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Atomic Bodies, Atomic Landscapes: Making Fission Legible

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by

Joshua Nicholas McGuffie

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ABSTRACT OF THE DISSERTATION

Atomic Bodies, Atomic Landscapes: Making Fission Legible

by

Joshua Nicholas McGuffie

Doctor of Philosophy in History

University of California, Los Angeles, 2023

Professor Soraya de Chadarevian, Chair

This dissertation tells the story of the doctors and biologists who worked for the Medical Section of the Manhattan Engineer District of the United States Army Corps of Engineers during and after World War II. It tracks how this unlikely and close-knit network of medical doctors and fisheries biologists used x-rays to irradiate animals to produce data that anticipated the exposure of human beings and entire environments to radiation from fission. By charting the development, spread, and evolution of the x-ray animal research tradition, this dissertation reveals how a unique type of biology grew up within the US atomic program in the 1940s and 1950s. This story has largely fallen out of the canonical atomic narrative told in the US.

I argue that Medical Section functionaries developed and then manipulated the x-ray animal research tradition to claim biological expertise over questions that arose at early US atomic sites. They deployed their knowledge of the biological effects of radiation to support the

early atomic project, making the case that plutonium production and atomic testing could be safely accomplished. Theirs was science developed to support federal goals. This dissertation uses the work of the Medical Section's most important installation, the Applied Fisheries Laboratory at the University of Washington, as the core of its narrative. I follow the expansion of the laboratory's research program across the US's nascent atomic geography. The scientists took their research toolkit to the plutonium production site at Hanford, to Hiroshima and Nagasaki after the first atomic bombs fell, and to the test sites at Bikini, Enewetak, and Rongelap Atolls in the Marshall Islands. Medical Section practitioners studied the biotic populations in all these places after exposure to radiation from fission had transformed them and their biotic populations. These scientists continued their work even after the US Congress disestablished the Manhattan Engineer District in 1946, replacing it with the Atomic Energy Commission. Charting their path as they became scientific experts at atomic sites shows how federally funded biology helped underpin the United States' quest for nuclear hegemony during World War II and the Cold War.

The dissertation of Joshua Nicholas McGuffie is approved.

Stephen A. Aron

Elizabeth DeLoughrey

Theodore M. Porter

Soraya de Chadarevian, Committee Chair

University of California, Los Angeles

2023

To My Family

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Acknowledgements

This project unfolded over the course of ten years. More importantly, it unfolded in the midst of so much support, warmth, and wisdom from colleagues, friends, and family members along the way.

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Over the course of my graduate study, several external internships, fellowships, and workshops have offered me the opportunity to explore ideas and archives. I am profoundly thankful to the Columbia History of Science Group for monies from the Steven Straker Graduate Student Fund which funded the travel for me to give my first academic paper in the winter of 2014. I am also grateful to the Oregon State University Special Collections and Archives Research Center for selecting me as a Resident Scholar during summer 2014. I am indebted to UCLA Library Special Collections for monies from the James and Sylvia Thayer Short-Term Research Fellowship, awarded over the summer of 2015. In 2018, I had the pleasure of taking part in the Arizona State University History of Biology Seminar at the Marine Biological Laboratory in Woods Hole. I have special thanks for Christian Young and Tiago Saraiva who mentored me during the seminar. The Huntington Library has been a source of constant support during this project. In particular, the Residential Institute in the History of Science, Technology, and Medicine during the Summer of 2019 gave me the opportunity spend time in that institution's collections. Both Daniel Lewis and Joel Kline at the Huntington have been immensely supportive. I am also grateful to Andrew Isenberg and Beth Bailey at the University of Kansas for having me to the workshop that they organized on the United States, War, and the Environment in the Twentieth-Century Pacific World in the autumn of 2021.

My graduate school journey began in 2013 at Buffalo State College. Initially, I began working on a master’s degree in education with a focus on Earth Science and Physics. One year into my course of study, I opted to pursue the history of science. Thank you to Richard Batt who brought stratigraphy to life but, more importantly, wrote a letter of recommendation indicating that I should pursue an MA at Oregon State University. The letter worked and I arrived at Oregon State in the autumn of 2013. What a wonder! Words cannot express how my master’s advisor Jacob Darwin Hamblin, Mike Osborne, and Anita Guerrini opened up a whole new world by making the history of science come alive. Their support has been steadfast throughout my graduate studies. At OSU I also had the immense pleasure of meeting Linda Richards. She introduced me the depths of the US atomic story. She also instilled, I hope, the conviction that our academic work should reflect the need for social justice in a world ravaged by things atomic. So much of my scholarship relies on her insightful ability to ask just the right question. Finally, I owe thanks to Anne Bahde, Rare Books and History of Science Librarian at OSU’s Special Collections and Archives Research Center. She introduced me to the joys of the archive, a gift for which I can never fully repay her. Finally, I am overjoyed to thank my graduate student colleagues from OSU: Claude Bullock, Anna Dvorak, Emily Simpson, Matthew McConnell, Julio Orozco, and Elizabeth Nielson. What a time we had discussing Foucault.

I am similarly fortunate to have had amazing mentors during my doctoral studies at UCLA. I owe a debt of gratitude to Steve Aron, Elizabeth DeLoughrey, and Ted Porter. Ted, you, taught me to think about data. More importantly you taught me to root behind scientific claims about objectivity in order to see their social and political origins. You have also been an example of good-hearted decency in an academic world that sometimes wants for that virtue. Steve, you directed me though a very focused study of the history of the US West while in the midst of being department chair. I am in awe of your ability to have conversations in 20 minutes that covered material that should have fit into an hour-long talk. You opened up key historiographic insights for me, and I am thankful. Elizabeth, thank you for supporting my foray into the history of the Marshall Islands. I am obliged to you for how the creativity of your work on atomic islands informed and improved my research.

To have a supportive and patient advisor is a singular pleasure. Soraya de Chadarevian made this dissertation possible through her kindness, incisiveness, and inquisitiveness. No typed words can express my gratitude. You have managed to ask questions about this project for the last five years that have improved it in ways that I cannot quantify. Walking and talking with you about historiographic issues, about how histories are told and written, and about what the actors who appear in this project were really getting at has been a joy. I think I am most indebted to your personal inquisitiveness. Loving ideas for their own sake is a powerful thing. I have experienced this with you as you have advised me and as your TA for Society and Genetics 105a. Thank you.

A variety of archivists and Special Collections librarians have made this project possible. I owe many thanks to Russell Johnson at UCLA's Special Collections. Russell, you not only guided me to key sources but have always been a kind listener as I have thought through my project. Katherine Maslenikov, who is Collections Manager at the University of Washington Fish Collection in the School of Aquatic and Fishery Sciences, took time to show me specimens of fish from Bikini that my main actors collected in 1946. Anne Jenner at the University of Washington's Libraries Special Collections provided immense help. The host of librarians the Department of Energy Reading Room in Richland, Washington have provided immense help. Martha DeMarre, at the Las Vegas DOE reading room also provided immense help and access to documents that would have otherwise been impossible to find.

The History Department at UCLA has also provided incalculable support for this dissertation. The staff have made everything possible. I am especially indebted to Ann Major. Ann, your willingness to listen to my wanderings for the last eight years has been such a support. Kate Aquino and Tessa Villaseñor have provided both moral support and immense practical help. Faculty members from across the department have also assisted me along the way. I owe so many thanks to Amir Alexander, Mary Terrall and Teo Ruiz. This journey would not have been possible without the friendship of fellow graduate students. To Rob Schraff, Iris Clever, Scottie Buehler, Jacob Green, Claire Votava, and Sebastiaan Broere, I did not expect the depths of friendship during graduate study that I have been fortunate to find with you all.

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Throughout this project, I have been able to maintain my work as a pastor in the Evangelical Lutheran Church in America. I owe thanks to many church folk. To the people of St. Peter, Medina, and Trinity, Wolcottsville, thank you for forming my work ethic by your example. I owe special thanks to everyone at Ascension, Sierra Madre, for your support of me and Jobi during the last eight years. To my mentor and Rector at Ascension, Michael Bamberger, I am particularly grateful. You helped me find a path that is both academic and ecclesial. I am grateful also to Deacon Ed Sniecienski for being such a supportive co-worker at Ascension. I owe thanks to Lavette Teague, who supported me from the choir loft and from his perspective as a long-time academic. I also owe thanks to Gordon and Diane Tomaski, Diana Rhodus, Carl Foote, Eric Mulfinger, and the whole discussion group who met between the Masses. You all made the pursuit of intellectual rigor your business at Ascension. I am wiser for having spent so many years with you. Finally, to the people of the Church of Hope in Canyon Country. You went out on a limb to call me as your pastor in March 2023. I look forward to learning from you as I continue to live in the liminal space between the church altar and the academic podium.

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Vita

Education

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2023	"The First Accounts of Radiation Sickness" in *Making the Unseen Visible: Science and the Contested Histories of Radiation Exposure*, eds. Jacob Darwin Hamblin and Linda Richards, Oregon State University Press (manuscript in preparation).
2021	Engineering Spaces for the Biological Effects of Fission" in *Nature Remade: Engineering Life, Envisioning Worlds*, eds. Luis Campos, Michael Dietrich, Tiago Saraiva, Christian Young (Chicago: University of Chicago Press, 2021).

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Selected Presentations

2022 "The Biological Foundations of Hanford's Radiological Disaster"
American Society for Environmental History, Eugene, Oregon
Panel: "Nuclear Ecologies: Islands, Deserts, Rivers, Mines," March

2021 "Ashes to Ashes, Dust to Dust"
The United States, War, and the Environment in the Twentieth-Century Pacific World, Workshop at the University of Kansas, October

2020 "The Biological Effects of Radiation and the Castle Bravo Disaster"
Pacific Coast Branch of the American Historical Society, online, December
Co-Organizer for the panel: "From Hegemony to Resistance: Science and the American Empire in the Pacific"

2019 "City of Angels/City of Atoms: LA's Obscure Atomic Past"
Huntington-USC Institute on California and the West, "ENGINEERING LA: Science and Technology in Southern California," Pasadena, California, March

2018 "Imaging Hiroshima and Nagasaki: Knowing the Bomb by Knowing the Bodies of its Victims"
Columbia History of Science Group, Friday Harbor, Washington, March

2017 "New for '51: Radiation Monitoring and Novel Atomic Geographies"
Pacific Coast Branch of the American Historical Society, Northridge, California, August

2017 "Hidden Atomic Loci: Cooperation in Radioecology at the UCLA Atomic Energy Project and the University of Washington Applied Fisheries Laboratory in the 1940s and 1950s"
International Society for the History, Philosophy, and Social Studies of Biology, Sao

Paulo, Brazil, July

2015 “No Significant Risk: Creating the Norms for Public Irradiation at Hanford”
UC Berkeley Center for Science, Technology, Medicine, and Society “Faking It: Counterfeits, Copies, and Uncertain Truths in Science, Technology and Medicine,” Berkeley, California, April

Introduction

X-Rays, Salmon, and the Biological Effects of Radiation

On 29 October 1943, in a laboratory on the north shore of Lake Washington in Seattle, an egg-laden adult female chinook salmon found herself constrained in a home-made canvas sling, suspended in a tank of flowing water for just over 33 minutes.[1] Six feet way, though she scarcely knew it, a Picker-Waite Shockproof Therapy Unit created a focused beam of x-rays that passed right through her restrained body. Lauren Donaldson, Dick Foster, Kelshaw Bonham, and Art Welander, the four biologists who made up the scientific team at the newly formed University of Washington's Applied Fisheries Laboratory (AFL), had calibrated the x-ray machine the week before. They set the machine to expose the female to about 100 Roentgens of radiation. It was a low dose. Later, they exposed a male chinook in the same way. The biologists then spawned the female, killing her in order to take her eggs. The male they used to fertilize her eggs. The union produced a generation of eggs whose parents had both been irradiated. These were the first experimental salmon produced by the Applied Fisheries Laboratory.

The new lab had been organized by Colonel Stafford Warren, the chief of the Medical Section of the Manhattan Engineer District (MED), in order to study the biological effects of radiation. Because

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1 Section I Chinook Salmon Adults, P-45, Box 9, Folder 20, Lauren R. Donaldson papers, Special Collections Division, University of Washington Libraries (Hereafter cited as MSS Donaldson). For a write up of the entire experiment, see: UWFL-6, "Preliminary Report Concerning X-Ray Effects upon Chinook Salmon (*Oncorhynchus tschawscha* Walbaum) Observed Through More Than One Generation," Box 9, Volume 1, University of Washington, Laboratory of Radiation Biology records, 1944-1970, Special Collections Division, University of Washington Libraries, Seattle, Washington (Hereafter cited as UWLRB).

of wartime secrecy, Donaldson and his biologists did not know they were working for the MED Medical Section when they irradiated their first chinook salmon. They just knew they had a contract with the federal Office of Scientific Research and Development to do basic research on x-ray exposure. Warren had big plans for the lab. He had arranged for the used Picker-Waite to travel from the x-ray ward at Strong Memorial Hospital in Rochester, New York, where he was on the medical faculty, to Seattle. The new lab, he hoped, would not just provide data about what x-rays did to salmon. He wanted to the lab to produce data about what the new fission would do to human beings.

Expecting fish exposed to x-rays going to reveal truths about people exposed to radiation from the first atomic bombs required a leap of faith. Warren had to assume that x-rays behaved like the host of subatomic particles, waves, and radionuclides produced by fission in a bomb. He also had to assume that the organs and tissues of fish would behave like the organs and tissues of human beings. In particular, he had to trust that x-rays would affect blood formation in fish in the same way that fission would affect blood formation in humans, since this physiological process was one of his major concerns on the eve of the atomic bombings. Fortunately, Warren was an expansive character. His physical stature and his personality were big. So was his ability to believe that the data his fish lab produced could reveal fundamental truths about the biological effects of radiation in humans.

In the autumn of 1943, when the AFL got off the ground, no one imagined that the work of Medical Section research would act as a thread tying together exposed people, animals, and plant populations across the World. It did. By the end of the decade the Section had made researches at Hiroshima, Nagasaki, the Hanford Engineer Works in central Washington, Bikini, Enewetak, and Rongelap atolls in the Marshall Islands, Alamogordo in New Mexico and the Nevada Test Site. In 1943, none of these places had yet been irradiated by fission. Anthropogenic fission had barely existed for eleven months when Donaldson and the biologists exposed their first chinooks to x-rays. But the little lab on the north shore of Lake Washington would find itself an important node in the new geography that weaponized fission created.

This dissertation describes the development of the Applied Fisheries Laboratory and the other labs that grew out of the MED Medical Section, showing how their scientists and doctors played important roles in the nascent years of atomic development and testing. Canonical histories of the Manhattan Project, the bombings of Hiroshima and Nagasaki, and of the environmental consequences of plutonium production and atomic testing have tended to relegate the Medical Section labs to the margins, if paying them any attention at all. This project shows that the early US atomic project relied on biology and was never the sole realm of physicists and politicians.[2]

Atomic Bodies, Atomic Landscapes: Making Fission Legible looks at Medical Section work between 1943 and 1963, roughly covering the period that the US detonated atomic and thermonuclear bombs in the atmosphere. The story begins in the first days of the MED and moves through the end of atmospheric nuclear testing because of the Treaty Banning Nuclear Tests in the Atmosphere, in Outer Space and Under Water, commonly known as the Partial Test Ban Treaty. This is a US story, that focuses on the local, on individual laboratories and landscapes used for field research. In this regard, the dissertation is a contribution to the questions about lab and field science. But this dissertation investigates a far-flung geography because the atomic story is a one of colonial science. Tracking the work of the Medical Section recapitulates a map of US territorial expansion across the western half of North America and across the Pacific Ocean. Because the US bombed Japanese populations and tested

2 For the most popular, canonical story of the Manhattan Project, see: Richard Rhodes, *The Making of the Atomic Bomb* (New York: Simon and Schuster, 1986). In this magisterial effort, Stafford Warren appears once. For a scholarly retelling of the canonical story focusing on physicists and politicians, see: Jon Agar, "Science and the Second World War," in *Science in the Twentieth Century and Beyond* (Cambridge: Polity, 2012), 263 – 300.

bombs in the occupied Marshall Islands, this dissertation necessarily engages questions of science, race, and power. Where appropriate for the story, Japanese and Marshallese voices appear alongside those of Medical Section actors. My project also thinks about the quantification of biology and its increased reliance on measurement technologies in the mid-20th century. This story aims to show how the study of the biological effects of radiation disrupted both distinct cultural communities and discrete domains of science.

Context and Approach: Moving Biologists to the Center of Atomic History

Wilhelm Roentgen first explained how to produce an x-ray by using a Crookes tube in late 1895. When he showed the world an image of the clearly visible bones inside his wife's hand that the new rays produced, he scarcely imaged the impact of his work. A new age was born in his laboratory and soon labs across Europe, the British Empire, the US and Japan as all manner of scientist dove into x-ray experimentation. Henri Becquerel's discovery of the production of rays by uranium salts in 1896 coupled with Marie and Pierre Curie's discovery of radium in 1898 added fuel to the craze's fire. Becquerel and the Curies received the 1903 Nobel Prize for Physics for theorizing how radioactivity, what they described as the spontaneous production of waves and particles from the decay of unstable elements. Rays and radiations created a time of cultural and intellectual foment at the turn of the 20th century that focused on the work of great chemists and physicists.[3]

3 For the early history of x-rays, see: Matthew Lavine, *The First Atomic Age: Scientists, Radiations, and the American Public, 1895–1945* (New York: Palgrave Macmillan, 2013). For the radium craze and radium's role in early genetics research, see: Luis Campos, *Radium and the Secret of Life* (Chicago: University of Chicago Press, 2015). For the early controversy about the reality of atoms among physicists, see: John Blackmore, "Ernst Mach Leaves 'The Church of Physics,'" *The British Journal for the Philosophy of Science* 40, no. 4 (December, 1989), 519-540.

But even as physicists made their names by discovering and studying new radiations, the new rays and emanations breached the divide and entered the domains of biology and medicine. Doctors loved x-rays for their ability to make the unseen seen, to show bones and bullets under the skin. Similarly, they anticipated radium's ability to destroy tumors. But as they applied both technologies to patients, they quickly saw radiation's dark side. "An Austrian doctor who treated a five-year-old girl for a mole on her back with heavy doses of x-rays in 1896," Samuel Walker explains, "reported that although the process helped with the mole, it also caused severe burns."[4] The First World War made x-rays a fundamental part of 20th century western medicine. Marie Curie's *petite Curies,* mobile x-ray imaging labs trundled up and down the western front taking images of soldiers wounded in battle so that surgeons could address their internal injuries. Curie blamed her untimely and eventually fatal illness on her exposure to x-rays during the war, not to her chemical work in the laboratory.[5] Radium, infamously, made young women who worked as incandescent watch dial painters sick in the US in the late teens and 1920s.[6] After the great war ended, doctors set out to quantify just how much radiation exposure a person could tolerate.

By the 1930s, practitioners of the new discipline of radiology had established a thriving, international research program to discern what radiation did to the tissues, organs, and bodies of living organisms. To do this, they exposed animals to x-rays and then charted the progression of symptoms, and often death, based on the length and intensity of exposure. Stafford Warren learned this style of

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4 J. Samuel Walker, *Permissible Dose: A History of Radiation Protection in the Twentieth Century* (Berkeley and Los Angeles: University of California Press, 2000), 3.

5 Susan Quinn, *Marie Curie: A Life* (New York: Simon and Schuster, 1995).

6 Claudia Clark, *Radium Girls: Women and Industrial Health Reform, 1910 – 1935* (Chapel Hill, North Carolina: University of North Carolina Press, 1997).

research during his medical studies at the University of California, San Francisco in the late teens and early twenties. We will learn more about his experiments exposing dogs with x-rays in chapter two. At any rate, while European physicists postulated the possibility of atomic fission and worried over the growing specter of fascism on the continent, American doctors kept exposing human beings, animals, and plants to x-rays in order to see what would happen. In 1928, the US National Research Council created its Committee on Radiation to support this research program.[7] With the generous support of the General Electric X-ray Corporation, the same committee had by 1936 sponsored a series of conferences that resulted in a volume dedicated to the biological effects of radiation. Warren wrote a chapter for the book. My dissertation shows how this historically neglected pre-World War II x-ray tradition became reinvigorated at the Applied Fisheries Laboratory, and in the Medical Section more generally, to answer questions about the new fission.

The demonstration of fission in the laboratory hit something of a reset button for the story of radiation, catapulting great physicists back to the center and making the phenomenon a matter of life and death for entire populations rather than individual victims of medical overexposure. Very little time elapsed between Lise Meitner' and Otto Frisch's February 1939 letter to *Nature* describing the process and the beginning of efforts to weaponize the process. At war with the Nazis, the British began to examine the feasibility of a fission bomb in 1940. The Americans got on aboard in 1942 and the Manhattan Engineer District came to be. The Germans began their own bomb project. The war became a physicists' war.

7 Benjamin Duggar, ed., *Biological Effects of Radiation: Mechanism and Measurement of Radiation, Applications in Biology, Photochemical Reactions, Effects of Radiant Energy on Organisms and Organic Products* (New York: McGraw-Hill, 1936), v.

But the doctors and biologists were not far behind. This dissertation examines the creation of a laboratory research program designed to ask "what is fission" from a biological perspective. At the beginning of the US program, biologists had not access to fission, since the MED had not yet built the massive infrastructure across the US to make the fissile elements.[8] The effort cost around $2 billion. But even as production ramped up, all of the special products went to the bomb design and construction laboratory at Los Alamos, New Mexico. Unable to access the elements they were meant to study in 1943 and '44, the MED's doctors and biologists turned to a familiar and accessible technology: x-rays.

This dissertation investigates how x-ray research on animal subjects became a key part of the MED Medical Section's biological program during and after World War II. I use four approaches to unfold how this research program became significant for the US atomic story. First, this project investigates the position of biologists and doctors within the Manhattan Engineer District and, after 1946, within the US Atomic Energy Agency (AEC) as scientists working in service of the US government. In this way, *Atomic Bodies, Atomic Landscapes* researches what it means for science to be federal science in the US context. The AFL and the other laboratories that grew out of the Medical Section worked for the government under contract, part of a long tradition of the government funding and relying upon scientists from universities and from industry for their expertise.[9] Though they

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8 For the story of how the MED built a massive factory complex at Oak Ridge, Tennessee to enrich uranium and a reactor complex at Hanford, Washington to produce plutonium, while also contracting with countless local industrial suppliers across the US, see: Thomas Hughes, "Tennessee Valley and the Manhattan Engineer District," in *American Genesis: A Century of Invention and Technological Enthusiasm, 1870 – 1970* (Chicago: University of Chicago Press, 1989), 353 – 442.

9 For a discussion of the federally chartered but independently operated National Academy of Science, of which the National Research Council was an organ, see: Rexmond Cochrane, *The National Academy of Science: The First Hundred Years, 1863 – 1963* (Washington, D.C.: The National Academy of Science Printing Office, 1978). For the crisis of decentralized scientific organization after World War II, see: Daniel Kevles, "The National Science Foundation and the

worked as contractors for the MED, the Medical Section biologists came to resemble scientists working directly for federal agencies like the Park Service, the Forest Service, and the Bureau of Biological Survey. The shift happened because their research became tied to the management of federally administered sites.[10] As their science became tied to the land, and to the people, animals, and plants living at irradiated landscapes, the biologists left the domain of science and entered the complex world of federal management. This dissertation's main narrative arc describes their transformation from scientists doing laboratory research into scientists whose biology had bureaucratic implications for sites deemed necessary for national projects during World War II and the Cold War. This is a story about science and state power.

Second, this project looks at the historical development of radiological research during the 1920s and '30s. The study of radiation's biological effects took place in academic and corporate labs around the world. The 1936 National Research Council volume shows the question merited interest from medical doctors, physicists, biostaticians, zoologists, botanists, and practitioners of sundry other

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Debate over Postwar Research Policy, 1942-1945: A Political Interpretation of Science-The Endless Frontier," in *Isis* 68, no. 241 (March, 1977), 4 – 26.

10 Hal Rothman shares a case study of the development of National Park Service science and authority at Bandelier National Monument. He also shows how the Park Service engaged in a classic case of competition between federal agencies in its conflict with the MED/AEC over Bandelier because of the monument's adjacency to Los Alamos: *On Rims and Ridges: The Los Alamos Area since 1880* (Lincoln, Nebraska: University of Nebraska Press, 1992). For a National Forest Service case study set on the federally managed Kaibab Plateau, see: Christian C. Young, "Defining the Range: The Development of Carrying Capacity in Management Practice," *Journal of the History of Biology* 31, no. 1 (Spring, 1998), 61-83. For a case study of wildlife management within in the Bureau of Biological Survey (now the Bureau of Land Management) that parallels the experience of the AFL biologists, see: Thomas R. Dunlap,"Wildlife Policy and Environmental Ideology: Poisoning Coyotes, 1939-1972," *Pacific Historical Review* 55, no. 3 (August, 1986), 345-369.

disciplines.[11] The key questions that defined the research program centered around somatic insults from radiation, or what x-rays did the bodies, tissues, and organs. How did high-energy, or hard, x-rays enter the body in contrast to low-energy, or soft, x-rays? How did different tissues react to exposure? How did x-rays behave differently than alpha particles or other electromagnetic waves? The concern with immediate effects of living tissues tied the research program together. In this respect, study of radiation's biological effects existed in a different world than the burgeoning study of genetics and cytogenetics, which concerned themselves with change over generations.[12] In chapter two, we will see how Stafford Warren and his Japanese counterpart Masao Tsuzuki both used their experience with animal x-ray research to inform their understandings of the sickness suffered by the *hibakusha*, the people in Hiroshima and Nagasaki exposed to radiations from the atomic bombs. Here the dissertation uses a history of medicine lens to ask how exposure to radiation became a sickness in the weeks after the 1945 bombings.

Third, this dissertation engages with the porous border between the laboratory and the field in the formation of Medical Section biology. No discrete frontier marked the boundary between the lab and the field for the AFL biologists, they did their work amid the lab/field borderland. The very first experiment they planned, using the spawn from the two chinook we met at the beginning of this introduction, involved raising eggs to youth in the lab in order to release them into the wild so they could mature and return for future study in the lab. Historians of science have spilled much ink

11 See: "Contents" in Duggar, *Biological Effects of Radiation,* 1936.

12 See: Soraya de Chadarevian, *Heredity Under the Microscope: Chromosomes and the Study of the Human Genome* (Chicago: University of Chicago Press, 2020).

theorizing about the relationships between lab science and field science.[13] Traditionally, laboratory science has been esteemed as more empirical and rigorous than field science. This dissertation argues explicitly that the AFL biologists, as well as the biologists at their offshoot lab at Hanford, overtly valued laboratory findings over field findings. At the same time their story shows how they required access to the field to do research and collect specimens for laboratory analysis. Theirs was an intensely place-based biology. Thinking about place, this project builds on the work of Elizabeth DeLoughrey, who has argued that islands distant from the metropole have been "deemed peripheral to modernity" but actually have "been at the center of the development of modern ecological thought."[14] Medical Section doctors and scientists relied on colonial power dynamics to exploit populations and environments in order to create radiological knowledge for the sake of mainlander concerns. This dynamic appears most clearly in the chapters about taking case histories and samples from the *hibakusha* and about taking specimens from the occupied Marshall Islands. But this can also be seen in the chapter about the Hanford Engineer Works in central Washington State. I argue for a continuity between spaces in the western US and occupied spaces in the Pacific.[15] In both regions, Medical Section science relied on the dispossession indigenous peoples and the ill health of exposed peoples that resulted because of federal military goals.

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13 For a synoptic view of this question from the 1990s, see: Henrika Kuklick and Robert E. Kohler, eds., "Introduction," *Osiris* 11, (1996), 1 - 14. For a recent, reassessment, see "Focus: Fields," in *Isis*, 113:1 (March 2022).

14 Elizabeth DeLoughrey, "The myth of isolates: ecosystems ecology in the nuclear Pacific," *cultural geographies* 20, no. 2, (2012), 167 – 184.

15 For an analysis of the Hanford Engineer Works as place defined by America's westward expansion and conquest, see: Patricia Nelson Limerick, "The Significance of Hanford in American History," in *Washington Comes of Age: The State in the National Experience*, ed. David Stratton (Pullman, Washington: Washington State University Press, 1993), 153 – 171.

Finally, this dissertation thinks about what it means for scientific expertise to fail. This story crescendos with questions about scientific expertise because the AFL biologists found theirs strained in the wake of the 1954 Castle Bravo disaster. The crisis occurred when an experimental thermonuclear device produced significantly more force and fallout than the Los Alamos physicists who designed it anticipated. Detonated at Bikini Atoll, Bravo sent a cloud of lethally radioactive fallout 100 miles downwind to Rongelap Atoll, which had a population of around 90 people. Fallout blanketed them, and their islands and lagoon, like snow. The Navy evacuated the Rongelapese to another atoll after two days. Their sickness and exile became a black eye for the US atomic program both at home and aboard. The powers in charge of the testing program began to plan almost immediately to repatriate the Rongelapese. The AFL biologists became part of the story because the AEC's Division of Biology and Medicine sent them in to make radiological surveys of the atoll and to study the movement of radiation through the local food system. The biologists would use their expertise to determine if the land and lagoon could safely support Rongelapese agriculture, fishing, and foraging once they returned. During the islanders' three years of exile, the AFL biologists established that many radionuclides from Bravo had entered the food system. But they believed that most all local foodstuffs could be eaten safely because radiation levels fell below a threshold of danger.[16] The Rongelapese returned and by the early 1960s, all manner of ill health set in, including thyroid cancer in children, failed pregnancies, and children born with horrible deformities. My dissertation relies on Rongelapese memory of ill health to balance the reporting of the AFL biologists. The voices that appear in the historical work of Martha

16 For a description of the tolerance dose, maximum permissible dose, and the fight between biologists about whether any exposure to radiation could ever be considered safe, see: J. Samuel Walker, *Permissible Dose*, 8. Also see: Jacob Darwin Hamblin, "Threshold Illusions," in *Poison in the Well: Radioactive Waste in the Oceans at the Dawn of the Nuclear Age* (New Brunswick, New Jersey: Rutgers University Press, 2008), 10 – 38.

Smith and ethnographic work of Glen Alcalay appear prominently.[17] Holly Barker and Barbara Rose Johnston's ethnographic and theoretical work has also made this work possible.[18] Finally, I rely on sources from Marshallese scholarship, especially from Anono Lieom Loeak, Veronica Kiluwe, and Linda Crowl's collection *Life in the Marshall Islands*.[19] Johnston and Barker remind us that "over the years, Marshallese complaints have been easily dismissed as anecdotal accounts that fly in the face of scientific findings."[20] This dissertation seeks to put on display the colonial power dynamics that made Medical Section science influential enough to negate Marshallese experiences.

Argument: A Contextual Research Program

This dissertation argues that the biologists and doctors of the Manhattan Engineer District's Medical Section developed, applied, and modified their animal x-ray research program to address questions about the biological effects of radiation from fission. They constructed a novel program that did not fit easily into any one academic framework. From the disciplines of radiology and medical pathology, they

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17 For interviews taken by Glenn Alcalay, see: "Marshall Islands Field Report (March 4 – April 7, 1981)." New Brunswick, New Jersey, https://www.atomicatolls.org, accessed 21 May 2023. For a history of colonial dispossession in the Marshall Islands, see: Martha Smith, *Domination and Resistance: The United States and the Marshall Islands During the Cold War* (Honolulu: University of Hawai'i Press, 2016).

18 For a thorough description of the Castle Bravo disaster from the Marshallese perspective, see: Barbara Rose Johnston and Holly Barker, *Consequential Damages of Nuclear War: The Rongelap Report* (Walnut Creek, CA: Left Coast Press, 2008). Johnston highlights the question of radionuclides in food at Rongelap in her chapter, "Nuclear Disaster: The Marshal Islands Experience and Lessons for a Post-Fukushima World," in *Global Ecologies and the Environmental Humanities*, ed. Elizabeth DeLoughrey, Jill Didur, Anthony Carrigan (New York: Routledge, 2015).

19 Anono Lieom Loeak, Veronica Kiluwe and Linda Crowl, eds, *Life in the Republic of the Marshall Islands* (Majuro: University of the South Pacific Centre, 2004).

20 Johnston and Barker, *Consequential Damages of Nuclear War*, 24.

borrowed the use of x-rays and the practice of histology, visually inspecting tissues and cells under the microscope.[21] From fisheries biology, they borrowed practices for spawning, hatching and raising young fish. They also borrowed measurement techniques and statistical methods for interpreting population-level data. From laboratory chemists at Los Alamos, they borrowed the use of electronic radiation meters like Geiger-Muller meters and proportional counters. From soil scientists and foresters they borrowed ecological tools, like making transept lines and using lysimeters, measuring devices emplaced in the soil around plants to quantify chemical interactions between the organism and the land. The Medical Section biologists cobbled all these practices and technologies together because they wanted to provide a synoptic study fission, a phenomenon that had never existed in human experience, in a variety of distinct contexts. Malleability characterized their attempts to study fission where it was not yet even present, where it took place in reactor cores, and where it occurred because of atomic bombs.

A major aspect of this argument is simply revelatory. The Medical Section and the Applied Fisheries Laboratory have faded into history.[22] *Atomic Bodies, Atomic Landscapes* places them back into the Manhattan Engineer District's history and into the history of biology within the AEC. No

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21 For a description of early histological practices and the interpretation of microscopic visual evidence, see: Lorraine Daston and Peter Galison, "Mechanical Objectivity," in *Objectivity* (New York: Zone Books, 2007), 115 – 183.

22 For a sense of the University of Washington's School of Aquatic and Fishery Sciences, which minimizes the role of the AFL, see this timeline: https://fish.uw.edu/about/legacy/timeline/. The Hanford Fish Lab and UCLA Atomic Energy Project have faded as well. Their buildings have been demolished and their histories have been lost to the institutional memories at what is now the Pacific Northwest National Laboratory and the UCLA Institute of Genomics and Proteomics. For the contemporary situation at Hanford, see: https://www.pnnl.gov/biology, accessed 3 October 2022. The UCLA lab has a sense of its historical origins, but one that is somewhat incomplete. See: David Eisenberg, "UCLA-DOE Institute for Genomics and Proteomics Final Technical Report," https://www.osti.gov/servlets/purl/934813, accessed 3 October 2022.

scholarly institutional history of the Medical Section exists. Simply establishing the network of laboratories that Stafford Warren founded between 1943 and 1947 goes a long way to place the organization back into the atomic narrative. Why did the Medical Section fall out of memory? I suspect that Warren's demeanor must have had a part in this erasure. He had an ego. Donaldson got on with him well, but many others in the MED, AEC, and at UCLA did not. Robert Sproul, President of the University of California when Warren became the first Dean of UCLA's Medical School, considered him a pest always scrounging for money for this, that, or the other project.[23] Perhaps more importantly, however, Medical Section research really existed for the sake of atomic testing. When the Partial Test Ban treaty ended atmospheric testing in 1963, the program lost its major reason for being. The federal government no long needed arbiters of fission's effects at the Pacific Proving Grounds and the Nevada Test Site.[24] As all the original plutonium production reactors at Hanford shut down, during the 1960s and '70s, the biologists lost their secondary reason for being as keepers of radiation on the Columbia River. This dissertation shows that Medical Section biology existed, and then fell by the wayside, because of very specific historical and legal circumstances.

A second part of this argument distinguishes Medical Section biology from other mid-twentieth century ways of studying life exposed to radiation. This program was unique because it always existed as an amalgam of medical and biological ways of doing and knowing. Perhaps the story of the Hanford

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23 See Sproul's incredulity in a 1947 letter to Warren after the new dean demanded over $150,000: "I cannot understand how you could have reached the conclusion… that there would be [such money]." President Robert Sproul to Dean Stafford Warren, 4 April 1947, Box 38, Folder "Budget." School of Medicine. Office of the Dean. Administrative files of Stafford L. Warren (University Archives Record Series 300). UCLA Library Special Collections, University Archives.

24 The program spread to the site of the 1945 Trinity Test and to the Nevada Test Site as well. Though this dissertation does not treat that expansion and the work of the biologists at the UCLA Atomic Energy Project led by Stafford Warren, they will ideally be included in a monograph version of this project.

Fish Lab's foundation, found in chapter three, shows this dynamic most clearly. In June 1945, two meetings took place to define the Hanford lab's program. Donaldson led the first meeting in Seattle with all AFL hands on deck along with on MD, Hymer Friedell. The fisheries biologists wanted the new lab to do a multi-generation study just like the one they had planned for the offspring of the chinook we met at the beginning of the chapter. Two days later, in Berkeley, Donaldson and Friedell met with Warren and two other medical doctors. The doctor-heavy meeting planned for histological studies and population statistics on somatic injuries from radiation. The lab's actual program, under Dick Foster, ended up a mishmash of the two.

This hybridity distinguished the MED research program competing federal ways of knowing radiation. In the US Navy, medicine and biology existed independently of each other. A team of Navy doctors visited Japan after the bombings in 1945. A very separate team of Navy biologists performed the animal physiology studies a year later during Operation Crossroads at Bikini Atoll. Attached to the powerful Office of Naval Research, those biologists famously put goats and pigs on the decks of the ships that were bombed by the Crossroads Able test in Bikini lagoon. The twain never met. In contrast medical doctors and fisheries biologists consistently worked together in the MED. This medical-biological hybridity also distinguished Medical Section biology from the developing program of ecosystems ecology within the Atomic Energy Commission.[25] This type of ecology grew out of practices for quantifying in a precise way how nutrients moved through the environment. The practice lent itself to showing how radionuclides moved through the environment as well as to the use of computers for modeling their movement. Far more systematic than the Medical Section's biology,

25 For ecosystems ecology at Oak Ridge, see: Stephen Bocking, "Ecosystems, Ecologies, and the Atom: Environmental Research at Oak Ridge National Laboratory," *Journal of the History of Biology* 28, (1995), 1 – 47.

ecosystems ecology only edged out the earlier x-ray program within the AEC after the end of atmospheric testing.[26]

A final element of the argument, and perhaps the broadest, considers the nature of scientific expertise. The biologists began their careers and their radiological research at a time when American culture esteemed scientists very highly. Far from causing the US public to fear science, the detonation of the atomic bombs over Hiroshima and Nagasaki seemed to confirm that humankind had mastered even the smallest building blocks of nature. Moreover, science had mastered nature for the sake of democracy. Bruce Hevly and John Findlay begin their canonical treatment of Hanford with a story of a US veteran's widow who wrote to the MED after the bombings to give thanks, "P.S. Your bombs are certainly wonderful."[27] Vannevar Bush wanted to capitalize on this good feeling in this 1945 missive "Science, the Endless Frontier."[28] He hoped for a new national organization that would fund basic research and allow scientific experts to choose their own research regardless of any potential applied use. In the end, Congress created the National Science Foundation, not exactly along Bush's lines but still in keeping with the exalted status of mid-century scientists. The Atomic Energy Commission and the new foundation funded all kinds of science across the US. In this milieu, the AFL biologists found

26 For the Applied Fisheries Laboratory's ill-fated dalliance with ecosystems research in the 1960s, see: Matthew Klingle, "Plying Atomic Waters: Lauren Donaldson and the 'Fern Lake Concept' of Fisheries Management," *Journal of the History of Biology* 31, no. 1 (Spring, 1998), 1- 32.

27 Mrs. J. W. Nichols to Colonel Franklin Matthias, 17 August 1945, in Bruce Hevly and John Findlay*, Atomic Frontier Days: Hanford and the American West* (Seattle: University of Washington Press, 2011), 3.

28 Vannevar Bush "Science, the Endless Frontier," 1945, https://www.nsf.gov/about/history/nsf50/vbush1945_content.jsp

themselves as minor celebrities in Seattle, especially as their research in the Marshalls ramped up.[29] Celebrity and scientific expertise existed hand in hand in the wake of World War II.

This dissertation contributes to historical ideas about expertise by using the AFL biologists to show that experience relies on place. It must be grounded. Historians and sociologists of science have already convincingly shown that expertise has spatial bounds.[30] This dissertation's argument deepens these understandings by exploring not just the practices and ideas that make place important for expertise, but also the bureaucratic exigencies that make discrete places powerful as sites for knowledge production. This story shows that the dynamics of US colonialism and the federal management of landscapes across the western US and Pacific helped produce the Medical Section research program. Their expertise, in turn, relied on the power dynamics of dispossession and occupation, of being able to turn entire landscapes into research areas. Canonical histories can forget the violence of each atomic detonation, especially as they zero in on political or scientific details. This dissertation reminds its readers that Donaldson and his team of Seattle biologists relied on the violence of fission in the moment and over time.[31] Their expertise relied on death, the deaths of human beings, of animals, and of plants exposed to heat hotter than the sun and to subatomic particles that ripped apart the atoms comprising living beings at sites deemed specifically useful for fission. Destruction on this level existed because politicians decided it was in the national interest. The expertise of the Medical

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29 For an example of the lab's favorable coverage by the *Seattle Times* see: "Biological Research at Bikini," 16 October 1949, Box 13, Folder 28, UWLRB.

30 See: Harry Collins, *Changing Order: Replication and Induction in Scientific Practice* (Beverly Hills, California: Sage, 1985).

31 For a reflection how the violence of a detonation must be acknowledged but also held in tension with the *longue durée* violence that radiation causes to unfold in the environment, see: Elizabeth DeLoughrey, "Radiation Ecologies and the Wars of Light," in *Modern Fiction Studies* 55, no. 3 (Fall, 2009), 468 – 498.

Section doctors and biologists cannot be separated from the spatial dynamics created by the political powers interested in their science. Nor can their scientific practices be seen apart from the variety of contexts into which atomic production, warfare, and testing, sent them.

Periodization, Nomenclatures, and Literature

The atomic age, though short in timespan, has inspired a wide variety of historical reflection and interpretation. Before thinking about the atomic age, a note periodization will be helpful. This dissertation will treat 1895, when Wilhelm Roentgen displayed x-rays, and early 1939, when Lise Meitner and her nephew Robert Frisch described fission in the pages of *Nature*, as the age of rays and radiations.32 Meitner and Frisch's publication on fission heralded the dawn of the atomic age.[33] The first anthropogenic nuclear chain reaction on 2 December 1938 at Chicago Pile-1 brought the atomic age to maturity. Enrico Fermi's reactor at the squash courts at the University of Chicago showed that people could make fission work. The next boundary moment that this dissertation makes use of is the Partial Test Ban Treaty in 1963, which forbad atmospheric testing by signatory countries. After this moment, anthropogenic fission stopped contributing radionuclides to the environment in a meaningful way through global fallout.[34] A fourth period began with the 1996 Comprehensive Test Ban Treaty, which stopped most underground nuclear testing. These four periods, like so many historical ideas, are

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32 For a thorough description of this period's early years, see, Campos, "The Birth of Living Radium" in *Radium and the Secret of Life*, 2015, 11 – 55.

33 For Meitner's escape from Nazi Germany, she was Jewish, and fission's entanglement with that wicked regime, see: Ruth Sime, *Lise Meitner: a life in physics* (Los Angeles and Berkeley: University of California Press, 1996).

34 France, China, and North Korea have not signed the treaty and have tested atomic weapons in the atmosphere in the years after 1963.

porous. But they make some sense in terms of the literatures that exist about atomic matters. This dissertation attends to the first two periods.

Next a note on terminology will be helpful for this dissertation's look at the atomic age. Chronologically we can begin with **rays** in the late 1800s, when researchers used vacuum tubes to create cathode rays. Wilhelm Roentgen used this nomenclature when he called his unexplained phenomenon x-rays. When Henri Becquerel discovered that uranium ore gave off emanations in the year following Roentgen's announcement, he called them **radiations**. He and the two Curies later described the production of these radiations as **radioactivity**. **Fission** came into the scientific and popular vocabulary in 1938 because Robert Frisch had a chat with a biologist friend who used the term to describe cell division. Since fission involves splitting a heavy atom, like uranium, in two, the biological term made sense for the physical event. **Atomic** came into vogue in the 1940s to describe the first fission bombs since it simply points to action going on at the level of the atom. **Nuclear**, which just refers to action going on at the level of the atomic nucleus, postdated atomic in popular usage. Since atomic and nuclear refer to the atom, x-rays cannot be considered atomic at all, since they are very high frequency waves. Atomic bombs work because either uranium or plutonium atoms are split by fission. **Thermonuclear** bombs, also known as "the super" or hydrogen bombs, work because a fission reaction then sets off a **fusion** reaction, in which very small atoms are mashed together to create a larger atom. Fission and fusion produce great deals of energy because when mass converts to energy, its output is multiplied by the speed of light squared. This was Einstein's great insight and helped transform radiations into tools of mass destruction.[35]

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35 For a look at Einstein's work in context, see: Peter Galison*, Einstein's clocks and Poincaré's maps: empires of time* (New York: W.W. Norton, 2003).

Looking at these periods and terms, we can see that this dissertation takes place in the age of rays and radiations but most occurs in the atomic age. It deals primarily with rays, fission, and fusion. The timing and naming schemes I describe belong largely to physics and to technologies relying on the work of physicists. In this regard, *Atomic Bodies, Atomic Landscapes* uses canonical timelines and viewpoints but aims to show that they exist within arbitrary disciplinary and cultural constructions. A major historiographic intervention that I make will be to show that looking at radiation from a biological perspective confuses canonical narratives that rely on the histories of great physicists and the politicians who used the technologies produced by those physicists.[36]

As this chapter has already shown, doctors and biologists quickly hopped onto the research bandwagon during the age of rays and radiations. Medical doctors began to use x-rays very quickly as a diagnostic tool. The new rays allowed doctors to see broken bones and other insults to the body that would have otherwise been hidden. Just over a month after Roentgen announced his new rays, a medical doctor in Liverpool used an x-ray exposure to remove a bullet from hand of a child who had been shot in the wrist.[37] It was the first documented time x-rays had been used for a medical procedure. We have already seen that x-rays became an important part of diagnostic medicine in World War I. Experimental programs using x-rays took longer to develop than diagnostic techniques did. This was in

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36 For a treatment of European theoretical physics at the turn of the 20th century, see: Richard Staley, *Einstein's Generation: The Origins of the Relatively Revolution* (Chicago: University of Chicago Press, 2008). For a classic treatment of physics in the interwar period, see: Paul Forman, "Weimar Culture, Causality, and Quantum Theory, 1918-1927: Adaptation by German Physicists and Mathematicians to a Hostile Intellectual Environment," *Historical Studies in the Physical Sciences* 3, (1971), 1-115. For the story of physics in the United States, see: Daniel Kevles, *The Physicists: The History of a Scientific Community in Modern America* (Cambridge, Massachusetts: Harvard University Press, 1971).

37 Robert Jones and Oliver Lodge, "The Discovery of a Bullet Lost in the Wrist by Means of the Roentgen Rays," *The Lancet* 147, no. 3782 (22 February 1896), 476-477.

part because x-ray tube technology needed to advance before the machines could be used in a controlled and calibrated fashion to do research. By the 1920s, x-ray technology had improved from the early days and medical experimentalists embraced the technology. Lisa Cartwright has shown that x-rays became an exciting frontier of medical research. Doctors even created moving x-ray films. For this short, Cartwright's description of Stafford Warren's creation of mammography to diagnose breast cancer proves important.[38] The new rays proved themselves a key medical tool right off the bat.[39]

Early geneticists also employed x-rays. Robert Kohler has famously told the story of Thomas Hunt Morgan and the fly room at Columbia University.[40] There the great biologist created standardized populations of *Drosophila melanogaster*, the fruit fly, in order to research mutations on their large and easily visible chromosomes. Morgan's lab did not employ radiation to drive mutations, but Herman Muller, his most mercurial student, did once he spirited some Columbia *Drosophila* to the University of Texas in the 1920s.[41] A lab a Caltech also grew out of the Columbia lab. Though the age of rays and radiations saw the growth of x-ray studies in the laboratory among scientists, the lay public also embraced x-rays. Helen Anne Curry has shown that farmers and horticulturalists in the US embraced x-rays as a means to increase crop yields. By the 1930s, academics at state agricultural colleges had

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38 Lisa Cartwright, *Screening the Body: Tracking Medicine's Visual Culture* (Minneapolis: University of Minnesota Press, 1995), 126.

39 The history of radium research is outside the scope of this project, but interested readers may consult Maria Rentetzi's excellent monograph on the Vienna Radium Institute: *Trafficking, Materials, and Gendered Experimental Practices: Radium Re-search in Early Twentieth Century Vienna* (New York: Columbia University Press, 2009).

40 See: Robert Kohler, *Lords of the Fly: Drosophila Genetics and the Experimental Life* (Chicago: University of Chicago Press, 1994).

41 See: Elof Axel Carlson, *Genes, Radiation and Society: The life and Work of H.J. Muller* (Ithaca, New York: Cornell University Press, 1981).

developed portable x-ray machines for use in fields.[42] X-rays made sense as a technology for genetics research just as they made sense for medical research during the age of rays and radiations.

Having looked at medical and scientific stories that began in the age of rays and radiations, it will be helpful now to show how biological stories have bucked the timelines and periodizations that rely on histories of physics to define the big narrative about radiation. Both Kohler and Curry's stories begin before World War II and end after it. Geneticists easily adopted new radiation technologies as they became available. Soraya de Chadarevian has shown that x-rays and radioisotopes from fission played key roles in the cytogenetics research at Britain's Atomic Energy Research Establishment after the war.[43] This dissertation hopes to further show that the categories of biologists confuse the timelines of physicists.

Historians of science and of the US atomic program have often been blinded by the light of the physicists and have accepted their scheme for marking time. The literatures most important for *Atomic Bodies, Atomic Landscapes* have largely abided by these divisions, between the age of rays and radiations and the atomic age. We turn to these overtly atomic stories now.

Histories of Atomic Sites

This dissertation relies significantly on-site histories in the US context, literature devoted to a particular atomic place that developed because of the Manhattan Engineer District's bomb project or the Atomic Energy Commission's bomb production and testing program. The work of Hal Rothman on Los Alamos, John Findlay and Bruce Hevly on Hanford, Kate Brown on Hanford and its Soviet sister city

42 Helen Anne Curry, *Evolution Made to Order: Plant Breeding and Technological Innovation in Twentieth-Century America* (Chicago: University of Chicago Press, 2016).

43 Soraya de Chadarevian, "Radiation and Mutation," in *Heredity Under the Microscope*, 15 – 38.

Ozersk, and Andy Kirk on the Nevada Test Site offer focused, place-based monographs that consider atomic sites.[44] These historians come from a variety of sub-fields – Rothman and Findlay, western history; Hevly and Brown, history of science; and Kirk, public history – yet they all see the value in addressing the atomic age on a site by site basis. Rothman uses his study of Los Alamos as a *longue durée* reflection on federal power over landscapes with the development of the atomic city as an inflection point for the land's story. Findlay and Hevly tell a hybrid story about Hanford, bouncing back and forth between cultural concerns and scientific details as they describe the site. Brown also moves back and forth, though spatially, as she compares the American and Soviet plutonium production facilities the cities filled with nuclear workers that grew up around them. Finally, Kirk uses atmospheric testing at Nevada Test Site as a launch pad for larger questions about Cold War politics and the federal use of western lands.

These four examples point to the ecumenism of the atomic story. Historians, sociologists, and ethnographers of all kinds who are concerned with the American nuclear program have written site histories over the past 30 years since the US Department of Energy declassified the bulk of its wartime and Cold War atomic library.[45] The idea of the site history comes very much from the old Atomic

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44 Rothman, *On Rims and Ridges,* 1992. Findlay and Hevly, *Atomic Frontier Days,* 2011. Kate Brown, *Plutopia: Nuclear Families, Atomic Cities and the Great Soviet and American Plutonium Disasters* (Oxford: Oxford University Press, 2013). Andy Kirk, *Doom Towns: The People and Landscapes of Atomic Testing* (Oxford University Press, 2017).

45 The US Department of Energy is the major successor agency to the Atomic Energy Commission. In 1993, Secretary of Energy Hazel O'Leary announced Operation Openness, which eventually resulted in over six million pages of formerly classified or inaccessible documents becoming available (see the Federation of American Scientists report: https://sgp.fas.org/othergov/opendoe.html, accessed 17 March 2023). The Department also created the Advisory Committee on Human Radiation Experiments, which investigated human experimentation under the AEC (See the Department's description of the project at: https://ehss.energy.gov/ohre/roadmap/whitehouse/part1.html#findings). The latter committee

Energy Commission and the new Department of Energy's own self-understanding. From the beginning, the production of US bombs existed in a geographically compartmentalized fashion. Leslie Groves, who ran the Manhattan Engineer District organized the atomic endeavor in this way to promote secrecy. The left hand never knew what the right hand was really up to, so workers at Hanford had no idea that their special product was destined to go to a town in New Mexico where it would be weaponized. Once the veil of wartime secrecy lifted, distinct sites continued to operate as islands within the AEC. Varying in size, some were as small, like the plutonium fabrication site at Rocky Flats in Colorado, and others were vast, like the Pacific Proving Grounds. At any rate, site histories make sense because historical actors related to the atomic project in the US have thought primarily in terms of the site they worked at. Archives tend to be related to specific sites, which makes them natural objects of investigation. Of course, focusing on a single site bounds the work that historical accounts can accomplish.

In spite of their focused scope, site histories have produced a broad literature about the US atomic project. A key set of sites histories have focused on the MED and AEC, discussing their institutional histories as well as the science and engineering that made the atomic program possible. Frank Szasz's 1984 history of the July 1945 Trinity Test discusses the science behind the bomb through the lens of life at Los Alamos.[46] Michelle Stenehjem Gerber's 1992 treatment of Hanford's history also

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produced a host of oral histories of scientists who worked at sites across the country. The Department argued that both its openness and human experimentation initiatives grew out of an urge within the bureaucracy to promote transparency. Members of the public have sometimes viewed this explanation with skepticism, given the Department increasingly found itself in legal trouble during the 1990s over the ill health of former workers exposed to radiation and over environmental damage that took place at sites like Hanford.

46 Ferenc Szasz, *The Day the Sun Rose Twice* (Albuquerque: University of New Mexico Press, 1984).

tells administrative and scientific histories.[47] Findlay and Hevly's 2011 also considers the institutional history at Hanford. At the Nevada Test Site, J. Samuel Walker, historian for the Nuclear Regulatory Commission, described the plan to build a long-term radioactive waste depository at Yucca Mountain in 2009.[48] These works all share an interest in the machinations of federal employees and contractors as well as an interest in science and engineering feats as the drivers for their stories.

Atomic site histories have proven useful as forums for cultural histories and ethnographies of the atomic US atomic project. In *Plutopia*, Kate Brown makes use of oral histories and interviews to supplement her description of day-to-day life at the two plutonium production centers in the US and the Soviet Union. She is not the first scholar to take to the atomic field in search of personal stories. Cultural Historian Peter Bacon Hales and anthropologist Joseph Masco have looked at life in atomic site, thinking about the cultural dynamics produced by the nuclear program.[49] Cultural historians have addressed matters of race at atomic sites, in particular the relationships between American Indians,

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47 Michelle Stenehjem Gerber, *On the Home Front: The Cold War Legacy of the Hanford Nuclear Site* (Lincoln, Nebraska: University of Nebraska Press, 1992).

48 J. Samuel Walker, *The Road to Yucca Mountain: The Development of Radioactive Waste Policy in the United States* (Los Angeles and Berkeley: University of California Press, 2009). Walker has treated the 1979 accident at Three Mile Island through a site history: *Three Mile Island: A Nuclear Crisis in Historical Perspective* (Los Angeles and Berkeley: University of California Press, 2004). The Nuclear Regulatory Commission and the Department of Energy are both successors of the old Atomic Energy Commission, which was broken up by the Energy Reorganization Act of 1974 because skeptics within and outside of the federal government questioned the wisdom of one Commission to both promote and regulate nuclear energy and weapons production.

49 Peter Bacon Hales, *Atomic Spaces: Living on the Manhattan Project* (Urbana-Champaign: University of Illinois Press, 1999). Joseph Masco, *Nuclear Borderlands: The Manhattan Project in Post-Cold War New Mexico* (Princeton: Princeton University Press, 2006).

Hispanos, and Anglos at Los Alamos.[50] Tracy Voyles has written on race and uranium mining on the Navajo Reservation.[51] Mary Mitchell has recently looked at matters of atomic testing, race, and territorial governance in the Marshall Islands.[52] Barbara Rose Johnston has also investigated radiation exposure at Rongelap Atoll in the Marshalls.[53] Kim TallBear and Noriko Ishiyama have investigated the history of the Wanapum tribe, who were dispossessed from their homes along the Columbia River for the construction of Hanford.[54] This dissertation uses translated primary sources from Japanese actors and from Marshallese actors to take seriously the intersection between race and sites taken by the MED and AEC for atomic production and testing.

Historians have further used site histories to tell stories of declension, of human ill health and environmental destruction. In the US literature, people whose health has been impacted by atomic processes tend to be called downwinders based on their living in an exposure pathway. In her 2018 look at uranium mining, *Downwind*, Sarah Fox makes the connection overt.[55] She writes as an activist as

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50 See Rothman. Also see: María E. Montoya, "The Roots of Economic and Ethnic Divisions in Northern New Mexico: The Case of the Civilian Conservation Corps," *Western Historical Quarterly* 26, no. 1 (Spring, 1995), 14-34. Hispanos are descendants of settler colonialists in New Mexico whose ancestors arrived during the rule of the Spanish Empire.

51 Tracy Volyes, *Wastelanding: Legacies of Uranium Mining in Navajo Country* (Minneapolis: University of Minnesota Press, 2015).

52 Mary Mitchell, "The Nuclear Charter: international law, military technology, and the making of strategic trusteeship, 1942–1947," in *Living in a Nuclear World: From Fukushima to Hiroshima,* Benadette Bensaude-Vincent*,* Soraya Boudia, Kyoko Sato, eds. (London: Routledge, 2022), 85 – 108.

53 Johnston, "Nuclear Disaster: The Marshal Islands Experience and Lessons for a Post-Fukushima World," 2015.

54 Noriko Ishiyama and Kim TallBear, "Nuclear Waste and Relational Accountability in Indian Country," in *The Promise of Multispecies Justice,* eds. Sophie Chao et al. (Durham, North Carolina: Duke University Press, 2022), 185 – 203.

55 Sarah Alisabeth Fox, *Downwind: A People's History of the Nuclear West* (Lincoln, Nebraska: University of Nebraska Press, 2016).

much as she writes as a scholar. Downwind histories in the US experience tend towards moral arguments about the atomic project.[56] Rebecca Solnit has addressed the history of the Nevada Test Site with unmitigated activist zeal.[57] As we have seen, Canadian historian Martha Smith has written on dispossession and disease in the Marshall Islands, looking at the US overseas possession in order show how imperial ends foster environmental degradation and ill health.[58] Downwinder histories fill, to my mind, a vital moral void that often makes explicitly scholarly histories seem detached from the experiences of people who have suffered from atomic injuries and lands and water that have been rendered uninhabitable. With that said, *Atomic Bodies, Atomic Landscapes* is not overtly a work of activist history. The dissertation's focus on the Medical Section doctors and biologists shows how they understood radiation in their own terms and then tries to show how those historical understandings created foundations for the situation today at Hanford and in the Marshall Islands.

A final style of site history proved important for this project, the multiple site history. Two stand out. Gabrielle Hecht's 2012 work on the global uranium mining and milling trade. Her book moves with alacrity to atomic sites all around Africa.[59] She uses uranium production to move from site to site, but with each chapter treats the political and cultural situation of a particular locale. Angela Creager's 2013 treatment of medical radioisotopes fits the multiple site history mold as well.[60] Hers is a "thing history" tied to a series of places. She moves through canonical places for the US atomic story, like Los

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56 See: Linda Richards, "On Poisoned Ground" *Chemical Heritage Magazine* 31, no.1 (Spring 2013), 32-38.

57 Rebecca Solnit, "Dust, or Erasing the Future: The Nevada Test Site," in *Savage Dreams: A Journey into the Hidden Wars of the American West* (Los Angeles and Berkeley: University of California Press, 1994), 3 – 214.

58 See: Martha Smith, *Domination and Resistance*, 2016.

59 Gabrielle Hecht, *Being Nuclear: Africans and the Global Uranium Trade* (Cambridge, Mass.: MIT Press, 2012).

60 Angela Creager, *Life Atomic: A History of Radioisotopes in Science and Medicine* (Chicago: University of Chicago Press: 2013).

Alamos and Hanford, but she also visits hospitals and university laboratories. Multiple site stories manage to transform local stories into transnational and global stories.[61] *Atomic Bodies, Atomic Landscapes* operates on this model, focusing on a series of sites tied together by a research program. One of this dissertation's overt contribution to the literature involves showing how Medical Section research moved from Seattle to Japan to Hanford to Bikini to Rongelap.

Biology and Radiation

This dissertation engages with a second, broad literature that deals with radiation, medicine, and biology. In the atomic age, radionuclides created by fission caused sickness and cured it. Fission products poisoned entire environments while also allowing scientists to study the functioning of environments. Radionuclides allowed for new kinds of genetics and microbiological research. Radiation from fission also encouraged both scientific nationalism and internationalism around biological research. Historians of radiation and biology have had to cope with these Janus-like aspects of radiological danger and possibility. This dissertation seeks to compliment the literatures that address the production of medical knowledge and the production of place-based environmental knowledge about biotic populations and environmental health.

Radiation and medicine in the atomic age collided with the use of the bombs at Hiroshima and Nagasaki. Americans did not immediately learn about the medical effects of the bombs because US forced banned the spread of images or news from the two cities in the autumn of 1945. John Hershey's

61 For other atomic stories that treat networks of global sites, see: Jacob Darwin Hamblin, *Poison in the Well: Radioactive Waste in the Oceans at the Dawn of the Nuclear Age* (New Brunswick, NJ: Rutgers University Press, 2008) and Robert Jacobs, *Nuclear Bodies: The Global Hibakusha* (New Haven: Yale University Press, 2022).

Hiroshima in 1946 introduced the US public to the horrors of the bombs and of radiation sickness.[62] A journalist and not a medical man in any way, Hershey still described injuries from the bombs in explicit detail using material from interviews he conducted. In a way his was the first US medical history of the bombings. No focused, scholarly American history of medicine concerning the bombings exists. Instead, US literature on the bombings tends towards policy stories about the decision to use the bomb.[63] Susan Lindee's telling of the Atomic Bomb Casualty Commission (ABCC) story gets closest to an American medical history of the bomb.[64] Her account of the ABCC accomplishes two important things. She establishes the colonial dynamics that the US occupation enforced in the years after the bombing. Stafford Warren's easy access to medical histories and biological samples from *hibakusha* took place in this moment of unequal political power. Lindee also shows how radiation's effects lingered, both medically and culturally, for those exposed. The ABCC studied human genetics in those exposed to radiation from fission. Telling its story, and the story of the survivors it studied, she displays how radiation can be both a harm to subjects and a boon to researchers.

An important literature also exists that shows how the federal government conducted uninformed research on human beings in the US using radiation. Eileen Welsome won the Pulitzer Prize for her book about the MED's plutonium injection studies.[65] In the book she covers a variety of experiments conducted on medical patients without their knowledge by US atomic operatives. Stafford

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62 John Hershey, *Hiroshima* (New York: Alfred A. Knopf, 1946).

63 For a recent history of the bomb's use, see: Michael Gordin, *Five Days in August: How World War II Became a Nuclear War* (Princeton: Princeton University Press, 2007).

64 Susan Lindee, *Suffering Made Real: American Science and the Survivors at Hiroshima* (Chicago: University of Chicago Press, 1994).

65 Eileen Welsome, *The Plutonium Files: America's Secret Medical Experiments in the Cold War* (New York: The Dial Press, 1999).

Warren himself ordered the very first wartime plutonium injections. Gerald Kutcher picks up on the uniformed testing story with his account of whole body irradiation at the University of Cincinnati in the 1960s and '70s.[66] Angela Creager, in her radioisotopes book, also visits hospitals that conducted unethical research.[67] These works point to the irony that the US failed to live up to the standards it helped create in the Nuremberg Code as a response to Nazi research atrocities. Radiation experimentation funded by the AEC and the Department of Defense failed to rely on informed consent after World War II.

Even as the AEC sponsored medical testing on unsuspecting subjects, it was trying to show that it could protect those who worked with and around radiation. The new discipline of Health Physics grew up in the AEC, which proposed to use a combination of physical and medical techniques to protect against radiation exposure. Histories of radiation protection tend to be inside jobs, produced by academics with connections to the atomic establishments. This was thoroughly true of Barton Hacker's 1987 monograph on radiation safety in the MED years.[68] A true believer in the atomic project, Hacker portrayed efforts to keep radiation safe as imperfect but getting better all the time. J. Samuel Walker offers a somewhat more muted look at the task in his 2000 history of radiation protection, but the piece retains an insider's perspective.[69] These stories focus on practices to shield individuals from radiation exposure and on administrative standards designed to keep radiation exposure to a safe minimum. This dissertation will investigate the practice of establishing permissible doses of exposure in chapter five. A

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66 Gerald Kutcher, *Contested Medicine: Cancer Research and the Military* (Chicago: University of Chicago Press, 2009).

67 Creager, "Guinea Pigs," *Life Atomic,* 260 – 310.

68 Barton Hacker, *The Dragon's Tail: Radiation Safety in the Manhattan Project* (Los Angeles and Berkeley: University of California Press, 1987).

69 J. Samuel Walker, *Permissible Dose*.

challenge to the narrative of radiation protection comes from Catherine Caufield, in her long history of radiation exposure and regulation.[70] She argues that radiation protection has always been a euphemism, especially as federally conceived and regulated. Her work points to the series of accidents the AEC and Department of Energy have presided over to make the case that radiation's medical effects cannot be mitigated by setting exposure standards. *Atomic Bodies, Atomic Landscapes* adds to this literature by showing how the AFL biologists' trust in exposure standards failed to help the people of Rongelap Atoll after fallout from the 1954 Castle Bravo test blanketed their homes and food sources.

This dissertation also engages with literature on the relationship between ecology and the environmental sciences after World War II. In the US context, the development of ecosystems ecology has been tied to funding from the AEC. Ecosystems were themselves a novel idea dating from around World War II that relied on the notion that nature and the flow of energy through nature could be quantified. Joel Hagen and Sharon Kingsland both place the idea of ecosystems within the development of American ecology as the discipline moved way from qualitative work towards a more numerical practice.[71] Techniques for tracing nutrients through ecosystems leant themselves to tracing radionuclides through ecosystems. AEC ecologists jumped on the discipline at Oak Ridge.[72] Most famously, Eugene and Howard Odum engaged in ecosystems research at the Pacific Proving Ground and at the Savanah River plutonium production site. Their 1953 *Fundamentals of Ecology* became the standard introductory textbook for nascent ecologists in undergraduate study across the US.

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70 Catherine Caufield, *Multiple Exposures: Chronicles of the Radiation Age* (Chicago: University of Chicago Press: 1989).

71 Joel Hagen, *An Entangled Bank: The Origins of Ecosystems Ecology* (New Brunswick, New Jersey: Rutgers University Press, 1992) and Sharon Kingsland, *The Evolution of American Ecology, 1890 – 2000* (Baltimore: Johns Hopkins University Press, 2008). Also see: Donald Worster, *Nature's Economy: A History of Ecological Ideas* (Cambridge: Cambridge University Press, 1977).

72 See: Bocking, 1995.

Ecosystems ecology helped create a utilitarian view of environments that the federal government confiscated for military goals. The Odums tacitly assisted the work of the AFL in the Marshall Islands by positioning irradiated landscapes "outside of history (i.e. human experience) and accountability, encouraging scientists to 'attack' environments already devastated by nuclearization."[73] This dissertation shows that Donaldson and his biologists shared this worldview with ecosystems ecologists while not embracing their scientific practices. During atomic testing, the AFL never engaged in research from an ecosystems standpoint. Only after the test ban did the lab begin to do ecosystems work in order to get funding from the AEC.[74]

If *Atomic Bodies, Atomic Landscapes* converses directly with literatures on radiation and medicine and radiation and ecology, it stands astride the historiography that considers radiation and genetics. A strong literature exists on the development of this lab science in light of radiation advances in the atomic age. Susan Lindee has shown that ABCC research genetic effects in *hibakusha* has contributed to foundational, and notably porous, understandings of what constitutes a mutation.[75] Her 1992 reflection shows the power of radiation to uncover the presuppositions built into basic 20th century biological pursuits. In 2006, Angela Creager and María Jesus Santemases edited a special volume of the *Journal of the History of Biology* to address "Radiobiology in the Atomic Age."[76] The volume focused squarely on the laboratory. The explain that "the leading fields of postwar biomedical research – such as biochemistry, molecular genetics, endocrinology, and physiology – benefited

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73 DeLoughrey, "The myth of isolates," *cultural geographies,* 2012.

74 For a look the lab's attempts to work and think in terms of ecosystems, see: Matthew Klingle, "Plying Atomic Waters."

75 Susan Lindee, "What Is a Mutation? Identifying Heritable Change in the Offspring of Survivors at Hiroshima and Nagasaki," *Journal of the History of Biology* 25, no. 2 (Summer, 1992), 231-255.

76 Angela Creager and María Santemases, "Radiobiology in the Atomic Age: Changing Research Practices and Policies in Comparative Perspective," special issue, *Journal of the History of Biology* 39, no. 4, (Winter, 2006).

directly from these atomic energy programs and the new tools they provided"[77] Soraya de Chadarevian and Karen Rader especially highlight the role of genetics research and the use of irradiated mice within this laboratory tradition. The volume also develops the connections between these lab sciences and state patronage, in the forms of funding and access to special radiological research conditions. Here the themes converge those found in this dissertation. The genetics story, however, largely does not map onto the story of the Medical Section. Angela Creager shows this in her most recent work on the opposition to geneticists to one of the Medical Section's most cherished ideas, the notion that there can be a biologically safe level of exposure to radiation.[78]

A corollary to these stories about lab biology and radiation in the Cold War has to do with the internationalism of science as it rubbed up against state secrets in the decades after World War II. The literature that considers this aspect of radiobiology has looked at both the work of the ABCC and at US atomic policy. Susan Lindee and John Beatty have both analyzed the ABCC as an alternately colonial and transnational forum for using science to guide the relationship between the postwar US and

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77 Creager and Santemases, "Radiobiology in the Atomic Age." 638. For the story of genetics research in the UK context, see: Soraya de Chadarevian, "Mice and the Reactor: The 'Genetics Experiment' in 1950s Britain," 707 – 735. For laboratory biology at Oak Ridge, see: Karen Rader, "Alexander Hollaender's Postwar Vision for Biology: Oak Ridge and Beyond," 685 – 706. For competing biological programs in postwar France, see: Jean-Paul Gaudillière, "Normal Pathways: Controlling Isotopes and Building Biomedical Research in Postwar France," 737 – 764. On radioisotopes and endocrinology and molecular genetics in Spain, see: María Jesús Santesmases, "Peace Propaganda and Biomedical Experimentation: Influential Uses of Radioisotopes in Endocrinology and Molecular Genetics in Spain (1947–1971)," 765 – 794.
78 See Angela Creager, "Radiation, Cancer, and Mutation in the Atomic Age," *Historical Studies in the Natural Sciences* 45, no. 1 (February, 2015), 14 – 48.

Japan.[79] Lindee tells the story of the repatriation of body parts taken from ABCC subjects for research in the US. As I discuss the use of specimens for data production at the AFL, I am indebted to her reflections on how irradiated organs and tissues were "scientifically shepherded through a system of analysis, imaging, classification, and preservation."[80] By telling the story of these body parts' repatriation, she makes them diplomatic objects. Their return to Japan strengthened a political relationship. Doing so, she anticipated John Krige's work on Dwight Eisenhower's "Atoms for Peace" program, which also used radiobiological research for diplomatic ends.[81] He has emphasized the desire of the US political establishment to use science for the sake of an improved international reputation. Of course, the project was fraught because the US wanted to act as an atomic benefactor while also maintaining its edge on new technologies and scientific research.[82] In all these stories, atoms and biology exist transnationally and bear significance because of their diplomatic import.

In the midst of these literatures, this dissertation makes room for the unique style of Medical Section biology. Their unique way of seeing, by means of histology, population statistics, and data from

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79 See: John Beatty, "Scientific Collaboration, Internationalism, and Diplomacy: The Case of the Atomic Bomb Casualty Commission," *Journal of the History of Biology*, Vol. 26, No. 2 (Summer, 1993), 205-231 and M. Susan Lindee, "The Repatriation of Atomic Bomb Victim Body Parts to Japan: Natural Objects and Diplomacy," in "Beyond Joseph Needham: Science, Technology, and Medicine in East and Southeast Asia," special issue, *Osiris* 13, (1998), 376-409.

80 Lindee, "Repatriation," 379.

81 See: John Krige, "Atoms for Peace, Scientific Internationalism, and Scientific Intelligence," *Osiris* 21, (2006), 161–181 and Krige, "The Peaceful Atom as Political Weapon: Euratom and American Foreign Policy in the Late 1950s," *Historical Studies in the Natural Sciences* 38, no. 1 (Winter 2008), 5-44. For the peaceful atom in Latin America, see: Gisela Mateos and Edna Suárez-Díaz, *Radioisótopos itinerantes en Latinoamérica: Una historia de ciencia por Tierra y por Mar* (Mexico City: CEIICH-UNAM, 2015).

82 For an analysis of secrecy and the US's first foray into making atomic knowledge available to the civilian public, see: Peter Galison, "Secrecy in Three Acts," *social research* 77, no. 3 (Fall 2010), 941 – 974.

"counting" the radiation in biological samples, placed them outside of the major biological disciplines of the atomic era. Their work at restricted sites under US political control made their story a national story. The core of the Medical Section doctors and biologists never participated in the international conferences organized by the United Nations under the banner of Atoms for Peace. Since the Medical Section acted apart from the high-profile biologists and doctors who studied radiation's biological effects, their stories have not made it any meaningful way into the literature. John Beatty, writing in 1992, could say that "While Manhattan Project officials had planned ahead of time to survey the physical effects of the explosions, they had made no special provisions for investigating the biological effects."[83] He wrote this based on misinformation provided by Shields Warren, Stafford's rival within the AEC's Division of Biology and Medicine.[84] *Atomic Bodies, Atomic Landscapes* follows the entire story of the Manhattan Project's efforts to understand the bombs' biological effects, a story erased from the literature. This dissertation places the Medical Section back into histories of atomic biology along with its bigger project of placing biology into canonical stories about the atomic age.

Geographic Scale and Perspective

This story takes place in the United States. Most of the main actors come from the US. Geographically, this story unfolds in the Pacific Northwest of the United States, in Japan, and in the Marshall Islands in the central Pacific. This is a national story and part of its aim is to establish how scientific connections between sites grew up amid the rush to weaponize fission during and after World War II, like the University of Washington and the plutonium production site at Hanford. But this national took place within the context of the US colonial expansion. When this story took place, the US territorial control

83 Beatty, "Scientific Internationalism," *Journal of the History of Biology*, 1992.

84 See footnote 13 in Beatty.

in the Pacific reached its territorial zenith. As the war started, the US governed the Philippines as well as Hawai'i and Alaska. When the war ended, the Philippines gained independence. But Japan would remain under US occupation until 1952 and its old South Pacific Mandate from the League of Nations passed to US administration. This is how the Marshall Islands, Palau, Micronesia, and the Northern Mariana Islands became part of the US's sprawling Pacific empire. The Medical Section doctors and biologists found themselves in a Pacific very much dominated by American power.

In terms of analytical perspective, I approach this as national story set in the context of US colonialism. Thinking about science done in colonial settings helps to explain two major dynamics at play in the story of the Medical Section. The first is the power of the federal government to take entire landscapes and repurpose them for a national project. The genealogy of atomic sites in many ways begins with the massive tracts of land taken for National Parks and what would become National Forests in the late 19th century.[85] As it repurposed lands in the western US and Pacific, the federal bureaucracy sent expert scientists to examine and manage the land.[86] The AFL biologists especially fell

85 This story of the federal government appropriating massive sites to fulfill a nationally significant purpose has its origins in the creation of the first national parks. These were lands taken from indigenous inhabitants for the sake of an idea, the conservation of nature. For the connections between lands taken for national parks, see: John Wills, "'Welcome to the Atomic Park': American Nuclear Landscapes and the 'Unnaturally Natural,'" *Environment and History* 7, no. 4 (November 2001), 449 – 472. For the exercise of federal power in the dispossession of American Indians from federally significant spaces, see: Harvey Meyerson, *Nature's Army: When Soldiers Fought for Yosemite* (Lawrence, Kansas: University Press of Kansas, 2020) and Louis Warren, "Blackfeet and Boundaries in Glacier National Park," in *The Hunter's Game: Poachers and Conservationists in Twentieth-Century America* (New Haven: Yale University Press, 1997), 126 – 151.

86 For federal scientific management on the mainland, see: Andrew C. Isenberg, "The Returns of the Bison: Nostalgia, Profit, and Preservation," *Environmental History* 2, no. 2 (April 1997), 179-196. Also see: Christian C. Young, "Defining the Range." For the rise of ecological management more generally, see: Donald Worster, "Producers and Consumers," in *Nature's Economy*. For an example of American experts doing field work while supported by the Army in the colonial

into the mold of federal scientific managers as they worked to understand how radiation acted on particular landscapes at particular sites. They practiced place-based science, engaged in long-term studies, and wrote reports for bureaucrats in Washington D.C. that suggested the best possible management of their landscapes. Because that land was on the far side of the Pacific Ocean, this story investigates another dynamic inherent in colonial science, the power imbalance between the scientists and between local populations in the occupied territories. This power imbalance comes to the fore in this story when Stafford Warren and his team of doctors go to occupied Japan to collect tissue samples and case histories from the *hibakusha*. It rears its ugly head again when the AFL biologists to go study Rongelap Atoll after the Castle Bravo fallout disaster. This is very much a story of US scientists having power over local populations and the power to define landscapes for the purpose of their research.

What did Medical Section science look like in the colonial context? Historians of science of late develop postcolonial perspectives to think about science that took place in occupied territories. I follow this trend by working to make federal excesses and the power imbalances in this story overt. Tiago Saraiva has shown that national aims or goals, in this case the production and testing of the atomic bomb, have been instrumental in the transformation of colonial spaces across the globe.[87] He discusses sites developed for plantation agriculture and animal breeding in European colonial contexts, but his description of territorial administrations transforming the land for an ideological goal is instructive for this project. After they were bombed, Hiroshima, Nagasaki, Bikini, Enewetak, and Rongelap all became sites valuable to the US federal government for the data they could produce in service of

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Philippines, see: Amy Kohout, *Taking the Field: Soldiers, Nature, and Empire on American Frontiers* (Lincoln, Nebraska: University of Nebraska Press, 2023).

87 Tiago Saraiva has written about national styles of science and agriculture in imperial contexts in his monograph *Fascist Pigs: Technoscientific Organisms and the History of Fascism* (Cambridge, Massachusetts: The MIT Press, 2018).

atomic hegemony. Their geographies assisted in the creation of new knowledge useful to the occupying government in the federal capital. US experts had to go far afield to produce this knowledge.[88]

When they took the territorial field, the doctors and biologists of the Medical Section mistrusted any kind of knowledge possessed by local actors. The doctors openly antagonized Japanese medical practitioners as they formulated ideas about what medical effects exposure to radiation from the bombs might really cause. In the Marshall Islands, relationships between the AFL biologists and the people of Rongelap Atoll deteriorated to the point that the US administrators of the Trust Territory of the Pacific forbad any field research during 1960. In this story we see US actors injudiciously exercising power over local inhabitants of the places they have been sent to study. Yet while the Americans looked down on the peoples of irradiated landscapes, they also relied on them. Susan Lindee has described this dynamic in postwar Japan. She defines colonial science as "science, conducted by outsiders, that depends on local knowledge."[89] The Medical Section doctors in Hiroshima and Nagasaki totally relied on local knowledge. They needed guides, translators, and the help of medical men to secure access to patients. In the Marshalls, the AFL biologists relied on local knowledge of marine species and foodstuffs for their research. Very rarely did the Medical Section practitioners acknowledge their indebtedness to local actors and their emplaced knowledge. Looking at these examples through a postcolonial lens, I have worked to incorporate local voices and ways of knowing into *Atomic Bodies, Atomic Landscapes's* story. In this regard, I follow Rosanna Dent's 2022 reminder that "the field is not

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88 Historians of science have also, in recent decades, insisted the transit helps shape the production of knowledge. This is very much the case for the Medical Section, which relied on collecting biotic samples in the hinterlands and transporting them back to mainland laboratories for analysis. The AFL especially trusted data it created in its lab in Seattle, even when it acquired a field laboratory at Enewetak Atoll in 1954. For a canonical reading on transit, see: James Secord, "Knowledge in Transit," *Isis* 95, no. 4 (December 2004), 654-672.

89 Lindee, *Suffering Made Real*, 20.

only or even primarily defined by conditions of research or spatial boundaries. Most important, it is composed of human relations."[90] With Dent's words in mind, I need to acknowledge that the Marshall Islands continue to be unequally tethered to the United States through a legally binding Compact of Free Association dating from 1986. The Compact provided for the creation, in 1988, of a Nuclear Claims Tribunal to adjudicate matters of reparation and cleanup.[91] So, while this project situates itself in the boarder postcolonial turn that has recently developed within the history of science, colonial dynamics continue at the many of the sites that appear in this story.[92]

Sources and Narrative Arc

This project relies on rich archival sources to drive its narrative. A combination of academic special collections and documents available through the US Department of Energy's archives form the core of the dissertation's sources. Far and away the most important sources come from the University of Washington Libraries' Special Collections. These house the Applied Fisheries Laboratory's papers as well as the personal papers of two founding lab members: director Lauren Donaldson and Arthur Welander. The UW School of Aquatic and Fishery Sciences also maintains a small collection of AFL materials as well as many physical specimens that the biologists collected between 1946 and 1963.

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90 Rosanna Dent, "Whose Home Is the Field?," in *Isis* 11, no. 1 (March 2022), 137 – 143.

91 See Johnston and Barker, *Consequential Damages*, for the 2001 report of the Tribunal.

92 For an excellent and timely reflection on postcolonial analysis of scientific field sites, see: Etienne Benson and Cameron Brinitzer, "Introduction: What Is a Field? Transformations in Fields, Fieldwork, and Field Sciences since the Mid-Twentieth Century," *Isis* 113, no 1 (March 2022), 108 – 113. See the volume's Focus Section for other postcolonial treatments of field science. For a classic postcolonial analysis of science in the field, see: Warwick Anderson, *The Collectors of Lost Souls: Turning Kuru Scientists into Whitemen* (Baltimore: Johns Hopkins University Press, 2008).

Materials from the UCLA Library Special Collections contribute to the story as well. Stafford Warren's personal papers and the administrative archives from his time as first dean of UCLA's Medical School reside there. Papers from Hanford, curated by the Richland Operations Office of the Department of Energy, provide source material. So do the files of Holmes & Narver, the AEC contractor at the Pacific Proving Grounds, which were preserved by the National Archives and Research Administration at its regional archive in Riverside, California. Finally, materials held at the National Nuclear Security Administration archives in Las Vegas fill in lacunas missing from the other collections.

These collections contain correspondence, reports, and laboratory and field notebooks. Using the field notebooks has given me the ability to relate the work of the Medical Section doctors and biologists very much as a story. The notebooks from Warren, Donaldson, Welander, and other AFL biologists are filled with wonderful sensory details and parenthetical remarks that bring them to life. Norton Wise has argued that scientists themselves rely on narrative to produce coherent stories about nature. "Explanations of the behavior of complex systems," he explains, "may always require a turn to historical narrative."[93] I have found that in their hand-written notebooks, these actors have told stories as much as they have logged values and tabulated data. Since the group of AFL biologists worked side by side for so long, their journals and correspondence reveal a richness in the personal relationships as well as in their scientific work. They complained about AEC bureaucrats and they talked about going to college football games as they wrote. Using these more personal sources, I have worked to bring life to the very cut and dry reports that give this dissertation the bulk of its scientific content.[94]

93 Norton Wise, "Science as (Historical) Narrative," *Erkenntnis* 75, no. 3 (November 2011), 349 – 376.

94 I am grateful to Mary Terrall who encouraged me to spend the winter quarter in 2016 diving into very dry AEC reports in order to figure out how to bring them to life during her history of the book course.

Beyond these traditional collections, archives, and sources, this project relies on oral histories from a variety of from outside the Medical Section scientists. The translated oral histories of doctors Michihiko Hachiya, courtesy of the Huntington Library, and Raisuke Shirabe, courtesy of the Nagasaki Association for Hibakusha's Medical Care, offer insights into the problems faced by *hibakusha* in the days and weeks after the bombings of Hiroshima and Nagasaki. Their firsthand stories of the bombings bring a depth to the second chapter that could not have existed had I only used US sources. Moreover, their interactions with Medical Section doctors should be more accessible to readers of English language scholarship. The same is true of the oral histories from the people of Rongelap Atoll, also in translation, that I use in chapter five. These personal reflections and recollections help to make their story of their interactions with the Seattle biologists after the 1954 Castle Bravo disaster sensible. Rongelapese sources also make the ecology and food systems at their home atoll more sensible to mainlander readers who have never visited the Marshalls.

Relying on this breadth of sources, the chapters of *Atomic Bodies, Atomic Landscapes* move from the 1940s through the 1960s. Chapter One, a detailed lab history, describes the foundation of the Applied Fisheries Laboratory. It charts the work of Lauren Donaldson, Art Welander, Kelshaw Bonham, and Dick Foster as they adopted Warren's animal x-ray research program. They learned to use an x-ray machine they Warren had secured for them. They also learned how to do histological analysis. This practice involved them dissecting fish, making very thin samples of organ tissue, and then interrogating those samples visually to identify radiation injuries. Over the course of 1944, they became adept in seeing damage done by x-rays to kidneys, livers, and even blood cells. They performed this expert work in the midst of the minutiae required to keep thousands of young salmon alive. They made fish feed, reared eggs, measured fingerlings, and took counts of how many fish died and developed deformities. Finally, they released salmon into the wild so that they could go out to the open ocean in order to mature. Since salmon return to their home stream the AFL biologists hoped that some of the salmon they released would return so that they could spawn them and engage in a multigenerational study of radiation's effects.

Chapter Two leaves the Seattle biologists to follow Warren's MED mission to Japan in the weeks after the bombings of Hiroshima and Nagasaki. Vignettes in the chapter point back to the 1920s and the foundations of the animal x-ray research program. In particular, we encounter Warren's x-ray research on dogs and his publication in the *Journal of the American Medical Association* in which he argues that data from dogs should reveal truths about human beings. We also see that Masao Tsuzuki did x-ray research on rabbits before the World War brought him and Warren into close contact in Tokyo just weeks after Hiroshima and Nagasaki were bombed. Despite common research and training foundations, the two men ended up disagreed about medical definitions regarding exposure to the bombs' radiation. Tsuzuki described a discrete atomic bomb disease. Warren denied any such thing existed. Amid their disagreement, we also meet local Japanese clinicians, Hachiya and Shirabe, who developed their own local understandings of the bombings.

Chapter Three returns to Washington State, to the plutonium production works at Hanford. This chapter follows Dick Foster after he left the AFL to become Donaldson's man in central Washington. He reproduced the animal x-ray tradition in his new lab, only he used radioactive reactor effluent from the F Pile to irradiate his salmon. The chapter follows the development of his lab and lab practice, explaining how he came to trust his data from his bench over data from the landscape at Hanford. This chapter closes by recounting a scientific dispute between Foster and his Hanford cronies and a group of sanitary engineers from the US Public Health Service and bureaucrats from the Washington D.C. headquarters of the AEC. It is a classic clash between local experts and D.C. outsiders. Foster weaponized his lab data against the Public Health Service officials who seemed sure that the radiation in the Columbia River was not as safe as the Hanford biologists said it was. Medical Section biology won the day.

Chapter Four takes the story to the Marshall Islands for the first time, for the atomic tests at Bikini Atoll in 1946. This chapter focuses on how Warren and Donaldson transformed their research program to accommodate field work. Certainly, the AFL had done field work in Washington state. But Crossroads presented them with a new situation because they would be studying the landscape and its biota directly after the detonation of two atomic bombs. Bikini's radioactive lagoon behaved very little like their organized lab on the mainland. The biologists had to make sense of their new research field site. Then they had to develop field practices that could help them collect data in this new and foreboding setting. Very importantly, they began to use electronic radiation meters, like Geiger counters, to produce data about radiation exposure. Using meters marked a transition for their research program because metrical data took its place alongside visual data from histological analysis. The story is one of scientific fluidity, of research that could be molded to answer established questions in a novel environment.

Chapter Five remains in the Marshalls, showing how the AFL Biologists applied their research program to human problems in the wake a massive thermonuclear test, Castle Bravo, in 1954. The shot produced much more force and fallout than the physicists from Los Alamos who designed it anticipated it would. Fallout traveled over 100 miles from Bikini Atoll to Rongelap Atoll, where just under 90 people made their homes. When it fell on their lagoon, beaches, gardens, and houses, it was thick like snow. So great were the radiation levels in the fallout that the Rongelapese began to experience the same symptoms that the *hibakusha* had nine years earlier. The navy evacuated the entire population a few days later. Donaldson and his team became tied up in the fallout disaster because the AEC and the administration of the Trust Territory of the Pacific, the US colonial administration in charge of the Marshalls, wanted to repatriate the Rongelapese. The biologists studied the food system at Rongelap to investigate whether local foodstuffs were safe after the fallout. After three years of exile, the Rongelapese returned home. The AFL biologists remained at Rongelap as well, working with members of the local population to study the safety of their diet. The biologists told the returnees that local foodstuffs, with the exception of coconut crabs, would not expose them to unsafe levels of radiation. But as the biologists did their research between 1957 and 1959, their relationship with the Rongelapese soured. Things got so bad that the Trust Territory administration forbad the biologists from traveling to Rongelap in 1960 to do field work. This year without research marked the beginning of the end for the biologists' research program in the Marshalls, since atmospheric testing ended in 1962 and biology designed to understand atomic bombs became needless. In the meantime, sickness stalked the Rongelapese, whose life experience showed that the radiation in their food, water, and land was not safe.

Atomic Bodies, Atomic Landscapes tells the story of doctors and biologists who found themselves at the center of the atomic age. This dissertation employs a historical viewpoint, trying to understand the scientist on their terms. By telling their stories I hope to fill out the broader atomic literature. I also hope that this project can speak, in some small way, to the contemporary situation. As I write this in March 2023, as children play and learn at their schools, as everyday people go about their everyday business across the globe, somewhere around 3,700 nuclear weapons are deployed by the world's atomic powers for operational use.[95] This should trouble any thoughtful person. Only a very small percentage of living humans can remember what atomic bombs actually did. Atomic Bodies, Atomic Landscapes reminds contemporary readers that the biological effects of radiation from atomic bombs are disastrous. I hope this reminder will encourage introspection amid our fraught global situation.

95 "Status of World Nuclear Forces," Federation of American Scientists, accessed 15 September 2022, https://fas.org/issues/nuclear-weapons/status-world-nuclear-forces/

Chapter 1

Laboratory Practices for the Biological Effects of Radiation

Introduction: A New Kind of Laboratory

What can a fish tell a scientist about the biological effects of nuclear fission in human beings? This was the question that Colonel Stafford Warren wanted Lauren Donaldson, a fisheries professor at the University of Washington, to answer in 1943. Donaldson knew a great deal about fish, in particular the salmon and steelhead trout endemic to the waterways of the Oregon, Washington, and British Columbia. But he know nothing about fission, the process of bombarding a heavy element like uranium with a neutron to make it release energy as it spilt. Neither did Donaldson know who Warren really was. When they first met on 21 August 1943 the fisheries biologist had no idea he was discussing a potential research contract with the chief of the Manhattan Engineer District's (MED) Medical Section. Warren organized the *tête-à-tête* through the Office of Scientific Research and Development in order to keep Donaldson in the dark about the fact that the new lab's proposed research would fit into the massive atomic effort within the Army Corps of Engineers.[1] The covert meeting went well and Donaldson retuned home to Seattle with plans to set up a laboratory that would expose salmon and steelhead to x-rays and then study effects of that exposure. Warren would get an answer about fission from Donaldson's x-rayed fish.

Warren believed that fish exposed to x-rays could anticipate the biological effects of radiation from fission in humans because he assumed that fission would behave like x-rays and because he

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1 Neal O. Hines, *Proving Ground: An Account of the Radiobiological Studies in the Pacific, 1946-1961* (Seattle: University of Washington Press, 1962), 9.

believed that animal research could accurately explain questions of human biology. As we will see in chapter two, Warren exposed dogs to radiation in the 1920s and published his results in the *Journal of the American Medical Association,* arguing that the results from his dog research were commensurable with humans.[2] In 1943, Donaldson knew little about the history of the x-ray research program that his lab was about to embark on and any connections between animal experimentation and human health. Instead, he thought the lab would engage in basic biological research about radiation effects over time. Geneticists like Herman Muller had been using x-rays for basic research since the early 1920s, using model organisms like *Drosophila melanogaster*.[3] Thinking along genetics lines, Donaldson designed one of the lab's first experiments to investigate the effects of low-level x-ray exposure over multiple generations of salmon. But Warren wanted no long-term study of low-level exposure. He wanted to know about the immediate effects of high-level exposure, especially as it related to the health of blood-forming organs and blood health itself.

This chapter offers a laboratory history of Warren and Donaldson's new venture in order to establish its research program as the foundation for the medical and environmental studies that grew up in the Medical Section. *Atomic Bodies, Atomic Landscapes* will show how Applied Fisheries Laboratory's (AFL) program informed US doctors in Hiroshima and Nagasaki, molded salmon research at the first plutonium reactors at the Hanford Engineer Works in Washington state, and morphed into a foundation for environmental research at the Pacific Proving Grounds in the US-occupied Marshall Islands after World War II. For now, however, answering "why a laboratory

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2 S.L. Warren and G.H. Whipple, "Roentgen-Ray Intoxication: Roentgenology in Man in the Light of Experiments Showing Sensitivity of Intestinal Epithelium," *Journal of the American Medical Association* 81, no. 20 (17 November 1923), 1673 – 1675.

3 Robert Kohler, *Lords of the Fly,* 1994.

history?" seems worthwhile. Historians of science have focused on the lab as a unit of study for some time. In terms of wanting to highlight the mundane details of how a lab produces new knowledge, this chapter follows the Bruno Latour and Steve Woolgar's 1987 classic *Laboratory Life*.[4] Their work revels in little details, at one point the describe a printer at length. This chapter dwells in the minutia as well. The particulars of how to manufacture fish feed, how to measure a salmon, and how to tag a dorsal fin matter for this story.[5] So does the laboratory's ability to create a scientific community.[6] With the AFL as a beachhead, Warren and Donaldson produced a cadre of scientists devoted to a very particular kind of radiological research that thrived for two decades. This chapter begins the long narrative by introducing Lauren Donaldson, Art Welander, Dick Foster, and Kelshaw Bonham. All these biologists would remain affiliated with the laboratory in Seattle throughout this story. Finally, this lab history places the AFL in its larger context as a federal installation.[7] The lab's science travelled because its main mission involved producing knowledge that solved government problems at government-administered sites.

To tell the story of the Applied Fisheries Laboratory biologists, I first examine how Lauren Donaldson and the team built their laboratory and treated subjects with radiation during the autumn of

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4 Bruno Latour and Steve Woolgar, *Laboratory Life: The Construction of Scientific Facts* (Princeton: Princeton University Press, 1987).

5 See: Harry Collins, *Changing Order: Replication and Induction in Scientific Practice* (Beverly Hills, California: Sage, 1985)

6 For a recent assessment of the social function of the lab, see: Robert Kohler, "Lab History: Reflections," *Isis* 99, no. 4 (2008), 761–768.

7 For lab histories focused on federal institutions, see: Peter Westwick, *The National Labs: Science in an American System, 1947 -1974* (Cambridge, Massachusetts: Harvard University Press, 2003) and Lillian Hoddeson, Adrienne Kolb, and Catherine Westfall. *Fermilab: Physics, the Frontier and Megascience* (Chicago: University of Chicago Press, 2011).

1943 and winter of 1944. Warren, who had been professor of radiology at the University of Rochester's Medical School before the war, worked to have them trained in the x-ray program that would come to be the core of their research. His laboratory tradition trusted in the bench. In 1943, the two most important techniques used by practitioners of the tradition were histological analysis of organ tissues in search of somatic insults and population statistics regarding development and mortality, a sort of animal epidemiology. But why did Warren arrange for a laboratory comprised of fisheries biologists? Why not study mammals if he wanted to learn about possible human effects? It turns out Warren justified the laboratory to Leslie Groves, commanding officer of the MED, by arguing that it would produce useful information about what could happen to the fisheries stocks in the Columbia River once the plutonium production reactors at the Hanford Engineer Works came online.[8] From the start, the lab would produce data useful for medical science and for the environmental sciences.

Second, I consider the lab's observation and data collection practices as they overtly began to create data that would mimic human exposure to an atomic bomb. In Winter 1944, Warren became more and more insistent that the laboratory produce quick data about fish exposed to high levels of radiation. 100 Roentgen exposures gave way to 1000 Roentgen exposures. As the device being designed at Los Alamos inched towards being a reality, the colonel's mind never strayed far from thoughts about what a fission bomb would do to a human population. Having never experienced fission before, he had to trust the knowledge that x-rays could give him. During this time, he and his lieutenants visited the Seattle laboratory repeatedly to learn about the research program's results and to see how the fisheries biologists managed to tease radiological data out of fish. Though Warren did not know the details of his own trip to see the human survivors of the first atomic bombs, he learned in

8 Leslie Groves, *Now it Can be Told: The Story of the Manhattan Project* (New York: Harper and Row, 1962), 82.

August 1945 that he would lead a team of doctors to Japan. Warren used AFL data to anticipate what kind of data he wanted to collect, or steal, from survivors of the atomic bombings.

Third, this chapter turns to the lab's quantification and statistical practices as they investigated insults to blood formation and the blood itself. This work required the use of new bench techniques and technologies as well as mathematical methods that were not native to fisheries biology. Photography, microscopy, and histological technique allowed the team to mathematize the fish as they counted sick and healthy cells. Blood cells became a focus for the lab because Warren, again concerned with humans, dictated that it be so. Precise ways of investigating the health of the blood created the need for statistical analysis at the laboratory in order to show that they actually found the effects of radiation, not insults produced by random chance or environmental circumstances. Statistical practice showed them that radiation was at work in the premature deaths and deformed cells of their fishy subjects. This success edified Donaldson and his men while allowing Warren to travel to Japan with little question in his mind about radiation could do.

The story of the bombings of Hiroshima and Nagasaki and of atomic testing in the Pacific and the Nevada deserts do not tend to begin with the stories of salmon bombarded with x-rays in a little laboratory on the north shore of Lake Washington. *Atomic Bodies*, *Atomic Landscapes* argues that they should. This chapter dives into the minutiae of how a laboratory program ties the fish, the *hibakusha*, and the irradiated test sites together. Lauren Donaldson's little lab anticipated a whole new atomic world.

Learning to Use X-Rays

On the face of it, the Manhattan Engineer District's Medical Section seemed an odd choice to organize a laboratory dedicated to understanding the biological effects of radiation on fish. But the District organized the Medical Section with a broad mandate. Stafford Warren enunciated the Section's responsibility in June 1943 for "the supervision of research designed to establish the presence of hazards and limitations to be set up for the elimination of health hazards in the various aspects of the project."[9] A professor at the University of Rochester's Medical School, Warren built his career in the 1920s and '30s as a radiologist interested in research on both animals and humans. He created moving x-ray films. He also somewhat accidentally stumbled on the technique for mammography in 1930.[10] Groves called on Warren to head the Medical Section from his laboratory in Rochester in March of 1943. There the Chief Medical Officer commanded a state-of-the-art million-volt x-ray machine in a space purpose-built for biological research.[11] Warren's scientific expertise and his experience with building a laboratory around radioactive technologies commended his unit as the natural home for research on the Colombia River effluent problem. While his home lab at Rochester would work on the question of radiation exposure during the war, it housed an important hematology group, the fish work needed to be close to the proverbial action.[12] Warren cast his gaze out west. Donaldson's name came up because he held a tenured position in the University of Washington's School of Fisheries, had worked for Washington's State Department of Hatcheries, and participated in the joint US-Canadian International Pacific Salmon Commission.[13] His connections with these networks would come in handy once the ambiguously named Applied Fisheries Laboratory got to work. To mask the project's connection to the atomic bomb project, Warren chose the Office of Scientific Research and

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9 Stafford Warren to Colonel K.D. Nichols, 17 June 1943, NV0714118, NNSA/NSO Nuclear Testing Archive, Las Vegas, Nevada (Hereafter cited as NTALV).

10 Lisa Cartwright, *Screening the Body: Tracking Medicine's Visual Culture* (Minneapolis: University of Minnesota Press, 1995), 126.

11 The Rochester Story, NV0707326, NTALV.

12 Ibid.

13 Hines, *Proving Ground*, 8.

Development as buffer between him and Donaldson. The two men met at that organization's Washington DC headquarters on 21 August to discuss the new laboratory. Donaldson learned nothing of the Hanford reactors or the bomb.

To study irradiated fish, the lab needed a radiation source that they could reasonably use. But neither Donaldson, nor Foster, nor Bonham, nor Welander had any experience with radiation in general or x-rays in particular. Warren sent his right-hand man in Rochester to Seattle on 20 September to remedy this. Francis Bishop, the self-taught technician in the Division of Biophysics at the university, arrived bearing decades of radiological expertise. He also brought with him the lab's x-ray machine, the Picker-Waite Shockproof.

Figure 1.1. The Picker Waite Shockproof X-ray Unit at the AFL. Source: UWFL-1, "Equipment and Procedures used in Irradiation of Fish with X-Rays." UWLRB, Box 9, Volume 1, Figure 1. University of Washington Libraries, Special Collections, Laboratory of Radiation Biology records. Accession no. 00-065. Republished with permission of University of Washington Libraries. *Page 51.*

In the weeks between Donaldson's meeting with Warren and Bishop's arrival, the lab's team had taken over the hatchery building at the School of Fisheries and began moving furniture. Donaldson recalled, "it was necessary to remove six of the hatchery troughs to make room for the installation of the X-ray equipment."[14] That Bishop brought the Picker-Waite from Strong Memorial Hospital in Rochester, where the university conducted its clinical work, offers a first glimpse of the porous boundary between human medicine and animal biology that would come to characterize the work of the Medical Section's labs. Arriving in Seattle, the Picker-Waite machine had come a long way from its manufacture in Cleveland and hospital use in Rochester. It had also come a long way in terms of use. No longer revealing maladies in humans, it would induce them in fish. Bishop installed the machine and calibrated it to work at a strength of 200 kilovolts and 20 megaamperes, about one-fifth the power of the machine in Rochester.[15] Bishop also calibrated the lab's Victoreen Condenser R-Meter, the device that allowed the biologists to calibrate the x-ray machine so that they could treat fish up to a specific number of Roentgens.

Bishop's visit set the lab up with technologies and some rudimentary techniques for using radiation to transform fish, but Donaldson and the team needed more direction than Bishop's short visit afforded. The two men struck up a robust correspondence. Perhaps Bishop's most important letter arrived in Donaldson's hands on 11 October. He had requested radiological literature from Bishop, who in turn pointed him to Benjamin Duggar's two volume 1936 collection *Biological Effects of Radiation*. "Dr. Warren," Bishop relayed, "has suggested that you buy or otherwise obtain a complete set since it

14 UWFL-1, "Equipment and Procedures Used in the Study of the Effects of Irradiation of Fish with X-Rays," Box 9, Volume 1, UWLRB.

15 Ibid.

contains a good deal of data which may be helpful."[16] The work opened Donaldson's eyes to the breadth and depth of the research program guiding his own lab. Duggar held the chair in plant physiology and applied botany at the University of Wisconsin and headed the National Research Council's Committee on Radiation in the 1930s. The Committee gathered a grab bag of researchers interested in the question of radiation and biology. Physicists; meteorologists; a biostatistician; chemists; physiologists; animal physiologists; zoologists; biologists; a medical doctor; biochemists; a silviculturalist; botanists; plant biologists; plant physiologists; geneticists; and pathologists contributed chapters to the work.[17] Warren was the medical doctor. The good people at the General Electric X-ray Corporation defrayed much of the work's cost. The two volumes thus constituted the result of a well-funded multi-year effort to amass research on x-rays, γ rays, α and β particles as well as on a host of animals exposed to these radiations, and some research on humans. Duggar's volume became a touchstone for the lab as the Seattle biologists as they irradiated fish.

As the biologists embraced their new radiological research program, they readily employed familiar material practices from fisheries biology. Donaldson responded to the letter in which Bishop suggested Duggar by sharing expertise of his own. Having seen the fishery lab, he resolved to raise and research his own fish, guppies rather than salmon. He asked that Donaldson send him the lab's fish food recipe. In a letter four days later, Donaldson obliged:

> 30% dried liver
> 30% quilcene meal (quilcene meal is prepared from air dried spawned out salmon to which 5% oat flour and 5% kelp meal have been added)
> 10% dried tomatoes
> 10% soy bean meal
> 10% ground whole oats
> 5% live yeast
> 5% wheat germ[18]

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16 Bishop to Donaldson, 11 October 1943, Box 1, Folder 8, UWLRB.

17 Duggar, ed., *Biological Effects of Radiation*, v – x.

18 Donaldson to Bishop, 15 October 1943, Folder 8, Box 1, UWLRB.

A sample of the food arrived with the letter. The recipe highlighted Donaldson's position within the world of Pacific Northwest fisheries science and its network of hatcheries. The US Fish and Wildlife Service developed Quilcene meal at its hatchery near the eponymous town on the Olympic Peninsula. Since pacific salmon die after spawning, the meal put them to one last, good use. Kelp abounded in the Puget Sound, providing an abundant and nutritive resource. The Seattle biologists had both in abundance at their new lab. The food source was so important that Donaldson made sure the food preparation room abutted the lab's main room, a short walk from tank to butcher's block.[19] Unfortunately for Bishop, who had no local salmon nor any kelp in Rochester, the recipe likely disappointed. The local knowledge and environmental circumstances that helped the Seattle lab thrive did not translate to Rochester.

In late October, the biologists turned to the state hatcheries system for the most important technology in their lab, the fist who would embody and reveal radiation's biological effects. The biologists arrived on 26 October from the state's Green River Hatchery on Soos Creek in Auburn, about 30 miles south of campus to collect some. They marked the occasion by beginning a log book to track their new research subjects. "Received fifteen (15) chinook salmon (male) from Auburn at approximately 11:45 A.M. All fish were in good condition."[20] These fish set eyes on the lab for the first time that morning. The site would have seemed familiar, since the lab approximated the layout of a state hatchery, though on a smaller scale. Both the facility at Green River and the Seattle lab relied on controlled places indoors and out. The 15 chinook males may have gone right into a cement trough in

19 Figure 9, UWFL-1, UWLRB.

20 Notebook, Section I, 26 October 1943, UWLRB.

the main room upon their arrival. More likely, though, the chinook went immediately into one of the lab's six outdoor ponds. Much larger than the indoor troughs, the ponds could better house adult fish.

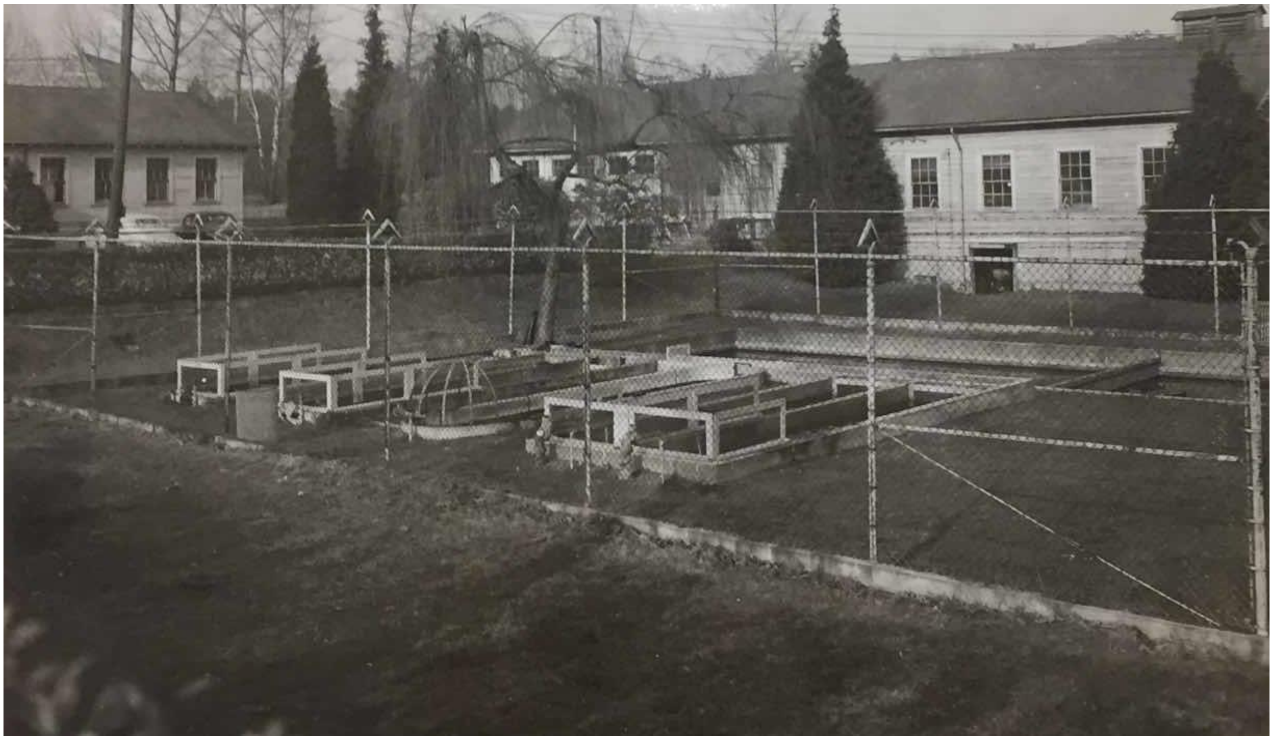

Figure 1.2. Rearing and Holding Ponds next to the main laboratory space at the AFL. Source: UWFL-1, "Equipment and Procedures used in Irradiation of Fish with X-Rays." UWLRB, Box 9, Volume 1, Figure 12. University of Washington Libraries, Special Collections, Laboratory of Radiation Biology records. Accession no. 00-065. Republished with permission of University of Washington Libraries.

The largest pond measured "49.5 feet in length, 19 feet wide and 39 inches deep, with the bottom slightly sloping."[21] This tank recreated the physiology of a river's channel where it meets the sea, a fluvial home for adult salmonoids. Thus, the fish arriving at the lab entered a complex space. Open to the weather and the elements and engineered to mimic wild habitat, the ponds participated in some aspects of what could be considered natural. On the other hand, the biologists managed the ponds. They maintained the pumps and filters that circulated water. They made the regulated the food available for the fish. They noted escapes, "one unexposed steelhead jumped out of the pond last night and was

21 UWFL-1, UWLRB. Also see, Figure 12.

found dead this morning."[22] Quasi-wild but rigorously administered places, the ponds a constitute second porous boundary at the lab, between the built and controlled and the natural and wild. The biologists needed space, needed natural spaces, for their fisheries work. Their researches moved seamlessly, at least in their imagination, between indoors and out-of-doors, between the lab and the landscape.

The biologists needed the fish from Soos Creek to start producing data immediately, even at this early hour the lab felt the need for expedience that drove the entire MED. After only a few days at the lab, the fish found themselves in the purpose-built room that held the Picker-Waite's massive, movable x-ray tube.

Figure 1.3. X-ray tube and moveable tank used for irradiating fish in the canvas retaining sling. Source: UWFL-1, "Equipment and Procedures used in Irradiation of Fish with X-Rays." UWLRB, Box 9, Volume 1, Figure 2. University of Washington Libraries, Special Collections, Laboratory of Radiation Biology records. Accession no. 00-065. Republished with permission of University of Washington Libraries.

22 Notebook, Section I, 7 December 1943, UWLRB.

Lead sheets ¼ inch thick lined the rooms walls and a window made of leaden glass four-fifths of an inch wide allowed the operator in the main room to see inside.[23] To irradiate the fish, the team placed the adult fish into a sling. A long canvas tube that hung horizontally in the tank, it immobilized the fish while still allowing them to breath by means of water flowing over their gills.[24] Laden with eggs, females took longer to irradiate than their future mates. All the fish got a short reprieve in the middle of their treatment. "After one half of the total exposure had been administered the fish was turned end for end and the other side irradiated."[25] Once treated, the October chinook received tags. "To identify the individual fish, numbered, colored, plastic tags were fastened to the fish by inserting a nickel-coated pin through the base of the dorsal fin..."[26] Those irradiated to 100 Roentgens sported a red and yellow model. 50 Roentgen fish wore white and yellow, 25 Roentgen fish red and white, and the 0 Roentgen control group wore double white tags.[27] When the sun set on 30 October 1943, the lab had its first lot of irradiated salmon in hand.

These were the fish whom the biologists would spawn in order to study the effects of x-ray exposure on unfertilized eggs. Warren had tasked Donaldson with investigating the biological effects of radiation over time, over generations. Hence, spawning began on 31 October and continued to 4 November:

> In order to get all of the eggs, the females, which would normally die after spawning, were killed and the body cavities opened, allowing the eggs to flow into an empty pan. For the purposes of this experiment the eggs from one female were usually divided into lots before being fertilized with the sperm induced to flow from a ripe male salmon by a milking action of the fingers along the belly toward the vent.[28]

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23 UWFL-1, UWLRB.

24 See: Figure 3, UWFL-1, UWLRB.

25 UWFL-6, UWLRB.

26 UWFL-1, UWLRB.

27 Notebook, Section I, 29 October 1943, UWLRB.

28 UWFL-6, UWLRB.

Once fertilized, the biologists placed the eggs in the lab's homemade drip-incubator. Not unlike a flat file cabinet for maps, the incubator held 144 trays. "The water dripping from above provided cool, oxygen-laden water," just like in the shallows of the mountain tributaries in which chinook historically spawned.[29] The eggs lived segregated lives in the drip-incubator. Donaldson and the team kept each lot separate because each lot bore the imprint of the particular combination of its parents' irradiation. Some lots had a control father and a 100 r mother. Others a control mother and a 100 r father. Others had both control parents or both 100 r parents. The lab created 34 egg lots to cover the host of exposure patterns. The lives of these eggs, along with their eventual offspring and their parents, the original October chinook, became the content of the lab's report entitled, "Preliminary Report Concerning X-ray Effects upon Chinook Salmon (*Oncorhynchus tschawytscha* Walbaum) Observed Through More Than One Generation," or UWFL-6 in report numbering scheme the lab eventually adopted after the war.[30]

After irradiating, spawning, and killing the first chinook, the lab turned to the mundane tasks of rearing and establishing their research populations. They hit a hitch on 5 November when they broke their Victoreen meter. Unable to fix it themselves Dick Foster took it next day to Standard X-Ray in downtown Seattle. When the experts there told him they could not fix it, Foster packed it up and Donaldson shipped it to Victoreen, which like the Picker X-Ray Corporation was headquartered in Cleveland.[31] It took about a month for them to get the meter back. Donaldson and Bishop kept up their vigorous correspondence. On 15 November, Bishop suggested *Radiologic Physics* to the lab's director for his edification.[32] The same day, Donaldson and Foster began radiating sockeye salmon from Cultus

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29 UWFL-1, Figure 8, UWLRB.

30 UWFL-6, Frontispiece, UWLRB.

31 Notebook, Section I, 8 November 1943, MSS Donaldson.

32 Bishop to Donaldson, 15 November 1943, Folder 8, Box 1, UWLRB.

Lake in British Columbia up to 100 r.[33] Donaldson and Foster had researched stock from Cultus Lake before, so irradiating these sockeye showed the pair's preference for using fish stock from sites they knew and with which they maintained professional connections. The Cultus Lake sockeye remained healthy after treatment. Treating the sockeye did not take up all their time, the team also began constructing glass-fronted wooden tanks. This required that they contract with a local creamery supply company in Seattle to purchase waterproof primer and enamel to protect the tanks' marine plywood walls.[34] The lab's fish would grow from fry into fingerlings in tanks coated and waterproofed with paint designed for industrial dairy usage. From the get-go, the search for the biological effects of radiation in the Medical Section proceeded in a do-it-yourself style. The new tanks looked good and, with the exception of the Victoreen, everything moved along swimmingly in November. The egg lots spawned from the original chinook did experience some mortality during this time. For example, by 3 December, one 100 r egg lot suffered 142 mortalities. The dead eggs were in turn "picked off," removed from their tray by the biologists.[35] Still, mortality rates seemed within the noise range and the remainder of the developing eggs throve. They all developed eyes by the end of November, right on schedule.

Things went too smoothly from Warren's vantage point in Rochester, he wanted the lab to produce fish populations that showed real radiation-induced injuries. In early December, the colonel admitted to Hanford Thayer, his liaison at the Seattle Corps of Engineers office, that:

> I am very interested in the fact that there are no physiological results of several 100 r dosage to the adult fish.[36]

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33 Notebook, Section I, 15 November 1943, MSS Donaldson.

34 Donaldson to Bishop, 18 November 1943, Folder 8, Box 1, UWLRB.

35 UWFL-6, Table 2, UWLRB.

36 Warren to Thayer, 6 December 1943, Folder 23, Box 3, UWLRB.

Then he continued:

> I believe that Dr. Donaldson would be wise to follow Mr. Bishop's advise [sic] of using 10 times the present maximum exposure and if that doesn't show results in a short time, increase the dosage again times ten.[37]

Warren knew about the effects of high x-ray exposure in mammals at Rochester, including "a bloody and fluid diarrhea and death."[38] He also knew about these symptoms from his own researches on dogs in the 1920s and '30s.[39] Warren wanted to know about the somatic results of extreme exposure. He concluded his letter to Thayer by asking him to pass on these concerns to Donaldson and arrange a trip for the director back to Rochester for further conversation. Donaldson responded directly to Warren a week later, but his response did not fully internalize Warren's sense of urgency. The biologist explained his plans to irradiate a new batch of chinook eggs from Soos Creek. "We plan to use 25 r, 50 r, and 100 r."[40] Scarcely the leap Warren desired. Absent the Medical Officer's intervention, this research proceeded. On 16 December Foster and Donaldson took a truck from the state motor pool to Soos Creek to collect 11,960 chinook eggs.[41] They irradiated the new eggs per the plan two days later. But Warren was coming to Seattle and the plan would change.

Increased Exposures

Warren arrived in Seattle on 19 January to make it clear to Donaldson that his lab needed to produce results about gross exposure to x-rays as quickly as possible. The colonel's prodding worked even before he arrived. In anticipation of the visit, Kelshaw Bonham initiated a hasty experiment on 13

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37 Ibid.

38 Ibid.

39 See Chapter 2.

40 Donaldson to Warren, 14 December 1943, Folder 23, Box 3, UWLRB.

41 Notebook, Section I, 16 December 1943, MSS Donaldson.

January that employed just eight adult silver salmon.[42] He treated them at 25 r, 50 r, 100 r, 250 r, 500 r, and 1000 r, leaving two unexposed control fish. Bonham wrote up their lives in the report "Histological Effect of X-Ray on Adult Male Silver Salmon, *Oncorhynchus kisutch* (Walbaum)" or UWFL-4.[43] He designed the experiment as a direct response to Warren's call to up the maximum exposure tenfold. When Warren arrived on the 19th, the changes pleased him. He met with Thayer, Donaldson, Foster, and Bonham to talk things over. The next day Warren observed the autopsy of one of Bonham's silvers.[44] After the display, Donaldson and Warren had time to go fishing together. Presumably they had some candid conversation about the future of the lab's work. Warren left that night. More changes lay in store. On 25 January, Dick Foster took the truck down to Soos Creek to collect 13,000 chinook eggs. Back at the lab, he turned these over to Art Welander. He re-calibrated the Picker-Waite over the next two days in order to quickly expose these eggs to high doses of radiation. On the 27th, Welander treated egg lots with 250 r, 500 r, 1000 r, and 2500 r. The next day he exposed egg lots to 5000 r and on the last day of the month exposed another set of lots to 10,000 r.[45] Warren's demand became reality.

By the end of January, the biologists were running three experiments at once, positioning them to create long-term data about low exposures and short-term data about high exposures. The egg lots from the original October and November chinook began hatching in late December. By 6 January the biologists moved all the newly hatched fry into the troughs in the main room.[46] The team referred to

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42 UWFL-4, "Histological Effect of X-Ray on Adult Male Silver Salmon, *Oncorhynchus kisutch* (Walbaum)," 2, Volume 1, Box 9, UWLRB.

43 UWFL-4, Frontispiece, UWLRB.

44 Notebook, Section I, 19 January 1944, MSS Donaldson.

45 UWFL-2, Arthur Welander, "Studies of the Effects of Roentgen Rays on the Growth and Development of the Embryos and Larvae of the Chinook Salmon (*Oncorhynchus tschawytscha*), Box 9, Volume 2, UWLRB.

46 UWFL-6, UWLRB.

this first batch of offspring by number: lots 1 – 34. Art Welander, meanwhile, took over responsibility for the chinook eggs that were treated in mid-December as well as those treated in the last week of January. The lab called these the A-lots in order to distinguish them from their older cousins in lots 1 - 34. This second group of chinook eggs lived their entire lives in the laboratory. Welander wrote up the A-lots' lives in his dissertation, "Studies of the Effect of Roentgen Rays on the Growth and Development of the Embryos and Larvae of the Chinook Salmon (*Oncorhynchus tschawytscha*)" or UWFL-2.[47] He used them to develop statistical practices that would become normative for the lab's work. He also honed his histological practice with them. Taking measurements and collecting samples took up the bulk of his time, just as it did for Bonham with his adult silvers. The lab notebook entry from 11 January indicated the busyness that juggling multiple experiments at the same time created. "Took egg pick off of the A Chinook series, abnormality pick off of the Chinook lots 1 though 34 and fry pick off of the Chinook egg lots No. 1 – 34. Worked on summary table of the Chinook egg lots."[48]

Over the course of the month, Welander mainly collected the kind of data that made up the stuff of the lab's research program. He took mortality data and histological samples, to start looking at cell deformations, from the A-lots. By documenting mortality from the egg lots, the lab could quantify how the exposure of adults affected their offspring. The lab needed precise counts, so Welander tried to account for all the fish in each lot when he tallied mortality. For example, one lot spawned from two 100 r parents suffered losses of 479 fry by the end of January. Only 2121 of the original offspring remained in early February.[49] Welander explained in his final report that "the mortalities of the treated groups were significantly greater than the control group for those in which the males were irradiated

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47 UWFL-2, Frontispiece, UWLRB.

48 Notebook, Section I, 11 January 1944, MSS Donaldson.

49 Ibid.

and not significantly different for those in which the males were not irradiated."[50] Busy with lab work in winter 1944, Welander would only do the statistical analysis that proved this assessment in the summer of 1944. In the meantime, he counted mortalities, picked dead chinook fry out of the 1-34 lots and picked off dead eggs from the A-lots. He also took live eggs, which he sliced for histological study.

Bonham spent the end of January and beginning of February taking tissue samples from his remaining silvers. He also sectioned dead silvers for histological study. To take tissue samples, he immobilized each adult fish in a home-made "straight jacket" that used canvass straps to pin the fish to a wooden board.[51] Bonham did not describe how he took skin samples, but he and Donaldson had worried about how to do this without irredeemably wounding the fish. Donaldson wrote to Bishop for advice in December and Bishop obliged him with some suggestions, including a design for a totally new biopsy device that employed piano wire as a means of cutting skin.[52] In lieu of this, Bishop also suggested a modification to a surgical implement, the Lowsley Prostatic Biopsy Punch, another technological bridge between humans and fish.[53] At any rate, Bonham took tissue samples from the silvers every 96 hours and prepared them for mounting on slides. To preserve tissue samples, Bonham first immersed them in Bouin's solution. Created by French biologist Pol Bouin in 1897, the mixture of acids and formaldehyde fixes dead tissues. After 24 hours, Bonham moved the tissues to a bath of 70% ethyl alcohol. From there, he dehydrated the samples and embedded them in paraffin. Encased and immobilized, he could then cut sections five microns in width by very carefully using a knife. The

50 UWFL-6, UWLRB.

51 UWFL-1, Figure 19, UWLRB.

52 Bishop to Donaldson, 12 January 1944, Box 1, Folder 8, UWLRB.

53 Ibid.

samples could then be stained red with the organic dye hematoxylin.[54] Bonham taught this technique to Welander, who did not immediately perfect the highly delicate procedure. The two men's work highlights the importance developing bench technique for investigating the biological effects of radiation. Whether eggs, fry, fingerlings, or mature adults, the bodies of exposed fish had to go through a series of chemical and physical transformations before their tissues and cells could yield quantifiable data. Controlled lab space made the work of the blade and the lens possible.

As February progressed, the growing chinook hatchlings created logistical complications when they transitioned from fry, who feed from their yolk sacks, to fingerlings, who must find their food. The next day, they left their trough and moved into one of the lab's tanks with a plate glass front. For the first time in their lives, they mingled with other offspring from the October and November spawnings. The lab lacked space, so the biologists joined lots with similar exposures. Lots 24, 26, and 31 joined each other on the 12th, each came from two parents treated to 100 r. They found their new home together in tank number nine.[55] 0 r control lots came together in tank number 10. The chinook fry from the A-lots promptly moved into the newly vacated troughs. Welander focused intensely on these fish for the time being, following Warren's mandate to zero in on the effects of very high exposures. He subjected them to a thorough measurement regime. Once a week, he sacrificed somewhere between four and 10 individuals so he could weigh them, measure their length, and sometimes prepare them for histology. To find length, he removed them from their alcohol bath after 24 hours and then used Vernier calipers and a dissecting microscope.[56] He measured "standard length," from the snout to the base of

54 UWFL-4, UWLRB.

55 Notebook, Section I, 12 February 1944, MSS Donaldson.

56 UWFL-2, UWLRB.

the caudal fin, the tail.[57] Here we see him using a practice and norm standard to fisheries biology. He then calculated mean lengths and the standard deviation for each lot. The goal of quantifying the biological effects of radiation began to take shape.

As February slid into March and April the biologists eased into the rhythm of maintaining and measuring their research populations. Ennui set in. The lab notebook read “routine care of fish” or “routine care of test animals.”[58] These lackadaisical accounts masked important developments. On 13 March, the last of the A-lot fry that had been irradiated to 10,000 r had died.[59] The last of those irradiated to 5000 r died two days later and the 2500 r lots only survived six days past that.[60] Their short lives from the end of January to the middle of March fulfilled Warren’s desire for fish treated to the point of significant somatic insult. Welander reported that as death neared, “the fish in these groups were very weak, almost unable to swim, the heart beat in each was slow and spasmodic, and many seemed unable to… move the lower jaw normally in respiration.”[61] These highly irradiated fish also appeared wan, with a “comparative lack of pigment… as compared to control fish.”[62] Though the highly irradiated fish died, the A-lot chinook irradiated to up 1000 r survived and Welander’s study continued. While he furiously worked to take data on dying chinook, Welander and Foster worked on honing their photographic technique. Just a day before the last of the 10,000 r A-lot individuals died, “Dr. Bonham took pictures of kidney tissues and experimented on best method of taking

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57 Ibid.

58 Notebook, Section I, 22 and 24 February 1944, MSS Donaldson.

59 Notebook, Section I, 13 March 1944, MSS Donaldson.

60 UWFL-2, Table 2, UWLRB.

61 UWFL-2, UWLRB.

62 Ibid.

photomicrographs of tissue. Labeled slides."[63] The lab's researches came to the point at which they found as much value in the dead as in the living.

Though the team spent significant time in the Spring working on laboratory technique, they also began preparing for a new deadline that would move their research from the lab into the wild. Lots 1 – 34 had grown by leaps and bounds. Now five months old, they overtaxed their tank space even after the constant picking off of dead individuals and subjects for histology. On 20 March, the team started reducing other lots of offspring from the original October chinook down to 1000 individuals. They took "surplus fish" to Issaquah Creek, east of Seattle, to be released. Hundreds of chinooks whose parents had been irradiated entered the local biome.[64] Donaldson made no mention of any concern that the fish might harm local, wild populations. By freeing laboratory irradiated fish in a wild creek, the team displayed their tacit understanding that local environments could absorb the effects of radiation. Treated fish could mate with wild fish, Donaldson did not bat an eye. As the bulk of the offspring from the October chinook found freedom in the foothills of the Cascades, tanks nine and 10 suffered no attrition. These offspring of two 100 r parents or two 0 r parents, representing the ends of the exposure spectrum, received "more room to grow and develop. They are to be held for later marking experiments."[65] Donaldson had decided that he would release these two groups into the wild to mature and hopefully return as adults ready to spawn. The lab's research approached a critical juncture, when treated fish would leave the confines of inside troughs and tanks and even of outside ponds in order to travel down a freshwater river and out into the salty Puget Sound and the vast expanses of the north Pacific. "The chinook salmon," Donaldson would write of these fingerlings, "must migrate to the sea or

63 Notebook, Section I, 12 March 1944, MSS Donaldson.

64 Daily Log, March thru September, 21 March 1944, MSS Donaldson.

65 Daily Log, 20 March 1944, MSS Donaldson.

it will die."[66] The lab had to let go of its fish, if they were to create the kind of useful data that could anticipate the effects of fission on populations of wild salmon that naturally migrated from the Columbia to the open ocean.

Bishop and Warren visited the lab as the team prepared to set loose their first chinook into the wild. Bishop came first, on 20 April. "The day was spent in conference with him on normal and abnormal histology of fishs [sic]."[67] The team started off the day by taking tissue samples, a blood count, and a hemoglobin percentage measure from one of Bonham's rainbow trout. Then they picked one of the original chinook fingerlings each from tanks one through 10 for histological practice. With Bishop on hand, Bonham measured them and then made a series of cuts, taking seven sections from each fish. His lab technique shone for the visitor from Rochester. Warren arrived for a conference the following day, during which time "Mr. Tomlin took some pictures of the personel [sic] and Dr. Warren and Dr. Bishop."[68] The team knew Tomlin well as he was the local Corps of Engineers photographer and had visited the lab to take pictures of fish on a number of occasions. The mood in these pictures appears jovial, upbeat. I suspect that by this point Donaldson, Foster, Bonham, and Welander became aware, in some way, of their participation in the atomic project.[69] Certainly, after this all-hands meeting there would never be an instance of confusion and cross purposes as there had been the previous December. On the contrary, these days together indicated the beginning of a close and long relationship between Warren and Donaldson, in which the former acted as patron and the latter industrious disciple.

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66 UWFL-6, UWLRB.

67 Daily Log, 20 April 1944, MSS Donaldson.

68 Daily Log, 21 April 1944, MSS Donaldson

69 Daily Log, 22 April 1944, MSS Donaldson

Warren's schedule only allowed him one day in Seattle, but Bishop remained and spent the next day discussing photographic technique with Tomlin and the team.

At this point, Donaldson and the team had to begin preparations in earnest to release the October chinook into the Samish River, roughly 70 miles north of campus. On the 28th of April they weighed and measured 800 of the fingerlings from the lots that would not take part in the release experiment. The team developed a creative tool to speedily measure length. To a metal funnel they attached a curved piece of glass tube which "just allowed the fish to pass through it but gave the maximum amount of restriction to their wiggling movements."[70] They could pour in a dozen or so fish at at time. The human measurer trapped the fingerling at the horizontal end of the tube by using his thumb as a stopper. He then took the length with a compass. The whole contraption sat above a tank, so the liberated fingerling fell into the water after being measured. Having been turned into data, the 7960 fingerlings not designated for the experiment "were planted in the Skykomish River."[71] Like Issaquah Creek, this waterway became part of the lab's useful geography, tangential to its core experimentation but necessary for its day-to-day functioning.

Unlike the fish released hodgepodge into the Skykomish, the fish that would be released in the Samish River required markings more substantial than the multi-colored tags that classified them in the lab. Marking the fish would tie them to the lab even as they swam freely in the wild. "The accepted method now for marking small salmonoids with the expectancy to recover them… as adults in the fishery or on the spawning beds," Donaldson explained to a curious Bishop, "is to clip off one or more fins – and hope the fish can survive this mutilation."[72] By 1944, fisheries scientists in the Pacific

70 UWFL-1, UWLRB.

71 Daily Log, 28 April 1944, MSS Donaldson.

72 Donaldson to Bishop, 26 October 1943, Box 1, Folder 8, UWLRB.

Northwest had organized a strictly regulated marking scheme. Donaldson used his connection with the State Department of Fisheries to acquire two marking combinations. Between 29 April and 8 May, the lab marked 4,835 100 r chinook "by the removal of the adipose and left ventral fins" and 4,844 0 r control fingerlings "by the removal of the adipose and right ventral fins."[73] Cutting off fins created so much work that even the lab's secretary joined in. Marie Beach marked 644 fingerlings.[74] Donaldson's description makes the process seem almost sanitary. Of course, it was not. During the week of marking, Donaldson took two-day trips, one to Bonneville Dam and another to the federal hatchery in Leavenworth, Washington, to take delivery of new stock for the lab.[75] Perhaps he did so to catch a break from the slippery, bloody, smelly work of guaranteeing the lab's proprietary rights over its irradiated research subjects.

The marked fish felt the current of a real river for the first time in their lives about one mile upstream from the weir at the state hatchery on the Samish River. They had entered the river above the weir, since the hatchery could place traps at the concrete structure to capture them when they instinctually returned to spawn. Despite the intensive record keeping that that team had maintained within the lab, the numbers did not add up when it came time to release the fish. Somehow 75 of the 100 r fingerlings managed to disappear. So did 66 control fingerlings. Rather than worry about their earlier pick off counts, they noted that these escapees "probably jumped out or went down the drain."[76] The team could smooth out the losses by means of statistics when the time came to crunch the numbers. At the moment, the successful liberation of the remaining fingerlings mattered most.

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73 Donaldson to Fred Foster, Director Washington State Fisheries, 19 May 1944, Folder 22, Box 9, MSS Donaldson.

74 Daily Log, 4 May 1944, MSS Donaldson.

75 Daily Log, 2 and 6 May 1944, MSS Donaldson.

76 Ibid.

Donaldson liberated the 100 r fingerlings on 11 May. Foster and Bonham liberated the control fingerlings the next day. Nearly 10,000 fish, which had never lived outside the bounds of the University of Washington's campus took downstream past farms and fields to the mudflats where the Samish River meets Samish Bay. From there they passed Sinclair, Lummi, and Orcas Islands if they went north towards the Strait of Georgia and Vancouver. They would have passed Fidalgo Island if they traveled south to the Salish Sea. Either way, the wide, open Pacific awaited them. Into it they carried the effect of x-rays from the Picker-Waite machine.

By April 1943, Donaldson and his staff of biologist at the Applied Fisheries Laboratory had managed to rear, irradiate, and either kill or release thousands of salmon. The tracked mortality. They measured how big fish grew. They looked at tissues and at cells under the microscope in order to find traces of radiation's power to destroy. At the behest of their colonel, the civilian scientists ran multiple experiments that designed to show the effects of radiation over the long-term and the effects of excessive amounts of radiation in the short term. All the while, and unknown to the Seattle biologists the MED physicists plugged away at designing bombs fueled by Oak Ridge enriched uranium and Hanford plutonium. Every day it became more and more likely that the humans whom the fish anticipated, exposed to radiation from the new devices, would really exist.

Blood and Quantification

With the chinook liberated at Samish Creek, the biologists took the summer of 1943 to zero in on the creating the kind of somatic data for which Warren longed. They dissected, preserved, counted, tabulated, graphed, and photographed the irradiated chinook, silvers, and steelhead that remained in the lab. They innovated viewing technologies and techniques so that they could look at the cells, particularly in blood forming organs, with precision. They also engaged in a typically medical pursuit, the collection of blood samples to count the abundance of red and white blood cells. With cell counts and blood counts in hand, the team used statistical methods to show that radiation, rather than the environment, heredity, or random chance, had actually created observable somatic insults within the bodies of exposed individuals and populations. The biologists also tried their hand a micrography, developing competence in a technique that would become central to their practice. All this work marked an expansion of their efforts to organize and manipulate their researches to produce quantified data.

Warren had again inserted himself into the lab's work in May, writing to Donaldson with a sort of question about blood formation in salmon. The Chief Medical Officer had experience as a research anatomist working with mammals, so his visit in April raised a novel question in his mind. "The fact that the fish lacks a very definite bone-marrow has been intriguing me ever since my visit."[77] Unlike familiar mammals who produced blood in their bone marrow, fish did not. Blood production interested Warren because mitosis occurs so quickly and regularly in blood forming centers within the body. Accordingly, they respond to even short radiation exposures with more intensity than other regions of the body. Deformed blood cells move throughout the body, carrying the imprint of radiation long after the moment of exposure. Warren wanted to know where salmon and steelhead hid their hemopoietic spaces. He concluded his letter to Donaldson by remarking, "it will be important to know whether the irradiation will effect the development and function of these blood-forming centers if and when they are located."[78] The chief of the medical section surely had the problem of insults to blood formation in human beings exposed to an atomic bomb on his mind by this point. He needed to know just how his lab's fishy subjects could help answer questions about future human subjects.

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77 Warren to Donaldson, 4 May 1944, Box 3, Folder 23, UWLRB.

78 Ibid.

In response, Donaldson tasked Bonham with project of inspecting the literature to locate the salmons' hemopoietic regions. He turned to the work of two anatomists at the University of Virginia Medical School. Harvey Wilson and Carl Speidel had done work on blood formation in boneless fish and salamanders in the late 1920s and early 1930s in order to trace the evolution of hemopoiesis in vertebrates.[79] Bonham passed this on to Warren, "Since your visit we have had opportunity to look up the literature and have found the work of Jordan and Speidel on blood formation in fishes to be enlightening. It appears that the kidney of fishes is the primary blood-forming organ."[80] Warren's second visit to the lab had a focusing effect on its researches much as his first visit had. The team would interrogate blood and blood formation. "We shall according to your suggestion," Bonham concluded, "be on the lookout for changes in blood picture as a result of irradiation."[81] Doing so required finding and quantifying the blood forming spaces within the lab's fish.

Bonham and Welander took to the task of studying blood and blood formation in late May 1944. On the 29th, they hosted Hymer Friedell, Warren's executive officer in the Medical Section. He witnessed the irradiation of 200 immature chinook as well as the practice of taking blood samples from live fish.[82] The logbook fails to note whether Bonham and Welander discussed histological technique or hemopoiesis with him, though Friedell's close working relationship with Warren suggests that he might have blood on the mind. At any rate, in the days after Friedell's visit, Bonham created blood slides form adult steelhead and young chinook from the A lots. On 3 June he "spent the morning on fish blood and

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79 Wilson was an active and vocal eugenicist for much of his career. He became dean of Virginia's medical school in 1939.

80 Bonham to Warren, 18 May 1944, Box 3, Folder 23, UWLRB.

81 Ibid.

82 Daily Log, 29 May 1944, MSS Donaldson.

histology literature. In the afternoon he studied blood slides."[83] Two days later, he received a response from Warren to his letter from late May. "When you find a good section which indicates blood-formation in the cross part of the kidney, I would appreciate it if you would send me one for study."[84] After the letter, Bonham continued his work on fish blood itself, though he focused his energy on preparing slides with kidney tissue to provide a systematic look at blood formation in fish irradiated at different levels. By the end of July, he sent Warren the requested slides:

> Dear Dr. Warren:
> In compliance with the request in your letter of June 5, 1944 we are sending under separate cover two microscope slides and 25 photographs showing destruction by x-ray of blood-forming tissue in chinook salmon fingerlings.[85]

Bonham continued the correspondence by describing the technique used to create the slides. Each contained thin sections of kidney and spleen cells from fish treated with different Roentgen levels. Bonham prepared the samples from different fish together, embedding them in a single block of paraffin to ensure that "each sample received the same treatment… and differences that appear can not be attributed to the technique used."[86] Bonham also explained the layout of the samples on each slide. He arranged them in two rows, so that Warren could read the samples in order of increasing exposure. From the lower left corner Warren could see the 100 r sample. To its right Bonham placed the 250 r, 500 r, 750 r, and 1000 r samples. The row above, from left to right, revealed samples exposed to 1250 r, 2500 r, and 5000 r. Next to that last, highest sample, Bonham placed the 0 r control sample to provide maximum contrast. Nine living fish had the moment of their exposure essentialized and organized on this slide in order to make a visual argument for the Chief Medical Officer's trained eye. Though not an

83 Daily Log, 3 June 1944, MSS Donaldson.

84 Warren to Bonham, 5 June 1944, Box 3, Folder 23, UWLRB.

85 Bonham to Warren, 25 July 1944, Box 3, Folder 23, UWLRB.

86 Ibid.

expert on fish, Warren could identify malformed cells through the microscope. The slide constituted the first legible, systematic evidence of somatic insult from x-rays that the lab created.

While visual representations provided something tactile and legible for study, the lab wanted to create quantifications of radiation's biological effects. Bonham finished his letter to Warren by asking for advice for taking counts of damaged cells in order to start attaching numerical values to exposure levels. "We want to reduce this observation to a numerical statement..."[87] The path to making a numerical statement ran through the lab's visualization practices. The lab had a device for blowing up microscopic images. They built a plywood box nearly as tall as a lab bench and around two feet square with an acid-ground glass top just opaque enough to clearly display the projected image. This housed a microscope atop a light source. The beam passed through the microscope, though the slide, and up onto the glass.[88] It took some figuring to determine the scale of the projected image, but they had accomplished this by 17 April.[89] With the magnification calculated, they could make microscopic measurements on the macroscale using everyday devices. Welander ended up devising the solution to the problem of translating images into useful, quantified data. To do this, he figured the length of 50 microns on the blown-up image visible on the opaque glass at the top of the device. He then created a "square of glass all blacked out except for a central area carefully calibrated to correspond to the 50 by 50-micron area of tissue under the microscope."[90] He used fine wire to further divide the clear central area into four smaller boxes to make counting easier. This glass frame allowed him and Bonham to count magnified cells and take numerical values of "those cells which exhibited any definite stage of

87 Ibid.

88 UWFL-1, Figure 20, UWLRB.

89 Daily Log, 17 April 1944, MSS Donaldson.

90 UWFL-2, 56, UWLRB.

mitosis, from prophase through telophase, and definite state of pycnosis or nuclear fragmentation, and all erythrocytes..."[91] The technique sped their ability to take cell counts and process samples. Radiation's invisible biological effects became life-sized. To double check their counts from magnified images, they did occasionally resort to taking cell counts through the microscope "using an ocular micrometer ruled into squares."[92] Fortunately, they experienced "no significant differences between the two methods."[93] By 7 August, Welander felt comfortable enough with these counting techniques that he could devote entire workdays to "counting the hemopoietic."[94] Able to express a rational relationship between healthy cells and area, Bonham and Welander took an important step towards being able to make a meaningful numerical statement.

The lab employed statistical practice in order to interpret the numerical traces of radiation exposure that their fish yielded up. Individually, the fish embodied the effects of radiation as they grew and as they died. But the biologists wanted to know how lots betrayed radiation's biological secrets in the aggregate. This required certainty that treatment acted as a mechanism. Poor growth on the population level could be related to environmental factors, like fungal infestations in the lab's ponds. So could death rates. They needed to know, with a high degree of certainty, how radiation acted. Welander developed the lab's statistical technique to determine when radiation, rather than random chance, worked on lots. To do this, he calculated "student's" *t* by relating mean measurements in a radiated lot with those of a control lot.[95] This calculation allowed Welander to aggregate individual data

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91 Ibid., 56-57.

92 Ibid.

93 Ibid.

94 Daily Log, 7 August 1944, MSS Donaldson.

95 UWFL-2, UWLRB.

to show each lot's response to the moment of irradiation. Using student's *t* let him indicate the probability that "mean lengths, weights, or any other measure, would appear by chance in random sampling."[96] He calculated student's *t* by using a series of variables that related mean measurements, deviations from those means, and number of samples. With *t* in hand, he consulted the table in R.A. Fisher's magisterial book *Statistical Methods for Research Workers*. This table gave him the percentage, *p,* that his results were meaningful, or related directly to radiation exposure. This percentage, or likelihood that exposure to radiation was a matter of life or death, constituted one of the most useful pieces of information that the lab could produce in the summer of 1944. While he used student's *t* to consider rates of growth and mortality in lots, Welander most importantly figured *t* for damage to the blood-forming cells he counted in the 50-by-50-micron projections. In this case, the number of samples constituted not individuals, as in an assessment of weights within a lot, but rather "the number of areas counted per kidney."[97] Finding *t* by this method for the A-lot chinook, Welander determined that "the differences were real" for control populations and populations treated with 250 r, 500 r, and 1000 r.[98] *t* showed that the latter took longer to produce fewer hemopoietic cells because of radiation, not because of random chance. Using this statistical method, Welander finally used quantification, rather than observation, to make a claim about the biological effects of radiation.

Finding ways to quantify blood production constituted a major part of the lab's work over the summer of 1944. So did taking counts of white and red blood cells from living fish, especially from the chinook lots living in the lab's tanks and ponds. Bonham had begun taking regular blood samples back in April, as a result of conversation with Warren and Bishop during their trip to Seattle. Initially, he

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96 Ibid.

97 Ibid.

98 Ibid.

experienced challenges as he took samples because of the lab's inappropriately large pipettes. Donaldson complained to Bishop about this practical problem. Bishop in turn poked around and suggested a specialized fish pipette manufactured by the Will Corporation in Rochester. "They are about 1/3 the usual size, the dilution ratio is the same, and they cost about $1.25 each."[99] To sweeten the deal, Bishop sent a brochure containing "a statistical analysis of the standard and fish pipettes which shows that these small pipettes are just as good as the standard size."[100] Bonham could rest secure that statistical certainty supported his glassware choices and thus his bench work. By late May he had ordered "six fish pipettes for white blood cells and six for red blood cells according to the information you sent us."[101] Bonham needed to increase the efficiency of his blood sample technique to two important reasons. First, he needed to be able to take samples quickly from lots exposed to high levels of radiation. On 17 June, he had to take "the blood samples of the 5000 r and 2500 r which were dieing [sic] so rapidly."[102] These B lot chinook could not wait for death. Bonham had to kindly stop his daily routine to take useful data from them while they still lived and breathed. Quickly taken samples did not always make usable samples. He could see the nuclei in erythrocytes. He could also identify large leukocytes. But he expressed concern to Bishop that "there are smaller elements which may be white cells that are of doubtful identity."[103] Moreover, white blood cells clumped together on his slides. He explained that there was "some question about whether differential counts will be satisfactorily [sic] because of an apparent tendency for white cells to be localized."[104] Living blood cells did not fall into

99 Bishop to Donaldson, 9 May 1944, Box 1, Folder 8, UWLRB.

100 Ibid.

101 Bonham to Bishop, 18 May 1944, Box 1, Folder 8, UWLRB.

102 Daily Log, 17 June 1944, MSS Donaldson.

103 Bonham to Bishop, 18 May 1944, UWLRB.

104 Ibid.

place like kidney cells embedded in paraffin. Even with the new pipettes better suited to the bodies of fish, the reality on the microscale challenged the lab's ability to take useful snapshots of the somatic effects of x-rays in living organisms.

Taking snapshots of the blood and tissues samples, along with images of gross somatic development, took up another large portion of the lab's time and effort over the summer. Bonham and Welander had been working on microscopy since March, though their lack of competence frustrated them. By June, the Corps of Engineers photographer Tomlin had begun working with them on their technique. On 28 June, he and Welander spent the day practicing micrography of slides with prepared liver tissue using oil immersion magnification. Welander and Bonham experienced a steep learning curve over the summer. They learned to use new equipment. Bonham only ordered a light meter in the early summer.[105] They also learned the idiosyncrasies of Kodachrome with their camera and microscope. The day of practice on the 28th set them up for the work of 5 July, when Tomlin, Bonham, and Welander took the pictures of chinook kidneys that Bonham would send to Warren along with the prepared samples at the end of the month. With their Kodachrome and micrography set up, Tomlin and the biologists took twenty-five eight-by-ten photographs for Warren. The first set of nine photos showed chinook spleen tissue under oil magnification. Arranged in ascending order, the photos documented organs from fish exposed to 100 r, 250 r, 500 r, 750 r, 1000 r, 1250 r, 2500 r, 5000 r, and 0 r for a control.[106] The photos mimicked the order of the tissue samples on the slides sent to Warren. The next set of nine photographs showed five-micron sections of chinook kidneys, also arranged by ascending treatment levels, under low magnification. The final series zoomed in on these images, using oil magnification. Bonham marked the second series of photos to show the region under higher

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105 Ibid.

106 Bonham to Warren, 25 July 1944, UWLRB.

magnification in the third series. By arranging the photographs in this way, Bonham created two visual scales showing the effects of radiation. The viewer could easily read them from 100 r to 5000 r to see increases in somatic insult. The viewer could also compare the 5000 r photos with control photos. Such a view encouraged a sharp contrast between the look of normal tissue and the look of mortally pathological tissue. By including two magnifications of kidney tissue, Bonham provided something of a synoptic view. Looking at the two resolutions side-by-side allowed the viewer to see damaged cells in the context of entire organ systems. Visualizations like these became integral to the lab's interpretive work and to its reporting. They sent they photographs to Warren in July 1944 were the first of many images of irradiated organisms that the lab sent to their patron.

Conclusion: Foundational Literature for the Atomic Age

On 9 October 1946, the first adult chinooks lacking their adipose and left or right ventral fins began to appear at the weir on the Samish River. Donaldson and Welander had just themselves returned on 30 August from Operation Crossroads at Bikini Atoll.[107] 11 adult chinook from the 0 r control group and 12 from the 100 r group made it back to the hatchery on the Samish.[108] Some died in the rack meant to catch them and were sent back to the lab frozen for examination.[109] Conveniently two females from the control group and two from the 100 r group returned. These four females were spawned on 20, 21, and 26 October 1946 at the Samish River hatchery. Like their parents, they were sacrificed just after spawning. The lots spawned from 100 r parents suffered high mortality and deformity rates. Using the student's *t* test to compare their mortalities with the lots derived from the control fish yielded around a

107 See Chapter 4.

108 UWFL-6, Table 11, UWLRB.

109 Recovery of Chinook Planted in the Spring of 1944, Box 9, Folder 19, MSS Donaldson.

97% likelihood that the grandchildren of the fish treated at 100 r in 1943 were deformed and dying exactly because of that irradiation.[110] Even though the parent's generation had left the lab to mature in the ocean, the biologists could prove that their lab practice, in this case x-ray exposure, could be quantified in spite of time and generational change.

The returning chinook helped confirm that Donaldson and his team had, amid the hectic American war effort, successfully implemented a new laboratory program to study the biological effects of radiation in salmon and steelhead trout. In the years after the war, the biologists wrote up their hastily conceived and executed researches. Donaldson wrote up a something of a visual chronicle of the lab's first forays into x-ray practice, numbered UWFL-1 in October 1945. Using glossy black and white photographs, he documented what became the lab's origin story and explained the varying techniques and technologies the lab employed. In the same month, Welander submitted UWFL-2, his doctoral thesis on the chinook eggs irradiated in December 1943 and January 1944. Given the business that attended their trip to Bikini, the team had to wait until July 1946 to publish UWFL-3, the report chronicling their work with the A-lot chinook fingerlings who were irradiated in early 1944. Bonham published UWFL-4, his quick and dirty study of the adult silvers from Spring 1944, in July '46. Another year passed before the lab published UWFL-6, the comprehensive study of the original October 1943 chinook, their liberated children, and their grandchildren. The lab released it in August 1947. When Foster published his doctoral thesis, UWFL-12, in 1948, he released the last of the important reports from the lab's first phase of research that relied exclusively on x-rays from the Picker-Waite.

Taken together, these first researches produced with x-rays from the Picker-Waite machine formed the foundation for a research program that sought to know and quantify the biological effects of

110 Ibid.

radiation. The x-ray machine cast a long shadow. Though all the official reports that the machine made possible only came out in their final forms after the war, the biologists had already formed some key working assumptions about radiation during the war. The most important of these was a notion that some key thresholds existed between exposure levels. 2500r and above the biologists considered lethal doses.[111] But for fish born of parents exposed to 100r and below, the biologists could find no "definite treatment-mortality pattern."[112] Neither could the biologists find significant growth defects among the offspring of irradiated adults. In other words, low-level exposures produced mortalities and some deformities in the children of irradiated salmon but not at an alarming rate. We have seen that the grandchildren of irradiated salmon did experience high mortality and deformity rates, but that data only became available to Donaldson and the biologists in 1947 and it relied on an unhelpfully small sample population. In 1945, the biologists latched on to the data from the first generation of offspring that seemed to indicate that low-level exposures, produced essentially benign results. This threshold, this notion of benign exposure, became foundational for the lab's research program.

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111 Hines, *Proving Ground*, 16.

112 UWFL-9, "Project Chronology Chart and Summary of the Applied Fisheries Laboratory," 11 March 1948, Box 9, Volume 2, UWLRB.

Chapter 2

The Complex Case of the Atomic Bomb Disease

Familiar Tools for a Novel Disease

"Suddenly," recalled Dr. Michihiko Hachiya, "a strong flash of light startled me."[113] Hachiya directed the Communication Bureau's hospital in central Hiroshima. Immediately after the flash on 6 August 1945, the blast bowled his house over, injuring him and his wife, Yaeko-san. They lived just over a mile north and west of the blast site. The force tore open his cheek and lodged a massive shard of glass in his neck. Yaeko-san suffered burns and bleeding wounds. The couple struggled to his hospital that morning, though most of the building burned in the aftermath of the blast. "The sky became bright as flames from the hospital mounted."[114] They survived their wounds, largely with help from two doctor colleagues who also made the trek to the ruined facility. During the day's travails, Hachiya remained convinced that the US had dropped a 500-ton conventional bomb on the city. What else could have caused such destruction? Despite his wounds and uncertainty about the blast, Hachiya had to figure out what to do next, how to treat the host of patients pouring into the ruins of his hospital and exhibiting a suite of symptoms far more complex than burns and broken limbs. He needed to know why his patients suffered as they did.

This chapter examines the unfolding epistemic collision between the local clinicians who survived the bombings in Hiroshima and Nagasaki, the doctors from the Imperial military and medical

113 Michihiko Hachiya, *Hiroshima Diary: The Journal of a Japanese Physician August 6 – September 30,* trans. Warner Wells (Chapel Hill: University of North Carolina Press, 1955), 1.

114 Ibid., 6.

establishment in Tokyo, and the doctors of the Manhattan Engineer District's Medical Section as they investigated the biological effects of the two bombs. Placing their stories in conversation highlights distinctions between medical ways of knowing from the clinic and wardroom floor and ways of knowing developed in the university laboratory. The story also demonstrates national difference within scientific communities. The Japanese and American experimentalists shared comparable training, had published in the same journals, and looked for the same kinds of data from those exposed to radiation, the *hibakusha*. But political commitments pushed them to see the biological effects of the bombs in stark relief. Japanese doctors quickly and emphatically described a discrete atomic bomb disease. The Medical Section never did, denying survivors the legitimacy of a medical diagnosis and downplaying the bombs' radiological dangers. This controversy grew up in the weeks after the bombings.

Chronologically, the story starts with local doctors, like Hachiya, who survived the attacks and faced both an immediate public health crisis and a knowledge problem. Their patients' symptoms defied conventional wisdom about infectious disease. But knowledge about radiation from the bombs trickled into the ravaged cities slowly. Accordingly, the doctors quarantined patients to prevent the spread of disease. They assumed dysentery in Hiroshima and cholera in Nagasaki.[115] As their patients died, the doctors collected case histories, did rudimentary blood work, and performed autopsies in order to learn about the mechanisms that drove their patients' symptoms. When the trickle of news gradually let them know that their patients suffered from radiation exposure, they had to grapple with the problem of novelty. What was an atomic bomb? What did it mean for the palliative care they should offer?

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115 Ibid., 21 and Raisuke Shirabe, *A Physician's Diary of the Atomic Bombing and its Aftermath*, trans. Aloyius Kuo (Nagasaki: Nagasaki Association for Hibakusha's Medical Care, 2002), 31, http://www.nashim.org/e_pdf/phy/a_physicans_diary.pdf.

While doctors in Hiroshima and Nagasaki groped in the dark, Japanese doctors from imperial university faculties and from the nation's sundry military medical corps as well as Americans from the Manhattan Engineer District's (MED) Medical Section began systematic studies of the populations who had been exposed to the bombs. An important cohort of the Japanese doctors shared a scientific viewpoint with Stafford Warren's Medical Section. These experimentalists trained in the prewar x-ray tradition and knew about the biological effects of radiation in animals and humans. The Japanese ran no program analogous to that at the Applied Fisheries Laboratory that could look systematically for insults to blood formation. But imperial doctors like Tsuzuki Masao, who led the Japanese National Research Council's medical section, had the background and the resources to study the bombs' biological effects systematically based on what was known about x-ray exposure and its somatic insults. Still, both the Japanese experimentalists and MED doctors faced uncertainty as they approached the two devastated cities. Would fission in the field behave like x-rays in the laboratory? Would human beings respond like dogs, rabbits, or salmon?

The experimentalists answered these questions with amazing rapidity, given the chaos in the bombed cities. Both the MED and the Japanese imperial doctors produced preliminary reports on the medical situation in the two cities by November 1945. They had to visit the two bombed cities to gather data, which they did in fits and starts. Japanese experimentalists from the capital sometimes seemed out-of-touch to their colleagues who had survived the bombings and had personally offered care to dying patients. The Americans relied on Japanese doctors for access to the two cities and did not function well once they actually got to Hiroshima and Nagasaki. Warren's group eventually relied on the large naval hospital in Omura, to the north of Nagasaki, as their main site to collect data on evacuated *hibakusha*. Their shared desire to turn both the dead and the living into useful data aside, the experimentalists parted ways as they reported on what the bombs did. Was radiation sickness, or what came to be called the atomic bomb disease, a discrete medical reality? Or was it a suite of symptoms that occurred in differing degrees based on very local contingencies? Warren's Medical Section chose the latter as a means to mitigate the peculiarly atomic insults of the bombs.

Personal journals and early institutional reporting offer paths to trace these ways of knowing as they evolved in the chaotic weeks and months after the bombings. For initial, local, and clinical responses, the translated journals of Michihiko Hachiya, doctor and Director of the Communication Ministry's hospital in Hiroshima, and Raisuke Shirabe, doctor and Professor of Surgery at Nagasaki Medical University, constitute the main sources. The travel diaries of Stafford Warren, doctor and Chief Medical Officer of the Manhattan Engineer District (MED), and Ashley Oughterson, doctor and member of the US army's medical corps, provide a foundation for the experimentalists' story. Placed in conversation with journal publications from the animal x-ray tradition, these travel journals cast light on how the experimentalists used interspecies knowledge in the wake of the bombings. Reports submitted in November 1945 from the MED and the Army Medical College in Tokyo show the earliest examples of how the experimentalists' interspecies knowledge led to conflicting national formulations the sickness. Finally, talks given by Warren when he returned to the States after the trip to Japan provide glimpses of how he popularized the MED way of knowing fission. Tsuzuki Masao and his lieutenant, the hematologist Hitoshi Motohashi, play important roles throughout this story.

The bombs dropped on Hiroshima and Nagasaki produced novel radiations that in turn produced a novel suite of symptoms in those unhappy people irradiated by them. Doctors, confronted with the symptoms, did not describe a single new disease. Instead, Japanese and American doctors relied on pre-fission practices in order to describe a multiplicity of diseases. Local clinicians used traditional responses to a public health crisis in ways that allowed them to treat patients and exert some control over the ruins of their hospitals. Outsider experimentalists cast human data in dies left over from animal experiments in the teens, '20s, '30s, and '40s. These first accounts, that grew up in the weeks and months after the bombings mattered. Japanese clinicians and experimentalists argued that the bombs' effects constituted a new and devastating disease. American experimentalists from the section of the army that made the bombs claimed they did not. Their account of the bombs' effects went on to become the normative viewpoint of the future US Atomic Energy Commission's atmospheric testing program. These viewpoints served national interests, to be sure. Japanese clinicians and experimentalists ultimately described fission's injustice. The MED countered with a way of seeing fission's effects that made the bombs little worse than conventional weaponry. Despite these differences, both these initial accounts used tools from the pre-atomic past to make sense of the new phenomenon that became the stuff of diplomatic wrangling, long-term genetics research, and cultural introspection during the Cold War.[116]

Making New Knowledge Locally

As sick and injured patients streamed into his hospital the day after the bombing, Michihiko Hachiya still assumed that he needed to treat conventional maladies created by a conventional weapon. Since vomiting and diarrhea began the day after the bomb fell, Hachiya ordered an isolation ward organized to manage what he thought was an outbreak of dysentery. Over the next few days diarrhea turned to bloody diarrhea. The hospital ruins became more crowded and Hachiya struggled to isolate all the patients he thought suffered from the outbreak. Dr. Hanaoka, who ran the Communication hospital's

116 For the disease and diplomacy, see: John Beatty, "Scientific Collaboration," and M. Susan Lindee, "The Repatriation of Atomic Bomb Victim Body Parts to Japan." For the bomb and genetics research, see Lindee's *Suffering Made Real*. For a study of survivors' responses to the sickness, see: Naoko Wake, "Atomic Bomb Survivors, Medical Experts, and the Endless Radiation Illness," in *Inevitably Toxic: Historical Perspectives on Contamination, Exposure, and Expertise*, eds., Brinda Sarathy, Vivien Hamilton, Janet Brodie (Pittsburgh: University of Pittsburgh Press, 2018), 235 – 258.

outpatient clinic, began systematizing patients' symptoms on 9 August. He reported three groups of patients to Hachiya:

1. Those with nausea, vomiting, and diarrhea who were improving.
2. Those with nausea, vomiting, and diarrhea who were remaining stationary.
3. Those with nausea, vomiting, and diarrhea who were developing hemorrhage under the skin or elsewhere.[117]

Hanaoka described no conventional disease, but perhaps created the first systematic description of the radiation sickness.

On the day Hanaoka reported in Hiroshima, the third atomic device ever built destroyed Nagasaki. Raisuke Shirabe recalled "… a bright blue flash shone in my eyes."[118] Destruction engulfed Nagasaki Medical University. "… we saw that the hospital, basic science classrooms, and all the wooden buildings had collapsed and were burning."[119] He and the surviving faculty, nurses, and students fled up the hillside behind the campus, where they camped on the evening of 9 August. The next day they began to treat patients in the school's air raid shelters. Shirabe traveled a few miles north, to the less damaged Nameshi neighborhood. There he arranged to use a social club as a relief station for patients from Medical School's ruins. When patients began to arrive at the temporary clinic, bloody diarrhea had taken hold. "Suspecting cholera," Shirabe and his colleague Dr. Kido "moved these patients to a corner of the room to isolate them."[120]

In the first week after the bombings, the fact that the bombs were atomic meant little if anything to Hachiya, Shirabe, and the doctors and nurses scrambling to treat sickening patients. The military medical establishment in Tokyo did fear a problem with radiation if indeed the bombs were atomic, per President Truman's radio message of 6 August. They acted quickly to confirm the news. On the 10th a

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117 Hachiya, *Hiroshima Diary*, 36.

118 Shirabe, *A Physician's Diary*, 3.

119 Ibid., 5

120 Ibid., 31.

joint army-navy survey team pinpointed where the bomb had exploded over Hiroshima. They also found photographic film exposed even though it had been safely stored away from any light source.121 News of the radiation traveled out of the city, but not within the city. The bombs were already creating new geographies of knowledge, in which national interests outweighed local ones. Clinicians in the two cities did not know that the patients who seemed well one day and sick the next were dying from the inside out because of radiation.

Facing this bewildering public health crises, Hachiya and Shirabe provided what palliative care they could. Shirabe moved patients to relative safety in Nameshi to encourage his patients' recovery. "It would not be possible to give good patient care in the ruins… on the bare earth or concrete floors in the ruins."[122] In Hiroshima, Hachiya worked to improve his facilities in place. His old pharmacy storeroom became a dining room. There patients shared what little food was available. Faced with a shortage of nurses, he directed that ambulatory patients be taught how to dress their own wounds. He decided "to place a crock of Remaon's solution [a mild germicidal solution] near the entrance of the hospital, and notices posted instructing patients to soak their dressing in the solution before covering their wounds."[123] The system worked. The crock became a spot for socializing. Despite these improvements, doctors and nurses in both cities spent much of the first week after the bombings piling up the dead for cremation.

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121 The Committee For the Compilation of Material on Damage Caused by the Atomic Bombs in Hiroshima and Nagasaki, *Hiroshima and Nagasaki: The Physical, Medical, and Social Effects of the Atomic Bombings*, trans. Eisei Ishiwaka and David Swain (New York: Basic Books, 1981), 504.

122 Shirabe, *A Physician's Diary*, 14-15.

123 Hachiya, *Hiroshima Diary,* 74.

The clinicians longed to know about the mechanisms behind their patients' illness. On 13 August, Hachiya remarked that, "the most popular explanation was still that some poison gas had been liberated and was still rising from the ruins."[124] Frustrated with his lack of understanding, Hachiya ordered two of his doctors to take a thorough case history of each patient in the hospital on the 16th. By the 20th, the new wave of death began to crest. At that point Hachiya suspected a "suppression of the white blood cells" because previously healthy patients bled so much and suffered petechiae, pinpoint sized hemorrhages, all over their bodies.[125] He therefore rejoiced when a microscope arrived from the main Communications Bureau Hospital in the capital on 20 August.[126] With it, his pathology staff could make rudimentary investigations into patients' blood picture.

Hachiya's suspicion about low white blood cell counts proved prescient. Dr. Hanaoka shared data from the microscope after dinner on the 22nd:

> The white blood count in persons exposed in the Ushita area, between two and three kilometers from the hypocenter, ranged from 3,000 to 4,000. Patients nearer the hypocenter, although fewer in number, had counts around 1,000. Severely ill patients had counts lower than 1,000, and the nearer the hypocenter the patient had been the lower the white count.[127]

Counts like these fell far below what the doctors would have expected even in patients sick with a bacterial infection. Hanaoka's speedy processing of 50 blood samples in two days was impressive, working with no electric light. Paring his data with patient location from verbal case histories gave it radiological significance. The veil began to fall. "Our preliminary blood findings filled us with

124 Ibid., 69.

125 Ibid., 99.

126 Ibid.

127 Ibid., 108 – 109.

excitement and the feeling that for the first time we were coming to grips with this unknown enemy."[128] Now they could explain their patients' weakness and susceptibility to infection.

The doctors wanted a macroscale view of their ailing patients' bodies, so they began to prioritize autopsies. On 26 August, Hachiya and a colleague performed their first since the bombing. They found the dead woman's body cavity filled with blood that had not coagulated. The blood had hemorrhaged from countless points on her internal organs. To Hachiya, the autopsy proved an epiphany. "If we had begun to do autopsies sooner, perhaps we would not have been so in doubt about our patients' signs and symptoms."[129] He had been working on a text for an informative broadside designed to educate the local population about their symptoms. After the autopsy, Hachiya "tore up what I had done and started over."[130] The next day, his staff posted the revised text around the hospital and Communications ministry. The broadside pointed to the need for control over the continuing public health crisis. Hachiya encouraged those who felt well to continue working. He assured survivors who were losing their hair that they would likely live and ought not swamp his hospital based on that symptom alone. The broadside described a conventional and manageable disease. Hachiya only mentioned radiation and uranium in passing at the end of the text.

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128 Ibid., 109.

129 Ibid., 124.

130 Ibid.

NOTICE REGARDING RADIATION SICKNESS
HIROSHIMA COMMUNICATIONS HOSPITAL

1. No abnormal blood counts have been found in persons working in the city since the A-bomb who were not in the city at the time of the *pika*. No abnormal counts have been found in persons who were in the basement of the Telephone Bureau during the *pika*. Persons in this category are requested to continue their work as usual.
2. It has been found that those with low white blood cell counts were near the center of bombing, that is: employees of the Telephone Bureau, the Telegraph Bureau, and members of their respective distribution departments. The white blood counts are either normal or slightly decreased in persons who were working at the Communications Bureau when the bomb exploded.
3. There does not appear to be any relation between severity of burns and decrease in white blood cells.
4. Loss of hair does not necessarily have an unfavorable prognosis.
5. Persons whose white blood counts are low must take care to avoid injury or exertion because their body resistance is low.
6. Those with wounds must take pains that they do not become infected. Those with infection should receive treatment at once to prevent a spread of the infection to the blood stream.
7. According to reports by authorities from Tokyo University there does not appear to be any residual radiation from uranium.

THE END

(*Signed*): Michihiko Hachiya, Director
Hiroshima Communications Hospital

Figure 2.1. Source: Michihiko Hachiya, *Hiroshima Diary: The Journal of a Japanese Physician August 6 – September 30, 1945*, 125. Republished with permission of University of North Carolina Press.

Combining information from blood sample analysis and visible symptoms uncovered during autopsies allowed the Hiroshima clinicians to zero in on one of the new radiation's most devastating effects, lowered platelet levels. Continued blood work showed an almost universal dearth of platelets in the sickest patients. Hachiya marveled at this news. He ran to the autopsy shed to share it with Chuta Tamagawa, the professor of pathology from Hiroshima's Medical School who had fled the city but then returned. "Is that so!" he exclaimed. "Well! That explains everything… that's why blood hasn't clotted even after seven hours!"[131] Low platelet counts provided a mechanism for patients' inexplicable deaths by hemorrhaging. "We had interpreted," Hachiya wrote, "the low white count as characteristic of the disease, but it became obvious that this was only one feature of a disease that involved platelets as well… we had overlooked the platelets because they are more difficult to evaluate than white blood cells."[132]

The Nagasaki doctors never started any significant lab work in their makeshift relief stations due to the extent of the destruction in that city. By September, they considered their situation untenable. They arranged with Rear Admiral Kodo Yasuyama, a graduate of Nagasaki's medical school, to move the faculty and their patients at Nameshi to his Naval Hospital in the nearby port city of Omura. Located 22 miles from Nagasaki's city center, Omura suffered only minor damage from the bomb and its hospital had sent medical staff to Nagasaki to operate relief stations.[133] The hospital also received medical evacuees who arrived by train to its well-maintained grounds and 1700 bed facility. By bringing the medical faculty to Omura, Yasuyama added to the number of doctors and nurses he had on his staff. Shirabe made the trip to Omura on 26 September, among the first of the faculty to arrive.[134] Moving out of Nagasaki, the medical faculty positioned itself to care for and study patients in a controlled, familiar medical context. Though the Hiroshima clinicians performed medical investigations first, the work of Nagasaki doctors at Omura became key for knowledge about the new radiation sickness.

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131 Ibid., 147.

132 Ibid., 148.

133 Nobuko Margaret Kosuge, "Prompt and Utter Destruction: The Nagasaki Disaster and the Initial Medical Relief," *International Review of the Red Cross* 89, no. 866 (June 2007), 279 – 303.

134 Shirabe, *A Physician's Diary*, 42. Shirabe began journaling again when he arrived at Omura.

In the hands of local clinicians, radiation sickness scarcely had anything to do with radiation in the first weeks after the bombings. Cut off from information from the capital and without even basic laboratory equipment, they treated patients' symptoms as best they could. They cleaned wounds. They tried to help patients keep water down. They distributed preciously scarce food even as patients vomited it up or passed it in bloody diarrhea. News about radiation from the new bombs trickled into their hospitals and relief stations even as they did this. The news made little difference initially and in neither city did the surviving radiologists lead the effort to treat the novel sickness. In Hiroshima, blood work offered insights into the strange symptoms killing patients. In Nagasaki, only the hope of escape offered the city's doctors the possibility of understanding the disease. On the ground, fission remained largely absent from radiation sickness August 1945 rolled into September.

Outsiders and X-Rays

The symptoms that the *hibakusha* experienced systematically became the stuff of radiation when doctors from outside the cities, led by Masao Tsuzuki and Stafford Warren, arrived to collect biological data about the new fission. They did so armed with knowledge about animals exposed to x-rays. Their experience with this interspecies knowledge guided them as they chose what data to collect from patients. Warren and Tsuzuki prioritized learning about the survivors' blood picture. They also wanted tissue samples from the blood forming organs for analysis under the microscope – a practice called histology. They assumed that radiation from fission would insult blood just like x-rays did and that irradiated human beings would respond to those insults like animals. Armed with these convictions, they ventured from their labs to the devastated cities.

Though wartime adversaries, Masao Tsuzuki and Stafford Warren shared much in common professionally. Warren took his MD at the University of California's Medical School in San Francisco. Warren's mentor there, George Whipple, first irradiated dogs with x-rays from that school's new and powerful Coolidge Tube in 1919.[135] He observed the dogs, noting an inexplicable lag between exposure and the onset of clinical symptoms. In the early 1920s, Warren joined Whipple to continue the dog experiments. Together, they published six articles in 1922 and 1923 in the *Journal of Experimental Medicine.*[136] Methodologically, they relied on autopsy, urine analysis, and histology. Tsuzuki took his MD at the University of Pennsylvania. In 1926, he ran his own x-ray rabbit experiment. He worked to establish effects of x-rays on particular organs in healthy rabbits, especially using histological practice.[137] Warren knew Tsuzuki's piece and called it "a very rational attempt to arrive at the sensitivity of the various organs."[138] Both experimentalists grew up professionally with animal x-ray research. In August 1945, both found themselves leaders in their respective military's medical corps.

How did the two doctors deploy their animal knowledge in the wake of the bombings? Most importantly, they made the assumption that animal data mapped onto human data. In 1923, Warren and Whipple argued that the data from their recently completed dog experiments could describe human reactions to x-rays. In the *Journal of the American Medical Association*, they wrote, "Evidence from

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135 C.C. Hall and G. H. Whipple, "Roentgen-Ray Intoxication: Disturbances in Metabolism Produced by Deep Massive Doses of the Hard Roentgen Rays," *The American Journal of the Medical Sciences* 157 (1919), 453 – 482.

136 See: "Roentgen Ray Intoxication: I. Unit Dose Over Thorax Negative – Over Abdomen Lethal. Epithelium of Small Intestine Sensitive to X-Rays." *Journal of Experimental Medicine* 35, no. 2 (31 January 1922), 187 – 202, and, "Roentgen Ray Intoxication: Bacterial Invasion of the Blood Stream as Influenced by X-Ray Destruction of the Mucosal Epithelium of the Small Intestine," *Journal of Experimental Medicine* 38, no. 6 (30 November 1923), 713 – 723.

137 Masao Tsuzuki, "Experimental Studies on Action of Hard Roentgen Rays," *American Journal of Roentgenology and Radium Therapy* 16 (1926), 134 – 148.

138 Stafford Warren, "Organ and Body Systems," in *Biological Effects of Radiation: Mechanism and Measurement of Radiation, Applications in Biology, Photochemical Reactions, Effects of Radiant Energy on Organisms and Organic Products,* ed., Benjamin Duggar (New York: McGraw-Hill, 1936), 475.

animal experiments and scattered clinical observations is convincing that the human intestinal mucosa is peculiarly sensitive to the hard and short wavelength roentgen rays."[139] In the '20s they worried about the lining of the intestine, but by 1945, they wanted to look for damage to the blood. Tsuzuki studied the bone marrow of the rabbits he irradiated in 1926. By the 1930s, Warren could outline the timing of insults to the blood. "A profound leucopenia appears after 5 to 6 days… the platelets suddenly disappear from the blood smears the day before death."[140] When the experimentalists arrived in Hiroshima and Nagasaki, they looked for insults to the blood, treating human survivors of the bomb as pieces in an animal puzzle they had been trying to solve for decades.

Tsuzuki got the jump on studying what the bombs had done because he could get to Hiroshima sooner than Warren. A rear admiral in the Imperial Navy, used his administrative clout to initiate and epidemiological survey in Hiroshima in mid-August.[141] He managed to have volunteers pass out over 100,000 survey forms in the city. Hachiya never noted them, an indication of how chaotic things were in the ruined city. Hachiya did receive Tsuzuki's invitation to a symposium in Hiroshima on 3 September. The director eagerly anticipated the meeting. "Since Professor Tsuzuki was going to speak on radiation sickness this afternoon, I went to the wards after breakfast and spent most of the morning reviewing our records, questioning patients, and making notes so I might be prepared to comment if the occasion arose."[142] He brought local clinical data, exactly the kind Tsuzuki did not have, to the symposium. At the meeting, Tsuzuki gave a talk on the biological effects of radiation and his colleague.

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139 Warren and Whipple, "Roentgenology in Man in the Light of Experiments Showing Sensitivity of Intestinal Epithelium," *Journal of the American Medical Association,* 1923.

140 Samuel Shouse, Stafford Warren, and George Whipple, "Aplasia of Marrow and Fatal Intoxication in Dogs Produced by Roentgen Radiation of All Bones," *Journal of Experimental Medicine* 53, no. 3 (1931), 421 – 435.

141 Lindee, *Suffering Made Real,* 26.

142 Hachiya, *Hiroshima Diary*, 158.

A Dr. Miyake discussed autopsy data. Questions, answers, and discussion of the data followed the formal talks.

Tsuzuki immediately took the information he learned at the symposium back to Tokyo, which had become the node for both Japanese and US experimentalists by early September. Hachiya complained that the "outside investigators only stayed a short while and thus could never acquire the intimate knowledge of the situation permitted to those who were here all the time."[143] But Tsuzuki did not come in search of the "intimate knowledge" the clinicians had gained from sitting by bedsides and speaking with patients. He wanted quantifiable data that he could share with military medical establishment in the capital. He also knew the Americans would demand data. The US navy, the army, and the MED sent medical teams to Japan. Warren, head of the MED's team, arrived on 6 September after a harrowing journey across the Pacific. The next day he met up with Ashley Oughterson from the army. The two men interviewed a Colonel M. Hiraga that morning on medical data from Hiroshima. "Warren took" everything Hiraga said "down in long hand."[144] Later that afternoon, they met Tsuzuki and his assistant, Hitoshi Motohashi from the Army Medical College. For the next month-and-a-half, Tsuzuki and Warren existed in a strange symbiosis. Warren needed Tsuzuki for access to data in Hiroshima. Tsuzuki found Warren helpful as he tried to navigate the occupation government's new power structures. Each doctor found the other useful.

Warren benefited from this relationship with Tsuzuki once he and his team arrived in Hiroshima because they were unprepared to navigate cultural differences or to work in the utter devastation that

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143 Ibid., 160.

144 Oughterson Daily Journal, 7 September 1945, Box 292, Folder "Naval Mission to Japan," Stafford Leak Warren papers (Collection 987). UCLA Library Special Collections, Charles E. Young Research Library, University of California, Los Angeles (Hereafter cited as MSS Warren).

befell the city. Once there, they haphazardly collected any Japanese data they could. On the 9th, Tsuzuki arranged for Warren, Oughterson, and Shinohara, a translator from Tokyo, to make the rounds of the devastated city. They spent the morning at the Red Cross hospital, which sat less than a mile from ground zero.[145] Next, they interviewed the chief of Hiroshima's provincial medical department during lunch at the central police station. On the 10th, they went to Ujima Hospital. "Spent morning at Military hospital seeing patients, hematology and pathology."[146] In the afternoon, they shared tea with Colonel Subayashi at the Ono Military Hospital. After engaging in this important social exchange, the Americans listened to medical reports presented by a team of doctors from the imperial university in Kyoto who had been studying patients at Ono. None of these interactions could have occurred in such a timely and at least nominally organized manner had Tsuzuki not smoothed the way for the Americans.

Warren longed for a situation in which his men could control a systematic effort to collect data. This he found not in either of the two destroyed cities but at the Naval Hospital in Omura. Warren learned of Omura as he and Tsuzuki flew into its airport on their way to Nagasaki on 17 September.[147] He sent a team of four doctors to the Naval hospital on the 27th, a day after Shirabe arrived from Nameshi. Captain George Whipple, the son of Warren's mentor and coauthor of the dog experiments, led the team that included lieutenant Joseph Howland. The lieutenant's credentials commended him for the expedition. He had a PhD in zoology and an MD. But more importantly he injected Ebb Cade, an African American man who had been in a car accident on his way to work at the secret uranium

145 Oughterson Daily Journal, 9 September 1945, MSS Warren.

146 Ibid.

147 Joseph Howland to Robert Buettner, 5 November 1947, Box 65, Folder 3, Reel 13.1, MSS Warren.

facilities at Oak Ridge, with plutonium back in March 1945.[148] Cade had no idea that Howland injected him with the dangerous alpha emitter. Howland's willingness to extract data from human beings paid dividends because Admiral Yasuyama, director of the hospital, allowed the American access to patients. MED doctor Brichard Brundage noted, "Examinations and complete histories (with interpreter assistance) were made on all of the patients by our medical officers."[149]

By the end of September, the US occupation had advanced to the point that Warren's doctors could collect data in Omura with near impunity. Shirabe, still working at the hospital after his effort to evacuate patients from Nagasaki, noted the American's activities. On 28 September, he wrote, "An American was selecting specimens and wanted to bring home some interesting cases. He was the one who gave me cigarettes yesterday. With a smile, he said he got a backache from bending to get specimens."[150] These specimens largely went back to the University of Rochester Medical School.[151] The day after the doctor, likely Howland, complained about a bad back from the all the lifting, Warren arrived at the naval hospital to meet with Yasuyama. The admiral wined and dined him. Americans were confiscating Japanese medical facilities for use by the occupation government across the country. Warren's good graces went a long way toward his keeping control in Omura. Shirabe described the visit as jocular. "In the conference room we could see that a group of visiting foreigners, the superintendent [Yasuyama], and Professor Tsuzuki were enjoying dinner with drinks."[152] The Nagasaki professor joined the affair later that evening and met Warren. The MED colonel noted meeting Shirabe and

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148 See pages 83 – 86 in Eileen Welsome, *The Plutonium Files*, 1999. She provides an exhaustive history of the plutonium injections at Oak Ridge, Rochester, and elsewhere.

149 Brichard Brundage to Stafford Warren, 12 November 1947, Box 65, Reel 13.1, MSS Warren.

150 Shirabe, *A Physician's Diary*, 46.

151 Howland to Buettner, 28 October 1947, Box 65, Folder 3, MSS Warren.

152 Shirabe, *A Physician's Diary,* 49.

described the visit with joy.[153] He had reason to be happy. The overwhelming bulk of the data that Warren's Medical Section would use for its reporting on the biological effects of radiation from the bombs came from Omura.

Laboratory experience with animal experiments gave Warren and Tsuzuki a road map for very quickly delving into human radiological research in September and October 1945. Like the local clinicians, they fell back on familiar practices to understand the new fission. They took case histories and blood samples from the living. From the dead they took tissue samples. These they treated as data commensurable with data from animals. While Hachiya relied on his pathology lab to find the platelet problem in humans in early September 1945, Warren and Tsuzuki knew about it from animal experiments conducted over a decade before the bombs fell. In their hands x-rays insinuated themselves into the novel sickness caused by fission.

A Contested Disease

Despite their shared scientific foundation, the Japanese and American doctors betrayed competing political commitments as they began to publish on their data from the *hibakusha* in late autumn 1945. Warren's Medical Section forwarded a short but synoptic report to General Leslie Groves, officer in charge of the Manhattan Engineer District, on 27 November.[154] The faculty of the Army Medical College in Tokyo released a significantly more in-depth report three days later.[155] Motohashi, the

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153 Warren Daily Journal, 29 September 1945, MSS Warren.

154 Preliminary Report of Findings of Atomic Bomb Investigating Groups at Hiroshima and Nagasaki, 27 November 1945, Box 298, MSS Warren.

155 Army Medical College – The First Tokyo Army Hospital, Medical Report of the Atomic Bombing in Hiroshima, 30 November 1945, 16, Box 61, Reel 11.1, MSS Warren.

college's professor of hematology and Tsuzuki's assistant, co-authored the section on what it called radiation disease. The two reports systematized and visualized the onset of symptoms in comparable ways. They also shared a concern with blood formation and blood picture. Epistemologically, they came right out of the x-ray animal tradition. But these commonalities in form yielded no common conclusion. The Japanese experimentalists discerned a discrete atomic bomb disease while the MED never saw any disease at all.

In the report sent to General Groves, a single table showing the onset of symptoms encapsulated the MED's argument about how the biological effects of radiation had unfolded in Hiroshima and Nagasaki. In this view, the timing of the onset of symptoms determined life or death. The leftmost column counted days after the blast. The three columns to its right showed the onset of index symptoms, such as vomiting and bloody diarrhea, in three sets of survivors grouped by exposure: most severe, moderately severe, and mild. The table shared striking similarities with one created by George Whipple to describe the final days of one of his x-ray dogs in 1919. Again, the leftmost column highlights time after the moment of irradiation. The 'remarks' column offers a condensed prototype of the three right hand columns in the MED report. The key index symptoms appear. Next to each other, the two graphs present a unified experience of radiation, erasing most of the distinctions between x-rays and fission. Only the existence of quantified data in dog 18-45's table

Table I, a.

Symptoms in patients showing delayed effects.

Day after explo- sion.	Most Severe (Patients usually within 1.0 Km. of center)	Moderately severe (Between 1.0 and 1.5 Km.)	Mild (1.5 to 2.5 Km.)
1.	1. Nausea and vomiting	1. Nausea and vomiting	
2.	after 1-2 hours lasting	after 1-2 hours lasting	
3.	1-2 days.	1-2 days.	
4.	LATENT PERIOD		
5.	2. Bloody diarrhea		
6.	3. Vomiting		
7.	4. Fever	LATENT PERIOD	
8.	5. Rapid emaciation		
9.	Death		
10.	(Mortality probably		
11.	100%)	2. Beginning epilation	LATENT PERIOD
12.		progressing until death	
13.			
14.			
15.			
16.			
17.			
18.		3. Loss of appetite	
19.		and general malaise.	1. Epilation
20.		4. Fever	2. Anorexia and
21.		5. Herpetiform eruption	malaise
22.		about mouth and on	3. Sore thr at
23.		mucous membranes progressing	4. Pallor
24.		to necrotic stomatitis	5. Petechiae
25.		with hemorrhagic gingivitis.	6. Diarrhea
26.			7. Moderate
27.		6. Pallor	emaciation
28.		7. Petechiae, bloody	(Recovery unless co
29.		diarrhea, epistaxis, and	plicated by previou
30.		hematemesis.	poor health or supe
31.		8. Rapid emaciation	imposed injuries or
		Death	infections
		(Mortality probably 50%)	

Figure 2.2. Table systematizing Radiological Symptoms over time from exposure to the bombs in Hiroshima and Nagasaki. Source: Preliminary Report Atomic Bomb Investigation, 27 November 1945, Box 298. Stafford Leak Warren papers (Collection 987). Library Special Collections, Charles E. Young Research Library, UCLA. Source is in the public domain.

TABLE I.—18-45—ROENTGEN RAY, LETHAL DOSE.

Date.	Weight, pounds.	Urine, c.c.	Nitrogen, grams.	Diet.	Remarks.
Oct. 1	23.93	460	2.38	400 c.c. water	Dog normal; slight cystitis.
2	23.37	520	2.52	400 "	
3	23.00	440	....	400 "	
3	Roentgen ray—500 ma. min., 2 mm. aluminum filters, spark gap 9 ins.				
4	22.00	545	4.20	400 c.c. water	Dog dull.
5	21.81	550	5.88	400 "	Vomiting.
6	20.62	410	7.34	400 "	Dog very sick; vomitus; blood N. P. N. = 50 mg.
7	Dead	655	4.76	....	Much bloody diarrhea.

Figure 2.3. Whipple and Hall's Tabulation of Dog 18-45's Last Days in 1919. Note the Similarities with the Medical Section's symptom table. Source: C.C. Hall and G.H. Whipple, "Roentgen-Ray Intoxication: Disturbances in Metabolism by Deep Massive Doses of the Hard Roentgen Rays," *American Journal of the Medical Sciences* 57, no. 4 (April 1919). Source is in the public domain.

indicated difference in context. In the lab, the doctors could take measurements. In the ashen remains of Hiroshima and Nagasaki, such figures proved impossible to come by in the first days after the blast.

While the MED report adhered to norms from the animal x-ray tradition, it also benefited from contemporary animal research. Just a month before the Preliminary Report came out, Art Welander, a graduate student at the University of Washington's Applied Fisheries Laboratory, published a report on his long-term x-ray experiments with chinook salmon in 1943 and '44. Warren organized the lab back in 1943 and had tasked its researchers with an experimental program that expanded the animal x-ray tradition.[156] This they did, learning about x-ray practice as they reared irradiated fish in their lab. In November 1945 Welander reported that "during the course of the experiment it became clear apparent that the hemopoietic [blood-forming] tissue… was injured as much, if not more, than any other tissue."[157] The report to Groves followed Welander's lead as it discussed fission effects in humans, "the

156 See Chapter One.

157 UWFL-2, UWLRB.

important laboratory findings related primarily to disturbances in the hematopoietic function… the most striking findings at autopsy were signs of destruction of the bone marrow...[158] Of course fish lack bone marrow, a problem Warren floated past Donaldson in 1944. They make their blood in their kidneys. Regardless of physiological differences, the Preliminary Report followed Welander's verbiage as it singled out blood-forming tissue as a key histological interest. The MED's active x-ray animal research program allowed them to argue that they found fission symptoms "which would have been predicted from animal experiments..."[159]

Motohashi's reporting mirrored the MED's, a sign of the international norms established within the experimentalists' community. He argued that the radiation disease moved through the *hibakusha* in three stages. These temporal units roughly fit with the three groups in the MED report. He agreed with the MED doctors that "those who happened to be near the center of bombing and have received a good deal of gamma-rays and neutrons died in a few days or at least in about 10 days."[160] His timings for symptoms in stages two and three also lined up with the American data. He created a bar graph that showed the timing of symptoms in groups who died in stage one, stage who, and who survived through stage three. The image accomplished somewhat more elegantly what that MED's table attempted to. Having shown his readers the graph, he then quantified the occurrence of symptoms among those sample populations from Hiroshima. For example, "nausea and vomiting were pronounced symptoms on the day of the bombing, appearing in proportion of 99/287 for survivors and 38/228 for the dead."[161] Across the board, Motohashi presented more fine-grained data than the MED did.

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158 Preliminary Report, 27 November 1945, MSS Warren.

159 Ibid.

160 Medical Report, 30 November 1945, MSS Warren.

161 Ibid.

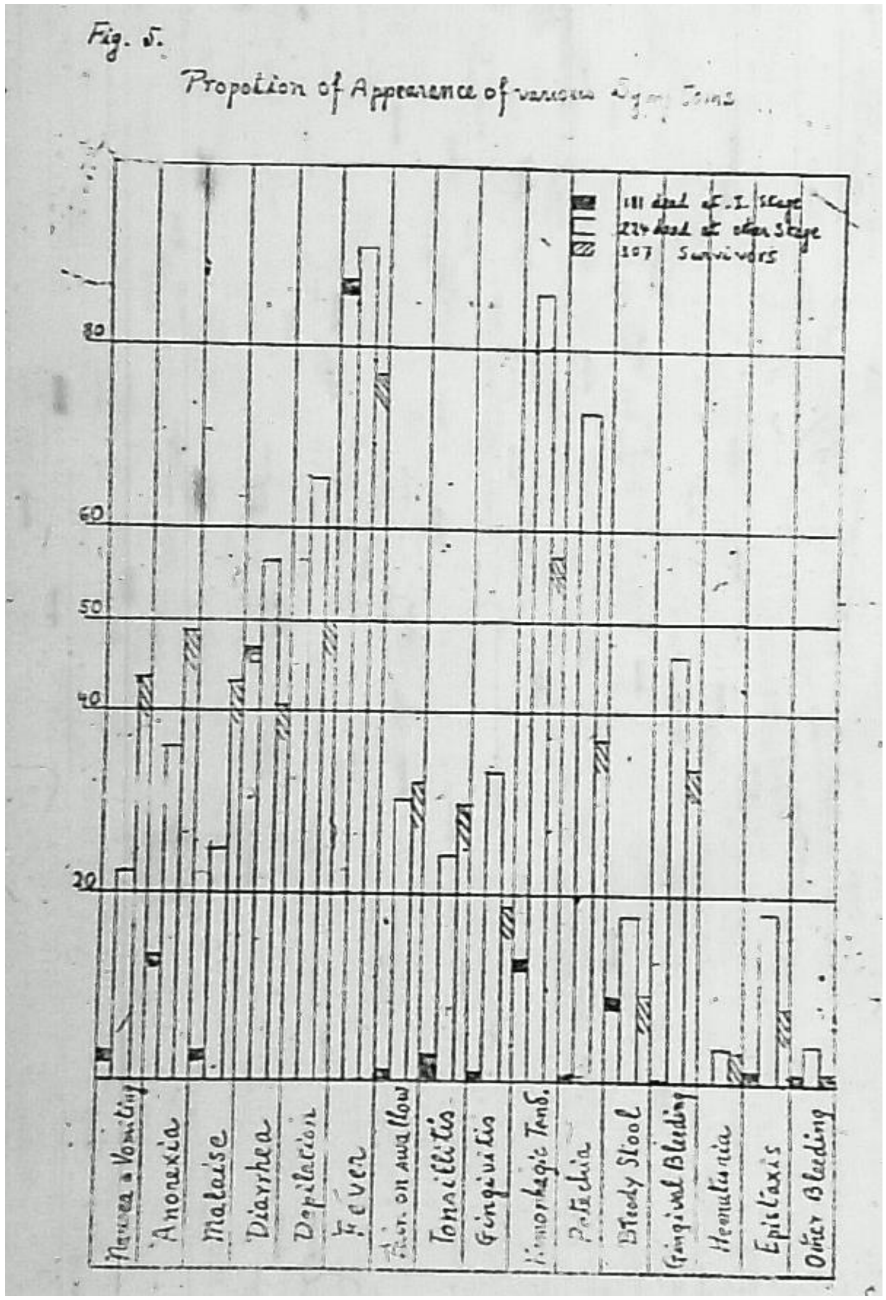

Figure 2.4. Motohashi’s Chart Showing the Appearance of Radiological Symptoms. Army Medical College – The First Tokyo Army Hospital, Medical Report of the Atomic Bombing in Hiroshima, 30 November 1945, 16, Box 61, Reel 11.1. Stafford Leak Warren papers (Collection 987). Library Special Collections, Charles E. Young Research Library, UCLA. Source is in the public domain.

Motohashi’s attention to detail perhaps anticipated differences with the US experimentalists. While the question of blood picture pushed the Americans towards contemporary fish data, Motohashi zeroed in on individual human beings in his report. In a series of four graphs, he described blood sedimentation, a measurement of inflammation based on the behavior of red blood cells. In each graph he described an individual whom he named. Certainly, Motohashi benefited from access to patient data from army hospitals in Hiroshima in his native tongue. But graphing the lives and deaths of individuals pulled his atomic practice away from the Americans. Though portrayed according to norms from the x-ray animal tradition, in these graphs Motohashi presented a properly atomic symptom. Data from fission stood on its own and could be interpreted on its own.

As the winter of 1945 spilled into '46, the Japanese and American experimentalists increasingly diverged as they interpreted the data collected from first three months after the bombings. In the suite of symptoms they quantified, the Japanese doctors identified a discrete disease with a clear genesis. Motohashi and the Army Medical College called it radiation disease in their November report. Here he closely followed Hachiya's practice on the 27 August broadside on radiation sickness in Hiroshima. In February 1946, Tsuzuki argued that "we would like to call such a pathologic condition as a whole an 'Atomic Bomb Disease.'"[162] In contrast, the MED never saw any wholeness that constituted a disease. Their November report referred to "the biological effects of radiation," a term directly plucked from the animal x-ray tradition.[163] In a comprehensive report published in June 1946, Warren and Henry Barnett, who had been at Omura, concluded, "radiation injury has the advantage of custom, since it is generally

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162 Masao Tsuzuki, "Report on the Medical Studies of the Effect of the Atomic Bomb," 28 February 1946. Translation in *General Report: Atomic Bomb Casualty Commission January 1947*, 74, U.S. National Research Council, http://www.nasonline.org/about-nas/history/archives/collections/organized-collections/atomic-bomb-casualty-commission-series/abccrpt_pt3app9ch1.pdf

163 See note 31. Both Warren and Tsuzuki shared a vocabulary about the biological effects of radiation. Warren had even praised x-ray rabbit experiments that Tsuzuki performed in the 1930s.

understood in medicine to refer to X-ray effect."[164] In Warren's view, fission remained tethered to x-rays.

The experimentalists parted ways at the end of 1945 not because of differences in practice but because they disagreed about to define the biological action of the new fission. The Japanese doctors described a unity, a single disease easily traceable to the moment fission. They saw the sickness as a continuation of the bombs' total effect. Fission created burns, broken bones, and radiation injuries. The Americans never understood fission in that way. Its blast effects and heat effects were essentially like those from conventional bombs. Its radiation was essentially like x-rays. In the lab, they never described exposure to x-rays as a disease. Why should they with fission? Charles Rosenberg has argued that "the existence of a disease as *specific* entity is a fundamental aspect of its intellectual and moral legitimacy."[165] Based on laboratory experiments with animals, the MED never afforded that legitimacy to the *hibakusha.*

Selling the Manhattan Engineer District Medical Section Synthesis

When the Medical Section team returned to the mainland in October 1945, they busied themselves with the preparation of the Preliminary Report for General Groves. Warren returned to Rochester, where many of the doctors sifted through that data and samples they lifted from Omura. Howland returned to Oak Ridge. Some returned to their postings at Los Alamos. Their reporting turned out to be the Medical Section's swan song. The unit as such wound down after the war. Its final, comprehensive report, in

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164 Leslie Groves, "The Atomic Bombings of Hiroshima and Nagasaki," 29 June 1946, accessed 12 May 2023, https://www.atomicarchive.com/resources/documents/med/index.html

165 Charles Rosenberg, "Framing Disease: Illness, Society, and History," in *Framing Disease: Studies in Cultural History*, eds. Charles Rosenberg and Janet Golden (New Brunswick, New Jersey: Rutgers University Press, 1992), xvi.

which Warren argued against calling the effects of the bomb a disease, came out at the end of June 1946.[166] The doctors largely returned to civilian life, though many stayed on at the hospitals and laboratories that made up Warren's network dedicated to researching the biological effects of radiation.

Concerned that his influence might wane within the atomic establishment as this transition occurred, Warren took as many opportunities as he could to bolster the Medical Section's work and worldview. The Colonel already felt a competition for resources and influence brewing. He looked with skepticism on the long-term American mission based in Hiroshima that would become the Atomic Bomb Casualty Commission. He also perceived competition from Sheilds Warren, no relation, who had led the Naval Technical Mission's Medical Section in Japan. A pathologist by training, Shields saw little use for Stafford's animal studies and environmental radiation monitoring. Beyond competition from within the nascent American atomic establishment, voices from within the Japanese establishment became more and more assertive as 1945 rolled into 1946. Invigorated by his own National Research Council's work, Masao Tsuzuki increasingly defied the occupation government in Japan by presenting research that emphasized the long-term dangers and damages of radiation.[167] In this competitive milieu, Stafford felt the need to trumpet the Medical Section's way of knowing radiation's effects.

A dinner reception held at Oak Ridge on 1 November 1945 afforded Warren his first opportunity to trump the Medical Section's successes and assert its way of doing radiation biology. A last hurrah of sorts, the evening featured remarks from General Groves, Warren, and others as they wined, dined, and handed out rank advancements to the men who would soon be rejoining civilian life. Warren titled his talk "Odyssey in the Orient," casting his doctors' visit to Japan in the mold of a heroic

166 See footnote 59.

167 When the first official Atomic Bomb Casualty Commission team visited Tsuzuki in November 1946, he offered them a reception that Susan Lindee described as "chilly" in *Suffering Made Real*, 41.

scientific quest.[168] Waxing on about one very dodgy plane ride from Tokyo to Hiroshima, he remarked, "I was very pleased with these men who had led a laboratory existence and come up against this risk of their lives and yet they didn't get upset or panicky about it."[169] He wanted his listeners to remember that heroics made the Medical Section's work possible.

When he was not spinning yarns, he highlighted the content of the Medical Section's key understandings. First, he argued that the somatic insults resulted from γ-rays and free neutrons created in the moment of fission. Long-term radiation danger was negligible. "There was no doubt that there was gamma radiation injury. It was also possible that were was a very slight amount of radio-activity on the ground, but very slight."[170] Second, he made an animal analogy, describing a bull at the Medical School in Nagasaki. "In the basement of one building, was a large bullock. This bullock was dead even though there was no fire in the building. This shows that the pressure [from the blast] was strong enough to cause loss of life."[171] Finally, distinguished between the bombs' radiological burden and their conventional attributes, comparing the atomic bombs to the firebombing of Tokyo. "The destruction… is unbelievable in Tokyo where the standard type of bombing is. The only difference is that the major destruction is in one spot and there is less destruction from there out."[172] These hallmarks, the argument that radiological danger was short lived, that animals could stand in for humans, and that the bombs acted like very large conventional devices characterized the biology that Warren practiced.

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168 Stafford Warren, "Odyssey in the Orient," 1 November 1945, Box 285, Folder 2, MSS Warren.

169 Ibid., 7.

170 Ibid., 5.

171 Ibid., 6.

172 Ibid.

Not content to rally just the true believers in the Medical Section, Warren took his show on the road. In the late January 1946, he delivered a lecture to an audience of medical students and faculty at Stanford. The Colonel spoke from note cards and shared case histories of patients from Nagasaki whom made it to the hospital in Omura. He prefaced his remarks by saying that they were not conclusive, that he hoped to offer the students a "stimulus to to [sic] study more detailed reports when they become available."[173] Evangelism came naturally to Warren, especially when he spoke to doctors whom he believed he could co-opt into his vision of the atomic future.

The case histories he shared contained a fine-grained detail that none of the MED's reports would. He described discrete individuals, including the minute details of their location at the moment of irradiation. The case histories also described the patients' experience of the onset of their symptoms. Of one Senji Yamaguchi, a 17 year old student, Warren reported, "as he was climbing over the hills he noticed that he was burned – the skin from the back of his hands had slid down."[174] 23 year old nursing student Matsuo Sachiko "noted that her hands were burned-- noted small blisters."[175] Sumiteru Taniguchi, a 17 year old postman, "had a severe diarrhea about 12 Aug – lasting two days."[176] The cases contained exactly the kind of detail that the Medical Section's reports did not. They did contain blood data though: white blood cell counts, red blood cell counts, and hemoglobin levels. Warren must have filled out the speech with off-the-cuff remarks which remain lost to time. So are the 79 prints which he managed to have declassified in order to use as visual aids. Nevertheless, given his epistemic commitment to a biology that normalized the bomb, one can guess at his commentary as he worked

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173 Patient Reports with SLW Speech, January 1946, Box 60, Folder 15, Reel 10.8, MSS Warren.

174 Ibid.

175 Ibid.

176 Ibid. Taniguchi survived his terrible burns and went on to become a globally prominent antinuclear activist.

through the case histories. He must have used the opportunity to sell his biological vision to the elite medical students in Palo Alto.

Warren knew that the Medical Section's way of knowing the biological effects of radiation existed as one among many in the months after the bombings. He wanted his men, his labs, and his viewpoint to endure, partially because of ego and partially because he thought it could best serve the US in its future atomic endeavors. Having spent time in the post-war chaos in the home islands, he understood just how epistemically up in the air the effects of radiation were. The last months of 1945 and first months of 1946 began a long-term struggle for Warren to popularize his understanding of what the bombs did to animals, humans, and the environment.

Conclusion: Atomic Visions

Biologically, what did it mean that two atomic bombs razed Hiroshima and Nagasaki in early August 1945? For a host of unsuspecting men, women, and children, it meant instant death. For those who survived the blasts, the answers to this question are complex and unstable, like the radioisotopes that fueled the two bombs. Michael Gordin has argued that the bombs themselves experienced an instability of meaning as they fell. Initially just very powerful firebombs, they underwent an "apotheosis" after the emperor announced Japan's speedy surrender in mid-August.[177] In Gordin's estimation, their destructive power mated with their political power to give "atomic" a new and singularly special definition. In their own contextual ways, the local doctors and the military experimentalists worked out what it meant that the symptoms ailing and killing the *hibakusha* were atomic, were born of fission. This chapter has argued that in the first three months after the bombs fell, radiation sickness existed both without reference to radiation at all and without the distinction of actually being a sickness. No

177 Gordin, *Five Days in August,* 14.

straightforward path led the suite of biological symptoms towards reification as a discrete disease, let alone one easily tied to fission, in the autumn of 1945.

Instead, the biological effects of the bombs became tied to the new fission in fits and starts. The novel disease took root amid prewar practices and knowledge traditions. Local doctors forced into clinical service in Hiroshima and Nagasaki reached backwards to classic responses in cases of public health emergencies. They treated infections. They created separate wards and worked to enhance sanitary conditions for patients whom they believed suffered from cholera and dysentery. In many ways their medical responses in the first few days after the bombings looked much like those in cities that had been firebombed by conventional ordinance. But as patients inexplicably died, they turned to traditional hospital practices like taking case histories and, when they got the equipment, taking white blood cell and platelet counts. They created knowledge, new to them, even as information about the bombs' radiation trickled into their destroyed cities. At the same time, outside doctors from the Japanese and US militaries reached into the past to deploy knowledge they had created in the laboratory using x-rays. They tied these two distinct radiations, known x-rays and novel fission, together. From the start, fission's agency remained in the background.

When accounts of the bombs' effects began to stabilize in late 1945 and early 1946, Japanese doctors and American doctors treated fission's work distinctly. Japanese accounts pointed to a clearly atomic disease, born of the new technology that ravaged Hiroshima and Nagasaki. Local clinicians made this argument by appealing to their personal experience. They suffered from the same disease they struggled to understand and treat. Japanese experimentalists privileged the action of the new fission by assigning to it a distinct disease. In many ways, the American-led Atomic Bomb Casualty Commission (ABCC), whose researchers studied the bombs' genetic fallout, tacitly acknowledged these conclusions in the decades after the bombings. "*What happened* to the survivors – the slow and invisible internal pathologies of their bodies over the decades," says Susan Lindee, "was gradually made visible and real by the science of the ABCC."[178] But such a disease, a coherent group of pathologies, never became clear to the Manhattan Engineer District, the progenitors of the bombs.

Instead, for Warren and his cadre of doctors and scientists, x-rays stood astride fission until the end of atmospheric testing in 1963. So would the tradition that data from animals and humans could interchangeably describe radiation's biological effects. Their bombs induced no new disease, they just produced more data. In many ways, Hiroshima and Nagasaki existed as experiments for the MED's Medical Section, albeit uncontrolled ones. With their experience from Hiroshima and Nagasaki, they looked forward to future tests in which they could more elegantly unify the controlled world of the x-ray laboratory with the uncontrolled world of the atomic bomb. Hiroshima and Nagasaki afforded the Medical Section the opportunity to collect blood data and human tissue samples for histological analysis. Already, x-ray lab techniques proved applicable to human fission cases. But a synoptic view of the bombs' biological effects continued to elude the Medical Section. Fortunately for Warren, the utility of his way of knowing radiation would afford his doctors and scientists opportunities to expand their reach within the growing US atomic program. They already had. Even as the Medical Section doctors collected data in Japan, their companions from the Applied Fisheries Laboratory collected data from a new laboratory built to study fission from the reactor cores on the south shore of the Columbia River in central Washington state.

178 Lindee, *Suffering Made Real*, 256.

Chapter 3

A River Runs Through It

A Laboratory to Diagnose a Landscape

On a cold February day in 1945, the operators at the newly completed F Pile at Hanford activated its massive cooling pumps. These pulled 35,000 gallons of water per minute from the Columbia River to cool the pile's massive reactor core. Electricity from the Grand Coulee Dam downriver powered these great cooling pumps. As they droned, the third plutonium production reactor at the Hanford Engineer Works officially came online. River water rushed through the intensely hot, radioactive core. Next, a warren of pipes carried the water to a massive retention basin. Exposed to the gusting winds that blow across the treeless steppe, the basin offered a space where the most dangerous and shortest-lived radioisotopes created in the core could decay. From the basin, a sewer line carried the somewhat less radioactive effluent back into the Columbia. A few weeks after F Pile began operating, and as the rump construction crew tied up the loose ends around the construction site, an order came to build a lone Quonset hut near the reactor.[1] After erecting the hut, construction workers ran a pipe from the main sewer line towards two small pumps that delivered effluent directly to the hut.[2] Inside the structure, the

1 J. Newell Stannard, "Oral History Interview: Dick Foster, Battelle, Pacific Northwest Laboratories," 11 June 1979, Stannard Interviews, Rad Research, Richland Operations Office Public Reading Room, Richland, Washington (Hereafter cited as ROOPRR).

2 HW-7-4759, Richard Foster, "Some Effects of Pile Area Effluent Water on Young Chinook Salmon and Steelhead Trout: A description of the experiments carried out at the Fish Laboratory between July 1, 1945 and July 5, 1946," 31 August 1946 Columbia River, HH 5-20 Rad Research Columbia River Study, ROOPRR.

builders installed 20 troughs that could house up to 500 young salmon each, awash in radioactive effluent pumped from the core. Drains carried the wastewater back to the river. Amid the bleak midwinter in the Pasco Basin, the Hanford Fish Laboratory came to life.

The new lab took its place on the southern shore of the Columbia River as part of America's massive wartime plutonium production complex, the likes of which the world had never seen. The lab's story cannot be separated from the larger narrative about plutonium production at Hanford. Loathe to occur naturally on earth, trace amounts of plutonium had first been produced in a Berkeley cyclotron in early 1941. Very quickly, Manhattan Engineer District (MED) physicists figured that plutonium could be produced by bombarding U-238 with free neutrons. These bombardments could take place during a nuclear chain reaction inside a pile like the one that Enrico Fermi built near the squash courts at the University of Chicago in 1942. To make enough plutonium to fuel an atomic bomb, the production piles would have to be significantly larger and would run much hotter than Fermi's experimental unit. To cool such a reactor would take amazing amounts of water. Fabricating unnatural plutonium required a very particular type of natural setting.

General Leslie Groves, who led the MED, approved Hanford for plutonium production because the site had an auspicious combination of natural and social advantages to aid the process. The Columbia solved the reactor cooling problem. Electricity from the massive federal Bonneville and Grand Coulee dams could power the massive pump houses that drew the water from the river into the piles' cores. Moreover, the site could easily be appropriated for federal use. Anglo farmers hung on to marginal landholdings and the Wanapum tribe, who lived along the river, had never signed a treaty with the federal government.[3] Both groups could be evicted efficiently. The scale of the site impressed Groves too. Piles could be spaced miles apart so that a disaster at one might not hinder production at another. Franklin Matthias, Groves' man in charge of procurement for the project, toured the Pasco Basin on 25 February 1943.[4] Du Pont, a seasoned government contractor, took on the project and by October that year they were milling uranium fuel rods to fit into the reactor cores they were building at the site.[5] They also built facilities, each hundreds of yards long, in which valuable plutonium would be chemically separated from the uranium fuel slugs that had passed through the pile cores. The tiny Quonset hut near the F Pile must have seemed an afterthought to the tradesmen who built such a massive complex in such a remote area in such a short period of time. Certainly, the Fish Laboratory did not share the limelight with the piles after it was announced that Hanford plutonium decimated Nagasaki on 9 August 1945.

This chapter is a study in how the biologists of the MED's Medical Section developed the Fish Laboratory to diagnose the effects of Pile radiation at the new plutonium production site. Doing so, they used fish in the lab to understand both how the reactors and how the biota of the newly radioactive landscape functioned. They used their laboratory data not just for science, but for political control of the site. The laboratory, and its benefits, did not grow up overnight. Lauren Donaldson, head of the Medical Section's Applied Fisheries Laboratory at the University of Washington, sent his graduate student Dick Foster to Hanford armed with the belief that the x-ray laboratory program and practices

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3 For a brief discussion of the Wanapum's eviction from Hanford, see: John Findlay and Bruce Hevly, *Atomic Frontier Days,* 21. For their own excellently curated telling of the story, visit the website for the Wanapum Heritage Center: https://wanapum.org/.

4 Franklin Matthias, Journal, 25 February 1943, NV0726446, NTALV.

5 Findlay and Hevly, *Atomic Frontier Days*, 23.

they developed at the mother laboratory in Seattle could be successfully translated to provide knowledge about the new fission from the piles.[6] Like the Seattle lab, the Hanford lab would produce empirical and visual data about irradiated fish that could be interpreted statistically to show how subjects and populations responded to varying levels of radiation exposure. Bruno Latour has quipped that laboratory data only makes sense out in nature if scientists can manage to extend the lab's conditions to the world. "If this means transforming society into a vast laboratory, then do it."[7] The Medical Section biologists did, envisioning the environment at Hanford from the start as landscape sensible according to the laboratory data they created. Or rather, data that the fish they used as a diagnostic technology in the Quonset hut near the F Pile created.

Highlighting the role of the Medical Section's x-ray research program in the development of biology at Hanford places the often-obscured laboratory bench back at the center of stories about the federal control of atomic sites in the US West and Pacific. That the federal government has relied on experts wielding scientific values to manage vast western installations is no new story.[8] But the biologists at Hanford worked differently than so many scientists dispatched from Washington DC or from eastern academies. They studied *in situ*, claiming a privileged relationship with the land based on

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6 See Chapter 1 for a description of the Applied Fisheries Laboratory's wartime research program.

7 Bruno Latour, "Give me a Laboratory and I will Raise the World," in *Science Observed: Perspectives on the Social Study of Science*, eds. Karen Knorr-Cetina and Michael Mulkay (London: Sage Publications, 1983), 166.

8 See Ted Porter on cost-benefit analysis, the construction of dams, and the conflict between the bureaucrats of the Army Corps of Engineers and the Bureau of Reclamation in "The U.S. Army Engineers and the Rise of Cost-Benefit Analysis," chap. 7 in *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life* (Princeton: Princeton University Press, 1995). For the story of biologists coming to Yellowstone National Park to conduct field surveys of brown bear populations, see: Etienne Benson, "The Poetry of Wilderness," chap. 2 in *Wired Wilderness: Technologies of Tracking and the Making of Modern Wildlife* (Baltimore: The Johns Hopkins University Press, 2010).

lived experience. Theirs was no seasonal field station. They worked out of a proper field laboratory, trusting the bench to stand in for the vast landscape they oversaw. As an element of the complicated web of federal oversight at Hanford, the Fish Lab's biology became a means for control and the exclusion of those not dedicated to the plutonium production mission at the site.

Accounts of institutional biology at Hanford tend to miss the lab, focusing instead on scientists' field researches. Naturally so, radiation from reactors and the chemical separation plants ended up in the field and in human populations living around the site. Angela Creager has told the story of Karl Herde's 1947 radiation bioaccumulation studies using fish from the Columbia and has connected him to the work of the great popularizer of ecosystems ecology, Eugene Odum.[9] Rachel Rothschild has also tied the biological work at Hanford to ecosystems research within the AEC during the 1960s.[10] The parentage of the Fish Lab complicates these well-told stories. Foster trusted his experience at the bench in his formative years at the Applied Fisheries Laboratory during the war. He trusted the data that his trough and pond-bound salmon populations could give him. He and his staff favored the lab over the land to create useful knowledge. The prominence of the bench, trough, and pond differentiated biology at Hanford from other AEC installations, like Oak Ridge and Savannah River, that embraced ecosystems ecology.[11]

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9 Angela Creager, "Ecosystems," chap. 10 in *Life Atomic*, 370. She tells a story about basic ecosystems ecology research that moves from Hanford and Seattle to the work of Odum, who held a position at the University of Georgia and did ecosystems research at the AEC facility at Savannah River. With his brother Howard, Eugene wrote the influential 1953 *Fundamentals of Ecology*. For a longer treatment of Odum's work with radiation and ecosystems see: Joel Hagen, "Ecology and the Atomic Age," chap. 6 in *An Entangled Bank*.

10 Rachel Rothschild, "Environmental Awareness in the Atomic Age: Radioecologists and Nuclear Technology," *Historical Studies in the Natural Sciences* 43, no. 4 (September 2013), 492–530.

11 See Bocking's, "Ecosystems, Ecologists, and the Atom: Environmental Research at Oak Ridge National

To show the first step in Hanford's "transformation according to laboratory experiments," I describe the origins of the Fish Lab's program and the details of its construction as a site that would mimic the Columbia River and its mother lab in Seattle.[12] This part of the story begins in the first full week of June, 1945 as Lauren Donaldson and Colonel Stafford Warren conducted two meetings to plan the details of the Fish Lab's first experiments. The colonel helped articulate a vision for the lab that would translate the x-ray animal tradition he knew so well to the problem of pile effluent in the Columbia. The Fish Lab's first experiments would be near exact copies, using radiation from fission, of work done at Seattle. Practices that involved taking population-wide growth measurements and emphasized visual investigations of individuals would form the foundation of the lab's research. Studies of subjects in the lab could be diagnostic of fish exposed to radiation in the Columbia because Foster's captive fish would "follow, as nearly as possible, the expected stages of development of the fish in the river."[13] Controlled by experts, the lab could provide data even more true than observations from nature. Warren, Donaldson, and Foster never worried that their captive hatchery populations and their captive effluent streams would fail to "reflect… biology as it really is." [14]

Next, I show how laboratory practices and data outcompeted collections and data from the river itself as the foundation for understanding the effects of radiation at Hanford. Foster and biologists from allied departments at Hanford engaged, from the very start, in both field and laboratory researches. Foster and Donaldson, having worked in rivers, hatcheries, and laboratories, moved "freely between

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Laboratory," for stories of ecology at other AEC sites.

12 Latour, "Give me a Laboratory," 167.

13DUH-7287, Lauren Donaldson, Program of the Fisheries Experiment for the Hanford Field Laboratory, June 1945, ROOPRR.

14 Karen Rader, *Making Mice: Standardizing Animals for American Biomedical Research, 1900 – 1955* (Princeton, Princeton University Press, 2004), 21.

field and lab, untroubled by the invisible boundary that, for other biologists, separated distinct and unequal areas of science."[15] Like the lab at Seattle, the Hanford lab itself would straddle the boundary between the bench and the field, since the lab used indoor and outdoor spaces to conduct all manner of experiments. But laboratory research quickly surpassed field observations as the *sine qua non* of what constituted biological truth at Hanford. This happened, in part, because Donaldson and Foster had really internalized the values of the laboratory tradition that Stafford Warren fostered within the MED's Medical Section. But lab data also grew in importance because of Hanford's vast size and the complexity of its environmental setting. The Fish Lab turned its salmon and steelhead into monitoring technologies that created data quickly, a virtue given the absolute novelty of the fission reactors' radiological outputs.

This chapter concludes with a story about how the Hanford biologists used their laboratory program to build scientific barriers around the site, to keep prying eyes from state and federal agencies away from their river. This part of the story begins after the MED had passed away and Du Pont had left Hanford. The AEC replaced the army as overseers and General Electric took over as prime contractor in 1946. As a response to the AEC's increased push to openness, administrators in Richland created the Columbia River Advisory Group in 1949. Comprised of representatives from the US Public Health Service, Washington Pollution Control Commission, and Oregon State Board of Health, the Group was to serve as something of a mouthpiece for the site's pollution control efforts. In fact, Hanford's scientific establishment used it as a forum to fend off the possibility of an incursion by the US Public Health Service in the form of a survey of the Columbia. The conflict played out like so many

15 Robert Kohler, *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology* (Chicago: University of Chicago Press, 2002), xiii.

contests over federal spaces in the West.[16] Data left the realm of the lab to take on bureaucratic and political significance at Hanford.

Biological labs bear transformative power when they produce data that represents environments and populations bound to real geographical space. The Naval Hospital in Omura became such a lab when Medical Section doctors used it to collect case histories and tissue samples that represented the biological effects of the plutonium bomb over Nagasaki. The Applied Fisheries Laboratory at the University of Washington served comparably as a site able to create data about geographies native to prewar Pacific Northwest fisheries biology. Its fishy subjects came from sundry hatcheries in Washington State and British Columbia and then disappeared into the vast Pacific when released. In 1945, the Fish Lab on the Columbia laid claim to all the stretches of that river exposed to radiation from the B, D, and F piles. The fish raised and data collected amid its radioactive troughs helped transform a huge swathe of western steppeland into a place dedicated to, and bearing the brunt of, American dreams of nuclear hegemony.

A Biological Lab for Fission

On 7 June 1945, Lauren Donaldson hosted an all-hands meeting at the Applied Fisheries Laboratory to discuss the future of the new lab that had been built next to the F Pile at Hanford. Donaldson's three assistants from Seattle attended: Dick Foster, Art Welander, and Al Seymour. Major A.A. White, the MED liaison, and Simeon Cantril, Hanford's assistant medical superintendent who had worked closely with Warren to establish the AFL, had driven over the Cascades from Richland. Hymer Friedell,

16 For an evocative description of federal and state conflicts over salmon in the Columbia River, along with a reflection on the use of the treaty of 1855 by the Yakima, Umatilla, and Nez Perce tribes to assert administrative rights over the river and its fish, see: Richard White, *The Organic Machine* (New York: Hill and Wang, 1995), 93 – 104.

Stafford Warren's second in command in the Medical Section came from Oak Ridge. There he had overseen Joseph Howland, one of the doctors who would collect biological samples from *hibakusha* in Omura after the bombing of Nagasaki, as he injected unwitting patients with plutonium in 1943.[17] Friedell had visited the Seattle laboratory before and had a good rapport with Donaldson and Welander. "The conference," according to the laboratory's daily logbook, "ran throughout the day."[18]

The fisheries biologists meeting on 7 June created a plan to closely reproduce the design of the Applied Fisheries Laboratory next to the F Pile. They used standardized hatchery fish, with which they were already familiar. The use of control species would allow them to vary radiation exposures to create novel data. The lab's architecture facilitated the novelty. It would hold 20 troughs. Through each some different ratio of effluent to river water would flow.[19] In troughs one, two, three, and four contained 100% effluent. Troughs five through 16 would contain some ratio like 1:250 waste to river water. Troughs 17 through 20 carried control populations in 100% river water. This experimental set up mimicked that of the Seattle lab as closely as possible. At the university, the biologists segregated fish by the levels of their x-ray exposure. Even though the nature of the radioactive sources differed at the two labs, Donaldson and Welander wanted to retain the end goal of each experiment, the quantification of somatic effects and mortality rates within lots. Foster would weigh and measure fish exposed to pile waste and he would count the number of deformities and deaths that lots experienced just like Welander in Seattle.

The fisheries biologists at this meeting also planned for a multi-generational chinook study as a way to understand the somatic and genetic workings of pile effluent over time. "When the fingerlings

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17 See Chapter 2.

18 OSRD Experimental Research Project Data – 9/21/44 – 6/11/45, 7 June 1945, Box 9, Folder 15 MSS Donaldson.

19 HW-7-1779, Simeon Cantril to W.D. Norwood, Regarding the Fish Program – 100-F, 13 June 1945, ROOPRR.

reach a stage when downriver migration would normally occur, it is planned to… tag and release a certain number of the fingerlings for eventual recovery."[20] Such a "rear and release" plan would follow the pattern of the chinook experiment begun at the Seattle Lab in 1943. In it they reared fish from irradiated eggs and then released them in the Samish River north of Seattle.[21] At Hanford, Foster would start with egg lots, tabulating developmental data until they were ready to release into the Columbia. Once the fish returned to Hanford in three years, he could spawn them and collect data from the next generation. These types of data were all reasonable to collect in the less-than-refined Quonset hut laboratory. Mortality and deformities simply involved visual counts. Length and weight could be taken using tried and true fisheries lab techniques. By tracing these numbers across a generation, they could establish the long-term effects of exposure to fission from pile effluent and begin to create a picture of what was going on in the Columbia.

With a good night's sleep behind them and some basic agreement about what the program at the Fish Lab should entail, Donaldson, White, and Friedell caught the noon flight to San Francisco on 8 June.[22] Back at the Seattle lab, Foster and Welander went about mundane tasks. "Got some liver and ground it up for fish food. Worked on statistics about chinook egg mortality."[23] Meanwhile the men who flew to San Francisco worked their way across the Bay to the University of California campus in Berkeley. Stafford Warren waited for them there, eager to finalize the details for his new laboratory at Hanford. Joseph Howland joined the group as well.[24] This gathering of biologists and medical doctors

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20 Cantril to Norwood, 13 June 1945, ROOPRR.

21 UWFL-6, UWLRB. See Chapter 1 for the Seattle lab's first release experiment.

22 OSRD Experimental Research, 8 June 1945, MSS Donaldson.

23 Ibid.

24 See Chapter 2.

in Berkeley perhaps, out of any wartime moment, best embodied the multidisciplinary and interspecies way of approaching radiation problems that grew up in the Medical Section.

The discussion at the Berkeley meeting, which ran from 9 to 11 June, reflected the sometimes efficient and sometimes awkward marriage of fisheries biologists and medical doctors. The three MDs deferred to Donaldson on matters of basic experimental setup. But they wanted more data than Donaldson had initially assumed the field lab could provide. "The studies on these fish should include mortality, growth in weight and growth in length. Additional studies on the red cell count and the relationship of length to weight should be carried on to provide information on the vitality of the fish."[25] With the Trinity Test fast approaching in mid-July and, assuming its success, the bombings of Japanese cities on the horizon, the medical doctors had blood and blood picture on their minds. Warren also wanted Foster to engage in microscopy. "It may also be possible to carry out some histological studies of the effect of the effluent waters on the gills, skin, etc."[26] Finally, the doctors vetoed the multi-generational rear and release experiment. They wanted data about somatic insults and about population epidemiology from pile effluent as quickly as they could get it. Warren had demanded similar quick data from the Seattle lab in 1943. Tagging, releasing, and waiting for a lot of salmon to mature and return to Hanford, a fisheries biology concern, took a back seat to population statistics, a medical concern.

The first researches at the Fish Lab created empirical and visual evidence because of the medical doctors' desire for quick somatic data. Warren had been trained since medical school to rely on this kind of data. So had Friedell and Howland. Just a year prior, the three men all concurred that human exposure would be the best way to understand the new element that Hanford was designed to

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25 DUH-7287, Lauren Donaldson, ROOPRR.

26 Ibid.

produce. Warren had instructed his lieutenant Andrew Dowdy at the University of Rochester to begin plutonium injections in December 1944. "It is the opinion of this section that a limited number of careful human experiments should be made with this material… these should include injection and skin application."[27] Dowdy oversaw the injections at Rochester as Friedell oversaw them at Oak Ridge. The two corresponded about their work in the Spring of 1945.[28]

By June, when the three doctors met with Donaldson and White, the human experiments had already yielded some data in the form of blood, urine, and fecal samples from the injected subjects. These were analyzed at Los Alamos.[29] Dowdy, and likely Friedell, had not anticipated that they would get very much metabolic data back from living subjects injected with plutonium. "To be of any value this information would have to be obtained from cases which would be apt to go to post mortem and on whom we could obtain an autopsy."[30] The assumption was that injected subjects would die of whatever malady brought them into the hospital, before their surreptitious injection. That subjects lived and yielded bodily fluids for study proved an unexpected bonus. The doctors brought this insight with them to Berkeley. Fish exposed to effluent could live and offer up blood and tissue samples. If the fish died, they could be autopsied so Foster could look for damage to organs and tissues. At any rate, the experience that the Medical Section doctors had with human subjects was fresh in their minds as they thought about what data would be most valuable from the fishy subjects at Hanford. The power of exposed subjects to best display radiation's biological effects was built into the Fish Lab's genome from the start.

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27 Stafford Warren to Andrew Dowdy, 1 December 1944, NV0709684, NTALV.

28 Hymer Friedell to Andrew Dowdy, 8 May 1945, NV0720607, NTALV.

29 See Chapter 4.

30 Andrew Dowdy to Stafford Warren, 6 December 1944, NV0709687, NTALV.

The initial experiments dreamt up in Seattle and Berkeley required Foster to spend long hours on logistical and technical work in the summer of 1945. After returning to Seattle on 12 June, Foster worked to get his dissertation research at the Applied Fisheries Lab in order so that he could depart for Hanford. He was running a study on the offspring of rainbow trout exposed to x-rays. They had grown enough that on 26 June he had to cull each experimental lot of fish.[31] Three days later he made the drive to Hanford to officially become a Du Pont employee. He immediately set to work making sure the lab's infrastructure would be ready to welcome the first lots of experimental fish. Unfortunately, it was not. The effluent that came from the reactors, even after traveling through the sewers and retention basins, was too hot for salmon or steelhead. The lab required an intricate refrigeration system involving compressors and cooling coils to bring the wastewater down the temperature of the river water. This cooling was especially important for troughs one, two, three, and four since they contained 100% effluent and no river water. Despite Foster's best efforts, the cooling system only came online in late July.[32]

As Foster tackled the refrigeration problem during the first week of July, Donaldson delivered fish, research subjects produced in the complex network of fisheries dotting the Pacific Northwest. The first fish that would swim in the lab's troughs were the offspring of chinook salmon from Spring Creek, nearly 200 miles downriver from the F Pile. Their parents had been captured by hatchery biologists before Donaldson traveled in the lab's truck to collect them. Spawned at the Seattle lab, these fish grew up in its troughs and outdoor ponds. At 4:00 AM on 9 July, Donaldson fired up the same truck that

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31 UWFL-12, Richard Foster, "Some Effects on Embryo and Young Rainbow Trout (Salmo Giardnerii Richardson) From Exposing the Parent Fish to X-Rays," 1948, Box 9, UWLRB.

32 HW-7-4759, Richard Foster, ROOPRR.

transported their parents from the river to lab in order to drive 2130 of them for nine hours over the Cascades and down to the Columbia.[33]

Donaldson and Foster had chosen this lot because they were at the same place in their life cycle as the chinook actually swimming down the nearby river. They made the lab a manageable proxy for the river. “By early summer of 1945, these fish had reached a size and age at which they might be expected to migrate downstream to the ocean, and thus were similar to young chinook salmon migrants which might be found in the Columbia River in the vicinity of Hanford.”[34] The biologists wanted their first experimental subjects to mesh with the temporality of the biota in the river as much as possible. The irony of using fish whose parents were captured along one stretch of the river, reared at a lab, and then driven over a mountain pass to a lab on a very different stretch of the river never seems to have occurred to Foster or Donaldson, so entrenched were they in the unlikely geographies of Pacific Northwest fisheries research.

Pile effluent began flowing into the troughs at the Hanford Fish Laboratory on 23 July 1945, making it the first biological research station in the world to study the effects of radiation from fission inside a reactor on animal subjects. Foster had roughly 100 fish in each of the 20 troughs, each with a Despite the success with the cooling system, Foster struggled to keep the rate of flow through the troughs standard. Were the rate too low, the fish could face asphyxiation. Foster and his helpers would have to tinker with the lab’s plumbing for the next month in order successfully bring the water that was pumped under high pressure down to a reasonable and regular rate so his fish subjects could thrive. Statistically significant fish kills began to plague the lab just after Foster managed to get effluent to

33 OSRD Experimental Research, 9 July 1945, MSS Donaldson.

34 HW-7-4759, Richard Foster, ROOPRR.

flow through its troughs. The first occurred on 28 July. Foster had placed 50 chinook in waste water the day before, in trough 1 or 2 he did not say. He had noted that they appeared nervous, an observation requiring some background in watching salmon and judging how they acted when calm. By midday, they showed only “a passive interest in food.”[35] 42 fish died overnight.

After the fish had become acclimated to the Columbia River water for a period of two weeks, they were divided into twenty lots of about 100 fish each and distributed among the troughs. In keeping with the experimental design an attempt was made to maintain the following water conditions in the various troughs:

Trough No.	Ratio of Area Effluent to River Water
1 & 2	100% effluent (partially cooled)
3 & 4	100% effluent (refrigerated)
5 & 6	1:500 (effluent water refrigerated)
7 & 8	1:50
9 & 10	1:100
11 & 12	1:250
13 & 14	1:500
15 & 16	1:1000
17, 18, 19 & 20	100% river water

Figure 3.1. Table of Effluent Exposures, July 1945“Some Effects of Pile Area Effluent Water on Young Chinook Salmon and Steelhead Trout: A description of the experiments carried out at the Fish Laboratory between July 1, 1945 and July 5, 1946,” 31 August 1946, 13, ROOPRR. Source is in the public domain.

Foster assumed that radiation from the effluent killed them and immediately set about examining the dead subjects. “Dissection of specimens which had recently died showed no apparent anatomical abnormalities.”[36] Foster’s experience in Seattle taught him to look for obvious somatic insults from radiation. Though his histological skill never matched Art Welander’s or Kelshaw Bonham’s in Seattle, he had spent significant time culling dead fish and examining the anatomical photographs his colleagues made. He had nearly an entire lot of fish dead from radiation exposure which showed no signs of radiation exposure. More confusingly, when he repopulated the trough with fish that had been

35 Ibid., 14.

36 Ibid.

held in pure river water, they experienced higher than average mortality but no massive die-off. Fission's effects, he concluded, were novel indeed.

Another die-off of the Spring Creek chinook occurred at the end of August, creating something of problem for Foster. The beginning of that month went smoothly at the lab. Foster and his assistants eased into a routine for fish care and data collection. They began a second experiment using steelhead fingerlings, placed in troughs 3 through 20 with the chinook. The period of relative calm passed on 31 August. That morning, "the fish in Troughs 1 and 2 would not eat – they were quite weak… by 3:00 A.M. on September 1, all of the fish were dead."[37] The steelhead trout in troughs three and four suffered attrition on the 31st as well. "Many were swimming near the surface of the water and breathing was rapid."[38] 20 per cent of the trout died. Again, Foster took to the dissection table. Again, he failed to find any radiological cause of death.

The culprit behind these high mortality events turned out to be a toxic chemical rather than radiation from fission inside the pile core. Foster only came to this conclusion after another massive die-off on 11 October. He began to suspect a cause other than radiation because of the nearly monthly regularity of the mortality events and because a few months of observations had given him insight into how his fish responded to pile effluent. Because reactor operations were classified Foster had to sleuth around to figure out what was killing his fish. He determined that the die-offs corresponded to the process of refueling the reactor. "The death of the fish was thought to be caused by the presence of

37 Ibid., 15.

38 Ibid., 25.

some substance in the Area effluent water which was added only when the pile was shutdown."[39] Further research revealed to Foster that the substance was a water-soluble lubricant called Calol.

Foster's fish died because the pile operators relied on a decidedly low-tech process for changing out the uranium fuel that drove fission within the reactor core. Through the F Pile's massive graphite core passed around 2000 aluminum pipes. The pile's operators loaded cylindrical uranium fuel slugs, each about one inch in diameter by three inches long, into the pipes. The pump house pushed water from the river through these same pipes, cooling the exceedingly hot fuel slugs as the fission reaction produced free neutrons that transformed uranium into plutonium. After a batch of fuel slugs had sat in the core long enough to optimize plutonium production, roughly a month, the operators used wooden push rods to glide the slugs through the pipe.[40] They used Calol to make this easier since slugs often got stuck during removal. At the rear of the core, the plutonium-rich slugs fell into a pool of water where they could cool before being taken by rail car for processing at one of Hanford's chemical separation facilities. The Calol and the waster effluent water still traveled through the sewer to the main retention trough. From there it flowed into the Fish Lab tanks, killing Foster's chinook and steelhead.

Having learned about Calol, Foster designed an experiment to test how lethal it was to his aquatic subjects. On 20 November, he subjected some steelhead to the lubricant. "Five trout," he exposed, "to a concentration of 10 ppm [parts-per-million] 'Calol' in river water for a period of eleven hours… the fish were obviously effected by the oil since they became somewhat listless… and refused food."[41] The fish recovered when after Foster stopped exposing them to Calol. Since the Technical

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39 HW-7-4243, Richard Foster, "Occasional Heavy Mortalities Among Fish Held in 100-F Area Effluent Water and Some Effects of 'Calol' on Steelhead Trout Fingerlings," 2 May 1946, ROOPRR.

40 HW-3-2492S, Paige to G.E. McMillan, "Removal of Stuck Slugs," 12 May 1945, ROOPRR.

41 HW-7-4759, Richard Foster, ROOPRR.

Department figured the highest concentration of the oil would ever be 20 ppm during a refueling, Foster reproduced the experiment using that concentration. At this concentration one fish died while all rest recovered after they were no longer exposed. In the midst of exposing the fish to the oil, he learned that the temperature of the effluent worsened its effects. Fish exposed to Calol in pure river water suffered less than fish exposed to it in pile effluent.[42]

The data from his Calol experiment and from the two fish experiments he began in the summer gave Foster confidence that his experimental setup had the ability to diagnose the effects of F Pile's effluent. By December he had a good set of mortality, growth, and weight data about the Spring Creek chinook and the steelhead trout from Seattle. Though he had to statistically finesse some of his numbers, the results largely made sense to him. Correcting for the Calol die-offs, the mortality rates of fish exposed to both unrefrigerated and refrigerated effluent were higher than the control lots held in pure river water. Fish in the pure effluent lots also failed to thrive, putting on significantly less weight than fish in river water and fish in lots exposed to only some small dilution of effluent. The same was true of length, the 100% effluent lots were not as long as the others. These trends, combined with the knowledge that Calol piped directly from the core could kill entire lots of fish, confirmed the hope that the Fish Lab could accurately and quickly display the effects of the reactor's operations. With nearly a half a year of data in hand, Foster could argue that his lab displayed the beating pulse of the F Pile.

Foster also had proven that he could rear populations of useful subjects in his new fission lab. Even after the Calol deaths and all the culls for growth data, some 507 of the original Spring Creek chinook lived to have Foster liberate them into the Columbia at the end of September 1945. The Steelhead, which came from stocks at the Applied Fisheries Laboratory, thrived as well. Foster

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42 HW-7-4243, Richard Foster, ROOPRR.

liberated that population's survivors in January 1946 to make room in the troughs. Room was needed since Foster was rearing chinook eggs from the Washington State Hatchery at Soos Creek south of Seattle. Donaldson and Art Welander had brought the 45,800 eggs over to Foster in October. They were beginning to mature and need more space by the new year. The success of these three original populations helped prove the viability and utility of the Medical Section's experimental design at the Fish Lab. Producing data almost immediately, the fish showed themselves to be effective diagnostic technologies.

The ability of the fish in Foster's lab to effectively diagnose the behavior and effects of fission within the F Pile's inaccessible graphite core gave that data he created a privileged place at Hanford. The fish lab at once studied and embodied the new radiological reality within and along the Columbia. Hard wired to the reactor and to the river, the lab's fish existed as data-producing subjects and as technologies that could indicate some irregularity in either system. By reducing the biome of a river many hundreds of miles long and the workings of a reactor core that smashed atoms apart to data about the growth and deaths of a few thousand fish, Foster's lab could claim to exhaustively oversee the novel radiological environments at Hanford.

Scale, Complexity, and the Virtues of the Field Laboratory

The morning of 2 April 1945 likely began clear and chilly at Hanford. The river ran low, waiting for the spring melt to deliver water from the Canadian Rockies down its channel. On this particular spring day, W.E. Jordan from the Technical Department took to the river in a small boat. He carried with him "a special 100 c.c. sampling can with hinged lid and insulated side walls and mounted on a 20-foot-long pole" for taking water samples.[43] He also carried a topographic chart showing the bathymetry of the

43 HW-3-2401, W.E. Jordan, "River Water Temperature Survey," 7 May 1945, ROOPRR.

river's bottom. Jordan aimed to take a temperature survey of the F Pile's effluent. Since the pile generated so much heat, measuring its temperature seemed the best way to track the movement of its effluent once it re-entered the Columbia. Though he could potentially have used a Geiger meter to track the plume's radiation, a mercury thermometer would be much easier and straightforward to use on the river. He could simply dip it into the sampling can and observe its measurement without worries about calibration or false readings.

Under the low-hanging morning sun he slid the sampling can into the water right where the F Pile's main sewage pipe emptied itself into the middle of the river. 34 degrees Celsius, deadly hot for salmon and trout.[44] Next, he took a sample away from the sewer to learn the ambient water temperature. 6.3 degrees Celsius. Using range poles spaced at even measures on the southern bank to judge his distance from the sewer outlet, he began to methodically work his way downstream. At just over 1/10th of a mile from the sewer, he began to cross the channel, taking water samples roughly every 30 feet. Some he took from the surface and some at a depth of five feet. He tabulated the temperatures as he made this transect. Next, he moved his boat down to about 1/6th of a mile from the sewer. Again he made a crossing, taking temperature measurements at five and ten foot depths, following the plume of effluent as it sank and dispersed throughout the Columbia's wide channel. He found the plume hovered around 7 degrees Celsius, much cooler than it was at discharge but still warmer than the river's ambient temperature. Jordan's hands-on field work created a first glimpse of effluent in the Columbia.

Just over three months later, on 10 July, the Medical Section biologists looked over Jordan's data as they met to plan a systematic survey of the Columbia River. They looked favorably on his work. Foster, the group decided, should work with the Technical Department to ensure that future surveys produced data that would best support the biology program. The men, most of whom had helped plan

44 Jordan provides these temperature values in his report.

the Fish Lab's research program in June, also resolved to start collecting their own field data from the river. They were concerned with heat and radiation but also with bacterial load in the water. It was agreed that a water sample would be collected upriver from the B Pile weekly to serve as a baseline showing the river's bacterial load before it encountered the reactors. They would collect bi-weekly samples of water from Columbia as it flowed past Richland. They would also collect water from the Yakima River, which flows into the Columbia south of Richland. These disparate collection points would hopefully give the biologists a synoptic view of water quality around the plutonium production site.

Though Jordan's survey and the weekly work of collecting waters samples produced useful snapshots of the radiological situation in the river, they also showed how unwieldy it was to collect field samples in 1945 and 1946. The temperature survey required specially fabricated, if simple, equipment and the better part of a day to collect data about scarcely a mile of the river. The river ran for over 50 miles through the reservation. The weekly collections involved significant mileages as well. Collecting an upriver sample from above the B Pile required a 15-mile drive over shoddy dirt roads from the Fish Lab at the F Pile. The drive to Richland was around 30 miles, a few more to get to the Yakima River on the south side of town. Taking weekly samples from the B Pile and three bi-weekly samples from Richland involved someone driving around 170 miles over poor roads each week carrying water samples. Over the course of a month, and so much traveling, the Fish Lab would end up with about 100 samples in need of processing.[45] This work just to create a snapshot of the effluent's behavior required significant man-hours, which were in short supply at Foster's lab. Scale worked against the landscape's epistemic utility during Hanford's early days.

45 Ibid.

So great was the Columbia's expanse at Hanford that when Foster and Donaldson organized the first survey of fish life at the site, they used a plane. They made their first foray on 27 September 1945 something of a spectacle by inviting Colonel Matthias, who had selected the site for Hanford and administered it for the MED during the war. Donaldson and Matthias flew low over the river from the B Pile towards the F Pile. The biologist gave the Colonel something of a crash course in the river's hydrology and biology. "The composition of the river bottom was studied and areas in which it was thought further observations should be made were noted."[46] Having taken the plane ride, the two men joined up with Foster and some others to survey the river by boat.[47] A motor boat ferried them from the dock in the abandoned town of Hanford up the river to Locke Island, where the great channel curves from its north-south orientation to head westwards. On the sandy southern bank of the river the men traded their motorboat for an inflatable rubber boat in which they "slowly drifted downstream."[48] The leisurely trip gave them time to talk and to take close looks at sundry fluvial environments as the current carried them downriver.

The men encountered a variety of distinct habitats as they floated down the Columbia, driving home the complexity of understanding radiation in the river. Since the river was running low and clear, they could often see the bed of the channel. South of Locke Island "the river bottom was composed of large gravel of a size thought to be suitable for nests of salmon and trout."[49] The men saw none of those fish, however, since the river's ambient temperature was still too warm in the shallows. Minnows and

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46 DUH-7541, Lauren Donaldson, "Notes of Lauren R. Donaldson of a Fisheries Inspection Trip of the Columbia River in the Area about Hanford, Washington, September 18, 1945," ROOPRR. Donaldson records that the trip took place on 18 September while Foster says it took place on 27 September. Foster's attention to detail is to be preferred over Donaldson's.

47 HW-7-2514, Richard Foster, "Fish Life Observed in the Columbia River on September 27, 1945," ROOPRR,

48 Ibid.

49 Ibid.

whitefish, endemic and ubiquitous in the upper Columbia, swam past the raft in droves. As the boat approached the F Pile, its crew of biologists and military engineers paid special attention to the fauna living in the effluent plume. They found fish in abundance. "Samples of the small fish found along the shore just downstream from the 100 F sewer were captured with a small seine and preserved in formaldehyde for future reference."[50] Looking out the middle of the channel, they saw a large bass in the eddy created by the sewer's outflow. The experience showed them that fish in the river could live in effluent rich waters both along the banks and in the deep channel.

The informal survey of the Columbia on 27 September pointed Donaldson and Foster again to the problem of scale that they faced in trying to understand the Columbia and its environs at Hanford. The excursion took up the whole day between the airplane survey and the float down the river. The exercise yielded great results, at least in terms of he and Foster's gaining intimate knowledge about the actual state of things in the river. They needed to learn its bends and eddies, its currents and channels. By identifying potential salmon and trout nests, they set themselves up for another survey later in the year when the water temperature would be cool enough for spawning. They also became more familiar with the behavior of the main F Pile sewer out in the channel, watching the eddy it created. They could only get this on-the-ground knowledge by spending time on the Columbia, time they did not have. Donaldson had to return to his duties in Seattle. Foster had exhausting lab duties as well, caring for and taking data on the Spring Creek chinook and the Seattle steelhead. They could only experience the luxury of time in the field from time to time.

The complexity of radiological problems at the site, alongside problems of time and scale, kept Foster in the laboratory. In September 1945, he began a collaborative study into the accumulation of radiation in the organs of his test fish. The biologist worked with Jack Healy, a chemical engineer in Du

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50 Ibid.

Pont's employ before the war recently transferred by the company to Hanford. In late 1945 he belonged to the Special Studies unit in Herbert Parker's influential Health Instrument Divisions. Healy arrived at the Quonset hut on the 14th to perform the first of a series of tests meant investigate the theory that fish accumulated radiation in their bodies over time. The troughs provided a perfect environment for the study since each maintained a steady level of radiation exposure. Healy lacked formal biological training, so Foster had to teach him how to dissect a fish and identify its organs.[51] Healy was well acquainted with the use of electronic radiation meters and radiochemistry, so he got at the question of accumulation by analyzing his hard-won tissue samples for radioactive content. Samples that needed to come from standardized populations of fish carefully reared and exposed to constant radiation levels.

Healy's basic question investigated the ability of organs to accumulate, or concentrate, radionuclides borne by the pile effluent. He had access to an internal report from the University of Chicago's MED operation indicating that goldfish did accumulate radiation over time. Foster, of course, could point to his experience with x-rays doing focused damage to specific organs in fish at the Applied Fisheries Laboratory. Healy described his experiment by writing that it "was carried out in an attempt to measure the accumulation of activity so that the dose received by any organ could be calculated."[52] The Seattle laboratory had never looked for quantitative data from the tissues they exposed to x-rays since they did not use electronic radiation meters. Healy's data would be novel since he would look for that data and since he was using Foster's fish exposed to pile effluent. It would also be very much about the environment at Hanford since the scientific bureaucracy at the plant did not want radiation to be passed from fish at the site to humans or livestock living downriver from the site.

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51 John W. Healy, interview by Darrell Fisher and Marisa Caputo, 28 November 1994, transcript, DOE/EH-0455.

52 HW-3-3442, John Healy, "Accumulation of Radioactive Elements in Fish Immersed in Pile Effluent Water," 27 February 1946, 2, ROOPRR.

How did Healy look for radiation accumulated in Foster's experimental fish? With great care. Dissection was not straightforward because he was concerned about tissue sample contamination. "It is to be expected that the skin and scales of any fish in active water would become highly contaminated since these portions are in constant contact with the water… it was necessary to perform the dissection with extreme care to prevent the spread of activity from one portion to another."[53] Healy used separate scalpels to make his initial incision and to then take out organ samples. After he had an organ tissue sample, he weighed it and then ashed it. This process involved exposing the sample to about 800-degree centigrade heat in a special furnace and then dissolving the resultant ash in nitric acid. This mixture could be placed on a glass slide and its radioactivity measured by a Geiger meter. Healy then converted the meter reading to microcuries per kilogram, a measurement that indicated the number of radioactive decays per second by the mass of the tissue. Ashing served as an important lab technique at Hanford from 1945 but Donaldson and the Seattle biologists only really began to use the technique in 1947.[54]

Healy's test results from the autumn of 1945 and winter of 1946 taught him that the fish held in effluent water did experience some accumulation of radiation in their organs. Healy knew from the chemists in the Production Department that the pile effluent largely contained significant amounts of very-short-lived Manganese-56 with a 2.5 hour half-life and Sodium-24 with a 14.8 hour half-life. The time it took him to dissect and ash the samples precluded a search for accumulation of the radiomanganese. Instead, he measured accumulations of radiosodium. After his initial foray into Foster's lab on 14 September, Healy took three Spring Creek chinook out of a pure effluent trough and placed them in pure river water for three days. Then he dissected, ashed, and measured them. Their

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53 Ibid.

54 See chapter 5 for a fuller account of ashing.

livers, kidneys, and gills showed more activity than their bones, stomachs, or muscles. Based on radiosodium's half-life he extrapolated the level of the radionuclide in their bodies when it would have been most prevalent. His curves showed that at "zero time, the concentrations would be 30-50 times the concentration in water."[55] Curves he extrapolated from six of the Applied Fisheries Lab steelhead that he removed from effluent exposure for 12 days showed lower values at the time of dissection but agreed with the curves from the chinook. So did curves from steelhead he exposed from August to November 1946.

That Healy turned to Foster's lab and his stocks of fish in 1945 to study the accumulation of radiation from exposure to effluent rather than to fish in the river shows the early utility of the Quonset hut for the creation of biological knowledge at Hanford. At no point did he ever indicate any worry that Foster's laboratory fish could not accurately represent the situation that existed with effluent in the river. While he did analyze one fish caught in the river just downstream from the mouth of the F Pile's sewer, primitive, jawless Pacific Lamprey, it failed to yield anywhere near the data of the dozens of lab fish he studied. The lamprey gave Healy data about the very local context of the F pile's sewer outlet. This provided a perfect habitat for the specimen to filter feed and accumulate radionuclides. Like the salmon and trout, it showed the most radiation in its liver and kidneys. In contrast to the lab fish, the samples from the lamprey indicated the presence of radioactive Phosphorus-32, which has a half-life of 14.3 days.

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55 HW-3-3442, Healy, ROOPRR.

Healy noted the presence of the unexpected radioisotope and moved on. Rather more importantly, the curves from the lamprey confirmed that his lab-reared populations could produce accurate accounts of radiation in the Columbia biota.

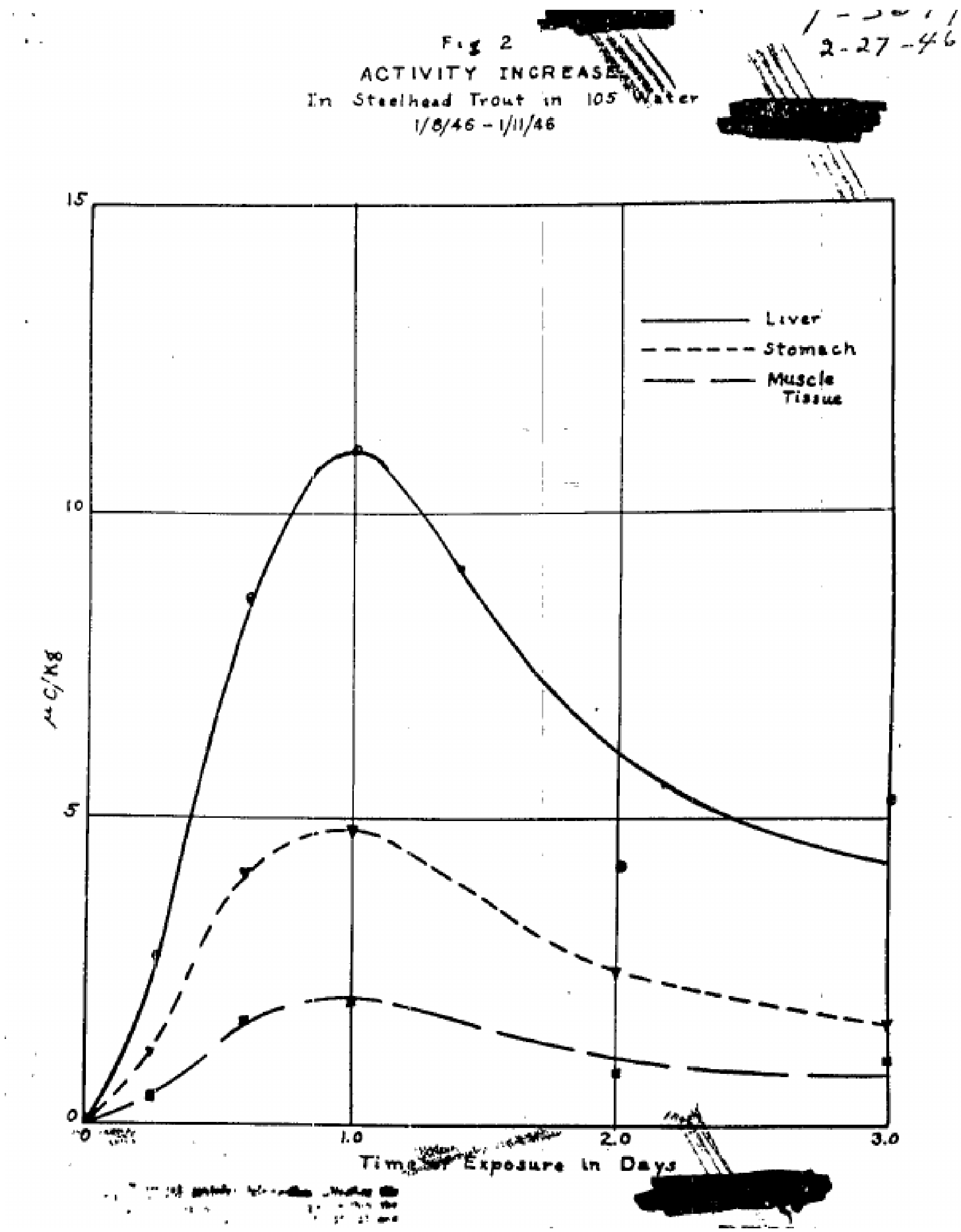

Figure 3.2. Accumulation Curves, Healy 1946. Source: HW-3-3442, Accumulation of Radioactive Elements in Fish Immersed in Pile Effluent Water," 27 February 1946, 4, ROOPRR. Source is in the public domain.

By the time Healy wrote up his fish accumulation experiment in February 1946, Foster was busy with fundamental work in both the lab and on the river. The Soos Creek chinook eggs that Donaldson delivered the past October had hatched. As such, Foster had all 20 troughs in the lab full of fry whose development he needed to document. He spent the latter part of February taking pictures of fish from each lot so that he could correlate developmental deformities to effluent exposure. By 20 February, Foster could show a clear distinction between fry reared in pure river water or in low concentrations of effluent and those unlucky fish reared with high concentrations of effluent. "The few weak and dying fish which remain in Trough 3 and 4 supplied with refrigerated effluent water" were not long for the world.[56] They would all be dead by early March. In the meantime, the healthier fish grew to the point that Foster had to cull each trough to 500 individuals. The excess fish he liberated into the Columbia. Foster had had other business on the Columbia. He assisted in the temperature survey that had been commissioned back at the 10 July 1945 all hand's meeting. Its results came out on 1 March.[57] This survey gave him a more precise understanding of the F Pile's effluent plume.

Though doing the mundane work of writing up data from the Soos Creek chinook took up much of Foster's time during the first months of 1946, he also ensured that the lab become a hub for research at Hanford. Karl Herde, also employed by Parker's Health Instrument Divisions, began a study in the lab in February designed to follow up Healy's accumulation research.[58] A biologist by training, Herde planned to delve deeper into the problem than the chemical engineer had. He wanted to examine the

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56 HW-7-4759, Healy, ROOPRR.

57 HW-7-3684, R.H. Osterloh, "Preliminary Report, Columbia River Temperature Survey at Hanford Engineer Works," 1 March 1946, ROOPRR.

58 HW-3-5064, Karl Herde, "Studies in the Accumulation of Radioactive Elements in Oncorhynchus Tschawtische (Chinook Salmon) Exposed to a Medium of Pile Effluent Water," 14 October 1946, ROOPRR.

presence and concentration of long-lived isotopes as well as the relationship between metabolism and radioactivity. Like Healy, he got his data by sacrificing specimens, ashing them in a furnace, and then exposing the ash to a Geiger meter. Unlike Healy, he ran a properly long-term experiment. Beginning in February he took out seven-week-old fish and exposed them to effluent. He started culling and counting specimens after three days of exposure. The last he counted after 14 days of exposure. By taking fish each day, he created a curve showing when radiation levels peaked within the population. Herde repeated this process when the fish were 13 and 15 weeks old. He also lengthened the exposure time to 21 days. For over seven months, Herde counted the radioactivity in specimens and tried to tease out which radionuclides they harbored in their bodies.

Over the course of his study, Herde found that his subjects did indeed accumulate, metabolize, and excrete radionuclides. All of the fish that he counted showed a routinely higher level of radiation than the water in which they lived, indicating their ability to accumulate radionuclides within their bodies.[59] He was also able to find evidence of Phosphorus-32, which Healy had identified in the lamprey from the river in his earlier study, in fish exposed to effluent for over three weeks. Finally, he showed that active specimens with high metabolisms showed higher rates of radioactivity than sluggish fish with low metabolic rates. Herde's findings painted a complex picture of how fish processed radionuclides as they were exposed to effluent over time. His lab practice, which involved the use of Geiger meters to provide measurements of radiation by volume of organic material, made his data particularly useful as a tool for understanding what was going on in the Columbia without actually having to spend the man-hours necessary to collect data from the river.

While Herde conducted his counting study over the course of 1946, Foster worked to maintain the lab's experimental populations and collect empirical data about them. Foster did not use radiation

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59 Ibid. Herde tabulated the low radiation levels for the trough water and high levels for fish.

meters for his research, focusing instead on the kind of data that he had learned to collect at the Applied Fisheries Laboratory. He counted deaths and deformities and measured the weights and lengths of his fish lots to create a comprehensive picture of how pile radiation created somatic effects. Foster would not use radiation meters for research until his colleagues in Seattle became acquainted with them during their participation in Operation Crossroads, in the summer of 1946.[60] Foster did not join his old boss Donaldson and Art Welander for that trip, the day-to-day responsibilities at the lab kept him from leaving the south bank of the Columbia to go to Bikini Atoll that summer.

The Fish Lab became so busy over the course of the summer that Foster's supervisors at Hanford agreed to expand his facilities and staff. In October, as Herde was writing up his long-term exposure experiment, Donaldson and Foster began recruiting Philip Olson to come to the lab.[61] Olson worked as a field biologist in British Columbia for the International Pacific Salmon Fisheries Commission. Donaldson had worked for the Commission, a joint Canadian-US effort to maintain commercial salmon stocks, prior to his arrival at the University of Washington. By recruiting Olson to Hanford, Foster received an expert biologist who was well connected within the Pacific Northwest's fisheries infrastructure. Around the same time the biologists planned to build 13 outdoor ponds at the lab. Expanding beyond the walls of the Quonset hut would also to conduct experiments on a larger scale than the indoor troughs allowed. Construction began in January 1947 and was completed by March.[62]

Foster set about immediately to use the ponds for a food chain experiment. Healy and Herde had measured the accumulation of radioactivity in fish based on their exposure to radioactive water.

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60 See Chapter 4.

61 Lauren Donaldson to Herbert Parker, 12 November 1946, Box 1, Folder 12, UWLRB.

62 HW-7-5901, Richard Foster, "Fish Laboratory Report, Second Half of February 1947," 6 March 1947, ROOPRR.

While Herde had correlated physical behavior, as an indicator of metabolism, to radioactivity levels, neither man had established any actual mechanism to determine how radiation entered the fish or how the fish processed radionuclides within their bodies. A Dr. Berry from Parker's Health Instrument Divisions came to the lab in early 1947 to raise algae cultures in effluent. By April, he had enough radioactive algae to populate four of the new ponds:

> #7 and 8 – are to be used to culture algae and fish food organisms in active water. The organisms will be fed to the fish in Ponds #3, 4 and 5.
> #9 and 10 – are to be used to culture food organisms in active water. Later fish from Ponds #3 and 4 will be placed in these ponds to eat the food.[63]

Foster and Olson would use Geiger meters to make counts of the "fish fed food reared in active water."[64] Studying the mechanisms by which radiation moved from the water to food sources and then to fish eating that food would give the biologists a quantified snapshot of the actual circumstances in the effluent-filled river.

In the first months of 1945, after all three reactors had come online at Hanford, no one at the site knew how their radioactive effluent behaved in the Columbia. W.E. Jordan used heat to track the movement of the hot wastewater down the river's great channel. Lauren Donaldson took to the air, attempting to see how fish populations clustered around effluent plumes. Later that year, Dick Foster sent runners to sites along the Columbia and Yakima rivers, driving huge distances to collect water samples for laboratory analysis. When Foster, Healy, and later Herde, began to take fish collections from the river, they only ever caught a very few specimens. In late 1946, Herde began collecting fish from the river as a follow up to his radiation accumulation study in the Fish lab earlier that year. He collected around 100 fish over four months. They yielded good data when ashed and counted in the lab. But even after his long hours spent fishing and working at the bench, they gave Herde little to say about

63 HW-7-6095, Richard Foster, "Fish Laboratory Report, First Half of April 1947," 16 April 1947, ROOPRR.

64 Ibid.

what was actually happening with radionuclides in Columbia River fish. He finished his report on the study in May 1947 with something of a lament about radiosodium data. "It remains to be demonstrated whether this sodium activity is a function of season, fish metabolism, content in water, or of food available."[65] The effects of radiation in the river itself remained hard to discern after years at the site.

While the newly irradiated river gave up only a few of its secrets, the Fish Lab offered up radiological data liberally. Just a year after Donaldson brought the first lot of chinook salmon to the Quonset hut, Foster had reared research populations of those fish and of steelhead trout. He accumulated hordes of empirical data about the effects of effluent on growth and deformity. He had data about mortality and effluent concentrations. Beyond producing data about the river's most valuable fisheries stocks, Foster had turned the lab into a site for scientific collaboration. Healy learned to work as a fisheries biologist. Herde had a bench and research populations at his disposal. By 1947, when Berry began his algae work and Olson had come on board as a second trained biologist, the laboratory was a hub for research about the river. In its first three years hundreds of thousands of eggs, fingerlings, fry, and adult fish passed through its radioactive troughs and ponds. Conveniently situated near the F Pile and compact, the lab could produce data the river simply could not. The lab's ability to produce data quickly turned into an ability to produce a story about radiation and the Columbia.

The Columbia River Advisory Group and the Power of Laboratory Knowledge

Herbert Parker, head of Hanford's Health Instrument Divisions, spent 22 December 1949 responding to correspondence before the Christmas holiday. He dictated a memo regarding a new research program that would investigate liquid waste from the plutonium separations facilities just up the road from his

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65 HW-3-5501, Karl Herde, "Radioactivity in Various Species of Fish from the Columbia and Yakima Rivers," 14 May 1947, ROOPRR.

office.[66] He also penned a letter to the manager of the Atomic Energy Commission's (AEC) Richland Operations Office, Fred Schlemmer.[67] The latter's office sat just a few miles due south of Parker's in Richland. Parker worked for General Electric, the contractor at Hanford. Schlemmer worked for the AEC and was the liaison between the contractor and the Commission's head office in the federal capital. Parker was angry and wanted Schlemmer to let his superiors back east know that things were amiss along the banks of the Columbia.

What had riled up the English physicist who emigrated to Seattle in the 1930s and then settled in as the radiation expert at Hanford during the war? It was a phone conversation between Arthur Gorman, a sanitary engineer who worked at AEC headquarters in Washington, D.C., and Emil Jensen, an engineer with the Washington State Department of Health and member of the newly created Columbia River Advisory Group. Gorman had contacted Jensen, unsolicited from D.C., to complain about a press release that the Advisory Group had promulgated after its inaugural meeting just a month earlier in November 1949. Gorman griped that the press release painted too rosy a picture of the atomic waste problem in the Columbia. Jensen, who supported the plutonium production facility and its job-creation role in Washington state, then contacted Parker to share his concern about the naysayer from the federal capital. Parker wrote to Schlemmer down in Richland to tell him that the AEC needed to get its house in order and that he would brook no criticism of either his atomic waste program or his in-house biology program at Hanford.

The Columbia River Advisory Group began as a mouthpiece for Parker and Hanford's scientific administrators to project their story about radiological safety along the Columbia. Sympathetic state

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66 HW-15494, Herbert Parker, "Proposed Research Program – Treatment of 200 Area Non-Uranium Wastes," 22 December 1949, ROOPRR

67 RL-1-332306, Fred Schlemmer to Walter Williams, 4 January 1950, NTALV.

officials from Washington and Oregon, like Emil Jensen, as well as a representative from the US Public Health Service comprised the Group. Gorman, D.C. bureaucrat in every way, saw Public Health Service's membership in the Group as a means for establishing some sort of regulatory foothold at Hanford that did not rely on Parker's Health Instrument Divisions. Parker saw Gorman and the Public Health Service as unqualified meddlers in scientific questions and practical solutions that his own biologists already had under control. He fought to limit the Public Health Service's access to both the Columbia and to lab space at Hanford. Taking up Parker's fight, Foster positioned his lab as a bulwark against the intruders and a mouthpiece for Hanford's public relations.

The Columbia River Advisory Group came into existence at the behest of Schlemmer and the AEC as a forum for communication between General Electric and the various bureaus responsible for public health around Hanford.[68] Schlemmer sent out invitations in July 1949 and the four visiting Group members met at Hanford for the first time between 21 and 23 November. From Washington State came the Director of the Pollution Control Commission, Edward Eldridge, and Jensen from the Department of Health. From Oregon came Curtiss Everts, a sanitary engineer from the State Board of Health. Another sanitary engineer, Robert Harris, represented the US Public Health Service. These four met with six General Electric men and two bureaucrats from the AEC's Richland Office. Parker attended with Harry Kornberg, the head of his Biology Division and Foster's immediate supervisor. Foster did not attend. According to the meeting's report, the visitors came to Hanford so they could "become familiar with the safeguards and techniques employed at Hanford Works in controlling environmental contamination by radioactive and other substances."[69]

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68 HW-15861, F.E. Adley and W.K. Crane, "Meeting of the Columbia River Advisory Group November 21 – 23, 1949," 2 February 1950, Columbia River, ROOPRR.

69 Ibid.

Parker organized a series of lectures from members of his Health Instrument Divisions to introduce the visitors to the radiological situation at Hanford. The chief himself gave the first talk on the 21st, discussing the radiation exposure limits that his group had instituted at the site. Kornberg gave the last talk of the morning, in which he described the biology program in general and the aquatic biology program in detail. He explained how Foster kept salmon continuously in pile effluent. He also explained the lab's accumulation studies, candidly sharing how algae, plankton, and fly larvae concentrated radiation to levels far exceeding levels found in diluted effluent plumes within the river. Despite this admission, he pointed to the work of the river as an agent of dilution and to the work of the fish lab as an agent of useful and satisfactory data for the control of the site.

Kornberg also used his talk to introduce a trope that would become endemic at Hanford, the idea that chemical and toxic pollution from the reactors actually caused more harm than any radiological contamination they produced. He hearkened back to the Calol story from 1945 in order to establish his argument. "It has been found that the toxic effect from the pile water treatment seems greater than that resulting from the radioactive contamination."[70] Emphasizing toxicity and downplaying radioactive dangers made Hanford seem like any normal industrial site, the kind with which the state regulators dealt routinely. Kornberg had the data on his side. Foster had shown in the lab that mortality from exposure to Calol outmatched mortality from exposure to even 100% effluent. Normalizing Hanford's identity as an industrial site went a long way toward keeping alarm about its radioactive burden at bay.

After Kornberg's lecture, the visitors toured the site to learn about the plutonium production process and to visit Foster's lab. The afternoon started out on Hanford's southernmost edge, where uranium was milled into fuel slugs for the reactors. From there, the group traveled north along the

70 Ibid.

Columbia to the F Pile. They visited the great water intake just upstream from the reactor. Then the followed the flow of the coolant water to the great pump house. From there, a short walk to the pile itself and past it to the retention basin in which the most dangerous and short-lived radionuclides decayed. From there they visited Foster's lab as well as the nearby botany lab. At the Fish Lab they could see with their own eyes the research that Kornberg had described to them earlier in the day. Next, they went down to the huge plutonium separations buildings in the heart of the site. The tour finished with a presentation in the geology lab about the movement of radioactivity in the groundwater table, replete with flashy maps. Shepherded by Parker and his lieutenants, the site must have seemed to the visitors like a well-oiled, well-regulated machine.

So satisfied were the four outside Group members with what they had seen that, when the conference ended two days later, they signed their names to a press release that trumpeted the safety of the operation at Hanford. Two of Parker's men wrote the release and it very much read like an inside job. "Waste disposal is a major problem," the text acknowledged.[71] "However, the operating agencies are using every means at their command to keep it under control."[72] The release also let the public know that the Advisory Group members had spent two and a half days touring Hanford and had, in that time, come to understand the site's unique problems from a professional viewpoint. Perhaps most pointedly, the text informed readers that "so far as the Columbia River is concerned, there are no apparent water pollution hazards resulting from operations at present."[73] This last remark, meant to assuage downstream readers of the *Herald* in Kennewick, Washington, and of the *Oregonian* in

71 Ibid.

72 Ibid.

73 Ibid.

Portland, raised alarm bells for Arthur Gorman when it came across his desk at AEC headquarters in Washington D.C.

That Gorman phoned Emil Jensen so quickly after the press release went out on 25 November 1949 indicated his discomfort with its message. No direct record exists of their 5 December phone conversation, but it may be that the AEC man felt he could reason with a colleague. Both were sanitary engineers and had worked together.[74] Gorman was wrong. The phone call went poorly, prompting Jensen to contact Herb Parker. To him Jensen quoted Gorman directly as having said the Advisory Group "jumped the gun" and had "gone overboard" by giving Hanford "a clean bill of health."[75] Parker included these quotes in his 22 December 1949 letter to Schlemmer, the AEC chief in Richland. Parker also set one of his lieutenants to find out if Gorman had contacted any other group members. He had. Robert Harris, the sanitary engineer from the US Public Health Service found himself in Gorman's crosshairs on a trip to D.C. after the Advisory Group's meeting. Gorman expressed concern to him about the press release in person.

Why was Arthur Gorman so concerned about the November press release? Even as the Advisory Group met at Hanford in November 1949, the sanitary engineer from AEC headquarters had been meeting with a team from the US Public Health Service to organize a comprehensive scientific survey of the Columbia River. On 31 January 1950, he met with Assistant Surgeon General Mark Hollis and a team of engineers and chemists from the US Public Health Department as well as

74 Arthur Gorman to L.R. Hafstad, Director, Reactor Development Division, Columbia River Advisory Group Conference, 3 February 1950, RL-1-332295, ROOPR.

75 Schlemmer to Williams, 4 January 1950, NTALV.

members of the AEC's Division of Biology and Medicine to discuss the survey.[76] The public health service had requested a budget of $105,000 to carry out the survey. Hollis planned that the survey be cooperative, relying on help and data from Parker's men at Hanford. "He [Hollis] said the P.H.S. did not desire to duplicate to any marked degree work that was already being done by other competent agencies, but felt that a reasonable amount of overlap might be desirable."[77] Saying that a reasonable amount of overlap might be desirable likely meant that Hollis wanted his team to be able to study everything about the river, including the biological effects of radiation. The group concluded that they would create an outline for the survey to be forwarded to Hanford for comment.

Though the memo from the Public Health Service in D.C. took some time to reach Hanford, Gorman scarcely had to wait any time at all to hear about Herb Parker's displeasure. The controversy had moved up the AEC chain of command from the Richland Operations Office to the Director of the Reactor Development Division at headquarters. He passed on the complaint to Gorman, who responded in turn. "I have read carefully the Schlemmer to Williams memorandum of January 4, 1950 and the copy of the attached Parker… letter dated December 22, 1949."[78] The sanitary engineer struck an initially ironic tone in his response. "It seems to me that there has been an unfortunate misinterpretation of my motive in calling Emil Jensen… it is my belief that when all the facts are out and evaluated, they will show that all parties… are and have been working toward a common objective."[79] He went on to argue, somewhat limply, that he worried about the November press release because it could have

76 Arthur E. Gorman, Sanitary Engineer, Division of Engineering, Survey of Columbia River, 31 January 1950, NV0750540, NTALV.

77 Ibid.

78 Gorman to Hafstad, 3 February 1950, ROOPRR.

79 Ibid.

convinced legislators in D.C. that the Public Health Service needed no funding for a survey of the Columbia since pollution posed no threat to the river at all. Only concerned with funding, Gorman proclaimed himself a team player after all.

The sanitary engineer did not content himself with making amends, however, and he finished his letter by listing some real concerns about scientific oversight of the radiation problem at Hanford. Gorman began his argument by claiming some expertise, he had made regular visits to the site since 1947 in his official capacity. These trips convinced him that Parker's Health Instrument Divisions had not put together anywhere near a synoptic picture of the radiological situation in the Columbia. "It is my opinion that insufficient data are available adequately to appraise what effects the wastes discharged into the river have or may have on the use of this important natural resource."[80] Gorman then argued that scientific collaboration with qualified state and local agencies could remedy this deficit:

> It is my sincere belief that it would be in the interest of the AEC if more basic and applied research in problems of disposal of radioactive and toxic wastes from atomic energy operations and a certain amount of off-site control monitoring were carried out by established and experienced federal and state agencies normally having jurisdiction over public health and national resources.[81]

Gorman wanted outside oversight at Hanford because he felt that General Electric ought not both produce and monitor the site's radioactive waste. The US Public Health Service's survey of the Columbia River could be just the opening he needed to break into the site's scientific citadel.

Herb Parker and his scientific lieutenants found the suggestion that outside agencies have any access to the study of pile radiation at Hanford beyond onerous. In a letter to the Chief of the AEC's Operations Division Parker outlined his complaints with Gorman's argument. He accepted the sanitary engineer's explanation of his concern over the November press release. But there ended the agreement.

80 Ibid.

81 Ibid.

Parker saw no role for any outside state or federal agency at Hanford. "In our opinion, not only does the Atomic Energy Commission and the prime contractor have the responsibility to decide on the amounts and storage conditions of hazardous wastes, etc., but they are together in a better position to make such decisions than any other organization."[82] Parker went to say that he felt Gorman had insinuated that his scientists manipulated data to "'white-wash' practices at Hanford," an accusation "natural resented by scientists in the Health Instrument Divisions."[83] Despite this perceived slight, Parker concluded that he would conditionality welcome collaboration with the U.S. Public Health Service as long as their research related to fields "exclusive of radiological and radio-chemical problems."[84] Parker would do everything he could to maintain the barrier of scientific secrecy behind which Hanford had operated since its wartime beginning.

By the time Parker sent his letter complaining about Gorman to the Chief of the Operations Division, he had already deployed Foster as a bulwark to fend off incursions from the US Public Health Service. The Columbia River Advisory Group had its second meeting at Hanford on 6 and 7 March 1950. At this meeting the Group received official notice of the proposed Health Service survey of the river. To address the situation, Parker made sure all his group heads attended the meeting, including Healy, from Methods & Control, Herde, from Zoology, and Foster, from Aquatic Biology. These men guided the Group's four outside representatives on an extensive tour of the site's scientific facilities. Foster lectured at length on the question of radiation in the river in a talk titled "Effect of Radioactive

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82 Herbert Parker to D.G. Sturges, "Columbia River Advisory Group Conference and Cooperation with the U.S. Public Health Service," 17 March 1950, RL-1-332274, ROOPRR.

83 Ibid.

84 Ibid.

Wastes on Aquatic Life."[85] In this presentation, he reiterated key parts of the site's danger-mitigation narrative. "By the time the pile effluent water is discharged into the river the radioactivity has diminished," he told the Group, "to such an extent that a person could swim in it for several hours every day without receiving a tolerance dose."[86] He also made the point that radiation from the piles trailed behind heat pollution and toxic chemicals used for reactor operations as a threat to the river and its biota. As he talked about chemical toxicity, he alluded to the fish kills caused by Calol in his lab. Foster finished the presentation by discussing his ongoing research with the chinook salmon reared in varying concentrations of effluent in the Fish Lab. Lab data took a front and center place in the Group's understanding of the radiation and the river.

Foster again played a major role at the Special Meeting of the Advisory Board on 14 April after they had received the full US Public Health Service blueprint for a survey of the Columbia. The star of the meeting, Foster gave the longest presentation of anyone involved and built on his talk from the month prior. The biologist led with a brief history of his lab program, including its origins in the Applied Fisheries Laboratory. Next, he outlined the Fish Lab's researches along with suggested future studies. These included the hallmark effluent exposure study, which he had described as the "continuous monitoring of the plant effluent as released to the river (with juvenile chinook salmon)."[87] In the confines of his lab, fish served as monitoring technologies, a first line of defense against any untoward Pile emissions. The data they created provided the foundation for Foster's whole scientific program, in the lab, in the ponds, and in the river itself. Foster continued by explaining to the Group

85 HW-17595, F.E. Adley and W.K. Crane, "Meeting of the Columbia River Advisory Group March 6-7, 1950, 21 April 1950, ROOPRR.

86 Ibid.

87 Ibid.

that further work was needed to explore the mechanisms of how particular radionuclides moved within and damaged fish. Naturally, this would take place in the lab where subjects were "readily available in statistically significant numbers, and are easily handled."[88] Foster finished his presentation by describing how his team's fieldwork augmented their laboratory program and how they manifestly needed no outside help to understand Hanford or the Columbia River.

Foster's talk and the whole effort of Hanford's biological apparatus on 14 March 1950 convinced the members of the Advisory Group to affirm Parker's insistence that any survey of the river performed by the US Public Health Service avoid any radiological work. The four Group members, Edlridge, Everts, Harris, and Jensen, sent a letter to Schlemmer at the AEC's Richland Operations Office suggesting that the proposed survey take place only if the Health Service could guarantee a minimum of interference with Parker's established program. "The proposed survey of the Public Health Service should be built around the work now in progress and should supplement and not duplicate this work."[89] More pointedly, they demanded "that there be no curtailment… of investigation, studies and research on radio-active wastes which are now under way or planned at the Hanford Operations."[90] The members of the Advisory Group took their place alongside Parker and his biologists as gatekeepers at Hanford.

The showdown over the final shape of the Columbia River survey took place in late June between the local interests from Hanford and the Pacific Northwest and the bureaucrats from

88 Ibid.

89 Ibid.

90 Ibid.

Washington D.C..[91] From the federal capital, three Public Health Service representatives attended along with men from the AEC, Gorman among them. From the local contingent, the four members of the Advisory Group attended along with five men from the Richland Operations Office and fourteen men from Parker's Health Instrument Divisions. Foster arranged that Lauren Donaldson come from Seattle to attend in his role as chief consultant for the Aquatic Biology Laboratory.

The symposium began innocuously enough. Foster and his colleagues from the Biology Division gave talks and took the participants on tours of the laboratories at the F Pile. The mood heated up on the last day. In something of a round-robin session, Parker suggested that the whole Public Health Service survey be run out of Bonneville Dam, over 200 miles downstream from Hanford. Abel Wolman, an ally of Gorman's, quickly replied that Hanford was "the logical point to start this survey."[92] The Washington group then worked to pinpoint details on when Health Service scientists could start and where they could find lab space. Parker suggested that Foster's laboratory had no extra bench space and that the new Aquatic Biology Laboratory would not be built for another two years. Gorman countered by asking if the Health Service could find space in one of the other biology labs. To this, all of Parker's group chiefs responded that they had no square footage to spare in any of their labs on site, including in the newly constructed central biology lab. Parker also managed to have his allies from the state agencies reaffirm that in their view General Electric had the responsibility, in the words of Mr. Everts from Oregon, "to carry out proper research programs and institute their own controls."[93]

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91 HO-1, R.L. Plum, "Report on Columbia River Symposium: A Joint Meeting of the Atomic Energy Commission, U.S. Public Health Service, Columbia River Advisory Group, and General Electric Company, June 19 – 21, 1950," 8 September 1950, ROOPRR.

92 Ibid., 19.

93 Ibid., 16.

By the end of the Symposium, the coalition of local scientists and bureaucrats carried the day by restricting the scope of the Public Health Service's proposed survey and its access to Hanford's inner scientific sanctum. The Health Service representatives from D.C. and the bulk of the group from AEC Headquarters agreed that "the primary responsibility regarding control of stream pollution rests with the operating contractor."[94] Gorman's push to create a breach in Parker's biology operations failed. The survey would take place, but only on the fringe. When the Advisory Group met over a year late in October 1951, a small group of only 10 engineers and scientists from the Public Health Service had arrived at Hanford. Denied access to any of Parker's labs, they were working in "three mobile trailer units located in the 100-F Area."[95] They would eventually move into the disused Ferry Building in the abandoned town of Hanford some six miles downstream from the biology complex at the F Pile. The team worked largely on matters of hydrology and bacteriology.

The Public Health Service's survey of the Columbia River came and went, a victim of Hanford's scientific secrecy regime. Dick Foster's Aquatic Biology Laboratory proved a steadfast guard against the potential incursion of Washington bureaucrats from the AEC and from scientists from the US Public Health Service. By 1950, he and his team of biologists had created enough data in their lab and ponds to present a coherent story about how pile radiation worked within the Columbia's fluvial environment. Portraying the salmon living in his lab troughs as monitoring technologies and presenting data that showed how toxicity from reactor operations actually proved more detrimental than radioactivity allowed him to play to the sensibilities of the state engineers who belonged to the Columbia River Advisory Group. The certainties created by his laboratory practice in turn spilled out

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94 Ibid., 20.

95 GEH-19226, "Summary Report of Joint Quarterly Meeting: Columbia River Advisory Group, U.S. Public Health Service, Atomic Energy Commission, General Electric Company, October 22 – 23, 1951," 23 October 1951, ROOPRR.

into his group's field work. Foster's men did develop a routine monitoring and research program along the river after their shaky start in 1945 and '46. By 1950 he could show the Advisory Group members a map of the fixed sampling stations from which his men collected biotic specimens, river sediments, and water for testing. But even as they expanded their field work, they always came home to the lab. Next to the F Pile beat Hanford's epistemic heart, for aquatic biology at least.

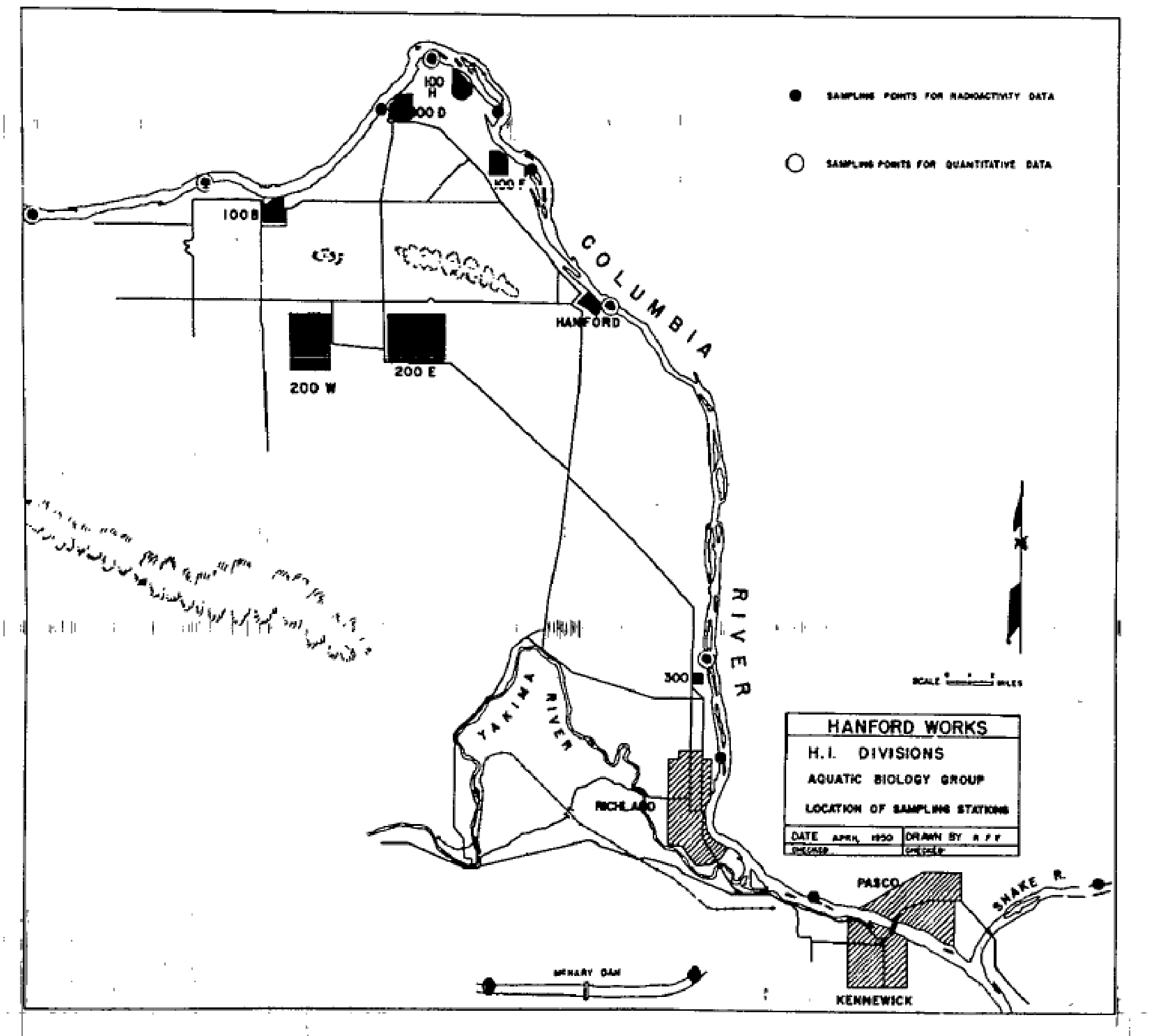

Figure 3.3. Map of Sampling Stations, 1950. Source: HW-17732, Harry Kornberg, "Special Meeting of the Columbia River Advisory Group, April 14, 1950 – Richland, Washington," 25, 27 April 1950, ROOPRR. Source is in the public domain.

Conclusion: The Research Program Applied to a Landscape

On 25 September 1951, the Erwen Construction Company of Pasco, Washington, broke ground for the new Aquatic Biology Laboratory near the F Pile.[96] The nearly $500,000 dollar facility had been designed by Portland architects Robert Barrett and Thayne Logan. Engineers from General Electric created plans for a whole new system to bring effluent to the lab from the pile, designed to maintain a constant water flow and temperature for the new lab's fish troughs. The new building was a far cry from the hastily-erected Quonset hut thrown up in February 1945.

Figure 3.4. Hanford Aquatic Biology Laboratory, with old Quonset hut in Foreground, 1952. Source: 374-NEG, Aquatic Biology Building, 30 January 1952, ROOPRR. Source is in the public domain.

The new lab utilized technological improvements that Foster and Olson had developed during their time in the Quonset hut. From the perspective of technology and scientific practices, the building

96 HW-24800-97, "Design and Construction History, Project C-364, Aquatic Biology Laboratory," January 1952, ROOPRR.

embodied the frontier spirit of advancement and improvement. From a fiscal perspective, the building embodied the epistemic value that the Aquatic Biology Unit's research program provided to the plutonium production mission at Hanford. The lab, and its assertion of control over the land, had become an invaluable piece of infrastructure at the site.

Dick Foster did not arrive at Hanford in 1945 meaning to set up a laboratory that could speak for the Columbia River and for the totality of the landscape at Hanford. He arrived to run a lab that would repristinate the conditions at his mother lab in Seattle, the Applied Fisheries Laboratory, with the exception that the site would use Pile effluent to irradiate its subjects rather than x-rays. But contingency based on the realities of the Pile operations and geography at Hanford molded his work and its meaning. In the last months of World War II and in the frantic months following the end of the war, Foster simply did not have the manpower or man-hours to conduct a field research program along the course of the Columbia River running through Hanford. Even if he had, the mighty river conspired to keep its secrets, refusing to give up statistically significant numbers of salmon or steelhead for Foster's lab at any given time. Lauren Donaldson, Foster's dissertation supervisor and mentor, had a solution for that problem. He relied on the trusted network of state and federal fish hatcheries in Washington to provide tried and true research subjects. The Fish Lab at the F Pile became a node in the geography of Pacific Northwest fisheries biology.

On site, the lab became a node for biological inquiry into the life of an irradiated river. Foster took most of 1945 to iron out the kinks in his lab set-up, but by the new year he could reasonably rear fish in his lab troughs. He began to collect somatic data about the fish he exposed to reactor effluent in the same manner that he and the other biologists in Seattle had collected somatic data from fish exposed to x-rays during the war and that Stafford Warren had collected from dogs exposed to x-rays in the 1920s. Measuring the weight and length of individuals as they developed and counting deformities and deaths, he transplanted the Medical Section's laboratory research program to the steppeland of the

Pasco Basin. In the new lab, however, these data became diagnostic, a quantifiable biological thumb on the pulse of the F Pile's core. The work that Jack Healy and Karl Herde did at the lab provided further numerical data on the ability of radiation to accumulate in the fish that lived in the lab, which represented the fish that lived in the river. Once the ponds were installed in 1947, the lab could really produce data about the accumulation of radiation through the food chain by raising irradiated food organisms to feed to the fish living in the lab. While Foster's work looked very much like the nascent ecosystems ecology studies that were becoming popular with university biologists and would take root at other AEC installations, he stayed true to the lab tradition in which he was trained and that he brought from Seattle to Hanford. Why traverse the river when the river already ran through the lab?

Foster's work bore fruit for his Hanford supervisor Herb Parker in 1950 when the latter needed data to show that the plutonium production site had its scientific house in order. Foster was able to deploy laboratory findings on a variety of occasions to satisfy the concerns of the Columbia River Advisory Group's members and to ward off possible incursions from Washington functionaries at the AEC and the US Public Health Service. His claims of a well-ordered river and landscape anchored by a n all-embracing laboratory allowed Parker to maintain barriers around Hanford and its biological programs. The two men argued that Pile effluent posed no danger to the site itself or to communities down the river. They appealed to their own expertise and to the culture of in-house problem solving that had grown up at the site amid its wartime secrecy regime. The data and the narrative they crafted served the two men well, no outside state or federal agency managed to gain a scientific foothold at Hanford during either man's tenure. Both retired from the site having held top supervisory positions and having continued their work as mouthpieces proclaiming site's safety. In a 1970 presentation to the Washington State Ecological Commission, Foster reiterated the power of his lab. "By Mid-1945, studies on the toxicity of the reactor effluent to fish had begun in a special laboratory built for the purpose… [it] showed that the concentrations of effluent that existed in the Columbia River downstream from the reactors were not harmful to trout and salmon."[97] He then went on to describe his early field program. Of course, long-term experience was already showing by the 1970s that radiation from Hanford was causing statistically meaningful harm, at least to local human populations. But to the in-house biologists, their lab and its certainties always came first at Hanford.

Turning back to 1946, the early successes of the Hanford field laboratory pointed to the utility of the Medical Section's research program to create data about both radiation from fission and from an entire landscape exposed to that radiation. These lessons acted as wind in Stafford Warren and Lauren Donaldson's sails when they learned that they would travel to far off Bikini Atoll in the heretofore innocuous, at least to American sensibilities, Marshall Islands. They would study the biological effects of radiation from Operation Crossroads, the US's first peacetime atomic test series. From a makeshift laboratory on the hospital ship USS *Haven* they would try to understand how radiation from an atomic blast could move through and harm exposed flora and fauna. Bringing specimens back to the mainland, they would also begin to remake the Applied Fisheries Laboratory into a control center for Bikini somewhat like the Hanford Lab. Knowing the biological effects of radiation meant scaling up and taking their place in the burgeoning atomic bureaucracy that would lay claim to so many thousands of square miles across the US West and the occupied Pacific.

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97 See: BNWL-SA-3679, Richard Foster, "Effects of Hanford Reactors on Columbia River and Adjacent Land Areas," 15 December 1970, Environmental Monitoring, ROOPRR.

Chapter 4

Defining the Atomic Field in the Marshall Islands

Producing Knowledge in the Occupied Pacific

When Vice Admiral William Blandy marshaled the roughly 42,000 American soldiers, sailors, and civilians at Bikini Atoll who participated in Operation Crossroads in the summer of 1946, he did so in the name of empirical inquiry. Under his command, Joint Task Force One planned at least two atomic bomb tests in order to "seek information acquired by scientific methods from which it will be possible to improve our military and naval equipment and tactics in the unfortunate event of an atomic war."[1] Lest his critics, he had many, think that narrowly military findings failed to justify the peacetime use of atomic bombs, Blandy suggested that Crossroads would produce all sorts of useful knowledge. "Much information of great value to science, medicine and industry," the decorated veteran trumpeted, "will also be obtained."[2] Since the need for wartime secrecy and expedience no longer hampered the military, they could properly and publicly test the bomb to unlock its scientific secrets.

The desire for information not strictly military in nature perhaps allowed Colonel Stafford Warren, lately of the Manhattan Engineer District's (MED) Medical Section and now head of Crossroad's Radiological Safety Section, to form and equip the Operation's Division of Marine Biology. Led by his increasingly devoted lieutenant, Lauren Donaldson, a small group of scientists and lay assistants traveled from the University of Washington's Applied Fisheries Laboratory to Bikini to

1 William Blandy, "Operation Crossroads," Box 3.022, Folder 22.1, Courtesy of the Eugene Starr Papers, Special Collections, Oregon State University Libraries.

2 Ibid.

do basic biological field research on the soon-to-be irradiated marine populations and environments at the atoll. Despite Blandy's desire for all kinds of new science to adorn his tests, marine biology did not pay the Seattle crew's way to Crossroads. The biologists had to work as radiation monitors in Warren's Safety Section. Their primary job as monitors required measuring radiation to produce data about the serviceability of a naval detachment after a nuclear attack. Indeed, the monitors found themselves sailing across the lagoon towards the blast site immediately after each test. Armed with Geiger-Muller meters and scintillation tubes, they counted radiation in the water, on the ships of the ghost fleet arrayed for the test, and in local marine life.

This chapter charts the transition that Warren, Donaldson, and the biologists who had been affiliated with the wartime Medical Section made as they worked to integrate Bikini Atoll into the program of laboratory and field research they developed during the war. The Medical Section had, by 1946, demonstrated its ability to address novel radiological questions in a variety of contexts. The lab in Seattle had shown itself capable of producing radiological data about salmon exposed to x-rays. The mission to Japan secured biological samples and data for return to the United States. It also allowed the MED to provide a report of the biological effects of radiation in Hiroshima and Nagasaki that emphasized the project's perspectives over against those of other branches of the US military and the Japanese medical establishment. Beyond its commitments in Seattle, Hiroshima, and Nagasaki, the Medical Section moved to Hanford, establishing its Fish Lab at the plutonium production site's F Pile on the Columbia River. Now, Warren's biologists need to bring Bikini, recently occupied and depopulated by the US military, into their scientific fold.[3] This would be no mean feat. Never had an entire landscape exposed to atomic bomb blasts been expected to yield useful biological data.

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3 For the dispossession of the Bikinians, see: Connie Goldsmith, *Bombs Over Bikini: The World's First Nuclear Disaster* (Minneapolis: Twenty-First Century Books, 2014), 14 – 17.

To tell the story of how the biologists brought Bikini into the constellation of sites under Warren's watchful eye, I track the semiotic and practical work they did during Crossroads. They left the familiar geographies of the Pacific Northwest to study a remote atoll thousands of miles from the US mainland. The geographic move mattered as much as the fact that the atoll would see repeated atomic tests. Nothing about their work with x-rays or with the moderated fission contained by the pile cores at Hanford prepared them for the violence of a fission bomb. Their work at Bikini began with making sense of how atomic bombs transformed entire environments. Next, they had to figure out how to study the places remade by the bombs, they had to find the entry points for their biological program. This they did by reconfiguring the atoll according to the data they desired. Finally, they had to engage in a specimen collection and processing regime. To integrate the land into their program and to immerse themselves in the landscape required both the novel application of familiar field and bench practices and the adoption of new ones.

The first part of this chapter analyzes how the biologists comprehended the meaning of a site transformed by fission, how they came to understand what it meant for a place to be atomic. This story begins in earnest aboard the USS *Haven* on 25 June 1946 in the officer's wardroom. That evening Stafford Warren showed, "The Effects of the Atomic Bombs Against Hiroshima and Nagasaki." Comprised of Japanese footage taken by cinematographers from the *Nippon Eiga Sha*, the Japan Film Company, that was confiscated and edited by propagandists in the US Army, the film documented the weeks after the bombings of Hiroshima and Nagasaki.[4] I encountered a heretofore unearthed copy of the formerly classified footage hidden in plain sight in the UCLA Special Collections, sitting for decades after Warren's death. The film's history made up an unlikely part of how the Seattle biologists

4 For an account of the *Nippon Eiga Sha* and the creation of film see Chapter 7 in: Abé Mark Nornes, *Japanese Documentary Film: The Meiji Era Through Hiroshima* (Minneapolis: University of Minnesota Press, 2003).

came to understand Bikini. It also existed as an antecedent to the films that they would make about the atoll, the most important of which was their 1950 effort, "Bikini: Radio-Biological Laboratory."[5]

In the second part of the story, I consider what it means for Bikini to be an atomic test site, a landscape dedicated to data created by fission. To tell this story, our narrative leaps from the wardroom theater back to early days of June 1946. I look at the field notebooks that Donaldson and his second-in-command Art Welander kept aboard *Haven* in transit from San Francisco to Bikini. I use the maps they drew in order to understand how their thinking about Bikini developed as Crossroads progressed. They visualized the atoll before they even saw it and then mapped it further after they walked its islands and sailed its lagoon. They mapped it after they watched at plutonium bomb tore it asunder. Nestled in the pages of their field notebooks, their visualizations captured the landscape's development as a test site and documented the familiarity with the place that radiation monitoring practices afforded them. The early life of a new kind of scientific place, the likes of which had never existed in such an organized way before, leaps off the pages of the biologists' notebooks.[6]

Finally, the story turns to the last weeks of July and August 1946 to look at the field practices that Donaldson's biologists employed in order to research their new field site. Using logbooks and reports, I show how the Seattle biologists developed field collection, radiation counting, and specimen processing practices in order to create data comprehensible to their way of understanding the biological

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5 The University of Washington's Media Center has digitized a copy of "Bikini: Radio-Biological Laboratory," which can be found here: https://archive.org/details/BikiniRadioBiologicalLaboratory_201509.

6 Stafford Warren considered three bombs detonated before Crossroads to be tests and in Japan, people the subjects of those tests. Crossroads was different since it was planned and American personnel present. "Even when it was militarily over Japan on August 1945, each bomb was still a scientific device, an experimental model…" Stafford Warren, "The Role of Radiology in the Development of the Atomic Bomb," in *Radiology in World War II,* ed. Arnold Lorentz Ahnfeldt (Washington, D.C.: Office of the Surgeon General, 1966), 831.

effects of radiation. Pre-atomic fisheries biology practices collided with overtly atomic technologies like Geiger meters and laboratory counters. Medical and biological techniques resided side by side. The biologists themselves transformed as they began to think in terms of metrical data rather than in terms of the visual and empirical data that they had come to know from their laboratory studies. Integration required flexibility. Like the forays to Japan and Hanford, working at Bikini required them to adapt their research program to account for local variables and constraints.

By looking at how the Medical Section biologists worked to understand Bikini and then adopted new biological practices relevant to the bombs tested there, this chapter tells the story of the movement by a small community of scientists to integrate a new type of field site into an already existing research geography. Much work has been done on the establishment of biological field sites. Robert Kohler has looked at the blurry boundaries that field study encourage.[7] More recently Etienne Benson has thought about biological field work in terms of the technologies that created new data collection possibilities in the mid-20th century.[8] He writes on the development of electronic animal tracking devices, a move towards electronic technologies for the creation of biological data not unlike the story of electronic radiation meters at Bikini. Just as new technologies open up new ways of knowing for Benson, newly colonized island spaces open up novel ways of creating ecological knowledge for Elizabeth DeLoughrey. She argues that islands in the occupied Pacific provided mainlander ecologists with ideal sites for systematizing nature because of their isolation.[9] Meanwhile, Gabrielle Hecht has argued that no atomic site can be understand without first acknowledging the cultural power dynamics that rank

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7 See Kuklick and Kohler's, "Introduction," in *Osiris*, Vol. 11 (1996), pp. 1-14. Also see: Kohler, *Landscapes and Labscapes,* 60ff.

8 Benson, *Wired Wilderness,* 2010.

9 See, DeLoughrey, "Myth of Isolates," 2013.

places and practices according to Western, technoscientific standards. "Designating something as nuclear," she reminds us, "carries high stakes."[10] This chapter finds its place amid these arguments by claiming that in 1946 no straightforward definition existed for either an atomic place in general or an atomic test site in particular. This story describes the power of scientists to create meaning, not just data, at a field site.

Film and Field

24 June had been a hectic day for Stafford Warren, Lauren Donaldson, and Art Welander because it was the Radiological Safety Section's dry run for Test Able. Warren commanded the effort to dispatch six patrols of monitors on small vessels – code-named Brass, Cobalt, Gold, Iron, Nickel, and Steel – which practiced sweeping the lagoon equipped with Geiger-Muller counters and ionization chambers for taking radiation measurements as well as bottles for collecting water samples.[11] Donaldson and Welander each commanded a patrol, so they spent the day running exercises out on the water. Having returned to their home ship, the USS *Haven*, in the evening, Donaldson remarked that "it was swell, having a shower and putting on clean clothes and sleeping in cooled quarters."[12]

Donaldson, Welander, and their metal-code-named radiation patrols existed as one very small element within a massive operation during Crossroads. US military planners birthed the idea for Crossroads in the last moments of World War II. The Navy wanted to know what would happen to a fleet were it attacked from the air by a nuclear device. The MED lab at Los Alamos wanted data about its bombs that could be collected in a peacetime setting. The Army Air Force wanted practice dropping

10 Gabrielle Hecht, *Being Nuclear,* 2012.

11 "Radiological Safety Plan Test Baker," 15 July 1946, Box 6, Folder 3, UWLRB.

12 Donaldson Crossroads Logbook, 24 June 1946, Box 10, Folder 27, MSS Donaldson.

atomic bombs from its B-29 Superfortresses. Construction of facilities for the tests began at Bikini in March 1946.[13] The 164 Marshallese residents of Bikini were forcibly removed to Rongerik Atoll around the same time.[14] The collection of ships from around the world to serve as a ghost fleet in the lagoon began before that. Captured Nazi and Japanese vessels took their place next to outdated US vessels in the great array that would help Naval engineers quantify the effects of an atomic blast. The Air Force had a wartime airstrip on nearby Kwajalein Atoll, though it had to be improved for the B-29s and the weight of the bombs. Using wartime infrastructure and building up newly captured atolls, the US built the site that Warren's men would monitor and study.

By the time the Joint Task Force arrived in the summer of 1946, the leadership wanted to create a spectacle as well as data. The first shot, codenamed Able, involved a plutonium bomb dropped from a B-29 on the target fleet. The weather cooperated and Able Day took place on 1 July 1946. Other circumstances did not cooperate. The bombardier missed the target ship USS *Nevada.* Spectators, so quickly jaded by the pace of modernity, conceded that the test was a disappointment. "Scientists, Congressmen, and United Nations observers," said the New York Times, "agreed today that the atomic bomb explosion had not been as spectacular as they anticipated."[15] For the second test, Baker, a bomb would be detonated underwater amid what remained of the ghost fleet. Baker did impress the onlooking crowd on 25 July, largely because it instantly vaporized millions of gallons of water and created a huge wave that rocked the entire lagoon. It created an unmitigated radiological safety disaster. Radioactive mist and water contaminated the lagoon, the atoll's islands, and the Joint Task Force. Radiation levels so worried Warren that he argued with Blandy that the Operation should be cut short and ships sent

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13 Philip Krueger, "Operation Crossroads," *The Military Engineer* 38, no. 249 (July 1946), 271 – 277.

14 Stafford Warren, "Evacuation of Atolls Neighboring to Bikini," 13 March 1946, Box 303, Reel 1, MSS Warren.

15 "Observers of UN Little Impressed," *New York Times*, 1 July 1946, ProQuest Historical Newspapers.

back to the mainland because of the lingering radioactive danger from the shot.[16] Of course, the radiation problem never made its way into the US media. Many propaganda pictures did, though. By the time the irradiated men and ships returned home, the Operation had been become "'the most photographed event in history' recorded by 1,500,000 feet of motion picture film… and over one million still pictures."[17] The American public had been introduced to an idealized view of atomic testing in real time on their televisions and in magazines. This view, curated for viewing audiences on the mainland, did not originate *de novo*.

Warren, Donaldson, and the members of the Radiological Safety Section came to understand the site of their summertime atomic field excursion in fits and starts. The day after their hectic preparations on the water, the monitors took it easy and enjoyed the atoll's arcadian pleasures. They enjoyed a lazy Tuesday under the tropical sun. Four of Donaldson's men "went trolling down near Enyu Island and caught 7 fish… one, a 25 pounder, was a Grouper."[18] The fishermen so prized this massive specimen that they presented it to the *Haven's* captain as a gift. Thankful for the gesture, "Capt Parsons asked Dr. White, Dr. Bradner, and me [Donaldson] to have dinner with him in his cabins and help eat the fish."[19] Hopefully the enlisted man, Freiland, who caught the fish, got to enjoy some himself out of the captain's company. "The fish was good," Donaldson reported, "and the service excellent."[20] As they enjoyed fine food, company, and surroundings, Bikini must have seemed a very decent sort of place that could comfortably accommodate university research faculty.

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16 See: Hacker, "Crossroads," Chapter 6 in *The Dragon's Tail*, 140 – 154.

17 DeLoughrey, "Radiation Ecologies and the Wars of Light," *Modern Fiction,* 2009.

18 Donaldson Crossroads Logbook, 25 June.

19 Ibid.

20 Ibid.

The day's lighthearted mood took a turn after dinner, however, as the men walked to the ship's company wardroom to watch film reels selected by Colonel Warren for the occasion. Popular films of varying quality had been staples on the voyage from San Francisco to the atoll. On the night of the 25th, Warren selected educational fare. Donaldson and the other men sat down to watch "The Effects of the Atomic Bombs Against Hiroshima and Nagasaki." One day after they had trained to witness and collect data from their own atomic bomb, they saw in gruesome detail footage of the destruction and disease wrought by the bombs dropped on Hiroshima and Nagasaki. Donaldson reflected pensively in his journal on that night. "One of the films by the Japanese showed the human side rather than the physical as shown by the American films. The burns and the wounds and the wasting of the injured people leaves one with a very <u>sickly</u> feeling."[21] Donaldson saw, likely for the first time given US policy prohibiting the circulation of any images from the two cities, the terrible medical effects caused by exposure to the device he would soon study.

The men knew the footage was Japanese but likely knew little more than that about the film's provenance. Warren had a better sense of the film's history but he never overtly referred to its complex history. Japanese cameramen and cinematographers created the original footage. American propagandists edited the film to make it a bizarrely hybrid piece of medical and military cinema. The film's path from the bombed streets of Hiroshima and Nagasaki stretched sinuously to Bikini lagoon, an early example of the nascent atomic regime's ability to circulate classified knowledge across its growing geography. Warren's choice to show his men the film made the footage an unlikely part of Crossroads' story.

The film itself, like so many wartime atomic artifacts, had been created out of a sense of urgency in the midst of unplanned contingencies. Documentarians working for the *Nippon Eiga Sha*

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21 Ibid., emphasis his.

took it upon themselves to travel to Hiroshima and Nagasaki to create visual records as they began to intuit the implications of American occupation just after the bombings. The film company existed as an appendage of the Culture Ministry and its photographers and cinematographers had documented the Japanese war effort across Asia and the Pacific.[22] Without funding and without a mandate from the reeling Imperial administration, they left Tokyo for the two cities in mid-September 1945. This timeline placed them in Hiroshima and Nagasaki even as Warren and his MED doctors combed the cities for medical data. Despite wartime shortages, they shot 35 mm motion pictures as well as medium and large format still photographs.[23] Their work progressed apace until 19 October 1945, when the Allied Occupation government in Tokyo banned the production, possession, or distribution of any images of Hiroshima, Nagasaki, and their inhabitants.[24] After the ban, American military police in the two cities began confiscating cameras and film from the *Nippon Eiga Sha* cameramen.

In the hands of the Americans, the footage quickly became contested and controversial. As they learned about the fullness of the project, squabbles emerged over who should get the film. The Joint Commission for Investigation of the Atomic Bomb, a group of doctors led by Warren's onetime travel companion Ashley Oughterson, wanted the footage for their postwar analysis. The Strategic Bombing Survey, a group of military men and academics who studied the effectiveness of the US's air warfare, also wanted the final Japanese cut.[25] Daniel McGovern, a cinematographer in the latter unit, won the dispute and began editing the film in Tokyo. Under his direction, most of the Japanese 35 mm footage

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22 See Nornes, Chapter 7.

23 Ibid., 196.

24 For a timeline of the censorship, see: Rupert Jenkins, ed., *Nagasaki Journey: The Photographs of Yosuke Yamahata, August 10,1945* (San Francisco: Pomegranate Artbooks, 1995.), 109-114.

25 Nornes, *Japanese Documentary Film*, 199.

and crates of annotated stills traveled to the Pentagon.[26] Some film, carefully hidden by its creators, remained in Japan. Meanwhile, McGovern worked out a deal with Warner Bros. to distribute a copy of the footage with English narration to theaters in the US for public viewing. His plan failed, however, when Manhattan Engineer District censors caught wind of the project and classified the project.

All these machinations took place before Crossroads and it seems as though Warren did not even know about the film when he set sail from San Francisco. Had he, he very likely would have included it in Radiological Safety Section's educational series during their cruise across the Pacific.[27] A series of memos indicate that Warren learned about the film once he arrived at Bikini. The reels were furnished by the Strategic Bombing Survey. The letter informing Task Force Commander Blandy that the film had arrived in Bikini offered no explanation for its appearance. This memo came from the office of Franklin D'Olier, the Strategic Bombing Survey's chairman.[28] The correspondence between the Survey, Blandy's ship *Mt. McKinley*, and Warren's ship *Haven* indicate that the film arrived on 26 June. But Donaldson's "sickly feeling" set in after viewing it with other officers on 25 June. In the complicated and often chaotic economy of the Operation, it is entirely likely that the reels of film moved about before the official correspondence attending their movement did.[29]

Projected in the *Haven's* wardroom, the film transported Donaldson and the Seattle biologists from the world of fisheries biology to the new landscape that would be created by the bomb. They had experienced hints of this new world before the film. Learning about the new meters that they would use

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26 Ibid., 202 – 204.

27 Stafford Warren to Lauren Donaldson, 15 April 1946, Box 6, Folder 3, UWLRB

28 Walter Wilds to William Blandy, 26 June 1946, Box 60, Folder 18, Reel 10.9, MSS Warren.

29 The *Haven* received a transmission with 16 July stamped on it indicating that the reels had arrived. F.R. Baird to Colonel Stafford Warren, "Transmittal of Letter from Untied States Strategic Bombing Survey dated 26 June 1945," Box 60, Folder 18, Reel 10.9, MSS Warren.

to measure radiation across Bikini's entire landscape surely gave them such a hint. Even though they had engaged in x-ray lab work for nearly three years, they did not know how to use standard radiological meters like Geiger counters and scintillation counters. Donaldson never really cared to learn. Of one shipboard lecture on radiation meters he remarked, "the discussion was… almost impossible to understand for one not familiar with the technical details."[30] Instead, he and men largely did what they knew in the weeks before the first shot. They spent time collecting specimens in order to have a baseline catalogue of individuals which had never been exposed to radiations from fission. But like the day of preparation on 24 June, the footage jolted them out of a biological field site and into one transformed by fission.

How did the film introduce the Seattle biologists, and the rest of the largely neophyte radiation monitors, into their new atomic surroundings? The footage gave them a sense of the bomb's power. Even with the array of ships in the ghost fleet and the buildings that the Joint Task Force had built on Bikini Island, the lagoon and the atoll seemed more open space than anything else. The relative lack of built environment contributed to the sense of disappointment felt by Test Able's official observers. The film of Hiroshima and Nagasaki supplied that sense of the bomb's ability to destroy, to level entire neighborhoods and cities. Just about 10 minutes into the film, a sequence of shots shows heaps of rubble and damaged houses in Nagasaki, where the hilly topography concentrated the bomb's blast.[31] The ground seems as though a flash flood had strewn great boulders about at random. Only visual cues, including shots of the personal effects of men and women killed by the bomb amid the rubble, indicate that the boulders are the remains of buildings. Floating aboard *Haven*, these images primed the

30 Donaldson Crossroads Logbook, 1 June 1946, MSS Donaldson.

31 Motion picture film relating to the Manhattan Engineering Project, 9 minutes and 35 seconds, Box 277, MSS Warren.

biologists to sail out into the ghost fleet after the shot and see the true scale of the bomb's destruction. Welander took four pages of detailed notes on the physical damage sustained by the fleet.[32]

Perceiving invisible radiation dangers across that landscape proved another key way to understand the new test site. Though they had seen fish deformed by x-ray exposure they had never seen fish exposed to radiations from fission and really had no idea what to expect. In this case the film filled in the gaps in their understanding by displaying somatic insults to human beings. The *Nippon Eiga Sha* cinematographers captured scenes of entire hospital wards abuzz with activity as well as close up shots of individual patients. The film showed gut-wrenching close ups of doctors and nurses working on horribly disfigured and burned patients. The most harrowing footage displayed children. One scene from a large hospital in Nagasaki showed a clinician cleaning the wounds of a boy, who looked to be around six years old. He lost most of the tissue around his mouth. His teeth poked out where his lips should have been. The doctor used tongs to hold a folded bandage to wipe the boy's wounds.[33] Footage of an emaciated toddler squirming and crying during an examination follow. In Hiroshima, likely at the Ujima Relief Hospital, another infant, ribs prominently sticking through her skin, screamed as a faceless doctor used a stethoscope. Burns covered the child.[34] The Japanese footage transported horrors that the Seattle biologists had never imagined to Bikini.

Seeing somatic insults sustained by living *hibakusha* trained the biologists to interpret harm from radiation based on distance from the bomb blast. Donaldson and his men expected to encounter dead fish after each test. They also suspected that radiation would discolor the scales of fish severely

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32 Welander Crossroads Notebook, 22 – 25, Accession No. 3346-001, Special Collections Division, University of Washington Libraries, Seattle, Washington, Arthur D. Welander papers, 1945-1947 (Hereafter cited as MSS Welander).

33 Motion Picture Film, 6 minutes and 55 seconds, Box 277, MSS Warren.

34 Ibid, 31 minutes and 28 seconds.

exposed. To this end, they arranged for an army photographer to take color Kodachrome pictures of fish they collected before 1 July so they could compare normal coloration with irradiated coloration.[35]But before the film and the first shot they had little sense of how deaths and discolorations might be distributed about the landscape. Having seen the footage and correlated it with remarks that Warren had made about the prevalence of radiological symptoms and mortality in relation to the blast site, the biologists started think in these terms. Welander remarked about the ghost fleet and the potential mortality rates had it been populated with sailors. Of the target ship USS *Nevada* he "would guess that all of crew would have died within the year."[36] In a place defined by an atomic blast the biologists had to be able envision proximity to the shot as it related to mortality.

Finally, the film shocked the biologists into a new understanding of their atomic test site by showing them the practices of Japanese pathologists, techniques very similar to their own bench work. The most important scene portrayed Japanese doctors desperate to understand the mysterious illness plaguing their patients by using tried and true pathology lab techniques. In one lengthy shot, two men worked in a dilapidated building cobbled together with irregular boards and pieces of corrugated metal. A sign read "Temporary Autopsy Room."[37] This was the autopsy shed at Michihiko Hachiya's Communication's Hospital in Hiroshima.[38] One of the men was likely the pathologist Chuta Tamagawa who helped Hachiya think through the problem of low platelet counts in their patients. In the footage, one man wore white scrubs and a dark apron while cutting an organ and placing thin sections in an

35 Donaldson Crossroads Logbook, 19 June 1946, MSS Donaldson.

36 Welander Crossroads Notebook, 23, MSS Welander.

37 Thanks to John Leisure, a fellow graduate student in the UCLA History Department, for the translation. Motion Picture Film, 31 minutes and 52 seconds, Box 277, MSS Warren.

38 See Chapter 2.

open jar of clear liquid, likely formalin or alcohol for preservation. The other sat at a desk with a white lab coat taking notes. They demonstrated the first steps of histological practice, taking a sample in order to prepare it for examination under the microscope. Later one man viewed a specimen on a slide and dictated notes to a nurse who wrote as the doctor gazed into the microscope.[39] Donaldson's men knew these bench practices well, at least with fish.

Sharing laboratory practices with Japanese clinicians in the bombed cities placed Donaldson's biologists squarely within the small community of doctors and scientists who could claim atomic expertise. Surely the Japanese medical doctors and American research biologists shared little in terms of formal academic training, wartime experience, and cultural outlook. But in terms of their lab practice, they looked nearly indistinguishable. Warren had, after all, trained them in a tradition that equated the health of dogs and other animals with human beings. The footage conveyed to Donaldson's men that the practices they used to study fish exposed to x-rays could work for specimens exposed to radiation from fission. It also strengthened the sense that human data and animal data could unlock the secrets of exposure, equally giving insights into the biological behavior of novel radiations. The film built a bridge between Tamagawa's temporary autopsy room and *Haven's* shipboard lab, between the Japanese cities plagued by gamma rays and neutrons and the remote Pacific test site.

39 Ibid., 25 minutes and 34 seconds.

Figure 4.1. Biological Field Practices at the Temporary Autopsy Room in Hiroshima in 1945. Source: Motion picture film relating to the Manhattan Engineering Project, 31 minutes and 21 seconds, Box 277. Stafford Leak Warren papers (Collection 987). Library Special Collections, Charles E. Young Research Library, UCLA. Source is in the public domain.

The day after watching the film that left him with a very sickly feeling, Donaldson did not record anything in his journal that indicated any sort of atomic epiphany. Indeed, the day's collecting excursion was slow paced and something of a disappointment. The team poisoned a poorly populated reef that yielded few specimens and little species variation. But the film had planted seeds in him and in his biologists that would bear fruit over the course of the Operation. After Test Able, Donaldson reported that "A series of Kodachrome photographs and colored movies have been made… some photographs of dissections have also been made."[40] If imitation be the highest form of flattery, then Donaldson and his biologists thought well of the *Nippon Eiga Sha* cinematographers and cameramen.

40 Report of the Division of Marine Biology for 19 July 1946, Box 13, Folder 11, UWLRB.


Figure 4.2. Biological Field Practices at Bikini in 1949. Source "Bikini: Radio-Biological Laboratory," seventeen minutes and four seconds. University of Washington Libraries, Special Collections, Laboratory of Radiation Biology records. Accession no. 00-065. Source is in the public domain.

Unfortunately, the Applied Fisheries Lab's footage from Crossroads has been lost. But the fact that they filmed and photographed themselves engaged in the same practices they watched in the Japanese footage shows that they experienced some kind of connection with the practitioners trying to understand radiation in the two destroyed cities. Fully a quarter of their 1950 film showed the biologists in the lab. "The Effects of the Atomic Bombs Against Hiroshima and Nagasaki" had already begun to inform them about what made a place atomic.

Mapping the First Atomic Test Site

On 3 June, as the *Haven* steamed towards its stop at Pearl Harbor on the way to Bikini, Lauren Donaldson and Arthur Welander each sketched a rough map of Bikini in their field notebooks. The men had started to notice the tropical heat and had spent the morning in classes on how to use "rate and total dose counters."[41] No doubt they looked forward to their leave in Honolulu, a last respite before two months of work at a very remote field site. In spite of the heat and the anticipation, they listened to Stafford Warren give a talk titled, in Warren's grandiose fashion, "The Duty of the Monitor."[42] Perhaps the colonel drew the map as he lectured and instructed his men to copy it. Perhaps he talked his men through the anticipated spatial layout of Test Able. At any rate, Donaldson and Welander drew maps similar but not exactly the same. Welander's map was characteristically more detailed than his supervisor's. Despite their differences, each man's map showed details important for the test. Both displayed a general outline of the atoll, though neither included the names of islands. They also showed the prevailing wind direction, a key detail for understanding fallout. Finally, they both included the locations of radiation monitoring vessels during the test.

If the film they would watch on 25 June taught them to think about the atoll in terms of previously irradiated environments, their work as amateur cartographers showed how they thought about Bikini's atomic transformation. The maps track their view of the place from before they even saw it through the entirety of the Operation. On the 3rd, Donaldson sketched one map of the atoll sight unseen while Welander sketched two maps.

41 Donaldson Crossroads Logbook, 3 June 1946, MSS Donaldson.

42 Donaldson Crossroads Notes, 3 June 1946, MSS Donaldson.

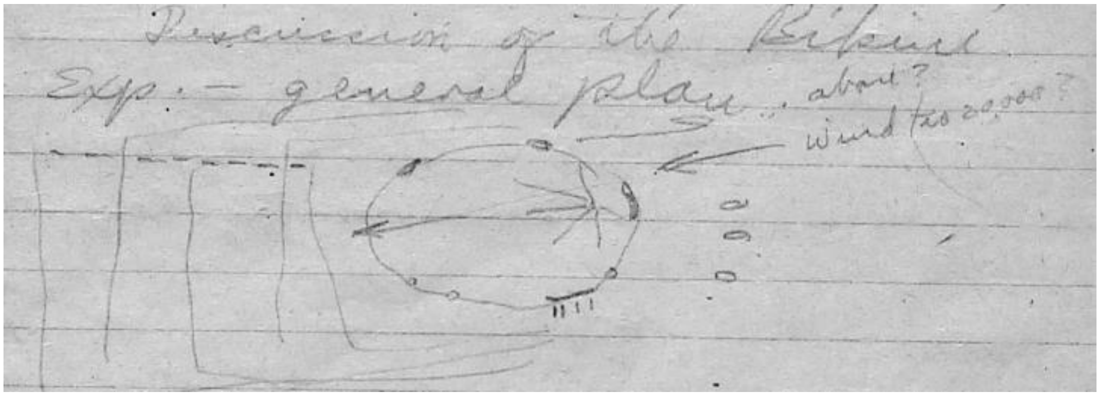

Figure 4.3a. Donaldson's First Map of Bikini Atoll During Operation Crossroads. Source: Donaldson Crossroads Notes, 3 June 1946, Box 10, Folder 29. University of Washington Libraries, Special Collections. Lauren R. Donaldson papers. Accession no. 2392-0007. Republished with permission of University of Washington Libraries.

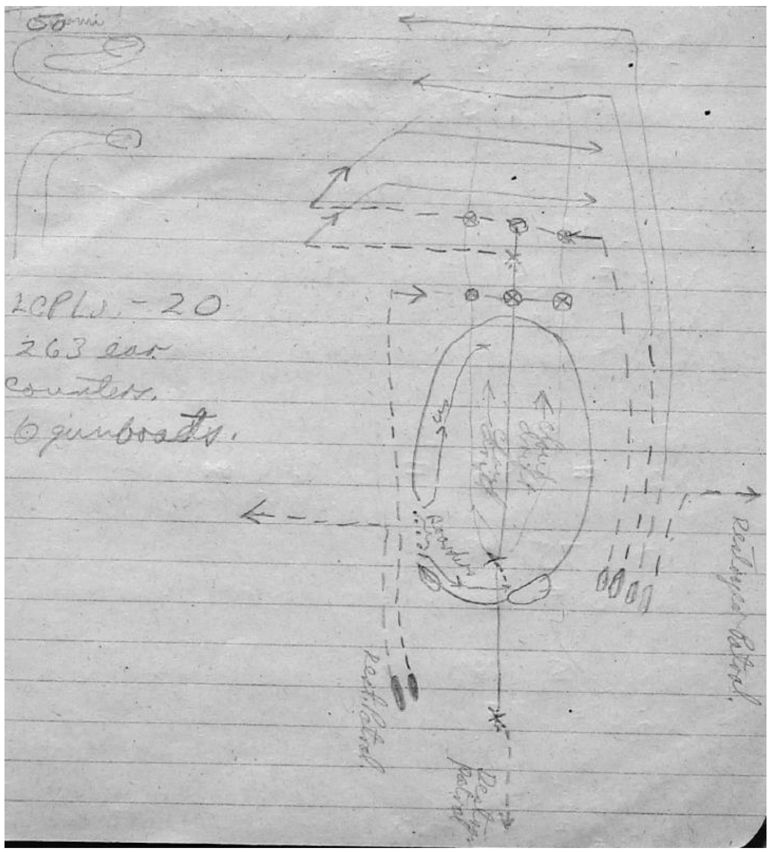

Figure 4.3b. Welander's First map of Bikini Atoll. Source: Welander Crossroads Notebook, 2. University of Washington Libraries, Special Collections. Arthur D. Welander papers. Accession no. 3346-001. Republished with permission of University of Washington Libraries.

Welander failed to note why he drew two maps. Perhaps he had some time after the lecture to sit down and pay attention to detail. Generally, Welander accentuated details in a way that Donaldson did not. At any rate, the three maps share form, content, and the notes taken from the same lecture surrounding them in the field notebooks. Each map contained practical information about the monitoring of Test Able. The only physical variables that the maps shared was some crude outlines of the islands making up Bikini Atoll and information about the wind direction. The islands went unlabeled. The maps did include information about the wind, since it would bear the radioactive particles thrown aloft by Able away from the test site. Welander even included the mushroom cloud on his second map. He did not draw the cloud but included the label "cloud drift" twice over Bikini lagoon with arrows pointing downwind. These first maps of Bikini made by the biologists who would research the biological effects of radiation already envisioned a space ordered by atomic testing.

If most everything natural, except the wind, had been erased from the landscape in the 3 June maps, then logistical elements took pride of place. Warren must have spent the lecture emphasizing the role of the destroyer patrols that would monitor radiation in the ocean around the atoll. Each man drew in the destroyers and made remarks about them in his notes accompanying the maps. "9 destroyers posted outside of the lagoon 6 will be downwind and 3 upwind."[43] Welander noted that the three upwind destroyers would collect control samples after the test.[44] Without having even arrived at Bikini, the biologists were being trained to put up boundaries around the site based on assumed radiological exposure. Both men also drew the paths of the destroyers as they would sail downwind to monitor fallout. Welander did so in detail, showing how they would systematically crisscross the path of the fallout from the detonation site. No doubt Warren ordered these maneuvers based on his experience at

43 Donaldson Crossroads Notes, 3 June 1946, MSS Donaldson.

44 Welander Crossroads Notebook, 6, MSS Welander.

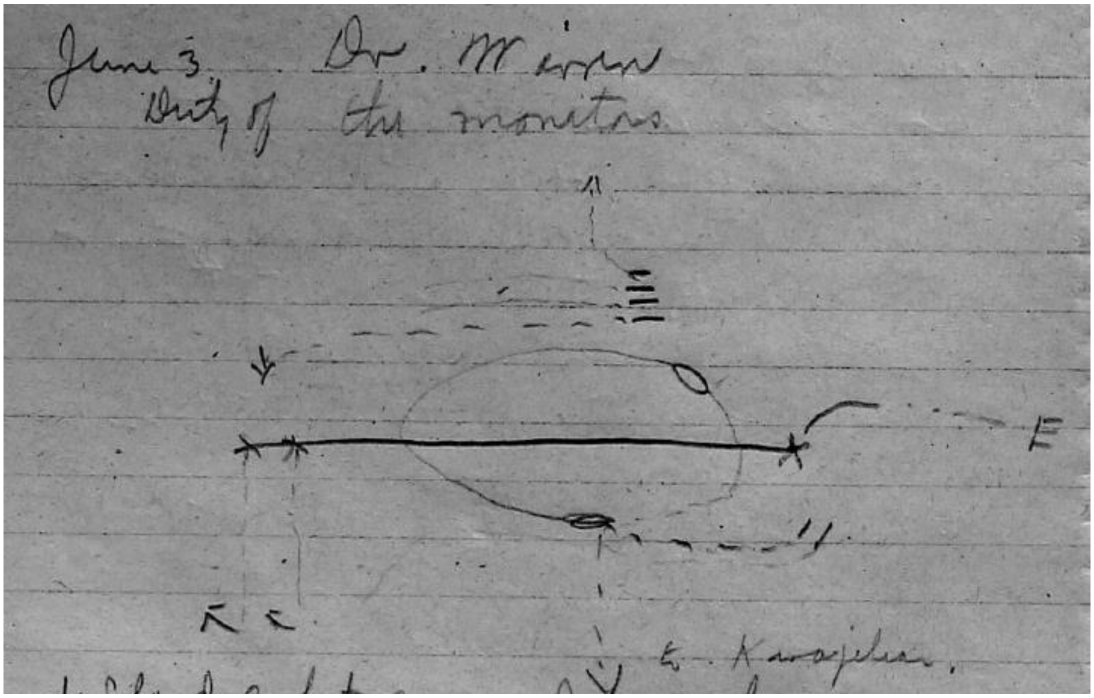

Figure 4.3c. Welander's Second Bikini Map. Source: Welander Crossroads Notebook, 6. University of Washington Libraries, Special Collections. Arthur D. Welander papers. Accession no. 3346-001. Republished with permission of University of Washington Libraries.

Trinity. There his radiation monitors had a hard time following the fallout because of their limited ability to traverse the inhospitable terrain of the New Mexican desert. On the open ocean the destroyers could sketch a rational monitoring pattern as though they were on a blank slate.

Donaldson and Welander developed their sense of Bikini's atomic geography after they left Pearl Harbor because Warren got increasingly into the details of what their work as radiation monitors inside the lagoon would entail. On 6 June, the day they steamed away from their shore leave at a hotel on Waikiki Beach, Warren shared the plan for monitoring patrols inside Bikini lagoon on Able Day. In the more detailed of his 3 June maps, Welander had drawn in these monitors waiting to enter the lagoon. He labeled them "boarders."[45] In fact, enlisted navy men would board the surviving ships of the ghost fleet after the shot. The Radiological Safety Section monitors would stay aboard small watercraft to take radiation measurements in the lagoon and around the ships. Sailing away from Pearl Harbor,

45 Ibid.

Warren announced the composition of the six monitoring patrols, code-named Brass, Cobalt, Gold, Iron, Nickel, and Steel. Equipped with Geiger-Muller counters, ionization chambers, and bottles for taking water samples, they would count and map the tests' radiological burden.[46] Donaldson led one patrol and Welander another. Preparing to ply its waters, the biologists began to think about Bikini lagoon as the heart of the atomic field.

Actually encountering Bikini after another six days at sea did little for Donaldson and Welander in terms of changing their view of the atoll. Donaldson noted nothing about the islands when they arrived on 12 June. He did comment that "the inside of the atoll swarmed with ships of every description and size."[47] Welander failed to erase the terrain as thoroughly as his supervisor, remarking, "saw ships before low-lying islands."[48] He then compared the size of the lagoon to Lake Washington, on whose shore the University of Washington and his home lab resided. They were roughly comparable. Most importantly, Welander drew a new map in his field book.

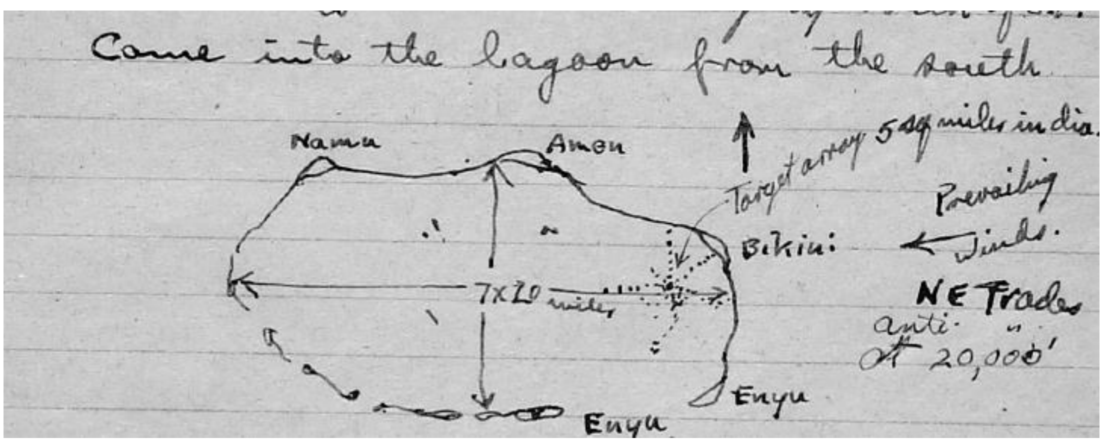

Figure 4.3d. Welander's Map of Bikini Upon Arrival at the Atoll. Source: Welander Crossroads Notebook, 12. University of Washington Libraries, Special Collections. Arthur D. Welander papers. Accession no. 3346-001. Republished with permission of University of Washington Libraries.

46 Radiological Safety Plan Test Baker, 15 July 1946, UWLRB.

47 Donaldson Crossroads Logbook, 12 June 1946, MSS Donaldson.

48 Welander Crossroads Notebook, 12, MSS Welander.

He gave the dimensions of the lagoon in miles and labeled the northeast trade winds with an arrow. He drew the ghost fleet in its star-like array, noting that the ships occupied a space of five square miles. He also gave names to the four largest islands in the atoll: Bikini, Enyu, Namu, and Amon. Arriving at the site gave him some new insights into how things looked there. His outline of the atoll was remarkably accurate. But if his map represented an argument about the place, then he arrived at a test site crafted more by humans than by nature.

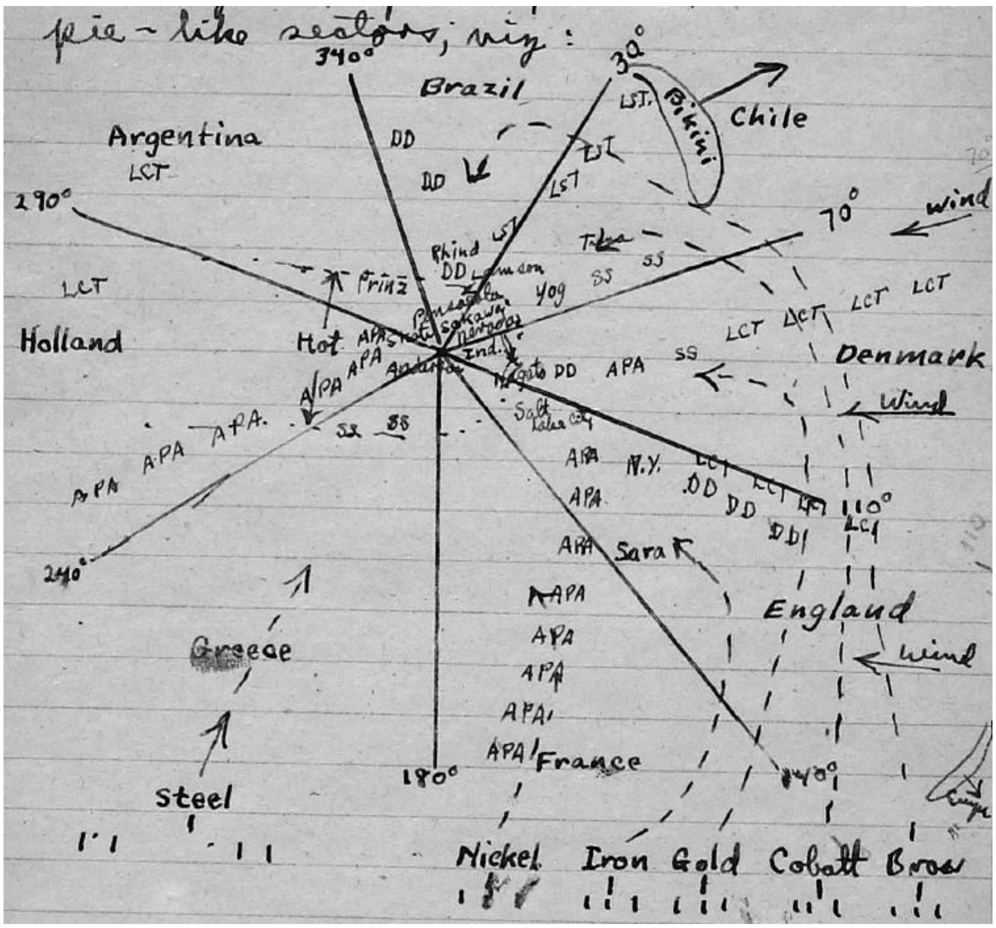

Figure 4.3e. Welander's Map of the Radiological Safety Section's Monitoring Plan for Shot Able. Source: Welander Crossroads Notebook, 12. University of Washington Libraries, Special Collections. Arthur D. Welander papers. Accession no. 3346-001. Republished with permission of University of Washington Libraries.

As the biologists spent the weeks between their arrival on 12 June and Able Day on 1 July preparing for the test by collecting a control population of marine specimens, their view of the test site became more complex based on the practicalities of their monitoring responsibilities. At some point during this time, Welander did not date his journal entries, he drew perhaps the most interesting map of Bikini lagoon to come out the Seattle biologists' work. Warren ran a dry run of Able Day with the patrol leaders on 14 June. Welander likely produced the map as part of that effort. That means he drew his map eleven days before Warren showed "Effects…" to the officers in the wardroom aboard *Haven.* To this map we now turn in order to see how logistical and radiological overlays came to characterize the atomic field.

The map depicts a landscape ordered entirely by the movements of radiation and those in search of it. Welander showed the lagoon divided into slices, like a pie. Each piece radiated out from the blast site and an inaccessible "hot zone." Welander noted each slice's code name and the names and locations of the ghost ships in each. For locational context, he included Enyu and Bikini islands on the far eastern edge of the map. Of course, he included the prevailing wind direction. Finally, he drew out the planned course of each monitoring patrol. Looking at the dotted lines showing the proposed post-shot journey of each patrol makes the map seem like a blown-up inset for his original 3 June map that showed the paths of the destroyer patrols outside the lagoon. The lagoon map completed his journey, not just in terms of space but in terms of understanding, from the mainland laboratory to the remote field site. Welander's first-hand knowledge of the site and Warren's indoctrination allowed Welander to envision a landscape ready to have its radiation counted. At its heart, the bomb blast dominated the lagoon, overwhelming its natural features. The dashed paths of the monitoring patrols created an orderly sweep of the space. Each pie slice, neatly geometrically defined, gave meaning to the radiation counts that would be taken within it. Covering 30, 40, or 50 degrees of the watery oval, each sector made the lagoon a geometric reality, a radiological chart understandable even after the violence of an atomic test.

What tasks did the radiation monitors actually perform amid the idealized pie slices on Able Day? "Our job was the determine the early boundaries of the contaminated area in the lagoon + trace the movement of that area."[49] Taking radiation counts to determine the boundaries of the contaminated area should have been straightforward. To count gamma ray intensities, they used a Victoreen Model 247 survey meter.[50] For beta levels, they used the Victoreen X-263, an instrument considered unreliable in the field and able to provide only "crude determinations of accumulated radioactive materials."[51] To take counts with each of the two meters, the monitor simply held the device's Geiger tube a few inches over the surface of the lagoon. Data recorders in each patrol plotted the count and the location at which it was taken. The patrols used a grid system that overlaid the pie slice sectors for plotting locations. Collecting counts would be relatively straightforward, excepting problems with the X-263 meters getting wet and failing to work.

Just as the maps indicated, Donaldson, Welander and their lagoon patrols waited in the open ocean upwind of the detonation site when the countdown started over the ship's loudspeakers on Able Day, 1 July. Donaldson's patrol waited on the transport USS *Henrico* and Welander's aboard the USS *Appling*, two dashes on the map to the east of the atoll. The plutonium bomb, like the one that leveled Nagasaki, flashed at 9:01 AM local time. "A ball of fire shot upward and outward."[52] The blast over, both transports moved to the mouth of Enyu Channel, again just as the two biologists had depicted in their field books. The monitoring patrols took to the lagoon in small power boars just before 11 AM and began to follow the dotted courses that Welander had drawn on the close-up map he made about two weeks before Able Day. They used their meters per the plan. In only one detail did the test fail to

49 Welander Crossroads Notebook, 18, MSS Welander.

50 Ibid., 17.

51 Appendix XIV – Radiobiological Studies Bikini Atoll June 12 to August 14. Preliminary Report, Dr. Donaldson et al., Folder 4, Box 6, UWLRB.

52 Welander Crossroads Notebook, 16, MSS Welander.

live up to expectations of the biologists' maps. The wind changed. "Our sector was changed from Argentina to Brazil," wrote Donaldson, "because of a shift of the wind."[53] Each group sailed to the pie slice clockwise to the one they had originally been assigned. In almost every detail, the next test site had lived up to the expectations that Warren's men had mapped in their notebooks.

After Able Day, Warren and his monitors had radiological data that they could map onto the site. Donaldson drew a final map in his field book on 6 July doing just that.

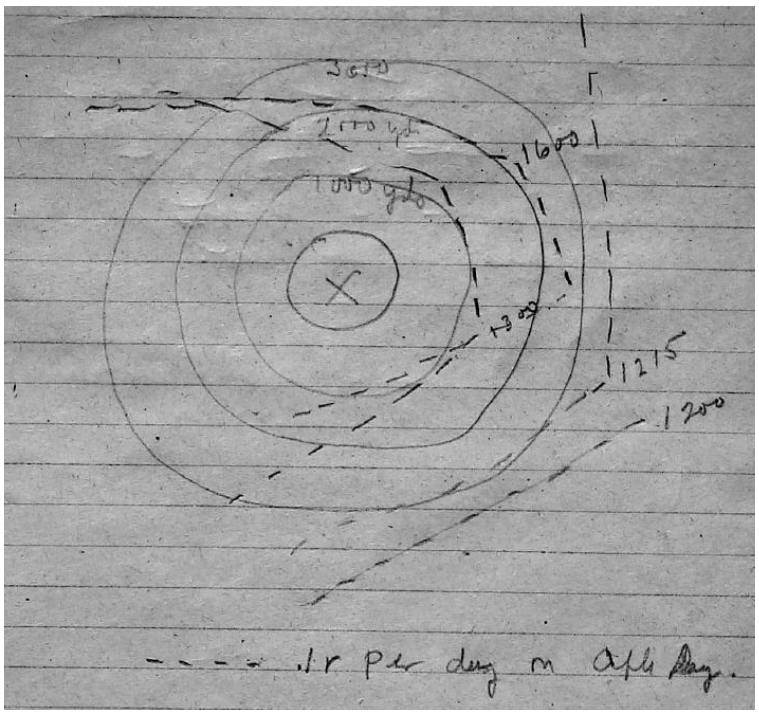

Figure 4.3F. Donaldson's 6 July Map of Radiation after Able Day. Source: Donaldson Crossroads Logbook, 6 July 1946. University of Washington Libraries, Special Collections. Lauren R. Donaldson papers. Accession no. 2392-0007. Republished with permission of University of Washington Libraries.

Though they had a bulk of detailed radiation data that included locations, the map Donaldson jotted down totally erased any physical features at Bikini and idealized the lagoon as a set of concentric circles. These radiated outward from the detonation point, spaced at 1000 yards. Dashed isolines showing radiation levels in tenths of a Roentgen curve around the upwind side of the detonation point.

53 Donaldson Crossroads Logbook, 1 July 1946, MSS Donaldson.

Donaldson seemed to cross isolines representing exposure rates of 1600 and 1300 tenths of a Roentgen-per-day. Perhaps he worked quickly or perhaps the map shows a movement in the contaminated area around the hot zone. At any rate, the map embodied the urge to erase the physical environment and idealize the occurrence and movement of radiation. Five days after the first atomic test at the atoll, Bikini already began to signify not a particular place rich in natural and cultural history but a generalized atomic environment. In the minds of the Seattle biologists, and the general public who watched the tests from the mainland on television screens, Bikini was becoming shorthand for a place scared by atomic testing.

Warren, Donaldson, and Welander set sail from San Francisco in late May 1946 headed towards a scientific *terra incognita*. As they crossed the Pacific, the men and their team began to build epistemic scaffolding around the site. By the summer of 1946, the biologists had some experience transporting their research program to a novel atomic field site. They had successfully done so at Hanford, where the Fish Lab began producing their style of research and manner of data very quickly. They had collected data from fish released into the northern Pacific at the Hatchery on the Samish River in 1944. But Bikini was no familiar terrain like the banks of the Columbia River. The atomic bomb was not really like a reactor core and certainly no x-ray machine. Outside their familiar Pacific Northwest fisheries geography and exposed to an unfamiliar source of radiation, they mapped Bikini to make it into a sensible atomic test site. Norton Wise has argued that maps become interesting when they make the leap "from natural history (as description and classification) to natural philosophy (as causal analysis)."[54] Drawing maps during lectures, Donaldson and Welander spent June and July 1946 trying to depict the bombs as causes, as mechanisms that transformed Bikini's environment into a new type of field site.

54 M. Norton Wise, "Making Visible," *Isis* 79, no. 1 (March 2006), 75 – 82.

Moving the Research Program into the Field

The rain came down in unrelenting sheets on the night of 8 July, drenching the biologists' field camp on Reere Island. "Just about got to sleep when a rain squall came up and soaked the entire group. Intermittent showers during the rest of the night," Donaldson complained.[55] The men had left *Haven* the day prior for a collecting excursion in Bikini's westward isles, downwind of Test Able's detonation site just seven days before. The first day of collecting had exceeded expectations. They collected over 300 specimens from a large tide pool.[56] But the long night in spartan field camp tested the already tired biologists. Morning coffee restored them enough to get to work. The tide was out in the morning so the men could poison a tide pool between Reeve and Bigiren islands. Like the night before, their luck had run out. "The tide evidently ran so strong through the pass that all the poison was washed away and diluted beyond the stage of use."[57] The team collected no specimens before they packed up camp and returned to the *Haven* "wet and bedraggled looking."[58] As a field site for biological research, Bikini could be exacting and uncooperative.

The tired and sodden biologists brought established collecting practices from the domain of fisheries biology to Bikini. Confronted by the violence and complexity of each atomic shot, they needed some sure foundation on which they could enact their research program. Familiar collecting practices put them on solid footing. The biologist needed large quantities of specimens in order to create statistically meaningful sample groups, groups like the thousand-fish-strong lots they reared

55 Donaldson Crossroads Logbook, 9 July 1946, MSS Donaldson.

56 Progress Report of the Division of Marine Biology, Box 13, Folder 11, UWLRB.

57 Donaldson Crossroads Logbook, 9 July 1946, MSS Donaldson.

58 Ibid.

troughs at Seattle and Hanford. So, when they arrived at Reeve Island for their two-day collection sortie on 8 July, they came equipped with poison. Once they made camp, team members walked the island's shoreline in search of a large tide pool. Finding a suitable site on the 8th, one of the men liberally dispersed the finely ground root of the derris shrub into the water. A plant native to east Asia, the legume's root contains a broad-spectrum piscicide that compromises the gills. "Two qts of derris root… for a great kill of fish."[59] While the poison spread in the warm waters, other members of Donaldson's team fanned out in the waist deep waters with large dip nets. They collected the over 300 fish that floated to the surface after succumbing to the rotenone. The men with nets labored to carry their quarry ashore. On shore, some of the specimens were counted for radiation with an X-263 meter. Because the meter created unreliable data in the field and because the sun was hot, the biologists only used it determine if the fish gave higher counts that the background radiation on the beach. These did not. After counting, the fish went on ice for transport back *Haven*. The work was labor intensive but straightforward enough.

Time was of the essence for collecting after Test Able because Donaldson wanted a useful number of specimens that had been exposed to radiation from that bomb but not from the upcoming Baker shot. Because the radiation burden from Able had been so low, it was detonated at an altitude that precluded the worst kind of fallout, Donaldson and Welander had covertly dropped their monitoring duties on 3 July to poison fish in the shallows off the western end of Enyu Channel. Warren did not chastise Donaldson and Welander for shirking their monitoring duties in part because the men donated a large portion of the day's 700 plus haul for an impromptu fish fry. "The ships cook Lopez cooked them and we had a fish fry about 10 P.M."[60] Boosting morale was a happy side effect of the

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59 Donaldson Crossroads Logbook, 8 July 1946, MSS Donaldson.

60 Donaldson Crossroads Logbook, 3 July 1946, MSS Donaldson.

Marine Biology Division's collection practices. Beside the successful trips on 3 and 8 July, the biologists had a good collecting day on the 15th. They poisoned 350 fish in a tide pool on northerly Ourikku Island.[61] To the 1926 fish that comprised their pre-Able baseline group they added another 1819 fish collected after Able but before Baker.[62]

Collecting did not always yield huge returns, the biologists succeeded or failed based on environmental contingencies. In the narrow pass between Reere and Bigiren Islands, the biologists had no luck on with their rotenone on 9 July as the tide carried the poison into the lagoon. Too diluted, the poison did nothing for them. Even when the poison worked, the process of collecting the fish could prove complex. During their great haul on 15 July, Donaldson griped that "the job of picking up the fish was extremely difficult for the area was covered with antler coral that really made it difficult to travel about" in the deep water.[63] Though the day turned out well, a troop of men weary from carrying hundreds of pounds of fish over a course, bumpy, and inhospitable reef returned to the *Haven* that night. Poisoning, a means for collecting, clearly worked in some instances but was less than optimal in others given the rough terrain and bathymetry around Bikini's lagoon. Hook and line fishing proved fickle as well, though the biologists relied on that more standard practice little since it yielded so few specimens even on a good day. Around 20 percent of the fish they collected during Crossroads came from hook and line fishing.[64]

As Test Baker approached, preparation for their radiation monitoring duties again began to monopolize the Seattle biologists' time. In the dual nature of their work, monitoring duties generally

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61 Appendix XIV – Radiobiological Studies Bikini Atoll June 12 to August 14, UWLRB.

62 Ibid.

63 Donaldson Crossroads Logbook., 15 July 1946, MSS Donaldson.

64 Appendix XIV – Radiobiological Studies Bikini Atoll June 12 to August 14, UWLRB.

outweighed research duties. Donaldson and Warren did find some free time on 17 July for a morning fishing expedition. Warren caught two large tunas. The fisheries biologist did not record the conversation he had with his MED superior, but happily noted that upon their return to the *Haven,* "Lopez, chief steward, fixed all the fish up and they were enjoyed by the ravenous group..."[65] The free time turned out to be their last before Baker. On 18, 19, and 20 July Donaldson and Welander led their patrols through practice monitoring exercises in preparation for the first underwater detonation of an atomic bomb.

Test Baker shook the atoll mid-morning on 25 July. "Saw a huge area of Bikini lagoon rise with lightning-like speed + and boiling violence to a height of Mt. St. Helens. Incredibly white dome."[66] A pervasive mist and then an hour of punishing rain, lagoon water falling back to earth, followed the blast. The column of water, mist, and rain carried radioactivity everywhere in the lagoon. The first monitoring aircraft that were to track the fallout quickly encountered dangerous exposure levels and were commanded to discontinue their work.[67] Just as they had on Able Day, Welander and Donaldson's patrols waited with Geiger meters in hand to trek across the lagoon in their small watercraft. They did so about an hour and a half after the blast. Some of Donaldson's monitors took readings showing exposure levels up to 20 Roentgens per day directly downwind of the blast site.[68] Warren had set the maximum allowable dose for daily exposure at 0.1 Roentgen.[69] The counters in the film badges worn by Donaldson's men showed that they hit that allowable dose in the afternoon. He cut their patrol short

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65 Donaldson Crossroads Logbook, 17 July 1946, MSS Donaldson.

66 Welander Crossroads Notebook, 27, MSS Welander.

67 Hacker, *The Dragon's Tail*, 138.

68 Donaldson Crossroad's Logbook, 25 July 1945, MSS Donaldson.

69 Welander Crossroads Notebook, 33, MSS Welander.

and returned back to *Haven*. On the journey back to the ship, they collected a red grouper, floating dead on the surface of the lagoon.

The grouper offered the biologists a radiological snapshot of how Baker's radiation entered the biota nearly immediately after the blast. They counted it with their unreliable but handy X-263 Geiger meter in their patrol boat. It showed a level of 0.04 Roentgens over 24 hours. That meant that a person in proximity to the fish would be exposed to their maximum allowable dose in around three days. The biologists wanted a more accurate measure, so Welander took the specimen to the X-337 tabletop counter in *Haven's* counting lab. In the lab, Welander first needed to dissect the fish to create organ samples. Here we see the fisheries biologist engaged in the same practices as the pathologists did in the ruins of Hiroshima. Using the skill he had developed over the last two years at the bench in Seattle, Welander sliced samples from the grouper's gills, intestines, skin, liver, muscle, and spleen. Next, he calibrated the counter using a sample of uranium oxide. After this, he placed the tissue samples on small aluminum trays. These each went in a counting chamber, which he placed within half an inch of the X-337's Geiger tube. He counted tissue for three minutes each with the machine set to run 1000 volts through the Geiger tube. The gills yielded very low counts. Welander failed to report on the counts in the other tissues. He finished work the work well after 9PM and noted that perhaps Wright Langham, the Los Alamos chemist who ran the counting lab, may be interested in assisting with fish counts in the future.[70]

Setting to work the next morning, the biologists of the Marine Biology Division encountered a field transformed by Test Baker's radiation in a way that it had not been by Test Able's. Dangerous levels of radioactivity kept the boarding crews who were meant to count radiation in the remaining ships of the ghost fleet away for days. Levels were so dangerous that Blandy called Warren and the

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70 Appendix XIV – Radiobiological Studies Bikini Atoll June 12 to August 14, UWLRB.

lagoon patrol leaders to his flagship, the *Mt McKinley,* for a conference in the very early morning after the blast. Despite the danger, the lagoon patrols set to work. Donaldson's patrol headed north, towards Aomoen Island. There, they would "patrol the area defining the .1r, .2r, and .5r lines."[71] His patrol would create for Baker the kind of isoline map he drew after Test Able on 6 July in his field notebook. Only the radiation levels were much higher after Baker. Donaldson and Welander led their patrols for similar work on the 27th and 28th. All the while, they kept their eyes peeled for significant fish kills. As the days passed, the bomb's radiation pervaded the lagoon. Levels remained so high that monitoring became something of a fool's errand. Nowhere was safe according to the exposure limits that Warren had set for the Operation's personnel. Accordingly, the Colonel released Donaldson and Welander from their monitoring duties on the 29th so that they could begin collecting specimens.

The biologists collected in the radioactive waters after Test Baker much as they had after Test Able. Armed with two quarts of poison they took to the reef northwest of Bikini Island on the morning of 30 July. The low tide cooperated, they collected over 205 fish.[72] They waded in the radioactive waters with their nets per usual. Both Donaldson and Clarence Pautzke, one of the lab assistants from Seattle, cut their hands on the sharp fin scales of two surgeon fish that they collected.[73] They counted the specimens once they got them on the beach. The Victoreen X-263, hated for its inability to give accurate low-level measurements, showed exceedingly high β counts. The beach itself registered at 1.5 Roentgens per day.[74] That evening, for the first time over the course of the Operation, Donaldson remarked that his men had experienced some radiological danger. "We all were contaminated with beta

71 Donaldson Crossroads Logbook, 26 July 1946, MSS Donaldson.

72 Appendix XIV – Radiobiological Studies Bikini Atoll June 12 to August 14, UWLRB.

73 Donaldson Crossroads Logbook, 30 July 1946, MSS Donaldson.

74 Appendix XIV – Radiobiological Studies Bikini Atoll June 12 to August 14, UWLRB.

to the extent that we were all in the dog house (shoes were the worst)."[75] The biologists presented none of the fish they collected on 30 July to Lopez, the ship's head cook, to prepare for dinner.

Since notable levels of radiation confronted the biologists, their collecting and counting efforts became time-sensitive since they wanted to see how radiation was moving through marine species. From their laboratory studies, Donaldson and Welander knew about how x-rays harmed the development of cells in salmon over time. From Foster's experience in the lab at Hanford, they knew about the effects of full-body exposure to constantly radioactive water. But they had never seen fish in the field exposed to radiation from a discrete event. The fish they began to pull out of the water on 25 July could give them information both about radiations from the fissile moment itself and about how radiation traveled through the biota in the lagoon. The counts from the grouper they collected on Baker Day begins to show what the biologists were after. Its gills produced very low radiation counts. Likely, the blast or gamma waves and neutrons from the bomb killed the fish. Dead, its gills ceased functioning. Meanwhile the fish that survived pulled irradiated water through their gills day and day out to breathe. By 1 August they were finding that the gills were the hottest organ on the fish they were catching.[76] At last, movement from bomb to fish had become clear.

The biologists learned to think about radiation in terms of counts as they took to the lab aboard *Haven* to document the movement of radionuclides through Bikini's biota after Test Baker. Before Crossroads, Welander's practice in Seattle and his colleague Dick Foster's practice at Hanford had relied almost entirely on documenting, counting, and measuring somatic insults in fish that they knew to be caused by exposure to radiation. They counted mortality rates in sample populations. They performed histological analysis to count deformed and dead cells in key organ tissues. The measured

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75 Donaldson Crossroads Logbook, 30 July 1946 MSS Donaldson.

76 Donaldson Crossroads Logbook, 1 August 1946, MSS Donaldson.

individuals exposed to radiation to find statistical trends tying exposure to growth and development. These visual and empirical data differed from the data a counter created because they all relied on numbering and interpreting the effects of radiation rather than instances of radiation itself. Geiger meters counted the number of atomic decays in a sample by converting radiations into electrical charges. For the first time, Donaldson and Welander really collected data about the presence of radiation itself, not radiation mediated by a fish's body and then interpreted by their expert gaze.

Metrical data came to dominate their nascent field practice because it was quick to collect and because it could show the movement and concentration of radionuclides within the biota in nearly real time. The leaders of the Joint Task Force wanted to know where radiation went immediately after each test. Warren especially wanted this data since he believed the entire Task Force was in danger. Much has been written about the algae that concentrated radionuclides in the lagoon and then worked their way onto ships' hulls into ships' water filtration systems.[77] Warren was right, the ships were unsafe and he managed to convince Blandy to wrap the Operation up ahead of schedule.[78] Practically, learning to think of radiation in terms of counts rather than biological effects meant that Welander needed to learn to effectively use counters and interpret their readings in the lab aboard *Haven*. He did garner the help of Wright Langham for this task. The Los Alamos biochemist had analyzed blood, urine, and fecal sample taken from the patients unknowingly injected with plutonium during the war under the supervision of Warren's lieutenants Joe Howland at Oak Ridge and Andrew Dowdy at Rochester.[79] Langham worked to measure precisely how much plutonium the human subjects had excreted. He

77 See: Laura Martin, "Proving Grounds: Ecological Fieldwork in the Pacific and the Materialization of Ecosystems," *Environmental History* 23 (July 2018), 567 – 592, and Barton Hacker, *The Dragon's Tail*, 141 – 143.

78 Hacker, *The Dragon's Tail,* 147.

79 For Howland's participation in the plutonium injections, see Chapter 2.

wanted to find, in Warren's words, "precise data on the metabolism of T material [plutonium]."[80] His experience using meters to trace radiation through human subjects positioned him to teach Welander to track radiation through marine subjects in the counting lab at Bikini.

As Welander grew increasingly competent in the counting laboratory during the first two weeks of August, the biologists developed an effective rhythm for conducing field work. Each day some of the party would go collecting. They had four really good days with the rotenone and managed to collect 1407 fish in the weeks after Baker. These specimens flowed into the counting lab, where Welander had set up residence. On 4 August Donaldson commented "Art counted all day."[81] Even though Welander did receive the help of Langham's group, he could not process and count all the specimens in the small lab. Preserving and packing specimens for transit back to the lab in Seattle became a big part of the biologists' work. There they would begin to use counters even more precise than the one aboard *Haven.* The days were long but the team managed to go into the field, work in the field lab, and prepare specimens for work back at the lab on the mainland with a minimum of difficulty. Donaldson himself slowed the process up as he took ill on the evening of 5 August. Diarrhea set in and after a sleepless night he felt "weak as a rag."[82] He could not stomach his breakfast and felt lethargic for the duration of the day. Though he did not diagnose it as such, he suffered textbook symptoms of radiation exposure.

By the time the Seattle biologists began their voyage back to the mainland aboard the *Henrico* on 16 August, they had pieced together the rudiments of how they could expand their biological program to Bikini. They took the field as they had in other research locations, armed with poison and nets, fishing poles and chests full of ice. But they had never taken Geiger meters into the field before.

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80 Stafford Warren to Andrew Dowdy, 1 December 1944, NV07079684, NTALV.

81 Ibid., 4 August 1946.

82 Ibid., 5 August 1946, MSS Donaldson.

Neither had they brought specimens back to a field laboratory in order to count them, to submit tissue samples to a radiation meter that could number the discrete moments in which unstable radionuclides decayed. The precise counting of specimens from the atoll would become an important function of the lab back in Seattle, where they could use high quality meters in a controlled setting. Counting tethered the test site to the mother laboratory and brought the atoll into the biologists' fold.

Conclusion: Practices for the Radiobiologcal Future

Lauren Donaldson disliked the tropical heat. Temperatures on the first three days of their voyage from Bikini to Pearl Harbor had been in the 90s and *Henrico* lacked air-conditioned quarters. The laboratory chief had a hard time focusing as he drew two maps, sadly lost to time, "showing the locations sampled before and after Baker Day."[83] In the afternoon, he met with Warren and Robert Buettner, the Colonel's administrative assistant and right-hand man. The meeting was likely a nice change of pace from the exacting work of plotting data from collection tables on maps. While the men certainly discussed findings from Crossroads, they turned away from data and thought about the future of their work after the Operation.

The men discussed the potential position of the Seattle laboratory and its field work within the structure of the new civilian Atomic Energy Commission that would replace the army's MED at the end of 1946. Warren knew that he would assist in the transition after giving up his commission and returning to academia. He shared with the two men that he would attend a meeting in September of what would become the new Commission's interim committee on biology and medicine.[84] The Colonel

83 Donaldson Crossroads Logbook, 19 August 1946, MSS Donaldson.

84 Richard Hewlett and Francis Duncan, *Atomic Shield: A History of the United States Atomic Energy Commission* (Washington D.C.: U.S. Atomic Energy Commission, 1972), 113.

wanted his wartime laboratories to continue their work. Donaldson, whose leadership of the Applied Fisheries Laboratory and Hanford Aquatic Biology Laboratory relied on Warren's patronage, wholeheartedly agreed. The men laid out three goals. They agreed that "the salmon work… has #1 priority."[85] None of the long-term x-ray studies conducted in Seattle had been written up yet. They wanted their foundational research to have pride of place. They also agreed that the Hanford lab needed to maintain salmon populations for basic research like the mother laboratory in Seattle. Finally, they agreed that "suggestions for further marine work at Bikini… should be submitted."[86] They intended to claim their scientific stake at the new test site.

Crossroads proved the pivot point for the biologists lately of Warren's MED Medical Section laboratories because they found a way to manipulate their laboratory research program for the new atomic field at Bikini. We have seen that in the Seattle lab, the biologists spent their time looking at somatic insults to entire salmon and steelhead populations. They also zoomed in on individuals, using histological analysis to look at insults to individual organs and quantify those visible blemishes. At Bikini, they continued to employ familiar practices. They tried to gather large sample sizes to reflect populations of individual species at the atoll. They continued to dissect specimens so that they could investigate how radiation from the bomb interacted with specific organs. But the biologists made a shift. They began to use and to trust electronic radiation meters to tell them about exposure. The move from primarily trusting visual evidence to trusting electronic counts may seem minor, but it was a key move that allowed the AFL biologists to export the way of thinking about radiation that they had developed on the mainland to new test site. Even though they produced a new type of data, they could fit Bikini into the atomic that they already felt comfortable with based on their research. This was a

85 Donaldson Crossroads Notes, 19 August 1946, MSS Donaldson.

86 Ibid.

world in which radiation below a certain threshold was essentially benign. This was a world formed in a lab and applied first to the landscape at Hanford and, in 1946, to the landscape at Bikini.

As Operation Crossroads faded into memory, Stafford Warren's vision that his Medical Section's biological program could be applied across the expanding atomic world began to bloom. Armed with years of experience in the lab and in possession of the newest radiation instruments available, Donaldson and his biologists would return to Bikini over the summer of 1947. Though the biologists still fell far below the physicists and military men on the new test site's org chart, they found a place in the Marshall Islands for their unique science. The next chapter unfolds how they increasingly integrated themselves into the life of the test site and claimed expertise over all things biological at Bikini, Enewetak, and eventually Rongelap atolls.

Chapter 5

Poisoned Peoples and the Failure of Radiological Expertise

When Science Simply does not work in the Colonial Field

"We were told," Lijon Eknilang recalled, "that we could eat everything but *barulep* (coconut crabs), so we ate *makmõk* (arrowroot) and *atüñ* and *jõbarbar* (smaller crabs), drank coconuts, and used the husks and shells as fuel for our cooking fires."[1] Eknilang received these instructions when she and her community returned to their home atoll, Rongelap, in 1957 after three years of exile. They had been gone from their islands and lagoon because of fallout from the 1 March 1954 Castle Bravo shot, the largest thermonuclear detonation ever carried out by the United States. Bravo's yield far exceeded the expectations of the Atomic Energy Commission (AEC) physicists and engineers who designed the bomb. So did the amount and intensity of dangerously radioactive fallout that the detonation created. Tragically for Eknilang and her community, the wind carried Bravo's fallout across the open Pacific from Bikini Atoll some 100 miles to their home atoll. "Later that day, there were a lot of powders that fell from the sky and we didn't know what it was and it looked like snow," Nerje Joseph explained in an interview just before her death in 2022.[2] Rongelapese accounts like Joseph's agree that the fallout

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1 Lijon Eknilang, "A Survivor's Perspective," in *Life in the Republic of the Marshall Islands,* eds. Anono Lieom Loeak et al. (Majuro: University of the South Pacific Centre, 2004), 125.

2 Nerje Joseph, "The Final Years of Majuro," interview by Sam Denby, video, 4 August 2020, https://www.youtube.com/watch?v=3J06af5xHD0&t=3881s.

drifted down like snow, about which they had learned in stories told by US missionaries. Children played in it.[3] The US Navy evacuated the sickened Rongelapese two days later to Majuro atoll.

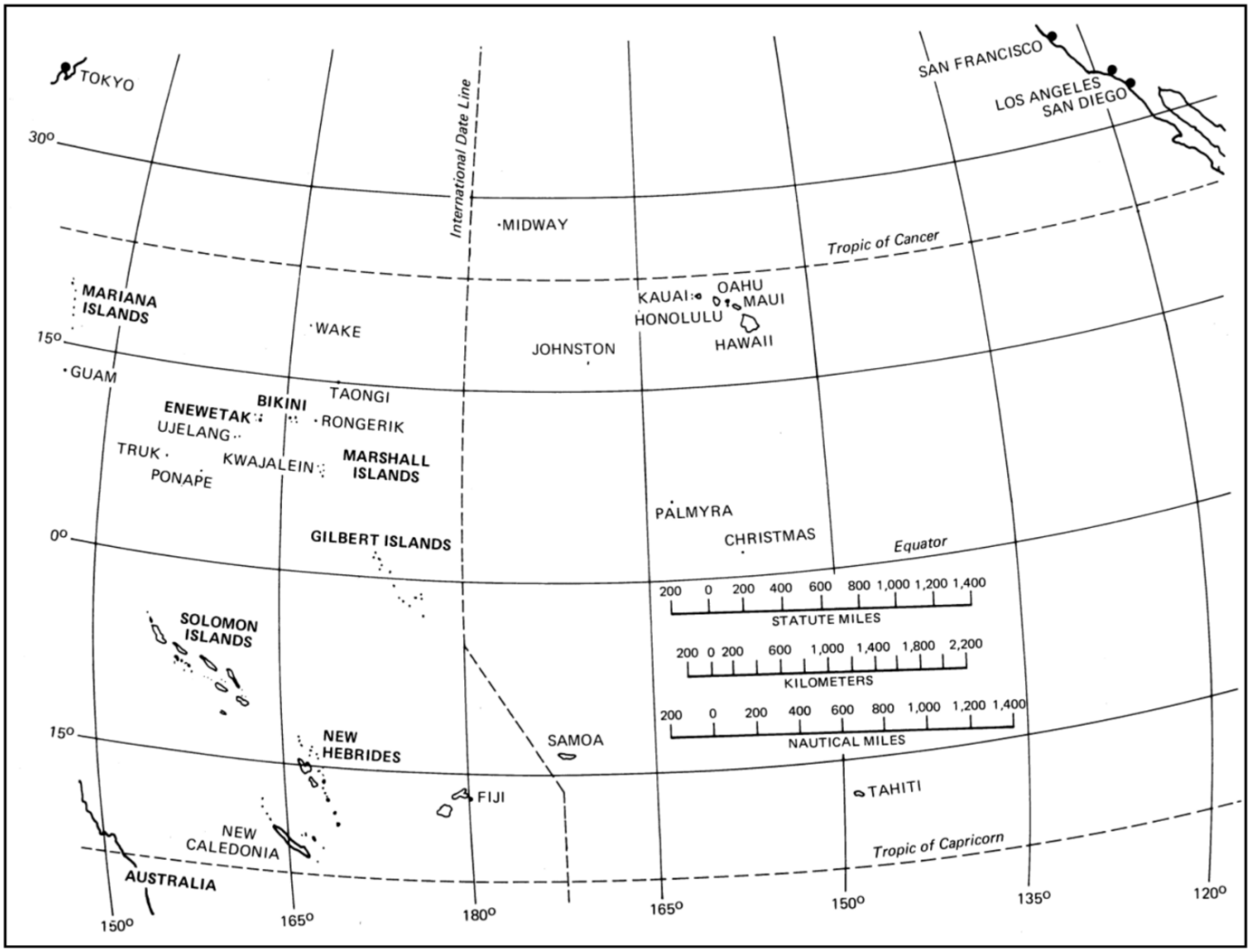

Figure 5.1. The Marshall Islands in Context. Note that Rongelap Atoll sits between Bikini and Rongerik Atolls. DTRA-TR-10-29, Science Applications International Corporation, "A Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments," October 2011, Figure Two. https://www.dtra.mil/Portals/61/Documents/NTPR/4-Rad_Exp_Rpts/DTRA-TR-10-29%20-%20Technical%20Basis%20for%20NTPR%20Expedited%20RDAs%20(Final%2011-29-2011).pdf?ver=2020-06-23-123836-417. Source is in the Public Domain.

Just weeks after the radioactive snow fell and the Rongelapese left their home atoll aboard a gray US naval vessel, the biologists from the Applied Fisheries Laboratory arrived at Rongelap because they seemed like the right experts to assess the radiological state of the environment. It certainly helped

3 Jeton Anjain, quoted in Martha Smith, *Domination and Resistance*, 78.

that Donaldson's team had already started congregating at Enewetak Atoll to get ready for the 1954 field season. To the administrators of Joint Task Force Seven, the military outfit running Operation Castle, and to officials from the Trust Territory of the Pacific as well as the Atomic Energy Commission's Division of Biology and Medicine, the AFL biologists had the experience necessary to diagnose the landscape's radiation danger.[4] After all, Donaldson's team had been a fixture in the Marshalls since Operation Crossroads in 1946. Present for Operation Sandstone in 1948 and Operation Ivy in 1952, they had seen and studied the effects of both conventional atomic devices and boosted thermonuclear devices like Castle Bravo that created yields thousands of times stronger than the bombs that destroyed Hiroshima and Nagasaki. Moreover, when the fallout blanketed Rongelap in March 1954 the biologists had already established themselves in the Division of Biology and Medicine's newly constructed Enewitok Marine Biology Laboratory, designed to be the hub for biology at the Pacific Proving Grounds.[5] The AFL biologists had experience and infrastructure at the fingertips with which they could address the crisis.

Why did the military, scientific, and territorial administrators in charge of Rongelap consider Castle Bravo a crisis in need of an expert response? In short, because competing ways of understanding the event became public. Fallout had sickened Japanese fishermen aboard the *Fukuryu Maru,* a fishing vessel caught in the path of Bravo's most dangerous fallout. One fisherman died and the sale of the irradiated tuna catch at home created panic in Japan.[6] Concerned housewives worried for the health of their children who had eaten potentially contaminated fish. Donaldson travelled to the home islands to

4 Donaldson Castle Notebook, 21 March, Box 11, Folder 13, MSS Donaldson.

5 Willis Boss to Lauren Donaldson, 19 November 1953, Box 7, Folder 14, UWLRB.

6 Jacob Darwin Hamblin and Linda Richards, "Beyond the Lucky Dragon: Japanese Scientists and Fallout Discourse in the 1950s," *Historia Scientiarum* 25, no 1 (2015), 36 – 56.

use his scientific experience to smooth over the crisis.[7] Making things worse, another headline hit in the presses in June 1954. The Associated Press released a story about the evacuation ominously titled "Natives Call Selves 'Poisoned Peoples.'" John Anjain, a Rongelapese leader, explained in the story that "there is anger among some people… I think it will disappear if we get back home."[8] The news threatened to upend the easy relationship that the U.S. had enjoyed with the United Nation's Trusteeship Council since the Marshall Islands' status had been codified as part of the Trust Territory of the Pacific in 1947. The news also played poorly on the mainland. As sickened lay people told their stories, the narrative about safety at the Proving Grounds slipped out of the U.S. atomic establishment's control in a way it never had before.

Trust Territory and AEC administrators very quickly decided that the Rongelapese needed to return home in the wake of Castle Bravo. Repatriation could end undesired public and political scrutiny. Accordingly, the Seattle biologists set out in 1954 and '55 to establish whether Rongelap's environment could safely produce foodstuffs traditionally used by the local population, animals and plants like the *barulep*, *makmõk, atüñ* and *jõbarbar* that Lijon Eknilang described. Though charged with understanding Rongelapese foodstuffs, Donaldson and his biologists did not begin their investigations by gathering knowledge from the Rongelapese. Instead, they trusted in their own research program, honed since 1946. In his study of scientific expertise and nature, Stephen Bocking has argued that "scientific knowledge has played a role in framing the questions at stake" about nature.[9] The Seattle biologists certainly used their laboratory knowledge about irradiated salmon and their field

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7 Neal Hines, *Proving Ground*, 187.

8 William Waugh, "Natives Call Selves 'Poisoned Peoples,'" *Washington Post,* 10 June 1954, ProQuest.

9 Stephen Bocking, *Nature's Experts: Science, Politics, and the Environment* (New Brunswick, New Jersey: Rutgers University Press, 2006), 9.

knowledge about the radioactive environments at Bikini and Enewetak Atolls to frame and answer questions about Rongelap. Trusting in their own research program, they helped give US atomic officials a scientific imprimatur for repatriation in 1957. Extensive study showed the experts that the environment was safe.

Only it was not.

In this chapter I argue that the Seattle biologists failed to produce data that described the movement of radionuclides through the environment at Rongelap after Castle Bravo in a way that meaningfully assisted the local population who relied on the land and sea for food. This argument requires something of a chronological sleight of hand. The claim that AFL science failed rests on documented instances of sickness among the Rongelapese population that began to occur at significant levels in the 1960s. Thyroid cancer from exposure to isotopes of radioiodine ravaged the community. So did miscarriages and birth defects, not tied to any one radionuclide but surely related to the presence of radiocesium, radiostrontium, and radiocerium in the biota. By the time these diseases became prevalent, Donaldson and his team of biologists had largely given up their annual field trips to the Marshall Islands because Limited Test Ban Treaty of 1963 ended atmospheric nuclear testing. The research program the biologists developed to study testing collapsed and they moved to field sites on the mainland and in Alaska where they were more apt to win funding.[10] The Seattle biologists only sporadically visited the Marshalls in the 1960s when the Rongelapese really began to suffer. To judge

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10 For their ill-fated ecosystems research at Fern Lake on the Kitsap Peninsula in Washington State, see: Matthew Klingle, "Plying Atomic Waters. For their adventure to Alaska as part of the AEC's Project Plowshare, see chapter 9, "From Bikini to the Chukchi Sea" in Neal Hines, *Fish of Rare Breeding: Salmon and Trout of the Donaldson Strains* (Washington D.C.: Smithsonian Institution Press, 1976). For a general history of Plowshares and the efforts to practically unfold the peaceful use of atomic bombs, see: Scott Kirsch, *Proving Grounds: Project Plowshare and the Unrealized Dream of Nuclear Earthmoving* (New Brunswick, New Jersey: Rutgers University Press, 2005).

their scientific practice in the 1950s by the fruits of ill-health in the following decade is unfair. But the analysis, I argue, makes sense. Using the timescale of Rob Nixon's slow violence, "delayed destruction that is dispersed across time and space… unfolding environmental catastrophe," allows for the analysis of US radiological expertise in the Marshall Islands.[11]

Confronted with a crisis at the intersection of technology and environmental health, the AFL biologists should have been able to produce data meaningful to answer the political question about repatriating a human population to an irradiated landscape. They produced reams of data. They took measurements. They used tried and true reporting techniques to share their data with other experts on the mainland. They showed in detail how particular radionuclides moved through the land, the water, and the biota. They judged that some species of plant and animal could be eaten safely while others could not. They did this all genuinely. The heirs of the Manhattan Engineer District's Medical Section, the experts, did good science. But their work failed to protect the health of the Rongelapese because it because it existed in a bureaucratic and cultural framework that precluded the creation of meaningful results for that task.

This chapter address how that framework created the conditions for scientific failure in three sections. First, I follow the AFL biologists on their journey towards expertise in the Marshalls, highlighting how their fight for access to the otherwise off-limits site positioned them as expert scientific managers beholden to the AEC for their scientific standing. We may recall here that as Stafford Warren and Lauren Donaldson left Bikini Atoll after Operation Crossroads in 1946, they committed themselves to the long-term study of radiation at the atoll. Both men saw a bright fiscal and research future for the lab in the study of environments exposed to fission from atomic testing. Warren

11 Rob Nixon, *Slow Violence and the Environmentalism of the Poor* (Cambridge, Massachusetts: Harvard University Press, 2011), 2.

was so excited by the prospect that when he founded the UCLA Atomic Energy Project as something of a sibling lab to the AFL in 1947, his first research outing was to the site of the 1945 Trinity Test to do environmental work.[12]

Why the expectation that their labs should attach themselves to landscapes and that the AFL should return to the Marshalls? In part this urge came from hubris, Warren and Donaldson really believed in their style of radiation study. Likely more important was their socialization into the idea that matured in the US over the first decades of the 20th century that expected the scientific management of federally significant natural resources.[13] By 1954 the Pacific Proving Grounds certainly constituted a US natural resource. Its atolls and open ocean offered a unique zone in which the country could test thermonuclear devices much too powerful to test on the mainland. Warren and Donaldson wanted the AFL to slide into a well-worn mold as federal experts whose job it was to understand a nationally significant environment. They had, in the words of Donald Worster from his magisterial history of American environmental ideas, a "built-in bias toward the management ethos, and even toward a controlled environment serving the best interests of man's economy."[14] But to become experts, the AFL biologists had to prove their usefulness to the atomic project in the Marshalls. To do this, they spent 1947 to 1954 fighting to show that they deserved privileged access to the test site. They

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12 For an early outline of the research at Alamogordo, see: Albert Belamy to James Jensen, 6 October 1948, NV0090386, NTALV.

13 For the management of bison at Yellowstone National Park, see: Andrew C. Isenberg, "The Returns of the Bison," *Environmental History*, 1997. For the story of deer management on the US Forest Service's Kaibab Plateau, see: Christian C. Young, "Defining the Range, *Journal of the History of Biology* 1998. For general survey of scientific management within the US Forest Service, see: Paul Sutter, "'A Blank Spot on the Map': Aldo Leopold, Wilderness, and U.S. Forest Service Recreation Policy, 1902 – 1924," *Western Historical Quarterly* 29 (Summer 1998), 187 – 214.

14 Donald Worster, *Nature's Economy,* 314.

also fought for funding from the new AEC. They gained both, but only in fits and starts. Still, by 1954, they had shown themselves useful enough to the atomic project they seemed the best experts to address the fallout from Castle Bravo.[15]

Second, I look at how the biological practices that the AFL biologists used in response to the disaster, between 1954 and 1957, simplified environmental processes so that their data pointed to what they considered safe radiation levels in the food cycle. Simplification as scientific strategy came out of the biologists' also cultural milieu. Like the notion of scientific management, simplifying complex problems just made sense to the Seattle biologists. They lived in an era of scientific standardization. Donaldson spent his graduate study working with standardized hatchery salmon. Karen Rader has shown the value of model organisms in *Making Mice* and Robert Kohler's *Lords of the Fly* points to the value of simplified organisms for the production of knowledge within specialized scientific networks.[16] Soraya de Chadarevian has shown the virtue of simplifying complex biotic units into manageable images by means of x-ray crystallography.[17] Across the disciplines, mid-20th-century scientists believed in using technology to simplify complex questions in order to address them. The AFL biologists' use of electronic radiation meters and the process of ashing to reduce entire environments to radiation measurements put them solidly in this tradition.

But reductionism was not the only means of simplification that the biologists took advantage of. In radiological circles, simplifying radiological dangers took a disastrous turn early in the 20th century.

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15 Donaldson Castle Notebook, 21 March, Box 11, Folder 13, MSS Donaldson.

16 For canonical stories about experimental animals, see: Karen Rader, *Making Mice,* 2004 and Robert Kohler, *Lords of the* Fly, 1994.

17 See: Soraya de Chadarevian, *Designs for Life: Molecular Biology after World War II* (Cambridge: Cambridge University Press, 2002).

The idea of the tolerance dose, a metric for defining safe exposure, is central to this story. The tolerance dose tried to quantify how much radiation exposure a person could safely experience.[18] This standard lumped exposure to all kinds of waves, particles, and radioactive atoms together. It also gave credence to the idea that exposure below some threshold could be safe. Not all scientists adopted this view, especially geneticists who argued that any radiation exposure could harm the genome.[19] In 1946 the tolerance dose gave way to the maximum permissible dose, which in theory acknowledged that no exposure could be safe.[20] But Donaldson and the Seattle biologists built their entire research program around identifying thresholds for safe exposure. They really believed that exposure to radiation under certain thresholds was safe.

Third, I show cracks and tensions in the AFL's science program after repatriation, when they had to interact with Rongelapese actors at their home atoll. The biologists' inability to observe the intricacies of nature, food, and lifeways in a foreign land hobbled investigations of the radiation at Rongelap. Their eleven years of radiological research made them experts in the eyes of mainland authorities, in the eyes of the (almost exclusively) men who had built and used the atomic bomb. But the biologists from the mainland never saw the Rongelapese environment like Eknilang or Nerje Joseph could. The latter benefitted from generations of knowledge about the land, the sea, and the biota of their homeland. The former, amid their urge to simplify, missed the complexity of land, sea, and life at the atoll. Given their impediment, Lorraine Daston might describe their inability of observe the

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18 For the contested bureaucratic and transnational history of these doses, see: Linda M. Richards, "1945–1964 WHO's Right to Health?," *N.T.M.* 30, no. 2 (June, 2022), 137–165. https://doi.org/10.1007/s00048-022-00333-y.

19 For an example of a genetics researcher opposed to any radiation exposure from fallout, see: Herman Muller, "The Problem of Genetic Modification" in *Studies in Genetics: The Selected Papers of H.J. Muller* (Bloomington: Indiana University Press, 1962), 256.

20 J. Samuel Walker, *Permissible Dose,* 11.

Rongelapese environment in terms of flawed ontology, which "is about how scientists furnish the universe with objects that are amenable to sustained and probing investigation but that rarely correspond to the objects of everyday perception."[21] The biologists saw unsafe tissue in *Birgus latro*, the coconut crab, while the islanders saw a delicacy that had sustained their ancestors for generations in *barulep*. In the years after repatriation, the crab as scientific object failed to resonate with the crab as object of everyday life. Discord between the biologists and the Rongelapese, and finally sickness, ensued.

This chapter tells the story of how, after Castle Bravo, the bureaucrats in charge of the AEC, Joint Task Force Seven, and the Trust Territory of the Pacific needed science to redeem Rongelap from the fallout that poisoned Lijon Eknilang, Nerje Joseph, their community, their food sources and their entire atoll. The Rongelapese had to return home so that the US could keep testing thermonuclear bombs in the Marshall Islands. The islands were a national resource after all, and their management needed to seem first-rate. The AFL biologists got caught up in this project. Ted Porter has argued that "quantification is a way of making decisions without seeming to decide."[22] The AFL biologists quantified the Rongelapese environment to the nth degree between 1954 and 1957. The numbers they produced all assumed that the Rongelapese would be exposed to a tolerable dose of radiation based on US standards. Their ability to quantify the environment lent expertise to the Trust Territory and the AEC's decision to send the exiles home. But the Rongelapese quickly learned truths the experts never seemed to understand. Sickness occurred even when the numbers said it should not have. In 1985, after generations of suffering, the Rongelapese re-exiled themselves in search of health. They left their

21 Lorraine Daston, "On Scientific Observation," *Isis* 99, no. 1 (March, 2008), 97–110.

22 Theodore Porter, *Trust in Numbers*, 8.

diseased island, and the legacies of the science that failed them, aboard the Greenpeace vessel *Rainbow Warrior*.

Access and the Path to Expertise in the Marshalls

Transforming Bikini, Enewetak, and eventually Rongelap atolls into a new type of national asset, the atomic proving ground, required the work of scientists to manage the atolls for the sole purpose of atmospheric nuclear testing. Privileged access to the Proving Grounds based on their history in the MED Medical Section allowed the AFL biologists to become the site's radiological experts. The biologists came to the Marshalls in the summer of 1946 with laboratory expertise on the biological effects of radiation. They had established a successful x-ray salmon laboratory program in 1943 that provided Stafford Warren's Medical Section with data useful for understanding radiation injury in human beings. Their spin-off lab at Hanford gave the cohort of fisheries biologists access to knowledge created by studying the biological effects of radioisotopes created by fission inside the world's first plutonium production reactors. During Crossroads, they began to mold their research program for the sake of studying irradiated landscapes. In the eight years after Crossroads, the AFL expanded their studies across the unique context of the Marshall Islands. Doing so, they shored up an expertise that existed in the domain of science, but that also relied upon the bureaucratic realities that governed the day to day reality in the Cold War era Marshalls.

A place-based interpretation of the Seattle biologists' expertise forms the foundation of this chapter. Thinking about expertise in terms of place is no new idea. Looking at historians of science in the year 2000, Robert Kohler wrote that "place is routinely used to enrich historical accounts..."[23] Four

23 Robert Kohler, "Practice and Place in Twentieth-Century Field Biology: A Comment," in "20th Century Field Biology," special issues, *Journal of the History of Biology* 45, no. 4, (Winter 2012), 579-586.

years later, Jim Secord famously cautioned historians of science to avoid "unconceptualized geographical… boundaries," a tacit acknowledgment of place's role in microhistories and focused sociologies of science.[24] Still four years later, Diarmid Finnegan, in his survey of the spatial turn within the discipline, claimed a central role for place in the production of knowledge. "Approached as a set of coordinated practical activities science can be described [as] a situated and social enterprise."[25] This chapter addresses questions about what scientific expertise situated in a unique and practically irreproducible place looks like. I suggest that environmentally situated knowledge feels much like tacit knowledge, the intuitive knowledge that comes from familiarity with a practice.[26] In this case, the intuitive knowledge comes from familiarity with a place. A riff on Michael Collins and Robert Evans's observation that "'enculturation' is the only way to master an expertise which is deeply laden with tacit knowledge because it is only through common practice with others that the rules that cannot be written down can come to be understood" may help here.[27] A place-based perspective argues not for learning based on social dynamics but based on being surrounded by an increasingly familiar and recognizable environment. For the AFL biologists, we might say that being embedded was the only way to master an expertise which was deeply laden with situated knowledge because it was only through localized practices in a particular environment that the rules which did not apply elsewhere came to be understood.

24 See: Secord, "Knowledge in Transit," *Isis,* 2004.

25 Diarmid Finnegan, "The Spatial Turn: Geographical Approaches in the History of Science," *Journal of the History of Biology* 41, No. 2 (Summer, 2008), 369-388.

26 See: Harry Collins, *Tacit and Explicit Knowledge* (Chicago: University of Chicago Press, 2010).

27 Harry Collins and Robert Evans, *Rethinking Expertise* (Chicago: University of Chicago Press, 2007).

Treating the AFL biologists' expertise as situated within a highly regulated federal space makes access a key part of the production of scientific knowledge. The AFL biologist worried very much about their access to the Proving Grounds and about their bureaucratic standing within the federal atomic regime. They worked to open up the bureaucratic channels that won them access to Bikini, Enewetak, and other atolls in the Marshalls. They fought to win funding for their field excursions. They reported data in ways that proved useful to the atomic bureaucrats on the mainland. To account for these dynamics, this first part of this chapter looks at the lab's efforts to gain standing in the new Atomic Energy Commission, the quasi-civilian organization that replaced the army's Manhattan Engineer District as the main arbiter of all things atomic in the US at the end of 1946. The story then moves on to the series of field excursions that lab made during the late 1940s and early 1950s, highlighting the biologists' increasing insinuation into the Proving Grounds' routine operation. This first section ends as they applied their situated expertise to the Castle Bravo problem in the spring of 1954.

The story of the AFL biologists' ascent to expertise in the Marshalls began when they returned to Seattle in August 1946 after Operation Crossroads. Both they and their Medical Section patron, Stafford Warren, enjoyed the satisfaction of a job well done during the tests. Warren had helped convince Admiral William Blandy, leader of Joint Task Force One and head of Operation Crossroads, to abandon Bikini earlier than scheduled. The whole atoll had become dangerously radioactive after the underwater detonation, Shot Baker, had covered the landscape in hot fission products. Radioautographs, images created by exposing film to a radioactive specimen, produced by the AFL biologists helped Warren direct Blandy's opinion.[28] The lab's science proved useful for protecting, in

28 Hacker, *The Dragon's Tail,* 141 – 143.

some small way, the lives of US servicemen involved in the operation.[29] Beyond proving their usefulness for the site's management, the biologists had collected thousands of marine specimens that they took back to their lab in Seattle for examination. Moreover, the biologists stood ready at the end of 1946 to publish their wartime x-ray research from the home lab itself. The lab anticipated another boon as well. Warren had left his job at the University of Rochester and taken up the first deanship of the new medical school at the University of California, Los Angeles in early 1947. There he would build the new faculty around sister laboratory for the AFL, the new UCLA Atomic Energy Project.[30]

Yet, the future of AFL's work seemed uncertain as the MED passed away and the new AEC began operations on account of the Atomic Energy Act of 1946. In November 1946, Donaldson wrote to Warren asking his superior to clarify what the new relationship between Seattle lab and the field lab at Hanford because of the reorganization. "Can you redefine our position" Donaldson pleaded, "or suggest some one who can give us our exact responsibilities."[31] General Electric took over the administration of Hanford from DuPont, so the Fish Lab got caught up in an administrative shuffle. When the dust settled, the Seattle and Hanford labs existed as something like siblings, with Donaldson a contractor at the Hanford site. Further changes ensued. At a conference on 13 January 1947, representatives from the Army Corps of Engineers told Donaldson, Welander, and Dick Foster that

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29 Of course, many servicemen did become sick and suffer from long-term effects of radiation exposure. See: Robert Stone, *Radio Bikini,* aired 10 June 1988, on PBS, https://www.youtube.com/watch?v=IVwzhGtzDuI&list=PLJyCw4Nlz8grvJq7VuX64XC5mmwo7IwOo&index=1&t=531s.

30 Stafford Warren to Robert Buettner, 8 October 1947, Box 30, Folder 600, School of Medicine. Office of the Dean. Administrative files of Stafford L. Warren (University Archives Record Series 300). UCLA Library Special Collections, University Archives.

31 Lauren Donaldson to Stafford Warren, 20 November 1946, Box 3, Folder 23, UWLRB.

operations at Bikini were "pretty much at a standstill – no further action."[32] Undeterred, Donaldson wrote to Warren on 28 January suggesting studies that the lab could conduct at Bikini to follow up on their work during Crossroads. "From our previous experience and the exploratory experiments we have conducted, it would seem the work could be directed toward very practical ends and contribute to the over all understanding of the problems [of radiation at Bikini]."[33] Donaldson went on to unfold how his lab could help chip away at the very practical problems of how radiation from the two Crossroads shots might behave over time.

The letter landed on Warren's desk at a sensitive time precisely because of the uncertainty about the future of biological research within the AEC. In the formative moments of the new civilian Commission, the physicists and engineers claimed pride of place. They comprised the Commission's General Advisory Committee, led famously by J. Robert Oppenheimer. In the meantime, no such committee existed for the biologists and doctors who had been in the MED. Carroll Wilson, the first general manager of the AEC, asked Warren to chair a meeting of the defunct Army advisory committee on biology and medicine on 23 January 1947.[34] Warren managed to steer the ad hoc committee to recommend $5.9 million in funding for the fifteen laboratories whose biological and medical research programs had begun under the MED.[35] This included the AFL. Still, the official Division of Biology and Medicine did not come into being until October 1947, with Dr. Shields Warren, no relation to Stafford, at its head. A hospital pathologist, Shields saw little value in the old Medical Section's preoccupation with environmental questions. Stafford Warren actively disliked the new boss.

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32 Conference in Seattle, 13 January 1947, Box 13, Folder 25, UWLRB.

33 Lauren Donaldson to Stafford Warren, 28 January 1947, Box 6, Folder 4, UWLRB.

34 Hewlett and Duncan, *Atomic Shield*, 113.

35 Ibid.

Nevertheless, the AFL, the Hanford Fish Lab, and Stafford's new lab at UCLA were all funded through the new Division for fiscal year 1948.

As the bureaucratic future of biology within the new AEC slowly took shape in 1947, so did the plan for continued research at Bikini Atoll. A return to the atoll began to take shape in the autumn of 1946 under the auspices of the Department of the Navy, not the new AEC. The summer field trip would be officially called the Bikini Scientific Resurvey and would be significantly smaller in scale than Operation Crossroads.[36] No new atomic bombs would be detonated. Instead, a cohort of biological and earth scientists would return to Bikini to investigate what the environment looked like a year after the two detonations in 1946. Roger Revelle, the great oceanographer who steered the University of California, San Diego in its early days, organized the resurvey in his capacity as a naval Commander. Officially, the Resurvey did not come into existence until 16 may 1947, though planning began before then.[37] Stafford Warren had no part in planning the Resurvey, but he had served with Revelle during Crossroads and managed to make sure that Donaldson, Foster, Welander, and eight other scientists affiliated with the AFL would return to Bikini as the Resurvey's Radiobiology Group.[38] Donaldson began to plan for the trip in late April 1947.[39]

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36 Bikini Scientific Resurvey: Technical Report, Armed Forces Special Weapons Project, December 1947, Box 11, Folder 1, MSS Donaldson.

37 Ibid.

38 Ibid.

39 Lauren Donaldson to Admiral William Parsons, 3 May 1947, Box 6, Folder 4, UWLRB.

Figure 5.2. Collecting fish after spreading the poison rotenone. Source: Bikini Scientific Resurvey: Technical Report, Figure 41. University of Washington Libraries, Special Collections. Lauren R. Donaldson papers. Accession no. 2392-0007. Republished with permission of University of Washington Libraries.

The Resurvey existed as something of a liminal moment for the Seattle biologists, they fit into a military operation even as they lurched into the civilian future of the federal atomic project. The AFL biologists thrived during the Resurvey, even though they had only cramped laboratory quarters aboard the USS *Chilton.* About 50 other scientists traveled with them across the Pacific to Bikini. Even though space was tight, they managed to organize their lab and hit the ground running when they arrived at the familiar atoll in mid-July. On the 16th of the month, they collected 169 marine specimens by poisoning a shallow reef with Rotenone, a practice they developed during Crossroads. By 15 August they had collected a total of 5883 specimens of which they preserved 5148 for study in the Seattle lab. The remainder they counted aboard ship in their small lab. The summer field trip proved a great success scientifically and in terms of the lab's standing within the AEC.

Having returned from the 1947 Resurvey, the Seattle biologist faced a new administrative reality as the new Commission took shape. Though the Navy would remain an important agency in the Marshalls, particularly since they would continue to provide transportation in the far-off territory, the service would never again organize a summer field trip like the Resurvey. Access to Bikini would have to run through the Washington D.C. headquarters of the AEC. Donaldson, whose political and administrative experiences with Washington State agencies and with the joint Canadian-US International Pacific Salmon Commission, felt ill at ease dealing with eastern bureaucrats like Shields Warren. But he felt pressure to win funding from the new Division of Biology and Medicine for continued researches at the home lab, on the Columbia, and at Bikini. He felt this pressure in part because the Lab's funding contract with the Division of Biology and Medicine was meant to expire in July 1948, even though its long-term projects would occupy the biologists through 1950.[40] In March '48, the lab did not yet feel a money crunch since $83,308 still sat in its accounts, but it would if the contract were not extended.

At the end of 1947 and into 1948, the problem of access to the Marshalls revolved around the prospect of renewed atmospheric nuclear testing in the territory. Operation Sandstone, which would involve three shots, had been scheduled for April and May 1948. The AEC and Joint Task Force Seven selected not Bikini but neighboring Enewetak Atoll for the tests. The AEC had chosen Enewetak as its long-term test site, to be called the Pacific Proving Ground. The AFL biologists found themselves confronting a whole new atoll and a whole new administrative landscape in the Pacific.

Donaldson had applied to the Division of Biology and Medicine for permission to conduct a summer field trip to Bikini in 1948, but planning for Sandstone made it so he receive no official response to his proposal in the first months of the year. No doubt he pled his case to return to Bikini at

40 Memo: Subjects for Discussion with Dr. Shields Warren, 27 April 1948, Box 1, Folder 34, UWLRB.

a two-day meeting for the Division of Biology and Medicine at Oak Ridge National Laboratory in late March 1948. Present were a who's who of biologists and medical men working at labs and universities affiliated with the AEC. Among them were Hymer Friedell, whom Donaldson knew from the war years, and Harry Kornberg, Dick Foster's supervisor at Hanford.[41] Most importantly, Lewis Strauss was present. An influential member of the Commission, Donaldson could have spoken directly with him about going to Bikini in the summer. Present also was the mercurial geneticist Herman Muller, who gave a talk on "Some Present Problems in the Genetic Effects of Radiation."[42] The program was stacked with geneticists, reflecting Oak Ridge's research emphasis. Donaldson, a field researcher as much as he was a laboratory physiologist, found himself in the minority at the conference. At any rate, Donaldson left the meeting with no news on his proposed summer trip to Bikini at the meeting.

Instead, Donaldson found out at the very last minute that he would attend Sandstone as an observer. He travelled by plane from Hickam Field in California across the ocean to Kwajalein Atoll, the hub of US military activity in the Marshalls.[43] From there he caught a flight to Enewetak, where the pilot flew all around the atoll, giving Donaldson a bird's eye view of the landscape he would come to know as intimately as he knew Bikini. He arrived a few days before the last shot of the operation, codenamed Zebra, which was detonated on 15 May 1948. Though he had not official role within Joint Task Force Seven, Donaldson did manage to organize a collecting trip. He hastily recruited three other scientists and found transportation to Runit Island the day after the shot. He managed to bring home

41 Information Meeting for Biology and Medicine Sponsored by the Biology Division of Oak Ridge National Laboratory, 26 and 27 March 1948, Box 13, Folder 25, UWLRB.

42 Ibid.

43 Sandstone Notebook, 11 May 1948, Box 11, Folder 8, MSS Donaldson.

188 tissue samples preserved in formalin in his personal luggage.[44] The team back at the Seattle lab took counts on the specimens when Donaldson returned home in the last week of May. His Sandstone experience indicated the fragility of the lab's access to the Marshalls. Donaldson managed to be present for one shot but did not manage to make his team of biologists a part of the official scientific apparatus of the operation.

If the AFL's incidental participation in Operation Sandstone marked something of a low point for their ability to get to the Marshalls, then the summers of 1948 and 1949 marked high points because the lab did manage to run a lengthy field trip during each of those summers. In their proposal to the Division of Biology and Medicine for the 1948 field trip, the biologists argued that "Biological studies are of necessity long-time, complex projects. The Bikini biological studies are so very complicated that only through continuous, long-time effort can we hope to understand the basic principles involved."[45] The biologists made a clear argument, they needed not just access, but continuous access to the atomic atolls for their research. Of course, a four- or five-week summer field trip scarcely constituted continuous observation. But with the right resources, a month in the field would allow the biologists to make significant sample collections and would allow them to get to know the two atomic atolls even more intimately. Fortunately for the lab, Biology and Medicine looked on the project with favor and offered the lab continued funding under their already existing contract. As it turned out, the biologists managed to spend nearly all of July 1948 at Bikini and Enewetak atolls. In 1949 they visited Bikini, Enewetak, and Likiep atolls from 19 July to 31 August. Likiep, a populous atoll to the east of Bikini,

44 Hines, *Proving Ground*, 89.

45 Preliminary Outline of a Program for the Second Radiobiological Resurvey of Bikini Atoll during the Summer of 1948 to be sponsored by the Atomic Energy Commission and the US Navy, Box 8, Folder 6, UWLRB.

offered the biologists the opportunity to collect marine specimens for something of a control population since the atoll had not been used for atomic testing.

The biologists' familiarity with the two atomic atolls had grown because of the time they spent traversing the atolls' islands and lagoons. A quip Donaldson made during a speech at the UCLA Atomic Energy Project hammered the point home. In the midst of describing experiments to measure radiation levels in microscopic hydrozoans, he said that "my wife says I call 'Bikini' home because I spend most of my time there."[46] Perhaps Donaldson included the passing remark as just that, a chance to lighten the mood of his talk about radiation and mortality in marine organisms. But I suspect that it speaks to the crux of doing situated science. His wife's observation that he valued Bikini as his real home points to the process of becoming so familiar with a place that the boundaries between research and home life start to crumble. Perhaps more telling, however, was the scientific context in which Donaldson related his wife's remark. He was describing the ability of hydrozoans in Bikini lagoon to accumulate, or biomagnify in today's terms, radioactivity. Radioactive organisms on the hulls of ships had been one of the reasons for abandoning Operation Crossroads in 1946. During the 1947 Resurvey, Donaldson's team had collected samples of hydrozoans from the hull of the USS *Chilton,* their small wartime-transport-turned-research-vessel. During the 1948 field season the biologists "repeated the experiment, only with much better coverage" because they used rigs attached to stationary buoys for collecting hydrozoans and algae. They would use the same practice in 1949. The progress of the experiment, from haphazard sample collection from the hull of a ship to a purposefully designed, multi-week collection points to the importance of a deep familiarity with the place.

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46 Speech by Dr. Lauren Donaldson, School of Fisheries, University of Washington, Seattle, Washington; Director AEP on Marine Biology, and Bikini Survey Party, 11 August 1948, Box 13, Folder 10, UWLRB.

Though the biologists won funding from the AEC and access to the Marshalls for the 1948 and 1949 field seasons, they had to fight to do so. Their position at the Proving Grounds was not guaranteed. For the 1949 field season, no one from the Division of Biology and Medicine informed the prime contractor at the site that the biologists were coming. A bewildered Kelly McBean, who ran operations for the Los Angeles engineering and infrastructure firm Holmes & Narver that oversaw the new Proving Ground, wondered who Donaldson and his team were in May 1949. He expressed regret in a phone conversation with one of his subordinates:

> Mr. McBean: I have observed info copies regarding the Donaldson survey.
> Mr. Miller: Yes—what is all of this about—do you know?
> Mr. McBean: I have no idea, but I was just going to suggest that if this is going to impose any burden on the guest facilities, that we better alert them on it.[47]

There was no room at the inn on Parry Island, the major scientific facility at Enewetak Atoll, for the summer of 1949. The biologists spent the field trip largely boarding on the LSI (L) 1091, the 160-foot-long wartime landing craft that had seen action at Iwo Jima which then housed their quarters and cramped laboratory. They made the situation work, but the biologists would have preferred more hospitable quarters on land.

In order to strengthen the lab's claim to field access in the Marshalls, Donaldson appealed to Sheilds Warren, head of Biology and Medicine, routinely during 1948 and 1949. Most importantly he sought to carve out something of an independent radiobiology unit within Biology and Medicine that included the AFL, the Hanford Fish Lab and the new UCLA Atomic Energy Project. The three labs, beyond sharing a genealogy in the old Medical Section, all worked on "unusual research problems."[48]

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47 Telephone Call from Herb Miller to Kelly McBean—5/20/49, Box 1, Folder 5, Records Group 326, #126477, Program Files Relating to the Development of Enewetak Atoll 1949-1951, National Archives and Records Administration, Riverside, California (Hereafter cited as H&N Program Files).

48 Lauren Donaldson to Shields Warren, 19 March 1948, Box 1, Folder 34, UWLRB.

To this end he asked if an arrangement between his lab, Dick Foster's lab, and Stafford Warren's new lab could "be compatible with your administrative procedures?"[49] Shields replied that it would be.[50] In turn Allyn Seymour, one of Donaldson's biologists, worked with Kermit Larson, on staff at UCLA to test water samples from the 1949 field trip.[51] The two labs would collaborate more and more in the 1950s, as the UCLA lab borrowed biologists from Seattle for radiobiological studies at the new Nevada Test Site.[52] Edward Held, who we shall see became central to the story of Castle Bravo, spent the 1952 field season with the UCLA lab in Nevada to study the effects of the atomic tests during Operation Tumbler-Snapper.[53]

Donaldson worked to create this informal radiobiological network because he believed that a larger network of scientist would strengthen all the labs' claims for access to the field. The UCLA lab under Stafford Warren initially struggled to gain access to Alamogordo, site of the very first atomic test in July 1945. The former chief of the Medical Section was convinced that Shields Warren did not want a microbiological study of the Alamogordo site, because of its proximity to population centers and active ranches. Funding had been denied for a survey in 1947 from the AEC so Stafford used University of California money to fund the first field trip to the site.[54] Of course, access to Hanford had never been a problem because Dick Foster, Donaldson's protege, worked for General Electric. The company oversaw the entire site and needed no permission from the AEC in Washington for research

49 Ibid.

50 Shields Warren to Lauren Donaldson, 25 March 1948, Box 1 Folder 34, UWLRB.

51 Allyn Seymour to Kermit Larson, 2 June 1949, Box 1, Folder 27, UWLRB.

52 Frank Lowman to AFL Staff, 2 February 1952, Box 7, Folder 20, UWLRB.

53 Allyn Seymour to Kenneth Englund, 17 April 1952, Box 2, Folder 21, UWLRB.

54 Adelaide Tusler, *An exceptional man for exceptional challenges: Stafford L. Warren* (Los Angeles: Regents of the University of California, 1983), 1089.

decisions. As we saw in chapter three, the biological establishment at Hanford occasionally challenged AEC headquarters like they did over the Columbia River Survey in the late 1940s. At any rate, by 1949, Stafford Warren's right hand man at UCLA, Andrew Dowdy, had formed a Subcommittee on Evaluation of Long-Term Effects of Acute and Intermittent Ionizing Radiations.[55] The group would advocate to the Division of Biology and Medicine for the AFL and the UCLA AEP as they sought field access to the Marshalls and Alamogordo.

Despite this organizing, the AFL would not return to the Marshalls between the 1949 field season and the 1952 season because of the Korean War. The Navy found itself simply stretched to thin to provide logistical support for non-essential work in the Marshalls while its attention was focused on the conflict with North Korea and China. A test series did take place at Enewetak in 1951, Operation Greenhouse. This series of four shots tested technologies that would be employed in the first truly thermonuclear devices built by the US. Atomic bombs relied on the fission, or breaking apart of heavy elements, to produce their vast energy. Thermonuclear bombs would use a fission blast to then produce a fusion reaction, or the slamming together of light elements in heavier ones. Based on the massive energy release from fusion, the same process that fuels the sun, thermonuclear bombs would create blasts many orders of magnitude larger than atomic bombs. Of course, the AFL biologists had no idea what the biological effects of a fusion bomb might be. Nor did they speculate on this possibility as they stayed in their home lab during the 1950 and 1951 field seasons. Instead, they continued their x-ray salmon researches and worked up data from their 1949 field trip. They also sent team members to do work at Hanford and in Nevada. Finally, they submitted plans to Biology and Medicine for their proposed continued research at Bikini and Enewetak once the conflict in Korea ended and they could return to the Marshalls.

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55 Andrew Dowdy to Lauren Donaldson, 14 June 1949, Box 7, Folder 19, UWLRB.

The AFL biologists returned to the Pacific Proving Grounds with a howl in 1952 because they took part in Operation Ivy, the first thermonuclear tests the world had ever seen. They got back because of global political contingencies. Though the Korean War dragged on, armistice talks had commenced. But more importantly, the Soviet Union detonated its first atomic bombs in 1949 and 1951. The largest of the tests yielded forces four times the size of the bomb that fell on Hiroshima. In order to stay ahead of the Soviets, President Truman had given the green light to the development of the thermonuclear bomb at Los Alamos.[56] The AFL biologists experienced a test on a scale they had never seen before when they witnessed shot Mike during Operation Ivy on 1 November 1952. They had arrived at Enewetak in late October to collect pre-shot baseline specimens.[57] Because of the anticipated scale and force of the bomb, one of their main jobs was to take samples showing the extent of radioactive contamination after the shot. They also researched any potentially new radionuclides produced by the thermonuclear blast that might insinuate themselves into Enewetak's flora and fauna.

The advent of thermonuclear testing in order to maintain nuclear supremacy over the Soviets helped integrate the AFL biologists into the essential workings of the Pacific Proving Grounds. The AEC bureaucrats in Washington D.C. found a new urgency for biological research as Operation Ivy wrapped up in late 1952 and plans for 1954's Operation Castle got off the ground. This urgency resulted in the creation of the Eniwetok Marine Biological Laboratory.[58] Holmes & Narver, still the prime contractor at the Proving Grounds, would build the lab on Parry Island at the southeast corner of

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56 See: Richard Rhodes, *Dark Sun: The Making of the Hydrogen Bomb* (New York: Simon and Schuster, 1995).

57 UWFL-33, "Radiobiological Studies at Eniwetok Atoll before and following the Mike Shot of the November 1952 Testing Program," Box 9, Volume 5, 10 June 1953, UWLRB.

58 The normative spelling is Enewetak. For the sake of fidelity to historical sources, the antiquated American spelling, Eniwetok, appears occasionally.

Enewetak's atoll. The lab accounted for only a small fraction of the $22 million that the AEC "budgeted for the engineering and construction of the added base and scientific facilities" being built in anticipation of Operation Castle.[59] The new field laboratory would serve a consortium of biologists, including teams sponsored by both the Office of Naval Research and the AEC's Division of Biology and Medicine. Robert Hiatt from the University of Hawai'i would direct the lab.[60] Though the Seattle biologists would only be one team using the space, Willis Boss, the point man for the project from Biology and Medicine, conferred with Donaldson on the design of the lab facilities. Boss felt Donaldson's expertise on biological research in the Marshalls commended him for the task. Donaldson, gleeful that his team finally would have a proper, permanent field laboratory at the Proving Grounds responded to Boss that, "after some of the patched-up and makeshift arrangements we have experienced in the past operations in the Pacific testing grounds, the present arrangement seems almost too good to be true."[61] The AFL finally solidified their privileged access to the atomic atolls based on their expertise.

Because they had access to the new lab for Operation Castle, Donaldson and his team embarked on their first truly long-term study of radiation in the environment at the Proving Grounds in 1954. They planned a full year study of radiation's movement around Enewetak and Bikini that involved being at the site during the springtime tests in 1954 and returning with teams of four to five men for quarterly surveys. Unlike their previous forays, which "lacked continuity and must be considered as

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59 Task Group 7.5 Historical Installment No. 1 of Operation Castle, 6 November 1953, 9, Box 1, Folder Castle, Operation—TG 7.5 Historical Installment #1 & 2 1953-4, Record Group 326, # 1361627, Project Files of Holmes and Narver, National Archives and Records Administration, Riverside, California.

60 Willis Boss to Lauren Donaldson, 19 November 1953, Box 7, Folder 14, UWLRB.

61 Lauren Donaldson to Wills Boss, 5 January 1954, Box 7, Folder 14, UWLRB.

only selected, partially complete investigations," the study attending Operation Castle would allow them to trace a full year of radiation's movement throughout the environment.[62] They planned to do so systematically, using aerial photography to determine the placement of transect lines across Aaraanbiru and Aitsu islands at Enewetak atoll. The transects would pass through the islands' sundry terrestrial and marine environments. Using them as guides, the biologists could collect specimens and take soil and water samples that would give them a comprehensive view of how radiation moved through all the ecological niches and communities at the atoll.

So it went that two AFL biologists were already on Parry Island preparing for their study of Enewetak when Castle Bravo sent snow-like fallout over Rongelap Atoll. The physicists at Los Alamos bungled Castle Bravo's design so that the shot produced around three times the yield they had anticipated, equal to roughly the force of 15 million tons of TNT. The bomb produced over 1000 times the energy of the either of the devices used over Japan during the war. It evaporated the stretch of coral reef upon which it was detonated. After about 10 minutes, a lethal cloud of coral, seawater, and fission products stretched 65 miles across Enewetak.[63] Its blast reached 100,000 feet into the atmosphere, where strong winds bore it eastwards. Traveling around 100 miles, this fallout would cause the Rongelapese to suffer symptoms of the Atomic Bomb Disease.

Those who saw and heard the shot reacted to its apocalyptic scope, intuiting the extent of its force if not the totality of its radiological danger. Only two of the Seattle biologists had arrived at Enewetak for the shot. The botanist Ralph Palumbo and the marine zoologist Ed Held had been working to get the new laboratory on Parry Island set up. If either left a written account of their

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62 UWFL-36, "Operations Outline for Program 19, Marine Survey Unit, of Operation Castle," 15 February 1954, 5, Box 9, Volume 5, UWLRB.

63 Smith, *Domination and Resistance*, 50.

impressions of the blast, it did not make it into the AFL's archive. Many of the 80 or so people living on Rongelap Atoll did leave accounts of the blast even though they were far away from it. Etry Enos, a teenager at the time, "heard the explosions and saw the sky turn red… it was still dark and I saw the entire sky change colors… I was afraid."[64] Aruko Bobo, a child, had gone on an early morning trip with her father and siblings to purchase coffee and pantry items. "We were in the middle of the reef between the two islands when the whole of the western sky lit up. It seemed like it was afternoon, not early morning. The color went from bright white to deep red."[65] The people on Rongelap, as well as nearby Ailinginae, Ailuk, and Likiep atolls, uniformly reacted with fear to the unnatural sunrise in the western sky.

Downwind witnesses described the fallout that arrived on the wind later that afternoon. US sailors aboard the USS *Bairoko*, close to Bikini, encountered the fallout first. At 8 AM, just one and a quarter hours after the shot, their radiation monitors encountered dangerously high gamma levels on the aircraft carrier's flight deck.[66] Sailors used fire hoses to wash the decks and instituted a decontamination bath for those who had been exposed to the worst of the fallout. Carried past the *Bairoko* by the wind, the fallout from the obliterated coral reef next fell like snow at Rongelap. "Several hours later, the powder began to fall."[67] Aboard the Japanese fishing vessel, *Fukuryu Maru*, the Lucky Dragon, fallout also came down like snow, resulting in the death of one sailor and a crisis

64 Etry Enos in "Marshall Islands Field Report (March 4 – April 7, 1981)," by Glenn Alcalay, New Brunswick, New Jersey. https://www.atomicatolls.org/_files/ugd/d75784_200481cd214242578eecb7dc3f932457.pdf

65 Aruko Bobo in Holly Barker, *Bravo for the Marshallese: Regaining Control in a Post-Nuclear, Post-Colonial World* (Belmont, California: Wadsworth, Cengage Learning, 2013), 51.

66 USS *Bairoko*, Radioactive Contamination, Summary of for Period 1- 8 March 1954, 11 March 1954, NV0410482, NTALV.

67 John Anjain in "Marshall Islands Field Report," 1981.

back on the Japanese home islands after the ship's catch was sold at market.[68] Ailinginae, an atoll to the south and west of Rongelap that was seasonally used for fishing and food collection, also experienced snow-like fallout. At Likiep and Ailuk atolls, further to the east of Rongelap and home to significant resident populations, the fallout did not come like snow but like a fine mist. "The atmosphere was foggy. It was like some dust falling from the sky on the lagoon and on the land."[69] Hundreds of Marshallese, Japanese, and Americans faced exposure to lethal or significantly dangerous levels of radiation from Bravo's fallout. By the time the Navy transport ship came to evacuate Rongelap two days after the shot, many residents were vomiting and losing their hair. They travelled to Kwajelein atoll, where they would be scrutinized by doctors from the Atomic Energy Commission's Division of Biology and Medicine.[70]

In the meantime, the bureaucrats in charge of Biology and Medicine, Joint Task Force Seven, and the Trust Territory of the Pacific responded to the fallout problem by calling on their biological experts to assess Rongelap itself. It was the AFL biologists' time to shine. The effort to get scientific boots on the ground took three full weeks after the shot because of logistical holdups. On 21 March, Paul Pearson, from the Division of Biology and Medicine, contacted Donaldson "with a request for some opinion of the feasibility of a trip to Rongerich [sic] to have a look at the food supply that was possibly contaminated by the fallout..."[71] Pearson, not familiar with Marshallese geography, mistook Rongerik for Rongelap in the message. Donaldson, who had arrived with two other biologists from the

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68 See: Hamblin and Richards, "Beyond the Lucky Dragon, 2015.

69 Lontak Jili in *Bravo for the Marshallese*, 53.

70 See chapter three, "US Nuclear Tests, the Environment, and Medical Research: Case Studies of the Rongelapese and Utirikese," in Smith, *Domination and Resistance,* 75 – 102.

71 Donaldson Castle Notebook, 21 March, Box 11, Folder 13, MSS Donaldson.

AFL on 18 March, obliged Pearson and agreed to join the effort that would work out the effects of Castle's fallout. A naval transport ferried the AFL team from Parry Island to Rongelap on 26 March 1954.

The AFL biologists' path to expertise that made them integral to the Castle Bravo response relied on the privileged access to the atomic atolls that afforded them nearly a decade of research in the Marshalls. They spent those years developing a suite of situated practices based on the unique irradiated environments found at Bikini, Enewetak, and later Rongelap. Creating their place-based program required as much administrative work as it did scientific research. The years between 1946 and 1954 saw the lab's biologists become more and more integrated into the funding apparatus of the Division of Biology and Medicine. On the eve of the Castle Bravo fallout disaster, Donaldson and the AFL biologists had shown that they were company men, that their biology would serve the goals enunciated by Washington D.C. bureaucrats. In the wake of the disaster, they continued to build their claim that only they, as the ones who really knew the land and sea, should be able to speak for the sake of the AEC about the radiobiological situation in the Marshalls. The next section of the chapter turns directly to the practices, and to the assumptions undergirding those practices, that the biologists used to produce data useful for the atomic bureaucrats who sought to manage Rongelap from the US mainland.

The Disastrous Simplification of the Land

When the team of team of AFL biologists headed to the most radioactive islands in Rongelap Atoll on 26 March 1954 they faced a problem, how to best quantify the effects of radiation from Bravo's fallout. Since they had learned to use electronic radiation meters in 1946, they had trusted those devices to show them real time levels of environmental radiation. A meter held close to a piece of coral, or the branch of a shrub, could tell them how radioactive that object was in that moment. They took many meter readings on 26 March. Some of the readings were so high that Donaldson made sure his men were only on land for a short duration lest they be exposed to dangerous levels of radioactivity. But meter readings could only provide a limited snapshot of the radiological situation at Rongelap. The biologists needed biotic specimens that could show them how radionuclides moved through the land, sea, and the biota. Specimens that could show them radiation's behavior. But since the radiation danger was high, the biologists could only collect so many specimens on their first foray to atoll. In their hazard-induced frenzy, they began the tragic process of simplifying Rongelap, of using a manageable sample set to represent a massively complex environment.

The AFL biologists had, by 1954, become accustomed to two types of simplification within their research program. The first involved the specimens that they collected and the way that they then processed organ and tissue samples from those specimens. Here we turn to the processes of ashing and counting biotic samples as a way of quantifying the presence of radiation. The process essentialized living beings into their component carbon atoms and whatever radioactive particles they had ingested. Life's complexities became the lab's simplicities as bodies became uniform piles of ash. Transforming an irradiated animal or plant into an ashen sample required many steps, but was much less labor-intensive than the histological analysis that the biologists engaged in with their salmon stocks back in the Seattle and Hanford laboratories.[72] Ashing, on the other hand, produced uniform samples that could be analyzed by machine to show just how much radiation existed within the original biological sample.[73]

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72 For an overview and early history of histology, see chapter three, "Mechanical Objectivity" in *Objectivity,* Lorraine Daston and Peter Gallison (New York: Zone Books, 2007), 115 – 190.

73 See UWFL-7, Radiobiological Resurvey of Bikini Atoll During the Summer of 1947," December 1947, Box 9, Volume 2, UWLRB, for an accounting of the process.

The second sleight of hand that the biologists used to simplify the problem of radiation at Rongelap involved how they thought about counts, about the raw numbers they produced. In short, they thought in terms of tolerance thresholds. Exposure below some numerical threshold could be safe while exposure above that threshold would be dangerous and result in ill-health. Called the tolerance dose, the idea had existed since the early days of x-ray research. In 1934, the US Advisory Committee on X-Ray and Radium Protection set the limit for safe exposure at 0.1 Roentgens per day for the whole body or 5 Roentgens per day for the fingers. [74] But by the end of World War II, many biologists and geneticists pushed back on the idea that any exposure to radiation could be safe.[75] The new US National Committee on Radiation Protection replaced the tolerance dose with the maximum permissible dose, an exposure value that excluded the notion of any safe level of exposure. But the tolerance dose did not die, especially among the most committed biologists and doctors who had come into the AEC through the old Manhattan Engineer District.[76] Moreover, the US Public Health Service continued to publish information on tolerance doses into the 1950s.[77]

The AFL biologists believed in the tolerance threshold because of their laboratory salmon research. Since 1943, they could show a distinction both empirically and statistically between very low and very high exposure levels to x-rays. Low levels of x-ray exposure, around 100 Roentgens, created

74 Walker, *Permissible Dose*, 8.

75 Ibid., 10 – 11.

76 For an example of the Tolerance dose simply renamed, see: National Bureau of Standards, *Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water,* Handbook 52, 20 March 1953, 1. Ronald and Susan Katherine Radiological and Affiliated Sciences Collection, Washington State University Library, Richland, Washington.

77 See: Simon Kinsman, ed, *Radiological Health Handbook* (Cincinnati: U.S. Department of Health, Education, and Welfare, 1954).

no or very few deaths and deformities in salmon populations while high exposure levels, over 10,000 Roentgens, created significant mortality and deformity rates.[78] They took this distinction, between benign, low-level exposures and dangerous, high-level exposures with them into the field. When they encountered biotic populations with many living individuals and few deformities, they proceeded with the assumption that any exposure to radiation from the environment must have fallen under the threshold for safety.

The biologists made it their business to research how radiation at levels below a tolerance dose behaved in Marshallese environments populated with seemingly healthy individuals. To do this, they first tried to understand the decay of unstable radionuclides over time as they cast off energy and subatomic particles on a journey towards atomic stability. One of the main goals of their research in Enewetak and Rongelap involved figuring out just how radiation decayed within the bodies of living animals and within the sundry parts of both food and non-food plants. They called decay within an organism the rate of decline. In Ed Held's words, this was "the rate at which radioactivity is decreasing in a given tissue, organ, organism in its native environment."[79] Other biologists in the AEC, as well as those who consulted for the National Bureau of Standards, called this the biological half-life. This value stood in contrast to a radionuclides' physical half-life, or rate of decay, the rate at which radioactive isotopes naturally decayed into stable isotopes of an element. The rate of decline showed how a species ingested and metabolized radioactive elements. If the rate of decline decreased more slowly than the rate of decay, that datum showed that the species in question was able to accumulate radiation from the environment over time. These species the AFL biologists considered dangerous.

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78 See Chapter 1.

79 Ed Held, UWFL-50, "Land Crabs and Radioactive Fallout at Eniwetok Atoll," 27 May 1957, NV1616812, NTALV.

Fortunately, few species in the Marshalls had the ability to accumulate radiation. Radiation levels in most species decreased, moving even farther away from any tolerance threshold over time. No foodstuffs displayed accumulation. The species that did were very small and aquatic: algae, plankton, and very small hydrozoans, which are animals related to jellyfish. It was hydrozoans that Donaldson discussed in his UCLA lecture when he talked about the microscopic lifeforms that the lab collected year after year while they were at their home away from home.[80] No macroscopic animal nor any food animal or land plant accumulated radiation like plankton or hydrozoans. On the contrary, the AFL biologists expected to see decreases in the presence of radiation in the bulk of the Marshall's species over time. The second disastrous means of simplifying the radiological situation at Rongelap happened because the biologists assumed that the living organisms they collected and studied bore consistently decreasing amounts of radiation that fell far beneath any kind of threshold for danger.

How did these two means of simplifying the radiological situation at Rongelap unfold between Spring 1954 and the unfortunate repatriation of the Rongelapese to their home atoll in 1957? Hurriedly. The AFL biologists made their first collections at Rongelap on 26 March 1954. These were necessarily rushed because the radiation from Bravo's fallout was still exceptionally dangerous despite nearly four weeks having passed since the fallout disaster. The biologists returned to the heavily irradiated Kabelle and Labarje Islands on 16 July, 8 and 18 December 1954, and then for an extended collection trip between 5 – 30 January 1955.[81] In Autumn 1955 they took more samples between 21 – 23 October and

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80 UWFL-11, "Concentration of Active Materials by Hydroids in the Bikini Lagoon during the Summer of 1947," 9 April 1948, Box 9, Volume 1, UWLRB.

81 UWFL-42, "A Radiological Study of Rongelap Atoll, Marshall Islands, During 1954 – 1955," 15 August 1955, NV0513170, NTALV.

on 7 November.[82] These six collections gave the biologists the data from which they compiled the two foundational reports on radiation at Rongelap after Bravo. Over the same period of time, Art Welander made an exhaustive investigation of radiation in reef fish exposed to Bravo at Bogombogo Island in Enewetak.[83] Ed Held simultaneously investigated radioactivity in a species of land crabs, *Coenobita perlatus,* on Bogombogo.[84] Both these studies belonged to the lab's originally planned program for studying Operation Castle. Both also contributed to the lab's conclusions about the situation at Rongelap, since the biologists treated the two atolls as reasonably interchangeable. All four reports relied on ashing as their primary method of collecting data about radiation in the biota.

Trusting ashen samples to tell the story of Castle Bravo's radiation required the AFL biologists to first and foremost trust their radiation meters and counting devices. They did, ever since they had learned about the utility of electronic radiation meters during Operation Crossroads in 1946. So, when Donaldson, Ed Held, Ralph Palumbo, and visiting fisheries graduate student Paul Olson travelled to Rongelap for the first time on 26 March 1954 they did so with meters in hand. They used their Juno Survey Meter, a portable ion chamber unit designed at Hanford, to take measurements of gamma radiation and then a combination of alpha, beta, and gamma radiations across the two islands they visited.[85] Powered by eight heavy duty batteries, the meter relied on an ionization chamber. Decay products from Bravo's fallout, in the form of alpha and beta particles and gamma rays, passed through

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82 UWFL – 43, "Radiobiological Resurvey of Rongelap and Ailinginae Atolls, Marshall Islands October-November 1955," 30 December 1955, NV0410696, NTALV.

83 Arthur Welander, UWFL-49, "Radioactivity in the Reef Fishes of Belle Island Eniwetok Atoll April 1954 to November 1955," 17 May 1957, NV16381247, NTALV

84 Ed Held, UWFL-50, NTALV.

85 J.C. Eliot to Commander Task Group 7.3, Report of Rongelap Survey Trip, 25 – 26 March 1954, 28 March 1954, NV0125308, NTALV.

the air-filled chamber. As they made their journey, they stripped atoms of their electrons and produced a positive charge that then moved through a reasonably simple circuit after being amplified by a vacuum tube. The circuit transformed the charge into a reading on the analog meter, given in milliroentgens per hour. The biologists used the unit when they tabulated their measurements.

In the table they transformed Rongelap from a complex landscape made up of sand, coral, grass, rocks, and Pisonia shrubs turned into a homogenous terrain given texture only by disparate radiation values.

Radiation Levels Labaredj Island

March 26, 1954 - mr/hr

Location	Height 3'	Height 1"
Intertidal zone	26 31	
High tide line	215 395	300 1000
Open grass area on island	250 330	370 900
Open grass area on island	240 500	280 (6") 700 (6")
In Pisonia woods	270 700	600 1500
Beach rock slabs	37 100	29 400
Beach above high tide line north side of island	180 300	220 600
East side of island above high tide line	200 350	220 700

Figure 5.3. The Conversion of Labaredj Island into Milliroentgens, showing the utility of electronic radiation meters. Source: J.C. Eliot to Commander Task Group 7.3, Report of Rongelap Survey Trip, 25 – 26 March 1954, 28 March 1954, NV0125308, NTALV. Source is in the public domain.

Even as Donaldson and his small crew rushed to take radiation counts on 26 March 1954, they collected specimens that they could process at the new lab on Parry Island and then count back at the University of Washington. What did they grab as they tried to both get a comprehensive view of the landscape's radiological health and not get sick themselves? Their official report explained that even on their first visit to Rongelap "particular emphasis was placed upon evaluation of the radioactivity in food used by the natives."[86] These included coconuts and *Morinda citrifolia*, or *nin*, a plant used for medicine and occasionally food. Donaldson's field notebook from the day pointed to less systematic collection. They took "algae, invertebrates, birds, and fish."[87] At any rate, the biologists packed the specimens from the day's hectic excursion on ice for the overnight journey back to Parry Island aboard the USS *Nichols*.

As they left the deathly sick atoll, Donaldson and his team of biologists had not yet internalized that Rongelap would become, in many ways, the focus of their research for the foreseeable future. They likely had few details about the evacuation of the Rongelapese and the irradiation of the Japanese fishermen on the *Fukuryu Maru.* Bravo's accidentally high yield had already made the American papers by the time the biologists visited Rongelap. The *Fukuryu Maru* had returned to Japan, its crew members had been quarantined in hospital and a national furor arose over the possibility of irradiated tuna making it to market. These global reckonings became pressing for the Seattle biologists on 13 April, when Colonel William Cowart from the Joint Task Force spoke with Ed Held because he had "been plagued with questions from Trust Territory regarding when natives can be returned + what foods

86 Ibid.

87 Castle Log, 26 March 1954, UWLRB.

will be safe to eat."[88] The biologists' ability to scrutinize an environment's radiological status became part of the story of the exile and tragic repatriation of the Rongelapese.

Back on 28 March, the biologists headed to the field lab on Parry Island to turn the specimens that would become part of the Rongelapese' story into ashen samples. The process started off in a mundane way. First, they unloaded the ice-filled transport crates from the *Nichols*. At the lab, they unpacked them. Next, they went to the bench. "Dissections were started to prepare materials and tissues for return to the laboratory [in Seattle] for final ashing and counting."[89] They produced 300 roughly one-gram samples. Each one they placed on a steel plate for weighing before drying for 24 hours in an oven. The dried samples, still affixed to their plates, went into bags made of a heat-resistant substance called pliofilm. With each sample traveled details about its provenance handwritten on card stock. The work took two days. "All hands packaged tissues most of the day and some of us far into the night."[90] Donaldson, Held, Palumbo, Olson, and an assistant supplied by the Navy, Charles Barnes, labored side by side in the heat to prepare the specimens. The smells of dried fish, nitric acid, and formaldehyde mingled in the humid open-air lab.

Once the samples arrived by airmail in Seattle the next week, they began the process of losing all semblance of whatever living object they had been. The samples underwent the final transformation to ash. No records indicate who placed specimens into the lab's muffle furnace, but four veteran members of the AFL had stayed in Seattle during March 1954. Kelshaw Bonham and Art Welander, who had been with the lab since the first x-ray salmon studies in 1943, Frank Lowman, and Allyn Seymour remained on the mainland and ashed the samples from Rongelap. They likely worked

88 Castle Log, 13 April 1954, UWLRB.

89 Castle Log, 28 March 1954, UWLRB.

90 Castle Log, 29 March 1954, UWLRB.

together since the process was something like a production line. Each scientist performed one step at a time. One saw that the samples were "ashed at temperatures up to 540ºC."[91] Another took the ashed sample out of the muffle furnace and then slurried it with ethyl alcohol in order to spread it evenly on a counting plate. The next applied Formvar, a resin produced by Monsanto, to fix the ashen slurry in place on the plate by drying it under a heat lamp.[92] Transforming a dried tissue sample that had come from the Marshalls by air mail took a good deal of work, but by March 1954 the process had become nearly second nature to the AFL biologists.

After they ashed the samples, they needed to count them, to effect the final transformation from living specimen to data. If ashing erased all the complexities that were part of a living organism, then counting proved the final step in the process of simplifying that life. Counting turned individuals and entire populations into numbers. This last alienation of the specimen from the landscape required a host of specialized technologies and machinery.

To transform ashed samples into data, the biologists relied on the internal gas-flow counting chamber and the scaler. The counting chamber was an ingenious device that saved time and produced easily readable numerical data. To use the counting chamber, a biologist first took one of the uniformly sized plates that had a formvar fixed sample on it and placed it into the counter's open sample well. Once the sample sat securely in the well, the biologist rotated the base of the counter. This moved the sample directly underneath the proportional counting tube that protruded like a tower from the top of the device. The tube operated much like the chamber in the Juno Survey Meter but with some minor differences. As the sample sat under the tube, methane gas flooded the well, ensuring that the tube could get the most accurate count without any interference from air around the sample. The biologist

91 UWFL-42, NTALV.

92 UWFL-33, NTALV.

left the sample under the counting tube for 10 to 20 minutes. During this time, he could set a new sample in the exposed well. All the while, the tube sent electrical signals a scaler via a chord. The scaler's circuitry aggregated the electrical signals from the counter. After 20 minutes had passed, the biologist could look at the analogue display on the scaler to see how many disintegrations per minute per gram of ash (d/m/g) the counter had picked up from the ash. More disintegrations meant more radioactivity, less meant a lower level of radioactivity. The biologist then tabulated the count data in the lab's daily logbook, making sure to place the count next to the collection data from the index card that had arrived with the sample.

The four veterans who stayed behind in the Seattle lab processed samples from Rongelap 24/7 for around a week after they arrived from the Marshalls because they felt pressure to create data about the Castle Bravo disaster quickly. They found themselves in a position utterly unlike the months after Crossroads, which it was unclear that they would get to engage in research in the Marshalls at all. Now, in Spring 1954, their research seemed immensely important for the future of atomic testing at the Pacific Proving Grounds. They therefore moved quickly to process the samples from the March 26 excursion to Rongelap so that they could begin to chart the fallout's behavior. They also had to move quickly because of their travel commitments. Welander went to join the team at the Eniwetok Marine Biological Laboratory on Parry Island later in the Spring. In the meantime, Donaldson travelled to Japan as part of the AEC's mission to reassure the Japanese public that irradiated tuna from the *Fukuryu Maru* ought not create a public health scare.[93] He spent the summer in Japan. Held collected more samples from Rongelap in July and sent them by air mail to Seattle for ashing and counting. The

93 Hines, *Proving Ground*, 183ff.

year ended with another push to collect specimens in the Marshalls and December saw Held, Olson, Welander, and Donaldson back at the lab on Parry Island.[94]

When 1955 began, the AFL had made three collection forays to Rongelap atoll in response to Castle Bravo's fallout, or what Lauren Donaldson called "the spring fiasco."[95] But Donaldson and the team felt that they still did not have enough samples to accurately reflect the radiological situation at Rongelap. To remedy this, lab veterans Allyn Seymour and Frank Lowman traveled to Rongelap early in the new year. They hopped a ride on the USS *Rio Grande* and made radiation measurements as well as collections between January 25 and 30.[96] Again they sent the specimens that they dried, along with their informational index cards, back to Seattle via air mail. By the middle of February, therefore, Donaldson considered that the lab had enough data to begin working up a report on the special fallout problem.

Producing a report for the Division of Biology and Medicine took time because the AFL biologists wanted to accomplish two things at once, to show how radiation would decline in the biota over time and to show which radionuclides entered the food system. Their counts could help them do both. Showing the rate of decline proved the easier task. This simply involved taking counts from individuals of a single species or class of species and showing how counts decreased, or in a few cases, increased over time. Figuring out which radionuclides ended up in which biotic populations proved a little trickier, but doable. The biologists sent samples out for chemical analysis in March and April 1955. This analysis would tell the biologists about the presence of radioactive elements like strontium, cesium, cerium, and iodine. But the biologists could also use their counts to figure this out. Isotopes of

94 Lauren Donaldson to Willis Boss, 8 November 1954, Box 1, Folder 39, UWLRB.

95 Ibid.

96 UWFL-42, NTALV.

elements have distinct half-lives, so the biologists could match their decay rate curves to the curves of known isotope decay to learn what element any given species had ingested or come into contact with. Still, this process took time.

Because they could plot rates of decline with relative ease, their 15 August 1955 report on foodstuffs at Rongelap focused on this technique's ability to show how radiation moved through the biota. Based on the decline curves they plotted, the biologists were optimistic about the radiological situation in Rongelap's foodstuffs. Why? The reason for their positive outlook lay in the source of the radiation. "From this data it appears that mixed fission products are the principal source of radioactivity in the food stuffs."[97] From the biologists' perspective, mixed fission products, or the radionuclides created when fission and fusion took place inside Castle Bravo's core, were a blessing because so many of those elements had very short half-lives. When they graphed key foods, they saw a significant rate of decline in radioactivity between March 1954 and January 1955. Though the graph showed some rebounds in radiation in the January data, the biologists felt secure that these fell within the error range and would be smoothed out once more data was available. Generally, the decline curves showed that food stuffs were not of concern in terms of radioactivity.

The biologists reported only briefly on the potentially dangerous foodstuff presenting radiological anomalies that did not fit their generalized decline curve. Only three foodstuffs seemed troubling. Bird thyroids collected Iodine 131, since the thyroid requires iodine. But that isotope only has a half-life of eight days, so it was not a worry from a food safety perspective. The gastric system in Coconut crabs, *Birgus latro* or *barulep*, showed a decay curve distinct from the average, so the biologists noted that but failed to say whether it was a problem or not. More data would be necessary in the crab's case. The biologists did highlight a real problem with coconuts, however. "Of greatest

97 Ibid.

concern is the coconut, in the mild of which the radioactivity may decay very slowly..."[98] The biologists also highlighted the ability of plankton to accumulate radiation in Rongelap's lagoon.

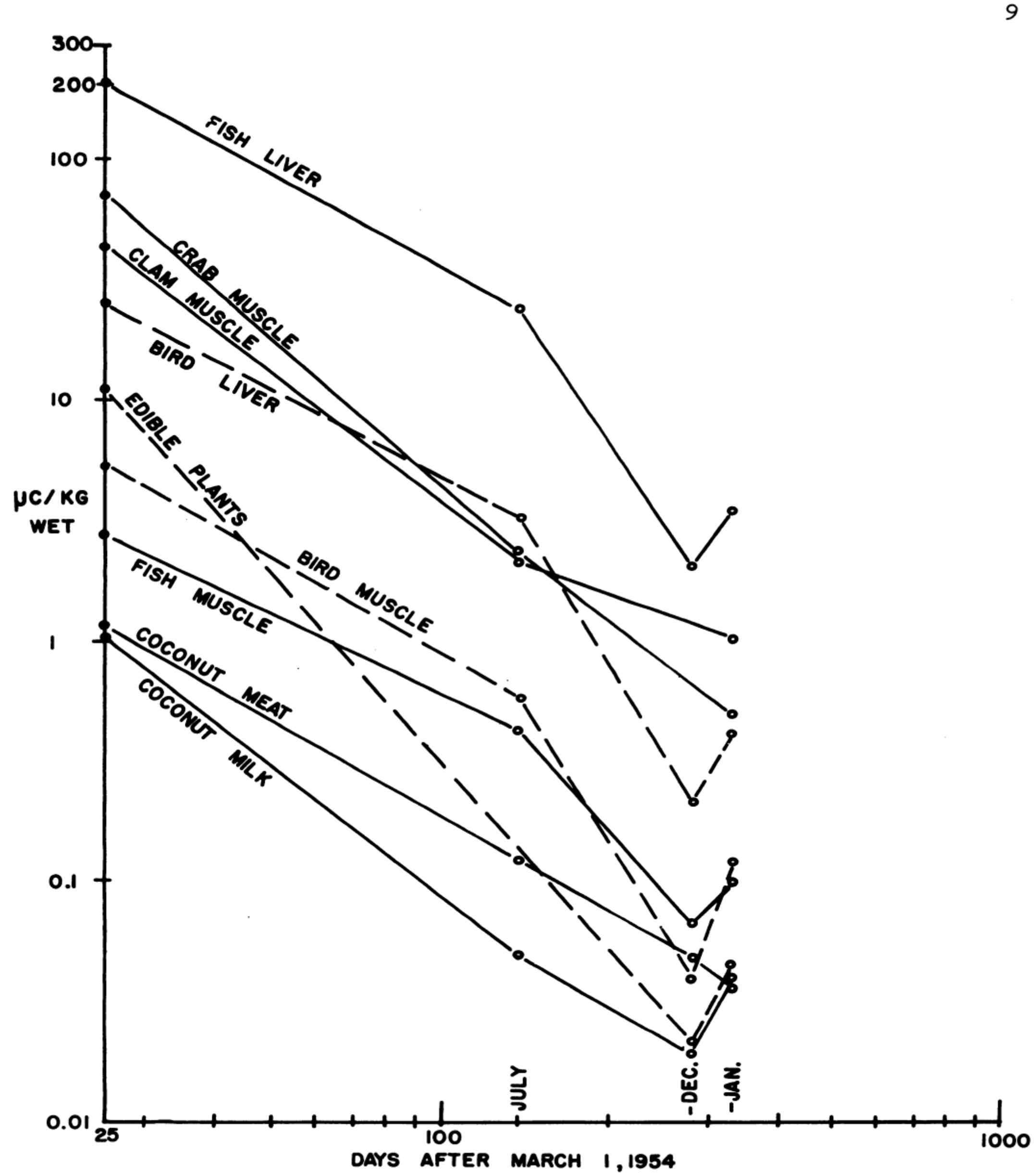

FIG. 2 RATE OF DECLINE OF RADIOACTIVITY OF RONGELAP FOODS

Figure 5.4. Mixed Fission Products after Castle Bravo. Though the curves show minor rebounds in radionuclide levels, the AFL biologists saw their general downward trend as a source for optimism. Source: UWFL-42, 9, NTALV. Source is in the public domain.

98 Ibid., 46 – 48.

"Radioactivity of the Rongelap plankton samples was more than one hundred times greater than that of plankton collected from the open ocean waters of the Western Pacific… during March and April, 1955…"[99] But, microscopic plankton were scarcely a foodstuff and the presence of radiation at the bottom of the food chain did not seem to be translating to fish, which adhered to the happy trend of significantly decreasing radiation levels over time.

The unclassified report that the biologists released on 30 December 1955 about radiation at Rongelap looked at the situation of foodstuffs with a finer toothed comb than the August report because the biologists finally had data about particular radionuclides. Their initial optimism that quickly decaying fission products accounted for most of the atoll's radiation faded, but not intractably so. In fact, the decline curves they created with the extra 11 months of data showed they were right about the January spikes. Only coconut milk bucked the trend. But now they could start to explain why some parts of the biota experienced a slower decline than others because they had radionuclide data. Strontium 90 appeared significantly in most food plants, except for coconuts. *Birgus latro,* which dwells on land and eats land plants, had high levels of radiostrontium in its liver and exoskeleton. Most land plants, including the coconut, also showed a preponderance of Cesium 137. Again, this radionuclide made its way into *Birgus latro*. Finally, the biologists noted the presence of Cerium 144 in marine animals and algae in the lagoon. Radiostrontium has a half-life of 28.8 years. Radiocesium, a half-life of about 30 years and radiocerium a half-life of around nine months.

With radioisotope data and decline curves in hand, the biologists could be somewhat more specific about the safety of foodstuffs than they had been in their August report. They continued to be optimistic as they did this. Of the coconut, whose milk failed to show a normal rate of decline, the biologists suggested that "the activity in the coconuts does not appear to decline appreciably with time,

99 Ibid., 31.

but since it is due mostly to CS[137], it does not present a health problem at this time."[100] Why did they claim that radiocesium did not constitute a health problem? Largely because they consulted the US Public Health Service's 1954 *Radiological Health Handbook*. The handbook indicated a maximum permissible amount of radiocesium in the human body, in water, and in the air.[101] Levels at Rongelap came nowhere close to these levels. On the other hand, the handbook did indicate a problem with the maximum permissible amount of radiostrontium in land plants. "Edible plants other than coconuts have been found to contain levels of Sr^{90} which are above the tolerance level as defined in the Radiological Health Handbook. Among these are Pandanus, papaya, Morinda, squash, and possibly arrowroot."[102] The ability to know what radionuclides appeared in which foods helped the biologists make judgements about safety. The only problem, in retrospect, was that they made a mistake which betrayed their interpretive bias. The biologists described radiocesium and radiostrontium levels in terms of tolerance doses. But the Public Health Service had followed the lead of the National Radiation Council and had abandoned tolerance doses by 1955. The table in the handbook shows permissible concentrations. Permissible dose, based on the work of geneticists, refused to humor the idea of a safe level of exposure. The biologists' familiar tolerance dose relied on the idea of a safe level of exposure.

In the pages of the AFL's December 1955 report on Rongelap after its irradiation by Castle Bravo, the lab's biologists wed ashing with a commitment to the tolerance threshold with disastrous consequences. First, they essentialized a complex biotic system by transforming animals and plants into ash. This totally decontextualized specimens from the niches in which they lived and were exposed to radiation. It took animals and plants out of the food web. Converted into ash and then into counts, the

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100 Ibid., 32.

101 Kinsman, *Radiological Heath Handbook*, 135.

102 UWFL-43, NTALV.

specimens produced curves that then gave the second method of simplification its power. These curves showed that radiation in the biota decreased over time. They disposed the biologists overwhelmingly to believe that any radiological dangers from foodstuffs must, by definition, diminish over time. They saw a landscape predisposed to safety based on the half-lives of Bravo's fission products. To this disposition they added the idea of the tolerance dose. Their deep belief that there could be safe levels of exposure to radiation, a belief developed in their laboratory, made them consider the decreasing levels of radiation at Rongelap as benign. The remark about radiocesium not constituting a health problem perhaps best encapsulates how their ability to simplify made them blasé. The observation showed that they trusted that their numbers showed safe levels of radiation in many of Rongelap's foodstuffs. And because the numbers were getting better all the time because of physical decay and decline within the biota, even unsafe foodstuffs in 1955 could be safe for when the Rongelapese might return in the future.

The Failure to Understand in the Colonial Field

The Rongelapese returned to their home atoll on 29 June 1957 because the AEC had proclaimed their home islands safe. Something of a spectacle accompanied their return. The 250 people returning to the atoll left their exilic homes on far-off Ejit and Ebeye islands on 26 and 27 June respectively. The exiles brought with them "30 pigs, 60 chickens, six dogs, one cat, one duck, and pet pigeon," in order to reestablish their traditional practices of raising livestock.[103] They had loaded 12 outrigger canoes aboard the navy transport to take home, so that they could traverse their lagoon as they had before the Castle Bravo disaster. When their home islands came into view, they gathered on the deck under an

103 Holmes & Narver, "Repatriation of the Rongelap People, November 1957," 1- 32, NV0043517, NTALV.

awning to sing hymns and pray, thanking "God for their safe return to their native land."[104] Holmes & Narver built a whole new village for the returning exiles and erected a large sign reading "Greetings Rongelap People. We hope that your Return to your Atoll is a Thing of Joy and Your Hearts are Happy."[105] After three years away from their home atoll the survivors of Bravo returned with their newborn children and, in some cases spouses, who had never seen Rongelap before.

This last section of the chapter thinks about how the AFL biologists contributed to the Rongelapese repatriation and then attempted to understand radiation and food after the exiles had returned home. This section begins with a look at how bureaucrats from the mainland used AFL research as they described the radiological situation at Rongelap to both US audiences and to the Rongelapese themselves. Next, we zero in on food studies conducted by the biologists in the late 1950s and early 1960s. Finally, we turn to the twilight of the AFL's research at Rongelap, and at Bikini and Enewetak, in the wake of the 1963 Partial Test Ban Treaty that outlawed atmospheric nuclear testing internationally.

Looking at how administrators from the AEC and the Trust Territory of the Pacific used AFL research to make the argument that the Rongelapese would have a safe return home, will show the tension built into atomic testing in an occupied land. In the minds of the US occupiers, the atolls existed to serve the goals of the federal atomic project. Mary Mitchell has argued that the US atomic establishment developed the Pacific Proving Grounds in such a way that "Islanders were collateral to the technological system, not entitled to meaningful consideration or participation where the nuclear

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104 Ibid., 1-33.

105 Ibid.

complex was concerned."[106] The biologists from Seattle, having become experts on the radiological situation at the site, helped make it appear that Rongelapese health was a central concern to repatriation when in fact their safety was always collateral to testing. Mainland bureaucrats mobilized AFL biology to create sometimes conflicting narratives about radiological safety depending on their audience. Even in the first days of repatriation we can see that the Seattle biologists' expert research proved, in Collins and Evans' formulation, "too fragile for the purposes of policy-making."[107]

The main problem that made the AFL research program fragile involved working with the Rongelapese themselves. After repatriation, Ed Held conducted research on foodstuffs at the atoll even as the Rongelapese community relied on those foodstuffs. But he and the other AFL biologists could not accept or understand Marshallese lifeways that did not mesh with their expectations. Returning again to Daston, we see that the biologists were confronted with Rongelapese "objects of everyday perception."[108] Rather than treating these objects on their own terms, the biologists manipulated them in order to create sensible objects of scientific investigation. The travails of doing imperial science in the territorial field come to the fore here. Historians of science have effectively argued that the production of knowledge in colonial contexts needs to be understood as a two-way street.[109] Certainly the AFL biologists learned from Rongelapese environmental expertise. But in this part of the story, we see mainland science exercising power over an occupied population. When that exercise of power became fraught, the story ended with a whimper. The AFL biologists eventually disengaged with their

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106 See: Mitchell, "The Nuclear Charter: international law, military technology, and the making of strategic trusteeship 1942 – 1947," in *Living in a Nuclear World*, 85 – 108.

107 Collins and Evans, *Rethinking*, 9.

108 Daston, "On Scientific Observation," *Isis*, 2008.

109 Helen Tilley, "Global Histories, Vernacular Science, and African Genealogies; or, Is the History of Science Ready for the World," *Isis* 101, no. 1 (March, 2010):110 –119. Also see: Kapil Raj, *Relocating Modern Science: Circulation and the Construction of Knowledge in South Asia and Europe*, *1650 –1900* (Basingstoke: Palgrave Macmillan, 2007).

routine studies in the Proving Grounds because atmospheric atomic testing ended in 1963 with the ratification of the Partial Test Ban Treaty. Global events took hold of the Seattle biologists even as the Rongelapese increasingly rejected their interventions. Disengagement marks part of the failure of science after Castle Bravo.

This story that shows the path to failure and the scientific abandonment of Rongelap begins with a press release that antedates their repatriation by a just over a month. The statement came from the Department of the Interior, which oversaw the Trust Territory of the Pacific's government. The Department had had a tough time with the media. Between the attention the Rongelapese had received during their exile, the continued mistrust of the Japanese public for the US Pacific atomic program, and the beginnings of a mass movement against fallout, atomic testing felt on its back foot. The successful return of the Rongelapese could go a long way towards restoring trust domestically and asserting competence and confidence abroad. The 24 March 1957 presser made the argument that Interior and the AEC had their atomic house in order.

The press release used AFL research to argue the Rongelapese would return to homes made safe by exhaustive scientific scrutiny. The text claims administrative and scientific authority from its opening lines. "Plans are being made for the return of the RONGELAP people… as a result of information from the Atomic Energy Commission."[110] What information did Interior receive from the AEC? Expert information in the form of:

> ...carefully evaluated data from several radiological surveys made during the past two and on-half year. The results of the latest survey indicate the presence of residual radioactivity at a level that is acceptable from a health point of view, both as regards the potential external gamma radiation exposure and Strontium-90 in the food supply, with the possible exception of land crabs.[111]

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110 Holmes & Narver, Repatriation of the Rongelap People, November 1957, 1-29 - 1-30, NV0043517, NTALV.

111 Ibid., 1-30.

The press release evoked the AFL biologists' expertise and familiarity with the landscape without ever mentioning them. It did so first by highlighting the longevity of their research. Then the presser invoked details opaque to the layperson on the mainland. Sr^{90} had yet to become a topic of household discussion in 1957. The Campaign for Nuclear Disarmament was only just getting off the ground and the St. Louis Baby Teeth Survey, concerned with radiostrontium, would not begin until December 1958.[112] By appealing notions accessible to experts alone, the release makes it clear that AEC has done everything in its power to scientifically assess the land for safety, even pointing out a lone danger in the form of land crabs.

What of the singular danger that the press release noted for the Rongelapese as they returned home? The text continued to explain to potentially concerned newspaper readers on the mainland that "the Rongelap inhabitants will be advised not to eat land crabs pending results of future radiological surveys. Land crabs are not a major item of their normal diet.[113] Here readers saw that the Trust Territory and the AEC had the situation under control because experts will continue to monitor the situation. Mainlanders could trust the government manage Rongelap in the same way that it managed federal spaces and indigenous peoples at home. The text also claimed cultural expertise, showing that federal operatives knew the Rongelapese diet and had planned around it.

Of course, the press release also misconstrued Rongelapese lifeways by claiming that *barulep* was not "a major item of the normal diet." The AFL biologists and bureaucrats from the Trust Territory knew well enough that coconut crabs did make up part of the Rongelapese diet. Lijon Eknilang attested

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112 Robert Alvarez and Joseph Mangano, "I gave my baby tooth to science: Project Sunshine's role in the Limited Test Ban Treaty and cutting-edge pollution research," *Bulletin of the Atomic Scientists* 77, no. 6 (2021), 312 – 317.

113 Ibid., 1 – 30.

to their understanding when she recalled that "we could eat everything but *barulep* (coconut crabs)."[114] The Department of the Interior seems to have used AFL conclusion in something of Janus-like way. they appeared to act as responsibly as the conditions allowed by informing the Rongelapese of a potential food danger in June 1957. But the Department also acted irresponsibly, or at least in a self-interested way, when it misled mainlanders who knew nothing about either radiostrontium or *barulep*. The discrepancy supports Mitchell's argument that the islanders existed as a collateral concern alongside the main goal of making the Marshalls ideal for continued atmospheric testing.

The misinformation fed to the US public by the Department of the Interior seems even more pointed in light of the "latest surveys" that actually did come out of the AFL in May 1947. These were the two reports about reef fish and hermit crabs at Bogombogo Island in Enewetak. Welander and Held used samples collected during 1954 and '55, but the techniques they used to investigate the movement of particular radionuclides made their conclusions even more incisive than those the lab enunciated in the December 1955 report about Rongelap. Even though the two reports covered Enewetak, the biologists considered their results commensurable with the radiological situation at Rongelap. Both 1957 reports explained what neither of the earlier 1955 reports did not, the existence of long-term radionuclide food cycles that had become endemic to the irradiated atolls.

Both reports painted a detailed picture of how radionuclides moved in the long-term through the environment. Welander showed that, generally, fish did experience a significant decline in radiation over time. But he did finally pinpoint how high levels of radiation in lagoon algae populations could move into some fish species. In particular 'surgeonfish take in considerable amounts of radioactive

114 Lijon Eknilang, "A Survivor's Perspective," in *Life in the Republic of the Marshall Islands,* ed. Anono Lieom et al., 125.

material by feeding on algae."[115] Surgeonfish made up part of the Marshallese diet.[116] In the meantime, Held made pointed conclusions about radiation in land-dwelling hermit crabs, *Cenobitia perlatus*. He showed the importance of metabolism for the movement of radiation through the crabs' bodies. The gut and liver showed significantly higher concentrations of radioactivity than the muscles or exoskeleton. He also managed to show that radiocerium and radiostrontium comprised roughly ninety-five percent of the radiation present in the edible parts of the crab, indicating that they had become integral parts of the food system at Enewetak. Troublingly, Held found that the crabs concentrated these durable radionuclides at rates three to ten times faster than plant-based foodstuffs. Based on the decline curves that showed this trend, Held concluded that "in so far as the long-lived fission products strontium, cesium and cerium are concerned there appears to be a strontium, cesium food cycle on land and cerium food cycle in the lagoon."[117]

In spite of their findings about significant long-term radiation levels, neither Welander nor Held raised any alarms about potential problems at Rongelap. Welander really offered no suggestions about food safety at all. Held did not either, but he did make an effort to tamp down any concern about the radiostrontium and radiocesium in hermit crabs. "The amount of radioisotopes are so small that they probably do not constitute a significant proportion of the naturally occurring isotopes" with each specimen.[118] In other words, hermit crabs naturally took up some amount of strontium or cesium from their food but they did not concentrate radioisotopes of either element at worrying levels. An analogy

115 UWFL-49, 18, NTALV

116 BNL-51313, J.R Naidu et al., "Marshall Islands: A Study of Diet and Living Patterns," 1 January 1980, NV0511413, NTALV.

117 UWFL-50, 22, NTALV.

118 Ibid.

can be made with a mammalian thyroid, which concentrates iodine. If a small portion of the iodine in the thyroid is radioactive, it likely presents little risk of sickness. Held argued that even though radiostrontium and radiocesium accounted for up to 95% present in the edible parts of a hermit crab, the real levels of those dangerous elements remained very low. The notion of threshold tolerance lurks behind his analysis.

So, as the Rongelapese returned to their home atoll in June 1957 the AFL biologists knew that that radionuclides from Castle had become constants in the Enewetakese food cycles and therefore wanted to continue their research at Rongelap. The biologists arrived at Rongelap in July 1957, just weeks after the islanders had returned to their new village. This would be the first of five field trips to Rongelap by AFL biologists between 1957 and 1960, when the Trust Territory administrator would call for a year-long moratorium on biological and medical research at Rongelap.[119] These post-repatriation visits took place in March 1958, August 1958, March 1959, and September 1959. The direction for the lab's research during these years came from the newly formed Environmental Sciences Branch of the Division of Biology and Medicine. In a January 1957 meeting, the Branch's chief, John Wolfe, suggested that the lab engage in basic research on radiation in the Rongelapese environment as well as on focused food studies.[120] The basic research would include investigations into how particular radionuclides moved through the soil and the biota, especially since the Rongelapese were desperate to reestablish agricultural production.

The AFL biologists made up only one half of the AEC's plan to continue studying Rongelap and the Rongelapese after repatriation, a medical team from Brookhaven National Laboratory on Long

119 Hines, *Proving Ground*, 260.

120 Revised Proposal for Rongelap Radiological, Ecological, and Native Food Study Program, 21 October 1957, Box 7, Folder 22, UWLRB.

Island made up the other half. The Brookhaven doctors had been studying the Rongelapese since they had been evacuated from their atoll in 1954.[121] Though their medical surveys are outside the scope of this chapter, their interactions with the AFL biologists and the Rongelapese help to show the disconnect that developed between the whole host of mainland scientists and the indigenous population by 1960. The biologists and the doctors traveled together during all the trips to Rongelap except for the September 1959 visit, which the doctors sat out. Held and Robert Conard, the head of the Brookhaven cohort, became fast work acquaintances and supported each other's data collection efforts on trip to Rongelap.

How did the biologists plan to understand the problem of radionuclides in the environment generally and in foodstuffs, in particular, after repatriation? During the July 1957 field trip, Welander repeated the fish study he had conducted at Enewetak in 1955 but at Rongelap. He focused his collections on foodstuffs. "Partly because of the omnivorous food habits of the Marshallese natives and partly because of variations in the samples, it is advisable to analyze many specimens of a variety of species."[122] Welander found that fallout from thermonuclear tests at Enewetak in 1956, during Operation Redwing, had re-contaminated the lagoon at Rongelap and at Ailinginae Atoll, which the Rongelapese visited on food collecting excursions. One of the devices tested during Redwing was the US's first bomber-ready thermonuclear weapon. The new reaction used to produce fusion in such a compact bomb made a host of new radionuclides that found their way into to two lagoons: Zinc 65,

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121 See: BNL-609, "Medical Survey of Rongelap People Five and Six Year after Exposure to Fallout," September 1960, NV0403544, NTALV.

122 UWFL-55, Art Welander, "Radiobiological Studies of the Fish Collected at Rongelap and Ailinginae Atolls July 1957," 5 March 1958, 2, NV0410203, NTALV.

Cobalt 57, Cobalt 60, Manganese 54, and Iron 55.[123] These radionuclides made their way into the soft tissues and the bones of fish. Zinc, cobalt, and iron began to replace cerium as the main radionuclides found in the lagoons. Welander found that this new suite of radionuclides had a biological half-life of 308 days in the tissues of the fish he studied. This value was higher than the simple decay rates of all the elements averaged out, which indicated some accumulation of the radionuclides in the biota. Despite this, and despite the outcome of the January 1957 meeting with Biology and Medicine refocusing the AFL on food safety, Welander made no reference to any kind of tolerance dose nor any prohibitions on eating popular reef fish like grouper.

The March 1958 trip also produced data but nothing in the way in assistance for the Rongelapese as they tried to move away from rations provided by the Trust Territory towards food self-sufficiency. When the biologists arrived the Rongelapese had only managed to begin some papaya seedlings.[124] Unconcerned with this effort, the biologists focused on collections and soil science during the field trip. They gathered twelve coconut crabs. Back in Seattle, new lab biologists Diptiman Chakravarti and Ronald Eisler, ashed the crabs to investigate Sr^{90} levels in fatty tissue.[125] The two managed to show that fats in the crabs' livers contained nearly no radiation, so more focused studies in the future should look for radioactivity in fat-free tissues. Their ability to separate fats from fat-free solids proved an advancement of the ashing technique. Back at Rongelap Held, Kelshaw Bonham, Paul Olson worked on soils studies with specialists in soil science from the UW School of Forestry, Stanley

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123 Ibid.

124 Hines, *Proving Ground*, 251.

125 UWFL-59, Diptiman Chakravarti and Ronald Eisler, "Strontium-90 and Gross Beta Activity in the Fat and Nonfat Fractions of the Liver of the Coconut Crab (*Birgus latro*) Collected at Rongelap Atoll during March 1958," March 1959, NV0407959, NTALV.

Gessel and Dale Cole. Cole had designed a new type of lysimeter, a device implanted in the ground to isolate a plant for research, that could collect rainwater as it worked its way through the soil. Collecting the water could show how radionuclides moved through the soil column. This would allow the biologists to think about how food plants might take up radiation based on their root structures. Neither of these researches, collecting crabs for fat analysis or the lysimeter installations immediately offered support to the Rongelapese.

But after a year of eating unfamiliar and unappetizing military C-rations, the Rongelapese had many questions about their food situation in March 1958. Held confided to his friend and former colleague Allyn Seymour that "many of the Rongelapese asked whether or not they were permitted to eat clams and coconut crabs."[126] Seymour had left the AFL to move up the org chart to the Division of Biology and Medicine's headquarters in the federal capital. Held wrote to Seymour as an old friend, not as a supervisor. He felt free to relate that the Rongelapese were collecting food from the islands in the north of the atoll that had borne the brunt of Bravo's fallout. The AEC had made the islands off-limits for food collection, but old habits quickly returned because the knowledge of where to find food had survived three years of exile. Held told Seymour the story of some Rongelapese fishermen who traveled to the north of the lagoon to collect spiny lobsters because the AFL biologists had failed to catch any in the south of the atoll. The story showed a tacit acceptance on behalf of the biologists for bending AEC regulations. Held failed to relate the prohibited excursion to the Deputy High Commissioner of the Trust Territory in a letter he wrote just a week later, instead focusing on the accomplishments of the soil study.[127]

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126 Ed Held to Allyn Seymour, 3 April 1958, Box 7, Folder 22, UWLRB.

127 Ed Held to Eugene Gilmartin, 11 April 1958, Box 3, Folder 19, UWLRB.

Though the March 1958 field trip yielded no solid advice for the Rongelapese about growing or collecting food, it did help solidify the bond between the Seattle biologists and the Brookhaven doctors. The doctors had a busy visit, since they needed to collect bloodwork from all the returnees. They also brought with them a whole-body counter aboard the main deck of the USS *Plumas County*. The counter, itself a 5 x 5 x 6-foot room, acted like the internal gas-flow counters the biologists for ash samples. But the human version could count the total body radiation burden of a person.[128] The doctors spent much of the trip leading members of the Rongelapese community up onto the ship to be counted. While the doctors were not taking counts and blood samples and while the biologists were not scurrying after coconut crabs or digging wells for lysimeters, the two groups spent time together. Held shared his affinity for Conard and the Brookhaven doctors with Seymour. "Much of the success [of the trip] was due to the co-operation of Dr. Robert A. Conard and his medical team."[129] Held went on to explain that the doctors and the biologists spent time thinking together about their respective research problems. "It was felt by all members of our group that there was a free exchange of information… which should enhance the interpretation of results and improve planning of future studies." [130] Confronted with presence of the Rongelapese on their home islands, the doctors and scientists chose to turn inwards, to their own mainlander community, to think about the objects of their study.

The biologists' unwillingness to address Rongelapese concerns and to take cues from them on matters of agriculture and ecology increased over the remainder of 1958 and 1959. During the joint medical-biological survey during August 1958, the biologists began to speak with members of the Rongelapese community about their diet. Things went shakily from the start, in part because the

128 Hines, *Proving Ground*, 250.

129 Held to Seymour, 3 April 1958, UWLRB.

130 Ibid.

biologists had to rely on translators since they had not learned Marshallese. Held explained the whole process to Seymour in a letter. “The idea of collecting daily rations at Rongelap had to be approached with caution… it became obvious that through misunderstanding we would ultimately receive merely a collection of miscellaneous food items.”[131] It took some work for the biologists to convey their request sensibly to the Rongelapese folks willing to assist them. When they finally did manage to, fourteen adult members of the community agreed to help by giving the biologists “one twenty-four hour ration of food stuffs grown or caught on at Rongelap."[132] Held did not seem to consider that such a donation of food constituted a major sacrifice for individuals who had chronically lacked food for over a year. Regardless, the biologists had begun their first food study that actually involved the Rongelapese.

They managed to learn a good deal in a short time from the members of the Rongelap community that helped them. In the letter to Seymour at AEC headquarters, Held was able to send a table quantifying the daily diet of the 14 individuals who offered food.[133] Working through a translator named Bwio, Held was also able to learn how the 14 individuals ate and prepared their foodstuffs. So, for example, some households baked their arrowroot, or *mokmok*, while others boiled it. Similarly, some bake or boiled fish while other households salted and dried fish. Bwio also helped get information on medical plants from Jabwe, a doctor, and Samson, a midwife. They explained how some inedible leaves turned into teas were good for headache, *kanon*, and for cough, *atat*. Other leaves, like *kiron*, served as salves for deep wounds. Jabwe also explained how the Japanese occupiers had

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131 Ed Held to Allyn Seymour, 23 September 1958, Box 2, Folder 4, UWLRB.

132 Ibid.

133 Ibid.

taught them to use coconut milk for "I.V. infusions in cases of severe blood loss" when sterile water was not available.[134]

Despite the initial successes that the biologists had during their 1958 field trips, the situation soured on Rongelap during 1959. This took place in part because the repatriates continued to lack for local foods. In his September 1958 letter, Held remarked that the Papaya crop was lackluster and that *mokmok* had not yet come into season. Hunger and distaste for rations soured Rongelapese opinions of the Americans. So did the continued invasive actions of the Brookhaven doctors. Held's attitude likely did not help the situation. He looked down paternalistically on the Rongelapese, whom he referred to consistently as "the natives" in his personal communications. He also felt as though they failed to understand the importance of his and Conard's research. He sent a letter to the doctor after an encounter with John Anjain, a community leader, in late 1958. Held ran into Anjain in Majuro Atoll, home of the largest city in the Marshalls. There, he and Amta, a member of the hereditary Marshallese nobility, questioned Held about the continued need for medical surveys at Rongelap. Held passed on to Conard that the Rongelapese were "dubious about the necessity for continued medical examinations."[135] The gravity of the encounter moved Held to write his friend nearly immediately.

Mistrust came to a head during the March 1959 field visit, when, by some scheduling chance, a delegation from the United Nations also visited Rongelap during their tour of the Trust Territory. Held, Conard, and Neil Morris, the agriculturalist sent by the Trust Territory to assist the Rongelapese in late 1958, greeted the delegation along with the elected leaders from the island. In the Congregational Church's sanctuary, the UN inspectors met with around one-third of the residents of Rongelap Island. After members of the delegation spoke, members of the Rongelapese community began to ask

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134 Ibid.

135 Ed Held to Robert Conard, September 1948, Box 2, Folder 22, UWLRB.

questions and air grievances. Tensions got hot. Islanders asked about funding for health. Given an unsatisfactory answer "some of the more vociferous Rongelapese were getting more than somewhat angry" according to Held.[136] He perceived a dark motivation behind their anger. "I was left with the impression that… there is at least a small group working, not to rebuild their life, but to get a large sum of money which will support them in leisure…"[137] The man who arguably knew the radiological situation at Rongelap best failed to understand, or even acknowledge, the concerns and pains of the people whose land he studied.

The biologists managed to make another collection of daily rations during their September 1959 visit, but research involving the Rongelapese was clearly needing to wind down. Bwio, who assisted the year before, and Morris, the agriculturalist, and Held, collected the rations for 10 willing participants over the course of 24 hours.[138] The report they eventually created from the data did explain how specific radionuclides entered the diet through specific foods. Cobalt 60 and zinc 65 entered human bodies through fish. Strontium 90 and cesium 137 entered the diet through fruit. Pandanus, *bob,* contributed the most radiostrontium to the diet. The report lacked the precision of earlier reports that included decline curves. It did include descriptions of how each food was cooked and consumed, but really did not contain appreciably more information than the letter Held sent to Seymour in 1958. The report suggested no prohibitions on any foodstuff. Held left Rongelap in late 1959 disillusioned. His team had lived and worked aboard their ship, rather than on Rongelap, because the magistrate asked that no scientists come ashore after dark. Held wrote to Conard that any future studies would have to be

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136 Ed Held to Lauren Donaldson, 11 March 1959, Box 3, Folder 19, UWLRB.

137 Ibid.

138 UWFL-77, Diptiman Chakravarti and Edward Held, "Chemical and Radiochemical Composition of the Rongelapese Diet," 1 December 1961, NV0050031, NTALV.

carried out with “a minimum disturbance to the natives.”[139] As it turned out, the Trust Territory shut research down in 1960, so no interaction between the biologists and the Rongelapese would take place.

The moratorium on research at Rongelap anticipated the AFL’s turn away from the Marshall Islands after nearly two decades of scientific work. Operation Hardtack, in 1958, would be the last test series at the Proving Ground. Frank Lowman and Ralph Palumbo represented the lab during that Operation while Held worked at Rongelap. Without further atomic testing, the AFL’s main purpose, understanding the biological effects of radiation from atomic tests, ceased to exist. Donaldson turned his attention to ecological research at Fern Lake, close to Seattle on the Kitsap Peninsula.[140] Held returned to the Pacific in the 1960s and ‘70s, but never engaged in research at Rongelap with the intensity of the late 1950s. He ended up working as part of the lab’s team for Project Chariot in the 1960s. This was the Atoms for Peace harbor-making project, which would use a series of bombs to excavate an inlet on the shore of the Chukchi Sea in Alaska. Held also led a biological resurvey of Bikini Atoll in the late 1960s. Of course, the Bikinians had not returned to their homes like the Rongelapese had so that landscape lacked the inconvenience of actual residents who relied on the environment for their sustenance.

By the early 1960s, the bad feelings that the Rongelapese had for the AFL biologists and the Brookhaven doctors had been compounded by the onset of sickness. Held and the biologists did return in 1961.[141] They also made occasional radiostrontium and radiocesium surveys in the following years when proximity to their main research projects permitted. But by and large they left Rongelap with the sense that the atoll was safe for its residents. They believed radiation was below tolerance dose levels.

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139 Ed Held to Robert Conard, 10 September 1959, Box 2, Folder 19, UWLRB.

140 Klingle, “Plying Atomic Waters,” *Journal of the History of Biology,* 1998.

141 Ed Held to D. Nucker, High Commissioner, Trust Territory of the Pacific, 2 March 1961, Box 3, Folder 19, UWLRB.

They also knew that radiation, even in the biota, was decreasing over time. In a 1964 letter to Marshall Islands District Administrator, Held called radiation levels in lagoon fish at Rongelap "so low… as to be undetectable by methods we have used in the past."[142] As low as to be undetectable certainly points to years of expertise at counting radiation in biotic specimens. But it also points to a myopia about exposure and safety. The myopia came from their research practices, from ashing, and from their view that safe levels of radiation exposure existed in the real world. These two factors, combined with their inability to ever really understand or sympathize with the Rongelapese, made it so their science never could help with the radiological problems that took place in the wake of Castle Bravo.

Conclusion: Slow Violence and Scientific Failure

By 1959 sickness and symptoms took hold in both people who had been present for Castle Bravo and for those who had not but had repatriated in 1957, indicating some problem with radiation that continued to linger at the atoll. Some medical predicaments directly related to food. Chiyoko Tamayose recalled that "we ate foods that made our throats swell and close up, and even made us shake like we had epilepsy. I remember this after eating a crab."[143] Childbearing became a tragedy across the population, as miscarriages and natal deformities became common. "I was not on Rongelap for the Bravo test," recounted Aruko Bobo, "but I returned with everyone in 1957… my second son, born in 1960, was delivered live but missing the whole back of his skull."[144] He died eight days after birth. Finally, a high rate of thyroid cancer set in by the late 1950s. Lijon Eknilang recalled three girls who

142 Ed Held to Peter Coleman, 21 September 1964, Box 3, Folder 19, UWLRB.

143 Chiyoko Tamayose in *Bravo for the Marshallese*, by Holly Barker, 64.

144 Aruko Bobo in *Bravo for the Marshallese,* by Holly Barker, 64.

"were taken to Guam for surgery" for their thyroid tumors.[145] None of them spoke English, so when they arrived at Guam's military hospital they must have been terribly disoriented. All these terrible experiences devastated the repatriated community, which had longed to return to their home atoll to steward the good earth and sea that had sustained them for generations.

The Rongelapese responded to their ill-health with mistrust of their US overseers. As they wept over woman after woman who miscarried or birthed children unrecognizable as humans they began to wonder if they were the objects of scientific experimentation. The Marshall Islands Nuclear Claims Tribunal found, in 2001, that the Rongelapese "served as unwitting subjects in a series of experiments designed to take advantage of the… exposure of a distinct human population to radiation."[146] At the time, many in the community pointed to the three days that elapsed between the arrival of Bravo's fallout in March 1954 and the Navy's arrival to evacuate them. "US ships were within four hours' sail from us" yet they did not come for over 48 hours.[147] Survivors have routinely enunciated that "they [the US] treated us like guinea pigs."[148] Barbara Rose Johnston and Holly Barker have authoritatively shown that the medical research performed by the Brookhaven doctors fell outside of ethical norms. Much of their research was "conducted without meaningful informed consent."[149]

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145 Lijon Eknilang, "A Survivor's Perspective," in *Life in the Republic of the Marshall Islands,* 125.

146 Johnston and Barker, *Consequential Damages*, 45. Two examples of deliberate human experimentation organized by the federal government stand out. For plutonium injections overseen by Stafford Warren's MED Medical Section, see: Eileen Welsome, *The Plutonium Files,* 1999. For a view of the Tuskegee syphilis study, see: Susan Reverby, ed., *Tuskegee's Truths: Rethinking the Tuskegee Syphilis Study* (Chapel Hill, North Carolina: University of North Carolina Press, 2000).

147 James Matayoshi, "The Mayor's Perspective," in *Life in the Republic of the Marshall Islands*, 127.

148 Tempo Alfred in *Bravo for the Marshallese* by Holly Barker, 57.

149 Johnston and Holly Barker, *Consequential Damages of Nuclear War,* 23.

It is this chapter's project to argue that AFL biology failed to protect the Rongelapese from environmental radiation danger because it simplified a complex environment and because the lab's biologists never fully appreciated the ways in which Rongelapese people used their complex natural world. Producing ash samples for the scaler in Seattle and then trusting that the machine's numerical counts showed safe levels of radiation hobbled any chance the biologists had at doing science in service of the Rongelapese. A lack of cultural understanding put the nail in the coffin as the Rongelap community looked for guidance about how live in their homeland after the fallout. The biologists could not give them guidance. Of course, any guidance would have been useless based on the pervasiveness of radiation in the food cycle. When it became clear to the Rongelapese that the biologists offered them almost not practical help and always seemed to be engaged in some sort of inconsequential research, the relationship between to two soured. The Trust Territory administration, hearing Rongelapese complaints, barred the biologists and the Brookhaven doctors from the atoll in 1960. After the moratorium year, sickness set in and Rongelapese trust in biologists and doctors eroded further.

Earlier in the chapter, I claimed that the AFL's disengagement with Rongelap constituted part of the failure of science at the atoll. The poor relationship between the scientists and the local community prompted the withdrawal, but so did global political events. As radiation from Rongelap's environment overwhelmed the atoll's population with ill health in the early 1960s, the world's atomic powers turned against atmospheric testing. The US signed on to the Limited Test Ban Treaty of 1963 in part because doctors and scientists used samples taken from human beings to show the presence of radiation in the American population. We return here to the story of the St. Louis Committee for Nuclear Information, made up largely of concerned mothers. Their 1958 effort to collect baby teeth from across the mainland resulted in 320,000 samples sent to doctors and scientists at Washington University in St. Louis. They used the samples to show increases in Strontium-90 that correlated with atomic testing in Nevada.[150] The scientists sent their data to John F. Kennedy's White House. The president, speaking to the public after signing the Test Ban Treaty in 1963, claimed to be deeply moved by the danger to mainland children that the data indicated. He emotionally argued that “the loss of even one human life or the malformation of even one baby who may be born long after all of us have gone should be of concern to us all. Our children and grandchildren are not merely statistics to which we can be indifferent.”[151] Of course, the danger to US babies ranked as only one of many scientific, political, and military reasons for Kennedy’s assent to the treaty.[152] Still, appealing to potential sicknesses and deaths among mainland babies played well on the television before a country filled with informed citizens fearful of fallout.

Here we see the distinction between the territorial field and the mainland in the strongest terms possible. On the mainland, robust science and medicine helped contribute to the end of atmospheric testing. Experts traced radionuclides through biotic populations in order to stop future contamination. To avoid sickness. At Rongelap, robust science and medicine had always contributed to the continuation of atmospheric testing. Experts traced radionuclides through biotic populations to minimize fears about future contamination. To claim that sickness would not take place, because foodstuffs and the people who relied on them for sustenance were only ever exposed to safe levels of radiation. Though the threshold dose proved a fiction, a very real threshold existed between the

150 Alvarez and Mangano, “I gave my baby tooth to science,” *Bulletin of the Atomic Scientists,* 2021.

151 John F. Kennedy, “Radio and Television Address on the Limited Nuclear Test Ban Treaty,” 26 July 1963, 13:55, https://youtu.be/F1zoWjQ6wAI, accessed 2 November 2022.

152 For an historian’s assessment of the Partial Test Ban Treaty, see: Lawrence Badash, *Scientists and the Development of Nuclear Weapons: From Fission to the Limited Test Ban Treaty, 1939-1963* (Atlantic Highlands, New Jersey: Humanities Press, 1995). For a nuclear scientist’s view of the treaty, see: Glenn Seaborg, *Kennedy, Khrushchev, and the Test Ban* (Berkeley and Los Angeles: University of California Press, 1981).

American mainland and the occupied Marshalls. The significance of science changed as it crossed that threshold. On one side, maintaining the health of mainlander babies argued for atomic discretion. On the other side, maintaining the health of marginalized subjects never properly became a scientific goal at all.[153]

When Lauren Donaldson, Art Welander, and Ed Held spent the July 1957 with Nerje Joseph, Lijon Eknilang, and the rest of the joyfully repatriated Rongelapese, they never meant to fail them. But they also never meant to fail their administrative and political overseers at the AEC who continued to believe in the need for atmospheric testing even as popular opinion turned against them. At the end of the day, AFL expertise failed the Rongelapese because the lab's biology was inextricably entwined in the political will and military goals of the US atomic project. Caught up amid the true believers in atomic testing, the AFL biologists practiced a thorough science that served dreams concocted on and for mainland. The Rongelapese dream of returning to their home atoll and to live off its natural riches ranked a distant second as the biologists designed and conducted their researches in the wake of Castle Bravo. The biologists watched as the Rongelapese dream began to wither in the first years after

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153 The threshold ran across the western US as well, distinguishing marginalized mainland populations, in particular American Indians and Mormons, from the majority population who deserved atomic safety. For a reflection on American Indians' relationship to toxic waste at Hanford, see: Ishiyam and TallBear, in *The Promise of Multispecies Justice*, 185 – 203. For Western Shoshone experiences with atomic testing in Nevada, see: Rebecca Solnit, *Savage Dreams*. For the argument that Mormons lacked the standing of the Anglo majority on the mainland and could be exposed to fallout and radiation dangers, see: Scott Kirsch, "Harold Knapp and the Geography of Normal Controversy: Radioiodine in the Historical Environment," in "Landscapes of Exposure: Knowledge and Illness in Modern Environments," special issue, *Osiris* 19, (2004), 167 – 181.

repatriation. By the time that sickness and death killed the dream, the biologists had gone back to Seattle. They left the radionuclides, and the Rongelapese, behind.

Science for a Time and a Place

Biological Research in Support of Atomic Testing

The stories that make up *Atomic Bodies, Atomic Landscapes* revolve around the biological research program practiced by the Medical Section of the Manhattan Project and by the laboratories that grew out of the Section after the end of World War II. The research program antedated the war, at least in its fundamentals. Its core rested on the belief that exposing animals to x-rays in a controlled laboratory setting provided the best way to understand the biological effects of radiation on both animals and humans. The program relied on practices native to both biology and medicine, distinguishing it from other biological ways of knowing at the time. In particular, the value of histology and the visual evidence accounted for much of the program's initial data. Seeing the insults of radiation to tissues, organs, and blood gave the program's practitioners the ability to define the behavior of an invisible menace.

Had research into the biological effects of radiation stayed in the lab and remained constrained to the use of x-rays, as it was in the 1920s and '30s, *Atomic Bodies, Atomic Landscapes* would have been a much different work than it is. If the story had remained small in scale, then this dissertation might have been a theoretical reflection on how scientific networks function, how knowledge travels, and how laboratories can claim to represent nature. Instead, the United States entered World War II and committed to developing atomic bombs. As soon as the Manhattan Engineer District came to be, the scale on which anthropogenic radiation could exist greatly expanded. Medical x-ray machines had been increasing in power during the 1920s and '30s, but no machine in any hospital could hold a candle to the potential of the new fission that Enrico Fermi demonstrated in his secret wartime reactor at the University of Chicago on 2 December 1942. On that day, the research program that Stafford Warren had practiced in medical pathology labs and in hospital radiology labs before the war became part of something much, much bigger.

Following this research program, the new world that fission created comes into a new kind of focus. This dissertation has shown that a single story ties together salmon in Seattle and in the Columbia River, the *hibakusha* in Hiroshima and Nagasaki, and populations of fish, plants, and people in the Marshall Islands. Atomic stories that have focused on physicists and on diplomacy have generally missed this thread. But the data about deformities and mortality in salmon populations that Lauren Donaldson, Art Welander, and Kelshaw Bonham produced by using x-rays on the north shore of Lake Washington in 1944 really did inform the medical investigations of Stafford Warren and Joe Howland when they travelled to Hiroshima and Nagasaki in August 1945. Seattle salmon also shaped how Dick Foster thought about the health of fish in Columbia River and about the environment at the Hanford Engineer Works in general. In the Marshall Islands, the practices and assumptions that grew out of the x-ray research tradition shaped how the Seattle biologists interpreted data from Geiger counters and other cutting-edge electronic radiation meters in the late 1940s and 1950s. The data from AFL troughs and tanks, which convinced the biologists that low-level radiation exposure could be basically safe, worked its way into the research at Rongelap in the wake of the Castle Bravo disaster. Medical Section research made irradiated people and landscapes legible in the 1940s and '50s.

As the research program moved, matured, and allowed its practitioners to claim that they knew what was going on across the new atomic world, they claimed expertise over irradiated bodies, irradiated populations, and over entire irradiated landscapes. Their data supported the arguments that US's atomic program was not only biologically and environmentally safe but morally good. Though Donaldson, Welander, and others at the Seattle lab publicly denounced the prospect of nuclear war, they never found fault with atmospheric testing. Warren, who retired in the year of the Partial Test Ban Treaty, never took issue with atmospheric testing either. Though he once hinted in 1947 that he was against testing in the continental United States, he did not oppose the program at the Nevada Test Site when it began in 1952.[1] His worry over Nevada grew out concern about the health and safety of US mainlanders who could be exposed to fallout. He never felt those concerns for the *hibakusha*. Until his death he argued that the bombings of Hiroshima and Nagasaki were sympathetic actions that saved more lives than they cost.[2] Meanwhile, Neal Hines, the journalist who traveled with Donaldson and the AFL biologists to the Marshall Islands on a number of research trips, clearly expressed the Medical Section's optimism that radiation from testing had never produced serious biological effects. In 1962, he wrote the biologists had "failed to find in the natural environment evidence of gross population or morphological change definitely ascribable to the effects of residual radioactivity alone."[3] *Atomic Bodies, Atomic Landscapes* is a story about US doctors and biologists who supported atmospheric nuclear testing and believed it to be safe.

Atoms for Peace, the Partial Test Ban Treaty, and the End of the Medical Section Program

The Medical Section's notion that atomic production and testing was essentially safe ran afoul of public opinion in the late 1950s as popular opinions about atomic testing grew cynical and fearful. Two important sociopolitical moments threw hurdles in path of Warren's disciples as they claimed that their science proved the safety of the weaponized atom. The first was Dwight Eisenhower's December 1953 "Atoms for Peace" speech to the United Nations. Long interpreted as a cover-up for his drastic

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1 Stafford Warren, "79th Charter Anniversary Address, UC San Francisco," March 1947, Folder 2, Box 285, MSS Warren. In the typed manuscript for his speech at his alma mater, he wrote. "… there are not any land masses, certainly on the North American continent, large enough to run a test safely… we might injure a large group of people." He then crossed the lines out with a pencil and presumably did not share the sentiment.

2 Ibid.

3 Neal Hines, *Proving Ground,* 309.

expansion of the country's nuclear weapons stockpile, the speech nonetheless galvanized the notion that atomic research and even the testing of atomic bombs should support peaceful ends.[4] Ike's speech may have initially seemed promising for the AFL biologists, since he made it just months before the Castle Bravo shot. We have seen that responding to what historian of technology John Krige called "a human and public relations disaster" for the US provided years of funding and access to the Marshall Islands for Donaldson and his team.[5] The biologists seemed, for a moment, to be the experts that a country dedicated to safe and peaceful atomic progress needed.

But the peaceful atom failed to create newly irradiated landscapes on the scale that nuclear weapons production and testing had. The heirs of the Medical Section relied on fallout, on large-scale biological harm. Peaceful atomic explosions needed to be small-scale and manageable. True, the US did continue to test high-yield thermonuclear devices in the Marshalls in the late 1950s. But On 19 September 1957, just months after the Rongelapese returned to their home atoll, Shot Rainier shook the desert floor in central Nevada. It was the first US's underground test, specifically designed to produce no fallout.[6] Rainier anticipated Operation Plowshare, the clearest instantiation of Atoms for Peace within the AEC. This expansive operation involved projects to peacefully excavate harbors and frack oil shale using small atomic bombs.[7] The AFL did take part in Project Chariot, a Plowshare scheme to

4 See: John Krige, "Atoms for Peace, 2006.

5 Ibid.

6 For the UCLA Atomic Energy Project's magisterial report on 1957's Operation Plumbbob, of which Rainier was a part, see: Kermit Larson, WT-488, "Distribution, Characteristics, and Biotic Availability of Fallout, Operation Plumbbob," 26 July 1966, NV0519242, NTALV.

7 For a general history of Plowshares and the efforts to practically unfold the peaceful use of atomic bombs, see: Scott Kirsch, *Proving Grounds*, 2005.

build a harbor on the west coast of Alaska using nuclear blasts.[8] A cohort of biologists left the lab to perform radioecological studies on the shores of the Chuchki Sea between 1959 and 1961. They studied local biota, doing much the same work they had done in the Marshalls. But the Inupiaq residents of Point Hope, Alaska, opposed Chariot. So did mainlander biologists who worked at the University of Alaska. This time, there would be no dispossession of the local population like at Bikini, Enewetak, and Rongelap. Under pressure to make the peaceful atom seem palatable, the AEC left Alaska. The Commission detonated a bomb to test nuclear earthmoving at the Nevada Test Site in July 1962.[9] As an excavating tool, the bomb worked. But it still created a small amount of residual radiation and proved inappropriate for peaceful applications.

Even before Operation Plowshare failed, members of the US public began to support the end of all atmospheric testing. By the mid-1950s, laypeople and scientists on the mainland started to push back against the assurances of the federal atomic bureaucracy that testing posed no health risks. We have already met Hermann Muller, the quirky geneticist who decried atomic testing in his 1946 Nobel Prize acceptance speech.[10] Linus Pauling, the rabble-rousing chemist, also used his Nobel credentials to proselytize against testing in the 1950s.[11] In 1957, Ralph Lapp, a physicist who had worked for the Manhattan Project, used the strontium-90 produced by the Castle tests in the Pacific as the centerpiece for his critique of atomic testing. In the pages of the august journal *Science*, he wrote "the biological hazard of Sr^{90} is most important in human beings born since the Castle series of nuclear tests

8 For the Applied Fisheries Laboratory's involvement in Plowshare, see chapter 9, "From Bikini to the Chukchi Sea" in Neal Hines, *Fish of Rare Breeding,* 1976.

9 For an evocative image of the Sedan Crater, produced by the Plowshare test in Nevada, see: Peter Goin, *Nuclear Landscapes* (Baltimore: Johns Hopkins University Press, 1991), 62 – 63.

10 See: Soraya de Chadarevian, "Mice and the Reactor" *Journal of the History of Biology*, 2006.

11 See: Angela Creager, "Radiation, Cancer, and Mutation in the Atomic Age," 2015.

(beginning with the 1 March 1954 explosion)."[12] In layperson's terms, Lapp showed mainlanders that fallout endangered their babies. Nuclear fear had reached the American and European publics. In the US, the anti-nuclear National Committee for a Sane Nuclear Policy began its work in 1957. So did the Campaign for Nuclear Disarmament in the UK. Perhaps the most influential citizen's group that took shape was the Greater St. Louis Citizens' Committee for Nuclear Information. Their 1958 strontium-90 study swept the mainland as mothers sent their baby's teeth to Washington University in St. Louis to be analyzed for that radionuclide.[13] We have seen how John F. Kennedy pointed to that study's conclusions in his speech announcing the end of atmospheric testing in 1963.

The 1963 Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water, or Partial Test Ban Treaty, ended all but underground atomic testing by the major nuclear powers. It also effectively ended the AFL's program in the Marshalls. True, Donaldson and his team would return to the islands, but never with the frequency that they had during testing. Their biological program devoted to fission lost its reason for being. The 1964 summer field trip did allow them to shoot film and make collections at Bikini and Enewetak. But the trip was more about producing "good public relations sort of material" rather than new science.[14] The biologists called their 1964 trip "The Great Glass Ball Expedition," referring to the Japanese glass fishing floats that they liked to collect on Marshallese beaches as souvenirs to bring home to the mainland.[15] They sensed the trip was a

12 Ralph E. Lapp, "Strontium-90 in Man," *Science* 125, no. 3254 (10 May 1957), 933-934.

13 Alvarez and Mangano, "I gave my baby tooth to science," *Bulletin of the Atomic Scientists,* 2021.

14 Lauren Donaldson to Simeon Cantril, 3 February 1964, Box 4, Folder 16, UWLRB.

15 "The Great Glass Ball Expedition of 1964," Box 7, Folder 42, UWLRB. To see Donaldson holding a glass ball at Bikini on the trip, see: https://digitalcollections.lib.washington.edu/digital/collection/donaldson/id/244/rec/1

swansong, because they knew without further atmospheric tests, their expertise in the field had become redundant.

Laboratories without a Purpose

As research tapered off in the Marshalls, the labs that grew out of the old Medical Section looked for ways to forge ahead with their radiobiological research despite the atmospheric test ban. In the moment, the scientists believed that their expertise could still be serviceable within the AEC's expansive biology and medicine program. Though the original conditions that made their research program useful had disappeared with the stroke of a diplomatic pen, Donaldson, Foster, and Warren saw no reason for the institutions they had built to fizzle out. We have already seen how the AFL managed to attach itself to Project Chariot. The biologists also continued salmon research on the University of Washington's campus. Finally, they dove deeply into a long-term research project at Fern Lake on the Kitsap peninsula. Just west of Seattle, the lake had become a new field site for the lab in 1957 when Donaldson initiated studies designed to show how organisms metabolized minerals and radionuclides.[16] This project, the Fern Lake Trace Mineral Metabolism Program, looked and felt much like the study of the biological effects of radiation in the Pacific.[17] The biologists even mapped the small pond like they mapped Bikini and Rongelap's lagoons into the 1960s.[18] But the research program at Fern Lake eventually left behind the presuppositions and practices of the old x-ray animal tradition.

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16 For a comprehensive assessment of the lab's work at Fern Lake, see: Matthew Klingle, "Plying Atomic Waters: Lauren Donaldson and the "Fern Lake Concept" of Fisheries Management," *Journal of the History of Biology* 1998.

17 Lauren Donaldson, Paul Olson, and John Donaldson, "The Fern Lake Trace Mineral Metabolism Program," *Transactions of the American Fisheries Society* Vol. 88 (No. 1), January 1959, 1 – 6.

18 Zella F. Short, R. F. Palumbo, P. R. Olson and J. R. Donaldson, "The Uptake of I(131) by the Biota of Fern Lake, Washington, in a Laboratory and a Field Experiment," *Ecology* 50, no. 6 (Nov., 1969), 979-989.

As the AFL took on graduate students and hired younger researchers, the practices and epistemic frameworks of ecosystems ecology crept in. The new generation of Seattle biologists no longer though in the terms that grew up inside the lab during the war, the ways of seeing radiation by means of histology and population statistics.[19] By 1972 Fern Lake had become an ecosystem and the old tradition had withered.

At Hanford, the end of atmospheric testing heralded the end of plutonium production. The original reactors, that passed Columbia River water as coolant through their cores and back into the great stream, began to close in 1964. With the F Reactor shuttered in that year, Dick Foster's original fish lab in the Quonset hut lost its source of irradiated water. Gone were the troughs of salmon continually exposed to fission products. Foster adapted and climbed up the organization chart within General Electric, the prime contractor at the site during the 1950s and into the '60s. By the 1970s, he became the Associate Director for all the Environmental and Life Sciences at Battelle Northwest Laboratories, General Electric's successor at the site.[20] By the middle of the decade, Battelle labs lost the responsibility of monitoring the Columbia River or doing biological research on local radiological problems to other subcontracts at the site, like the Atlantic Richfield Hanford Corporation.

Similar changes took place at the third Medical Section lab, Stafford Warren's UCLA Atomic Energy Project. Though this lab's story falls out of the scope of this dissertation, it is helpful to look briefly at the lab Warren founded in 1947. He did so when he arrived in LA to serve as the first dean of

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19 For a sense of how ecosystems ecology spread through academia, see Chapter 8, "Defining the Ecosystem," in Sharon Kingsland, *The Evolution of American Ecology,* 2008. For an example of a paper published in an ecosystems mode from the AFL, see: Sigurd Olsen and Douglas G. Chapman, "Ecological Dynamics of Watersheds," *BioScience* 22, No. 3 (March, 1972), 158-161.

20 See: BNWL-SA-3679, Richard Foster, "Effects of Hanford Reactors on Columbia River and Adjacent Land Areas," 15 December 1970, Environmental Monitoring, ROOPRR.

the campus's new Medical School. Warren designed the Project to embody his original vision for the Medical Section, an organization in which doctors and biologists could work side-by-side to explore radiation's biological effects. As atomic testing ramped up, the Project's biologists took on a role at the Nevada Test Site roughly comparable to the Seattle biologists' role at the Pacific Proving Grounds. The two labs routinely shared personnel for field exercises. Warren's research program flourished in LA, especially under the care of his radio-ecology division manager, Kermit Larson. He knew Donaldson's staff since he had analyzed water samples they collected at the Proving Grounds and since Frank Lowman and Ed Held from Seattle worked with Larson at Nevada in 1954.[21] Larson's 1966 magnum opus was the synopsis of Operation Plumbbob.[22] His tome was a final breath for the Medical Section's dying research tradition. The Los Angeles lab went the way of the Seattle lab, to ecosystems research. By the 1970s biology in Nevada was ordered according to a world of energy flows and tropic levels.[23] Meanwhile, research into medical technologies at the Project flourished because of Edward Hoffman and Michael Phelps, who co-invented the positron emission tomography (PET) scanner.[24]

The research program that grew up in the Medical Section laboratories continued in fits and starts after the end of atmospheric testing. The laboratories persisted, but their research no longer tied them to the program of the men who founded those institutions. The Applied Fisheries Lab lost its

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21 For Larson's work for the Seattle lab, see: Allyn Seynour to Kermit Larson, 2 June 1949, Box 1, Folder 30, UWLRB. For the Seattle biologists' time in Nevada, see: Frank Lowman to Kermit Larson, 19 July 1955, Box 5, Folder 7, UWLRB.

22 WT-1488, Kermit Larson, NTALV

23 For a history of ecosystems research at the Nevada Test Site, see: Philip Rundel, *Ecological Communities and Processes in a Mojave Desert Ecosystem* (Cambridge: Cambridge University Press, 1996).

24 Hoffman and Phelps co-authored a key series of articles while there were at UCLA in 1979, articles that pushed PET scanning forward as a technique. See: E.J. Hoffman, S.C. Huang, and M.E. Phelps, "Quantitation in positron emission computed tomography: 1. Effect of object size," *Journal of Computer Assisted Tomography*, 3 (June, 1979), 299-308.

original name. By Donaldson's retirement in 1973, the Applied Fisheries Laboratory had become the Laboratory of Radiation Ecology. By the end of the 1980s, it had ceased to function, its faculty and researchers folded into the University of Washington's School of Aquatic and Fisheries Sciences.[25] The Hanford Fish Lab became the Aquatic Biology lab by the late 1960s. Today the remnants of Hanford biology exist as part of the national laboratory and no longer focus on issues specific to the Hanford site or its environmental remediation, but on general biological research.[26] The UCLA lab underwent a similar metamorphosis It changed names to the Laboratory of Nuclear Medicine and Radiation Biology in the 1960s. In the 1980s it disbanded, leaving its home in Warren Hall. The bulk of the lab has become the nearly unrecognizable Department of Energy-funded Institute of Genomics and Proteomics.[27] The Medical Section labs, as they existed in the 1940s and 1950s, disappeared. The radiation they studied, however, studied remains.

A Never-ending Story

On 10 November 2019, *Los Angeles Times* investigative reporter Suzanne Rust released a series of articles that examined the environmental and health consequences of nuclear testing in the Marshall Islands.[28] In the articles, she documents the history of atomic testing in the Marshalls, explains how

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25 See: https://archiveswest.orbiscascade.org/ark:80444/xv21606?q=applied%20fisheries%20laboratory, accessed 3 October 2022.

26 See: https://www.pnnl.gov/biology, accessed 3 October 2022.

27 The current lab has a sense of its historical origins, but one that is somewhat incomplete. See: David Eisenberg, "UCLA-DOE Institute for Genomics and Proteomics Final Technical Report," https://www.osti.gov/servlets/purl/934813, accessed 3 October 2022.

28 See: Susan Rust, "How the U.S. Betrayed the Marshall Islands, Kindling the Next Nuclear Disaster," 10 November 2019, *Los Angeles Times,* https://www.latimes.com/projects/marshall-islands-nuclear-testing-sea-level-rise; "He saw a Marshall

thyroid disorders have sickened at least 1500 Marshallese downwinders since 1961, and tells stories of Americans who went to the Pacific Proving Grounds to witness thermonuclear tests. In the series, the voices of Marshallese people provide insights into the aftermath of atomic testing. Though Rust mainly seeks to address environmental and health woes that date from the atomic age, she also situates her work in the context of a new environmental crisis: climate change and its attendant sea level rise. Rust draws a clear connection between the legacy of radioactive waste and the problem of warming and rising oceans in the Marshalls. As tides get higher and tropical storms more violent, they stand to disturb the staggering amounts of waste that the US left behind.

Rising sea levels threaten to disturb atomic age waste nowhere in the Marshalls more than on Runit Island in Enewetak Atoll. There, on the far southern tip of the low-lying island, sits the Runit Dome. This acts as a cap for more than three million cubic feet of radioactive soil and other detritus.[29] The dome embodies the US's efforts at cleanup before the Enewetakese people were repatriated to their home atoll in 1980. Today the dome's concrete has crumbled and cracked from both neglect and from the effects of sea level rise, from tides that routinely wash up against the dome. The roughly 600 people who have returned to Enewetak Atoll to live call it "the tomb."[30] Dangerous radionuclides have likely

Islands nuclear bomb test up close. It's haunted him since 1952," 10 November 2019, https://www.latimes.com/world-nation/story/2019-11-10/marshall-islands-nuclear-test-eyewitness; "In Marshall Islands, radiation threatens tradition of handing down stories by song," 10 November 2019, https://www.latimes.com/projects/marshall-islands-radiation-effects-cancer/; "15 months, 5 trips, a gut-wrenching sight: How we reported the Marshall Islands story,"10 November 2019, https://www.latimes.com/world-nation/story/2019-11-10/marshall-islands-radiation-climate-change-reporters-notebook. Note that Rust also describes the chemical weapons testing that took place at Enewetak, a point that Holly Barker has also investigated in her assessment of the Marshalls as a militarized colonial site.

29 Rust, "How the U.S. Betrayed the Marshall Islands," *Los Angeles Times*, 10 November 2019.

30 Ibid.

already begun to leak from the tomb into Enewetak's lagoon. This is a reminder that though atmospheric testing ended in 1963, radiation lingers. Of course, Enewetak is not unique among the

atomic places that the doctors and biologists of the Medical Section once studied. Bikini, Rongelap, Hanford, and the Nevada Test Site all suffer from long-term radiological contamination today.

Figure C.1. The construction of Runit Dome. Source: LLNL-TR-648143, Terry Hamilton, "A Visual Description of the Concrete Exterior of the Cactus Crater Containment Structure," October 2013, Figure 2. This source is in the Public Domain.

Figure C.2. Runit Dome in 2013, showing cracks and discolored concrete. Source: LLNL-TR-648143, Terry Hamilton, “A Visual Description of the Concrete Exterior of the Cactus Crater Containment Structure,” October 2013, Figure 17. This source is in the Public Domain.

Radiation has not just lingered in the Marshallese landscape, it has lingered in Marshallese bodies. Thyroid cancer continues to plague the population. Rust introduces readers to Carlton Abon, who had a cancerous nodule removed from his thyroid in 2016.[31] Surgery can save the lives of most cancer sufferers. The doctors from Brookhaven National Laboratory who worked with Ed Held and the AFL biologists spent much of the 1960s arranging for Rongelapese cancer patients to receive

31 Rust, “In Marshall Islands, radiation threatens tradition of handing down stories by song,” *Los Angeles Times* 10 November 2019.

thyroidectomies. The doctors sent them to the hospital on Guam or to the mainland. But having thyroid surgery often destroys the voice, in particular the singing voice. This has created a cultural crisis for atomic survivors because the Marshallese rely on a long tradition of song to pass on historical memory. Abom was a balladeer in this tradition before he lost his voice. So was Lijon Eknilang, whom we met on the morning of the Castle Bravo disaster in chapter five. Doctors from the mainland removed her thyroid, though she continued to compose songs after the operation. Jessica Schwartz has done extensive fieldwork with members of the Rongelap community to demonstrate how they have melded their tradition of memory and song with their experience of radiation.[32] "Radiation songs take up Marshallese legal and political petitions… [and] work to engage the listener in a call to respond."[33]A couplet of Eknilang's shows the tradition of asking medical questions that have become part of the lament that Schwartz describes:

> Will I ever stop taking pills? Aspirin, calcium, gout medicine, medicine for thyroid
> Will these pills damage my kidneys, my brain, my heart?[34]

For Abom and Eknilang, along with the *hibakusha* who still live and with downwinders from Hanford, the biological effects of radiation have proven inescapable.

Atomic Bodies, Atomic Landscapes has told a story about the US scientists who tried to quantify these inescapable biological effects. This story pushes against canonical stories about the atomic project that are embedded in US memory. These tend to exalt the bomb as sublime or as an artifact of

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32 See: Jessica Schwartz, *Radiation Sounds: Marshallese Music and Nuclear Silences* (Durham, North Carolina: Duke University Press, 2021).

33 Jessica Schwartz, "Radiation Songs and Transpacific Resonances of US Imperial Transits," *Journal of Transnational American Studies* 11, no. 2 (2020), 153 – 171.

34 Rust, "In Marshall Islands, radiation threatens tradition of handing down stories by song," 10 November 2019, *Los Angeles Times.*

raw national power and revel in a uniquely American sense of destiny. These stories focus on brilliant physicists and American industrial largesse. In contrast, this dissertation has argued that nearly invisible biologists and the excesses of American colonialism should figure prominently in any atomic origin stories. Salmon at the Applied Fisheries Laboratory deserve a place just as prominent as Fermi's first reactor at the University of Chicago. The people of Hiroshima and Nagasaki and the people of Rongelap should appear more prominently than the fraternity at Los Alamos. In canonical stories, these people remain at the margins. But in the story of the Medical Section, they existed at the center of a unified, if flexible research program. But their stories humble, rather than exalt, US scientific, technological, and political achievements.

When Susan Rust interviewed Nerje Joseph for the *LA Times* in 2017, the Castle Bravo survivor wondered out loud: "In Los Angeles, you make movies about the Titanic. About people who lost everything. Why don't you make movies about us?"[35] Joseph's remark strikes at the heart of the American atomic narrative. It should be a story about the profound loss of environmental health, the loss of homes and livelihoods, the loss of human health, the loss of life. While Joseph was speaking to a popular audience when she gave her interview for the *Times*, historians might learn from her wisdom. Historians of science should attend to the cost of science, particularly in the 20th century. The losses that have made so many new ways of knowing possible continue to be felt by the often-marginalized people who have been forced to suffer so that federally funded science could thrive. Environments have borne the cost as well. This dissertation has aimed to make plain the workings of how the doctors and biologists of the Medical Section helped create the high human and environmental cost of the US atomic project that endure today.

35 Rust, "How the U.S. Betrayed the Marshall Islands," 10 November 2019, *Los Angeles Times.*

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