# To Fish In Troubled Waters

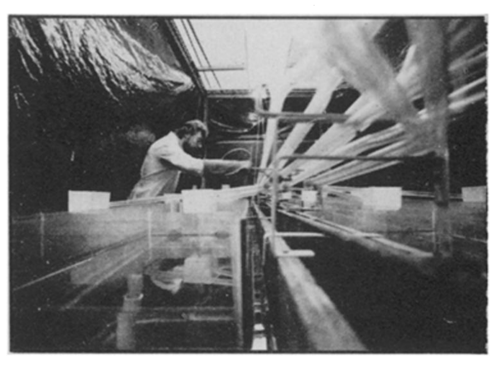
**Researchers are sampling fish from waterways to monitor for heavy metals and to determine how fish fare when they brave the elements**

BY LINDA GARMON

Jimmy Ellis wouldn't think of canceling his annual spring fishing trip to South Holston Lake — an East Tennessee body of water whose fingers reach up into the surrounding mountains and whose shores are dotted with wild turkeys and deer — even though several Tennessee waterways have naturally high levels of the heavy metal manganese. Ellis, chief photographer for the Johnson City (Tenn.) Press-Chronicle for 32 years, is stocking up on Spring Lizard bait and practicing his casting in the backyard as usual. Soon he will cross South Holston Lake for the twenty-fifth year in a row, well aware that a river parallel to the lake is closed for fishing due to mercury contamination.

And Ellis will continue his annual trips to South Holston as long as he and his fishing companions can manage each spring to lure 300 to 400 smallmouth bass out of the lake. Douglas Lake, on the other hand, is off limits as far as Ellis is concerned: That East Tennessee lake on the Nolichucky River, polluted by former mica and clay mine operations, harbors no smallmouth bass. Ellis explains, "When you have smallmouth, you have a clean lake."

*Photographs, from left to right, illustrate process of heavy metal research at the Columbia National Fisheries Laboratory in Missouri: Fish are raised in "holding tanks"; "exercise tanks" with circulating water are maintained for aquatic jet setters; pipes above test chambers disperse different concentrations of heavy metals into each chamber; fish are weighed and examined externally before internal tissue analysis; a separator funnel prepares fish tissue for the atomic absorption spectrophotometer; peaks on spectrophotometer readout indicate the quantity of a particular heavy metal in the sample undergoing analysis.*



Photos: U.S. Fish and Wildlife Service, Steve Hillebrand

Although Ellis's "smallmouth method" of detecting clean waterways may not be foolproof, it is a variation of a scientific technique — fish as biosensors of aquatic heavy metal concentrations.

Heavy metal pollutants enter fish by direct absorption into the gills or through the food chain. In the food chain, the heavy metals often are in the form of insoluble minerals absorbed onto the surface of organisms eaten by the fish. Although the study of these pollutants in fish is hardly an unpaved path, trails still are being blazed in the heavy metal area: Rather than documenting the effects only of acute concentrations of heavy metals on fish, for example, researchers have given new emphasis to the study of chronic, or long-term, exposure to low levels of heavy metals.

In fact, the U.S. Environmental Protection Agency's recently released proposed Ambient Water Quality Criteria for heavy metals includes both short-term and long-term exposure criteria for aquatic life. EPA's "Red Book" — still the official source for water quality criteria — includes only one general aquatic concentration limit for each pollutant.

The proposed criteria documents, expected to be in final form by summer, are the partial result of a lawsuit by the National Resources Defense Council against EPA for failing to meet its duties as specified by Section 307 of the Clean Water Act. A consent decree reached by the two parties in 1976 called for a list of toxic pollutants — including pesticides and heavy metals — along with criteria documents that summarize "the latest scientific information" on these pollutants, says David Sabock of EPA's Criteria and Standards Division.

Now, Dean Blevins of East Tennessee State University in Johnson City is joining the ranks of researchers gathering "the latest scientific information" on the effects on fish of long-term exposure to heavy metals. Blevins is studying fish in the Holston River and its tributaries — the main waterways running through 12 counties of upper East Tennessee. These waterways are in various stages of pollution, ranging from relatively unpolluted streams to those heavily polluted with metals from industrial wastes.

While certain heavy metals are harmful or poisonous, others — such as iron, manganese, copper, cobalt and zinc — are essential to the life of most organisms. Nonetheless, "all heavy metals are potentially harmful to most organisms at some level of exposure and absorption," Blevins explains. Furthermore, the heavy metals cadmium, mercury and lead are toxic to most organisms at the lowest concentrations. Blevins is studying the three most toxic elements, along with manganese, zinc and copper.

Blevins's recent analysis of raw data provided by the Tennessee Valley Authority water sampling program indicates that while the concentration of lead only approaches minimal risk value, concentrations of zinc, copper, cadmium and mercury in the Holston River Basin are considered by EPA standards to "pose minimal risk of deleterious effect." Moreover, with the exception of one sampling point, manganese "exceeds the recommended limits for contaminants in drinking water as set forth by the Bureau of Water Hygiene at all sampling points in the Holston Basin," Blevins says.

Blevins is interested in studying the heavy metal concentrations of the Holston River Basin because the region has a mortality rate higher than the national average for certain cardiovascular conditions and forms of cancer. Data compiled in 1979 by the National Center for Health Statistics of the U.S. Department of Health, Education and Welfare show that the rate of death for Caucasian males from cancer of the kidney, for example, exceeds the national average in the Tennessee counties of Sullivan and Washington. Blevins does not rule out the possibility of eventually correlating the levels of heavy metals found in a particular county with the incidence of malignancy and heart disease in that county.

At present Blevins is concentrating on the gizzard shad, smallmouth bass, rainbow trout and bluegill in the Holston River Basin. He and co-workers collect the fish from specific sites along the waterways of the basin, record the vital statistics — weight, length and estimated age — of the fish and note apparent physical condition (if the fish is covered with mucus or open sores or shows signs of external hemorrhaging, for example). The fish tissue is then subjected to the tried and true method of heavy metal analysis — atomic absorption spectrophotometry.

Atomic absorption spectra identify not only which individual elements are present in a sample, but also the concentrations of those elements. Each element has a characteristic energy absorbance. This means that different elements must absorb different wavelengths of light to excite their electrons. So, when Blevins places a sample solution containing heavy metals into an atomic absorption spectrophotometer, he shines a light through the sample and determines which wavelengths of light are "kidnapped" in the process. These "kidnapped" wavelengths of light have been absorbed by the heavy metals present in the sample. The specific wavelength absorbed identifies the metal and the amount of light absorbed indicates the concentration of that metal in the sample.

## Bumpass Cove Blues

The war on heavy metals is fought on several fronts inTennessee: Dean Blevins of East Tennessee State University in Johnson City is encouraging the state's public health department to test fish on a seasonal basis rather than every other year; state Rep. Bill Nolan's Joint Hazardous Materials Subcommittee is drafting several bills that would restrict the dumping of hazardous material; and Mike Ward, former operator of an oil-base waste recycling plant, now is recycling water-base hazardous wastes at a plant he developed in Mount Pleasant, Tenn. But Bumpass Cove Concerned Citizens Inc. packs the biggest punch in the heavy metal fight. This group recently filed a $20 million lawsuit in the Circuit Court of Washington County against the owners and operators of a landfill site at Bumpass Cove.

The landfill, owned by Bumpass Cove Development Corp. and operated by Waste Resources of Tennessee, sits near the Nolichucky River about five miles west of the North Carolina border. "The idea of the landfill in the first place was for municipal or household garbage," says J. H. Story, a member of the citizens group, "but it wasn't used as a landfill — it was used as a chemical dump." Story says industrial wastes were hauled to the landfill in overloaded open-bedded trucks that "just mangled the road up." Furthermore, Blevins says data collected by the East Tennessee Regional Public Health Office in 1977 and 1978 indicate "the ground water which flows into Bumpass Creek and then into the Nolichucky River contains a background cadmium level about nine times greater than normal." Fish caught downstream from Bumpass Cove had "thickly corrugated layers of mucus covering them, especially in the gill region," Blevins says. Damage to gills or precipitation of mucus on them can kill fish by inhibiting gas exchange.

Although the landfill has been a thorn in the side of Bumpass Cove residents for years, citizens did not join resources until last July when noticeably more waste material from the dump began washing into Bumpass Cove Creek. There are several different versions of the events that followed the "July washout." Tom Brown, an accountant for Waste Resources, says the citizens group "just blockaded our road and kept our trucks out of there [the landfill]." Story, on the other hand, says, "The trucks stopped themselves; they knew they were violating the law, they knew they were overloaded."

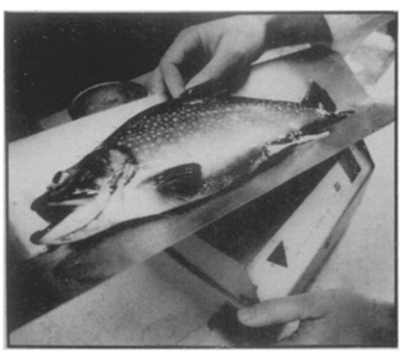
Regardless of who is responsible, Waste Resources has officially closed the landfill site. "We just figured it wasn't worth the trouble," Brown says. The closing of the landfill, however, has not satisfied the citizens group. "The landfill is closed, but we don't feel victorious," Story says. "That's only half the battle; the other half is to get it moved or to relocate an entire community."

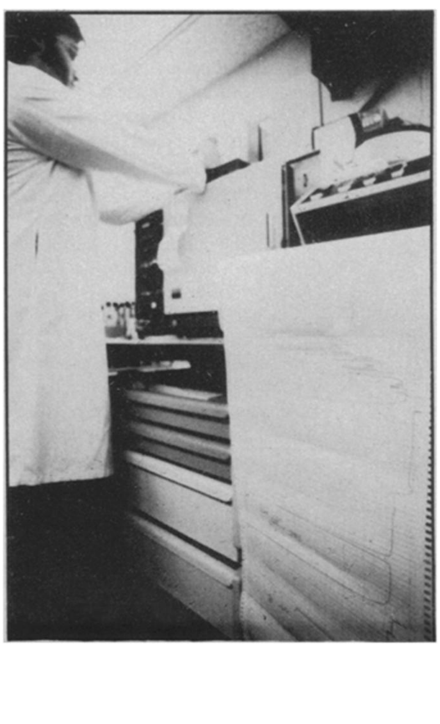
Measuring the effects of long-term exposure of heavy metals on fish seems simple: Collect fish, analyze their tissues for heavy metals and examine their physical condition. But, "There's more to it than just quantifying the amount of material in the water or in the animal," says Christopher J. Schmitt of the Columbia National Fishery Research Laboratory in Missouri.

"By and large we know very little about how well a fish can cope with chronic low levels of heavy metal in its environment," Schmitt says. "One of the reasons is we don't know in most instances what form the lead, cadmium, mercury or zinc, for example, is in when it reaches the animal." As a result, researchers studying heavy metals must first decide whether to measure the simplest or elemental form of the metal or the bound state of the metal — a state often found in aquatic environments in which the metal is chemically attached to another substance.

To further complicate the task, an accumulation of the contaminants can cause subtle changes in the fish's functioning abilities — changes that aren't readily detectable. The fish appears to be functioning normally "even though it may clink when you drop it on the floor," Schmitt explains, when in fact, the sublethal metal concentrations may be altering or compromising the fish's ability to respond to other environmental challenges — such as changes in temperature or predation.

To study these subtle, sublethal effects of heavy metal concentrations in fish, Schmitt and colleagues recently set up a "contaminated aquarium" program. Fish are bred and raised in the laboratory and placed for 90 to 120 days in 30-gallon aquariums containing known amounts of heavy metal. For each heavy metal, five different concentrations are maintained in different aquariums. In establishing this





# Selected Heavy Metals and Their Effects

*Information in this table is derived from proposed Ambient Water Quality Criteria Documents from the Office of Water Planning and Standards (Criteria and Standards Division) of the U.S. Environmental Protection Agency. The criteria documents are now undergoing review and are considered to be only draft documents. Manganese is not one of the 65 toxic pollutants for which* EPA *has drafted criteria documents.*

*The freshwater criteria for copper, zinc, cadmium and lead are expressed as a function of water hardness (h), or measure of the calcium carbonate in the water. Plugging a specific water hardness (h = mg/l) into the formula (e = 2.71) gives appropriate criterion (μg/l) for metal in water of that hardness.*

*The adverse effects of metal deficiencies are not considered in this table.*

| HEAVY METAL | ADVERSE HUMAN HEALTH EFFECTS | AMBIENT WATER QUALITY CRITERIA: To protect human health (mercury, lead and cadmium) or to prevent adverse taste (zinc and copper), concentrations should not exceed: | To protect aquatic life, concentrations should not exceed: Freshwater — As a 24-hour average | Freshwater — At any time | Saltwater — As a 24-hour average | Saltwater — At any time |
|---|---|---|---|---|---|---|
| **Mercury** | The 1956 outbreak in Japan of Minamata disease — characterized by neurological disorders — resulted from consumption of fish from the methylmercury-contaminated Minamata Bay. A recent study of bay children suspected of prenatal and early postnatal methylmercury exposure reports a high incidence of neurological deficits and learning difficulties in this group.<br>No mutagenic effects have been reported; however, a statistical relationship was found between the frequency of chromosome breaks and blood concentrations of methylmercury in Swedish fish eaters. | 0.2 μg/l | Inorganic: 0.064 μg/l*<br>Methyl-mercury: 0.016 μg/l | Inorganic: 3.2 μg/l*<br>Methyl-mercury: 8.8 μg/l | Inorganic: 0.19 μg/l<br>Methyl-mercury: 0.025 μg/l* | Inorganic: 1.0 μg/l<br>Methyl-mercury: 2.6 μg/l* |
| **Copper** | Copper toxicity — from sources including occupational settings, copper-contaminated fluids in dialysis and liquids vended from machines with copper-containing conduits — causes a metallic taste in the mouth, nausea, vomiting, epigastric pain and diarrhea. Severe cases cause jaundice, hemolysis, hemoglobinuria, hematuria and oliguria. Furthermore, there is evidence that copper may increase mutagenic activity of other compounds such as ascorbic acid. | 1 mg/l | $e^{(0.65\cdot\ln(h) - 1.94)}$ | $e^{(0.88\cdot\ln(h) - 1.03)}$ | 0.79 μg/l | 18 μg/l |
| **Zinc** | Excessive zinc intake can result in zinc interactions with other metals: Zinc can cause copper deficiencies, for example, resulting in anemia.<br>Aside from that adverse effect, zinc can be tolerated in large doses, reports indicate. Inhalation of zinc compounds, however, can cause acute pulmonary damage and even death. | 5 mg/l | $e^{(0.67\cdot\ln(h) + 0.67)}$ | $e^{(0.64\cdot\ln(h) + 2.46)}$ | Insufficient data | Insufficient data |
| **Cadmium** | Sources include drinking water, food, cigarettes and industrial settings.<br>Cadmium has been reported to cause chromosomal aberrations in mammalian cell culture lines, pulmonary emphysema and renal tubular damage.<br>The results of four occupational studies of highly exposed workers suggest that inhalation of cadmium may be associated with prostate cancer. Furthermore, it also is possible that cadmium in drinking water and fish induces prostate cancer in humans.<br>Finally, excess cadmium may aggravate nutritional deficiencies of calcium, zinc, protein and vitamins C and D. | 10 μg/l | $e^{(0.87\cdot\ln(h) - 4.38)}$ | $e^{(1.30\cdot\ln(h) - 3.92)}$ | 1.0 μg/l | 16 μg/l |
| **Lead** | The incidence of lead encephalopathy — characterized by dullness, irritability, headaches and loss of memory, often progressing to delirium, coma and death — has decreased dramatically in the past 15 years. The harmful effects of lead to the brain of the fetus are not now considered a major health problem.<br>The embryotoxicity of lead is more of a concern than is its teratogenicity.<br>Miscellaneous effects include reports of impaired liver function, impaired thyroid function and intestinal colic. The renal effects of lead include reversible proximal tubular damage and reduced glomerulor function. | 50 μg/l | $e^{(1.51\cdot\ln(h) - 3.37)}$ | $e^{(1.51\cdot\ln(h) - 1.39)}$ | Insufficient data | Insufficient data |

*Indicates criterion was established using procedures other than those specified in the May 1978 EPA *Guidelines* — a set of rules for developing a criterion from laboratory data.

range of concentrations for each metal, Schmitt hopes to find the "no-effect concentration" of each contaminant. The effect of a heavy metal is measured by the growth, mortality rate, bone development and histopathology of the fish.

Thus far, Schmitt has only confirmed general conclusions about the effect of heavy metals on fish — cadmium and methylmercury are the most toxic metals, for example. For the most part, the aquarium project at the Missouri laboratory—which began in November—is in its embryonic stages and the researchers continue to concentrate on the development of analytical techniques.

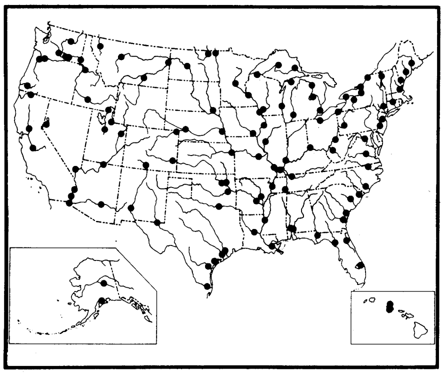
One potential technique for measuring metal poisoning in fish involves the enzyme ALDH — an enzyme important in hemoglobin synthesis. The concentration of ALDH in fish can be used to detect lead poisoning, Schmitt says. One of the signs of lead poisoning is the deactivation of hemoglobin. The animal responds to this hemoglobin deactivation by activating high levels of ALDH to synthesize more hemoglobin. "So, when we suspect high levels of lead in the water," Schmitt says, "rather than taking water 'grab' samples [a method of analyzing water, rather than fish, for heavy metal concentrations] or grinding up fish and analyzing them for lead, we think we can take a blood sample from the fish and measure the activity of this enzyme."

Although the ALDH technique has met with much success in Schmitt's laboratory, the real test will come in the spring when Schmitt collects fish from Missouri's Old Lead Belt — a former lead-mining area about 50 miles southwest of St. Louis.

In addition to the aquarium project, researchers at the national fishery laboratory are involved in heavy metal trend monitoring similar to Blevins's Tennessee project. The national laboratory receives fish from 110 stations set up on the Great Lakes and major rivers of the United States.

Schmitt and Blevins agree that fish samples, rather than the classic "grab" water samples, are indicative of the heavy metal concentrations that can ultimately affect human life. "The heavy metals are cumulative in human and aquatic life such as fish," Blevins says. "Fish then are biological magnifiers of these elements and thus can function as a more sensitive appraisal of heavy metal contamination than can the classical grab sample of water now being used by various environmental agencies."

In the case of mercury pollution, grab samples of water are nearly useless. Mercury in waterways becomes methylated—one carbon and three hydrogen atoms are added — through a bacterial process. Methylated mercury is extremely more toxic than elemental mercury. Unfortunately, almost as soon as the mercury is methylated, it is assimilated by a living organism, Schmitt says: "It's there and it's gone." Grab samples of water, therefore,



U.S. Fish and Wildlife Service

*U.S. Fish and Wildlife collection sites for monitoring contaminants in fish.*

cannot effectively measure its presence.

Because of the inadequacies of grab sampling, Blevins recommends greater use of fish sampling in Tennessee. Currently, owing to time and money constraints, the state's Division of Water Quality Control in the Department of Public Health tests fish for heavy metals only once every two years. But Blevins is a man for all seasons when it comes to monitoring fish for heavy metals. Fish should be monitored at least four times a year, he says. Supposing, for example, fish were taken from one particular sampling site during an unusually dry season. Since many of the waterways are polluted by runoffs from the surrounding countryside, monitoring less than four times a year, or seasonally, could result in rather misleading estimates of heavy metal concentrations at certain sampling sites.

Blevins is also concerned about the state's ineffective communication of heavy metal monitoring results to the public. "Water Quality Control will tell you that data are available," Blevins says, "but your getting them is nearly impossible."

Even the state's wildlife officers are confused about monitoring results. One case in point concerns the North Fork of the Holston River. This waterway has been "severely contaminated by mercury for the past decade," according to the 1979 *Water Quality Control Report on Heavy Metals In Fish Flesh From Selected East Tennessee Fisheries.* The origin of the North Fork pollution is a now-abandoned Olin Corp. Chlor-Alkali plant in Saltville, Va. Unfortunately, mercury continues to leach into the North Fork from muck ponds that formerly served the Olin plant. "The North Fork is classified for catch and release sport fishing only," according to the water quality report.

Although wildlife officer Wayne Lingerfelt, who patrols several East Tennessee counties, enforces the state's classification of the North Fork, "A lot of people slip out fish and eat them," he says. "There is no way to watch the river seven days a week, 24 hours a day." Besides, he says, "A university did some research that indicated a person would have to eat 5 or 6 pounds of the fish from the North Fork a day for 20 years for it to be dangerous."

But, according to the water quality report, the state's official decree is, "Fish from the North Fork of the Holston exceed the FDA [Food and Drug Administration] action level of 1.0 ppm in flesh and are classified as a health hazard."

In addition, "It can be expected that, as the mercury from the North Fork of the Holston River moves into the Holston River proper, the mercury levels will increase [there]," Blevins says. "Constant monitoring will be necessary in order to determine if a ban on fishing will be necessary in the Holston River as well as in the North Fork of the Holston River."

Meanwhile, Blevins is working with the Tennessee Environmental Council to help improve the communication flow of heavy metal monitoring results. The council, a nonprofit group composed of organizations — such as the Sierra Club — and individuals, operates on EPA and TVA grants "to help conserve the natural resources of Tennessee." Betsy Loyless, coordinator of the council's toxics program, recently began setting up community-oriented task forces that she hopes will "keep the public apprised of what public health is doing and thinking and keep public health apprised of what the public is doing and thinking."

Blevins says results of studies monitoring heavy metal concentrations in fish could be used not only by the task forces, but also by land-use planners. "If a stream already contains marginal [risk] levels of heavy metals, for example, you certainly wouldn't want an industry or landfill site locating there."

Land-use planning in Tennessee would be preventive medicine against a heavy metal plague in "one of the most rapidly growing areas in the United States," Blevins says. Industrial growth records from the Tennessee Department of Economic and Community Development indicate an average of 133.25 new plants and 193.9 plant expansions annually in the state since 1947.

"I believe we need to do as much from the standpoint of prevention as possible to preserve our natural waterways," Blevins says, "so that they can continue to sustain [aquatic] life — if that means anything."

It undoubtedly means something to fisherman Ellis, who is eagerly counting the days left until he can begin fishing in his favorite lake. To Ellis, preventing high-risk heavy metal contamination in the South Holston means preserving not only an abundant supply of smallmouth bass, but also something much less tangible: "A very close friend of mine who used to go up with us once said, 'If you can crawl out of your sleeping bag, wash your face with clear spring water, go back for your rod and reel, get in the boat and start across the lake as the sun comes up and still not believe in God, then you'll be an atheist for the rest of your life.'"

South Holston Lake, says Ellis, is "just beautiful, just beautiful." □