Environmental Review

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Stealth Attack on the Endangered Species Act.

Introduction:

Upper Klamath Lake is a twenty mile-long, shallow lake in southern Oregon near the California border. It is a natural reservoir that feeds the Klamath River, home to an endangered species of coho salmon. The lake itself is home to two endangered species, the Lost River sucker and the short nosed sucker. Both fish are endemics; that is, they evolved there and occur nowhere else; both species were important, first to the Native Americans and later as a sport fishery.

Upper Klamath is also the center of an enormous irrigation project that delivers 500,000 acre feet of water a year to farms and wildlife refuges. The Klamath Basin is semiarid country, which means farms need irrigation to survive, and several dry years have resulted in controversy over who has rights to the limited amount of irrigation water. This classic western water conflict has a new wrinkle in that federal law now mandates that water managers cannot harm the three endangered species in the ecosystem, two in the lake and one in the river. Many scientists from universities, government agencies and the tribes have worked in the Klamath Basin, and their expertise has been recruited to find out how much water can safely be removed from the ecosystem. The Klamath Basin is the size of a small state and has enough ecological complexity to keep scientists arguing for a good long time.

However, the Departments of Commerce and Interior charged a National Research Council committee to determine whether there was 'scientific proof' that the water restrictions the US Fish and Wildlife Service and the National Marine Fisheries Service were imposing would accomplish what they were intended to do; i.e. if holding back water in the lake reduced fish kills. This mandate is a fundamental misunderstanding of science: science never proves anything, it only eliminates the contenders among competing ideas; the smart people the President surrounds himself with certainly understand that.

The executive branch of government by demanding scientific proof of the effectiveness of a proposed action is trying to change the Endangered Species Act extralegally. The ESA as written instructs government agencies to use the best available science to protect endangered species. When the science is questionable the agency is to err on the side of conservation. This new mandate from the executive would establish unattainable standards and effectively gut the Endangered Species Act. There is a very good overview of the Klamath controversy written by Robert Service in *Science* magazine[1].

In an attempt to better understand some of the underlying natural history in Upper Klamath Lake we spoke with Professor Douglas Markle of Oregon State University about his work on the reproductive biology of two of these endangered species[2].

ER: Professor Markle, can you describe for us a little bit about the Klamath Lake suckers?

DM: These are large fish; especially the Lost River sucker, which gets to be over three feet long. The fish were valuable to the Native Americans and to early settlers who built a cannery for them. It became a popular fishery after World War II; it was so popular it became a regulated sport fishery by the state of Oregon. Suckers were considered and still are a valuable species for consumptive use by the tribe, and they were a valuable sport fishery for many years. Many people refer to suckers as

trash fish, and there were rumors in Klamath County that the state had previously tried to kill them off, which was completely inaccurate.

Part of the problem with the sucker is even though they were a popular fishery they weren't particularly well studied. The Oregon Department of Fish and Wildlife in Klamath Falls was aware that there was a pretty substantial fishery on these fish, but they didn't have the resources to monitor it.

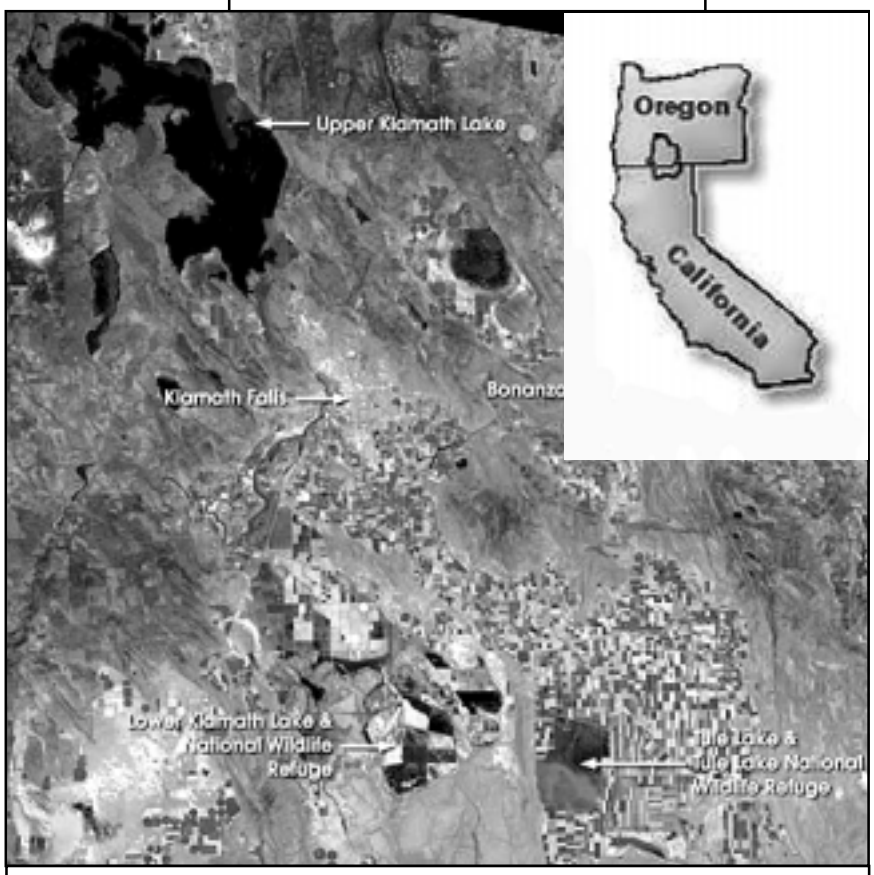
ER: When did they close the fishery?

DM: The tribe curtailed their activity around 1985 and then the state curtailed it for everybody a year or two later. The year after that they were listed under the Endangered Species Act.

ER: The population must have gone down pretty quickly.

DM: Based on the fishery data, we estimate the population declined 90 to 95 percent in the twenty years before it was listed.

ER: What about their natural history?



Landsat image of part of the Klamath Basin. Upper Klamath Lake is about twenty miles long.

DM: The Upper Klamath Basin Suckers are endemic to the Klamath Basin; that is, they occur nowhere else. There's a lot of endemism in the Klamath Basin; that probably has to do with historical connections of the river to other rivers. The region has a lot of endemics, the Klamath Basin and Klamath mountains botanically as well.

Suckers are long-lived fish and that is a key point in understanding their biology. It varies a little between the two species but males have to be three to five years old before they spawn and females are four to nine years old before they spawn. Not maturing until the fish is that old and then living twenty-five to thirty-five years is a life cycle that is adapted to variable conditions. It's not like a salmon that's putting all of its eggs into one effort and spawning one time. Suckers spawn every year although a mature adult might skip some years; each time a sucker spawns she can produce a huge number of eggs, a quarter million eggs in one female. That kind of life cycle is geared towards swamping the system every year with progeny and hoping that some will survive. It's important to understand how tenuous the survival of the population of the species can be. It's basically waiting for the occasional good conditions where everything goes right and lots of young survive.

The original petition was based on a fish kill in 1987. During that fish kill they aged the fish that they caught, and the youngest fish was eighteen years-old and the oldest were up in their thirties. That alone tells us there had been no young produced for eighteen years, throughout the 1970s no young fish survived.

ER: What were the conditions in the lake then?

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DM: One of my graduate students and I are in the middle of the weather data right now so it's not easy to talk about it because I'm not sure where it's going to go. There are some long-term climatic conditions that probably are affecting the fish. We're not able to say yet what conditions were responsible for the low production during that time.

ER: How big is Klamath Lake?

DM: Klamath Lake is a large and shallow alkaline lake, and extremely productive. *[Primary productivity refers to the abundant plant life in the lake. Ed.]* There's so much algae in the lake that it's green in the summertime. The alkalinity is photosynthetically driven because of all that productivity. When the algae die in the course of the year the decomposition uses up oxygen in the water and so you can get areas in the lake where the pH is at 10 and the dissolved oxygen is at zero. *[pH is a scale of acidity from 0 to 14, pH 1 is very acidic and pH 14 is caustic or alkaline. Ed.]*

Klamath Lake suckers were an important food for the Native Americans. The tribe shut down its fishery in 1985.

ER: Which makes it tough to live.

DM: It makes it extremely difficult for other organisms in the system. A number of people have been doing some toxicological studies of the suckers, primarily of juveniles, and the fish seem to be remarkably tolerant of bad water. My crew has caught them in areas where we've measured no oxygen in the water. Clearly they couldn't put up with that for long, but they certainly seem to be extremely tolerant.

ER: They must hold their breath when they swim through these areas.

DM: A lot of evidence suggests that when bad water conditions occur that fish do leave those areas. In a couple of years, 1997, for example, when the water quality got bad, large numbers of juveniles left the lake for the irrigation canals.

ER: Are there springs in the lake where they could find some fresh water?

DM: There are springs in parts of the lake where fish do congregate, primarily adults. Some of them are near shore and in the northern part of the lake. Some tagging data suggest that the lake has to have a certain amount of water in it or the fish won't go into these shallow areas or into these areas where the springs are.

ER: How deep is the lake?

DM: The average depth is about six feet in the midsummer. It varies by about three feet during the typical year. It's pretty shallow. There's one area on the western shore where the lake does drop down to over thirty feet, but for the most part it's quite shallow.

ER: Did the lake vary in elevation naturally before people got involved?

DM: That's correct.

ER: So the suckers evolved under circumstances that were quite changeable and frequently not good.

DM: Likely, yes. Some of the first suckers collected by biologists for taxonomic study back in the 1890s were collected during a fish kill. In one recent study where people have tried to reconstruct the number of these big fish kills, it looks like about once a decade there was a fish kill in the lake.

ER: When would that occur?

DM: Fish kills would typically occur in the summertime. Certainly the kinds of fish kills that are being talked about with the Fish and Wildlife Service are the summer fish kills. In the mid-90s there were three consecutive fish kills in 1995, '96, and '97.

ER: Did the lake elevation go up and down historically?

DM: It is a natural lake, and it did historically rise and fall. When the Bureau of Reclamation started the irrigation project they put a dam in the lake and they blew out a natural reef that was at the southern end of the lake. When they built the dam and the setup to feed the irrigation system they changed the hydrograph: the lake was kept higher in the springtime and then they could drop it down lower in the summertime, in August. The dam did raise the lake some of the time, but its primary purpose was to lower the lake; that is to use some of the water for irrigation. That was the way the system was set up, and that's pretty much the way it works.

ER: Does lowering the lake increase the likelihood of a fish kill?

The Klamath Lake sucker population declined 90 to 95 percent in the twenty years before it was listed as an endangered species.

DM: It's been difficult for some of the biologists who have been working with the fish kill data to understand whether the lake elevation has anything to do with the fish kills.

The managers here have been saying all along that the only tool they have, the only thing they can control is the amount of water in the lake. It looks in many cases that weather conditions and other things are what causes problems, so you have to look for relationships between the lake elevation and some of these other parameters to see if it makes any difference. If the lake were a little bit higher, would the fish kill have been less severe? If the lake had been lower, would the fish kill have been more severe?

There's no way to do controlled experiments, so it's been frustrating for the agricultural community when they hear the biologists trying to explain these issues and they don't have any experimental evidence to say, yes, if you drop the lake six inches you'll increase the probability of a fish kill by a certain percent.

ER: You work on hatching. Do you have to deal with the same kinds of uncertainty in your work?

DM: My research group's focus is on the early life history of the suckers, the first year of their life, and we have the same sort of problem. We're looking at the survivorship of the larvae when they first enter the lake, and that first three weeks of survivorship depends on the lake elevation, how much water there is, and on the weather. If there's more water and therefore more emergent vegetation inundated, there's better survivorship in the first three weeks.

ER: More hiding places for the young fish?

DM: It also could be protection from wind. If it's real windy they don't do well at all. That's a fairly common phenomenon in larval fishes. If it's windy and turbulent these small larvae 11 to 13 millimeters [0.4 inches] in length they can't feed if they're being tossed around in the water. If there is lots of water, calm winds, warm temperatures in the springtime, then there's lot of survivors in that first couple of weeks. But that doesn't tell us how many will survive into October. There is a series of potential bottlenecks that this early population has to get through before you can say it was a good year or not.

ER: When do the babies come into the lake?

DM: The 13-millimeter stage would be in June. This is one of those things that created the controversy here. With the Endangered Species Act any action that contributes to mortality is considered a taking, so by drawing the lake down you would be technically contributing to a take. If you asked, Does it make any difference to how many survive to become adults and spawn again? it's not clear. But that argument can only go so far, because if you get conditions that give you zero surviving through that first couple of millimeters then everything is gone.

ER: Where do they spawn?

DM: The spawning occurs in two places in the upper system. One is in the Williamson and Sprague Rivers.

ER: They leave the lake and go into the rivers?

DM: There's some that leave the lake and go up into the rivers, so they run up rivers like salmon do. There's another group that stays in the lake and spawns at springs that come out in the lake.

ER: Those need to be shallow?

DM: The ones we know about are shallow. They come into near shore, and most of the springs that we know about are on the eastern shoreline of the lake. The spawning in the lake has been going downhill dramatically. There

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used to be a lot more spawning in those springs in the lake, so those populations seem to be in big trouble.

ER: Do you have good numbers for that?

DM: We have a combination of anecdotal information along with some good numbers. Anecdotal things are observations such as Harriman Springs in the northern part of the lake, it used to have lots of suckers. The last sucker was seen there around 1976. They don't spawn there any more. There are another couple of places where we have information like that: they used to spawn here and now they don't.

Since about the early 1990s the tribe and USGS have been monitoring the adult populations that spawn at the springs. For the shortnose sucker their estimates now are that there are fewer than 100 adults that spawn there.

ER: How is the spawning doing overall?

DM: In-lake spawning is definitely going downhill. The river spawning went down during those three years of the fish kills in the 1990s and has since been rebounding. In 1991 and 1993 there was fairly good recruitment of young; those individuals are now coming into the population. Their arrival in the population has given some people ammunition to say that there's always been lots of fish in the lake and that the numbers are huge again. But it's just these young fish that are coming into the population now. They're now approaching ten years old.

ER: So they're old enough to spawn?

DM: Right. Probably a lot of them were lost during the fish kills of the mid-90s, 1997 primarily.

ER: What happens after they spawn?

DM: After they spawn in gravelly areas either in the river or the lake, the eggs incubate for ten days or so. When the larvae hatch out they stay in the gravel and use up some of their yolk sack. Then about ten days after they hatch, they still have a little bit of yolk left, and those that are in the river drift down into the lake.. Once they come up out of the gravel they get down into the lake in about a day or so.

In the fish kill of 1987 the youngest fish was 18 years old. That tells us that throughout the 1970s and much of the 80s, no young fish survived.

ER: How big are they then?

DM: They're usually around 11 mm when they first come into the lake. They've got a little bit of yolk left, but not much, and they need to start feeding.

ER: Where do they feed?

DM: We find the most of them in the shoreline areas with emergent vegetation. That's where we find the biggest ones, and that's where we find the fish that are the best fed. If you look in open areas without emergent vegetation or if you go to areas where there's woody vegetation or submerged vegetation, there are not as many fish and they're not as well fed.

ER: What do they eat?

DM: They're eating small zooplankton for the most part. Also you do see them picking off the fauna that's on the blades of grass: rotifers, cladocerans, small planktors.

ER: Is the emergent vegetation offering them shelter from predators there in the weeds?

DM: It's probably a combination of predator avoidance because they can hide more easily, a better food supply, and perhaps some protection from turbulence. And the water is going to be warmer because it's shallow. A fish might be in that habitat for several weeks to a month.

ER: It is midsummer when they need that habitat?

DM: They're in those habitats in June and July and they're growing fairly

fast, a quarter millimeter a day or so. When they get to be about 20 millimeters in length they become oriented more to the lake bottom. Before that they are primarily surface oriented. They do drift at night so they do get dispersed around the lake a little bit, but at about 20 millimeters or so they become bottom oriented. They prefer clean, sandy, gravel areas; they'll go around and they'll work into the bottom for potential food items.

ER: So they're similar to a chub?

DM: Their mouth is more subterminal than a terminal mouth like the chubs and minnows. Suckers are designed for feeding off the bottom. We find the juveniles pretty much on clean gravel areas along the shoreline towards the southern end of the lake.

ER: Which is the shallower end.

DM: It's shallow. It's also close to Klamath Falls, and it's also close to the outfall for the irrigation district.

ER: How big do the juveniles get?

DM: The juveniles are about 20 millimeters, so less than an inch through the rest of the summer; by the end of the summer they will be 75 millimeters long. *[3 to 4 inches. Ed.]*

ER: Do the juveniles stay in the south end of the lake?

DM: We find them primarily in the southern end of the lake. Then in the fall they move away from the shallow areas and out into deeper water. After that they are in a black box to us, and are not well sampled until they spawn again. There have been a number of people tagging them and looking at their movements. The adults, unlike the juveniles, tend to be in the northern end of the lake.

ER: The suckers are a native fish. Are they competing with introduced species?

DM: Yes. There's yellow perch and also fathead minnows, which is probably the most abundant fish in the lake.

ER: So if you're building up the numbers of sucker juveniles, you're growing perch food.

DM: Potentially.

ER: Why are you hedging? Because you're not sure?

DM: We don't know for sure. Also, one of the questions in the back of some people's minds has been that the efforts to help the suckers may also inadvertently help some of the introduced species. In many cases we're not exactly sure how that might happen or if it happens.

ER: Is agricultural runoff fertilizing the lake?

DM: The people that have been looking at the water quality issues are pretty convinced that there is a lot of anthropogenic input. It's primarily coming from cattle grazing. There are a lot of cattle that are grazed right on the margins of the lake and then in some of the incoming tributaries. There's been some concern that there's a fair amount coming from cattle, but there is a lot that's naturally in the sediments, for example.

ER: Important parts of the 1992 biological opinion weren't implemented. Is that why the 2001 opinion was tougher?

DM: The key request was for a screening of the irrigation districts, the A Canal, and that's going on right now. So it is happening.

ER: Ten years later.

DM: I don't want to make excuses for them, but it wasn't a simple matter to put up a screen there. The price is $15 million for the screen that's going in now, so it wasn't a trivial expense.

ER: Does it keep juveniles out of the irrigation canal?

DM: It's primarily to keep juveniles and adults out of the irrigation canal. The screen can't keep the larvae out.

ER: Suckers were listed under the ESA in 1988. Who asked for the 1992 biological opinion and who wrote it?

DM: The Endangered Species Act requires that any federal agency describe its actions relative to their impact on listed species. The Bureau of Reclamation first did that, after being requested to do it, in 1992. What they write is called the Biological Assessment, which is their assessment of what their activities will do to the listed species.

Any federal agency whose actions may have an impact writes an assessment. The response to the assessment is the biological opinion. One of the biological opinions was written by Fish and Wildlife Service regarding the suckers, and the other by NOAA regarding the coho salmon downstream in the Klamath River. The biological opinions are then what the agency, in this case, the Bureau of Reclamation has to follow.

The 1992 opinion was a ten-year program and it allowed some flexibility for management. It allowed the lake to be lowered to low levels, essentially as low as they could get them: 4,139 was the initial target, and then four out of ten years the Bureau could drop it down to 4,137. That was the flexibility. They were saying you could drop the lake to low levels, but you can't do it every year.

In contrast, the 2001 opinion was for a single year. So that eliminated any flexibility, and that decided they would raise the minimum level one foot to 4,140. That one foot gives you a lot more water in the lake.

ER: This is what upset the farmers.

DM: Obviously the farmers were upset. One of the contentious issues was the actual benefit to the fish of that extra foot of water in the lake. It was difficult for the biologists to say that if they have one more foot of water in the lake they will have 20 percent smaller probability of a fish kill, or that you'll have 20 percent greater probability of more young being produced. There wasn't quantifiable data available to show what that benefit of one more foot of water in the lake would be.

The control gates at the south end of the lake are used to draw off irrigation water.

ER: This is where terms like junk science were getting thrown around. But if you think about it the juvenile fish need shallow water when they come into the lake. If you take it down a foot their habitat goes away.

DM: Correct.

ER: And the water above the springs becomes shallower.

DM: That was the logic that was used by Fish and Wildlife Service in writing the biological opinion of 2001. The counter argument was brought up by the consultant for the water users, and then picked up by the National Research Council's report, which was that if that's the case, why were there so many young produced in 1991? My research group had shown that there were a lot of babies produced in 1991, and the monitoring of the spawners had seen the 1991 year class show up to spawn. So 1991 was a good year class, but the lake was relatively low that year. They said this proved that lake elevation doesn't have that big of a role in helping the young early on.

ER: What do you think about that statement?

DM: It's wrong. There are a couple of things to say about that. In 1991 the lake was not all that much lower in June. The way the lake level works with the emergent vegetation is not linear. If the water goes down past a certain point there is almost no emergent vegetation left. The vegetation available at the lake elevation that existed in June 1991 is 40 percent less than if the water is a foot higher; but it's 250 percent more than it is if the water is a foot lower.

At any rate, in 1991 there was still quite a lot of emergent vegetation available. The water level that was being requested though in 2001 would have dropped the vegetation down to

zero, and there is no evidence that there's ever been survivorship of any year class when the lake has been brought down to what they were requesting.

The other aspect is that the conditions that are necessary for getting fish through those first couple of weeks in June may not translate into a good year class. One of the key features that is important for these fish is warm temperatures. The warmer the water, the faster the fish grow.

ER: The faster vegetation grows too.

DM: And the faster the vegetation grows as well. That is true for the first part of the summer, but when August comes around it changes. If August is relatively cool, that is better for the fish. So everything can be going just dandy and the population in great shape, and then if August is too hot there's nothing left of that year class. But if August is cool, that covers a lot of problems earlier on in the year.

ER: The 2001 opinion was characterized as more conservative than the 1992. In what way is it more conservative? Just in the water levels?

DM: By keeping the water levels higher they seemed to take the position that they just weren't going to take any chances. Their read of the situation at that time seemed to be that the more water in the lake the better it was for the fish.

I think it was certainly conservative, and at the time I thought it was harsh and unnecessary. It goes back to the life cycle of the fish. I don't think anything could have happened in 2001 which would have caused either species to go extinct. The actions might have slowed recovery, which is something ESA is not supposed to let happen, but, by itself, the year would not have exterminated either species. I agreed that it didn't seem like it was wise to drop it down to the lower limit of 4,137 as would have been allowed in the 1992 biological opinion, but somewhere above that probably would have reasonable, especially if it mirrored 1991. It would have dropped the lake fairly low and would have allowed some irrigation, but not much. I think that would have been probably a little bit easier for Fish and Wildlife Service to defend and wouldn't have seemed so stubborn and so monolithic.

ER: They just shut down irrigation completely?

DM: What was shut down in 2001 was the Bureau of Reclamation's Klamath Project. The Bureau bought water rights and was ceded water rights from the state before they started the project in 1905, so the people who get water from the Bureau have contract rights to water. But there are many other ranchers and farmers who get water straight out of the lake or straight out of the Klamath River with their own pipes, and they have state water rights. All of those people with state water rights irrigated in 2001. It was the 1,200 or 1,400 farmers in the Klamath project who were cut off.

ER: They had contracts and they were denied water?

DM: They had contracts. And because the Bureau of Reclamation had to follow the biological opinion, they had no water to give them, so there was no water to fulfill their contracts.

ER: That explains a lot of the bad feeling.

DM: Right. Many other people were taking water. It was a situation where a neighbor is getting water because he's got a state water right and you don't get it because you have a contract right with the federal agency. It was patently unfair that there wasn't a way to share the misery and there wasn't a setup to prioritize. Bill Jaeger an OSU economist described a situation where you have one person who has a field and may get $10 an acre for the hay he grows and somebody else has a field and can get $200 an acre, but both of them get their water cut off. Economically that doesn't make a whole lot of sense[3].

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Health Effects of Indoor Air Pollution

Introduction:

One of the most pressing issues in development in the Third World is how to bring modern energy services to the 2 billion people who have little access to electricity and who depend for cooking and heating on local biomass in the form of wood, crop residues, and dung. Such fuels are often damaging to the local environment, inefficient, and harmful to people's health. The World Health Organization estimates that 1.6 million people die each year from the use of biomass fuels and coal in poor households. We spoke with Professor Kirk R. Smith of the University of California, Berkeley about his seminal work documenting the scope and nature of this major public health challenge.

ER: Professor Smith, what is your training?

KS: I did my dissertation back in the seventies during what was called the nuclear wars; that is, the discussions about the role of nuclear power and the U.S. and the world energy situation. I did a comparison of coal power and nuclear power in the context of health effects and risk assessment. When I finished my doctorate I went to the East-West Center in Honolulu where there was a new institute starting up looking at energy and environmental issues in Asia. At that time nuclear power was rapidly evolving in Korea, Taiwan, Japan, and coming up in China and India, and at the time it looked like it was going to come along in Indonesia and Thailand.

I had trained myself to look at the impacts on human health and was looking at the energy picture in general. I found to my initial surprise that the big public health issue around energy use in Asia is not really in the highly developed end, the nuclear power end or the power plant side of things, but in the energy used by the large majority of the population that are living in rural areas and still using the simple fuels, crop residues or wood or cow dung or similar biomass fuels for cooking and heating.

In poor countries like Nepal, 90 percent of their energy is in the form of these household fuels. Even in big countries with large industrial sectors like India, a large fraction, about half of the energy was in that form. It doesn't take too long spending time in rural areas to see the high air pollution levels inside houses that result from the use of these fuels.

Indoor air pollution exposures people receive while cooking over a wood fire are orders of magnitude higher than what people worry about in our cities.

ER: The numbers in your paper were astonishing.

KS: During field trips in Asia in the late 1970s, I noted the apparently high smoke levels in village homes, but in the literature I couldn't find any serious measurements in these settings. Thus my students and I did some back-of-the-envelope calculations to determine how much pollution probably comes from burning a bit of wood and what the indoor air pollution concentrations might be. The numbers seemed so incredibly high it was hard to believe, so in 1981 we organized a little project in West India and did the first assessment of what exposures people receive when cooking with this oldest of human technologies, the wood fire[1].

These measurements, which verified our calculations, showed that those levels of pollution are orders of magnitude higher than what people worry about in cities. If you want to have a measurable impact on health, and the health of the most vulnerable, it is the oldest not the newest technologies that need more control.

Then as we started to pin down the health impacts of the biomass fuels we came to realize that the current situation was highly damaging globally. Recent estimates done by the World Health Organization last year were that 1.6 million premature deaths a year can be attributed to household burning of simple solid fuels such as biomass and coal.

ER: That doesn't even consider the environmental degradation.

KS: That's right. In those parts of the world where the biomass resources are not harvested renewably, there's pressure added to deforestation because of fuel use. That's not true everywhere but it seems to be true in some places.

Then as we did more measurements during the nineties we realized that the inefficient use of these fuels, such as burning them in simple stoves, was contributing to the greenhouse gas problem. So from a standpoint of energy, ecology, health, and greenhouse gases, they weren't attractive.

As alternatives to biomass fuels fossil fuels in the form of gas or liquids could be transported easily and burned efficiently with simple devices.

There was a paper that was done for the Johannesburg Summit last year arguing that you shouldn't have the poor using these fuels because it'll add to greenhouse gases, which is a rather strange argument. The real problem with greenhouse gases in the world is not created by village stoves, no matter what they're burning in them. It's the SUVs and power plants and jet aircraft and so forth that the First World is using. Small changes in behavior in the First World would more than compensate for anything that the world's poor people were doing. It was a rather strange view of things to ask the poor to take on technologies that the rich weren't willing to, and which would have virtually no effect on climate change. So my suggestion in the *Science* editorial was a simple one: maybe we ought to use this onetime gift from nature, fossil fuels, for a high-value use and not just burn them in our SUVs[2]. What higher value use could there be than providing clean efficient cooking for the world's poorest populations?

I was trying to present a broader view of the petroleum picture: that petroleum has its advantages, and this is one of the advantageous places to use them. I got a lot of nasty emails from that editorial, however, people blaming me for the Iraq war, among other things. Also many emails in agreement.

Two billion people depend on wood, crop residues and dung for heating and cooking.

ER: This is a big health problem and nobody has addressed it yet. You can't help but think it's because this is a poor population and below our radar.

KS: It's certainly true. It's the most disenfranchised of the world's population. It's in the Third World, in rural areas, in poor households, and then it's women and children, about the lowest part of the totem pole. It's clear that the health effects are serious. One of the issues that isn't so clear, however, is whether there are there cost-effective ways to address the health effects for these people.

The history of my career in regard to indoor air pollution is that I go to air pollution meetings and I present some of the air pollution levels that we and other people find and people there say, 'These are twenty to fifty times greater than levels we know cause ill health, you don't need to know exactly how much ill health it causes. It's clearly unacceptable, and you should go out and fix it.'

Then armed with this encouragement I go to the international health meetings, and they listen to me and they say, 'We've got $5 per year per capita to spend in our country. Are you telling us we take away from antibiotics and vaccines and put it in improved stoves or clean fuels?' In a better world there would be more resources to deal with these populations, but in the world we live in you've got $5 or $10. It's $13 per capita in India, for example, and they still can't cover their population with vaccines and antibiotics. Vaccines and antibiotics are pretty cost-effective ways of improving public health. One of the things we're doing now is trying to pin down the health effects of indoor air pollution in such a thorough fashion that we can step up to the table and compete with these other needs.

ER: That's the point of your Guatemala project isn't it?

KS: That's right. Many studies have been done, for example, looking at children that live in houses with clean fuels versus children who live in houses with dirty fuels, and they find that in the houses with dirty fuels the children have more ill health. But then there are also other differences, nutritional differences, ethnic differences, and so

on. You can try to adjust for differences in these other factors in the mathematical models, but you're never quite sure that you've caught everything. The gold standard for showing causality is randomized trials where you randomly allocate the improvement in the population, and then if you see a difference it's most likely due to that intervention and not something else.

That's what we require for new drugs, for example, where we have placebo-controlled trials. But it's not easy to do randomized trials with air pollution or environmental factors. In household indoor air pollution, however, we can do a randomized trial. We first tried to get funding for this work in 1986 and got funding finally in 2001. I don't know who the slow learner was, funding agencies or us, but we finally got funding. We first tried to do it in Nepal, but in the early nineties we switched to Guatemala and have a good site there. We have thirty-five full-time people including three full-time physicians and we have an international scientific team involving people in Guatemala, Geneva, Liverpool, Bergen, Atlanta, and here in Berkeley.

We randomly allocated an improved stove called a plancha, which is a stove with a chimney, in a population that's using open fires. We've done a lot of pilot work. We know that it lowers the exposure substantially; we know that people like it and use it and will continue to use it.

ER: It just gets the smoke out of the house?

KS: It has an enclosed combustion chamber connected to a chimney that puts the smoke out of the house, so it doesn't reduce the smoke. It may actually increase it, but it puts it out of the house so that people's exposure is much less, although not zero. The levels of pollution are still above what would be considered acceptable in the U.S. They're maybe twice as bad as acceptable here, instead of twenty times as bad.

An improved stove, a plancha, lowers exposure to indoor air pollution. People like, use it, and will continue to use it.

ER: What do you expect to see as a result?

KS: The chief outcome we're examining is pneumonia in young children, which is the chief cause of death in the Third World. It kills two million children under five in the Third World every year, more than diarrhea or malaria or any of the other major illnesses. People worry about SARS. When I give lectures now I talk about New SARS. People have heard of New SARS because it killed 800 people over six months. Meanwhile, Old SARS — old sudden onset pneumonia — killed a million children.

ER: That's not a stretch. These are both acute lower respiratory diseases.

KS: That's right. In fact, one of the things that's fearsome about New SARS is how rapid it can happen. People can go from first symptoms to death in a week. We had a child in our site a couple weeks ago, however, who went from perfectly healthy to dead in two days with Old SARS.

Cynically, of course, the big difference is that businessmen don't have to worry about catching old SARS. They can walk through the slums of Kolkata where kids are dying every day and not have to worry about catching it themselves, so it doesn't get in the Wall Street Journal. New SARS was worrisome because we didn't know where it was going. It was obviously something we had to be concerned with, but you might also want to be concerned with two million kids dying of Old SARS.

Probably the most important risk factors for acute lower respiratory infections are malnutrition and crowding. But they don't account for all the incidence of it, so it's quite likely that indoor air pollution is responsible for a substantial portion. We can estimate that based on these twelve or fifteen

past observational studies, but we'll be able to pin it down much more convincingly once we get further along in our intervention trial in Guatemala.

ER: Can you compare the exposure of someone to indoor air pollution to a chronic smoker?

KS: That analogy leads to some problems. First of all, we don't know exactly what it is in any of these smokes that causes the ill health. More importantly perhaps, it depends on the end point. If you're worried about chronic lung disease, then it's one set of pollutants; if you're worried about lung cancer, it's another set of pollutants.

For cancer, one of the pollutants that's been most commonly used to compare one mixture to another is benzopyrene, a chemical known to cause cancer in every single organ of every single animal it's been put into. Of course, however, we don't put it into humans on purpose.

It's in cigarette smoke and it's in other things known to cause cancer. If you compare on the basis of benzopyrene, then a woman cook in a Third World setting is getting ten packs a day. But that's misleading. In cigarettes people have come down to two measures: tar and carbon monoxide. Tar is what's captured on a filter and looks tarish — is what air pollution people call respirable particles. If you compare on the basis of tar or particles, then a village cook in a Third World setting is getting five or seven cigarettes worth per day. That's probably a better analogy, and that's about where the risks are.

Active cigarette smoking where somebody is smoking twenty or thirty cigarettes a day is a huge risk. One out of two cigarette smokers die young. It's a 50 percent risk. Few wars have 50 percent risk. It's such as astronomical risk that it's astonishing as compared to almost anything else. If you wanted to think about the risk in terms of cigarettes, it's something on the order of quarter a pack or a little more a day. Of course, half the world's population is being exposed, and these are stressed people with poor nutrition, poor access to medical care, poor housing, poor education, and so the overall impact is high.

ER: Does that pollution exposure translate into symptoms you can see?

ER: What it does is it increases the risk of a background rate of disease, and if you have a high background rate of disease because of bad nutrition or other problems, then that ends up to be a big burden.

You can compare the impact of indoor pollution in China and India. In India it produces a lot of acute respiratory infections in children because the background rate is bad and there's bad medical care and kids don't get antibiotics. If you double the risk, you're likely to double the death rate.

In China, although the rural areas have still a long way to go to get good medical care, there aren't nearly as many kids that die of pneumonia. They do get the antibiotics before they die, and so the big impact of indoor air pollution in China is in chronic obstructive lung disease in adults, particularly women who cooked all their lives. COPD includes chronic bronchitis and emphysema, that set of respiratory diseases that smokers often get.

In China women don't smoke, at least not yet, and 18 percent of deaths in China are chronic obstructive lung disease. I think part of that is because of indoor air pollution in the women.

Those are the two effects we have by far the most information on, and they are big effects. We have studies now that show the relationship of the indoor air pollution with tuberculosis around several studies in India and a couple in Mexico. I have a student who's doing work on indoor pollution and cataracts in Nepal. We have studies that show a relationship with asthma. We have studies that show a relationship with low birthrate. Low birthrate is a risk factor in turn for a whole range of childhood and probably adult diseases.

These are less well established than the main two, which are pneumonia in young children and chronic obstructive lung disease, but we are trying to pin down the others as well.

In addition, one of the main outcomes of outdoor air pollution is known to be heart disease. Because we have this big effort in Guatemala and our own lab and clinic, we are now embarking jointly with a group at Harvard University on a study of heart disease. We may find that as well.

ER: Is that a big effect?

KS: In the U.S. outdoor air pollution might cause a 5 percent increase in heart disease. Since there's a lot of heart disease, that's a big effect. In Guatemala a 5 percent increase in heart disease may not be such a big problem. It may be the same percent increase, but if you start from a lower baseline it may be not particularly important from a population impact standpoint. These two issues sometimes get confused. The risk can be high, but if the background rate is low it doesn't really make much difference. If you double the risk of a rare disease, the increase is still relatively small.

ER: What's the connection between particles and heart disease?

KS: It seems that it's related to small particles, which you find in things like diesel exhaust and you also find in wood smoke. These particles penetrate through the lung into the blood stream and end up being sites for plaque formation in the heart and changing the electrical pattern in the cells.

I've got a pile of recent reviews sitting right here of people doing animal studies and trying to figure this out. In an epidemiological sense it's pretty clear that in outdoor air pollution studies hundreds of studies in the U.S. and Europe have shown a relationship between small particles and heart disease.

We wonder if we see this in Boston where the particle levels are 20, 30, or 40 micrograms per cubic meter; what is happening with our women in our Guatemala project who are getting 500 to 2,000 micrograms per cubic meter?

ER: How do you measure that?

KS: We now have these holter monitors, the portable devices recording the electrical signals from the heart. They put the leads on the chest like they do in an electrocardiogram, except instead of going to a big machine standing next to the bed it goes to a little device that you put on your belt and it records it on a tape. We just started that last month in Guatemala, so we should have some information before many more months.

My guess is it's going to show changes in heartbeats, which indicates an increased risk of heart disease, but these people don't have high cholesterol and they get plenty of exercise and thus do not have high heart disease rates.

But it also has an interest to people in the First World to try to understand this phenomenon of what seemed to be absolutely unconnected things — breathing small particles in the lungs and having heart attacks — but now through these animal studies they're finding that there are some plausible mechanisms such as changing the thickness of the blood.

New SARS killed 800 people over six months. Meanwhile old SARS (old sudden onset pneumonia) killed a million children.

ER: What kind of intervention do you see happening?

KS: It may be that we'll be able to show that the improved stoves or changing to a clean fuel like liquefied petroleum gas can be justified on a purely health basis. Because you're competing with antibiotics and primary health care and things like clean water and sanitation, however, it may be that we're going to have to add up pollution's effects across several diseases before interventions cross over the boundary of cost effectiveness.

On the other hand, if you could add in some of the non-health benefits like fuel savings and less impact on the environment, either cost savings for the family or time savings for the family, then you could more easily justify spending the money. I think we could justify it with what we know now, but one of the problems is when you've got benefits occurring in different sectors there's nobody to go to get a full accounting. The health people say it doesn't quite compete compared to the other things they're doing; and the deforestation people say it doesn't quite compete with other things they're doing. Then the development people say they've got better things to do in terms of saving people's time, but they discount the other activities because they aren't in their bailiwick.

One of the arguments we have to make is for integrative analysis, and this is often true with environmental interventions. Clean water is a good example. Clean water is not cost effective in many places purely as a health improvement, but if you look at the time savings because you bring the well close to the house and the women or young children don't have to spend hours every day climbing down the hill to get water from the dirty stream, you add the time savings and it's quite cost effective.

ER: Arguing that clean water isn't cost effective boggles my mind.

KS: In the First World setting there would be no question about spending money to do something about it

because we spend billions of dollars to protect ourselves from environmental hazards quite happily with much less firm evidence in the context of this strict look at causality.

Unfortunately we can't free up those billions from the First World into the Third World, although Bill Gates and other charitable agencies do help us move some of it into the Third World. You're just dealing with a different set of criteria because the resources are so constrained.

ER: It seems like we're dealing with a dichotomy here: a pre-industrial society on one side of the divide and us on the other.

KS: And yet we all live in a common world. One of the reasons that I'm pushing our research on TB so much is because people in Washington and London may be intellectually concerned about kids dying of pneumonia in India, but it does not threaten them, unlike TB, which threatens everybody. We think we can show an indoor air pollution connection with TB, even though it's not going to be the major cause of TB. If, however, you can reduce the TB risk by 10 percent that's going to register in some places.

TB is a worrisome disease in general because it's on the increase in the world because it is the chief outcome of HIV in the Third World. Then there are drug-resistant strains starting to show up, making it even more troubling.

It is much easier to argue the global village with an infectious disease like TB. I try to argue the global village with pneumonia as well, saying that we are all impoverished if there are children unnecessarily dying of pneumonia anywhere, but TB will make the argument easier.

Sometimes people, a bit unthinkingly, say you shouldn't be saving Third World children because there are already too many anyway. Of course, I don't think they really listen to themselves and what that implies. But my response to that is that no populations have ever reduced their fertility; that is, started having fewer children, until the child death rates have gone down. If you see children dying all around you, you're not going to lower your fertility rate.

No population has ever reduced its fertility until the child death rates have gone down.

It's not a sufficient condition. There are places where child death rates go down and then fertility doesn't go down because you have to provide access to contraceptives and women's education too, but you won't get lower fertility without reducing death rates no matter what you do.

We see that already in our Guatemala studies. We've had thirty deaths in our 500 children already, deaths or stillbirths. The first thing that happens is the family gets pregnant again. Paradoxically, you have to save children in order to have fewer children. That's even aside from the humanitarian and ethical issues.

ER: You mentioned environmental concerns as well.

KS: We've done measurements now in India and China showing that because of the poor combustion conditions in typical biomass and coal stoves that they produce a lot of greenhouse gas-related pollution.

ER: Carbon dioxide?

KS: Mainly methane. One of the products of incomplete combustion in these devices is methane, and methane is a twenty or twenty-five times more powerful greenhouse gas than carbon dioxide. If you're going to put carbon in the atmosphere, the best thing from a greenhouse gas standpoint is actually carbon dioxide. The methane turns to carbon dioxide eventually but in the meantime it is a more powerful greenhouse gas. This is not to suggest that Third World households are causing the greenhouse gas problem in the world. If there were only Third World households burning biomass there would be no greenhouse gas problem. Conversely, you can change all the Third World households to something else and you'd still have a greenhouse gas problem.

My argument is that if you're going to spend money to reduce greenhouse gases, why not spend it in places where

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you'd get other benefits as well? If you improve combustion in Third World households you not only get carbon savings and greenhouse gas reduction, you get health benefits and environmental benefits.

We need to control SUVs and many other things to reduce the pressure on the global climate, but in that list of things we do let's be sure to do some things that also have other benefits. Approximately 4-to-6 percent of human greenhouse gas contribution is from household combustion. Obviously, if you get rid of it you've still got a big problem. Nevertheless, if you're spending money why not do it and get some of the other benefits too? That's part of what's called a no regrets strategy. If it should turn out that greenhouse warming is not as dangerous as many people think, you haven't wasted your money. So do things that have other benefits and then buy the insurance also. If the insurance turns out not to be needed, you've got something else.

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