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## Grizzlies in the Yellowstone Ecosystem

Introduction:

The Yellowstone ecosystem is comprised of 2.2 million acres in the Park and about 4 million acres of surrounding wilderness areas, and is home to the largest remaining grizzly bear population in the lower forty-eight states. Yellowstone grizzlies were given endangered species status in the mid seventies and management programs were put in place to reduce their interactions with humans, the main cause of bear mortality. The actual number of bears in the Yellowstone population and the rate of increase of the population are a matter of fierce contention. The Fish and Wildlife Service is under political pressure to remove the grizzly bear from the endangered species list, and has said that the grizzly population has grown at 5 percent per year since the mid eighties. However, Craig Pease and David Mattson's demographic analysis of the Yellowstone grizzly population found that its size has changed little from 1975 when the bear was listed, to 1995 when some managers were claiming successful recovery. We spoke with David about his twenty years of work on grizzly bears.

**ER:** David what is your job and training?

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**DM:** I'm a research wildlife biologist with the Biological Resources Division of the U.S. Geological Survey. My bachelor's degree is in forestry, my master's in plant ecology, and my Ph.D., which I'm wrapping up, is in wildlife biology. I have been doing research on grizzly bears in Yellowstone for twenty years. The first fifteen years of that was field-work on their foraging behavior, diet, habitat relations, and their relations to humans. That work led me into making broader connections between what was going on with the habitat and what was going on with the demography.

**ER:** What do you mean by demography?

**DM:** The birth and death rates manifesting in growth or decline of the grizzly population. This analysis[1] was an attempt by Craig and myself to incorporate some of the insights that had been gained about what was important to bears living or dying in Yellowstone and then to reflect on the conventional way that we did demographic analyses in the past.

**ER:** How was the grizzly population analyzed before?

**DM:** The convention has been to organize the rates at which grizzlies live or die by whether they are male or female and by their age. That approach may work, if we sampled randomly, with respect to age in particular. Quite often we looked at the death and birth rates of female bears, assuming that what happens with the male fraction of the population is pretty much irrelevant as long as there are enough to breed the females that are available.

But I think it has not been fully realized that this is positing a model about what determines birth and death rates. This conventional way of organizing data presupposes that essentially the only things that matter as far as birth and death rates go, are whether the bear is male and female, and its age. When you state the assumptions in those bald terms, on its face it is a hardly defensible proposition because we know there are many things that affect birth and death rates: how much food might be available; how many predators there might be; the ambient conditions that may induce death from exposure or starvation, to name a few. So we did this analysis to model the effects of variables in the bears' environment that affected their birth and death rates.

The other big issue I mentioned was that we did not have a random sample of grizzlies. We did not have a good representation of birth and death rates relative to the different seasons of the year, or relative to the different types of years, or even relative to the age of the animal. So we had two issues we needed to address. We had sampling bias, and also many effects that we wanted to meaningfully represent in our analysis.

There were two primary effects that had been suggested by previous analysis and also by field observation. One of those was the effect of the size of the whitebark pine seed crop. The whitebark pine produces a fairly large fatty seed somewhat like the seeds of the piñon pines, and when whitebark pine seeds are abundant they can comprise almost the entirety of the grizzly bear diet.

The whitebark pine grows only up at the highest elevations in the ecosystem, above about 8,400 feet, which also happens to be far removed from where most humans are active. We had observed before that when white bark pine seeds were abundant the bears were not getting in trouble with humans nor were they dying as often at the hands of humans. When whitebark pine seeds were scarce, we saw the opposite, we saw a dramatic increase in conflict with humans and death at the hands of humans. About 80 to 90 percent of all the bears past the age of weaning that die, are killed by humans, so interactions with humans are critical to determining their survival. It appeared that abundance of food was directly determining the distribution of bears in the Yellowstone ecosystem, and then indirectly determining levels of conflict with humans and rates of death of bears.

We had also observed that bear behavior affected whether bears survived, in particular how much they tolerated humans. Bears that lost their fear of humans and then ended up spending more time around humans seemed to be dying at a much higher rate, whereas bears that remained fearful of humans tended to remain in the back country more and did a better job of staying alive.

**ER:** How many bears are there in Yellowstone?

**DM:** There are other people working on that. Craig and I did not try to deal with that issue directly, and it is important to know how many bears are out there. I'm reluctant to say the number because it's not my work and I don't know the details of what's been done. None of it's been peer reviewed; none of it's been published. The point that I try to make is that numbers are only numbers until they are imbued with meaning. For instance, how many bears we have now compared to how many we had in the past.

There is an effort right now to develop reliable techniques for estimating grizzly population size, but it unfortunately is a method that can't be retrospectively applied. So we may come up with an estimate now, but we don't have estimates of comparable reliability for the past for comparison, which is why Craig and I focused on estimating population growth rate as a

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means of coming to understand the current status and past history of the grizzly population. We are using a modeling approach to try to identify important factors for their survival or death, because I think that's the only way that we can come to grips with the future.

**ER:** What are the causes of death for grizzlies?

**DM:** The primary cause of death is trauma from a bullet wound. Second to that is a lethal injection, under a controlled situation in a laboratory because the bear had been deemed too dangerous to let live. There are four primary reasons why bears are killed by humans. The first is by managers because the bears are thought to be an unacceptable risk to human safety. The second is over conflict with livestock, primarily sheep, and that's a declining cause. The third is by big game hunters who are not hunting bears but hunting elk or moose or mule deer. Big game hunters kill bears because they are sneaking around in the woods and surprise the bears or, more often, the bears are killed in a conflict over possession of the animal that the hunter killed. The last cause is poaching, which is a garbage can category in some ways.

**ER:** What are the proportions of each of those mortality factors?

**DM:** The importance of the causes have changed over time. In the seventies sheep herders were killing a lot of bears. That cause has diminished to where it's not of great consequence any more, although we're seeing an upsurge in conflict between sheep herders and bears on the periphery of the ecosystem recently. Removal by managers peaked in the eighties but has dropped off recently.

One of the issues of greatest concern is death at the hands of big game hunters, which has remained a major cause of death over time. There are some pretty intractable elements of that conflict because people want to hunt elk; and I think it's gotten to the point where elk hunters attract bears. There's data to suggest that bears are attracted to the sound of gunshots during hunting season.

**ER:** What did your model suggest were the major influences on grizzly survival?

**The primary cause of (grizzly) death is trauma from a bullet wound. Second to that is lethal injection...**

**DM:** Previous work had suggested variation in whitebark pine seed crops and the level of fear of humans were two major effects on grizzly death rates, modified somewhat by the reproductive status of the animal and its age. We thought that perhaps abundance of whitebark pine seeds affected birth rates, and so we were exploring that as well.

**ER:** Not having a random sample of the bear population could wreck your computer models.

**DM:** There were many things that might affect sampling biases that we considered. We built a model in a rigorous way to incorporate all the effects that we were at least entertaining as possibilities, and dropped out those that did not have statistical weight. For instance we considered the effect of time period, especially the effect of bears living before the mid eighties versus living later. The reason we considered that is there had been some speculation, if not assertion, that improved management had resulted in an increase in the bear population since the mid eighties.

So in the model we were entering time period as a surrogate for management effect, in competition with primarily the effects of white bark pine seed crop size. We also looked at the effects of bear use of a couple of other foods. The bottom line is that white bark pine seed crop size had a very strong effect on death rates from one year to the next.

**ER:** Because the bears couldn't winter over?

**DM:** No. It was death rate during the same year. If there were large white bark seed crops it kept bears up in the high country and away from people. It wasn't so much nutrition, but keeping bears out of the way of humans, getting back to the point that what determines whether bears live or die are levels of contact with humans. So abundance of seed crops induced a refuge effect.

The other thing that had a strong effect on grizzly survival was whether a bear was judged to be wary of humans or habituated to humans; that is, had lost its fear. That was a little difficult to deal with because the criteria are ambiguous as to whether you would consider a bear to be wary or habituated except at the extremes. We used a surrogate measure, which was the reason why the bear was trapped and radiomarked in the first place. We considered a bear that had been first trapped as part of a management effort to be our habituated bears, the bears that had lost their fear of humans, because management trappings were a response to that behavior. The other class of bears were those that had been trapped first for research. There had been a trapping effort out in the back country, typically involving snares, and the bear was not targeted for any reason other than it was nearby.

The results were pretty clear. There was a two-fold difference in death rates of those two classes. The management-trapped bears were dying at roughly twice the rate of the research-trapped bears. We found there was a source-sink population structure. The wary bears, the bears in the back country, were producing a surplus of animals on average, whereas the habituated bears, the bears that lived near humans, were chronically in decline and recruiting bears from the back country into their population.

So what is absolutely critical to understanding the dynamics of this population and estimating its growth rate and understanding its long-term prospects is understanding the rate at which back country bears, the wary bears, become habituated front country bears.

**…large whitebark pine seed crops kept bears up in the high country and away from people… what determines whether bears live or die are levels of contact with humans.**

The back country population is losing bears in two ways; they die outright or they are recruited into a different population that is exposed to a different risk of death. Those were the main features of our results, and time period did not enter in a meaningful way. In other words, pre mid eighties, post mid eighties was redundant to and less of an effect on grizzly numbers than whitebark pine seed crop size.

There were more frequent good seed crops between the mid 1980s and the early 1990s than before that time. And it appears there was a relatively substantial increase in the grizzly population during that same time period. But our thinking is that this was due to better whitebark pine seed crops and that we'd had less of an increase, if not more likely a decline, before the mid eighties because we had had fewer good seed crops. So the evidence for an effect of management on overall numbers of bears dying is ambiguous, whereas the evidence for an effect of seed crop size is quite strong.

**ER:** What are the main grizzly management programs?

**DM:** There were two major grizzly management programs that were instituted, starting in the seventies but with greater vigor in the mid eighties that had an effect on the reasons why grizzly bears die. The first was to sanitize the ecosystem; in other words, to make our food unavailable to bears in places where we live and play. Many bears were dying because they were associating feeding opportunities with humans because we had our garbage or our food freely available to bears. That meant putting in bear-proof garbage, that meant closing down the remainder of the open-pit dumps in the core of grizzly bear range, that meant installing bear-proof food storage boxes in the back country. There were major improvements in that regard.

**ER:** They had to make a big dent in the population just to get rid of those garbage bears, didn't they?

**DM:** Absolutely. There were two major dents, so to speak, that were made. The first was when dumps were closed in the late sixties, early seventies. Depending on what years you count, there were probably 120 to 140 grizzly bears killed shortly after the major open-pit dumps were closed in the core of the ecosystem.

I alluded to a major spike in management-related removals in the mid eighties, and that was indeed what you just suggested, a cropping off of the bears that had come to associate humans with food; those animals were killed. The other major management program involved getting sheep out of the core of grizzly bear range, which was largely successful and was aided by the relatively dismal economies of raising sheep. Many of the people who had run sheep in bear country went out of business or shifted to raising something different. Those are the two major programs that had demonstrable effects on the reasons why grizzly bears die.

At the same time that those programs were put in, there were increasing numbers of people both living and recreating in the Yellowstone ecosystem. So it could be that these programs were mitigating against other negative trends associated with the numbers of humans, and so it all came out a wash in terms of management effects on numbers dying.

**ER:** The more you look at it, the more complicated it gets.

**DM:** That is a message that I've been trying to bring home to anyone who will listen. And all I've presented to you here is a superficial gloss. We are dealing with a complex system that is open to all sorts of influences on grizzly bears from all sorts of surprising and unexpected directions.

Recognizing that whitebark pine seed crop size has a major effect on death rate is critical to understanding the future prospects of the grizzly population. Whitebark pine is severely threatened by an exotic disease called white pine blister rust. It affects five-needled pines, and don't ask me why just five-needled pines, but whitebark pine is one of the five-needle pines, and it has virtually no resistance to this disease. The majority of the trees that are infected with it die. Blister rust is now in the Yellowstone ecosystem, and all of the predictions are for it to spread at an increasing rate. Also the prognosis for one effect of global climate warming is that we may lose 90 percent of the habitats in Yellowstone where whitebark pine can grow.

**ER:** Because it's high elevation?

**DM:** Right. That life zone is probably going to be pushed right off the top of the mountain.

**ER:** So the trees either have to develop disease resistance or heat tolerance or we may lose them.

**DM:** There is some pretty dramatic self selection for rust-resistant trees out there, but there are so few resistant trees that are going to survive that even if we have rust-resistant stock it's going to be the devil to get those few trees to establish over large areas on their own. There are efforts afoot to try to find those self-selected trees and start propagating them. But we're dealing with an ecosystem that's mostly legally-designated wilderness, and so just from that perspective we have limited options. Plus the trees are in rugged country with difficult access.

**ER:** How big is the Yellowstone ecosystem as far as grizzlies are concerned?

**DM:** The core of the grizzly bear range is the 2.2 million acres in Yellowstone Park, but there's an additional roughly 4 million acres outside the Park, primarily on Forest Service lands, primarily in designated wilderness, because that's where bears tend to survive.

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**ER:** There were huge wildfires in Yellowstone in the summer of 1988. How did that affect the grizzlies?

**DM:** In the northern part of the ecosystem in grizzly bear range we lost about one quarter of the whitebark pine trees to the fires. In other areas the loss was between 13 and 18 percent of stands of cone-producing whitebark pine. Controlling for the effects of the size of the seed crop, there was an even more dramatic decline in bear use of white bark pine seeds after the fires. In other words, we may have had a 25 percent loss (for example, in the north), but the decline in frequency of bear use was even greater than that, 30 to 40 percent.

The 1988 fires burned almost exclusively in the core of grizzly bear range; the periphery of their range was relatively unaffected by the fire, so this loss of whitebark pine was concentrated in the core. In certain areas the loss of cone producing white bark pine was quite high, up to 40 to 50 percent died.

**ER:** How do grizzlies get at white bark pine seeds?

**DM:** The primary means by which grizzly bears get whitebark pine seeds is by excavating cones that were cached by red squirrels, the red squirrel middens. The squirrels do the bear the favor of clipping the cones and bringing them down to ground level and aggregating them. The bears come along and excavate the caches. So squirrel densities are every bit as important to bear consumption of pine seeds as is abundance of white bark pine in the overstory. But the cache size matters a great deal as to whether a bear will excavate the midden. The larger the midden, the more likely it will be excavated.

So squirrels matter to grizzlies, and midden size matters a great deal.

> **... to understand its long term prospects, it is critical to understand the rate at which back country bears, wary bears, become habituated, front country bears.**

We had a study where we looked at these dynamics, pre fire, post fire, in an area that was burned about 40 percent. The squirrel density overall in the study area didn't decline that much. There were no squirrels in the burned areas as you might expect; they just packed into the unburned portions of the stands. But average midden size declined dramatically. And we saw a decline in bear use of middens in this study area that reflected not only the loss of middens from the burned area, but also the reduction in size.

When we looked on the ecosystem scale, we saw exactly what we would have expected, given our results from this study area. So it may be that this decrease that we saw in our more focused study area was widespread in the ecosystem, resulting in an even greater decline in bear use of whitebark pine seeds than we would expect by just simply the loss of cone-producing trees. And again, this loss was focused in the core of the ecosystem.

There is a lot of discussion as to why we seem to be seeing more bears on the periphery of the ecosystem in the last decade, but when I was out there working it seemed awful suspicious to me that the upsurge in sightings seemed to come on the heels of the fires, with a lag of a couple years in places.

I've done some modeling that would suggest that there was about a 20 percent decline in carrying capacity of the ecosystem, even accounting for compensatory increases in use of other foods concentrated in the core of the ecosystem.

So in the short term I don't think there's any doubt that the effects of the fires were negative for bears and that there is less whitebark pine seeds for them to eat. And again it's important not just as a source of energy, but because it attracts bears to places where they will be safe from humans.

**ER:** What might be the longer term effects of the fires?

**DM:** The fire could play out beneficially in the long term because whitebark pine is a shade intolerant species that can be replaced by other trees like subalpine fir. So the fires may have opened up opportunities for whitebark pine to reproduce and that may be a beneficial scenario relative to the effects of blister rust. But we don't understand yet how global climate warming interacts with fire and the establishment of whitebark pine. So it may be that fire could hasten the demise of white bark pine by eliminating it in areas where those trees might be able to hang on but where they may not be able to reestablish.

**ER:** What is the scientific part of the controversy over how fast the grizzly population is increasing?

**DM:** I would argue that the controversy is not about numbers, it's about trends in factors that determine birth and death rates. Whether we have 200 bears or 400 bears or 600 bears or 800 bears, if the trajectory of things that matter regarding whether those bears stay alive or die is negative, it doesn't take long to kill off a few hundred animals. History is replete with examples of that point, including the history of brown bears in western North America. We were able to eliminate 99,000 bears from 95 percent of their range in a 70-year period from 1850 and 1920.

**Whether we have 200 bears or 800 bears, if the trajectory of things that matter regarding whether they live or die is negative, it doesn't take long to kill off a few hundred animals.**

If we had taken some viability analysis model based upon the theory of diffusion processes and applied it in 1850, based upon what were probably somewhat positive trends from 1800 to 1850, starting with 100,000 bears in a metapopulation structure, we would have predicted there was absolutely no chance that we would have lost what we lost.

So what matters to the grizzlies is what's happening in the environment that affects birth and death rates. I think numbers are of some importance, but getting caught up in the numbers is somewhat pointless.

I think the areas of disagreement are over causation. We all agree that between the mid eighties and the mid nineties, especially the early nineties, there was a substantial increase in the grizzly population. Our model, and not just the model but everything else we know about the system suggests that the increase was due to the abundance of a particular food crop, as opposed to simple assertions that management was the cause. That's one point of disagreement.

The other point is what is the more meaningful point of reference for judging the current status of the grizzly population. We analyzed data back to the mid seventies and estimated a one percent per annum increase in the population was most likely from the mid seventies to the mid nineties, which is a lower rate than what we would have found if we had just gone back to the mid eighties. The mid seventies encompasses all of the data, it goes back to the time of the grizzly's listing under the Endangered Species Act, and I have yet to hear a cogent rationale for why the mid eighties would be a more meaningful point of reference. Those are the main points of disagreement.

Numbers can obfuscate those main issues. Numbers can be quite confusing because for many years we were simply estimating the minimum number of bears likely to be out there. Then with new methods coming online we started estimating the most likely number or the mean number of bears, the midpoint of some range. So we went from looking at a lower bound to a midpoint; we went from talking about roughly 200 to 250 animals to closer to 400. That has been represented as if that were a real increase. So again it seems like the numbers have been used to obfuscate rather than clarify the more substantive issues.

**Literature Cited:**

[1] Demography of the Yellowstone Grizzly Bears. Craig M. Pease and David J. Mattson 1999 *Ecology* 80(3):957-975

## Dead Water in the Gulf of Mexico

Introduction:

The Mississippi River receives about 1.82 million metric tons of nitrogen each year from farms, sewage plants, and even air pollution, and delivers it to the Gulf of Mexico. This is three times the amount of nitrogen in the river only forty years ago. Nitrogen in the water is a plant fertilizer which causes rapid growth or blooms of marine algae in the Gulf in the summer when the water is relatively warm and calm. When the algal blooms die, they sink and rot, and the decomposition process depletes the water of oxygen to the point that marine animals must either leave the area or die. The water remains depleted of oxygen until the fall when storms mix the water and reoxygenate it.

Fishers have long known there were areas of dead water in the Gulf, but systematic measurements of the extent of oxygen depleted water only began in the 1980s. In 1989 the dead zone covered about 9,000 square kilometers (about 3,500 square miles) off the Mississippi delta. The summer after the 1993 floods the dead zone increased to 16,000 square kilometers, and has decreased to about 12,000 square kilometers since then.

We spoke with Dr. Nancy Rabalais, one of the first to document the dead zone in the Gulf, about her work.

**ER:** Dr. Rabalais, what is your training and where do you work?

**NR:** I received my Ph.D. in zoology in 1983, and I'm an invertebrate zoologist and a benthic ecologist with the Louisiana Universities Marine Consortium.

**ER:** What is hypoxia?

**NR:** Hypoxia means low-oxygen, not enough in the water to support marine life as we know it, fish, shrimp crabs, starfish, clams, snails, and such, the typical marine life that you might encounter on the bottom of the ocean.

In the 1950s and 60s fishermen would talk about what they called dead water where they didn't catch anything.

**ER:** How do you decide how much is low oxygen?

**NR:** When the oxygen content of the water is below two milligrams per liter, which is the cutoff we use, the behavioral response of the fish and shrimp is that they move out of the area. So it's not a completely arbitrary cutoff point, it's based on observational data.

**ER:** When did we first find out about dead water in the Gulf?

**NR:** In the 1950s and 60s fishermen would talk about what they called dead water where they didn't catch anything. But the first measurement of hypoxia on the Louisiana shelf was made in 1972; there's no quantitative data prior to 1972. A couple research groups from different Louisiana institutions did surveys in 1975 and 1976 and found areas of hypoxic bottom water on the Louisiana shelf in places where we have also been finding it consistently over the last several years. But there weren't any systematic studies until we started in 1985.

Between 1976 and 1995 many people were out on the water for different reasons, either fishery surveys, or oil and gas production and development assessments, or oceanographic studies, a whole host of other studies, and if they were in the places where it occurs now, at the right time, they would also sometimes document hypoxia. So the observations increased in later years, but that doesn't necessarily mean the frequency of hypoxia increased.

We've been studying hypoxia on a fairly consistent basis since 1985 because the director of our lab and researchers in Louisiana knew it was an issue. State agencies and state research funding sources did not see it as an issue, but federal agencies did. They knew the Mississippi River had been changing and thought it was something that should be studied. They finally got the first batch of research funds from NOAA to get the project off the ground in 1985, and we pieced together funding from 1987 through 1990. Then NOAA had a large program investigating the Mississippi River-Gulf interactions from 1990 to 1995 in which hypoxia in the Gulf was a small component, and NOAA has been funding my work since that time.

**ER:** You say hypoxia is just a small part of the interaction between the Mississippi and the Gulf. What are some of the other interactions?

**NR:** Lots of things are happening in response to river changes. Hypoxia is an obvious change, but there are other things also: how the Gulf ecosystem responds to increases in plant nutrients; how changes in proportions of nutrients affects phytoplankton communities; how those affect food webs; how that can affect carbon flux and oxygen in the water.

**ER:** What causes the hypoxia?

**NR:** The physical structure of the water column and the biological processes control hypoxia. The Mississippi River delivers fresh water with its load of nutrients to the Gulf. When fresh water reaches the Gulf it sits on top of the saltier, denser Gulf water, which results in a stratified, two-layer system. That stratification is maintained most of the year because the input from the Mississippi is so high. It's higher in the spring than the summer, but we still see this stratification most of the year unless winds mix the water column and break down the two-layer system.

The nutrients in the water act as fertilizer for phytoplankton, which are the base for the food web. Some of the phytoplankton are not incorporated into the food web but die and sink. So about half of the carbon that's fixed in the surface waters of the Gulf gets to the bottom. On the bottom bacteria decompose the phytoplankton, use up oxygen at a faster rate than it can be resupplied to the surface because of this two-layer system. So the physics creates a barrier, but the biology leads to the depletion of oxygen.

**ER:** The effects of hypoxia?

**NR:** The obvious effect is that any marine life that can move, leaves the area, and animals that can't leave, if the oxygen is low enough for long enough, they start to die off. Those are the things that live in the sediments, like the worms and the clams and the snails and the sea stars. So hypoxia can wipe out the benthic community. The system loses diversity, it loses biomass, and recovery is slower and it is a less resilient system where the low oxygen events appear versus an area where it's periodic.

> When the oxygen content of the water is below two milligrams per liter, the fish and shrimp move out of the area.

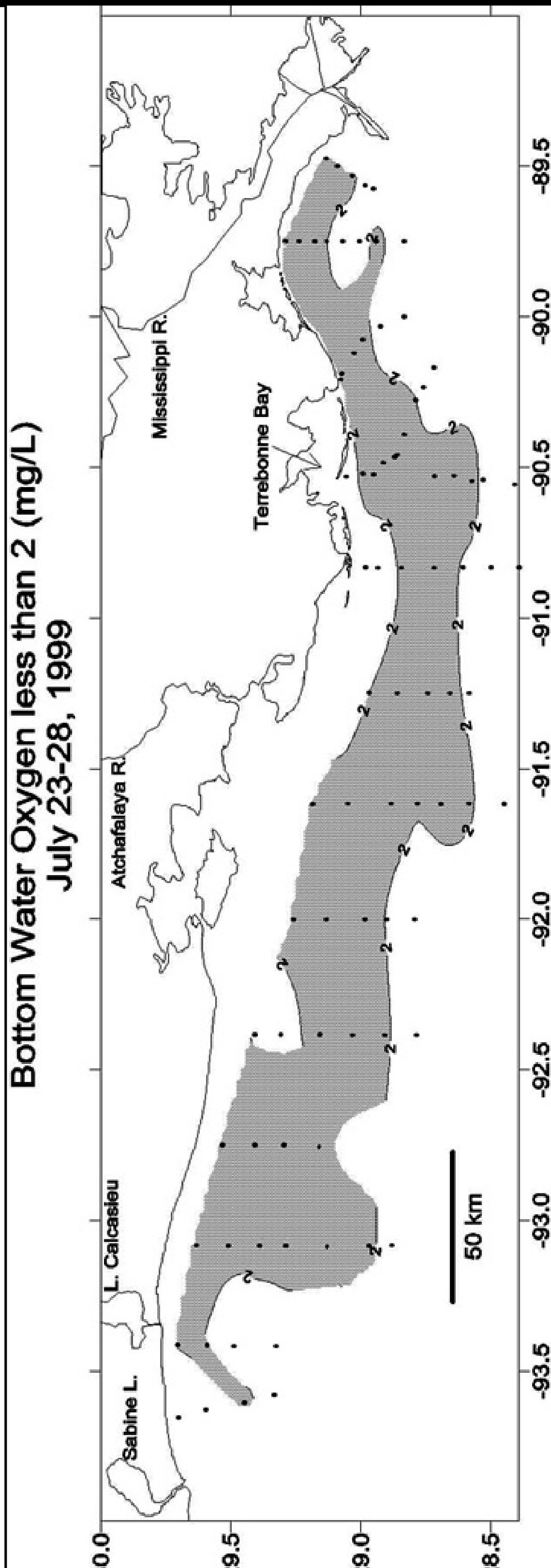
**ER:** What do you mean by less resilient?

**NR:** If the low oxygen condition disappeared in the fall, which it usually does, then you still don't get back to the same levels of diversity or biomass as compared to an area without hypoxia.

**ER:** How big is the dead zone?

**NR:** I spend seven days every summer mapping it, but that's just a five-day period; I could go out a week sooner or a week later and it might be configured differently in response to the winds and the currents. I don't know how big it is every day of the year, but I do know how big it is during a five-day period in midsummer. That one map is just a snapshot, and many people try to read too much into it. That map doesn't tell us the level of detail that we want to know about what's forcing the system.

We've got much better data for the southeastern shelf on a monthly basis. Between 1985 and 1992 the hypoxic area was about 7,000 to 8,000 square kilometers; beginning in 1993 through 1997 it was about 16,000 to 18,000 square kilometers; and in 1998 the size was down to about 12,000 square kilometers. We can't say there is a long-term trend because our data don't go back long enough, and it consists of five-day snapshots, but there was a definite step function between 1992 and 1993. 1993 was the year of a major




Mississippi River flood. Some people are making too much to do about the 1998 hypoxia number being lower. There were oceanographic conditions that explain to me why it was lower and not necessarily due to lack of productivity.

**ER:** How did the 1993 flood increase hypoxia in the Gulf?

**NR:** The flood increased the fresh water delivered to the Gulf, it increased the total nutrients and there was an increase in biomass and of phytoplankton offshore. Based on computer models we would predict a greater flux of carbon as a result, and based on the measurements, there was lower oxygen at more stations and for longer times than there historically had ever been. In 1994 the zone was still big, but 1994 was a normal flow year; in 1995 and 1996 it was still big, but those two years had a relatively late discharge of nutrients in the Gulf and water temperatures were higher, which also leads to high productivity. In 1997 the zone was a bit smaller. A hurricane developed in the study area before I went out and it might have made the area smaller. In 1998 there were persistent southerly and southwesterly winds, which pushed the whole hypoxic water mass to the east and into deeper waters. The area of hypoxia on the bottom was smaller, but it was in a different place because of the way the winds and currents were pushing it, and we don't know the actual volume of the water involved.

**ER:** When does the dead zone form?

**NR:** Hypoxia starts as early as February and I've seen it last as late as October. You don't usually see it in the winter because cold fronts move through that mix up the water column and break down the stratification. Even with high biological productivity, if the water isn't stratified, the water column is not stable long enough for the microbial respiration to draw down the oxygen and hypoxia won't develop.
But if the water is calm enough for long enough and there's sufficient phytoplankton production, hypoxia can develop. This year we've had it as early as February and consistently through June. It was sporadic and the areas are smaller and changed in the spring up until about May, and this is just on the southeast shelf where I have my monthly transect. Beginning in May it becomes fairly well developed and it's persistent and widespread through August or September, when we might get a tropical storm or cold fronts moving in and mixing it up.

**ER:** What effect does it have on fisheries?

**NR:** Well, there's obviously an area without enough oxygen to support marine life like shrimp, red drum, red snapper, and crabs for extended periods of the summer. In my opinion that's bound to have ecological repercussions, either through natural processing of materials through the ecosystem or in reduced fisheries production. The fisheries yield information we have is not conclusive because shrimpers can move and catch shrimp on the periphery of this area.

We don't know the long-term population effects of hypoxia. There are some indications that the catch may be going down over several decades. But there are many reasons the catch could be going down besides hypoxia. A concern for people who study hypoxia in other parts of the world is that there's not usually a gradual decline in fisheries, there's usually a crash once you've reached that tipping point in the system. I'm not saying that's going to happen in the Gulf, but it's happened in other places. For instance the fishery on the northwestern shelf of the Black Sea where there has been the same thing with increased eutrophication and more areas of lower oxygen over extended periods. There have been some fisheries losses in the Baltic that are also an extension of hypoxia.

**ER:** Does hypoxia affect the plant community structure in the water column?

**NR:** The amount of nutrients and the relative proportion of the nutrients can effect the phytoplankton community composition, and that can affect the flux of carbon through the system, which can effect hypoxia. Or it can affect the food web, which can affect animals higher up the food web like zooplankton or fish.

**ER:** What is being done about hypoxia in the Gulf?

**NR:** It's an education issue right now. There are many agricultural practices that have been applied within the watershed. The EPA is wanting to develop some non point source nutrient standards. There are many more people paying attention to it now than there were in the past.

**Nutrient levels in the Mississippi River have doubled or tripled since the 1950s and 60s.**

**ER:** What incentives would a farmer in Ohio have for reducing fertilizer use?

**NR:** Their own water quality and drinking water standards and the health of the natural landscape in their own region. Hypoxia is not just a Gulf problem, but I think that if the fertilizer costs go up it seems like it's a waste of money and nutrients. So you can tax; you can provide incentives not to over fertilize; you can regulate; you can encourage. Encouragement is probably the best. There are many extension agents and agricultural experimental areas right now trying their best to use less fertilizer and make it more efficient.

**ER:** You've got some cores through the delta sediments. Has that extended the instrumental record on hypoxia?

**NR:** Sediments accumulate under the plume of the Mississippi River and can give us an historical account of how the marine ecosystem has changed. Data from the sediment cores tell us that there have been some century-long changes, but that the productivity of the water column and the worsening of the low oxygen conditions started to rise dramatically during the 1950s, when the nitrogen levels in the river started to increase.

**ER:** How much higher is the nitrogen level in the Mississippi now compared to sometime in the past?

**NR:** Nutrient levels have gone up, they are stabilized now, but they have doubled or tripled since the 1950s and 60s. The system is noisy anyway with a lot of natural variability, so it's going to be a while before we either know exactly how the system is responding to flux of nutrients and/or if there are remedial actions that can be seen in changes in nutrient level. Then it's going to be a while before we can then, therefore, see changes in the offshore ecosystem. It's taken thirty to forty years to get to where we are now.

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# Extremely Low Frequency Electric and Magnetic Fields: The Phantom Menace

**An Editorial by Douglas Taylor, publisher of *Environmental Review***

The May/June issue of *Sierra* magazine, published by the Sierra Club, had an article titled Current Risks, under the headline "Experts finally link electromagnetic fields and cancer." The *Sierra* article is ostensibly about the recent study by the National Institute of Environmental Health and Safety which in fact did not report a link between cancer and low frequency electromagnetic fields (EMFs)[1]. How could *Sierra* take a carefully worded scientific report and turn its results upside down? It turns out there is a long history of confusion about possible health effects of EMFs and the media has not done a good job of reporting the topic.

**How could *Sierra* take a carefully worded scientific report and turn its results upside down?**

In the 1970s and 80s Paul Brodeur published a series of articles in *The New Yorker* magazine claiming that the dangers to peoples' health of extremely low frequency magnetic and electric fields such as those found near electrical appliances and power lines, were being hidden. This claim is difficult to reconcile with the millions of dollars being spent on research of this issue by numerous public and private agencies including the US Department of Health and Human Services, the US Department of Labor, the US EPA, the American National Standards Institute, the World Health Organization, and the National Academy of Sciences, to name only a few.

However, publicity surrounding Brodeur's articles and books produced support for more research on the possible health effects of EMFs. So in the late 1980s and early 1990s, a second wave of scientific reviews was funded, and have been coming out at intervals. They have all reached the same conclusion about the health effects of EMFs: not guilty, as far as we can tell. Not surprisingly these findings of no result received little attention by the major media.

### What Are EMFs?

We live our lives immersed in low frequency electric and magnetic fields. An example of natural EMFs is the Earth's magnetic field, which is what we detect when we use a compass, while an example of manmade EMFs are those very much smaller fields around electrical appliances and wires.

The static background from the Earth's electric field is about 120 volts/meter, about the same as the field found near a kitchen appliance. Electric fields are attenuated by the human body by a factor of about 100 million. That means the electric field that a cell in our body experiences from an unshielded hotplate is tiny compared to the Earth's static field.

Magnetic fields are a different story. Because our bodies contain almost no magnetic material, magnetic fields penetrate the human body without attenuation, and can generate electric fields in our bodies by the Faraday effect. Electric fields are also generated within our cells by the motion of ions (charged atoms and molecules); these naturally occurring fields are called thermally induced fields. Magnetically induced electric fields our bodies experience from power lines or household appliances are also small compared to thermally induced fields. However, small doses of EMFs does not necessarily mean they are harmless, for we know that many chemicals are toxic in small doses.

In the 1950s concern over the hazards of high frequency EMFs stemmed from soldiers and sailors having to work near radar and other transmitters aboard warships and aircraft; and standards for acceptable exposure to high frequency EMFs were worked out. In the 1970s and 80s epidemiology studies of the possible health effects of extremely low frequency EMFs were conducted by numerous public and private agencies, and the scientific consensus gradually emerged that there is no obvious health effect due to extremely low frequency EMFs. Higher frequency EMFs such as those used in military or medical technology are not under consideration here. In this article I refer to extremely low frequency electric and magnetic fields generated by electrical power lines simply as EMFs.

In the late 1980s further epidemiological studies suggested a possible link between EMFs and some kinds of cancer. Epidemiology works by looking at large populations to see if people with exposure to some toxin, cigarette smoke for example, have higher than average incidence of disease. Epidemiologists are the first to admit that their science is a blunt tool. Epidemiology looks for correlations between exposure and disease, but it does not provide information about cause and effect. The health effects of cigarette smoking are a classic example of epidemiology at its best. Epidemiolgy works well in that case because smoking is so unhealthy that its effects on people are hard to miss: higher rates of many kinds of cancer, heart disease, stroke, susceptibility to infectious diseases and so on. When the toxin to which people are exposed is very dangerous, like cigarette smoke, the epidemiology is consistent from one study to the next.

However when epidemiology is used to look for more subtle health effects the results can be inconsistent and confusing. The major media regularly report that scientists have found that some common food like chocolate or coffee or butter is bad for you. A few months later another study comes along finding the opposite result. This scare of the month syndrome is explained by the fact that most reporters and editors don't understand the limits of epidemiology, and by the fact that the industry has its own ideas about what is newsworthy.

This *Sierra* article is another example in the long running misunderstanding of the EMF issue which would be comic if it hadn't cost so many tax dollars and hadn't caused unnecessary grief and anxiety.

**…there is no convincing evidence to support the contention that exposures to extremely low-frequency electric and magnetic fields generated by household appliances, video display terminals, and local power lines are demonstrable health hazards.**

In cases where health effects are not obvious, epidemiology is working at the limit of its resolution. Even so, if epidemiology studies keep seeing the same small effect over and over, then scientists will start believing there is a real effect there. This appears to be the case with red wine: there seems to be a small health benefit associated with moderate drinking of red wine. We don't know why this is so, but the results keep coming back with the same answer so there is probably something to it.

The limitations of epidemiology is an important issue because the only evidence for adverse health effects of EMFs are epidemiological studies. These studies have found small correlations and have been inconsistent. Sometimes they see a correlation between EMFs and one or another kind of cancer, and sometimes they don't. This inconsistency should suggest caution on the part of those who claim EMFs are dangerous. There is just as much epidemiology suggesting no effect or positive effect of EMFs as there is of bad effects; and the information is equally suspect in both directions.

There are other ways of thinking about and investigating possible health effects of EMFs and they have not yet indicated that EMFs are dangerous. The use of electricity in the U.S. has increased enormously in the last one hundred years, with no apparent ill health effects: a natural experiment which appears to have a nil result. Moreover there is no known mechanism by which EMFs might cause disease. (This argument is hardly persuasive since we don't know how cancers get started anyway.) Finally, EMFs are so small as to be dwarfed by the background of EMFs from natural sources. Taken together, the evidence for adverse health effects of EMFs is shaky to non existent.

The following paragraphs are from the executive summary of the DOE 1992 report[2].

"This review indicates that there is no convincing evidence in the published literature to support the contention that exposures to extremely low-frequency electric and magnetic

**Table taken from ORI 1992 Report executive summary**

fields generated by sources such as household appliances, video display terminals, and local power lines are demonstrable health hazards."

"Epidemiologic findings of an association between electric and magnetic fields and childhood leukemia or other childhood or adult cancers are inconsistent and inconclusive. No plausible biological mechanism is presented that would explain causality. Neither is there conclusive evidence that these fields initiate cancer, promote cancer, or influence tumor progression. Likewise, there is no convincing evidence to support suggestions that electric and magnetic fields result in birth defects or other reproductive problems."

The report on health effects of EMFs that caught Sierra's attention was recently published by the National Institute of Environmental Health Sciences. It covered the same ground as the previous reports and reached the same conclusions: not guilty as far as we can tell. The following is from the NIEHS report executive summary: "The scientific evidence suggesting that ELF-EMF exposures pose any health risk is weak."

Scientists always hedge and never make absolute statements. Our conclusions are always provisional and subject to revision if new information becomes available. Therefore the more precise characterization of the EMF reports would be: not guilty as far as we can tell; we may have missed some health effect of EMFs but if we missed it, it is because it is a small one.

Reading the *Sierra* article mentioned above the unsuspecting reader would never guess that the NIEHS report reaches the same conclusions as the DOE report quoted above and all the others. The *Sierra* misrepresents the findings of the NIEHS report. It uses quotations taken out of context, a favorite rhetorical device of anti-environmentalists, to give the impression that the report has uncovered a threat to public health from EMFs when it has not.

This unfortunate article reduces the hard won credibility of the Sierra Club, its prestige, and its reputation for integrity. The anti-environmental propaganda from the radical right can be amusing in a perverse way. Much of its appeal can be likened to the thrill children get from using bad words. One can easily imagine anti-environmentalists saying, If the Sierra Club can't get its facts straight on EMFs, why should we believe them about anything else?

Perhaps the only benefit of advertising is that the American public is trained from an early age to detect and filter out propaganda. Environmental activists and educators must resist the temptation to exaggerate if they want to get people's

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attention and trust. We must use reason and example and trustworthy information to persuade people to take environmental issues seriously.

I urge you to join the Sierra Club, send them a donation, subscribe to the magazine and thank them for their magnificent conservation work. Having done so you will then be justified in asking the editors to cease and desist trying to scare the bejabbers out of us about EMFs. I would also suggest they organize a panel of scientists to review future articles that deal with technical matters such as EMFs or epidemiology.

Their email address is sierra.magazine@sierraclub.org.

Their mailing address is 85 Second St, second floor, San Francisco, CA. 94105-3441.

Their phone number is 415 977 5500.

**Literature Cited:**

[1] The NIEHS report "Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields" is available online at www.niehs.nih.gov/emfrapid/

[2] Health Effects of Low-Frequency Electric and Magnetic Fields. 1992 (ORAU 92/F8) US Government Printing Office # 029-000-00443-9

## NEXT MONTH

**TRADING POLLUTION PERMITS: Jay Coggins**

**IMPORTING EXOTIC INSECTS TO CONTROL EXOTIC PLANTS: Robert Ohmart**

**EMERGENCY FOR THE TROPICAL FORESTRY INITIATIVE: Carl Leopold**

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