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OCEANOGRAPHY: THE MAKING OF A SCIENCE  
*People, Institutions and Discovery*

Transcript of the Videotape-Recorded Interview with  
**WILLIAM WATKINS**

Conducted at  
Woods Hole Oceanographic Institution  
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Interviewers: Gary Weir and Frank Taylor

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Gary Weir and Frank Taylor,  
interviewers

**Gary Weir:** Dr. Watkins, thank you for coming in. We really appreciate it.

**William Watkins:** You're welcome.

**GW:** I've looked forward to this for a while, because ocean acoustics is something that interests me. I met Dr. [William] Schevill long ago, and we've only sort of bumped into one another casually since. So this is going to be a pleasure, I'm sure. One of the things that I did not get out of the material that I have on your background is your date or birth and where you were born.

**Watkins:** I was born in Conakry, Guinea, West Africa. My dad was a linguist working with a consortium of missions, so that's where I hailed from. Then I came to this country with some education and went back again, set up an international broadcasting station in Liberia. So I spent the first thirty years of my life, approximately, mostly in West Africa.

**GW:** That prompts a number of questions I'd like to ask. First of all, can you tell me a little bit more about your parents? You said your father was a linguist. What did he do for the missions?

**Watkins:** All kinds. He worked especially in the Fulani language, which is the language of Guinea, of the mountainous areas of Guinea, becoming an expert in it and learning all the details of it, interested in translations of all kinds, dictionaries, doing biblical translations as well as all the other various things that are related to breaking down a new language and trying to become as well acquainted with it as you possibly can. He was there for sixty-plus years.

**GW:** Was he native to Africa?

**Watkins:** No, he was from North Carolina. My mother was from Ohio. They spent some time at the Sorbonne in Paris, then went out and began his work out there. As you know, like in the field of oceanography, in the years previous to this generation you often had no way of being educated in what you did. So it was a case of on-the-job learning, and it certainly was with him. Both my parents were expert in their contributions in that way, so consequently it was a case of learning fast and making a real contribution.

**GW:** What was your father's name?

**Watkins:** Harry Watkins. Harry Oliver Watkins.

**GW:** And your mother?

**Watkins:** Mother was Milway Hutton Morrell [phonetic].

**GW:** And did you say that your mother had a college education?

**Watkins:** She went to Ohio State University and also went to Nyack College in New York. My dad went to Nyack College, took most graduate studies there as well, and also went to the Sorbonne.

**GW:** What did your mother do? Did she work for the missions also?

**Watkins:** She worked with my dad. She was his assistant. She had the ability to do several things at once, could proofread and type 100-and-some words a minute on a little portable, in other languages. [Laughter] So that it was a skill that was highly compatible with my dad's research in linguistic sequences. So I grew up with that.

**GW:** You had a growing experience that nobody in this room ever had. What was it like growing up in Africa?

**Watkins:** It was very different than it is now, so much so that one wonders if I ever really would enjoy a visit again, because there was freedom, the people were relatively happy, food was available, disease was not nearly a rampant thing that it is now, population pressure was not there. It was an enjoyable existence, so it was an interesting time. I don't believe I gave you my birth date. January 8, 1926. That's 100 years ago almost, right?

**GW:** [Laughter] It's got to be longer than that, because I'm 100 years ago. [Watkins laughs.]

Being educated at the primary level and secondary level in Africa, what was that like for you? Was it a church-related thing?

**Watkins:** No. Well, partially. It was boarding school, the only boarding school around, and it was in English. We had children from missionaries and diplomats and anybody else who was interested in English education. It was run by one of the missions. That was the grammar school part of it.

**GW:** Where was that? In the city?

**Watkins:** In Mamou. They weren't large towns. The town was named Mamou in the interland of Guinea. It coincided with the German takeover of Vichy. France and West African territories went with Vichy, so consequently we had German officers showing up to tell us what to do and so forth. So we had some time without schooling, and my dad looked at things and decided that it was getting too dangerous to be there.

So in the middle of the night one night, we threw things into the pickup that he had saved gasoline for, and we drove several hundred miles to the edge of a river, turned the car over to a prearranged buyer, and got into some dugouts across the river into Liberia, walked for several days, forded another river, went to Sierra Leone, and then waited for ten months for a U.S. expatriation ship to take us out of Freetown. By that time the Germans were shooting American

ships, although they kept saying they weren't. The repatriation ship was called the *Acadia*. It steamed into Freetown with this great big flag, U.S. flag on the bow, all painted and lit up, and within two days after we left, why, we heard that the Germans had sunk our ship, so the flag was painted out and they began a zigzag course back to the U.S.

**GW:** My forty-eight years sound boring by comparison. [Laughter]

**Watkins:** [Laughter] This is ancient history, isn't it. I'd missed essentially junior high school and high school, and so the next five and a half years I did junior high school, high school, and college. I made an agreement with the draft board that if they'd leave me alone, I'd study. And I did, and by the time I got out and finished my studies, why, they decided they no longer needed me in the service because the war was over.

**GW:** The entire time you were an American citizen, correct?

**Watkins:** Oh yes. As a child of American citizens, I was automatically American.

**GW:** Your education in Africa and your education here in the States, primary and secondary level, are there any people that you can remember being influential in your life, helping you to make a decision, interesting you in something that really occupied your time and your interests and became a portion of your existence over a period of time?

**Watkins:** Nobody stands out. It was small classes, there or four individuals in a class, means that everybody gets whatever attention the teacher can hand you, because he's got six grades to deal with, whatever.

**GW:** Where did you finish that secondary education in the States?

**Watkins:** I went to East High School in Columbus, Ohio, and I went to Reynolds High in Winston-Salem, North Carolina, and then I transferred to the Wheaton College Academy in Wheaton, Illinois. Then all this time, of course, I wasn't graduation from anything; I just transferred from the academy directly into the college. So my first graduation was in 1947, when I graduated from Wheaton College.

**GW:** What was your program of study at Wheaton College?

**Watkins:** Anthropology. I chose it because I knew a lot about it and felt that with my accelerated course, why, I really had better do something that I understood, so I emphasized that. I always had a bent for engineering sorts of things. I set up the college radio station, I worked for the college in their electrical department. After I graduated, I stayed on and worked a few years for the college in doing those kinds of things, working with the physics departments and so forth there.

I was scheduled to go on for Ph.D. at the University of Pennsylvania after I graduated, but having worked summer and winter as hard as I could, filled up my time, after I graduated I

just decided I couldn't stomach it, and told the University of Pennsylvania to keep my deposit, I wasn't coming.

**GW:** Where did your interest in electronics, engineering, and radio come from, do you think?

**Watkins:** I just had a bent that way and was interested enough to develop my own skills. I came here [Woods Hole Oceanographic Institution] specifically because I could build tape recorders, and back in the late fifties, why, one of the problems that WHOI had was no tape recorders that they felt would last a cruise. So when they talked to me, I had just built one for a radio station in Liberia, which could handle 100 or so inches of rain a year and within a few degrees of the equator, so I figured that it would sure work on the ships. So that's how I got my foot in the door here.

**GW:** When you finished your anthropology degree, you said you worked for a while at the college.

**Watkins:** I set up an international broadcasting organization called the West African Broadcasting Association.

**GW:** What led you to go back?



**Watkins:** Well, it looked like a fun thing to do. I knew lots of the languages, it was the right time as far as history was concerned, for the introduction to radio in these places like Africa. Previous to that, there was actually almost nothing in the way of any local broadcasts at all. There were international broadcasts stations that transmitted from other areas, but there was nothing local. So we set it up and started it as an independent organization. Then I realized that financial aspects were probably beyond me, so I looked around for a sponsor, and the Sudan Interior Mission, which is a nondenominational mission, then decided that they would sponsor it. By the time I left in '57, I guess it was, why, we were using ninety-one languages each week.

**GW:** What sort of broadcasting? What kind of content?

**Watkins:** Everything. Because of the religious aspect of it, why, the large part of the programming was, in fact, religiously based, but there were all kinds of other things because we had government interests in radio things--health, literacy. One of our first contacts in Liberia was through the International Literacy Program, and they were trying to see if they could coordinate radio with people learning how to read, read together, that sort of thing.

**GW:** When you returned to begin this, was this an idea that you brought with you, a germ that you grew on your own, or was there an opportunity there that you took advantage of?

**Watkins:** I went out on my own and built an organization, raised money, went to Liberia to see what we could do. Then my kids got old enough where they needed some schooling, it was time to get out of there, so I came here.

**GW:** Why Liberia and not Guinea?

**Watkins:** Guinea at that time was slanting toward Russia and the Eastern Bloc. Liberia was a democracy with a government that was much like our own--Senate, House of Representatives, President, so forth, and elected officials. Although it was really only a single-party system, still it had elements of democracy that worked quite well.

**GW:** How do you build a radio station, especially when you're virtually by yourself?

**Watkins:** [Laughter] This is ancient history, isn't it.

**GW:** It's also astounding.

**Watkins:** What I did was find out how the government worked and then I found a piece of land that looked like it might be big enough and open enough country that it might house it, so I campaigned and got the local House of Representatives and Senate to essentially grant me the land for this use. Then with that in place, why, I hired local hands and we built a road into it and put up a couple of buildings, brought in some equipment and some more experts, so that the staff

began to build. About that time, why, the Sudan Interior Mission got involved and so there was more of a financial backing.

**GW:** What sort of equipment did you originally use and what capability did your station have?

**Watkins:** We had--I think it was a 10,000-watt local broadcast. One of the things I did was build a 240-foot tower as the first thing. I don't get scared by heights very much, so I found that of all my staff, I was the only one that could do the top-man job. So we put that up and began broadcasting locally, and then we set up shortwave radio sequences to cover various nearby countries and language groups and so forth.

**GW:** Were there a sufficient number of radios in Liberia?

**Watkins:** Yes, there were a few, but my thesis was that as soon as there's something to listen to, that the receivers would be there. That proved to be true. We made some general agreements with things like Dutch Phillips and so forth to make sure that there would be a supply of radios relatively cheap and available. The audience built very quickly. Anyway, that's before Woods Hole by a long ways.

**GW:** That's right. Amazing. You mentioned earlier that it was basically the need of your children for a more formal education that led you to leave.

**Watkins:** All kinds of things entered into it, but that was one of the driving forces.

**GW:** But it was not as necessary to leave as it was earlier with your parents because of political situation?

**Watkins:** No, we weren't forced out the same way. Anyway, I came here looking for a job and did the same thing, tried to find out what the local politics were, what the needs were, and the only match that I could see immediately was the tape recorder aspect.

**GW:** What led you to come here?

**Watkins:** I was offered a job at WRUL and all kinds of other radio stations, but none of them offered me a living wage, so I began looking to see what else there was. This was, and still is, the largest employer on the Cape. I wanted to live on Cape Cod because I liked it, and it just seemed like a good place to push for entry, and it worked.

**GW:** And you showed them how to build tape recorders.

**Watkins:** Well, they gave me the chore of finding tape recorders that they could use. In fact, when you come down to my lab, you'll find these copies of some of the original tape recorders that we installed. They're still working. There's still two recorders that still have bandwidths that are better than the stuff I can buy now.

**GW:** Somebody should preserve those. [Laughter]

**Watkins:** [Laughter] They're being used.

**GW:** One of the excellent attributes of the WHOI Archives here is that when William Dunkel [phonetic] was the archivist, he always was sure that he had the devices on hand that would play back the intimation or data if that was required. So they have some machines down there, while rather antiquated, open the doors on some of the data they still have, and are very important to sustain and preserve. They're artifacts, but they also have great utility.

**Watkins:** Yes.

**GW:** With whom did you initially work at the institution?

**Watkins:** I was hired by Brackett Hersey in his group. He was the one that needed the tape recorders. Earl Hayes was one of his assistants that I worked with. I realized shortly after I began to work, though, that what they wanted was not only somebody who could design a tape recorder that they could use, but somebody who would go along on every cruise and keep that tape recorder running. I didn't really need that, so I looked around to see what other projects there were around here, found Bill Schevill and his interest in sounds and sounds analysis. Of

course, I was into linguistics, so it was an easy match for me to think in terms of how you analyze all these various kinds of sounds. It was a happy association from that point on.

**GW:** The difficulty of protracted ocean voyages, ocean deployments, is something that I study all the time because I work for the Navy, after all, and they have that problem. Was it difficult for your family, having you away for protracted periods?

**Watkins:** I'm sure it must have been, because they weren't used to it. I didn't enjoy it either. I remember on one cruise to the Mediterranean, which was a relatively long one, I told Brackett, I told him at the beginning, Brackett Hersey, that I was only going to be on for a certain length of time because I knew the machine would work and I just wanted to make sure that everybody else knew how to run the machine. So we got over to Italy and he had another couple of months of cruising all laid out for me. I told him it was unnecessary, got off the ship, and came home. Anyway, from that point on, they were a little more careful about the length of cruises they put me on.

But those are the days--you know, this is really ancient history--but we had no such things as travel cards. You got off of a cruise and somebody had to send you a ticket. On that particular cruise, why, I was instructed to--I got off down in the middle of Italy and they told me to find my way to Paris and go to the American Embassy and I would find my ticket, my airplane ticket, waiting for me.

So I did that. I got off and took a train up and found my way to Paris, went to the American Embassy and they said, "Who are you?" They'd never heard of me, and it took

between two to three weeks after that before I got a ticket. In the meantime, I had no money, no real place to stay, so I had a fun time in Paris waiting for WHOI to figure out how they were going to do all this.

**GW:** Who was director at the time?

**Watkins:** It was probably still--I'm not sure who the titular director was. As far as actual operations, why, Brackett Hersey had this huge department. The institution was mostly--you know there was Brackett Hersey's group and the rest of the institution. I don't know what the ratio was, but it must have been five to one or something like that. So he was technically in charge.

**GW:** Tell me about the first time you met Bill Schevill and the beginning of that collaboration.

**Watkins:** Well, very quickly, very soon after I realized what the situation was around here, why, I began looking to see what other prospects there were, so I interviewed with him. Bill Schevill was also working with Brackett Hersey. Everybody was working for Brackett Hersey, so it wasn't a case of having to shift much, except I shifted the kind of work that I did. So it was obvious that he had an interest in his animal sounds. It was obvious that I felt I could be of help engineering-wise, acoustically. Otherwise, I didn't know anything about animals, didn't know anything about biology really. I knew about people and languages, but didn't know much about

the animal side of things. I think he realized that I could make a contribution, so I spent the next few years learning as much biology as I could under his tutelage.

He was very smart. He saw to it--we'd talk about something and he would, sort of as an aside, make reference to some paper that had to do with the subject we were talking about. I would remember that as best I could, immediately go look it up, so the next conversation I would have read he'd referred to. I can think of no faster way to learn something. It was the kind of tutelage that he'd just bring me along. I tried the same thing with him, with acoustics, and it never worked. [Laughter] He was uninterested in that aspect. He felt, I guess, that as long as I was around, he didn't need that.

**GW:** Tell me about the kinds of tasks he needed you to do early on in that program.

**Watkins:** I joined in January 1958. He started looking at animal sounds ten years previously. There were a few things that we knew. We knew that several species made sounds under water. We didn't know very many of them. A lot of the first cruises that I had with Bill Schevill, we had no idea what the species was we were looking at. We would, in fact, have to actually catch a specimen of the dolphins or porpoises that we were working with and bring it home, clean it down to the bone, send the bones up to Harvard's MCZ, and Bill Schevill would call me up and say, "Put this name down next to that sighting." That was the state of our knowledge at that time. It was pioneering in every way.

Sperm whales had been--Val Worthington, of our water-catching group here, had identified sounds coming through an Ido sonar, an Ido sonar head, and had correlated that with



the presence of the animals. So he came back and gave us a vocal rendition of what he had heard that the sperm whales were producing, and so then Bill Schevill got together and the paper by Worthington and Schevill was Schevill's making Worthington write up that initial recording. That had occurred, I think in 1955. I came in 1958.

Bill had worked with beluga. We'd done some work with some p\_\_\_\_\_ whales previously, had done some work with the bottle-nosed dolphin, and that was it. We really knew nothing up to that point. Humpback whales, there were sounds that we called sofar sounds, because they were recorded on the deep hydrophones especially, at distances off of Bermuda, for example, and Hawaii. Bill, in '52, I think it was, '53, he went out on a cruise and spent a long time trying to identify the source. He came back convinced it was humpback whales, but he couldn't prove it. So his report at the time says exactly that, that he had failed to actually positively identify the source of that sound.

Hydrophones--I remember growing with salt crystals and actually cutting them into proper shape and putting them in boots with refined castor oil. There were some companies that were putting out hydrophones, geophysical hydrophones, at a time, if you remember, where they were huge things, large and round and very heavy because they were filled with oil, with quite inflexible cables and so forth, none of which lent themselves to working with animal sounds or deploying rapidly. When you go out to work with animals, why, they're close for a short time and then as they move on, you have to put yourself in front of them in order to get the next observation. So it's fast in, fast out, is what we had to do.

So I built hydrophones, amplifiers. Willie Dow had built a series of amplifiers called the suitcase amplifier. It was a suitcase that required four men to carry it because it had huge, huge

transformers and large tubes and so forth. That was the smallest amplifier that was available for it. So I got busy and started working with transistors and probably was the first engineer at Woods Hole Oceanographic Institution to design and build transistor amplifiers. We did that specifically for hydrophone amplifiers, both the impedance matching systems that went down in the hydrophone itself so that we could reduce the size of things, and then also amplifiers that were on deck. Then tape recorders. In spite of the fact the big tape recorders worked, still wanted a something a lot easier, so I adapted a hand-crank phonograph drive to pull the tape sequence through, and built my own heads and amplifiers in response to Willie Dow's suitcase system. This was a rowboat system. It worked well, gave us a good 30 kilohertz bandwidth, which was much wider than anything that was available otherwise.

**GW:** And it was basically off-the-shelf technology that you were building yourself?

**Watkins:** I guess off-the-shelf technology. It was discrete components that I put together, pieces of iron and so forth. As the years went by, why, I talked to various companies like Ithaco [phonetic] in Ithaca, New York, Ithaco Company, to build my ideal hydrophone for me.

**GW:** What was your ideal hydrophone?

**Watkins:** As a result of all my experimentation, I wanted a system that would give me from 100 to 500 kilohertz of bandwidth, and I wanted to be able to feed into the systems that I was building. So they built hydrophones for us. And tape recorders, with time, other people began

to bring in tape recorders that were a little more sophisticated than the basic stuff I had designed, although I think those original Crown tape recorders still had lower flutter and w\_\_\_ than any of the systems that exist today, really, in a direct-record system.

Then as things got improved, you had IEEE standards come in so that you began to lose all your low frequencies. They cut out everything below 300 hertz, and so instead of having a bandwidth that would cover from 10 hertz on up, you had to split the system. You had to have an FM system that would give you zero to maybe 6 kilohertz and then another one that would start at 300 hertz and overlap and go higher with direct record.

**GW:** [unclear]?

**Watkins:** Because those were designed by other people. I could build my own. But how many tape recorders can you build a year? I was not into the development of tape recorders. I was trying to get some answers from the animals.

**GW:** Did you go to sea with Bill?

**Watkins:** I did go to sea with Bill a lot. He was a wonderful shipmate.

**GW:** He told me initially in a very exciting fashion about his early small boat, his first hydrophone, and his tape recorder and the work that he did right out here in Vineyard Sound.

**Watkins:** Yes, he did that. Actually, his first recording was up in the Saguenay River with a home-grown r\_\_\_\_\_ salt crystal hydrophone, and it was recorded on a gray autograph disk, dictaphone, so that it was a wax disk. I'm trying to get the institution to reproduce that because it was fifty years, just about.

**GW:** Brackett Hersey used the gray autograph also [unclear] in his submarine recordings.

**Watkins:** That's right.

**GW:** They then started using those translucent disks that were floppy plastic.

**Watkins:** Yes. And then we went to transcriptions. We have some big transcriptions that we used to use in the radio system.

**GW:** Most of the funds to do this, I imagine came from the Navy and the Office of Naval Research.

**Watkins:** The first proposal that I wrote, which was probably about February 1958, was to the Bureau of Ships. ONR was not in existence at that time. ONR came in, I think two or three years later.

**GW:** '46.

**Watkins:** '46. Well, as far as we were concerned, we didn't know anything about it. [Laughter]

**GW:** That's probably why [unclear].

**Watkins:** Yes. So most of the early work that I did on animals was funded by BuShips.

**GW:** What rationale did you use in your proposal to demonstrate to King that BuShips should fund your work?

**Watkins:** I think that it's the same rationale that I have today, is that if you're going to be working with underwater sound in the ocean, you ought to know what's there and you ought to know all the details of it, and you want to know the nuances of it. If these are sounds produced by animals and you're going to be competing with them in any way, you ought to know the details of their behavior and how that whole acoustic behavior is modified over the year in social structure and all the rest of it. Everything that affects their production of sound you ought to know.

**GW:** You mentioned that Dr. Schevill was a good shipmate.

**Watkins:** He was fun.

**GW:** What makes a good shipmate?

**Watkins:** Well, he had a way of expressing himself that was both comical and wise, and there's no way I could repeat that. For one of the projects that I started, and for some reason or other was unable to complete, was to actually keep lists of the way he said things. But that got lost, unfortunately. He has a son, Edward Schevill, who speaks very much like him. So when I'm talking with him, why, I can hear Bill Schevill and how Bill Schevill would say these various things. It was a very unique sort of presentation.

He loved geography. He loved knowing exactly where he was. He loved knowing every detail of it. We traveled together all over the world, from the Antarctic to Japan, to Europe, to wherever, and every place he went, he would have researched ahead of time everything we were going to see and all the details, so he could give you the history and the geographic details, as well as the political history and so forth. He would try and get me to get into this with as much of the anthropology, the local anthropology as I could come up with. So they would be fascinating trips, just from that standpoint.

Of course, in those days, almost every animal contact was brand-new exploration. We had absolutely no idea what to expect in most cases, so we learned just a huge amount. That's been what's been so fun about the whole project even up to now, is that I know enough now so that almost every contact that I have puts a whole lot of things from the previous experiments into perspective. It's just wonderful.

**GW:** You really are on the right project when every time you turn the page, you find something new that excites you. [Volume level on microphone extremely low.] You know you're on the right track. No doubt about it.

You mentioned early on the difficulty of identifying the species. We've discussed, by and large, up to this point in time your contribution to the project and that the data had to be brought to the situation where you could feed it back to the lab and talk about it, analyze it. How did you manage to determine what you were listening to?

**Watkins:** As I say, of the smaller animals that we honestly didn't know, why, we would check with bones. Bill Schevill had a position also with Harvard's MCZ. He was the curator of whales up there. He had also previously served as librarian. He was probably the world's expert on the morphology of all these various animals, so consequently it was an ideal arrangement. If Bill Schevill couldn't identify it, then nobody could. It was that kind of a situation. He was very, very careful. He was fun to work with because of that. He was exacting, but I didn't mind that. Lots of other people seemed to not take it as well as I did, so I suppose that's one of the things that made it easy for us to work together. I liked the precision that he brought it together. If you read any of his old papers, they're beautifully written, really very beautifully written.

There are other individuals back in those early days that also contributed. I don't want to make it sound like it was Bill Schevill and me. Dick [Richard] Backus, for example. Dick Backus was often with us on these various cruises. Dick Backus was a fish person, but he also had a huge amount of experience at sea, and a lot of the early recording sessions and experiments were shared with Dick. As time went on, why, he concentrated more and more on his deep

scattering layer work and we went off and were more and more involved in the cetaceans and seals, marine mammal kinds of things.

In those early years, I presume that Brackett Hersey would have considered Bill Schevill and Dick Backus as his biological team, and I was along for the ride in that sequence and tried to be helpful to both of them.

**GW:** Did most of the voyages that you went on with Bill Schevill, were they Brackett Hersey voyages on which you guys would piggyback?

**Watkins:** The initial ones, I think that is entirely true.

**GW:** On *Chain*, I imagine.

**Watkins:** *Chain*, the *Yamacraw*, which was a Coast Guard vessel at the time, the *Bear*, heavy wooden thick-hulled wooden ship that was wonderful acoustically but awful to ride on because she would roll her rails under at the smallest sea. But you didn't transmit engine sounds to the ocean around much.

One of the things that I emphasized, kind of took on myself as the biggest contribution that I felt I could make early on was to try and work out techniques for approaching the animals, for being able to work with them acoustically, and I realized very quickly that just because you saw an animal, just because you could get up to it, didn't mean that you were observing normal behavior. The goal, as I saw it, was the recording of normal acoustic behavior, so consequently I



emphasized those techniques. A lot of our original experiments, in fact, were designed to demonstrate this, to demonstrate various aspects of it. You could see that when they were not disturbed, how they would continue to make sounds and things would continue. If you came up on a noisy ship, why, you had quiet whales.

**GW:** Did you have to go adrift? Did you have to cut engines?

**Watkins:** In fact, we built a quiet little boat called the *Grampus*, a plastic boat that we took out, and we would set it down, noisy as all get-out in the air, but silent under water. You could move around at 3 or 4 knots and pass within three feet of the hydrophone and I honestly couldn't hear it. I could note the bow wave and the stern wave, but I sure couldn't hear the engine. I sure couldn't hear the propulsion. So we used that quite a lot.

We got away from using institution vessels later on simply because the institution ships became so costly that you had to share, and often animals--you couldn't have predictable stations when you're working with animals, and so time-sharing just didn't work very well. So we began to hire other ships, everything from saving vessels, sail-teaching vessels, fishermen, all kinds of other kinds of boats as well.

**GW:** To what extent did the kind of understanding regarding the behavior of sound in water brought to our attention by people like Maurice Ewing and Brackett Hersey, Allyn Vine, Joe Worzel and others, to what extent did that knowledge and those people help you in your efforts to get data?

**Watkins:** It was an interactive sort of thing. I went out there and I would make some observation, then when I got back, I would immediately go to Brackett or Lays [?] and say, "Hey, look. What do you think would cause this?" Multi-path was a real problem, multi-path acoustic pathways, multiple acoustic pathways was a real problem, because you would get, on a very short-term basis, repetitions of the same sound, and sometimes the fourth or fifth repetition was louder than all these first ones. The whole business of how the acoustic pathways are developed under way, they weren't entirely understood in the early days. So in a sense, we were all flying blind. But as we learned more and more about it, then some of these things made much more sense. So, yes, it was an interactive sort of thing. We were observers, and anything we didn't understand, why, we tried our best to get other people to elucidate from their experience, because ultimately we were trying to find out something about the animals, how the animals use the sound, when they use sound, where they might be.

**GW:** [Volume level on microphone extremely low]. Maurice Ewing's program put some deep hydrophones in off of Bermuda. This predates SOSUS. Of course, Ewing is one of the people who is credited, at least in part, with the hypothesis, that was later confirmed, that demonstrated the existence of the deep sea sound channel. When you would go out on ships, were you able to take advantage of some of the Lamont [Lamont-Doherty Geological Observatory] or Columbia installations in Bermuda?

**Watkins:** Yes.

**GW:** The data or the listening capacity they had?

**Watkins:** We did that. We also worked right at St. David's Head, worked with the arrays, and we did that over the years. In fact, when they got rid of their drum recorder and the recordings, Frank Wadlington called me up and said they were on their way to the dump, and I begged him not to. So I sent down and we got them shipped us to us. They're in the archives right now after we spent three or four or five years analyzing them.

**GW:** Frank Wadlington?

**Watkins:** Frank Wadlington worked at the St. David's Head. He was the engineer there and is the one that did a lot of the animal recording. We interacted with him quite a lot.

**GW:** Did he work, in turn, for Gordon Hamilton?

**Watkins:** He worked for Gordon Hamilton. Gordon called me last week, actually, and we talked about some of these things.

**Frank Taylor:** I'm really curious. Your experience really kind of parallels the whole oceanographic experience. In the early years you were basically data collectors.

**Watkins:** Yes, you were learning as much as you could.

**FT:** Once you collected the data, what was next?

**Watkins:** Every time we learned something about an animal, we tried to put it out and publish it, so a lot of our early publications are the sounds of this species, underwater sounds of that species, underwater sounds of this species in such and such a behavior, because this was the first indication of what those sounds were. Those kinds of early sort of experiments were working with one observation, one observation that lasted five minutes. You'd be laughed out of the business if you tried to do that now. The whole field has migrated. Initially, we weren't even sure what they were, so it was a real discovery, what kind of sounds were produced in a very generic way.

Last cruise that I had, I used radio tags with telemetry of dye profiles, went to an area where I knew the animals, where specific kinds of animals were, they were in a particular type of behavior, and I structured the whole cruise to study those behaviors, not wildly looking at anything, but to study those behaviors. For example, the paper that we just sent off to editors is looking at four and a half days of continuous observations of every dye, the dye profile of every dye from a particular sperm whale, tracking the animal, following it, trying to relate it to what happened with all of its companions, relating it to the surface behaviors.

**FT:** So initially the whole goal was to develop equipment that you could do this with, then kind of refining that, then refining the way that you get the sound.

**Watkins:** Yes.

**FT:** But now you work with how they talk. "This is a distress call. This is a mating call."

**Watkins:** Yes. We've learned enough so that now we try to study a particular behavior. For example, in sperm whales, they have coda sequences that the different populations use. In the Caribbean population of sperm whales, that's sort of a pattern of clicks, is sort of "Get out of my face" sort of thing, an agonistic, an agonistic sequence used between whales when they really don't care much for the company of the next one. Then you have five clicks in a row, a sequence which is really sort of a "come hither" sequence. In particular situations where you have two or three animals at the surface and usually often in that area, females with or without calves, and a young male will try and come up to that group, so he'll sort of announce his presence with a coda sequence that may or may not be an identification coda. In any cases, it's adopted it temporarily to indicate that "I'm coming in." And he keeps sort of almost asking their permission to come in. In most cases they don't necessarily want company, so they'll give that agonistic coda back at him. Then there will be exchanges, and he'll give a friendly coda in exchange, and they'll go back and forth with these things. So, watching these sort of behaviors is where we're at now, trying to define exactly what those contributions to their sounds mean and what the details of their communication is.

**FT:** Is there a universal language? Can a m\_\_\_\_\_ speak to a sperm?

**Watkins:** No. Every species is different. In fact, most sperm whales produce only clicks, so the clicks are in pattern sequences. Humpback whales are moans. Finbacks and blue whales are moans, but they're below our hearing, extremely low-frequency kinds of things. Every species is different.

**FT:** Is it difficult to make these recordings? In the Arctic it's very icy conditions, high water.

**Watkins:** It is difficult. As Bill Schevill used to say, there's absolutely no substitute for experience. Certainly a new person going out, often there's a lot of stuff in the literature that is published as animal sounds, that is probably hydrophone cable noise. There's a lot of the techniques and so forth that you develop over time.

I was trying to learn what the animals did with their sounds. In order to do that, we had to first start with developing equipment that would do it. Then we had to develop techniques of using that equipment that would not stress the animals, so we were looking at normal behavior. It's still a problem. In fact, really most of the observations that are even now made of marine mammals are from noisy ships. The animals are not talking, they're silent, they've stopped whatever it is they're doing. The observations are of abnormal behavior. of the response of the animals to the observer, not to what they would normally be doing. So you have to go to extreme lengths to be able to accomplish that. Every once in a while, there will be a publication that will come out that will talk about something very different from a group of animals than all

the previous recordings, and if you look at it carefully, this guy's been careful enough so that he didn't disturb those whales. So, consequently, he got a very different result from the others.

**FT:** When you get this data back to the lab, if you will, do you use other kinds of equipment, like oscilloscopes and things like this?

**Watkins:** Yes. The world has changed. It used to be oscilloscopes and it used to be we designed our own timing circuits and that sort of thing. We used to use Polaroid cameras with oscilloscopes and do all that sort of thing. Now everything is computer and you have spectrum analysis, is the main tool that you use, combined with all kinds of things that give you the detailed timing between sequences, the frequency emphasis, the power spectra of the various components, and you're combining that with the detailed data.

The cruise that I was just talking about, we had towed hydrophones being towed behind the ship. Those were recorded. Every time we would stop for a length of time, we would put out floating hydrophones, an array, a three-dimensional array of hydrophones, so that you could get direction both horizontally and vertically. Those were all recorded on separate channels of a tape recorder. We had the radio tag, the radio tag signal on the surface was recorded, so you had the exact timing of that. All of these were related to a specific time base. Encoded in the signal was telemetry of the previous dives. That was recorded in a distinct way so that you had all that. You had logs that were being recorded simultaneously. You had observers up in the crow's nest recording what they saw, carefully following specific protocols and how to observe and how to

identify these things, all recorded and all related to the same time basis. You had the logs that we keep on there.

We recorded these SatNav information, where the ship was at any moment, to do the heading of the ship, the speed of the ship, the angle at which the signals came in from ABFs to the radio tag so that you could then go back and calculate where the whale was in relation to you.

We tried not to have the whale so close that it was paying attention to us at all. We sometimes worked miles away from the whale simply because we had the radio tags. We would kind of balance what the particular--what was going on. If there were several whales interacting, then we came in a little closer to try and use our acoustics. Otherwise, we stayed far away in order not to influence the behavior of the whale.

All of this, then, you come back to the laboratory and you have to analyze that and relate it and build a story of what happened.

**FT:** Could you take me through a little of that analysis process? When you say you analyze it, put me in there. Here's a bunch of stuff. What am I going to do with it? [Interruption.]

[Begin Tape 1, Side 2]

**Watkins:** Each segment of what I've just outlined is analyzed separately, but related to time. For example, the videotape that we used to keep a record of the time, [unclear] timing, is displayed, and on that same tape there is the acoustic record of the towed hydrophones. That's played and you're looking at a specific sequence. For example, one of the things we're looking at



right now is what changes occur as a sperm whale dives, what changes occur in the sound as a sperm whale dives. We have good evidence that, in fact, the spectra shifts upward with depth as the animal goes down. We try to pinpoint that and document that very, very carefully.

So we look for the places where the whale has gone down. We follow the next few minutes of sequence to see if he starts to click, and what those changes are as that animal goes down. We have the record of how deep he was at the moment. That is also looked at, because we have the separate record then of the dye profiles for each one. A time line is set up where every dive is put in its place with the sequence, the amount of time at the surface, the amount of time going down, how fast it went down, how long it stayed down, what happened when he came up.

Often these animals will have a little step, and they'll sort of hang in there for a while before they come up. Sometimes when they come up, they'll be at the surface, you'll hear the signal, but they will not have taken a breath until two or three or more minutes after they've hit the surface. That's all very carefully laid out. So as much as we possibly can, we're trying to figure out what that animal's doing, what it has been doing, and what the sounds mean in that process.

If it's a section with a four-hydrophone array, then you get the acoustic direction to where that individual is, any differences between the hydrophones, any pictures. You're comparing it then with the observations from the crow's nest. It's intense, detailed. You track him around the clock. Obviously you can only use the crow's nest when there's light. As soon as it's daylight, why, there's two or three people up there following the animal, using the tagged whale as the focal animal for actually paying attention to that animal and all the others. You have absolute

positive identification of the animal. When that animal comes to the surface, there's no question that he's it. You've got a signal. By using low-frequency radio, we're able to get relatively long distances. Waves don't interfere with the lower frequencies, so consequently we don't miss any surfacings.

Anyway, it's so different from the early days. The early days, why, one of our worries was, what kind of animal was it. So often my recording would be cut short with the anxiety that we had to catch that animal.

**GW:** You mentioned Gordon Hamilton. [Volume level on microphone extremely low] [unclear] and the knowledge brought to the entire analytical process by those who were working on deep acoustic on Navy projects, the nature of sound transmission in water, not necessarily marine mammals, but all sound transmission in water. This is why Gordon Hamilton came into the picture. About two years ago, I was on board USS *Albany Los Angeles*-class fast attack, sitting in the sonar shack off the control room with a headset on, and the sonar tech was trying to explain to me what I was hearing. He could explain the ships just fine, but quite a few other things he did not. But the absolute clarity of the sound was one of the best things I've ever heard, the calmness around the sound, all the details. I was an amateur listening. I couldn't help but feel that the best way to record these sounds in a non-interfering manner would be with some sort of submerged boat or installation.

**Watkins:** Yes, that's right. That's why I've always, as much as possible, worked with the Navy surveillance systems.

**GW:** When did that start? How hard was it to get in?

**Watkins:** I was granted clearance, I think in 1958, so I've been sort of on that circuit ever since. A lot of the things that the Navy calls noise I was interested in because I knew immediately that there were animal. I often didn't know what animal, but one of the benefits I got was to know where those sounds were occurring. So then I could take a ship out. Even though I couldn't divulge where or how I got the information, it sure helped me to know exactly what to do once I got out there.

For example, the pulses produced by finback whales. One of my first chores when I came to the oceanographic was to contribute to the effort to find the source of that. The Navy physicists were sure it was Russian because it was pervasive, it was loud, it was low frequency. They were intrigued with the precision of the repetition, that sort of thing. On the other hand, we looked at it as biologists and we said, "No, it's not all that precise. In fact, it's exactly what an animal would do." So we set out to try and prove it. It took five or six years to prove it. Of course, once we did, why, that was the end of that money. But in the meantime, we learned a tremendous amount.

At that time I used the SOSUS systems, for example, the system off Bermuda, the geophysical system off Bermuda, the surveillance systems up over our coast and off the Canadian coast.

**GW:** [unclear]?

**Watkins:** Dartmouth. It predated those other ones. We were to demonstrate that they occurred in particular sounds, that the sounds moved in ways that would be compatible with ships. One of our most solid demonstrations was up off of--we occupied the air space above an installation off of Dartmouth, Nova Scotia, and Bill Schevill circled forever while I sat in the shackle on shore, and we both yelled simultaneously, "Finbacks!" [Laughter] Because he saw finbacks and I saw the signal on shore. We were able to match that up.

**GW:** The early Navy surveillance system was built on Bell Telephone Laboratory's lofar technology. Lofar was derived by Winston Koke [phonetic] from voice analysis techniques. Were you able to use anything that derived from that technology at all to help you identify the species you were looking at?

**Watkins:** Yes. We used lofagrams because that was good at low frequencies. Most of the other spectrographic capabilities that we had in those days were not good at low frequencies, so consequently, that was our window onto low frequencies. So we used it extensively. Sometimes, in fact, we borrowed a machine to come up and look at some of our stuff up here and there was a Navy lieutenant essentially chained to the machines. [Laughter] So we used it as minimally as possible here.

**GW:** [unclear].

**Watkins:** That's right. One of the early ones. Right. [Laughter]

**GW:** There would be at that time, yes.

**Watkins:** Anyway, up until recently, of course, why, even the operators at the SOSUS stations were not allowed to tell even their families what they were doing, so consequently we were even farther down the chain, so it was not something--

**GW:** You said that for a while the Navy money flowed because you were trying to identify these noises that many of the Navy ships felt were Russians. Did the money stop?

**Watkins:** At that point, yes. We've had many--hot buttons bring in money, I guess, and that was my first experience with that. Other people, I'm sure, had it happen before and since.

**GW:** Did you have your security clearance yanked?

**Watkins:** No, because I was still doing other things and could show that there was progress. But the funding for--you know, we knew it was finbacks, but we didn't know why. We didn't know the details. It wasn't until struggling quite a few years later that we were able to demonstrate, in fact, that it was male advertisement during the reproductive period that was producing those sounds, only the males, not the females. And if we would have had that money

continue on so we could continue the intensity of study, why, those details and a lot of other details that we still haven't figured out would probably be there.

The hot buttons that come up periodically such as Navy standings that people might be worried are the result of loud noises produced by Navy ships, that sort of thing. Suddenly we're asked to look at it. On the other hand, if the funding had been consistent enough previous to that, we would probably have in our databases good examples that would exactly match what's out there. But because of the inconsistency of the funding, why, you essentially go from one project to the next, instead of being able to see a consistent development of a sequence.

**GW:** Were you supported by ONR at that time?

**Watkins:** We began to be supported. The first five years or so was Bureau of Ships, and then as far as Navy-related things, it switched to ONR. I can't remember the first officer. Helen Hayes was one of the early ones. Then [unclear] Bernie Z\_\_\_\_\_, and he continued on for a number of years thereafterwards and so forth.

**GW:** So this wasn't geophysics branch.

**Watkins:** No, no, this was biological oceanography. Geophysics, we actually, even in the institution, the geophysics department became increasingly uncomfortably with our work here because it wasn't dealing with earthly things, it was dealing with relatively imprecise biological things. So they moved us over to the fledgling biology department here when the departments

were organized. Actually, we ran the geophysics department here for quite a few years after the departments were organized. When Hertzler [phonetic] was department chairman, he decided that he'd rather have us not be in his department. [Laughter]

We still used a lot of the same equipment. One of the main arguments for us being in the geophysics department was that we used a lot of the same equipment, shared technologies.

**GW:** During the course of your work with Bill, you took time out to get an advanced degree.

**Watkins:** I did. I had an unusual offer from the Department of Education in Japan, and they essentially asked me to come over and do some specific work. They would have committees looking at us and so forth. They made me an offer I couldn't refuse, so I went to the institution and said, "If this fits your goals, I'd like to do it," so they let me go ahead. And ONR, to their credit, continued to support me and support the programs I was operating, even while I was in Japan. I tried to keep the lab running while I was here, as well as over there, and I did most of my writing and so forth here, so although I was only in Japan for several sequences of months, why, over something like three years they gave me what they called *huckshi* [phonetic], which is the highest degree. When I came back here, the institution translated it as a Ph.D.

**GW:** What did you study there? What was the program like?

**Watkins:** Whale biology. It's the only place in the world that I know of where you could, at that time and maybe still, study whale biology. So I worked at the University of Tokyo at their

Marine Research Institute, worked with Katsu Hedo Mesue [phonetic], who was a major professor there. The Japanese system is a system, as I'm sure you're aware, where it's a pyramidal thing, where the University of Tokyo is at the top and everything else is leading up toward it. The major professor at the University of Tokyo is at the top of that heap, and he has nearly anybody he wants to under him to call upon for various things. He asked me what I would like to find out about, and I said, "I'd like to find out about finback behavior and especially acoustic behavior." He said he didn't think they had much in the way of acoustics, but they sure ought to be able to find people who had watched them.

So I got sea captain after sea captain after sea captain come to my door with log books under their arms, and a translator, that would show me specifics from their experience and lay it out for me. It was a marvelous time, and I learned, sometimes worked right through the night and so forth, because these guys would show up at midnight. [Laughter] They had other work to do during the daytime. It was a rewarding experience, and that's the degree that they've now assigned to me. They call it the highest degree in Japan. The institution here must have had some sort of a series of meetings to figure out what they would call it here, but they decided to call it a Ph.D. Anyway, it was appreciated. I learned a tremendous amount, and I'm sure it has made it possible for me to continue on where I might not have been able to simply because of the lack of a union card.

**GW:** Did you add another language to your program?

**Watkins:** [Laughter] I defended my thesis in Japanese.



**GW:** I'm impressed.

**Watkins:** But I don't think I could even order a meal right now in Japanese. It was one of these situations where in real intensity I learned it. I emphasized the spoken, did not bother with reading, did not bother with their orthographies.

The first time I went to Japan, I went with Bill Schevill and Bill Evans. Bill Schevill had learned, because of his wartime efforts, had learned Chinese kanji. He could read it. So I realized that if he could read the kanji, my emphasis should be to learn to speak some Japanese. So it was interesting. We'd go to a train station and I'd ask the guy when the next train was going to be there, and he'd hand me the schedule and I'd hand it to Bill Schevill to read. So then the next question, he would turn to Bill Schevill to speak, and, of course, Bill Schevill would say, "No, no, speak to him." [Laughter] So anyway, that first trip, which was about six weeks in duration, I learned a tremendous amount, and it was a shared responsibility of getting along. It worked really well.

**GW:** You mentioned Bill Evans. I'm not familiar with Bill Evans.

**Watkins:** Bill Evans. He's now at Texas A&M. He's retired from Texas A&M. He used to be at Hub [?] Sea World Research Institute. He worked for the Navy for many, many years in lots of different areas. He took his Ph.D. under Ken Norse [phonetic] at Scripps. He actually has some acoustics under his belt. He was one of the few people working on this that has had some

formal education in acoustics. Did a lot of interesting work both there, then he was in Washington. My memory's failing me here, but I think probably with NIMPS [phonetic].

**GW:** With?

**Watkins:** NIMPS or NOAA [National Oceanic and Atmospheric Administration] for a few years, and then he went back to Texas A&M. He was director of Hub Sea World Research Institute for a while.

**GW:** [Volume level on microphone extremely low]. He mentioned in his early experience down there in the sixties the initial discovery by some of the scientists there, Dr. Sternberg [phonetic], among others, of the environmental prediction, the limited environmental prediction capability one could acquire through using acoustics, that doing acoustic studies in a close shore area off Florida and some of the variations they were detecting weren't so much acoustic as they were tidal problems that were presenting themselves. They suddenly discovered that they were having to go to the natural cycles of the earth and the moon, and this was an extraordinary discovery for them. [Harry] DeFerrari mentioned, when we were talking about it--we talked about it in some detail--that he believed it was the beginning of tomography and the uses of acoustics for environmental analysis and commentary.

Fairly recently Walter Munk has taken that to a fairly high level of application and has taken a great deal of flak for it from environmental groups. I know it's one of the things that he occasionally doesn't like to talk about, even with a historian. Given the fact that you are a

trained whale biologist and you spent most of your life in acoustical matters, is tomography an important scientific avenue to explore?

**Watkins:** I think it really is, and I think that it's useful in all kinds of ways. We've thought that maybe these animals that produce loud low-frequency sounds may be using tomographic information themselves simply because they're producing sounds in the right spot, they have a sensitive ear, and they put themselves in the locations that might make hearing about as good as anything.

However, we have yet to demonstrate that the animals use anything like that. In fact, it kind of goes counter to what we know about the animals. Finbacks, for example, produce low-frequency sound that would be useful for tomographic exploration or long-distance transmission, echo ranging, whatever. But if they produce those sounds nearly always within 50 feet of the surface, it's not going to go very far because of the mixed layer in the surface. It will go far if you have a sensor on the bottom at some distance while you hear them at great distances, but unless you had another finback down at that depth, it wouldn't be useful for long-range communication.

Roger Payne and Doug Webb here, of the institution, wrote a paper years ago about how that if the tomographic channels, if the sofar channels worked as well that way, whales could communicate around the world and so forth. But that would imply that both listener and speaker were down at some depth, deep enough to be able to do that. This just doesn't fit what we know about these animals at all.

**GW:** How deep can the deepest diving whales go?

**Watkins:** Sperm whales we've followed to 235 meters. Fin whales go maybe to 300 meters on occasion. Mostly they're in the upper 50 feet. Blue whales often feed apparently on the scattering layer, so consequently they're liable to be down to 300 to 500 meters. So they would be the deepest ones of the baleen whales. Right whales, bowheads are mostly in the upper couple hundred meters, sometimes in shallow water. You'll see mud on their face when they come up, so they've bumped into the bottom and come up with the mud sort of streaming out. Humpback whales are mostly fish-eaters, though they also do eat plankton, so it would be entirely possible in some parts of the world for them to go down to the thermocline, though we don't have any evidence for that.

**GW:** Do you think that introducing sounds into the water at the levels encouraged by some tomography programs could hurt the whales?

**Watkins:** Yes. If--a big if--if the whales are in the right place to receive them at higher levels, I think there's no question that it would be--okay, this flies in the face of my--my goal has always been to study normal behavior. In the presence of a loud sound, you are never going to see normal behavior because the animal is going to be noticing and reacting to that. So that's my biggest worry about it.

As far as the animal being harmed by it is a different thing. That would imply that the animal had to be quite close and that the levels had to be above some magic number like 200 db

or whatever relative to 1 micropascal in order to create real trauma in the animal. That sometimes occurs. It sometimes has occurred relatively recently, and I suspect a lot of the times we don't recognize it because some of our sonars are very, very loud and if there was an animal relatively close that we didn't know anything about, he's on the bottom someplace and probably hasn't come up for his next breath. On the other hand, that's a relatively few animals compared to what's there.

I don't like to get into this, but when Walter Munk originally proposed his H\_\_\_\_\_ Island experiment, I was probably the one that initially said, "Hey, you've got to bring the level down. You've got to figure out how you can not cover quite such a wide area, because it has the potential of affecting an awful lot of animals." I told him initially that if they would do it in the wintertime in the deep sea, they would affect very few animals, but if they went to the Antarctic in the summertime, why, they had the potential of touching a large number of species. Of course, that's exactly where they went, but at that time they had, in fact, changed their levels and modified things. We had meetings in Marine Mammal Commission and all that sort of thing. I think for a while Walter Munk didn't really want to talk to me again. He and Bob Spindell used to call me up in the middle of the night and talk at length about these things.

I think, done wrongly, it could be a real problem. Done correctly, it need not be a problem. To do it right means that you really want to find out what animals are there, make sure that the animals are not close enough to be harmed, and do it as minimally as you can, rather than just have a constant sequence, because the constant sequence is going to create a long problem for the animal, and its normal behavior is going to be affected for very much longer.

The animals do habituate. We don't know enough about that yet. We don't know how long it takes them to habituate. They obviously do. When I first started to work with finbacks in the open sea, you'd come up in a noisy boat and next time you'd see the animal, he was on the horizon. Now we have finbacks in Boston Harbor. They don't care a wrap. Same species, even from the same families, they've habituated. How long it takes to habituate and take a stimulus from being a disruption to something that is normal in their background, we don't know yet, but that, I think, is one of the problems that need to be worked on, because going blindly into these things, I think all of us have the potential of running into much more environmental roadblocks than we need to and much more the potential of creating disruption for animals is certainly there.

**GW:** You mentioned earlier when I brought up the issue of listening to the animals in the deep ocean via submarine or via-- [Interruption.]

**GW:** I wanted to go back and explore the nature of your relationship with the Navy, because we established earlier on that one of the best ways to listen to the animals would naturally be from a submerged location, as the Navy discovered back in the fifties, probably the best platform for antisubmarine warfare was from a submarine. You mentioned that you had a clearance dating back to 1958 and periodically you would have funding for specific aspects of bioacoustics that would interest the Navy. Was this common for the actually to clear people at WHOI and other places to work with the SOSUS system?

**Watkins:** Certainly it was common for ONR and the biological division of ONR to support biological research that was perceived to be useful to the Navy, and in some years where they even went further afield and supported because it had potentials in other areas that might ultimately be useful.

Most universities were objecting to working with restricted data, and Woods Hole was one of those places that did not have that restriction, so I was happy to continue here working with the Navy and happy to use whatever information I could get from sources and other of the surveillance information. I would get recordings from ships, Navy ships, observations from submarines and different other groups that would have a question about what they were hearing or what the response was, or they would have a sonar experiment and they would see a target, try to figure out why it disappeared, that sort of thing. So I ended up by being on the question-and-answer circuit, and a lot of those questions essentially required that I have the clearance in order to deal with the data.

I have carefully--at the institution I've tried to not ever have classified data here simply because it was unnecessary. I maintained my lab as an unclass facility completely, but recognized, and I think everybody else recognized, that a lot of the data I used was data that was collected with classified systems. There were a number of researchers, especially here at the institution periodically, who had clearances, but a lot of our colleagues in other places didn't want it or were not in a position to make use of it. So I feel myself lucky to have had this special relationship with the Navy that way. It's been rewarding in all kinds of ways. I think they learned to trust me, and I certainly learned to trust them. As a consequence, it's been a good relationship.

**GW:** Were there any recognized limits that you had to place upon yourself in terms of publications and discussion of various aspects and issues that derived from classified data?

**Watkins:** Yes. Mostly I couldn't mention it. [Laughter] Mostly the uses I was able to accrue from the classified data was where and when, so that I could go and confirm it, so that I could take my airplane out or I could take my ship out and work in a particular area, or the SOSUS data, for example, would confirm a pattern, a seasonable pattern and that sort of thing. But I would then go down, for example, to the geophysics station at St. David's in Bermuda and record a portion of that during the time that I knew that that pattern existed and could confirm the seasonability in that particular area, so I could publish that, even though I couldn't publish the contributing data up to it. It just made me much more comfortable with my overall perspective because I had a wider view. I tried to get the data in such a way that I could demonstrate what I already knew.

**GW:** Did your access enable you to go to virtually any SOSUS station that you wanted to go to?

**Watkins:** Yes, but I didn't do it very much. Mostly I relied on developing relationships with individuals at those stations so that they knew what I was looking for. They would become intrigued because one of the things I was doing was try to develop an understanding of what they were calling noise, and so when that noise showed up in a particular way, and I would sometimes forecast, ask them to look for it at a particular time, and then when it came in, they would say,



"Yeah," and they would sometimes give me coordinates of where they thought it occurred and at what depths things may have happened and that sort of thing. So I would get that kind of confirming data. Mostly I didn't go to many of the SOSUS sites. To a certain extent, while keeping a relatively low profile made the access even more important. I had the confidence of individuals, and that's what I needed.

**GW:** One of the things that interests me, having spoken to a member of the SOSUS operators and in the current project I'm working on, [unclear] at the Pentagon are still trying to write guidance for these people so they can speak to me about certain things and not about others, but it strikes me, in speaking to some of them, that listening and interpreting in the way they do is a combination of technology and art.

**Watkins:** I don't think it's art. I think art. Let's substitute "experience" for art. It looks like art because your experience isn't enough to fit it in. But having looked at this, thousands of hours of a particular signal, you can recognize it back into the background. It looks like art, but it isn't. It's an experience that's there. That's one of the things that the Navy is losing, incidentally, is this kind of capability because of the fact that they've downgraded the operator's status. They now have sonar operators from the ships taking the OT's position, and they just cannot, in the two or three years that they're there, develop enough experience to be able to do that.

And so consequently I'm pleased for the experiments I'm doing right now with the North Pacific SOSUS data, is that I've trained experienced operators over the years. I've worked with some of them for ten to fifteen years, and these individuals I've hired, they're ex-Navy now, and

I've hired to go back in and to look at the data and to catalog the information that comes in. Then in an unclass way, they send those data to me and here at Woods Hole I put them into databases and analyze it. For example, we've just put out a publication where we're looking at blue whale, fin whale, and humpback whale sounds over that entire North Pacific Basin, and we've learned a tremendous amount.

**GW:** What's your base of operations for that experiment? Where are they doing their listening?

**Watkins:** They're doing their listening at Whidbey Island, is the local site for that, although as I mentioned earlier, when it came to the publication of that, the Navy asked me not to mention that it was done at Whidbey Island.

**GW:** And how long ago was that publication?

**Watkins:** Last week.

**GW:** [unclear] copy of it.

**FT:** I'm just curious, do you ever play whale sounds back to them?

**Watkins:** It doesn't work very well. The short answer is yes. It doesn't work very well, and my excuse has been that transducers are normally not broadband enough to be able to do it really

well. That's probably an excuse, but I suspect there are other things that are also involved. I think there probably needs to be more cues than just the sound. I think the more sophisticated a species you work with, the more cues you have to give. You can play back to frogs, for example, and you get really good responses, but it's pretty hard to get a wolf to respond beyond the first few minutes. He needs a whole lot more cues, like the presence of that animal there, who that might be in his territory, all that sort of thing. I can play back to seals. I've played back to whetle [phonetic] seals and got lovely responses. They just were stupid enough to think that my hydrophone was another seal, and their reactions were just classic. But I've not done nearly as well with whales.

**FT:** So in other words, you're saying that this whole thing is, for lack of a better term of speech, really is a very, very involved--there's a lot of different things involved in this.

**Watkins:** I don't like to use the word "speech," because speech implies lots of things that just aren't there. They communicate. On the level of a good horse or a good dog, they can be taught. They can be taught the wonderful mimics. They can develop relationships with their trainers and become really involved that way. Dr. Lou Herman [phonetic] out in Hawaii is probably the person that has carried this on the farthest, but they've had video, trying to teach the animal to look at a video screen and recognize on the video screen the things that they're seeing, so you've got a flat presentation. Lots of the other animals, like cats and so forth, don't quite recognize it that way. They don't recognize themselves in those kinds of things.

Communication involves all kinds of other things rather than just the sounds. Now, in things like the sperm whales and those interactions, ultimately we may know enough to be able to interact in a sufficiently reasonable way, but I'm not sure that it's ever going to work that way. We had one example in which that agonistic coda that I talked about, the sequence, we were working with animals for several hours, the ship was quiet, we had our hydrophones. My crew wanted desperately to hammer on the hull with that sequence and see what would happen, so I finally agreed that after the experiment was over, we could do it. So Peter T\_\_\_\_\_ climbed out on the bow with a hammer and hit--this was a fiberglass boat and there was a metal strip along the bow, so he hammered this out on that bow. That was the end of all the sperm whales. They not only shut up, but they disappeared.

**FT:** What did he say to them?

**Watkins:** He said, "I really don't want you here," and so they disappeared. But, you know, to have an interaction that would be useful, I think you'd need more cues than just that sound. Okay, the sound was enough to make them sit up and notice, but not enough to make them do anything but just get out of the way.

Whales, all of these whales, they're living in a glass house. There's nothing that they do that is hidden in an acoustic world. So for miles around, anytime any of these animals says anything, everybody else knows it. So communication involves between two individuals, it's not just between two individuals, it's between that individual and everybody else, even though he may be directing it at that particular individual. So if you disturb them, the first indication

normally is that they shut up. It's their only way of hiding. They shut up and move quietly away. Submarines have learned a few tricks.

I was just intrigued, I was just looking at a set of data which one of my things has been to tag. I use tags because I can get individual identification and get the details of behavior, but I have to do it really carefully so that I'm not disturbing the animal, so that the animal doesn't react and stay abnormal for hours or weeks. I just have to be awfully careful. So we've learned techniques of approaching and letting the animal come up, and when the animal's in the right position, then we remotely--it's essentially shot out of a shoulder piece with gas propulsion from a variety of different powders. So you can tag up to 50 meters away, so it's not right there.

With these tags, when you don't disturb the animal otherwise, it's just as if it doesn't happen. There's no reaction whatsoever, but it's hard to demonstrate this to other people. You can take videocameras and all that sort of thing. But the combination of acoustics at that time is sometimes hard to orchestrate because you need to have the ship so it can maneuver, so you often don't dare have hydrophones hanging down right by the propeller in the back and that sort of thing, just for the safety of the ship and the vessel and everything else that's happening.

However, we had a hydrophone in the water in that particular instance. We attached a tag, and lo and behold, here's this whale gives the "come hither" sound. [Imitates the sound by tapping on the desk.] He wasn't disturbed whatsoever. He was continuing his reaction with the other whale that was there, not producing an agonistic thing or anything that would be negative, but the positive sequences. So, okay, give us time and we'll really get some of these things tied down. You know, it's an expanding base of knowledge that's there.

**GW:** One question. In your techniques for approaching the whales, having done a lot of work on the history of antisubmarine warfare and having listened to ships on submarine sonar sets that are so incredibly loud, even at great distances, do you occasionally, as, for example, Maurice Ewing and others used to do on the old *Atlantis*, by cutting off the engine and drifting in, or putting the hydrophones out and letting them go slack to reduce any acoustical interference from the environment or, of course, from the ship as well, do you use drifting techniques to be silent and "friendly"?

**Watkins:** The ship, yes, we always turn things off, and we always try to put ourselves in the way of the animals so we can figure out what they're doing or come up silently. In any case, you don't come up with the engine running at constant speed, because the intensity of sound increases dramatically as you approach, so you have this crescendo of increasing noise if you come up at a constant speed. So I try to reverse that, cut it down as I'm coming up, the crescendo, so that if anything happens, it's a relatively constant level of noise, and I try to shut it off completely as far as I can.

Our silent ships are silent. Depending on the ship and the equipment, nobody goes to the head when it's silent ship, there's no pump that's turned on, there is nothing running.

**GW:** In most cases, the whales, biologically or physically, are they using the same organs or techniques to manufacture their sounds?

**Watkins:** We don't know that. We don't know that. Very few animals, there's been enough experimentation to where we're sure how they make the sounds. The bottlenose dolphin is one that's been a lot of experimentation, and so for those particular sounds produced by that species and presumably similar species, the sound is produced at the nasal plugs below the blow hole. It has two chambers on either side, and those chambers apparently allows it to--it's too simple a description, but in any case, it can vibrate rapidly so that you get a whistle on one side and vibrate very slowly so you've got clicks coming out of the other side simultaneously. Most of the other species, we honestly don't know enough that. There's been a lot of discussion about how sperm whales produce sounds, none of which do I find fits my data, so at this point I will say I don't know.

Certainly the animals like fin whales and blue whales that produce these loud low-frequency sounds, I have no idea. There is a pouch in both those species that has a very, very strong valve on it that could maintain--you could imagine it could maintain a particular pressure inside it, and be made to resonate, but the volume is not big enough to quite accommodate the sounds that we hear. So I don't know. Each species is different. The sounds produced by each species is different. The way those sounds are used are very different. Even similar species often have very, very different behavioral contexts for their sounds.

**GW:** Some of your current work at the oceanographic, even though you're technically retired--

**Watkins:** [Laughter] Yes.

**GW:** I assume you enjoy it so much, you simply don't care to stop. You're publishing still a great deal.

**Watkins:** Yes, it seems silly to stop. I'm working at least four days a week and I try to put in a certain amount of time at home, of course. Trying to keep the laboratory operating, trying to continue to make a contribution.

**GW:** Do you still go to sea?

**Watkins:** I haven't gone to sea in the last little bit because of my back.

**GW:** I understand.

**Watkins:** I canceled cruises last year because of it. This year I haven't even applied for support for it. In fact, I've been scared to get in an airplane recently. So anyway, I think I'm certainly capable of it, and I would like to organize one or two or three more of those complicated cruises that give us some definitive answers about some of these things, sort of continue to build on what we know of these animals.

As far as what I would like to see happen, I would like to have the accumulated knowledge and historical understanding of what we have been translated into Marine Sound Archive that includes not only the animal sounds, but all the various geophysical sounds, f\_\_\_\_ float sounds, all the data that we've had over the years, multiple sound paths, that sort of thing. It



would be very easy to bring it and include, and it would suddenly translate a library that's wonderful for me into something that would be wonderful for everybody else.

**GW:** I understand. We did an exhibit at the Navy Memorial Museum about eighteen months ago employing a lot of the oceanographic instrumentation that built up in the collection over the years. I wrote the exhibit text, and one of the interactives that we had was based on borrowed recordings from the Naval Research Laboratory, and there are a lot of underwater sounds. This is the first time I had ever heard of them. We had underwater recordings of seismic events, but also a number of mammal sounds. The kids just about wore the buttons out because they had to press a button to identify the source of the sound. [unclear] kids just want to press buttons to press buttons, but if you watched them, some of them stayed and lingered, and the sounds fascinated them.

**Watkins:** Our exhibits center here at Woods Hole had some of my stuff on a computer that allowed them to see a picture and hear the sound sequences and so forth.

**GW:** Dr. Clyde Nishimora [phonetic] at NRL provided us with some of the seismic events and some of the other recordings.

Are there any questions you expected me to ask that I didn't?

**Watkins:** One of the things I expected you to ask, and I'm not disappointed that you didn't ask me, but I'm surprised, what do I consider my main contributions. [Laughter] I don't know. I

was probably the first one to really develop tagging in these animals, to try and get the precision that we need and to emphasize identification. I think we are still the only ones who use low-frequency radio waves, 30 megahertz instead of the VHF stuff. The VHF stuff has an advantage because it's simple and cheap to use, but you lose most surfacings simply because the wavelets get in the way, it's line of sight only, whereas the lower frequency becomes much more useful. You can work out to 30 kilometers or more and be absolutely every time that antenna comes out of the water, you've got a good signal. That has been one of the biggest contributions that I've been able to make from a technological standpoint.

The other one, that probably we were the first to use three-dimensional arrays at sea on animals, a floating array with hydrophones off the bow and stern and floating off the side and one deep, and use that with animals, and we still use that effectively because that allows us to separate whether it's Animal A or Animal B that's making the sound, and if the geometry's right, where you can get a good location as well as a direction. And even if you can't get a good location, you can get a direction from sounds coming in at great distances. Those are probably the two technological kind of things that I think have contributed to my success, anyway.

**GW:** Scientifically you and Bill Schevill created the field almost by yourselves.

**Watkins:** Bill Schevill created it. I don't take credit for that. Certainly it was a wonderful cooperative thing. We meshed really well. What I didn't know, he certainly did. What he didn't know, I could find out, whether it was technology or historical things on sound analyses or those kinds of things. It was extremely productive during the time Bill Schevill was there. I was

afraid the productivity would drop off. I'm fortunate that during the time he was a close mentor, he brought me up fast enough so that I was able to not feel too deprived from the standpoint of biology. I'm sure I made my faux pas because I'm not biologically trained. On the other hand, as far as marine mammals are concerned, it's been a long and productive career. I've been here forty-two years since last January.

As I said earlier, without that continuing sequence, without being able to see the development of things, I don't think we'd have learned nearly as much. I really feel sorry for these newcomers who have to make a huge amount out of a thesis experiment and hope that they can make enough of a splash to where they find a job, and then the likelihood of them finding a job that allows them to continue what they're studying is very low. I've had the luxury of really watching almost everything I touch is building on what I've had a good background in from before. It's just extremely rewarding. I think that's why I stick it out. [Laughter]

**GW:** Thank you for your time. We appreciate it.

**Watkins:** You're welcome. I hope this is severely edited. [Laughter]

**GW:** [Laughter] I hope not.

[End of interview]