Oral History
of

Larry Kolz

Date of Interview: November 22, 2011

Location of Interview: National Conservation Training Center, Shepherdstown, WV via phone

Interviewer(s): Mark Madison, and Alan Temple

Approximate years worked for Fish and Wildlife Service: 1969 to ?

Offices and Field Stations Worked, Positions Held: Denver Wildlife Research Center as electrical engineer

Most Important Projects: Working on wildlife telemetry and electrofishing.

Brief Summary of Interview: Larry talks about his background, such as where he was born and where he went to college for his undergraduate and graduate degrees. He mentions working at several different places before a friend suggested he apply for the Fish and Wildlife Service, where he was offered a job at the Denver Wildlife Research Center as an electrical engineer working on wildlife telemetry. He shares several stories of work that he did, people he came across, and how he eventually got into electrofishing. He discusses the power of transfer theory, how many people did not accept it at first, how Steve Miranda applied the theory to work he did, and how now the theory is being recognized. Larry has worked with many different companies and has designed many components for work in telemetry and electrofishing that are used today.

Oral History Program
U.S. Fish and Wildlife Service
National Conservation Training Center
Shepherdstown, West Virginia

Mark: Today is November 22, 2011 and we are recording this in Shepherdstown, WV and Alan Temple is here, TEMPLE, and Mark Madison. And our subject is Larry Kolz, KOLZ, and thanks for agreeing to do this Larry.

Larry: You're welcome.

Mark: Well the first question we asked everybody and that's where and when were you born?

Larry: I'm actually the third generation in my family to be born in Durango, Colorado. My family was there before the city was named in 1880; that's my family history with Durango.

Mark: And when you were born, Larry?

Larry: In Durango.

Mark: No, when?

Larry: Oh when, February 1936.

Mark: Okay.

Larry: I'm 75 years old.

Mark: All right, and what's your degree in and what did you do after graduating from college?

Larry: Okay, my degree was from Colorado State University in the undergraduate work, and my degree was in electrical engineering. Upon graduation from CSU, I was awarded a fully funded fellowship from the Hughes Aircraft Company in Tucson where I attended the University of Arizona and received my master's degree. That would have been in 1960. I continued to work for Hughes Aircraft for six years and then I left in 1964; I moved back to Colorado.

Mark: Okay, and when did you first come to work for the Fish and Wildlife Service?

Larry: When I was working for a company called Kaman Nuclear in Colorado Springs, and I walked into a friend's office one day and he handed me a federal employment application and said, "You should fill out one of these. There's lots of interesting jobs in the federal government." So I filed the employment form, never expecting to be hired and a few weeks later I got a call from the Denver Wildlife Research Center telling me that I was in consideration for a job as an electrical engineer in the Fish and Wildlife Service; that would have been in 1969. I thought the guy was kidding me because I could not believe there was an electrical engineering job in the Fish and Wildlife Service.

Mark: Well Larry what were some of your first job activities when you came to work for us?

Larry: Actually I was hired to develop wildlife tracking equipment, this development was just coming to the forefront, there were no companies selling the equipment, there were a couple garage shops building make shift equipment, so they hired me to basically set up the lab and build this equipment. And I had, I think, three technicians at the time and the laboratory had been put together by a television technician, so we could work on television sets but we couldn't work on radio telemetry.

Mark: Was there a lot of literature or knowledge out there at this time for wildlife tracking; this is pretty early on.

Larry: No, there really wasn't. As I said people were just working out of garage shops, everybody had a different idea how the equipment worked. Nobody knew what kind

of power levels they were transmitting or at what distance they could be receive. Nobody had the equipment to even make some basic measurements. One of my first jobs for the lab was to actually search the government GSA excess property sites. I essentially had no funding but the free equipment was available to me, and so, that's how I equipped the lab. I simply hounded the people working at GSA and told them what I needed and you'd be surprised what I picked up free.

Mark: What type of wildlife were they trying to track with radio telemetry in the '60's?

Larry: You know they gave me the hardest job first, the biologists wanted to track Peromyscus that weighed less than 10 grams; that was my first assignment.

Alan: Holy smokes.

Larry: I built little transmitters that fit on the pinky of my finger and we went out and successfully tracked Peromyscus in an orchard, at very short ranges because the small circuits couldn't radiate much power, but we were successful in actually registering a rodenticide chemical to kill these critters because of this radio tracking program.

Alan: Where'd you go to from there, Larry, as far as the tracking goes?

Larry: Well it just expanded into everything. We were part of the AID Program; actually I was hired under the Agency for International Development funding. So we were working all over the world and we built a lot of transmitters for rodents and coyotes, and all kinds of problem species. We never worked on big game species; that was not part of the program. A lot of my work was involved with the Endangered Species Program. So we were doing endangered species like the Kirtland's warbler, black snakes back east, polar bears, sea turtles, quelea finch in Africa, eagles, hawks, condors; the work just expanded over the years. I was the only electrical engineer as far as I know in the entire Fish and Wildlife Service; we had the only electronics lab.

Mark: We have some of the old condor radio transmitters here in the archives; they're huge.

Larry: Yeah. Depending on the vintage they could weigh over 100 grams.

Mark: Yeah, yeah.

Larry: Yeah, we did that; it was kind a crash program; that condor program had contracted with an engineer in Illinois to build those transmitters and they had to be built by January of the year, I don't remember the year. He defaulted in December. We received a call saying they had to have the transmitters by January 1st, could we do it. So we set priorities and built those transmitters and had them to the biologist by January, you know we worked through holidays and everything getting that job done.

Mark: Larry, can I ask you, what was the technology like when you started this program and how did it change over the years you worked in it?

Larry: Are we talking about telemetry?

Mark: Yeah, telemetry. I just got fascinated; we will get to electrofishing, I promise.

Larry: Okay. Well like I said there was no equipment; nobody understood the circuits and how they might be improved with the new semiconductors. I went back through the literature to understand how the oscillators worked. Engineers using vacuum tubes had designed most of those circuits years before. The transition was that we now had transistors, and we could make them much smaller and

lighter, that was our main advantage. But, you know, we just kept improving the small transmitters. It was also important that we consider the weight of the components for the circuit designs. The weight of the batteries was especially critical when you're attaching something to an animal.

Another aspect that most people don't think about is the attachment method to the animal's body because nobody had really worked on that problem. We had an enclosed flyway at the Denver Wildlife Research Center and we would try different attachments on birds by putting them on their tail feathers or wings or legs or necks or backs, trying to figure out where a bird could most easily carry the weight. We were bringing animals into the electronics lab where we could actually measure the radiated power from the transmitters when attached to the animal. I was probably one of the few engineers that had a live coyote in my electronics laboratory with a radio transmitter attached. We had sheep in the laboratory, all kinds of rodents, and birds. You know that was a really fun project.

Mark: You said two interesting things about the attachment and the weight. How did you get guidance on how to attach these things, like to wings or to fur and so on?

Larry: We would take the instrumented animals and watch their behavior. For example we would monitor birds in our 50-foot flyway. We would feed them a high protein diet and then force them to fly until they couldn't fly anymore; we'd count the number of trips they could make back and forth in the flyway. We did this with different attachments, and in this way we could judge how tiring it was to use particular attachments on the birds. For the rodents we would observe if the transmitters interfered with their digging, feeding, or grooming. We determined that, in general, birds that were living in a given area and not in migration could carry about 3% of their body weight; however, if they were migrating, about1% of their body weight. For mammals, we were limiting our transmitters to 5% of the body weight; these are general rules of thumb that we just learned by trial and error.

Mark: That's fascinating. I just read a whole book on wildlife telemetry and they never mentioned this at all.

Larry: This was all experimental because of our unique situations with cages, pens, flyways and biologists to handle it. Its was also convenient back in those early days that even I as an electrical engineer could grab a bird or a mammal; I didn't have to have a enlist the help of a vet or file a 10 page protocol. Of course, that has all changed with animal handling regulations and paperwork. Just before retiring, my work on zebra mussels was halted by the animal care committee because I had not answered one of their protocol questions regarding the pain and suffering of zebra mussels to electrical shock.

Alan: Now Larry you did something, I seem to remember, with polar bears like some of the first satellite tracking. Am I right about that?

Larry: Oh yes, we had the opportunity to develop the first successful satellite tracking transmitter ever put on an animal. Actually, satellite tracking of animals had been tried in Yellowstone NP by Frank and John Craighead. They instrumented two elk on two different occasions with large satellite transmitters. Unfortunately, one elk died shortly after being instrumented, and a hunter apparently shot the other elk. These incidents reflected negatively on NASA's image, and for a period of about 10 years, NASA refused to cooperate in any wildlife research.

Then the Fish and Wildlife Service requested permission to put a satellite-locating transmitter on a polar bear. NASA agreed to this proposal. That was a project on which I worked; this would have been with the Nimbus 3 Satellite System. My first assignment was to evaluate the proposals submitted from companies that wanted the contract to build the bear transmitters. It was also decided that I should be prepared to use our conventional small transmitters as a backup for locating the bears from an aircraft. Three companies submitted proposals, and I selected the company that had no previous experience. The senior biologist really didn't appreciate my selection. The two companies that I rejected were known for supplying satellite transmitters for attachment to ocean buoys, but I found technical flaws in their proposals. I picked a company with only two engineers that had previously been employed by Hewlett- Packard. Their proposal described very unique circuitry that allowed the weight of the transmitter to be reduced. Since they had no animal experience, I agreed to design the battery power pack shaped into a molded urethane collar for attachment around the bear's neck. And by darn, we pulled it off! We tracked, well several polar bears. One of the polar bears actually went passed Wrangel Island in Russia, which we did not expect. The bear actually wintered and probably had a cub on the islands north of Wrangel Island. That's what we wanted to find was a polar bear in her den with her young; that was the whole purpose of the study. But, the Russians would not allow us over there to perform our work. Instead, they wanted to borrow our equipment so they could locate the bear, but this was all classified equipment from NASA. And so, it was a real standoff, and I have piles of newspaper articles that were written about this polar bear, and it generated an international incident that had to be handled by the state department. But anyway, the net result was that we tracked that female bear for about 1,000 miles, and the transmitter operated for almost a year. I designed the battery for a year of life, and it lasted about 360 days before the transmitter went off the air.

Mark: That's amazing. I guess that was your other challenge too finding long-lived batteries?

Larry: Well about that time they came out with lithium batteries, and these of course are high capacity batteries that can operate at very cold temperatures. I tested those batteries down to about minus 100 degrees F, because the polar bears were living in temperatures down to minus 60 degrees F. I wanted to make sure that we didn't lose the transmitter because of battery failure. We probably did some low temperature battery testing that nobody else was doing at that point in time.

Alan: So lithium did take the low temperatures pretty well then?

Larry: Oh yeah, it changed our lives when they came out with lithium batteries. I mean before we were using alkaline and mercury batteries on our transmitters, and they were very iffy; all a sudden we have lithium batteries with high capacity, low temperature reading, higher voltages, and transmitter designs were totally changed.

Alan: Did you do something similar then with sea turtles as well?

Larry: Actually my sea turtle escapade started before the polar bear. I was called by an engineer from National Marine Fisheries Service, and he said, "We're raising baby sea turtles in Galveston; we raise them for three years, we put them in the ocean, and we have no idea if they survive. Can you build a transmitter for a sea turtle?" And I said, "Well you can't transmit radio signals from underwater but I can put an antenna on it and

when the turtle is on the surface we can track it." So that's what I did, I built little transmitters into fishing float bubbles that you can buy at any store. We actually broke them apart, put our transmitter inside with a wire antenna sticking out of it. Then we tethered these bubbles behind the baby sea turtles. In this way were able to actually track these little baby sea turtles in the Gulf of Mexico to determine that 'yes' they were surviving and in fact they were doing quite well. Well with that history with NMFS, when they discovered that we had a polar bear transmitter that would hit a satellite they asked if I would build something similar for our sea turtles. Incidentally, NMFS had previously contracted for construction of a satellite transmitter from one of the companies whose proposal I had rejected, and their transmitter was an operational failure. So I took the basic circuitry from the polar bear transmitter and packaged it in a piece of sewer pipe that we attached by a tether to the carapace of a logger head turtle that we named Diane; she weighed about 350 pounds. Diane was released in the Gulf of Mexico where she spent about two months at the mouth of the Mississippi River. As winter approached, she started west towards Galveston and then moved south off the coast of Mexico. She wintered there in the warmer water, and in the spring of the year she started back north. Just before I went on vacation, I called the engineer at NASA and asked him to locate my sea turtle. He answered, "Well we've got a problem here. Go on vacation, I'll tell you about it when you get back." So when I came back, I called him and he said, "You know what, your transmitter's in Galena, Kansas." That's a long way from the Gulf of Mexico. So I called the sheriff in Galena, Kansas and he went out and found the transmitter in a farmer's yard, a dog was playing with it. The farmer had ignored the label requesting, "Please return to the Fish and Wildlife Service." But the tether had obviously been cut; it had not fallen off the turtle. So we don't know what happened to the turtle, but we did get our transmitter back. The transmitter was then taken to Florida and put on a green turtle. Within a couple weeks, the transmitter showed up in a guy's garage. Again, the tether had been cut. A NMFS engineer attached the transmitter to another turtle in the Gulf, and the transmitter was eventually retrieved from a Mexican village. Again, nobody would admit to having killed or taken the turtle. So the transmitter had been on three different turtles and all three turtles disappeared. That operational transmitter could be found anywhere in the world by the NIMBUS satellite system.

Alan: Wow.

Mark: That's a great story.

Alan: You know speaking of stories, Larry, you've got kind of a story, I think, about how as an electrical engineer you expected data to be very tight. And then you mentioned rats earlier that you all were looking at, and I think you did a study in the Philippines with rats and you might want to relate your impressions of the data and your boss's, who is a biologist, impression of the data.

Larry: Okay. My supervisor wanted me to design a feeding monitor for rodents that could be placed in the field. As designed, the feeding station consisted of a waterproof platform measuring about 18 by 12 inches with about 8 inches in the middle that was covered for the placement of the food or bait. When a rodent climbed on the platform, from either end, a treadle would activate a switch to count the number of visits and accumulate the total visitation time. I did this with a component called an E-cell, which is probably not available any more. This work was accomplished before digital circuits, so this was a state of the art device at the time. I initiated a study in Denver in an enclosure

with a number of rice field rats. After a number of days, I removed the feeding stations and analyzed my data. My conclusion was that my results were inconsistent and pretty lousy. I went to my supervisor, Dr. Dan Thompson, and said, "Dan this is no good, you know, I didn't do very well." And Dan said, "Well let me look at the data." A couple of days later he came back and said, "You have 90% correlation." I said, "Correlations, what are you talking about?" I'd never had statistics. "This is the way we biologists work." He was very pleased with the data and we used these devices over and over for a variety of studies.

Mark: Yes, us biologists are a sloppy lot. [laughing]

Alan: It's like oh that's…

Mark: That's great. [laughing]

Alan: Another man's trash is…

Larry: As an engineer, we weren't even taught statistics because when you're measuring physical things they repeat and as soon as you toss in the biology that's a whole different game of wax.

Mark: That's a great story too, Larry. Well should we move on to the electrofishing? I'm going to turn this part over to Alan, 'cause he's the subject matter expert on EF.

Larry: Okay.

Alan: Well okay we did have a course come out of the telemetry stuff too, the telemetry course.

Larry: I taught that telemetry class in the Philippines, Morocco, and the World Health Organization in Rome, where we had biologists from Africa come to learn how to instrument radio tracking equipment on lions, elephants, and all sorts of animals.

Alan: Wow.

Larry: I was also invited to present a telemetry workshop at a beautiful research center in Grimsö, Sweden. Judy went with me and we spent a month working with their equipment. We held a number of telemetry sessions with biologists from Norway, Denmark, and Finland. I also gave special talks to the military and homeland security.

Alan: I think you really had a lot to do with these companies forming up too, they all knew you.

Larry: Oh yeah. I was working with Motorola and other semi-conductor companies to develop special components like crystals and transistors. Actually, I was provided with my own part numbers and when equipment suppliers wanted to order them, they had to get my permission. And so yeah I knew them very well.

Alan: Well, there's all kinds of good stories Larry talks about I can tell you. Okay well then switching to electrofishing then, Larry, you know you came on as a telemetry expert and an electrical engineer and that. And so then you were exposed, I mean that's not a very good choice of words, but to the electrofishing course that was going on out of the Fisheries Academy, I think maybe back in 1978 or something like that. So would you talk about how you became involved with the electrofishing course.

Larry: Certainly, I like to do that; it's kind of an interesting story. I have a note before me stating that on May 12, 1980 I attended my first electrofishing course in San Marcos, Texas; well that's when it started. What really happened was I was sitting in my office one

day when Al Knight from New Hampshire walked in. I had previously worked with Al for telemetry projects and helped him build transmitters for fish. Dick Widowski from the National Fisheries Academy in Leetown, WV was with Al. They simply told me that they were going to San Marcos to give an electrofishing course and would I like to come along. And I said, "What's electrofishing?" And they said, "Well we put electricity in the water and we catch fish." And I said, "You're kidding me? You know, nobody's that dumb." Al responded, "That's what we do, and we're going to teach a course on it and there may be some electrical problems and maybe you can help us out." And so I said, "Well you're going to have to send me literature because I don't have a foggiest notion what you're talking about." So they sent me a pile of literature and I started reading it. What I discovered was that the literature didn't make any sense. In the articles that they sent, there was only one article that was technically appropriate and that was from Georgia Tech where a graduate student was working on some of the electrofishing problems. He was basically applying the concept of power, but he wasn't there yet, but what he said in his thesis did make some sense. All the other articles were mixes of volts and amps and they had not a clue where they were going. So I went to this first course but I'd already prepared what I wanted to say; even though I wasn't invited as a teacher, I was just a guest. Al and Dick started lecturing and I realized that they were basically regurgitating these articles that I'd already turned down as bogus. So I took over the class. I basically discussed how to do a circuit analysis and reduce the electrical circuit for an electrofishing boat; the resulting circuit was no more complicated than that of a flashlight. I told them the correct parameter to measure was not voltage or current but power and this is the parameter that had been ignored. So that was the first class that I taught, and after the class ended, we went outside and saw my first electroshocking equipment: a Smith-Root Mark VII backpack.

But I'd like to tell you about my background because it's unusual. In graduate school at the University of Arizona, I wrote my thesis on microwave propagation in ionized media. This topic was not something in which I had any real interest but I needed a topic for my thesis and that's what I picked. I applied Maxwell's equations in the thesis, and summarized the results with about100 pages of theory; never thinking that I would have a job to use this work. I continued working at Hughes for six years and then wanted to move back to Colorado. I happened to see an ad in a newspaper from Kaman Nuclear in Colorado Springs for an engineer to predict the magnitude and characteristics of radar signals from a missile reentering the Earth's atmosphere. This was during the Cold War with Russia and our military wanted to ensure our defenses against possible ICBM intrusions. This meant that our radars had to be capable of detecting and discriminating objects moving at hypersonic speed and surrounded by a cloud of ionized, atmospheric gases. You have probably heard of this blackout phenomena when astronauts are returning to Earth following a space flight. It is the ionized gas that surrounds the space capsule that blocks the communication signals. I was probably the only applicant for this job because of my experience at the University of Arizona. I worked on this project for about three years during which time I had access to the most current information regarding the transmission of electrical energy in ionized media. It was during this experience that I realized that the critical electrical parameters were the transmitted and reflected power levels. So, when I started reading the electrofishing articles I thought, "I've already worked on this problem. Water is nothing more than an ionized medium." Thus, my approach was totally different than what anybody else had

ever tried, and fortunately it seems to have worked. It's so unusual that my background just happen to fit into something that biologists needed at that particular time. I don't know of another engineer that has my background with ionized media.

Alan: I'd say.

Mark: Pretty unique.

Larry: So it just happened to work out for me.

Alan: So really, the electrofishing technology and concepts weren't well determined were they? It just sounds like the prior work had all been trial and error without any theoretical basis.

Larry: Well the engineers and biologists were basically using the instruments that were available to them: ammeters and voltmeters. There were no power meters. Perhaps this is why no one had considered the concept of power and how it is the power that must be transmitted from the water into the body of a fish. As you know, Alan, you cannot make voltage and current measurements at the generator and predict what's happening to the fish in the water; it just doesn't work that way. You basically need in-water measurements and apply my power transfer theory. Power is the necessary parameter to study the in-water effects of electroshock.

Alan: So you had that idea of a power transfer theory, and what kind of, maybe you saw it right away but did you have something like an "Aha" moment when you saw this electrofishing gear for the first time and to lead you to the power transfer concept?

Larry: No, I had the concept when I went to the first class. I had outlined what I was going to say in that first course, I already had the power concept. I knew where I was going. So it wasn't a matter of searching because of my background in ionized gases, I was very confident that I knew how to solve this problem.

Alan: So how did you proceed then, you know, you had this power transfer theory, you know it comes from ionized gases and signal transmission through that. And then you had these biologists that are electrofishing and oblivious that the literature is way off the mark. And so what did you think about, I mean, what did you think about as far as trying to improve the situation for these electrofishing folks, these biologists relative to power transfer?

Larry: Well I was really naïve; I thought that if I gave my little story to the biologists in these classes, someone would do the research, and that just didn't happen. I'd give these lectures in the classroom and everybody would shake their head "yes" and they'd go home and I'd never hear from them again. Then I finally realized there was no money for research, it simply wasn't there.

Let me back up just a minute and get Jim Reynolds into this story. I had taught these classes for four years before I met Jim Reynolds and I had given 12 workshops. It's remarkable that I'd given my second and third lectures in Fairbanks and Anchorage, and nobody ever mentioned the name of Jim Reynolds. He lived in Fairbanks and was the principle author of the electrofishing chapter in the Fisheries Techniques Manual. I had not been introduced to him or known about him. It was not until 1984 that I met Jim when we were put together for a class in Marquette, Michigan. I was already 12 workshops down the road when I met Jim, and Jim kind of turned my thinking around. We had a lot of discussions about my theory because Jim had never been introduced to my power concepts.

When he finally accepted the basic theory, Jim started pushing me to conduct in-water, laboratory, electroshock studies. That's is why I finally performed the goldfish experiments in 1988. It had taken about 8 years before I even considered doing this work, and I have to attribute that to Jim. He insisted on my performance when I thought the biologists should do it. Jim said, "No, if anybody's going to do it, you're going to have to do it." So we got together in'88 and conducted the experiments that resulted in my publication of the Power Transfer Theory. The process of preparing for these experiments is humorous, and I'd like to tell you about it.

Jim called me, "You've got to put together a study." I said, "Jim, I'm in wildlife research, I'm not into fins okay. I don't do anything with fish. I don't have an aquarium, I don't have any facility to work with fish." He said, "Well, figure something out because I'm going to be coming to Colorado, and I want to do something with you." So, upstairs over my office was a vacated chemistry lab so I infringed on that space. A McDonalds had just opened across from the Federal Center in Denver, so I walked over and asked, "What kind of large containers do you have that I could put fish in?" The employee answers, "We have pickle barrels." I said, "What's a pickle barrel?" He says, "That's what we get our pickles in, they're just really a big bucket." I said, "Can I have some?" And he said, "Oh yeah, we just throw them out." So, he saved me green pickle barrels/buckets, and they became my aquariums. I had about ten or twelve buckets. I then went to the local aquarium/pet store to get some fish and I walked in, "What's the cheapest fish you have?" The clerk replied, "Goldfish, feeder goldfish." I said, "How much?" And he said, "Ten cents each." My reply, "I'll take all you got." About twenty bucks worth: about 200 fish. The fish were equally divided among the pickle barrels and I added salt to the water in the barrels to produce different levels of water conductivity. I had aquariums that ranged from roughly 200 to about 10,000 microsiemens per centimeter of conductivity. I acclimated those fish in their respective barrels for three or four weeks before Jim arrived.

I had no electrofishing equipment so I jerry-rigged a power source by combining power supplies from the electronics laboratory. In this manner, I created my own electroshocking equipment and my electrified volume of water was contained in a10-foot section of plastic rain gutter. This is how I prepared for Jim's arrival.

Jim and I anticipated that the "U" shaped power transfer curve would make its bend between 1,000 and 2,000 microsiemens per centimeter based on published research. So, I acclimated my collection of aquaria to accommodate this range of water conductivity. Well, we ran our first tests and our expectation did not happen. We were getting consistent data but my predicted U shaped curve was not being produced. I remember Jim saying, "It's not working Larry, it's not working." And I said, "Well, we'll just keep reducing the value of the water's conductivity." It became obvious that the conductivity of the city's water was too high, and I had to go to our main chemistry lab and start hauling distilled water. I also had to recalibrate the water in my fish holding aquariums to lower values of conductivity. Basically, I had to restart the experiments, and unfortunately, Jim had to return to Alaska. I continued the electroshocking tests, and when the water conductivity was reduced to less than about 125 microsiemens per cm, the data produced the predicted "U"curve.

It took a while for Jim and I to realize that we had not actually measured the conductivity of fish flesh. Previous studies had ground the bodies of fish and measured the conductivity

of the slurry mix. We were actually measuring the, what I have named the "effective conductivity" of fish. I would describe this term as a biological fish response; not an electrical term. I still struggle to understand the measurement. The historic research papers describe attempts to measure the true electrical conductivity of fish flesh, which is a different parameter that does not take into account the response and behavior of fish.

Alan: Did that kind of change, once you put those results out and started incorporating them into the electrofishing class, did it make a difference to the course participants or am I just thinking of a particular workshop in Wisconsin.

Larry: Yes, it did! I was surprised by the intensity of the controversy. However, I was in a good position because I had no meat in this fight. I was totally independent, my job was telemetry and electrofishing was simply an avocation. It was something I did for fun and of personal interest. But there were serious, established researchers that did not appreciate these new power concepts from an outsider.

Jim Reynolds presented my first Power Transfer manuscript at an international conference in Oxford, England. The power concept was met with a lot of opposition. The conference was co-chaired by Dr. Cox from Oxford and Dr. L from France. Dr. L insisted that my paper was insufficiently qualified for publication in the book that would be forthcoming from the conference. Fortunately, Dr. Cox supported the publication of my paper, and it was finally included with the other presentations from the conference. Apparently, the power concept seriously conflicts with Dr. L's personal research.

I was also surprised that the equipment manufacturers in the U.S. did not acknowledge the concept of power of transfer in their equipment designs. Instead, they simply ignored it; you know that Alan. Their interest is selling their on-the-shelf equipment, and they never responded to this new theoretical concept.

Alan: So, what changes do you anticipate in the future?

Larry: The situation will change as biologists recognize that electrofishing can serve different research objectives. For example, if the goal is simply to collect a lot of fish and injury is not a concern, then the applied power is of little concern: just catch fish. However, for those fish studies that involve endangered fish or fish injury concerns, the power concepts offer important guidelines. In an electrofishing study conducted by Steve Miranda in 2003, Steve suggests that the power transfer model offers a protocol for standardizing electrofishing. There is no other approach that can predict the best power setting depending on the conductivity of the water. Since Steve Miranda's paper, I am observing more interest in the power theory. At a recent symposium held by the AFS [American Fisheries Society] in Seattle, Pat Martinez (my colleague at the Colorado Division of Wildlife) observed a general agreement among the audience with the power transfer theory. You knew that Alan?

Alan: Yes, sure did.

Mark: Larry, why do you think they were opposed to it? They just didn't understand it or inertia?

Larry: You know, the opposition from engineers surprised me. In general I received more flack from electrical engineers and technicians than fish biologists. I remember a workshop in Minnesota. Jim and I didn't realize what were getting into. The biologists

and the engineers at the University were having a dispute. So the biologists invited us to give a workshop, but what they were really doing was inviting me to argue with the engineers who were opposed to the power concept. I sensed something different when I found myself entering a large auditorium, and Jim and I were on a stage. On one side of the auditorium were the physicists and engineers and on the other side were the biologists, and I was in the middle.

Alan: Kind of like Congress.

Larry: Yeah, yeah, it really was! The engineers just asked me very snotty questions; I mean really snotty questions. And the biologists were trying to better understand the theory that I was trying to put forward. I never did convert those engineers. At the end of the workshop, one engineer came up to me and said, "Well some of what you said is alright, but most of it was…"

[Laughing]

Mark: "Thanks for coming."

Larry: They didn't thank me.

Alan: Now there was also someone else from Wisconsin that took the course as an early class participant and published a paper that applied to his electrofishing studies on the Mississippi: Randy Burkhardt, I believe.

Larry: Oh yes, Randy gets a gold star. He actually applied the theory to his work on the Mississippi River. He was able to convince his electrofishing cohorts to standardize their electrode arrays and apply the transfer theory. By so doing, he was able to collect and analyze their data to determine that they actually had much higher correlation in their data by using the power of transfer theory than they ever had previously. That paper was the first field application of the power of transfer theory. Randy came to another course and I requested that he describe his experience with power transfer to the class; I can't remember where we were located. Randy also attended a third class and participated as an instructor. Another workshop participant from Canada attended the course on five occasions; that's another tidbit of workshop history.

Alan: So, do you think that the course was a sort of interplay between the research and field programs? Larry, did one sort of feed into the other?

Larry: Well yes! This electrofishing research has a tremendous impact on the field programs in the U.S and Canada. I presented a number of courses in Canada that were not sponsored through the Fish and Wildlife Service; I was personally invited. I have also been to Australia three times and they are now well acquainted with the power theory. Jim and I were also invited to present a workshop in Ireland in 2005. This electrofishing training has been a slow process but I see it gaining in momentum. I would suggest that in the future that the courses emphasize standardized protocols based upon power transfer theory. I'd like to see that happen; I think you're doing that.

Alan: So really, it is interesting Mark, because Larry and Jim published this in 1989. There were folks that started coming to the course, I think Randy might have come two or three times, and then applied the concepts to the upper Mississippi River long term monitoring program. So it was like six states, this was a very significant field application, and they were able to apply the theory and decrease the variability in the data by 15% or something like that. So, in1995, they published in the *North American Journal of Fisheries Management*. Then it was not until 2002 when Steve Miranda at Mississippi State and

the Co-op Unit started publishing verification of Larry's theory of power transfer that a movement toward acceptance by field personnel started. But look, it took like 14 years before Steve turned things around. He wrote a lot of papers I guess, and that has attributed to its general acceptance.

Larry: Well it's amazing how slow the progress has been, and I think this definitely happened because the equipment manufacturers refused to build equipment with specifications that were suitable to the electrical theory. You have to have equipment that is compatible with the theory or the field biologists will not understand why the theory does not apply. This is not to say that the commercial electrofishers could not catch fish, but the data collected from fishing in different water conductivities could not be standardized. In my opinion, we have lost many years of what could have been standardized data because the companies did not accepted the tenets of power transfer in designing their equipment.

Alan: What, better metering and better controls?

Larry: Well as you know some of the electrofishing equipment is sold without any meters, you have to operate by trial and error. Worse yet are the GPP meters, the purpose of which I cannot understand. However, I'm glad to report there are now at least two electrofishers designed with accurate, peak reading meters. I think within the next year we're going to see some changes. Pat Martinez and I are currently measuring the output characteristics of four of the most popular boat electrofishers, and I hope this comparison disclosure will revolutionize the industry. At least, the biologist will be able to compare valid equipment specifications. I always tell Pat that we don't want to be the Underwriters Laboratory for electrofishers but no one else seems willing to make the comparison measurements.

Alan: And one of those companies that you mentioned, that does have good metering, was a person that came to the course and then understood what Larry was talking about. He actually was working for the Missouri Department of Conservation. He then quit his job and started a pond management company that also develops electrofishing equipment. I believe that you and Pat tested one of his units last week.

Larry: Yes, I spent all weekend in cold water fishing last week.

Alan: Speaking of, Larry, that's kind of a good segue to say that you'll still very active in research and doing this work.

Larry: Well I've been fortunate to have met Pat Martinez when I moved to Grand Junction. One morning I was getting into a canoe on the Colorado River and heard some one yelling my name; it was Pat. He said, "What are you doing in Grand Junction?" I told him I moved here. He replied, "Well, we're going to have to get together." So Pat lined me up to work with the Fish and Wildlife Fund. I'm not quite sure what the Fish and Wildlife Fund is but they support the Colorado River Recovery Program. For the last six or seven years I've been working with Pat to standardize the program's 17 electrofishing boats and 14 electrofishing rafts. Unfortunately, there are a variety of electrofishers involved. It may not be possible to standardize the metering but we are trying. I would judge that I have done more electrofishing research in the last three years, because of Pat, than I was ever able to do as an employee of the Fish and Wildlife Service, because it is the first time that I have had access to the boats and equipment. After all, my real job was the development of wildlife telemetry equipment.

Mark: Any memorable characters or anecdotes from your career you want to share?

Larry: There were a lot of characters.

Mark: I bet here were.

Larry: There was one guy from Canada by the name of Mel. Mel took the course five times, and the last time I let him teach. He enjoyed the course so much. I often wondered if he's retired now; I'm sure he has. Another character, I don't know his name, but Jim and I were presenting a course near Spokane, somewhere in the northwest, for a class of Native Americans. We had never done this before. I've had never had another class like this one! They sat there, unresponsive, without facial expressions, and only a few were taking notes. I began to watch one of the guys in the back row; he sat there with his arms crossed, with a smile on his face, and with no notes; I thought he was totally bored out of his mind. At noon on the first day, Jim and I went to lunch and Jim said, "We've got to change, this class is absolutely not responding. What are we doing wrong? They're simply not responding." So we tried to change things around and it helped a little bit. Then, we finally took everybody to the field and by God that class turned around. It turned out these guys were field people, they didn't care about all this theory stuff. Their interest was in the fieldwork. At the end of the class, this guy that I'd spent so much time watching came up to me and said, "You need to know I'm an electrical engineer, and this is the best class I ever took."

There were other characters; one in New York that was known for his specialize interest with a particular species. I'm trying to remember the technical name, but I don't even remember the common name of the fish. Anyway, he was outstanding in his work and bragged about his boat (named E- Shocks) all the time. When I inspected his boat, he had the anode/cathode wires reversed. He was very embarrassed and finally said, "You know I've always wondered why the fish were bumping on the bottom of the boat."

Mark: Larry, you've had a very long career. Do you have advice for future workers that might do electrofishing or telemetry?

Larry: You know I should tell you another little personal story too.

Mark: Sure.

Larry: It means a lot to me. So when I was in high school…

Alan: Larry, we could call you again, finish it up; I know your throat might be bothering you.

Larry: Maybe I can get through this. When I was in high school I wanted to be a fish biologist. I mentioned this to our counselor and some other teachers that were kind of favorites to us students. One particular teacher took me aside and said, "You know you're good at math and you're good at science, why would you want to major in an occupation where you'll never find a job?" And so I took their advice but I have always wondered what would have happened on the other path.

Alan: Well Larry we can call you back. I was surprised you made it his long on your throat.

Larry: Yeah it's a problem, but anyway, as you know, Alan, I received the USDA Engineer of the Year Award in the 1984. I wish that I could relate this story to my high school teachers..

Alan: I might be the only one. That was, too bad you couldn't go back and say, "Look here, you were wrong!"

Mark: To your high school advisors.

Alan: Exactly.

Larry: Yeah I wish I could go back and talk to those guys.

Alan: But it was interesting because of the background you had, you never would have been able to make those contributions that still continue today in a big way.

Larry: Yeah I think so. I think we're going to see more of it Alan. I'm pleased that you're a part of it and that the courses are continuing. You're doing a good job. I don't know how many workshops you're giving every year, but I think if you emphasize standardization, it'll really improve.

Alan: Actually we've done five this year, besides what's on the online course. But yes, it's all your stuff and we've been able to use excel to do a lot of calculations for them and graph things. So you know the calculations are a little bit easier for them to do because the computer power has helped us out there. And people understand it, and as I told you yesterday or the day before, the course still gathers data from student activities and class activities to look at better ways of doing this power of standardization. And you know there are definitely favorable patterns that are showing up.

Larry: Well you discussed yesterday the fact that power is not the only critical parameter. I need to talk to you about that because there may be pitfalls.

Alan: Definitely.

Larry: Good.

Mark: Larry this was fascinating, we don't want to wear you voice out anymore. We may see if we can call you again. I mean you're career was so important, it covered so many aspects of fish and wildlife science. We may ask to call you again, I mean this was fascinating; all this was new to me, I really enjoyed it.

Larry: One thing I would like to talk just to get it on the record is how animal telemetry affected the military.

Mark: I think that's a whole new oral history. I would like to do that Larry. What do you say we give you a break, let your throat recover and maybe I can call you or try to set up time; next week I'm out of town but the week following.

Larry: Yeah let's do that because I think somehow we need to document this.

Mark: We do.

Larry: Wildlife telemetry played a very important role at the Joint Special Operations.

Mark: I would really want to hear that Larry, that sounds awesome.

Larry: Okay. This was fun guys.

Mark and Alan: Thank you.

End of interview.