# Environmental Review

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## Salmon Without Rivers

Introduction:

The title of Jim Lichatowich's book, *Salmon without Rivers, A History of the Pacific Salmon Crisis*, refers to a statement attributed to the Washington state department of fisheries in 1960 and deserves to be quoted in full[1]. "... new simplified methods of salmon egg incubation and predator and hydraulic control in water areas, plus the impoundment of migrating salmon at or near the rearing ponds for the artificial taking of spawn, may provide the reality — salmon without a river."

Wild salmon have a complicated life history. They are born in shallow freshwater gravel beds, live as juveniles in freshwater streams, as adults in the ocean, and return to their natal stream to reproduce and die. If any one part of their life history is blocked, the salmon will disappear from that system. They can have pristine habitat inland and ideal conditions in the ocean but if a dam blocks their return, the salmon will disappear from that watershed in one generation. These facts of salmon life have been known to fisheries managers for 125 years. Rather than restrict development in salmon habitat we chose to rely on artificial propation of salmon in hatcheries. This was a reasonable seeming solution to the conflict at the time, but it has not worked. Salmon populations are in trouble up and down the West Coast of the United States except for Alaska.

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We spoke with Jim Lichatowich about the natural history of salmon and what can be done for their recovery. Jim has worked on Pacific salmon issues as a researcher, manager, and scientific advisor for thirty years. He has served as a member of three independent science panels studying issues related to Pacific salmon management and recovery. He specializes in evaluation of the ecology and status of salmon and steelhead populations and the development of restoration plans. His new book, *Salmon Without Rivers*, describes the roots of the salmon crisis. His book is written for the general audience and is documented with a large bibliography.

**ER:** Jim, how far back do we need to go to understand the salmon problem?

**JL:** I think to understand the salmon's problem we have to touch briefly on their evolutionary history. The Northwest is one of the more geologically active regions in North America. That means the salmon had to survive a rough evolutionary trip. Over the last several million years the salmon had to survive mountain building, which drastically changed their rivers as the Coast Range and the Cascade Ranges rose up; they had to survive volcanoes, and they had to survive rivers of lava that filled river channels when the Earth literally opened up and spread twenty to forty feet of lava over large areas of Oregon and Washington. The salmon had to survive ice ages when their rivers were under glaciers and then an intense, hot, dry climate for several thousand years following the the last Ice Age.

To understand the salmon's problem today we have to understand the evolutionary legacy they acquired during that trial by fire and ice. I'm going to focus on three key traits of that legacy. One is the ability to recolonize new or renewed habitat. Geologic events such as mountain building, ice ages, and lava flows continuously rearranged river channels, the salmon's habitat. Old channels were cut off and new ones were created. Some habitat was degraded in

quality while other habitat was restored through natural processes. For salmon to survive they had to be able to find and recolonize those new or restored habitats.

Furthermore, to survive they had to adapt to the particular conditions in the recolonized habitat. The geologic history of the Northwest created aquatic habitats with very diverse attributes: short coastal streams and streams that penetrate to and into the Rocky Mountains, streams that flow through deserts and streams that flow through rain forests, some salmon and steelhead streams do not flow throughout the whole year. The salmon had to adapt to these very different environments.

So the ability to colonize and adapt to local conditions were real important. The third trait and the one that facilitated the first two is the salmon's rich life history diversity. Most of us are familiar with the diversity of life histories between salmon species. For example, the differences in pink and chinook salmon in their age at maturity, time spent in the ocean and fresh water and their spawning habitats. But, within a species and within a single population there is also a rich life history diversity, a rich diversity in the way the salmon use their home stream for spawning, rearing, migration, and feeding as juveniles.

**ER:** You mean they use different parts of the habitat at different stages in their life?

**JL:** Yes, and at different times. So in a healthy salmon population, individual fish spawn at different times and places and the juveniles use different rearing habitats and migrate downstream to the ocean at different times. In other words, within a healthy salmon population, the fish follow many different pathways through the fresh water and marine environments.

This rich life history diversity is how they not only survived the geologic history of the Northwest, but it allowed them to become productive in the diverse array of habitats they were found in when the Euro-Americans arrived in the Pacific Northwest. They flourished because they didn't all do the same thing at the same time and in the same place. They diversified, much the way a smart investor diversifies his portfolio as a hedge against the ups and downs of the market. The salmon population diversified their use of the habitat, their life history, as a hedge against environmental variability.

Since the arrival of Euro-Americans we have been destroying life history diversity through our destruction of salmon habitats and even through our management, the way we operate hatcheries and regulate harvest. We have been destroying the salmon's evolutionary legacy, the basis for their productivity. We have been destroying their ability to cope with changes in their environment such as changing ocean conditions.

It's important to recognize that while we destroyed habitat and over harvested the salmon, we really did not intend to bring these fish to the brink of extinction. In fact, just the opposite was the case. Very early, state legislatures enacted laws to protect salmon from sawdust in the streams and from dams that blocked their migration. The state legislatures also set up institutions like the fish and wildlife agencies to manage and conserve the salmon for present and future generations.

By the late 1800s political and business people recognized that the salmon canning industry was going to be an important economic asset for the region so they became concerned about maintaining the supply of fish. They asked the U. S. Fish Commission

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for answers to two questions: What was going to cause the decline in the supply of salmon and what can they do about it? Spencer Baird, the U.S. Fish Commissioner wrote back and said there were three things that would cause the decline of salmon: over harvest, habitat change, and dams.

**ER:** When was that?

**JL:** That was 1875. The main causes for the salmon's decline haven't changed for 125 years. However, knowing what was going to deplete the salmon and establishing institutions to prevent it wasn't enough. The obvious question is why? The answer to that question is in the second part of Spencer Baird's report. He said the solution to those problems is not more regulations but investing money in the artificial propagation of salmon. Hatcheries would make fish so abundant we wouldn't have to worry about the other problems.

That report set salmon management in the wrong direction and it created a very simple salmon management model: We would raise fish in hatcheries and feed those fish directly into the fisheries. To implement this model managers had to focus on two things, artificial propagation, the farming of fish, and the allocation of harvest to the various fisheries. Habitat was not given a very high priority until recently.

Salmon managers accepted that simple model wholeheartedly. They accepted it so wholeheartedly they didn't even bother to seriously evaluate for another fifty or sixty years whether it was working. When hatcheries were proposed by Spencer Baird in 1875 he had no scientific basis for his recommendation. In fact, when Spencer Baird wrote his report in 1875, the first salmon hatchery on the Pacific Coast was only three years old. The first adults from the first artificially propagated brood had not returned as adults yet. So Baird had no scientific basis for his recommendation.

**ER:** Why did we buy into hatcheries lock, stock, and barrel?

**JL:** Artificial propagation was accepted so readily because it fit the laissez-faire ideology of the time. Hatcheries allowed cannery operators access to the salmon with few restrictions; hatcheries permitted full development of the watersheds — dams, logging, irrigation, grazing, etc. — while promising to maintain the supply of salmon.

Hatcheries were a technology derived from the prevailing ideology rather than science. In his book, *Imagined Worlds*, the physicist Freeman Dyson talked about ideologically driven technology. He said one of the problems with ideologically driven technology is that it's never allowed to fail, and the signs of failure are ignored until great damage has been done. Hatcheries fit that scenario very well.

**ER:** Hadn't there been some experience with hatcheries in the East Coast and in Europe prior to the 1870s?

**JL:** The first person to artificially propagate Atlantic salmon was a German nobleman in the late 1700s. He published his results but the technology didn't become popular, except in a few academic circles. In the 1840s artificial propagation was rediscovered in Europe. It was imported to the United States in the 1850s, but it didn't reach the West Coast until 1872. At that time there was no track record of success.

The evolutionary history of the salmon and the history of artificial propagation collided in the Pacific Northwest in the late 19th century. Hatcheries themselves and the activities they permitted (overharvest and habitat degradation) eroded the salmon's evolutionary legacy, their biological diversity.

**ER:** Is there any salmon habitat that isn't degraded?

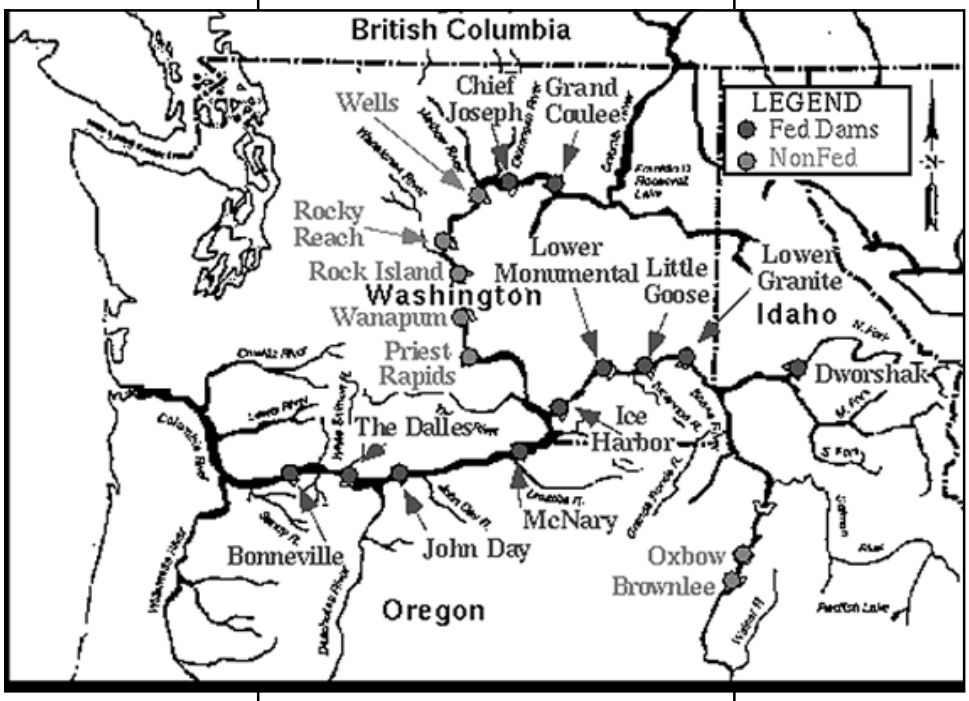
**JL:** There are some rivers that still contain relatively undisturbed salmon habitat. The Elwha River above the dams flows through the Olympic National Park. If the dams are removed salmon will have access to that habitat. Parts of the Salmon River in Idaho are still pristine. But salmon are migratory, so a salmon that hatches in a pristine section of the Salmon River still has to face degraded habitat in the Columbia River as they migrate downstream.

The salmon's life history can be visualized as a chain of places — habitats — where they carry out important life functions like spawning, rearing and migration. Each of the places is like a link in the salmon's life history chain. These life history chains extend for thousands of miles. Parts of the chain may still be intact —

pristine — while in other parts the links are broken, degraded. Few rivers and salmon populations have all the links in their entire life history chain intact.

**ER:** How are salmon doing in the open ocean?

**JL:** Between 1976 and 1977 oceanographers measured a dramatic change in several attributes of the oceanic environment. That change coincided with the collapse of the Oregon coho fishery in 1977. Other stocks have also shown lower survival during the oceanic phase of their life history.




In 1977 there was little more than a hint that the cause of the lower production was in the ocean. Since then the oceanographers and fishery biologists have been studying the problem and have been unraveling more and more of the connection between ocean conditions and the survival of Pacific salmon. These studies suggest that there is a forty to sixty-year cycle of these lower productivity regimes in the ocean. That cycle has probably existed for many centuries.

We tend to think of the rivers and ocean as completely different ecosystems, but the salmon integrate the fresh and salt water parts of their ecosystem. The loss of the salmon's biodiversity that I mentioned earlier has reduced the salmon's ability to cope with natural environmental fluctuations including changing ocean conditions.

**ER:** The forty years is going to be up in about fifteen years, and so you would expect them to rebound if the other parts of the system were in place for them.

**JL:** You're right, that is a big question and it breaks down into two parts. The first question is, have the marine communities changed during this period of low productivity in a way that will retard the recovery of salmon? Are we going to see salmon rebound when the ocean conditions become more favorable? No one knows the answer to that question.

The second question is, are we going to allow a robust recovery of salmon or will we immediately crank up the harvest and keep the wild salmon in a depressed condition? When we do see increasing numbers of fish, will we back off on our commitment to habitat protection and restoration? If we don't implement a strong conservation approach to salmon management and permit a strong recovery; if we don't maintain a strong commitment to the protection and restoration of habitat, then when the ocean shifts to another low survival regime we will see salmon extinctions again and much of the effort and expense of the current recovery programs will be wasted.

**ER:** What's the mix between wild salmon and hatchery-raised salmon? Are these population crashes hatchery fish?

**JL:** Hatchery and wild both.

**ER:** So what should be the role of hatcheries in salmon recovery?

**JL:** That's a good question, and the fact that we are still asking that question 128 years after we started using hatcheries points out one of our major failures. Three independent panels have looked at hatchery performance in recent years. One conclusion of all three panels is that we have done a poor job of monitoring

salmon hatchery programs. We've done such a poor job of monitoring, we really don't know why hatcheries failed to live up to their promise. As a result, the solutions, the corrective actions are not clear.

**ER:** Do you see hatcheries as part of the solution?

**JL:** Yes. Even though they failed to achieve their objectives, I do not believe we should close the hatcheries. There are still a lot of possibilities for the use of artificial propagation in support of healthy salmon populations. What we do have to discard is the simple management model of hatcheries feeding salmon into the fisheries; a model that gives little priority to watershed health and habitat protection.

As long as the dominant policy framework in salmon management institutions is derived from this model, there will be little progress in salmon recovery. Hatcheries must be subject to scrutiny and to tough questions. Today if you ask critical questions about hatcheries with the intent to try to improve them, you're labeled as a hatchery basher. Hatchery advocates are too defensive.

**ER:** They perceive that you're trying to put them out of business, and on the first pass it looks like that.

**JL:** Which is not the case. I don't know of anybody that's seriously looking at salmon recovery that's saying we ought to put all the hatcheries out of business. But I do know a lot of people who are saying that hatcheries have to improve their performance.

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**ER:** What about habitat restoration efforts?

**JL:** Habitat protection is much more effective than restoration. We ought to bend over backwards to protect the good habitat that remains. The most effective restoration is the approach that lets the river heal itself. To accomplish that we have to stop interfering with the natural ecological processes that can bring about recovery. In addition, there are things we can actively do to help the stream recover. But natural ecological healing is most important.

One additional point with regard to salmon habitat restoration needs to be made. Recall that I said earlier that the salmon's life history could be viewed as a chain of places where the salmon carry out important life functions. The specific habitats or places are links in the life history chain. The key to habitat restoration is not to fix a broken link here and a broken link there, but to fix the entire chain so the animals can survive all the way through their chain of habitats, through their entire life history.

Part of the reason the region has spent so much money on salmon restoration and seen so few results is that we've focused on very narrow habitat projects relative to the salmon's life history. We have been fixing links, but not the entire chain. If a life history chain for a salmon population has four broken links and we fix two of them, the chain is still broken and the salmon following that pathway will die.

**ER:** I know this is a politically charged subject right now but is dam removal going to bring back the Snake River salmon runs?

**JL:** I would only say with regard to dams removal: there are no silver bullets in the recovery of Pacific salmon. The dams are a big obstacle to recovery. But we need to be sure that the steps we take to save the Snake River salmon end up fixing the entire chain of habitats that those fish need, from headwaters to the ocean.

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[1] Salmon Without Rivers: A History of the Pacific Salmon Crisis. Jim Lichatowich 1999 Island Press, Washington D.C.

## Why Use Biological Weapons?

Introduction:

The first attempts at biological warfare were probably throwing dead animals into an enemy's wells. In modern times biological warfare agents use diseases aimed at humans or animals. During World War II the Allies — Canada, Great Britain and the U.S. — started a major biological warfare research and development program in response to a perceived biowarfare threat from Germany. It turns out Germany had no such program, but Japan did have one that remained undetected until after the war. During the Cold War the Soviet Union developed a large, sophisticated biological warfare capability that probably would have been effective if used in war. Most other attempts to develop and use biological weapons before and since have not succeeded because of technical difficulties.

President Nixon disbanded the U.S. biological warfare offensive program in 1969 but the Soviets continued their program until President Yeltsin declared it disbanded in 1992. The Clinton administration spends 10 to 12 billion dollars each year to protect our military and civilian populations against biological threats from terrorists or rogue nations. However the major proportion of the biological threat to the U.S. comes from nature in the form of emergent diseases and antibiotic resistant bacteria. Our current defensive program is strengthening our abilty to respond to infectious diseases in general. The benefits of this program will be an increased ability of our public health system to deal with infectious diseases whatever the source. We spoke with Raymond Zelinskas about the history of biowarfare and its current status.

**ER:** Professor Zelinskas, what is your training?

**RZ:** My bachelor's is in biology, and then I earned a Filosofie Kandidat, the equivalent of a master's degree, in organic chemistry at the University of Stockholm, Sweden. When I returned from Sweden, I worked for about fifteen years as a clinical microbiologist at an acute care hospital in the San Fernando Valley.

**Biological weapons have not been effective when used in the past.**

During that time, I became interested in the interactions between law and politics and science and technology. So I enrolled at the University of Southern California's School of International Relations, where I earned a Ph.D. in International Relations. My specialization in international science policy is reflected by the subject of my dissertation, which dealt with the international implications of recombinant DNA research.

Of course, there are many of these, so a picked the three that I considered most import: (1) how does one assess risk when there is no basic data on exposure and who is exposed; (2) might recombinant DNA research be applied for biological warfare; and (3) does biotechnology hold promises for the economic development of the Third World?

After graduating in 1981, I was hired by the now defunct U.S. Office of Technology Assessment, to work on a project that produced the report *Commercial Biotechnology: An International Analysis*[1]. Upon departing the OTA, I moved to Vienna, to work for the United Nations Industrial Development Organization (UNIDO). At UNIDO, my major responsibility was to help with the establishment of the International Center for Genetic Engineering and Biotechnology, which now operates in Trieste and New Delhi[2]. After a 3½-year stint with UNIDO, I got a job with the Center for Public Issues in Biotechnology, University of Maryland Biotechnology Institute, where I stayed for the next eleven years. My research there focused primarily on biotechnology for economic development in the Third World and international biological arms control.

In 1993, I was appointed a William Foster Fellow at the U.S. Arms Control and Disarmament Agency (ACDA). For some months I worked on matters related to the Biological and Toxin Weapons Convention, which we were trying to strengthen by drafting a protocol to set up an inspectorate. However, in April 1994, ACDA seconded me to the United Nations Special Commission (UNSCOM), where I was to spend the next seven months working as a biological analyst. During that time, I

participated in two biological warfare inspections in Iraq[3]. When the fellowship was over, I returned to the University of Maryland Biotechnology Institute and remained there until 1998, when they decided to de-fund the Center for Public Issues in Biotechnology. Fortunately, I had the opportunity to join the Center for Nonproliferation Studies at the Monterey Institute of International Studies, where I now work.

I am also an adjunct associate professor at the Department of International Health, School of Hygiene and Public Health, The Johns Hopkins University, where I have been teaching two courses per year on emerging issues in international health.

**ER:** What is the difference between chemical weapons and biological weapons?

**RZ:** They're associated in international law because they're both anti-personnel weapons that are dispersed by environmental forces, especially wind. However, they are in fact quite different. Chemical weapons contain inanimate chemicals that wound and kill persons by directly affecting physiological systems; biological weapons depend on the actions of pathogenic organisms, which invade and infect persons, animals, or plants of a targeted population, wounding or killing by causing disease.

The chemical or biological agent is not a weapon by itself. A weapon is a system consisting of the agent, a munition that stores and carries the agent, and a dispersal mechanism. The most difficult technical problem facing anyone who wishes to use either biological or chemical weapons is how to achieve the effective dispersal of the agent over the target area.

So when Secretary of Defense William Cohen sits in front of the television camera with his five-pound bag of sugar and tells the audience that if that bag contained *Bacillus anthracis* — the causative agent of the disease called anthrax — instead of sugar, it would be sufficient kill millions of people, the listener should know that this is a theoretical estimate. The technical problem, and it is a substantial one, for anyone who would try to use a biological weapon is how make certain that a few thousand of the bacilli contained in the bag are delivered to each individual of a target population. Everyone who has tried effective dispersal of biological warfare agents in the past has failed.

**In capable hands biological weapons probably would be effective.**

**ER:** When did biological weapons become a part of warfare?

**RZ:** Biological weapons have been around for a long, long time. It probably started when people contaminated wells possessed by the enemy by throwing dead animals in them. It became more systemized during World War I, when the Germans developed methods for using pathogens, such as anthrax and glanders, against pack animals. They employed this type of biological warfare in both the United States and Northern Europe. It is important to recall that in World War I, almost all supplies were transported to the front lines on the backs of horses and mules, so if you could destroy them, the enemy would face significant logistical problems.

**ER:** That was done?

**RZ:** Yes. There were German saboteurs working in the United States who attempted to inoculate animals being sent to the European theater with glanders. In northern Europe, German agents used both glanders and anthrax. Anthrax is essentially an animal disease. These events are described by Dr. Mark Wheelis in a chapter that appears in a recently published book *Biological and Toxin Weapons*[4].

**ER:** It appears biological weapons didn't alter the course of the war.

**RZ:** No, no. They have never altered the course of any war. As a matter of fact, these weapons have not been effective when used in the past. To briefly recount the history of biological warfare, before World War II there were rumors circulating in Europe that the Germans had set up a biological warfare program, so when war commenced the English thought it was wise to set up their own program at Porton Down. By 1942 they had substantial program going, which was expanded during 1943 and 1944. Their Canadian allies also started a biological warfare program about the same time.

Then, when the U.S. entered the war, the British of course influenced its leaders, so the U.S. set up its own program in 1943 at Camp Detrick, Maryland. By 1944, the American

program was much, much larger than the English program. In that year, the English came to depend on the Americans to mass-produce biological warfare agents, which mostly were based on anthrax, for their weapons.

**ER:** Anthrax to be used against humans?

**RZ:** Yes. But in the early 1940s, the English had started a program aimed against the animal population of Germany. For this purpose, they had manufactured millions of so-called cattle cakes, which were patties that looked like cattle feces and were contaminated with *Bacillus anthracis*.

The plan was to drop the cattle cakes over the agricultural areas of Germany, with the expectation that the *Bacillus anthracis* in the cattle cakes would infect cows, pigs, and other animals important to Germany's animal husbandry. It was hoped that if this were done on a large scale, Germany's economy would have been severely damaged. This, then, was England's first biological weapons system. Although it was developed, produced, and ready to be used, in fact it never was used.

The English also produced anthrax for use against human beings. Their basic munition to carry anthrax was a four-pound bomblet, which originally was designed for incendiary warfare. As usually deployed, 166 of these four-pound bomblets were bundled in one package. After being jettisoned by the bomber, the package would bursts asunder at a pre-set altitude, spreading the bomblets over a wide area. Millions of them actually were used to firebomb German cities, often with horrendous results.

But the English also found that these bomblets would be effective for dispersing biological agents. Lacking large-scale production facilities for the anthrax bacilli, they provided many thousands of bomblet casings to the Americans for filling with anthrax. The four-pound bomblet was to become the basic biological weapon for both U.S. and British forces during World War II.

Of course, the Americans had to do a lot of work to adapt the bomblet so it would carry biological agents. In particular, when a filling of living agents first was put into the bomblets, the metal constituting the warhead quickly poisoned the bacteria.

There are historical accounts of Churchill wanting to use biological weapons against the Germans after they began an indiscriminate bombardment of the English civilian population with the V1 and V2 rockets.

Interspacing an inert material between the bacilli and the metal casing solved this particular problem. There were other problems, but the four-pound bomblet biological warfare system was largely perfected by early 1945. Also by that time the Americans had built a large factory at Vigo, Indiana, to mass-produce biological warfare agents. However, the war ended before any production took place, so the factory was mothballed and, a few years later, disassembled. Eventually, the Vigo site with its crumbling buildings was sold to the Pfizer Pharmaceutical company.

**ER:** Were the anthrax bacilli modified in some way?

**RZ:** The American weapons scientists did develop an especially pathogenic strain of *Bacillus anthracis*, called Vellum, for the purpose of warfare. To do this, they used the classical genetic techniques of mutation, selection, and propagation.

These same techniques had been employed for some decades in the civilian industry to, for example, develop industrial strains of bacteria; i.e., strains that produce more of a desired chemical than strains normally found in nature. This pathogenic strain was slated to be mass-produced at the Vigo facility.

**ER:** I have heard that the British were close to using biological weapons.

**RZ:** There are historical accounts of Churchill wanting to use biological weapons against the Germans after they began an indiscriminate bombardment of the English civilian population with the V1 and V2 rockets. One can imagine his anger at having these horrific weapons, which could not be aimed with any degree of preciseness, raining down on England. He might have used biological weapons for reprisal if they had been available. But they were not.

**ER:** What happened to biological weapons after the Second World War?

**RZ:** Well, the biological warfare program continued in the U.K., the U.S., Canada, and the Soviet Union.

There are indications that other nations also possessed biological warfare programs, such as France. I refer you to a monumental study by the Stockholm International Peace Research Institute, which documents biological warfare-related events after World War II[5,6].

It is ironic that after the war ended, the Allies found that their intelligence estimates were all wrong. Germany, which was thought to be developing biological weapons by Allied intelligence, in fact never had a biological weapons program. Conversely, Japan did have a very large biological weapons program, but it remained undetected by Allied intelligence until after the end of the war. Only at that time were the Allies, mainly the United States, able to find out that the Japanese had instituted a biological warfare program already in 1933 and that it involved many thousands of scientists and engineers by the time the war ended. This shows how difficult it is for outsiders to discover a secret national biological warfare program.

**ER:** Were the Japanese held accountable for their biological warfare program?

**RZ:** The general who was the head of the program, *Shiro Ishi*, escaped to Japan, as did most of his senior staff. None of them were arrested or even charged with war crimes. The Red Army captured some of Ishi's underlings and they were tried and convicted; some serving as long as fifteen years in jail. Yet, the United States chose not to do the same; this in spite of these people having been responsible for truly reprehensible acts, such as large-scale human experimentation and human vivisection.

I think that since at the time many in the American military were already considering the Soviet Union as a future enemy, they wanted to use the knowledge possessed by the Japanese weapons scientists to assist in the further development of the U.S. biological warfare program, but without letting the Russians know what was happening. So the Japanese weapons scientists were hidden away, and the American interlocutors got all the information they could out of them, including photos, laboratory records, and results of field tests. In the end it wasn't useful because it turned out that the Japanese didn't do controlled studies and were generally sloppy about how field test were conducted. So it is dubious whether or not any information the Japanese divulged was ever used in the American program.

But the ethics of this was, of course, all wrong. It is horrendous to think that these people who committed terrible crimes were never held accountable for their actions. In fact, the Americans protected them from any kind of retribution. Some of the Japanese weapons scientists were to rise to high positions in Japanese industry and academe.

> The Iraqis certainly had a fairly large biological warfare program, which began in 1985, and they had some 200 bombs and 25 SCUD missiles armed with biological warheads by the time Desert Storm occurred.

As I said, the U.S. biological warfare program continued after World War II. Then, in 1950, during the Korean conflict, the Chinese and North Koreans accused the U.S. of having used biological weapons against their civilian populations. This turned out to have been a propaganda exercise; recent information unearthed from Soviet archives by Milton Leitenberg proves that[7]. But it is a fact that the U.S. biological warfare program kept growing during the fifties and sixties, which was the time of the Cold War when mutual nuclear annihilation loomed. We still don't know if the U.S. program grew in response to our intelligence having determined that the Warsaw Pact had a biological weapons program, or because it took on a life of its own, becoming a juggernaut. In any case, it was rather large in 1969, when President Nixon decided, mostly for political reasons, to terminate it.

**ER:** There's been a book recently published by the former director of the Soviet, then Russian, biological weapons research program.

**RZ:** Right. Dr. Ken Alibek, a former deputy director of the Biopreparat system, which was the ostensibly civilian part of the Soviet Union's biological warfare program, has written about his experiences in a book called *Biohazard*[8]. From him we know that the planning for this program commenced in 1972 and it started in 1973.

Alibek is a relatively young guy, so he didn't get involved in this program until 1975, by which time it was going full blast. The interesting

part about the Soviet biowarfare program is that before 1972 it wasn't very effective, so there was talk within the military of terminating it. We know this now. However, in 1972, Dr. Yuri Ovchinnikov, who was in a few years to become the youngest ever vice president of the USSR Academy of Sciences, recognized the promises inherent to genetic engineering, which was just then being described in the Western scientific literature. Ovchinnikov, who was a very imaginative, very bright guy, latched on to biological warfare because he saw it as a way of getting support for genetics and molecular biology from the Soviet Ministry of Defense.

You have to remember that the charlatan T. Lysenko had to a large extent controlled the life sciences in the Soviet Union for many years, during both Stalin's and Khrushchev's reigns, so they were far behind the West in such bioscientific disciplines such as genetics.

By Ovchinnikov intervening with the military, lots of money and talent was injected into a field that was until about 1972, essentially moribund. The result was that not only did Ovchinnikov receive sufficient funding to build his own institute, the M.M. Shemyakin Institute of Bioorganic Chemistry, but the biggest and most sophisticated biological warfare program the world has even seen.

**ER:** Do you really believe that Ovchinnikov learned so soon about recombinant DNA research?

**RZ:** Yes. The groundbreaking articles by Paul Berg, Stanley Cohen, Herb Boyer, and their co-workers were published in 1972 and 1973[9,10]. Obviously they had been working to perfect techniques for transferring DNA from one organism to another for some time, but it was in 1972 and 1973 that their accomplishments really became known.

This kind of work was scary to a lot of people, especially a method called shotgun cloning, where the scientist uses special enzymes to break up the genome of a bacterium into small DNA fragments, and then he inserts these fragments into other bacteria and observes whether they function in the new host.

When news about the new technique spread, many people became concerned about the risks that might attend recombinant DNA research, so in response prominent bioscientists organized a conference on the safety of recombinant DNA, which was held at Asilomar, California, in 1975. The aims of the conference were to determine how risky this kind of research was and design rules and methods for managing risks.

> Out of fear of being left behind, the Soviet military provided funding to Ovchinnikov to set up Biopreparat.

The conference had two major accomplishments. First, conference participants agreed that some types of recombinant DNA research did present risks, but that the degree of risk depended on what was being attempted and the organisms that researchers were working with. In other words, while most research was perceived as being innocuous, some of the research being done or proposed was deemed as being risky. Accordingly, the conference participants adopted a set of rules that delineated four categories of risk, P1 thru P4, and developed protocols for carrying out research work in each category.

Some types of research were forbidden. These rules were soon to evolve into something more formal; the so-called NIH guidelines. An organization, called the Recombinant Advisory Committee was set up to oversee the operation of the NIH guidelines.

The second achievement was that the conference agreed to develop a weakened strain of bacteria that could be used as a safe host for transferred genes. Less than a year after the conference, the so-called K12 strain of *Escherichia coli* was in fact developed and it has become the most used strain in laboratory studies. It is safe because it needs nutrients only found in laboratories, so if it escapes into the open environment, it dies.

**ER:** What would be an example of forbidden research?

**RZ:** At the time there was a proposal, for example, to insert a gene coding for the production of cellulase into *E. coli*. The idea was that cellulose, which is a major waste product in agriculture and the forestry industry, could be degraded by using microorganisms that were able to secrete cellulase, which is an enzyme that breaks down cellulose into sugars and alcohols. But then somebody asked, what would happen if this altered bug

would become established in the intestinal tracts of humans and animals? *E. coli* is a normal inhabitant of animal intestinal tracts and as such assists in the digestive process. However, a cellulase-producing *E. coli* might very well completely disrupt the digestive process by breaking down bulk fiber, producing intractable diarrhea.

There were also worries about people indiscriminately transferring genes coding for antibiotic resistance into bacteria that normally are sensitive to antibiotics. So these types of research were forbidden.

**ER:** One wonders how much of that open literature was taken to the USSR and used by Alibek in his biological weapons research.

**RZ:** Well, not by Alibek, but by Ovchinnikov and his colleagues. In 1975 Alibek was just starting his scientific career, but Ovchinnikov was already a highly regarded molecular biologist in charge of possibly the best bioscientific institute in the USSR. At the beginning, molecular biology was primarily a means used by Ovchinnikov to get funding from the military to jump-start the biosciences in the Soviet Union.

Of course we don't know exactly how it was done, but I think that Ovchinnikov told the generals that the West would use genetic engineering for weapons development and that the USSR would be left far behind because the biosciences were in such poor shape due to the influence of Lysenko and his followers, many of whom were still in positions of power. Out of fear of being left behind, the Soviet military provided funding to Ovchinnikov to set up Biopreparat.

No question that the Soviets did get an effective biological weapons program out of that investment, but it was not based on molecular biology. Five Soviet scientists were participants at Asilomar, and some of them were advisors to the biological warfare program. Ovchinnikov didn't attend, but we can safely assume that he was well informed on what happened. But it should be made clear that initially, the Soviets did not use molecular biology in their biological warfare program. For the first fifteen or so years of its existence, achievements were accomplished through the use of classical techniques, such as mutation, selection, and propagation.

No question that the Soviets did get an effective biological weapons program out of that investment, but it was not based on molecular biology.

Eventually, in the eighties, Biopreparat introduced molecular biology techniques into its research, especially at its best institutes at Koltsovo, Lyubychany, and Obolensk**.**

**ER:** Alibek claims that his scientists were using molecular biology in the eighties and nineties to try to engineer more effective pathogens.

**RZ:** Yes he does. His claim has not been proven, but it is probably true because at, for example, Vector, their premier virus research institute, they had, and have, very good scientists, access to the literature that describes molecular biology methods, and the right equipment to perform genetic engineering of viruses. So, why wouldn't they use these techniques? It wouldn't make sense for them not to do it.

**ER:** What happened to the Soviet BW program in present-day Russia?

**RZ:** We know some about what happened, but certainly not all. In 1992, Boris Yeltsin acknowledged that the Soviet Union had operated a biological warfare program in violation of international law. At the same time, he ordered its closure and promised to fire its directors. Since then, we know that most of the Biopreparat facilities have been converted to civilian use and are able to continue operations by receiving funding from international sources. To be eligible for this funding, they must be transparent; i.e., the work they perform is open to inspection by outsiders.

However, there are four military biological institutes that are to this day closed to any outside inspectors or visitors, so we don't know what's going on inside them. My gut feeling is, I don't think they're making biological weapons, but I think that they're keeping the institutional memory intact, so in case they wanted to enter into this field again, they would be ready to do so very quickly.

**ER:** At some point wasn't the U.S. considering a defensive program?

**RZ:** We do have a defensive program. By 1972, we had disassembled our biological offensive program. In 1975,

Congress passed a public law saying that we cannot do this kind of activity. In effect, the Congress enjoined the U.S. military to do whatever is necessary so the U.S. would be in compliance with the 1972 Biological and Toxin Weapons Convention.

When Nixon dissolved the offensive U.S. biological warfare program in 1969, he stated that defensive work could proceed. But the formal defensive program, called the Biological Defense Research Program (BDRP), was established in the early 1970s and is unclassified. The lead agency of the BDRP is the United States Army Medical Research Institute for Infectious Diseases (USAMRIID) at Fort Detrick. The BDRP has several aspects.

Primary biological threat assessment is done by the Armed Forces Medical Intelligence Center (AFMIC), which is headquartered at Fort Detrick. It tries to determine or assess the biological threats, and once it makes its assessment, this information is sent to USAMRIID. Its management then tries to set up research that aims to defend against the major biological threats facing U.S. military forces. Some of them, or most of them are natural threats, like emerging infectious diseases, diseases that are easily transported to the United States, or diseases that could be waiting for U.S. servicemen who are sent overseas. They also try to defend against deliberately caused diseases, such as those that result from biological warfare and terrorist attacks. Once a determination has been made on biological threats, USAMRIID scientists are put to work to develop appropriate defenses. It could be vaccines, it could be therapeutics, or it could be protective equipment, either personal or communal.

**ER:** Could you address the effectiveness of biological weapons?

**RZ:** Well, there are two levels of effectiveness. The first is that so far, biological weapons have proven ineffective when used in the field. The Japanese used it against the Chinese population during World War II. There were two results: first, they didn't produce many casualties among the Chinese and, second, they ended up in at least one instance producing several thousands of casualties among their own army. It demonstrates the big problem with biological weapons; namely, it is technically difficult to disperse biological warfare agents effectively.

The Japanese terrorist group Aum Shinrikyo worked on biological weapons for at least three years, perhaps as long as five, but for all their efforts, their biological attacks were a big failure. They tried several times to disperse both *Bacillus anthracis* and botulinum toxin within cities, but produced no casualties.

**... of the totality of biological threats, 90 percent comes from nature, mainly emerging infectious diseases and transported infectious diseases.**

The Iraqis certainly had a fairly large biological warfare program, which began in approximately 1985, and they had some 200 bombs and twenty-five SCUD missiles armed with biological warheads by the time Desert Storm occurred. But their weapons were, as far as I can assess them anyway, ineffective because they depended on explosive force for dispersion of agents. The explosion kills about 99% of the agents in the warhead, and drives much of the rest into the ground. As you can imagine, not much is left to do the dirty work.

So, you can see that there are substantial technical problems that can limit the effectiveness of biological weapons. So far, neither terrorists nor nations have overcome then.

The second level is that in capable hands, biological weapons probably would be effective. I believe that what the Soviet program accomplished, and what the program that the United States had until 1969 accomplished, did produce effective biologi-

cal weapons. In the case of the U.S., we had good scientists and engineers staffing the program, as did the Soviets. We can be certain that they knew how to deal with the meteorological forces and had perfected dispersal mechanisms. I estimate that if the U.S. had used the biological weapons it possessed before 1969, they probably would have been extremely effective, causing thousands to possibly hundreds of thousands of casualties among the target population.

The Soviet program, which existed until 1992, probably would have been capable of producing even larger casualties since they deployed weapons carrying contagious organisms, such as smallpox and plague.

**ER:** What is the military value of that?

**RZ:** As far as their strategic value, I think the Soviets were thinking about using them against ports and staging areas. You could easily close down a whole port city with biological weapons. You could use them against the rear of your enemy's lines where training was taking place or where the reserves were gathering. You could close down Washington, D.C. Soviet biological weapons probably would have been used in combination with nuclear weapons.

**ER:** Should we in the U.S. worry now about biological weapons?

**RZ:** Well, if people want to worry about something, they should worry about something real, namely, natural biological threats. If you look at the totality of biological threats that are facing us, I estimate that about 90 percent of the total comes from nature, mainly emerging infectious diseases and transported infectious diseases. Of the remaining 10 percent, approximately 8 percent consists of nosocomial infections, that is, infections emerging from institutions like hospitals caused by, for example, antibiotic-resistant bacteria. Now, only about 2 percent of the biological threat remains to be considered. That small number would include the risk that an accident would happen in a high security laboratory (such as at a laboratory operated by the Center for Disease Control and Prevention, National Institutes of Health, and USAMRIID) that would liberate pathogens. We could also include in this category an accident in a biotechnology firm that works with genetically engineered organisms (most of which are innocuous), which would liberate a mass of these organisms. And, finally, that 2 percent would include that highly theoretical threat of a biological weapon being used against our population by another nation, terrorists, or criminals.

**Even though the threat posed by biological weapons is small, the Clinton administration has gone to extremes to protect our military and civilian populations against terrorism…**

Even though the threat posed by biological weapons is small, the Clinton administration has gone to extremes to protect our military and civilian populations against terrorism; taxpayers are funding a defensive effort that cost us somewhere between 10 and 12 billion dollars per year. Now the beneficial part of that effort, and why I am not against it, is that a large chunk of that huge amount is applied in such a way that we are not only dealing with the less than 2 percent threat, but we're simultaneously addressing the larger, the 90 percent, threat. We are in effect using this funding to immensely strengthening detection and surveillance mechanisms for infectious diseases on both national and local levels. We are training people throughout the U.S. to deal immediately with biological events and their consequences.

When a primary responder, such as a policeman, fireman, or emergency medic, is faced with a biological event, he or she doesn't know whether its cause is nature, a deliberate act, or an accident in a laboratory. So by training first responders to deal with the first kind of threat, the terrorist threat, you're simultaneously training them to handle the second type of threat, and that's just wonderful.

It could be that five or ten years from now, when we look back at the Clinton administration, we're going to be grateful to it for having been responsible for tremendously increasing the ability of our public health system to deal with infectious diseases, and that I think will indeed be a lasting legacy. Most likely, its efforts to deal with biological warfare or bioterrorism will be forgotten.

**ER:** There is concern about smallpox virus being held in reserve. What would be the worse case scenario there, if someone did get their hands on these viruses?

**RZ:** Well, the worst-case scenario is that one or more laboratories in Africa, Asia, and elsewhere that once were part of the global effort organized by the World Health Organization to eradicate smallpox have deliberately or accidentally retained vials of samples containing the smallpox virus. Continuing this worst-case scenario, an evil leadership or terrorist group gets hold of some of these vials and does two things. First, it acts to produce a vaccine that protects its own people against the virus it possesses. And second, it uses the virus it has to initiate a smallpox epidemic amongst an enemy population.

Even the most virulent smallpox virus will kill no more than about 35 percent of those it infects, so an attack with smallpox virus is not going to kill everybody in the attacked population. And, depending on the nation, millions of doses of smallpox vaccine are still being stored, so some people would be able to protect themselves. What would happen to the attacked population is that most of its members would become infected and very ill, many of them would remain scarred for life, and about 35 percent of all infected people would die. If the virus were a particularly virulent strain, such as some of the ones developed for biological warfare by the Soviet Union, then the mortality rate probably would be higher.

In any case, it would be very difficult, probably impossible, to contain the epidemic to the target population, so it would spread to other populations. If so, a worldwide pandemic would ensue, with billions of casualties. That's the worst-case scenario.

A more moderate scenario is that industrialized nations, like the United States, Sweden, the U.K., and others, would see the pandemic developing and would respond by cranking up their production of smallpox vaccine. If this were done in a timely fashion, they would be able to protect a large proportion of their populations. But certainly in countries or in parts of the world where they don't have a substantial capacity for vaccine production, their situation would resemble the worst-case scenario.

**ER:** This is similar to our flu surveillance program where we try to identify emerging strains of flu early in the flu season and then inoculate people.

**You could easily close down a whole port city with biological weapons. Soviet biological weapons probably would have been used in combination with nuclear weapons.**

**RZ:** Right. But having said that, I don't understand why anybody would use a weapon based on smallpox. In most instances when nations had biological warfare programs, they tended to use non-infectious or non-contagious agents because they did not want to have the problem of secondary or tertiary spread. The Soviets, interestingly enough, did in fact develop smallpox as a biological weapon, which seems to me the height of irresponsibility because they would have wiped out a large part of the world's population if the virus had been released by accident or if they actually ended up using it as a weapon.

**ER:** Because their delivery systems were so effective?

**RZ:** Yes.

**ER:** Just now you said 35 percent mortality rate, but are you now saying that their program could have developed a more virulent virus than that?

**RZ:** We don't know for sure. It is my gut feeling that Soviet scientists had weaponized a highly virulent smallpox strain, but this is yet to be proven. Because their accomplishments were so terribly irresponsible and horrific, I don't think any of their virologists, many of whom still are working in military and Biopreparat laboratories, are willing to own up to what they did.

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## WARMING OF THE WORLD'S OCEANS : Sydney Levitus

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