of sockeye numbers in one Alaskan lake suggests that variability in abundance is also natural. Other evidence, including Hudson's Bay Company records, indicate that salmon were extremely scarce in the early 1800s. Recently, a significant drop in coho numbers in BC prompted the department to launch a coho marine survival study.

A comparison of recent studies conducted in the Strait of Georgia, Puget Sound and Oregon shows a large decline in coho salmon populations over a large area since the late 1980s. This decline has mirrored climate changes, which suggests that climate is a common factor.

Three indices are used to measure the climate of the Northern Pacific ocean. The first tracks the intensity of the Aleutian Low and indicates the degree of winter storminess. The second is the Pacific Decadal Oscillation, a monitor of climate change strongly influenced by sea surface temperatures. Third, the Winter Pacific Circulation Index (PCI) monitors the position of the jet stream, which is the boundary between polar and tropical air masses. Another tool, the PCI index, indicates the combined effects of these three indices. In recent years, changes in the PCI index correspond very closely with fluctuations in the total North Pacific salmon catch by all nations. If recent climate variations such as El Niño/La Niña have affected abundance, it can be predicted that global warming will also have an effect.

Global warming models suggest that in addition to rising ocean temperatures, the Aleutian Low may intensify. A stronger Aleutian Low, as occurred in the late 1980s, causes cooler waters in the Central Pacific along with warmer coastal waters. Cooling in the Central Pacific means more food and therefore more salmon, as happened in the late 1980s.

The climate change models still contain many uncertainties. In addition, they are more accurate in predicting broad changes and are not advanced enough to show regional detail. For example, mid-ocean and coastal temperatures could respond quite differently to global warming. Still, it is now certain that warming will occur, and that it will impact salmon abundance.

Conclusions

- There is a major change in our understanding of the factors that affect the abundance of salmon.
- Climate is recognized as a factor that changes the capacity of the ocean habitats to sustain salmon.
- West Coast ecosystems have changed and the species abundance and distribution in these ecosystems have been affected.
- In some cases, for example the decline of coho in the Strait of Georgia, there is a clear relationship between changes in winds, sea levels and salinity, without a temperature effect.
- Total North Pacific salmon production is currently at the highest level for this century but the Canadian level is at an historic low.
- Climate is clearly involved in the recent population changes, but the natural component cannot be separated from the global warming component.
- There is no agreement on how global warming will affect the patterns of winds and related changes in the sub-Arctic Pacific.

- We need a strategic plan to learn how global warming will affect salmon habitat and how to manage salmon so that they can adapt.

Twelve Rules for Salmon Management

1. Protect freshwater habitat, as it is a safe refuge for spawning and for baby salmon to grow.
2. Respect the marine habitat of salmon because most salmon do not survive the complexity of factors that can cause their death.
3. Recognize that the life histories of various wild species have evolved to adapt to a wide range of natural conditions, which means that if salmon were left alone they could solve their own survival problems.
4. Be concerned that we have not left salmon alone.
5. Be even more concerned that we have intervened in the natural regulation process while understanding very little about the natural mechanisms that affect survival.
6. Fishing should not prevent a stock from replenishing itself but knowing the safe level of fishing will always be a challenge.
7. Be careful how you use the word "rebuild."
8. Accept that climate affects survival trends in salmon.
9. Believe that the climate is warming and the climate is changing but don't delay in responding while scientists debate whether the cause is from greenhouse gases or natural trends or probably both.
10. Recognize our uncertainties and speak openly about what you know and don't know, as expectations will become more realistic and people will like fisheries biologists better.
11. Remember that everyone cares for salmon, and it is the interpretation of our ignorance that creates conflicts.
12. Expect the unexpected. Prepare for change as do all animals and believe that the future survival of salmon is a measure of our ability as a species to live in balance with other species.

Discussion

One participant asked what Fisheries and Oceans Canada (FOC) staff are doing to ensure that the federal government takes steps to reduce greenhouse gases.

Dr. Beamish responded that he could not speak for the department. As a scientist, he wished to see the department's program on climate change expanded. He said funding is becoming available and scientists are starting to include climate in management plans, but better models must be developed.

Another participant listed a chain of potential problems that could result from changes in the salmon life cycle in response to global warming. These included earlier hatching times, migrations mis-timed with river flows and smaller fish that are more vulnerable to predators. Dr. Beamish agreed that all these consequences could result from climate change and added that more study of this is needed.

A participant challenged Beamish's use of total landed value of the catch as an indication of salmon abundance, noting that this value also reflects market prices and management policies. Beamish agreed, noting that landed value is not used as an absolute measure, but together with other data it supports the conclusion that numbers have changed dramatically.

Another participant discussed the need to manage other factors that affect salmon habitat, such as reducing greenhouse gases, protecting freshwater habitat, controlling logging and development that affects river flows. Beamish agreed that protecting freshwater habitat is important.

A participant expressed concern about funding cuts and the need for more research, noting that scientists must send a serious message to the federal government to act now.

Another one urged that Beamish's twelve rules be widely distributed, and complained that FOC's "unabashed support" of aquaculture is "deplorable" at a time when more resources are needed to study climate change.

One participant observed that much of Beamish's research is based on incomplete data and noted that Canada's per capita spending on research is very low. Beamish agreed that more resources are needed to study the oceans and interrelationships among ecosystems.

Another referred to the theory that a stronger Aleutian Low might mean more salmon, though warmer ocean temperatures may drive them northwards. If this happens, he wondered whether fisheries officials will focus on salmon stocks in the north or on trying to save threatened populations in the south. Beamish reiterated that much uncertainty remains over what will happen. Better and timely information is needed so that good decisions can be made.

One participant asked what is being done to preserve the gene pools of several aberrant wild salmon groups that have adapted to non-typical environments. Beamish said he believes it will be very important to have a policy that protects these important wild stocks.

Council Chair John Fraser closed the morning session by commenting that the council is very interested in the level of funding and capacity of the federal fisheries department. Noting that the council reports to both levels of government and to the public, he stressed the importance of an informed public. Public support plays a crucial role in empowering ministers to take the needed actions, he said, and urged participants to voice their concerns in letters to ministers, Members of the Legislative Assembly and parliament.

PANEL: WHAT IS THE MOST ALARMING POTENTIAL IMPACT OF CLIMATE CHANGE ON SALMON STOCKS?

Mr. Narcisse began by noting that in the discussions so far, scientists have done little more than allude to the potential impact of climate change on salmon. He believes the time for alluding is over, because these impacts are already being experienced. The impact is being accelerated by continuing emissions of greenhouse gases, and we can't afford to wait another ten years to act just because scientists are not yet confident that they have all the facts, he added.

Narcisse said more continuity is needed to link the information coming out of the many meetings, workshops and conferences on salmon conservation. The information presented by scientists at these gatherings is often difficult for non-scientists to grasp. For example, it has taken him two years to fully comprehend that changes in the Aleutian Low will mean that salmon must travel seven to ten days longer to return home.

He is very concerned that climate change is already skewing normal weather patterns. The situation is like the song that says we're on the road to hell. "We seem to be in an orgy to grab as much money as we can to take to the grave and to hell with the consequences," he continued. The situation is worsened by defeatists who say that if the weather is responsible for the problems, then nothing can be done about it.

Even positive effects like the recent heavy snowpacks have had drawbacks, as the snow is contaminated by pollution from distant countries that lack environmental controls.

The recent El Niño raised sea surface temperatures in the Pacific Ocean, requiring salmon to swim farther. They returned to the mouth of the Fraser River seven to nine days later than normal. Narcisse observed the consequences of this in the interior, where the late migration upriver was significantly impeded by heavy water flows. Such weather-induced problems are becoming more common.

He disagreed with Dr. Beamish's opinion that salmon have been well-managed, arguing that years of over-exploitation have contributed to the current decline in stocks. Ensuring the long-term survival of salmon must be foremost in management regimes.

At numerous world conferences, scientists have warned of the many negative effects of continuing greenhouse gas emissions, and of the impact of deforestation on freshwater habitat and carbon dioxide levels. Yet destruction to the environment continues with no politician willing to take up this cause.

Other climate-related consequences being experienced in the Nicola Valley include higher water temperatures in the summer and faster runoff, which damages the gravel beds that are crucial to spawning. This resulted in the loss of a whole population of salmon, and along with it, the unique knowledge that we could have gleaned from this particular group.

Scientists predict that global warming will increase water temperatures by several degrees in winter, which will mean a shorter incubation period for salmon. Effects like this may seem inconsequential on their own, but all the changes taken together will have disastrous consequences.

For the First Nations people, losing salmon will mean losing a significant part of their identity as indigenous people. Future generations of all cultures will lose something valuable.

The situation now is like a bulldozer coming downstream while in its path, stewards tinker with fish survival methods. What are needed are not incentives, but penalties for industries that exploit natural resources.

"The scariest part is that no one is listening. We're all the converted here. We all know what's happening," he said. That knowledge must become general knowledge. Politicians must play a more active role too, and challenge what Canada as a country is doing to address climate change. It is one of the most daunting issues now facing humankind.

Discussion

One participant wondered whether Narcisse agreed with the emphasis that fisheries officials are placing on promoting farmed salmon instead of saving wild species. Narcisse replied that this was part of the defeatist mentality he had described. With their genetic diversity, wild fish will be far more capable of adapting to the changes coming with global warming as well as other potential threats, such as the recent bacterial outbreak among fish on the East coast.

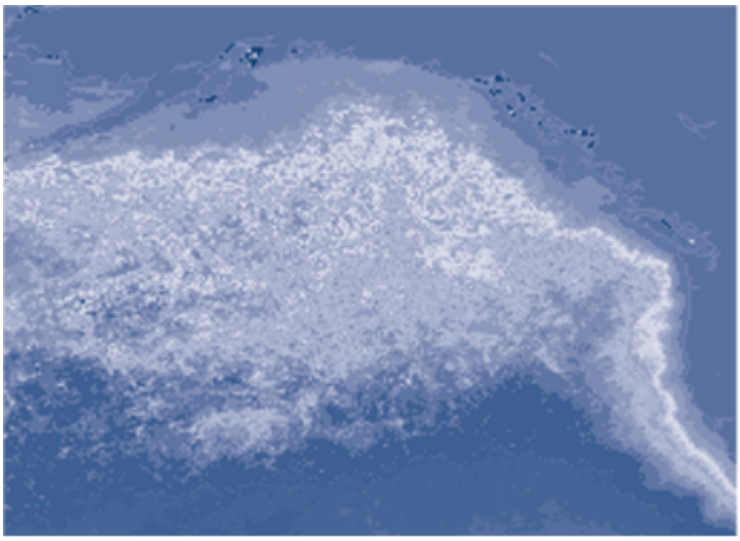
Another participant commented that no fish may be left by the time scientists get all the proof that they want about climate change. Narcisse agreed, saying scientists are traditionally reluctant to "stick their necks out," and the problems are already so serious that we can't afford to wait longer.

Frank Whitney, Fisheries and Oceans Canada, Sydney

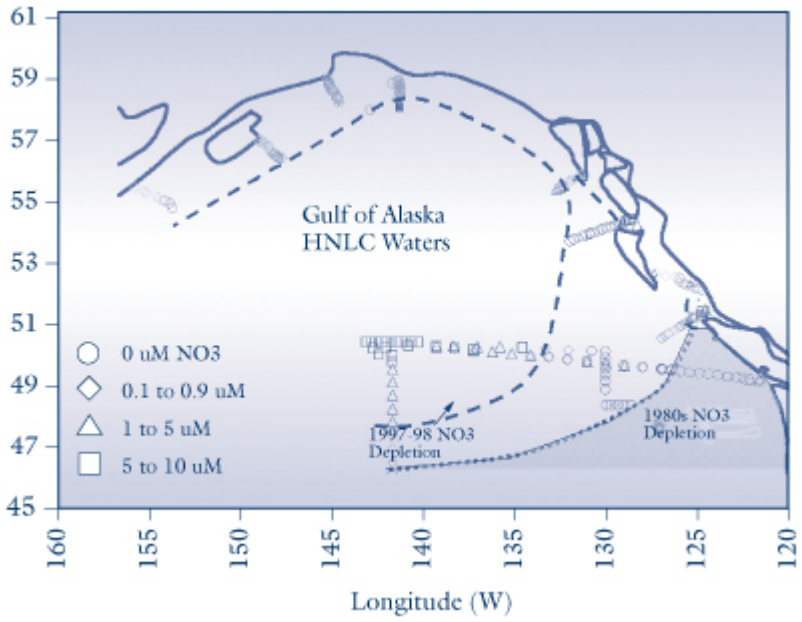
Mr. Whitney described his research with the Institute of Ocean Sciences, which focuses on climate-induced variability in nutrient supplies in the Pacific Ocean. He said that as the global climate is warming, his research shows warming spots in the Pacific in which nutrient levels are declining. The result is less food for salmon and other species. We are entering a period in which lower levels of nutrients will be available to support bio-mass, he said.

Mr. Whitney displayed a map of the Pacific showing varying distribution levels of chlorophyll off the coast of British Columbia and the Gulf of Alaska [Figure 1]. The map indicated that coastal waters were the most productive areas. Comparison with a second map showed how the areas of abundant nutrients shrink as ocean temperatures rise [Figure 2].

Whitney (Panel 1) Figure 1. Satellite image showing the concentration of chlorophyll in surface waters of the Gulf of Alaska.

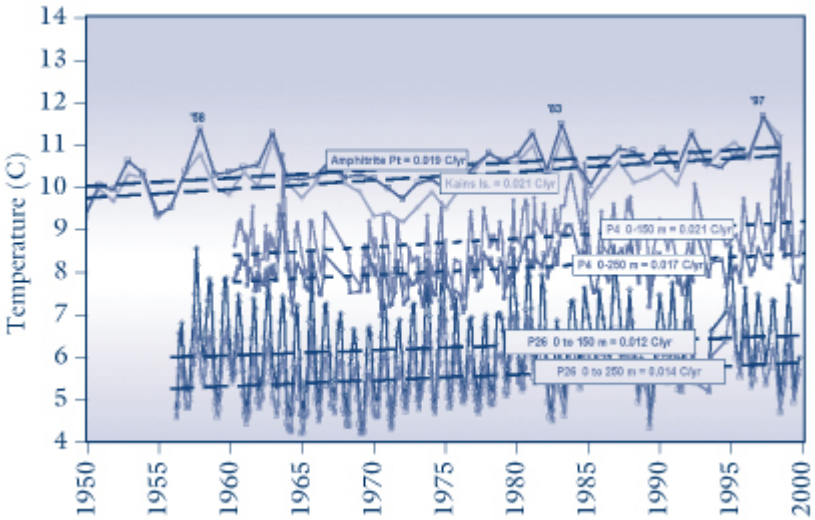


Whitney (Panel 1) Figure 2. 1997–98 El Niño—July to September.



Whitney's studies use data on sea surface temperatures and nutrient levels collected in the Gulf of Alaska. The data show a distinct warming trend in sea surface temperatures at all sites [Figure 3]. A graph mapping the temperature changes over time clearly showed warmer peaks experienced in El Niño years. Data gathered along the P Line indicates that warming is occurring more rapidly near the coast than in the open ocean. At the two ocean stations, data on subsurface water temperature is also monitored, and this indicates that the warming trend extends to deeper levels.

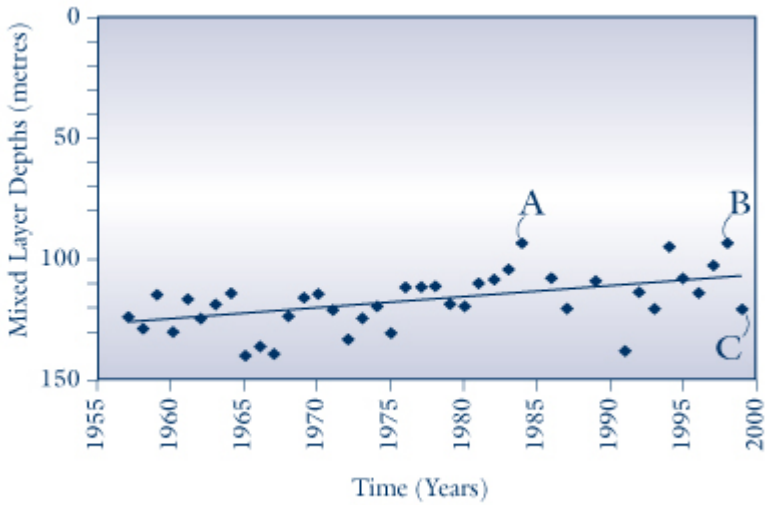
Whitney (Panel 1) Figure 3. N.E. Pacific temperature trends.



The upper layer of ocean water is normally stirred up by winter storms, bringing to the surface the nutrients that are produced in the deeper layers. However, the layer that is stirred up by winter storms is becoming shallower [Figure 4], and as a result less nutrients are being brought to the surface. A chart comparing nutrient levels measured in the 1970s to those measured in the 1990s shows a decrease in the winter supply of nitrates [Figure 5]. The consequence is a widening area of nitrate depletion in the summer. By late summer, no nutrients remain to support feeding.

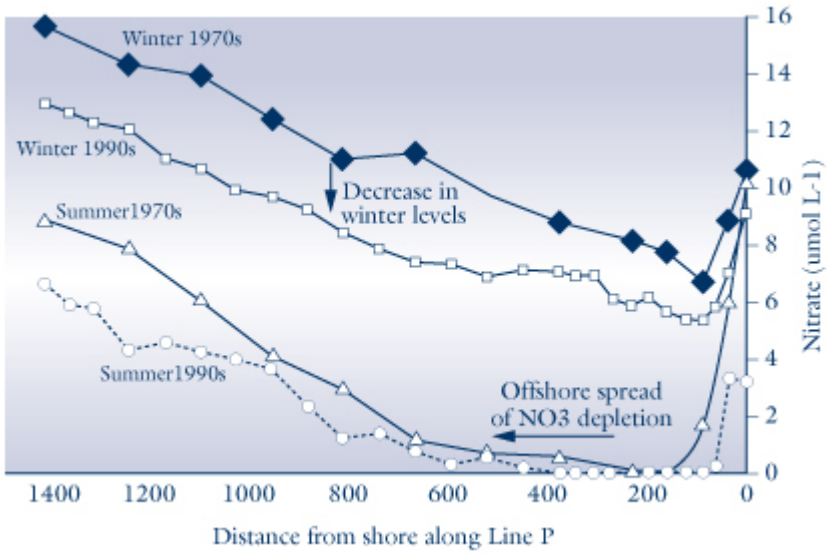
Whitney (Panel 1) Figure 4. Change in winter mixed layer depth at Ocean Station Papa

Points A & B are El Niño winters, C occurred during the 1998 La Niña.



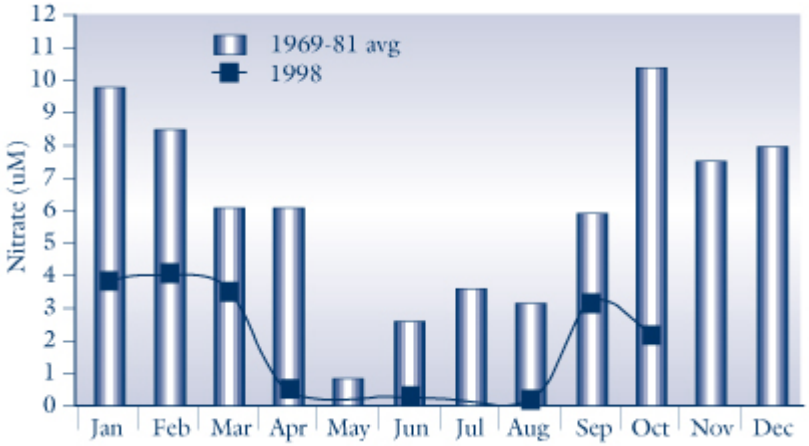
Courtesy, Howard Freeland

Whitney (Panel 1) Figure 5. Line P surface Nitrate 1969–81 and 1992–98.



A study of the impact of El Niño on nutrient levels showed that warmer water was preventing nutrients from reaching the surface. A comparison of the late 1980s to the El Niño experienced in 1997/98 indicated that subtropical water was penetrating further north along BC's Pacific coastal shelf reducing nutrient supply [Figure 6]. Juvenile salmon feed along this coastal shelf for the first six months of their oceanic lives, and scientists estimate that these El Niño conditions result in 40 to 50 percent less productivity to feed these fish compared to a normal year.

Whitney (Panel 1) Figure 6. Nitrate in Surface Waters. Southern BC Coast to 70 km offshore.



David Welch, Fisheries and Oceans Canada, Nanaimo

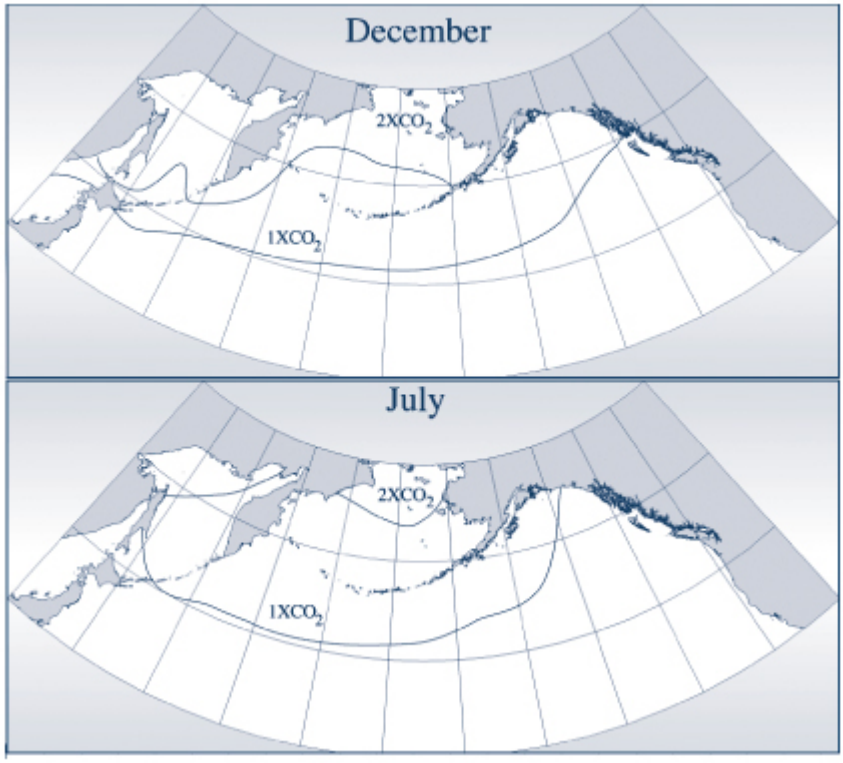
Dr. Welch said that in a broad sense, climate change presents a serious potential threat to salmon.

Forty years of data gathering shows that salmon move within very specific temperature boundaries in the open ocean. With current predictions for ocean warming, entire species of salmon could move out of the North Pacific by the year 2050.

The scenario for steelhead, which prefer water warmer than do other salmon species, is slightly more optimistic. However, in the best-case scenario, even those species that tolerate the warmest water will experience a significant reduction in acceptable ocean habitat as a result of global warming, and there will probably be a decline in numbers and productivity as a result of climate change.

Early, cruder models for predicting the effects of global warming were based on much simpler models of the oceans than the current generation of models, and simply examined what the climate might be like if CO_2 was to double its current level within the next century. With the development of more sophisticated new models such as the UK's Hadley model, scientists can examine the effects of gradually varying levels of carbon dioxide over the coming years. British scientists have used this model to forecast the effects of an increase in emissions of one percent per year. The results [Figure 1] showed that the initial conclusions remain the same, and that projected levels of warming would be sufficient to eliminate several species of salmon (chinook, sockeye, pink and steelhead) from the Pacific by roughly 2040 AD, and possibly one or two species from the Bering Sea by the end of the next century if CO_2 continues to increase at 1% per year. Coho, one of the species that tolerates warmer water, would also move out of the eastern half of the North Pacific entirely. The conclusion is that several species of salmon will disappear from the North Pacific or the eastern half of the North Pacific within 50 to 70 years. There will also be very large shifts in the distribution of remaining salmon species. This means they will have to swim longer distances to return home to spawn. That is expected to set off a chain of consequences that are as yet poorly understood. If this comes to pass, the fish may be smaller, weaker, and/or they may be capable of laying fewer eggs. Nevertheless, despite uncertainty about the details, scientists can be more reasonably confident in predicting the broader problems that will occur, such as lower overall productivity, because salmon are cold-water species that will be adversely affected by warming.

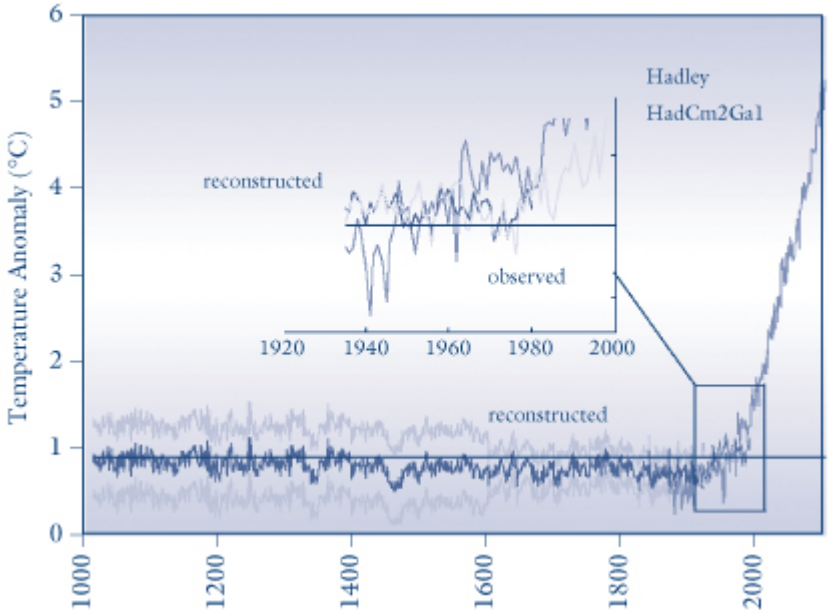
Welch (Panel 1) Figure 1. Effects of an increase in emissions of one percent per year.



The Northeast Pacific is an unusual ecosystem because prior to the 1990s it was not nitrate limited, and served as a feeding ground for many fish species. During the 1980s improving conditions allowed populations of many species to increase. However, major climate changes since 1990 have affected the population sizes for all species. The depletion of nitrates due to warming appears to be affecting the entire food chain.

Using tree rings, scientists have reconstructed climate records for the past thousand years. The records show that climate of the Northern Hemisphere remained stable for 900 years, followed by a rapid warming trend that began early this century and is now clearly accelerating [Figure 2]. The overall warming trend for this century has totalled just 0.7°C but scientists predict accelerated warming of five degrees in the next century, or 0.5% per decade—nearly as much as the warming experienced over this entire century. The rapidity of this change is unprecedented in our experience. Our society, salmon and other species have developed within very stable climatic conditions, so science cannot predict how this change will affect them.

Welch (Panel 1) Figure 2. Mean temperature of the Northern Hemisphere.



While the major climatic fluctuations of this decade have been caused by naturally recurring weather patterns such as El Niño/La Niña, the unprecedented severity of these changes indicates that global warming is also playing a role. For example, the El Niño of 1997 was the strongest of the century. Statistically, the late summer peak temperatures experienced that year would have occurred only once in 10,000 years. Temperatures in 1996, the coolest year of this decade, were almost as warm as those in 1983, which was the second hottest El Niño of the century.

Discussion

One participant referred to the period 10,000 years ago when a significant period of warming occurred, and wondered whether research could be done to show how salmon survived and adapted during that period. Such research could then be applied to the present. Dr. Welch said such a study would not be feasible. He added that it will be difficult to devise effective salmon management plans under global warming, since they are so sensitive to climate changes.

Another participant asked about the effects on salmon as they have to move further north to feed. Dr. Welch said scientists are now observing reduced size among returning adults, which may be linked to a decline in nutrient levels.

A participant observed that as feeding grounds shrink, the salmon will be unable to return home. So even if nations comply with the Kyoto cap on greenhouse gas emissions, there will be no salmon left in 50 years. Dr. Welch responded by noting that the Kyoto limit is not really a cap. Countries that comply will continue to increase their emissions at a constant rate, but will not permit this increase to accelerate. Despite the large uncertainties that still surround global warming projections, he added that there remains very little doubt that global warming will occur. Even if the predictions are way off, the impact will be very serious. The links between climate and salmon have been studied extensively, but very little is known about how other plant and animal species will be affected.

One participant asked why Alaskan salmon numbers are up despite all this. Dr. Welch said both Alaskan and Canadian waters are warming. The warming trend did not have negative consequences for species in BC waters in the 1980s, but as it continued in the 1990s, salmon productivity has declined. Similarly, Alaska should begin feeling the effects as the trend continues.

A participant wanted to know how much of the nitrate depletion was attributable to global warming and how much to natural oscillations in climate patterns. Mr. Whitney noted that the data collection on nutrient levels was interrupted in the 1980s, so the best that he could do was to compare nutrient and temperature levels from the 1970s to those of the 1990s. The conclusions drawn from that data are that the ocean is warming and that the stirred layer at the ocean surface is thinning.

Another participant asked whether some of the recent negative effects might be reversed in the present colder La Niña weather pattern. Dr. Welch said scientists will be more able to answer such questions after studying the effects of these two La Niña years.

A participant questioned the message being sent out by scientists. If global warming is coming, salmon will disappear despite all conservation efforts, unless people are prepared to change their lifestyles to reduce emissions. Mr. Whitney agreed that no matter what we do, climate change is already a reality and many other species will be affected besides salmon. Dr. Welch added that he is being blunt in his assessment of this problem. He said he is personally concerned and the first step towards addressing the challenges ahead should be public education.

A participant from a maritime coastal community in northern BC said he fears his community will be devastated by these changes. He referred to complications arising from the large salmon ocean ranching operations by Alaskan fishers and asked whether this was being addressed in the Pacific Salmon Treaty. Dr. Welch replied that he is not involved in the treaty negotiations, but commented that we will have to decide whether we want to preserve wild salmon genes or whether we want to maintain bio-mass through farmed stock.

One participant expressed concern over contamination and higher temperatures in the Strait of Georgia. He said salmon fry and smolts have to make it through this stretch of water before they reach the ocean, so resources should be spent studying this area instead of the open ocean. Mr. Whitney replied that extensive research is taking place in the Strait of Georgia and that the amount spent on open ocean research is minimal by comparison. He said both areas need more study.

PANEL: WHAT IS THE BEST STRATEGY TO ADOPT?

Dr. LeBlond introduced the panelists, noting that Dr. Carl Walters belonged with the first panel but had been unable to attend at that time and would instead be the first speaker on the second panel.

Dr. Carl Walters, UBC

There are things that we've heard so far that we shouldn't doubt, said Walters. These include:

- that the climate is changing;
- that the changes are more extreme than at any other time in the past 1000 years; and
- that there is a human component influencing the changes.

Walters said that the effects of climate change are already so severe that even if humans all around the world stopped driving cars today, the effects—including the endangerment of the salmon—would be with us for a long time. What then, he asked, can we do to save the salmon?

We are seeing a domino effect of declining marine survival rates at least for coho and chinook salmon, said Walters, with the greatest declines occurring in coastal areas. These trends first appeared as early as the late 1970s and should be a central concern regarding the salmon's survival. Today, only one out of every five coho that previously returned to spawn is returning. "This is a major, catastrophic decline," said Walters.

The biggest problem is not in fresh water but in the coastal environment among small salmon. Once the fish leave the rivers, he noted, "we don't know where or when mortality is happening or what is causing it, but if we knew, we might be able to do something about it." Some possibilities are:

- That disease is being transmitted from farmed to wild fish. If we could show that is the case, we could definitely do something about it.
- That as conditions off California change and marine life moves north, some predators are moving in and killing the fish at sea. It would be difficult to do anything about that as, on the open ocean, it's difficult to find and monitor the predators, and assess their impacts.
- That warming temperatures are reducing food supplies. But we're not seeing growth rate changes among returning salmon on as large a scale as would be expected if there were major food problems. If there is a food problem, it may be that the fish are spending more time feeding (a risky behaviour) and are therefore more vulnerable to predation.
- That there is direct physiological stress from the water itself being too warm. However, if this was the case, the fish would move to cooler environments.

The best information we have today about climate impacts is from correlative studies, but correlations tend to break down over time and fail to indicate what's causing the mortality. But the fact that science lacks definitive answers and that it's unlikely the fish will recover soon does not provide an excuse to fish them into extinction in order to keep the fisheries going. There has been no concerted fisheries department program to track the fish and determine where, when, and why they're dying.

Can we find what's causing the mortality? The research to answer that would be more difficult and expensive than anything attempted in the past. It would involve following them out to sea, but we lack the marking and tracking methods to do so. It would mean determining the causes of individual deaths, but we don't have good methods of doing this, either. It would mean measuring mortality risk factors, but we don't know how to do this, so even with a lot of money there would be no guarantee of finding an answer, or that the answer would be something we could act upon.

So what should we do? Walters offered several suggestions:

- Pray for adaptation. The surviving fish may carry genetic traits that make them more adaptable to the new conditions evolving out there. Therefore, every returning fish should be allowed to spawn to maximize the species' adaptability. The fisheries should be closed.
- Find what's causing the mortality. This would require massive research to follow the fish and determine what's killing them, which would cost tens of millions of dollars and take money away from other programs, such as compensation for fishermen and habitat restoration.
- Be patient. Resist demands to reopen fisheries at the first signs of recovery. This may be the most important. We can't accelerate change, we can only wait for it.

"To end on an optimistic note, you could say that the changes that are happening out there represent an opportunity to address a problem that's plagued us for years," said Walters. It could be time for us to develop selective fishing methods so that no endangered species are taken out of the water. It could be time to recognize that techno-fixes like hatcheries are not working, because despite hatchery releases returning stocks are declining. It makes a basic, public commitment to a diverse, healthy, natural production system with no room for write-offs or die-offs.

Fred Fortier, BC Aboriginal Fisheries Commissions

Mr. Fortier welcomed his council colleagues and scientists. He said the scientists "shouldn't have to take abuse" as they had been throughout the day. Their job is to bring information to the public to enable decision-making, and we should be asking how to help them do that instead of condemning them because they're employed by the government or a Crown corporation.

Here are some international fish facts, said Fortier:

- an estimated 15–20% of all animal protein comes from aquatic animals;
- fish is high in protein and other essential nutrients not found elsewhere;
- all but four of the 30 countries that depend most heavily on fish are in the developing world; and
- fishing is vital to the global economy, providing 30 million people worldwide with their livelihoods, 90% of them in the developing world.

It's good to have science, said Fortier, to lay out research methods, and come up with testable theories. But there is a need to incorporate traditional ecological knowledge with modern science. Under the Convention on Wildlife Diversity, Canada agreed to accept indigenous science at par with western science. Indigenous people have had 10,000 years to observe and record what happens at sea, and that's what science is about. Yet, indigenous people are rarely invited as experts to scientific conferences. So the question before us is how to incorporate traditional ecological knowledge in management of the salmon.

Most indigenous knowledge is based on natural or customary laws, said Fortier. "I read a report the other day that was looking at the positives of global warming," he said. It looked at quick techno-fixes to the salmon dying off, like altering them genetically so that they'll return to warmer waters or looking into cryo-preservation. These kinds of discussions highlight the need for information dissemination—"It's no good to have information if it's just stored in a computer somewhere; it has to be in the hands of the people," he said—and some of our strategies may need to focus less on managing salmon than managing people.

Fortier listed numerous things that should be on the table for discussion, including:

- Defining sustainable development. We talk about it but we really haven't defined the term. Maybe it's just a matter of leaving the fish alone and letting them adapt.
- The needs of the fish. We know they need water—and sometimes we don't give it to them. We need to know what we have.
- What stocks we have and which are most in need of protection. Which fisheries should receive the highest priority, Aboriginal, commercial, or sport?
- Fresh-water problems like snowmelts and high water at Hell's Gate. It's creating a wall of water that the fish can't get past and nobody's talking about it. That's a collective responsibility, involving the US as well as Canada.
- The responsibility of business and industry. We need to talk about incentives and disincentives regarding the role they're going to play in reacting to global warming.
- The role of western science. The burden of proof regarding climate change and salmon stocks can't be on the scientists. They can't prove everything so there's no point in waiting for them to do so. Their role is to collect information to bring into the debate, and they need to be allowed to do their work.
- International research strategies. We look at everything as if it's a problem, but instead we need to begin, as citizens of the world, looking at these things as challenges.

Finally, said Fortier, we all have to ask, what is our responsibility? What am I going to do? In other words, we need to take spiritual responsibility. We have a responsibility not just to ourselves but to our great-great-great grandchildren. There is a Cree prophecy, he said, that goes like this:

> "Only after the last tree has been cut down,
> Only after the last river has been poisoned,
> Only after the last fish has been caught,
> Only then will you find that money can't be eaten."

Bud Graham, Assistant Deputy Minister, BC Ministry of Fisheries

"Fish will be an important indicator of the impacts of global climate change," said Bud Graham, "and fisheries professionals will be challenged with the task of addressing the effects of climate change." The complexity of the challenge is evident in the diversity of species native to BC. Although the focus is on salmon, these species include both salmonid and non-salmonid species. The salmonids include:

- five species of Pacific salmon;

- steelhead and rainbow trout;
- lake trout, dolly varden, bull trout, and brook trout;
- coastal cutthroat and westslope cutthroat trout;
- brown trout; and
- nine species of Arctic grayling and whitefish.

The non-salmonids include 17 other families of fish, encompassing 65 species. "It's important to recognize that our emphasis on the protection of wild fish goes beyond popular game fish, which make up only about one in four of the freshwater fish in BC," he said. This is vital to the biodiversity and basic functioning of BC's ecosystems.

In attempting to understand the impact that climate change will have on fish resources, said Graham, within each species we must consider the following:

- Basic life history and behaviour information associated with migration, spawning, incubation, emergence, and growth and development in the fry-to-smolt and smolt-to-adult stages of life.
- Habitat requirements in fresh water and/or marine environments, including the needs of water, food, cover, and passageway.
- How different species or life-history stages are limited by other environmental factors such as the hydrologic and temperature regime.

These features combine to form recruitment mechanisms based on life-history stage, said Graham. The challenge is to develop models of life history, habitat requirements, and recruitment, and then test these models with predicted impacts of climate change by season. Already, we have experienced abrupt and dramatic changes in fish abundance and survival rates, which have resulted in significant disruptions to Aboriginal, recreational, and commercial fisheries. Our concerns must focus on species other than salmon, such as herring, shellfish, and groundfish, which also play significant roles in BC's fishery mosaic. It will be important for us to diversify BC's harvest.

Therefore, what strategy should we adopt? "Our task goes beyond documenting the declines," he said. "We are being called upon to provide advice on what actions we should undertake to address these problems." In answering that question, Graham said we must consider both the biological impacts of the change, and the social and economic consequences on the people who depend on fisheries. "In addition," he said, "we need to focus on the activities that we can manage."

Graham put forth a multi-faceted strategy, including the following components:

- Protect existing fish habitat. There must be an emphasis on implementing existing provincial and federal legislation, such as the *Fisheries Protection Act.*
- Maintain genetic and ecosystem diversity. Activities such as gene banking can help to protect us against losing severely endangered species forever.
- Increase productive capacity of fish habitat. This will involve improved communication between, for example, provincial and municipal authorities, and better compensation for individuals who are called on to make personal sacrifices in order to protect habitat.

- Maintain the precautionary principle. We must improve escapements, especially for weak stocks, and recognize that many populations will take years or decades to recover.
- Monitor and inventory stocks. Assess changes to stocks in a timely manner and improve index systems for tracking changes.
- Reduce fishing pressure on stocks. In future, there will be lower catchments and that will mean fleet reductions.
- Develop more selective fishing technology. We must improve technology to ensure protection of weak stocks.
- Increase fishery and community diversification. We must look at harvesting other species in order to keep fishing communities alive. We must also look at aquaculture, to supplement rather than replace wild stocks, and with species other than salmon.
- Improve value. We must look at the value of smaller catches, and work to diversify the markets for other species.

Climate has a history of changing, said Graham, but we don't know if the changes currently occurring will be permanent or cyclical. We do know the changes are not necessarily gradual but can occur quite suddenly. Because of that, we must improve our ability to anticipate and react to them. In doing so, we must understand that salmon ecology in relation to climate change is complex. It's not just that we don't know the answers to many of our questions, but that we don't always know how to find the answers.

Finally, said Graham, "we need to improve cooperation between all levels of government in order to address the impacts of climate change on our fisheries resources." There is a lot of money being spent on different programs to protect our fisheries. We need to come to some agreement on our priorities and focus our resources in order to get the best possible value for our dollars.

Gerry Scott, Climate Action Team, David Suzuki Foundation

Mr. Scott noted that a key component of addressing the impacts of climate change must be involvement of those people who are most directly affected by it. Across the globe, billions of people could well be affected by outbreaks of tropical diseases or impacts on industry, including those in resource industries such as fisheries, forestry and agriculture. Although some people will feel the impacts of this problem more quickly or more directly than others, "none of us can walk away from it."

As a nation, said Scott, Canada has failed to deal with its responsibility for climate change. Canadians are the highest users of energy per capita in the world. Canadians use as much energy as the entire population of the continent of Africa. We also have the second highest per capita emissions of greenhouse gases. Beginning in 1988, we've made commitments to the international community to reduce our energy use and emissions. None of those commitments have been met, "even the minimal ones made at Kyoto," said Scott. Instead, our response has been to increase our emissions.

Nationally, our response has been to "study and delay," said Scott. "We've had umpteen tables examining key sectors responsible for greenhouse gas emissions, what the sources and remedies might be. It's been a failure. The automobile and other industries have used tax dollars to say that nothing can be changed and nothing will be changed." Although there have been some good ideas on the tables, dominant interests at every table oppose change.

"Meanwhile, many other decisions are being made that are driving emissions up," said Scott. For example, the federal government is now considering sinking up to $15 billion into highway development to enhance Canada's trucking industry. Over our history, we've gone from moving freight primarily by rail to moving it primarily by highway. But this increases greenhouse gas emissions. New passenger vehicles in Canada now use 13% more fuel on average than ten years ago. Yet we remain the only OECD nation that is not putting a cent into public transit.

"We're going backwards," said Scott. We must stop making the wrong decisions. We must kill the $15 billion investment in highways and invest in other ways of moving people and freight. As individuals, we should think it through when we choose a new SUV or when we fight municipal zoning changes that would increase density but create more compact communities.

During the energy crisis in the 1970s, said Scott, "we saw incredible adaptations in the way people used and even produced energy." Those adaptations were lost when the crisis ended, but they don't have to be lost permanently. The Suzuki Foundation has produced a report called *Canadian Solutions,* which provides practical steps that Canadians can take to get to the Kyoto commitment.

For example, we must see growth in renewable energy. In Denmark, 13,000 people work in the wind-energy industry, which is making money by exporting high technology to the rest of the world. In Germany, there's been tremendous growth in solar and wind energy. At the same time as British Petroleum is expanding its use of fossil fuels, it's investing $500 million in producing solar energy. Recently, said Scott, he and Dr. Suzuki attended the commencement of the retrofit project at Cadillac-Fairview's Toronto-Dominion Centre in Toronto, which is the largest lighting retrofit project currently underway in North America. The energy savings will allow Cadillac-Fairview to cut their operating costs by over 30% at the same time as the project is producing hundreds of well-paying construction jobs. Retrofit of buildings is happening throughout Canada, said Scott, yet many new buildings are not designed and built with the kinds of energy efficiencies that are going into the Cadillac-Fairview project.

"In Toronto right now," said Scott, "two or three municipalities are fighting over the right to tap methane gas from garbage dumps." That gas can produce electricity, which can produce revenue, so the municipal leaders are fighting over whose garbage went into the dumps and by what ratio so they can divide up the revenue appropriately. Even Dupont Chemical has made a commitment to cut greenhouse gas emissions by 65% over ten years. They're not doing it as volunteers, said Scott, but because it will cut their operating costs, which in turn will make them more competitive. Recently, he said, Dr. Suzuki joined with two gas companies that promote energy efficiency and gave away 1000 copies of a book called Cool Companies, which cites 100 case studies of companies that cut their emissions by up to 60% and made money doing so, to government and corporate leaders.

"Part of the message I'd like to leave here is that the solutions are at hand and they're profitable," said Scott. What we need now is leadership to build public and institutional change. We need to see real carbon taxes, based on the idea that the polluter pays. The atmosphere is not a free dumping ground. We all pay for solid waste disposal and there's no reason why we shouldn't pay for air pollution. If we stopped paving over the Lower Mainland, we could not only preserve fish habitat but cut deaths from air pollution and save health dollars.

"This problem is too immense and far-reaching for us to ignore," said Scott. "We need massive change from above and below. We need bold and decisive leadership. As citizens we must demand that and settle for nothing less."

Lydia Dotto, Science Writer, Author, Storm Warning: Gambling with the Climate of our Planet

Public opinion polls in many countries indicate that citizens want governments to do something about global warming, said Lydia Dotto. Yet politicians remain reluctant to act, perhaps because they pay more attention to what people do—such as buying SUVs and raising a hue and cry over any increases in gas prices—than what they say. And the media perpetuate the problem.

A lot of people don't understand what the problem is. They think the ozone hole causes global warming and ozone has been taken care of. They are unaware of how much emissions must be reduced, or that the 5–6% reduction goals set at Kyoto will, even if implemented, "be barely enough to get the ship stopped, never mind turned around" said Dotto. They're unaware that the Kyoto treaty hasn't been ratified. They don't know that emissions already in the atmosphere will hang around for a century. They think we have time to wait for scientific proof. And they believe the well-financed campaigns by the skeptics that play on their lack of information and understanding.

The debate over global warming has been effectively derailed by skeptics because of a public and media-based preoccupation with legal definitions of proof, a refusal to deal realistically with scientific uncertainty, and a failure to address the question of risk. The demand for proof that global warming is happening, that human activities are causing it, and that it will have negative consequences is a key strategy deployed by the skeptics. Scientific uncertainty fuels these disputes, focusing the scientific community, the media, the public, and policy-makers on the wrong question, which is whether global warming projections will come true, instead of the real question, which is how we'll deal with the consequences if they do.

No one advocates expensive and draconian efforts to prevent global warming without any evidence that it's happening and having adverse impacts, said Dotto. But scientific research has provided compelling evidence that the climate is changing and substantial grounds for concern about its environmental, social, and economic impacts. Yet many skeptics demand a standard of proof associated with a criminal trial—beyond a reasonable doubt—and they have thrust upon the scientific community the burden of proving the global-warming "case" to this standard. Scientists are often preoccupied with such demands for proof, yet no one questions this setting of ground rules by one of the combatants in the dispute. Perhaps, if we are going to look at the subject from a legal perspective, the criterion that should apply is that of the civil case: the preponderance of evidence. It provides the foundation for the precautionary principle, since it's generally considered sensible to take precautions against adverse consequences that are more likely to happen than not.

Scientific uncertainty is one of the most misunderstood aspects of this issue, said Dotto. Scientists classify things as uncertain at a much higher level than most of us do in our daily lives. Most disputes among scientists occur when their level of confidence is from 90–99%, but the public often concludes that scientists can't agree on anything and that, if they can't agree, the problem must not be that bad or must not exist at all. They fail to realize that uncertainty goes in both directions, that it's just as likely the situation will be worse than scientists project as that it will be better.

There is and always will be uncertainty. But the fact that elements of global-warming theory are uncertain does not negate the high levels of confidence that most climate researchers have about the fundamental elements of the problem. Unfortunately, many people still believe the skeptics when they exhort us to wait for proof before doing anything. "It's like driving down an unfamiliar

mountain road in the dark, a place that you've been told is subject to rock falls," said Dotto. "Do you speed up or slow down? It's a perverse logic that uses ignorance of what lies ahead as a reason to speed up." It doesn't matter whether the skeptics win the debate over proof because simply creating the debate has achieved the objective of delaying measures to reduce greenhouse gas emissions.

Media coverage generally exacerbates the problem, said Dotto. Some critics argue that, in trying to appear balanced and fair, the media often create the impression that the weight of scientific opinion is more evenly divided than it really is. The media understand their duty to be to give both sides equal weight, as they might in covering a war or parliamentary debate. This stems from the inability of most journalists, few of whom are science writers, to weigh the scientific merits of the two sides. Tom Yulsman, an American professor of journalism, argues that journalists covering complex environmental issues "should not give equal weight to both sides of an issue if, in fact, the balance of scientific opinion weights on one side over another." Journalists need to "assess where the balance lies and report what they learn to their readers. The skeptics should get time, but not equal time." This is heresy to most journalists.

But nothing much will happen politically until public and media perceptions shift from proof to risk. Risk has two components: the probability that something will happen and the consequences if it does. "This concept is not difficult for the average person to grasp," said Dotto. "In our own lives, it's called insurance." We buy insurance not because we're sure disaster will occur but because we don't want to face catastrophic loss if it does. It's because the consequences are potentially devastating that we protect ourselves against them even if we believe their probability of happening is very low.

There is evidence that we are facing increased floods, droughts, tornadoes, hurricanes, and ice storms, "which raise the stakes in this gamble we're taking with the earth's climate," said Dotto. Scientists are reluctant to connect specific events with global warming, although some say they are consistent with what would be expected in a warmer climate. We need to understand scientists' need to be careful, but we must also consider the effect this has on the public and the media: People believe that if the scientists don't say there's a problem, there must be no problem.

This hesitancy makes it difficult for the media to take the science behind climate change seriously. Coverage of most extreme weather events focuses on human-interest aspects and economic impacts. We get saturation coverage of the event itself, but little interest in the science that might explain it. The underlying attitude is that "we've done global warming."

What we need to do is get the media and public to reframe global warming, to understand that there is no proof that global warming will cause catastrophic damages, that there probably will be no proof unless and until it happens, but that the probability that it will do so is at least as high as for many of the risks against which we routinely protect ourselves. The argument that we're waiting for proof is a misleading way of presenting an option that does not involve waiting at all, but is an affirmative decision to allow our experiment on the earth's climate to proceed unchecked. We must recognize waiting for proof for what it is: a form of gambling.

It is said that one of the things that distinguishes humans from other animals is the ability to perceive the future. But as Nobel Laureate Sherwood Rowland has said, "what's the use of having developed a science well enough to make predictions, if in the end, all we're willing to do is stand around and wait for them to come true?"

Discussion

A participant made two points. To Bud Graham, he said that the *Fish Protection Act* is not "worth the paper it's written on," noting that although DOF biologists had listed 200 sensitive streams in the Fraser Basin, only 14 were receiving protection because the others were too controversial. To Carl Walters he said spending money to find out why fish are dying in the ocean would not be productive because, "What if we find out it's because of predators—we go out and shoot all the seals in the Strait?" He said the money should be spent on things that can be fixed, like buying out water licenses because "fish don't survive well in dry river beds."

Graham responded that the "controversy" preventing so many streams from being protected involves individual people who fear the impact on their homes and/or livelihoods. Therefore, protecting streams can take a great deal of negotiation. He noted that another stream had been added to the list of those being protected and said, "15 is a start and it's better than zero." Walters said he suspected what they'd find through research is disease originating in production systems. If the problem turned out to be with predators, that would be managed through applied ecology.

A participant asked Graham how the government could reconcile its emphasis on wild fish production with a recent announcement regarding the creation of more fish farms. Graham replied that the provincial government believes wild salmon is important, but that wild salmon harvests will be different in the future than in the past. This will affect a lot of people and increased emphasis on fish farming will help people make the transition. The province commissioned a report on salmon aquaculture, he said, and the authors saw it as a legitimate industry, albeit with certain recommended restrictions. The government is now trying to provide incentives in the form of new tenures on the condition that those receiving them will use closed containment technologies.

A participant commented to Graham that she understood the resistance to the *Fish Protection Act (FPA)* on the part of many small landowners whose properties include small streams. She noted "callous disregard" for people who are living on small pieces of property who are told that their land must become "93% riparian" without any compensation for their loss. "This is part of the political opposition," she said. Graham said that one object of the *FPA* is to guide development, and that the *FPA* people are committed to working with municipalities to establish rules that will be acceptable. But small streams are vital to wild fisheries, and BC people have said they value the wild fisheries, so the government is not showing callous disregard of the rights of individuals by recognizing widely-held values and acting to protect them.

A participant told Dotto that the media covers things that appear to be life and death, so maybe better media coverage is a question of the way global warming is being sold. Dotto responded that when there are extreme weather events, the media cover them. However, she said, her point is that they cover the extreme weather event itself rather than looking into the science behind the event.

CONCLUDING REMARKS

John Fraser expressed his appreciation to all who attended, "especially those who took umbrage with the issues. That's part of a vigourous exchange." The general consensus, he said, is that we're going through a period of climate change. The disagreement surrounds whether it is natural or caused by human activity. The probability of increased problems requires that we:

- Determine what to do about saving the fish. We must ensure that as many fish as possible from all species spawn in order to maximize genetic diversity among the survivors. Although we need more information in order to determine where money will best be spent, we must ensure that governments know that the vast majority of Canadians care deeply about this issue.
- Recognize that the entire issue has been around for a long time and is intensely political. "I spent many years working on the climate change issue as an MP," he said, noting that he sees signs that the federal government is beginning to take the issue seriously. It's becoming clear, he said, that it is not a question of proof but of risk, and that we can't afford to do nothing about it.

It's important to remember, Fraser said, that this is not just a BC issue and it's not just about fish. It's international. The US Senate says that it won't do anything about emissions until emerging nations say they'll do something. Meanwhile, emerging nations are saying to industrial nations, you started the industrial revolution, you take the first step in addressing the damages. At the same time, Canadians think that because we only produce a small percentage of emissions overall, we don't need to do anything.

We can't be leaders if we don't set an example, said Fraser. We must face facts, because not facing them is unrealistic. The facts are not pleasant but the possibilities are there for better cars, wind and solar power, and other methods of being more energy efficient. We must focus on the positive aspects, the opportunities, he said. Because if we only focus on how bad it is, we will lose hope and do nothing, and that's a course of action we can't afford.

COUNCIL'S COMMENTS

The October 27 workshop presentations and discussions on climate change provided a necessary baseline for the Pacific Fisheries Resource Conservation Council to comment on the issues that arose and to offer guidance for public policies.

Council members emerged from the workshop with a sense of apprehension and concern. While an array of contrasting opinions and differing interpretations regarding the effects of climate change had been expressed during the course of the day, still the overwhelming impression was one of disturbing implications in the impact of climate change for current and future generations.

Much of the available evidence about climate change illustrates disconcerting trends and influences that affect the viability of Canada's wildlife, traditional industries, and ways of life.

The workshop reinforced that the research and knowledge base that underpins much of what we know about climate change is still in its formative years. But, the risks associated with climate change are becoming more apparent as we observe, but do not clearly understand, the impact it appears to be having. The scientific knowledge that is being generated may only rarely be definitive. It may be unable to give immediate guidance to governments to mitigate the negative aspects of climate change associated with human activities. But, science provides a necessary set of rational boundaries within which climate change issues should be debated. The importance of persuasive evidence and cause-and-effect relationships is crucial to ensure that the issues are given full and fair consideration.

At the same time, the lack of absolute scientific certainty or the inability to identify every causal factor cannot be an excuse for government inaction where effects and evidence can clearly be inferred, even if not immediately proven.

The examples of the asbestos and tobacco industries and their claims of insufficient proof linking their products to health conditions have provided vivid illustrations of how scientific proof from research can lag behind the ability to make inferences from convincing, though not irrefutable, evidence. Government action in such conditions is justified by its adherence to the precautionary principle.

In dealing with issues related to climate change, governments can focus on the contributions of science and recognize the value of the knowledge it offers. At the same time, government decision-makers must deal with the uncertainties that inevitably come from a lack of absolute sureness. They must be ready to assume effects based on the risks of inaction in the face of the weight of evidence. Here, too, adherence to the precautionary principle exhibits the reasonable exercise of judgement in a field where there are no absolutes.

No one should underestimate the seriousness of climate change issues for salmon or other species. A great deal can already be inferred from what we know about matters such as the growth of greenhouse gases and their effects. Recognition of this issue in the Kyoto Accord, for instance, illustrates the stated intent and official commitment of governments to act more decisively.

Climate change is not merely a matter of naturally evolving conditions over centuries. What we are doing now in terms of polluting activities with direct environmental effects is speeding up the process and risking the creation of uncontrollable conditions in the near future.

The prospects for survival of Canada's Pacific salmon may be determined largely by what can be done to counter the effects of human activities that are impacting climate change. The discussion

of this workshop provided a strong first step towards understanding and dealing with climate change impacts on salmon.

Observations and Findings

Some crucial information and comments were presented by participants in the course of the workshop, and they are worth noting as highlights. Climate is the average of the weather: at any one place climatic conditions vary seasonally, according to some expected pattern based on the experience of many years. For instance, Vancouver's climate is recognizably different from that of Prince George, or that of Honolulu.

Over long periods of time, however, climate itself may shift. British Columbia's climate was certainly quite different during the last Ice Age, which ended about ten thousand years ago. Since then, climatologists have identified, in tree rings and ice cores, other long-term climate fluctuations. Recently, there have been signs of a gradual warming: the last few years were the warmest on record. Trends in climate properties have been associated with El Niño, an equatorial Pacific phenomenon, or with a general warming of the atmosphere related to human activities.

In his presentation, Henry Hengeveld outlined the current scientific views on global climate change and its causes. He showed that there is solid evidence for long-term global trends in atmospheric and oceanic properties. For example, average ground-level temperatures in the North Hemisphere have increased by about 0.6°C in the past century. Slow rising trends in ocean temperature and total volume have also been observed. Scientific consensus indicates that such trends are most probably linked to human activities and result from increased concentrations of greenhouse gases in the atmosphere.

While uncertainties remain in just what we should expect in fifty years, the probability that "global warming will cause catastrophic damages", to quote Lydia Dotto, "is at least as high as for many of the risks against which we routinely protect ourselves".

Projections of long-term climate change, both at sea and on land, as well as uncertainty regarding possible changes in the major sources of short-term climate variability suggest future environmental conditions potentially quite different from today's. They could be different enough that they may not have been encountered by salmon for many millennia, if ever. Again, in the presence of such possibilities, it is only prudent to respond to the risk by taking appropriate mitigating measures.

As we heard from Dr. Brian Shuter, freshwater fish are sensitive to changes in the climate of their habitat. Fish thrive in lakes and rivers within a range of climatic conditions. Warm-water species are found only so far north; cold-water species, on the other hand, have a southern limit. Shifts in climate cause these limits to change. During those parts of their life spent in fresh water, salmon are responsive to changes in lake or river environments. Juvenile salmon are affected by lake and river temperatures, food availability, and presence of predators. When they return as spawners later in their life cycle, salmon are also sensitive to changes in flow regimes, as well as to thermal conditions along their migration paths.

Fisheries scientists are still exploring the links between changes in ocean properties and the survival rate of salmon at sea where they spend much of their life. It appears that broad ecosystem variations associated with temperature changes are probably more important for salmon survival than the direct influence of physical variables like temperature on individual fish.

The ocean realm in which salmon are comfortable may also shrink, as Dr. David Welch pointed out, thus decreasing the area of ocean available for salmon production as well as stretching the migration path to their natal systems.

Marine survival is thought to be determined mostly during the first few months of marine life. Changes in the properties of coastal waters or of the ecosystem they contain will affect young salmon. Once in the open ocean, salmon are found in cool waters, north of a certain ocean surface temperature that varies with the seasons. Global warming would push that temperature northward, shrinking the area available to salmon and extending their migration path. Adult salmon may thus be seriously impacted by climate change.

There is too much that we do not know about what happens in the ocean to project future conditions of fish stocks with any confidence. Natural fluctuations in the presence and abundance of most marine species are the rule rather than the exception. Reasonable hypotheses for these fluctuations are not lacking, but few of even the worst fisheries collapses have been explained.

The ecosystem is complex in structure and heterogeneous in space. Changes in primary productivity—microscopic algae—are related to rapid renewal of nutrients in the ocean's surface waters that, in turn, are sensitive to changes in winds, ocean circulation and water temperature. Small shifts in basic productivity may be amplified in the food chain when they persist for years at a time. A variety of other fish species besides salmon—such as hake, herring, halibut and cod—are showing declines in growth and/or abundance indicative of a persistent change in ecosystem productivity.

Persistent changes appear to be particularly strong in a few coastal areas (Georgia Strait, Rivers and Smith inlets), with some hints that north coast areas may soon be affected. Thus, much may be happening to fish as they disperse in the ocean and interact with their environment, but science does not possess the power of infinite observation capacity and information storage to follow their fate.

Salmon in the Ecosystem

From the Council's perspective, the most immediate and relevant issues of climate change are those that have an impact on salmon and conservation in the Pacific fisheries. Salmon serve as a bellwether of the more wide-reaching effects of climate change. It is crucial to maintain the perspective of this larger context and the impact on salmon and other species. In fact, the impact of climate change on vegetation has also been identified in several instances.

The impact on salmon serves as an indicator of the prospects for other species. Their sensitivity to temperature is widely recognized, and climate change seems likely to take a particular toll on their survival prospects ahead of others. Like the canary taken into a mine, salmon may be the precursor of problems that all of us will face as the consequences of climate change become more evident.

It is important that action on climate change should not be predicated only on mitigating the effects on salmon. Salmon is just one example, however important to this Council, of a species impacted by climate change. The effect on salmon should be recognized in terms of the entire ecosystem that is being influenced. This greater economic and social context should be a prevailing element in any research or government action that may be considered to assess climate change impacts on salmon.

Changes in the ocean ecosystem affect all living marine resources, not only salmon stocks. What is at stake is not just the salmon capture fishery that is in the throes of uncertainty in its competition with salmon farming, but all marine food production, wild and farmed.

Research and Action

Canadians need to know more about the impact of climate change and its effects on salmon and other species. That said, the reaction of calling for more research is not necessarily the appropriate course.

The members of the Council working in universities and research institutions have, to their credit, been the first to point out that merely spending more on research is not automatically going to produce valuable information or generate solutions to mitigate climate change problems. More research can have considerable value, but this should not be the only response to the uncertainty and lack of knowledge about climate change.

The Council is concerned that, in a cumulative sense, the current research agendas of universities and government agencies may not be leading to the kind of information needed to cope with fisheries challenges that seem to be related to climate change. Some of the studies and on-going research appear to yield limited useful information about the correlation between climate change and fisheries.

Clearer and more regionally specific projections of climate change are needed. Regional modeling and an assessment of the sensitivity of marine coastal areas will be necessary to get a firm grip on projected climate change and variability. Computer simulations may help, but they must be well based on observation if they are to be trusted.

Council members will be considering this issue of research in more detail in upcoming discussions. Suffice it to say for now that research may have to be altered in order to begin measuring the impacts of climate change in ways that will enable governments and the Canadian public to understand and respond to the challenges.

Canadians will be supportive of government decisions based on the premise of the precautionary principle. Too many fundamental environmental changes related to human activities can never be undone, no matter how much money is spent after the fact.

It would be unwise and a potential tragedy for generations to come if governments were to allow climate change to be accelerated merely because of the absence of absolute or irrefutable specific evidence in every instance. The validity of empirical evidence and the legitimate inference of facts should also be guiding standards for governments in such circumstances. Delaying action where reasonable evidence is available is not an acceptable or responsible alternative.

In terms of immediate action, governments and individual Canadians have to become more seriously committed to reducing greenhouse gas emissions. There is no reason for confidence, given the level of effort and limited funding provided so far, that Canada will meet its Kyoto Accord commitments. This country may not even maintain its current greenhouse gas emission levels, never mind reduce them. Without more recognition of this issue and a combination of stronger sanctions and incentives, greenhouse gas emissions will take a serious toll in accelerating climate change.

AGENDA: PACIFIC FISHERIES RESOURCE CONSERVATION COUNCIL CLIMATE CHANGE AND SALMON STOCKS

The Pacific Fisheries Resource Conservation Council (PFRCC), chaired by the Hon. John A. Fraser, will host a one-day conference on "Climate Change and Salmon Stocks." The conference will take place at the Simon Fraser University Harbour Centre Campus in Vancouver on October 27, 1999. A copy of the program follows.

09:00—WELCOME

Hon. John A. Fraser, Chairman of the Pacific Fisheries Resource Conservation Council

09:10—INTRODUCTION

Dr. Paul LeBlond, Council Member of the PFRCC

Mr. Henry Hengeveld, Environment Canada:
"Climate Change and the Ocean Environment—Understanding the Science."

BREAK

Dr. Brian Shuter, University of Toronto:
"Climate and the Life History and Zoogeography of Fish."

Dr. Richard Beamish, Fisheries and Oceans Canada, Nanaimo, BC:
"Why a Strategy for Managing Salmon in a Changing Climate is Urgently Needed."

11:00—QUESTIONS AND GENERAL DISCUSSION

12:00—LUNCH

Afternoon panels will be followed by questions and discussion.

13:15—PANEL 1

"What is the most alarming potential impact of climate change on salmon stocks?"

Mr. Arnie Narcisse, BC Aboriginal Fisheries Commission
Dr. David Welch, Fisheries and Oceans Canada, Nanaimo, BC
Mr. Frank Whitney, Fisheries and Oceans Canada, Sydney, BC

BREAK

15:00—PANEL 2

"What is the best strategy to adopt?"

Ms. Lydia Dotto, Peterborough, ON; author of Storm Warning: Gambling with the Climate of Our Planet
Mr. Fred Fortier, BC Aboriginal Fisheries Commission
Mr. Bud Graham, Assistant Deputy Minister, BC Ministry of Fisheries
Mr. Gerry Scott, Climate Action Team, David Suzuki Foundation
Dr. Carl Walters, UBC

16:45—CONCLUSIONS

Hon. John Fraser, Chairman of the Pacific Fisheries Resource Conservation Council

SPEAKERS' BIOGRAPHIES

Dr. Richard Beamish

Dr. Richard Beamish is a senior scientist at the Department of Fisheries and Oceans' Pacific Biological Station in Nanaimo BC, of which he was the Director from 1980–1993. At the beginning of his career, Dr. Beamish studied freshwater fish; he was the first to recognize the impact of acid rain on freshwater fisheries. He has made significant contributions to the biology of ground fish in BC waters, discovering that some rockfish live to be 100 years old! Dr. Beamish has been very active in international fisheries flora in the North Pacific and has collaborated widely with foreign scientists on a variety of fisheries issues, more lately on the identification of the impacts of climate change on fish stocks. Dr. Beamish is a graduate of the University of Toronto. He is an Affiliate-Professor at Malaspina University College in Nanaimo and the recipient of many awards, including the Order of Canada.

Lydia Dotto

Lydia Dotto has been a science writer for nearly 30 years. She is a former science reporter for the *Globe and Mail* and ran Canadian Science News Service for ten years. She has written for many Canadian magazines (e.g., *Equinox, EnRoute, Canadian Business*) and has worked on science television documentaries broadcast on CBC and the Discovery Channel. Dotto is the author of more than a dozen books, including three on environmental themes: *Storm Warning: Gambling with the Climate of Our Planet, Ethical Choices and Global Greenhouse Warming,* and *Thinking the Unthinkable: The Social Consequences of Rapid Climate Change.* Other books focus on sleep research and the space program.

Dotto also teaches science writing and conducts communications workshops for scientists. She is a member of Environment Canada's Science and Technology Advisory Board and NSERC's Communications Advisory Board. She has received many awards from the Canadian Science Writers Association and is a recipient of the Royal Canadian Institute's Sandford Fleming Medal for outstanding achievement in promoting understanding of science among the Canadian public.

Fred Fortier

Fred Fortier is a Senior Councilor for the North Thompson Indian Band, one of the 17 Shuswap or Secwepemc First Nations from the South-Central Interior of BC. His Peoples are known by the Secwepemc as the Simpc, or "the people up-river". His occupation and avocation in the last decade has been almost exclusively fisheries related. He has become known for his work to recover wild fish populations and as an advocate of aboriginal rights and responsibilities in fisheries.

Fred works as the Chairman of the Shuswap Nation Fisheries Commission and the Columbia River Inter-tribal Fisheries Commission in his territory, and is responsible for coordination of fisheries management in the Columbia and Fraser Rivers involving the area Bands including related government arrangements. Fred was recently appointed Chair of the BC Aboriginal Fisheries Commission (BCAFC), where he is responsible for the regional coordination of information and policy associated with aboriginal fisheries in the province. A key component of his work in the last ten years has been the development of an international working group of indigenous peoples on aquatic biological diversity, and has played a leadership role in related work with the Convention on Biological Diversity.

Fred sits on the Board of the Global Indigenous Knowledge Program, the World Fisheries Trust and the Pacific Coast Sustainable Fisheries Strategy.

Hon. John A. Fraser

Raised in Vancouver, Mr. Fraser has had a lifelong interest and commitment to environmental matters. After graduation in law from the University of British Columbia in 1954, he practiced law until his election to the House of Commons in 1972. During his 21-year history with the House of Commons (1972 to 1993), Mr. Fraser served in a number of positions that addressed environmental concerns. These included positions as Minister for the Environment, Minister of Fisheries and Speaker of the House of Commons. In the latter post, Mr. Fraser was responsible for the establishment of the House of Commons Environmental Program, *Greening the Hill.*

In 1994, Mr. Fraser was appointed Canada's Ambassador for the Environment. In this role, he has been responsible for Canadian follow-up to commitments made not only at the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992, but to related events and activities such as the Convention on Biological Diversity, Desertification, and Climate Change; the ongoing discussions on forests, the United Nations Environment Program, and the United Nations Commission on Sustainable Development. This included liaison with a variety of international bodies, federal departments, provincial governments, the private sector, academic institutions, community groups and interested individuals. Mr. Fraser also sits on a wide range of domestic and international bodies which address environment and sustainable development issues; including the International Institute for Sustainable Development, the UNESCO Canada Man and the Biosphere Committee, the Advisory Committee for Protection of the Seas, and the Kitlope Management Committee. Mr. Fraser is an officer of the Order of Canada (O.C.), a member of the Order of British Columbia (O.B.C.) and holds the Canadian Forces Decoration (C.D.). He is also a Queen's Counsel (Q.C.)

Bud Graham

Bud Graham joined the BC Ministry of Fisheries in May 1998 as Assistant Deputy Minister, Programs and Operations. Previously, he spent 27 years with the Federal Department of Fisheries and Oceans in various roles including Director, Fisheries Management (1994–1998) and Chief, International and Intergovernmental Affairs (1986–1993). Mr. Graham is also a founding member of the association of Professional Biologists of BC. He has served on the executive of the Association and as a member of the Board of Examiners. Mr. Graham is a graduate of the University of Victoria and of Simon Fraser University.

Henry Hengeveld

Henry Hengeveld obtained his BSc in Mathematics and Physics in 1968 and his MSc in Meteorology in 1970, both at University of Toronto. After more than a decade of studies related to remote sensing of sea ice, he began his role as science advisor on climate change within Environment Canada in 1982, a role he continues to undertake today. As science advisor, he undertakes regular assessments of international scientific literature related to climate change and communicates related information to a broad range of scientific and lay audiences, including policy makers, industry groups and the general public. Throughout the past decade, he has been actively involved in a variety of international meetings dealing with both climate change science assessment and the development of related global agreements on mitigative action.

Dr. Paul LeBlond

Dr. Paul LeBlond retired from The University of British Columbia in 1996 following a teaching and research career in the physics of the oceans. He is a member of the Canadian Meteorological and Oceanographic Society, which awarded him the President's Prize (1982) and the Tully Medal (1991). He was the Scientific Leader of the OPEN Network of Centres of Excellence and Chair of the National Committee for the World Ocean Circulation Experiment. Dr. LeBlond is a member of our Pacific Fisheries Resource Conservation Council; he chairs the Science and Industry Advisory Board of the Institute for Pacific Science and Technology as well as the Science Advisory Council of the Department of Fisheries and Oceans. He is also a Fellow of the Royal Society of Canada and a Foreign Member of the Russian Academy of Natural Sciences. Dr. LeBlond studied Mathematics and Physics at McGill University, Oceanography at the University of British Columbia (PhD 1964) and undertook a post-doctoral fellowship in Germany.

Arnie Narcisse

Arnie Narcisse is the Interior Co-Chair of the B.C. Aboriginal Fisheries Commission and the manager of the Nicola Watershed Stewardship and Fisheries Authority. As a fisherman who depends on salmon to feed his family, Mr. Narcisse brings a down-to-earth approach to salmon stock and habitat stewardship while keeping abreast of modern ecological and management ideas. Mr. Narcisse is an effective consensus-builder who has succeeded in bringing together "the cowboys and the Indians" in a number of fisheries projects in the Nicola Valley.

Gerry Scott

Gerry Scott, of the David Suzuki Foundation, is the Director of the Climate Change Campaign. Gerry has worked with the Foundation for the past 18 months, building up the Foundation's climate change program, which includes research and communications initiatives, public education, and identification of climate protection solutions. Gerry spent many years working in political and governmental circles, in the areas of communications, strategy and policy research. A good deal of that work involved natural resource and environmental issues and his involvement in public policy advocacy started in 1971, with the Great Vancouver Freeway debate.

Dr. Brian Shuter

Dr. Brian Shuter is a research scientist with the Aquatic Ecosystem Science Section of the Ontario Ministry of Natural Resources. He is also an adjunct professor at the Zoology Department, University of Toronto. His research focus is the dynamics of fish populations. He has worked extensively on the ways in which climate affects populations of small mouth bass, yellow perch and other North American freshwater fish. He is senior author of the Fisheries Chapter in the recently completed assessment of impacts of climate change on Canada: *Canada Country Study: Climate Impacts and Adaptation.* He received his PhD from the University of Toronto in 1975.

Dr. Carl Walters

Dr. Carl Walters is Professor of Graduate Studies in the Fisheries Centre and Zoology at the University of British Columbia. He holds a PhD and an MS from Colorado State University in Fort Collins, Colorado, a BSc from Humboldt State College in Arcata, California, and is a Fellow of the Royal Society of Canada. Mr. Walters' main research work is on the theory of harvesting in

natural resource management. His chief interest is in the basic problem of how to behave adaptively in the face of extreme uncertainty. Mr. Walters also maintains an active field research program on recreational fisheries in the British Columbia interior.

Dr. David Welch

Dr. David Welch received a BSc in Biology and Economics from the University of Toronto in 1977 and a PhD in Oceanography from Dalhousie University in Halifax, Nova Scotia, in 1985. His doctoral research was in the area of mathematical population dynamics applied to fisheries management. After several years conducting stock assessment research on Pacific salmon stocks he was appointed Program Head for the Canadian Government's High Seas Salmon Program in 1990. Since that time he has been responsible for developing ocean research programs on the effects of global warming on Pacific salmon stocks and for investigating the overall capacity of the Pacific Ocean for supporting salmon stocks under changing climates. Dr. Welch's work on potential impacts of global climate change on Pacific salmon stocks has been widely described in the popular media. A one-hour television documentary describing his ocean research program was also aired in 1997. Dr. Welch is the author of over 100 primary scientific publications and technical reports, and has also served as an expert consultant to both governments and the private sector regarding potential societal impacts of climate change. He has received several awards and frequent invitations to speak to both scientific and lay audiences. Dr. Welch speaks fluent Japanese.

Frank Whitney

For the past several years, Frank has lead the Line P program at the Institute of Ocean Sciences, DFO. Line P surveys have been the mainstay of his open ocean research since 1956, and were part of both the World Ocean Circulation Experiment (WOCE) and Canadian Joint Global Ocean Flux Studies (JGOFS) of the mid 1990s. His specific interest is climate-induced variability in nutrient supply to the upper ocean. Frank graduated with a BSc in Chemistry from the University of British Columbia in 1969. Since then, he has worked in oceanography on the BC coast with UBC and DFO.

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