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Abstract

This article explores how the concept of ecosystem ecologies, one of the most influential models of systems thinking, was developed in relation to the radioactive aftermath of US nuclear weapons testing in the Pacific Islands. Historian Richard Grove has demonstrated how tropical island colonies all over the globe served as vital laboratories and spaces of social, botanical, and industrial experiment in ways that informed modernity and the conservation movement. I propose a similar relationship between the militarized American island colonies of Micronesia and how their constitution as AEC laboratories contributed to both atomic modernity and the field of ecosystem ecology. This was enacted through metaphorical concepts of island isolation and distributed visually by Atomic Energy Commission films that upheld an aerial vision of the newly acquired atolls for an American audience. Finally, the myth of isolation is also at work in the ways in which Marshall Islanders exposed to nuclear fallout became human subjects for radiation experiments due to the idea of the biological isolate.

Keywords

aerial vision, cold war, ecosystem ecology, Eugene P. Odum, Howard T. Odum, island isolation, Marshall Islands, nuclear, radioactive fallout

The Age of Ecology began on the desert outside Alamogordo, New Mexico on July 16, 1945, with a dazzling fireball of light and a swelling mushroom cloud of radioactive gases.

– Donald Worster, *Nature's Economy*¹

Laboratories generate so many new objects because they are able to create extreme conditions and because each of these actions is obsessively inscribed.

– Bruno Latour, *Science in Action*²

While many scholars have explored the rise of ecological thought, few have traced the close relationship between the rise of the Age of Ecology and the Atomic Age, the multi-constitutive relationship between radioactive militarism and the study of the environment.³ Donald Worster's foundational

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book *Nature's Economy* suggests that nuclear weapon fallout catalyzed public consciousness about the pollution of the environment, while others suggest that the planetary extent of this militarized radiation inspired the modern concept of globalism itself.⁴ Worster's history of environmentalism gives us a vital starting point for assessing the paradox of how Cold War science was utilized to both destroy and conserve nature. Here I build upon his work to examine how American ecosystem ecology, one of the most influential models of environmental thought, was created by scientists funded by the Atomic Energy Commission (AEC), particularly in its surveys of the radioactive aftermath of its Pacific Island nuclear tests. American environmentalism and militarism are paradoxically and mutually imbricated, particularly in their construction of the isolate. Thus the ecosystem paradigm relies on the idea of a closed system, a concept that was constituted by the island laboratory and the irradiated atoll and perpetuated by the aerial view utilized by AEC films to introduce US viewers to the newly acquired island territories in the Pacific Islands. As I will explain, the production of the myth of the biological and geographical isolate has ethical implications, contributing as it did to the AEC's justifications for human radiation experiments on Marshall Islanders for 40 decades.⁵

In 1947, David Lilienthal, head of the AEC, declared that '[t]he atom is center of reality at council tables . . . all over the world. No nation in the world can make decisions these days without thinking of the atom.'⁶ While a mere five atomic weapons had been detonated on earth by then, new uses of the atom were creating dramatic political, scientific, and environmental changes. Since the end of the First World War, nuclear physics grew exponentially; by the 1940s the field was being cultivated by the enormous budgets of the Manhattan Project (1942–46) and the Atomic Energy Commission (1946–74). Although it is not often recognized, these political shifts made a remarkable impact on studies of the environment, a field that was initially considered a 'soft' science consisting of 'butterfly chasers'⁷ until it began to engage with a 'big science' like physics. While nuclear physicists focus on the subatomic and inanimate world, and ecologists privilege observable and living matter, the 20th-century crisis of nuclear fallout brought these disparate fields together. This is remarkable because the new field of quantum physics determined that the subatomic world was not legible if one used the models and laws of classical matter. So while an emergent quantum physics was breaking away from its roots in natural history (*physis* means nature), ecologists sought to bring the fields together by using two key concepts: the island isolate and the flow of energy. Both research concepts grew out of an unprecedented era of US militarization, sustained and often funded by the AEC.

The concept of the island or isolate was vital to ecosystem ecology from the very beginning. In popularizing the new term 'ecosystem' in 1935, the botanist Alfred George Tansley drew from the field of physics to describe the relationship between organisms and their habitat, arguing that one might conceptually isolate ecosystems as a model to study 'the universe as a whole down to the atom.'⁸ He explained: 'The point is to isolate ecosystems mentally for the purposes of study so that the series of *isolates* we make become the actual objects of our study, whether the isolate be a solar system, a planet . . . or an atom. The isolation is partially artificial, but it is the only possible way we can proceed.'⁹ Key to this new conceptual rubric was the theme of isolation, a model that had been deployed in the 19th century to propose the theory of evolution, and which re-energized the longstanding colonial understanding of the island as a laboratory.¹⁰ Tansley's invocation of the atom as a synecdoche for ecosystem ecology was prescient: in less than 20 years, the American militarization of science would usher in a new era of ecological thought drawn from the notion of isolated landscapes permeated with nuclear radiation.

Ecosystem ecology

The theoretical connections made between physics and ecology were largely attributed to AEC-funded research during the Cold War. Joel Hagen has traced out what he calls the 'symbiosis . . .

between atomic energy and ecosystem ecology,' particularly as it was organized by brothers Eugene and Howard (Tom) Odum, the field's 'founding father(s)'¹¹ It is important to note, as do Chunglin Kwa and Stephen Bocking, that it was not the AEC that pioneered this shift in ecological thought. Instead, the development of radiation ecology was due to public pressure on the agency to clean up its nuclear waste and to efforts by some AEC-funded scientists.¹² Global atmospheric levels of militarized radiation (fallout) were alarming the public to such an extent that the field of 'Health Physics' was created to determine the impact on human bodies,¹³ and secret AEC projects such as Operation Sunshine were established to collect cadavers, fetuses, and human limbs from mortuaries around the world to measure radioactive traces in bone and tissue.¹⁴ Like the Manhattan Project before it, the AEC was notoriously resistant to publically admitting any danger from nuclear tests. In fact, the military head of the Manhattan Project, Lieutenant General Leslie Groves, lied to a Special Senate Committee on Atomic Energy in 1945, testifying in the wake of the radiation deaths of Nagasaki and Hiroshima that 'they say it is a very pleasant way to die.'¹⁵ This was counter to the ample evidence of gruesome radiation deaths from the radium dial painters of the 1920s, nuclear accidents in AEC laboratories, and the military's study of postatomic casualties in Japan.¹⁶ Although the AEC's stance was to publically deny any human or environmental impact from the nuclear tests, as early as 1952, two years before the first thermonuclear weapon, the head of Brookhaven Laboratory's Health Physics Division admitted that 'the days of undisturbed natural background (radiation) are gone perhaps forever, as a result of the continuing detonations of atomic bombs.'¹⁷

With the rapid expansion of nuclear testing in the Cold War and the subsequent radiological contamination of the planet, the AEC contracted a number of biologists to study the radioactive fallout from the newly acquired American territories in the Marshall Islands (Micronesia).¹⁸ Appropriated under the unprecedented concept of a US-Navy controlled 'Trust Territory' (Article 82 under the UN Charter), Micronesia became a nuclear colony under President Truman's doctrine of oceanic colonialism. Thus at the start of the Cold War the US enacted a state of exception to appropriate an enormous portion of the Pacific to detonate hundreds of deadly weapons, rationalized by the misconception of island isolation. Of course, the radioactive by-products of these weapons were never contained to a presumably isolated atoll and were distributed globally.¹⁹ In claiming Micronesia and expanding the American exclusive economic zone, Truman tripled the territorial size of the United States.²⁰ Although the land-base of Micronesia is 846 square miles, the oceanic territory, vital to US naval and airforce transit, represents three million square miles.²¹ By 1946, the AEC began relocating islanders in order to detonate atomic and hydrogen weapons in the atolls, turning the Marshall Islands into a 'Proving Ground.' With the advent of the far more powerful hydrogen weapons, the AEC in 1954 cordoned off an enormous area of the Pacific, banning the passage of ships or planes for 400,000 square miles.²² This was in direct contradiction to the international law principle of freedom of the seas, which stipulated unrestricted international access for navigation, fisheries, submarine cables, and flight above the high seas.²³

Eugene and Howard Odum were sent to Enewetak Atoll in 1955, and thus the field of what they termed 'radiation ecology' began in the Pacific with their study of a chain of islands that functioned as an AEC laboratory for nearly 50 nuclear weapons tests between 1948–58. So irradiated was the marine life in Bikini Atoll that the fish produced auto-radiographs; impressing their own images onto photographic plates and film.²⁴ By the time the Odums arrived for their six-week study, 18 nuclear weapons had been detonated at Enewetak and Bikini Atolls. This began with Operation Crossroads, tests *Able* and *Baker* at Bikini Atoll in 1946, weapons that so irradiated the islands that the Bikinians, originally asked to vacate for a few weeks, were permanently displaced from their homeland. The extensive radioactive fallout from the *Baker* shot became a scandal and caused President Truman to cancel the third test of the operation. According to Paul Boyer, 'it was Bikini, rather than Hiroshima and Nagasaki, which first brought the issue of radioactivity compellingly to

the nation's consciousness.²⁵ Operation Sandstone was staged in 1948 and Operation Greenhouse, a series of four nuclear explosions, was executed in 1951. Richard Grove has argued that Europeans utilized their tropical island colonies as botanical laboratories or greenhouses for experiments in transplantation and hybridization.²⁶ The name of this 1951 operation overtly labeled the islands as a contained ecological space, a 'greenhouse' for experiments in nature/physics. Ironically, AEC films of these test areas demonstrate that the islands are denuded of botanical life; they are paved over for military transport and anything but green.

The Odums arrived shortly after Operation Ivy, another naturalizing and 'green' title for deadly experiments in nature/physics. This important test was known for the world's first thermonuclear (hydrogen weapon) explosion called *Mike*, a 12-megaton device that produced a mushroom cloud 25 miles high and 100 miles wide. *Mike* blew the island of Elugelab out of existence, leaving a 6200 foot wide crater, giving new meaning to the term 'zero-island' (Figure 1). In the words of the AEC film *Operation Ivy*, 'in the early months, Elugelab was just another small naked island of the atoll but by midsummer, it began to look like the thing it was selected for: a shot island.'²⁷ As such, the repeated production of island craters suggests the AEC's nuclear testing program was dependent on an island laboratory that then became its opposite. In the words of E.B. White in *The New Yorker*, the 'laboratory was a paradise' and they conducted 'an experiment in befouling the laboratory itself.'²⁸

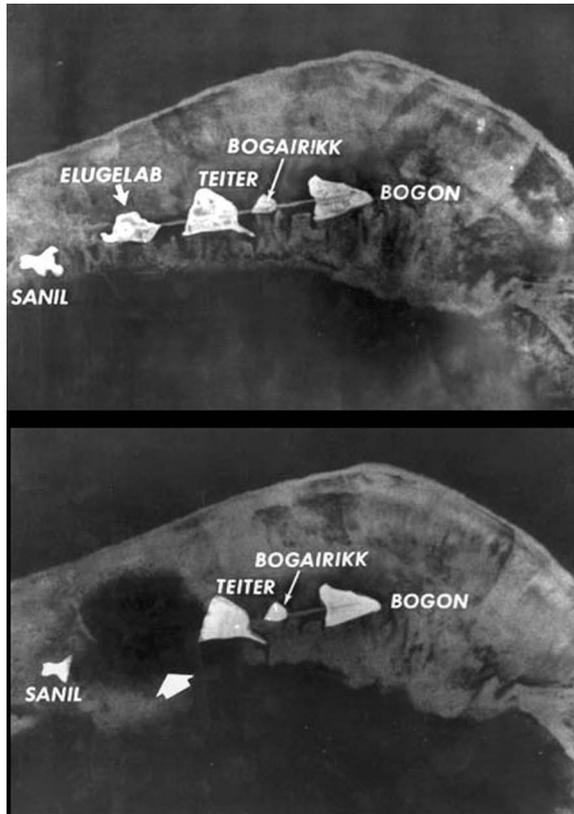


Figure 1. Elugelab crater

The most controversial test of all, the reason why the AEC started to increase its funding to the field of radioecology, was Operation CASTLE, a series of six nuclear explosions at Enewetak and Bikini Atolls in 1954 that featured the notorious 15-megaton thermonuclear weapon *Bravo*, which left a crater (or ‘anti-island’) 6500 feet wide and 250 feet deep (Figure 2). Hydrogen weapons are some of the radioactively ‘dirtiest’ of nuclear devices due to their outercasing of uranium²³⁸, which has a half-life of over 200,000 years.²⁹ As is well documented, *Bravo* covered the surrounding islands with radioactive strontium, cesium, and iodine, and became an ecological and political relations disaster. In addition to exposing a Japanese fishing vessel to lethal levels of radiation that killed its crew and created a transpacific ban on consuming fish, *Bravo*’s fallout exposed hundreds of Marshall Islanders to nuclear radiation, contributing to countless miscarriages, leukemia deaths, thyroid cancers, and the kind of chromosome damage that knows no temporal or genealogical limit. It covered the neighboring island of Rongelap with radioactive ‘snow’ and permanently displaced its residents due to continuing lethal levels of cesium¹³⁷, even 40 years later.³⁰ The 1954 Petition from the Marshallese People Concerning the Pacific Islands: Complaint Regarding Explosions of Lethal Weapons within Our Home Islands, an ‘urgent plea’ to the UN to cease the tests due to extreme radiogenic illness and land displacement, went unheeded.³¹ In the clinical words of the AEC film *Operation Castle*: ‘These islands, functioning as *accidental total fallout collectors*, gave us our first real clues to the vast area affected by contamination from a high yield surface burst.’³²

Estimated at one thousand times the force of the bombs dropped on Hiroshima and Nagasaki, *Bravo* has been called the worst radiological disaster in history. In addition to spreading lethal levels of radiation over 5000 miles of the Pacific,³³ *Bravo*’s fallout was detected in the rain over Japan, in lubricating oil of Indian aircraft, in winds over Australia, and in the sky over the United States and Europe.³⁴ It caused the radiogenic illness of the crew of a Japanese freighter 1200 miles away.³⁵ Designed as a weapon of radiological warfare, *Bravo* catalyzed a worldwide outcry against the H-bomb and forced the AEC to more thoroughly assess the radiation impact of its weapons testing program.³⁶ In the antinuclear activism that followed, the militarized island became configured as a synecdoche for the world. The irradiated atoll, as an ‘anti-island’ or ‘zero-island,’ became a catalyst and signifier for a global consciousness about an increasingly militarized planet.³⁷



Figure 2. Bravo crater

Western colonizers had long configured tropical islands into the contained spaces of a laboratory, which is to say a suppression of island history and indigenous presence. This generation of AEC ecologists embraced nuclear testing as creating a novel opportunity to study a complete ecosystem through the trace of radiation. As the Odums remarked, '[s]ince nuclear explosion tests are being conducted in the vicinity of these inherently stable reef communities, a *unique opportunity* is provided for critical assays of the effects of radiations due to fission products *on whole populations and entire ecological systems* in the field.'³⁸ Although Enewetak and Bikini were already heavily irradiated, the Odums injected additional radioactive isotopes in order to study ecological metabolism. While it seems paradoxical for ecologists to celebrate the 'opportunities' provided by irradiated landscapes and displaced peoples, Frank Benjamin Golley, one of Odum's colleagues, remarks that they all 'seemed oblivious to the connection between ecosystem research and the military activity of the U.S.'³⁹

Of course, AEC-funded ecologists were also studying the radioactive impact of non-island sites, such as nuclear power plants, nuclear dumps, and the impact of weapons tests in the continental US.⁴⁰ Yet I want to underline the importance of the island as isolate as a conceptual rubric as vital to a historical moment that brought together newly acquired island territories, the development of ecosystem concepts of closed space, and nuclear militarism that relegated these islands to laboratories. Understood as a 'landmark in ecological research,'⁴¹ the Odums' work on the irradiation of Enewetak's coral reefs provided ecologists with a model of a structured, self-regulating ecosystem and the first theorization of shared resource relationships in nature, which they termed 'mutualism.'⁴² As such, systems ecology emerged from the field of 'radiation ecology' in the Pacific Islands.⁴³ The concept of the closed system or isolate was tied closely to the colonization of islands and rendering them into nuclear laboratories. After researching in Enewetak and publishing about what he termed the 'strontium ecosystem,' Howard Odum coordinated a research grant from the AEC to irradiate El Verde, a tropical rainforest in Puerto Rico, which killed various plants, trees, animals and birds. Describing a project that irradiated the forest with cesium¹³⁷ and strontium⁸⁵, Odum, senior researcher at the University of Puerto Rico's AEC-run Nuclear Center, concluded that the El Verde forest was an ideal 'teaching laboratory.'⁴⁴ Ironically, one of the major catalysts for the study was the discovery in 1962 of high fallout levels in the El Verde mountains from the atmospheric testing of nuclear weapons in the Pacific Islands.⁴⁵ As such, their model of the ecological or biological isolate was already rendered a fabrication by the global distribution of militarized radioactive fallout.

An American empire of tropical islands, circling the globe from the Pacific to the Caribbean, became a strategic space for military experimentation and the production of new scientific epistemologies like ecosystem theory. The militarization of the atom created the new availability of radioactive isotopes, allowing the Odums and their contemporaries to study nuclear fallout and waste sites as well as to introduce radioactive tracers into the environment to determine how energy was transformed in a presumably contained system. By comparing Enewetak and Puerto Rico, Howard Odum hoped to use the concept of *energy* as a 'universal principle' of any ecosystem.⁴⁶ Thus, ecosystem theory encodes a tension between the ways in which the island is thought to contain and concentrate space, and the concept of energy, which is understood in relation to mobility and transmission. The AEC's support of ecosystem ecology must be considered influential to 20th-century theories of energy and space, particularly when we consider the islands that were subjected to Cold War irradiation. This is how Howard Odum came to conclude that 'ecological and biochemical cycles' are 'driven by radiant energy.'⁴⁷ It seems no coincidence that the enormous energy released by the splitting of the nucleus of an atom suddenly became a universal framework for understanding any isolated system. As Chunglin Kwa argues, the Odums hoped that this model of

how energy moves between elements of nature would 'revolutionize' ecology.⁴⁸ Since to revolutionize is to break from institutional models rather than to assimilate them into the nuclear politics of the military state, one could not really say the Odums' work 'revolutionized' ecology, but it certainly catalyzed remarkable institutional expansion. AEC-funded research laboratories and over 50 programs in radiation ecology (radioecology) were organized in universities and at nuclear power sites all over the United States, creating what Golley terms an 'invisible college'⁴⁹ and catapulting ecosystem ecology into a veritable institution.⁵⁰

From our contemporary viewpoint, the ecologists' obliviousness to the militarization of their research may seem incredulous. Yet this militarization of space also permeated the language of ecosystem ecology. For instance, Eugene Odum's 1957 article, 'Ecology and the Atomic Age,' argued that:

science advances on a *broad front* . . . It is analogous to the advance of *an army*; a breakthrough may occur anywhere, and when one does it will not *penetrate* far until the *whole front* moves up. Thus, ecologists need not feel bashful about *attacking ecosystems* so long as they observe the rules of good science.⁵¹

Although Eugene Odum is considered an inspiration to the environmental movement because his theories integrated humans into natural systems,⁵² his Cold War writing demonstrates the mutual permeability of the militarization of the island laboratory, science, and the language of ecosystems. In bracketing off ethics in this war for knowledge, Odum's model of the ecosystem positions laboratory space outside of history (i.e. human presence) and accountability, encouraging scientists to 'attack' environments already devastated by nuclearization. This grammar of assault is possible because of an American empire sustained by the concept of an isolated and ultimately disposable laboratory, at once conceptually isolated from indigenous presence and yet, as recent research demonstrates, also demanding human subjects for experimentation.

Visualizing the laboratory

I would like to turn to how islands were conceived by their continental visitors in order to tease out this relationship between the concept of the laboratory and the ecosystem. Since ecosystem ecology is modeled on the concept of a closed system, it is no coincidence that island colonies were chosen for nuclear tests and their radioactive surveys. While often deemed peripheral to modernity, we know that islands have in fact been at the center of the development of modern ecological thought. As I mentioned, historian Richard Grove has demonstrated how tropical island colonies all over the globe served as vital laboratories and spaces of social, botanical, and industrial experiment in ways that informed 17th- and 18th-century modernity and the conservation movement that followed. I would like to propose a similar relationship between the militarized American island colonies of Micronesia and their constitution of atomic modernity and the field of ecosystem ecology.

Just as the AEC manipulated landscapes in an era of what Ward Churchill calls 'radioactive colonialism,' the new field of ecosystem ecology emphasized the management of the environment in a way that could be extended to social relations.⁵³ Thus, the ecosystem is based on the concepts of the closed system, stabilization, and control. In the words of historian Gregg Mitman:

Ecology not only appropriated military funds, it also appropriated the cybernetics narrative that emerged from military research on aircraft-missile guidance systems. The ecosystem blurred the distinction between inorganic and organic by reducing everything to energy as the common denominator. Nature had become a system of components that could be managed, manipulated, and controlled.⁵⁴

Part of this process of communicating the significance of the newly acquired Pacific territories to the average continental American was through film, particularly the use of an aerial view that demonstrated how the island could be ‘managed, manipulated, and controlled.’ The conversion of populated islands into ahistorical laboratories of radiological experiment is particularly visible in AEC films of the 1950s, newsreels that were released to American audiences that utilized aerial surveillance as vital to the scientific and military control of the Marshall Island atolls. While some have argued that the development of the 20th-century aerial view could lead to a new transnational consciousness and to the blurring of the boundaries between nations, Gillian Beer points out that the aerial view of an island reinscribes the concept of boundedness, since ‘centrality is emphasized and the enclosure of land within surrounding shores is the controlling meaning.’⁵⁵

Elsewhere I have argued that the production of the isolated island requires the erasure of the technologies that enable mobility. In other words, this concept of isolation suppresses the ships and airplanes that make travel to islands possible.⁵⁶ Thus, the tropical island is configured as distant and isolated even as it becomes accessible – through print, photography, or film – to the reader/viewer. With the democratization of air travel in the mid-20th century, the vision of islands shifted from a ‘deck-eye’ view of an arrivant ship to an aerial view. The US military films of Micronesia excessively employ an aerial view that renders the atolls into a panopticon, thus domesticating (and destroying) new territories for the consumption of the American public. For instance, in the film *Operation Greenhouse* (1951), the AEC employs an aerial view to juxtapose the modernity of American science – the master lab at Los Alamos – against the purportedly ahistorical and depopulated Marshall Islands, which are viewed with detachment from a military plane. As such, modernity is seen to be exported from the US to ‘distant and primitive’ yet vitally important ‘test islands . . . a giant lab in the middle of an ocean.’ To quote from this Hollywood-produced film:

One of the proving grounds is an outdoor laboratory: Enewetak Atoll in the Pacific. This Trust Territory of the United States has been used before as a testing ground for Operation Sandstone (1948). But three years have passed, three years to bring new and improved atomic weapons to this secluded equatorial land . . . Since Enewetak is a distant and primitive area, men have to leave their stateside laboratories and homes for a period of months. [*Image of an American man with suitcase entering his car and waving goodbye to son and dog*]. Now the proving grounds come alive like a university campus when students return from a summer holiday . . . [*aerial view of islands from military plane*] these are the dormitories of ‘Enewetak university’ . . . individual test islands, seemingly like so many science buildings on college grounds.⁵⁷

In its persistent references to flight and aerial images of the islands, this film harnesses what Denis Cosgrove has termed the ‘Apollonian eye’, a gaze that is ‘synoptic and omniscient, intellectually detached’⁵⁸ as it surveys a colonial island laboratory and presents it as an extension of the long reach of the arm of the US Air Force. As Cosgrove and Fox point out, ‘widespread familiarity with the aerial view in the post-war years came not only from actual flights, but also – for most people – from photographs . . . newsreels and movies.’⁵⁹

It is no coincidence that the first inter-continental ballistic missile (ICBM) developed in subsequent years was called Atlas; as Cosgrove has demonstrated, aerial vision has long been tied to conceptualizations of the globe and often to territorial claims over it.⁶⁰ The airplane radically changed the perception of space and time, producing an ‘aerial subjectivity’,⁶¹ a cosmic view or aerial gaze born out of colonial mapping practices and tied to the often violent geopolitics of knowledge accumulation.⁶² ‘The airman’s vision evolved into a powerful trope not only for military strategy . . . but also for political shaping of the postwar global order.’⁶³ This was particularly important for the large oceanic spaces of the Pacific, which were visualized aerially in US military

films. Released in 1951, *Operation Greenhouse* predates the *Apollo* space mission photographs of the earth (1969–71) so a photographic global vision was not yet possible. However it is prefigured in these US military surveillance films in which the island is a world, a microcosm of the potential global destruction that would be unleashed should this nuclear warfare be expanded to other targets outside the Pacific Island colonies.⁶⁴

While ‘vision has been the privileged sense in Western science’ for centuries⁶⁵ it was through airplane technologies since WWI that new ideas of space, vision, photography, and patriotic nationalism came together.⁶⁶ Flight and cinematic photography emerged nearly simultaneously and are constitutive of modern war.⁶⁷ Ernst Junger has argued that ‘war making and picture taking are congruent.’⁶⁸ That was certainly the case in the Pacific Proving Grounds, where the 1946 Operation Crossroads test at Bikini Atoll was recorded by 1,500,000 feet of film and over 1 million still pictures.⁶⁹ Paul Virilio has argued that ‘if you can see a target you can destroy it’⁷⁰ and this seems to be confirmed by the US nuclear tests in the Marshall Islands, where islands become, in Godfrey Baldacchino’s words, ‘*tabulae rasae*, potential labs for any conceivable human project.’⁷¹ As Baldacchino and others have argued, the Pacific Islands have long been fashioned as laboratories for western colonial interests, from the botanical collecting of James Cook’s voyages to Darwin’s theories of evolution to structural anthropology.⁷² In the words of one historian, ‘the Pacific and its peoples were both a *laboratory* for the study of human prehistory and a major *testing ground* for Enlightenment and subsequent science.’⁷³

Ecosystems ecology drew from the grammar of the AEC and its nuclear tests and therefore it is not surprising that it focused on energy as a universal means of exchange and that it upheld the concept of isolated spaces. While the film *Operation Greenhouse* juxtaposes the complex laboratories and lives of Los Alamos with the depopulated and defoliated Enewetak Atoll in ways that emphasize that they are bringing ‘new and improved atomic weapons to this equatorial land’ – that is to say civilization to the savages, an old colonial trope – we see the ways in which space is not, as Johannes Fabian might say, coeval.⁷⁴ In this narrative, modernity emanates from the US colonial center, visible in the way in which the camera lingers on the uniformed officers, airplanes, and laboratory space, and is being imported to the tropical island, bereft of history and indigenous inhabitants. Thus it produces a paradox, a ‘distant and primitive area’ yet at the same time a place of ‘individual test islands’ much like the ‘science buildings on college grounds.’ In positioning Los Alamos as a ‘modern pueblo’ as much as an ‘atomic city’ and ‘isolated mesa,’ the film *Operation Greenhouse* unwittingly suggests the ways in which indigenous appropriation and erasure in both the American west and its new frontier, the Marshall Islands, are constitutive in visualizing and creating the concept of the isolated laboratory.

Rethinking the ways in which science used the isolated island concept to produce some of the most apocalyptic technologies on earth challenges both the assumption of the primitive ahistorical island and what constitutes the laboratory itself. For instance, David Livingstone’s *Putting Science in its Place* argues that there are four distinct spaces of science: The space of manipulation (the lab); the space of expedition (the field); the space of presentation (museum); and the space of circulation (the archive).⁷⁵ *Operation Greenhouse* suggests that these spaces were condensed in the Pacific Proving Grounds. The space of masculine expedition, signaled in the film by the Los Alamos scientist leaving his boy and dog to travel to the Pacific, is not a field so much as ‘a giant lab in the middle of an ocean.’ The excessive photographic documentation of the Pacific nuclear tests, where the high speed camera and color film were developed, suggests that the ‘field’ is also the space of presentation and of circulation, in which one tropical island stands in for the next, a virtual archive of nuclear irradiation, and a virtual island laboratory. Yet the visual production of nuclearization has amnesic effects. This is precisely the structure of erasure theorized by Teresia

Teaiwa about how extreme visibility, evidenced in the ways in which the bikini bathing suit emerged from nuclear colonialism and suppressed the histories of 's/pacific' islands.⁷⁶

Metaphoric displacement

Teaiwa's groundbreaking work on the historical and semantic production of the radiation-prone bikini helps us understand the function of 'objectification through excessive visibility,'⁷⁷ a process of erasure that is fundamentally tropological. As a form of trope, metaphor moves from one object to another – in this case, island to laboratory – in a way that foregrounds resemblance and renders what might be invisible visible.⁷⁸ But metaphor is equally about displacement, subsuming other possible modes of relation between objects and suppressing the ways in which the island is not a laboratory and vice versa.⁷⁹ Metaphor is how nonhuman nature is rendered knowable and, following Girard Genette, the way that 'language spatializes itself' so that space becomes language and thus articulates itself to us.⁸⁰ Thus remote islands of the Pacific, for American viewers, become legible by likening them to island laboratories. This displaces the inhabitants of these islands who must be suppressed in order to naturalize the islands as nuclear testing zones and laboratories, bereft of human history. Thus in the AEC's aerial surveillance films, images of the Marshall Islanders have been removed, their housing and cemeteries plowed down. Even the foliage has been bulldozed 'for elbow room' as one AEC film declares, fashioning a laboratory and also a tropical playground for soldiers to play volleyball and sunbathe.⁸¹ Marshall Islanders rarely appear in these films, except a brief appearance of displaced Bikinians where the narrator declares, 'the islanders are a nomadic group, and are well pleased that the Yanks are going to add a little variety to their lives.'⁸² Generally speaking, the human subjects who appear in these films are American scientists at work with instruments, generals explaining military exercises to the audience, and servicemen – future Atomic Veterans – at leisure on the beach. Such images anticipate Teaiwa's theorization of what she terms 'militourism,' the mutual constitution of the tourist and military industry in the Pacific Islands.⁸³ In erasing the presence of the islanders, AEC newsreels instead celebrate the collection of scientific data, the nuclear yield, and the size of craters or 'zero islands' left behind. Employing an Apollonian eye, the films encourage the US audience to become vicarious masters of all they surveyed, inscribing a new era of empire.

Native Pacific Studies has long emphasized a horizontal view produced from the centrally located voyaging canoe, in which the islands, ocean and stars are seen to move towards the voyager.⁸⁴ Vicente Diaz's theorization of the 'moving island' foregrounds the dynamism of animate space, a place from which we might glean the 'currents' of militarization 'across spatial and temporal boundaries,' to borrow from Setsu Shigematsu and Keith Camacho.⁸⁵ In contrast, the aerial gaze of these AEC films displaces horizontal island stories – the complex social and historical relations between the islands, the creation of nuclear nomads and the political legacies of the displacement, as well as the history of the AEC's collection of the islanders' biomaterial without consent for decades after the tests. The island as laboratory metaphor – and the aerial gaze – displace the most criminally and ethically negligent results of these 67 nuclear tests in the Marshall Islands, such as the occupation and contamination of the environments and people of the western Pacific and the denial of their well-being by a Cold War superpower that held them 'in trust,' as assured under UN Article 73. Moreover, the AEC medical experiments conducted on the Marshallese are in violation of the 1949 Geneva Convention and the 1998 Rome Statute of the International Criminal Court.⁸⁶

The recent work of Barbara Rose Johnston and Holly Barker has brought to light disturbing evidence that suggests intentionality of radiation exposure. For instance, the Rongelap islanders

had been relocated for previous nuclear tests but not for *Bravo*, even though this test was designed to spread radiation. The Rongelapese were covered in radioactive fallout and not evacuated for three days even though neighboring servicemen were removed within 24 hours. While the US had blamed the fallout on a last-minute weather change, recently declassified documents demonstrate that the Navy knew about the wind shift towards Rongelap hours before the nuclear test.⁸⁷ In the language of the AEC, the boundedness of this chain of islands was thought to allow the division of 'test' and 'control' groups to indicate radiation exposure, but as recent work demonstrates, all 28 Marshall Islands were seriously contaminated with fallout, not merely the four islands indicated by the AEC.⁸⁸ (In fact, one of the northern Marshall Islands has been declared by the AEC as uninhabitable for 25,000 years.)

The declassification of a 1957 memo from Brookhaven National Laboratory's medical researcher Dr Robert Conard, the doctor in charge of testing and caring for the hundreds of Marshallese exposed to radiation, has confirmed suspicions that it was the islanders as much as the environment that were subject to an AEC experiment. To his colleagues he wrote, 'The habitation of these people on the island will afford most valuable ecological radiation data on human beings.'⁸⁹ Arguments like this appear elsewhere in AEC records. For instance, the director of the AEC Health and Safety Laboratory described neighboring Utirik Atoll in 1956 as 'by far the most contaminated place in the world' but that it will be 'very interesting' to get data from the environment and islanders when they are returned there. Referring to genetic tests about the impact of radiation on fruit flies and mice, he observed of the Marshall Islanders: 'While it is true that these people do not live, I would say, the way Westerners do, civilized people, it is nevertheless also true that these people are more like us than mice.'⁹⁰ As Mbembe observes about the state of exception that characterizes the racism of colonial rule, 'in the eyes of the conqueror, *savage life* is just another form of *animal life*, a horrifying experience, something alien beyond imagination or comprehension.'⁹¹

Johnston and Barker's work not only brings to light how the Marshall Islands were used as living ecological laboratories but also documents that the Rongelapese were used for human subject research for four decades without their knowledge or consent.⁹² From 1954 until their removal by Greenpeace from contaminated Rongelap in 1985, the islanders were studied by AEC scientists but not always treated and rarely informed about the nature of their illnesses. For instance, when the Rongelapese were first exposed to *Bravo* fallout, some with radioactive burns over 90 percent of their bodies and causing skin to peel down to the bone, they were not given pain medication.⁹³ With the declassification of the AEC's Project 4.1, 'Study of Response of Human Beings Exposed to Significant Beta and Gamma Radiation Due to Fallout from High Yield Weapons,' evidence has come forward that scientists collected blood, tissue, bone marrow and teeth samples for decades – extracting even perfectly healthy teeth – to measure bioaccumulation without consent.⁹⁴ When Rongelapese women began giving birth to babies without skulls and without skeletons ('jellyfish babies' and 'grape babies'), infants with severe brain damage and missing limbs, scientists informed them that these miscarriages and defects were 'to be expected in a small island population.'⁹⁵ Although scientists from the AEC Division of Biology and Medicine had ample evidence of the extensive radiological contamination of Rongelap, they allowed the islanders to return in order to deflect criticism of the AEC's atmospheric testing program, and thus exposed the islanders to another 22 nuclear tests on Enewetak and possibly to biological weapons tests.⁹⁶ Moreover, they did not warn against the consumption of certain plants, animals, and fish that bioaccumulate and concentrate deadly levels of cesium¹³⁷, strontium⁹⁰, and iodine¹³¹, the most lethal isotopes to humans.⁹⁷

Over the course of 67 nuclear tests, many of which were designed to spread deadly radioactive isotopes, the Marshall Islanders were exposed to over 8 billion curies of iodine-¹³¹. Comparatively,

the Chernobyl accident, widely known as one of the world's worst radiological accidents, released 50 million curies.⁹⁸ Their return home exposed the Rongelapese to another three decades' worth of additional radiological contamination without ample medical treatment, except for annual visits from AEC director Robert Conard, which Barker and Johnston have shown were visits focused on sampling bones and tissues. Even more disturbingly, this population, perhaps the most radiogenically exposed and studied people on earth, was subjected to the injection of radioactive isotopes without their knowledge or consent.⁹⁹ Despite the excessive surveillance and documentation of their radiogenic illnesses, to this day the majority of affected islanders have been refused access to their medical records and have inadequate medical treatment. The Department of Energy Advisory Committee on Human Radiation Experiments concluded in reviewing this history 'that the AEC had an ethical imperative to take advantage of the unique opportunity posed by the fallout from *Bravo* to learn as much as possible about radiation effects in humans.' In light of this response we can understand why, as Linda Tuhiwai Smith observes, "research" is probably one of the dirtiest words in the indigenous world's vocabulary.¹⁰⁰

After decades of suffering, the Rongelapese magistrate Nelson Anjain had this to say in an April 1975 letter to Conard:

Your entire career is based on our illness. We are far more valuable to you than you are to us. You have never really cared about us as people – only as a group of guinea pigs for your government's bomb research effort. For me and for other people on Rongelap, it is life which matters most. For you it is facts and figures. There is no question about your technical competence, but we often wonder about your humanity . . . We want medical care from doctors who care about us, not about collecting information for the US government's war makers . . . America has been trying to Americanize us by flying flags and using cast-off textbooks. It's about time America gave us the kind of medical care it gives its own citizens . . . We no longer want you to come to Rongelap.¹⁰¹

While ecosystem ecology did not catalyze the AEC's decision to detonate 67 nuclear weapons in the Marshall Islands and to study radiological data on humans, we must raise the vital question as to how, as a methodology and system of thought, it sustained the concept of isolation, despite all evidence to the contrary. Elsewhere AEC studies of the same era were experimenting with radioactive isotopes on indigenous peoples in the Amazon and Alaska based on a similar concept of the 'biologically discrete.'¹⁰² This model of isolation perpetuates the neat division of 'test' and 'control' groups, and the presumed isolation of the Marshall Islands colonies from the continental US and its responsibility to the rule of law. As I have argued elsewhere, the colonial concept of island isolation has worked – too effectively – to suppress the ongoing history of military expansion and new forms of colonialism.¹⁰³

Ecosystem ecology, with its emphasis on closed systems, management, control, and equilibrium, drew tremendous support in part because it was appealing to the military, which sought to expand its weapons testing program, and to industry, which began working with the AEC to capitalize on the opportunity to build more nuclear plants.¹⁰⁴ Although it was discarded as a scientific model in the 1960s for more dynamic approaches to the environment, as late as 1968 Glenn Seaborg, the Chairman of the AEC, had this to say in a press release:

While Bikini is best known as a weapons testing site, it has also contributed significantly to man's knowledge of the long term effects of radiation on an environment. During the years when radiation levels were too high for people to live there permanently, the AEC sponsored several scientific studies on the atoll. In fact, Bikini truly served as a living ecological laboratory.¹⁰⁵

Metaphor not only connects two disparate entities but validates and naturalizes this new relationship and thus is crucial to constructing new paradigms of knowledge.¹⁰⁶ This has not been lost on theorists of the lab such as Bruno Latour, who has long argued against the concept of the bounded laboratory, and Isabelle Stengers, who argues ‘isolation is a dangerous game, and those who can purify their objects in fact intervene actively in the significance of the object they observe.’¹⁰⁷ Clifford Geertz has observed that the ‘the natural laboratory notion has been . . . pernicious, not only because the analogy is false’ since parameters are always porous, but because the data is no more pure or fundamental.¹⁰⁸ In *Nuclear Playground*, Stewart Firth deconstructs the island laboratory metaphor, arguing

[t]he nuclear bomb men have always assumed that atolls and deserts are a long way from anywhere. But they are wrong. Nuclear explosions in the atmosphere, which occurred frequently in the Pacific Islands between 1946 and 1975, were global in effect . . . In preparing for war we were poisoning our planet and going into battle against nature itself.¹⁰⁹

The lie of isolation has indeed been a dangerous game, to the Marshall Islanders especially, and beyond. Due to these thermonuclear weapons, the entire planet is permeated with militarized radiation. *Bravo* and the subsequent 2000 or so nuclear tests on this planet, Eileen Welsome observes, ‘split the world into “preatomic” and “postatomic” species.’¹¹⁰ Radioactive elements produced by these weapons were spread through the atmosphere, deposited into water supplies and soils, absorbed by plants and thus into the bone tissue of humans all over the globe. The body of every human on the planet now contains strontium⁹⁰, a man-made byproduct of nuclear detonations¹¹¹ and forensic scientists use the traces of militarized radioactive carbon in our teeth to date human remains (as before or after the 1954 *Bravo* shot).¹¹² At very conservative estimates, these nuclear weapons tests have produced 400,000 cancer deaths worldwide.¹¹³

There is a long history of using the myth of island isolation to mystify the extent of the military irradiation of the planet and to deflect from what many would suggest are human rights violations in the Marshall Islands. As a transoceanic culture, Pacific Islanders have not historically harbored a binary division between land and sea nor have they conceived of their islands, before colonialism, as peripheral to an American metropolitan center. With this horizontal view, we might say that many in the region might wish for *more* isolation from the United States and its expanding military (especially given the post 9/11 build-up in Hawai‘i and Guam). The late anthropologist Epeli Hau‘ofa has importantly argued against the colonial concept of isolated islands and brought our attention to a dynamic ‘sea of islands’ long connected by histories of migration, nuclear colonialism and globalization. A world of islands.¹¹⁴ Thanks to their irradiation, we all carry a small piece of that island world in our bones.

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Notes

1. D. Worster, *Nature's Economy: A History of Ecological Ideas*, 2nd ed. (Cambridge: Cambridge University Press, 1994), p. 339.

2. B. Latour, *Science in Action: How to Follow Scientists and Engineers through Society* (Cambridge, MA: Harvard University Press, 1987), p. 90.
3. In addition to Worster, vital contributions connecting the US rise of ecology with federal nuclear weapons programs include S. Bocking, M. Klinge, C. Kwa, F. Golley, J. Hagen, S. Kingsland, and S. Kirsch.
4. Worster, *Nature's Economy*, p. 339; E. DeLoughrey, 'Radiation Ecologies and the Wars of Light.' *Modern Fiction Studies* 55(3), 2009, pp. 468–495; J. Masco, 'Bad Weather: On Planetary Crisis.' *Social Studies of Science* 40(1), 2010, pp. 7–40.
5. This essay traces military developments under the jurisdiction of first the Manhattan Project (1942–46), then the Atomic Energy Commission (1946–74), and finally the US Department of Energy (1974–present).
6. Quoted in Daniel Lang, *From Hiroshima to the Moon* (New York: Simon and Schuster, 1959), p. 89.
7. S. Bocking, *Nature's Experts: Science, Politics, and the Environment* (New Brunswick, NJ: Rutgers University Press, 2004), p. 18.
8. A. Tansley, 'The Use and Abuse of Vegetational Concepts and Terms', in D. Keller and F. Golley (eds), *The Philosophy of Ecology* (Athens, GA: University of Georgia Press, 2000), p. 64.
9. Tansley, 'Vegetational Concepts', p. 64.
10. The concept of isolation has been vital to theories of ecology, evolution, and the laboratory. The works of Charles Darwin and Charles Lyell are famous for utilizing the concept of the biological isolate and this was developed by Robert MacArthur and Edward Wilson in their influential *The Theory of Island Biogeography* (Princeton, NJ: Princeton University Press, 1967). Recent work in island studies has called attention to and problematized the notion of the island isolate: see Richard Grove's *Green Imperialism: Colonial Expansion, Tropical Island Edens and the Origins of Environmentalism 1600-1860* (Cambridge: Cambridge University Press, 1995); Hau'ofa's 'Our Sea of Islands', in A. Dirlik and R. Wilson (eds), *Asia/Pacific as Space of Cultural Production* (Durham, NC: Duke University Press, 1995); and G. Baldacchino's 'Coming of Age of Island Studies', *Tijdschrift voor Economische en Sociale Geografie*, 95(3), 2004. This is further discussed in the introduction to E.M. DeLoughrey's *Routes and Roots: Navigating Caribbean and Pacific Island Literatures* (Honolulu, HI: University of Hawai'i Press, 2007).
11. J. Hagen, *An Entangled Bank: The Origins of Ecosystem Ecology* (Piscataway, NJ: Rutgers University Press, 1992), p. 101.
12. C. Kwa, 'Representations of Nature Mediating between Ecology and Science Policy: The Case of the International Biological Programme', *Social Studies of Science*, 17(3), 1987, pp. 413–42, pp. 418–21; S. Bocking, 'Ecosystems, Ecologists and the Atom: Environmental Research at Oak Ridge National Laboratory', *Journal of History of Biology*, 28(1), 1995, pp. 1–47.
13. Bocking, 'Ecosystems', p. 4.
14. E. Welsome, *The Plutonium Files: America's Secret Medical Experiments in the Cold War* (New York: Dial Press, 1999), p. 30.
15. Quoted in Welsome, *Plutonium Files*, p. 118.
16. Welsome, *Plutonium Files* and C. Caufield, *Multiple Exposures: Chronicles of the Radiation Age* (Toronto: Stoddard Publishing Co., 1988).
17. F. Cowan, 'Everyday Radiation', *Physics Today*, 5(10), 1952, pp. 10–16, p. 14.
18. See M. Klinge, 'Plying Atomic Waters: Lauren Donaldson and the "Fern Lake Concept" of Fisheries Management', *Journal of the History of Biology*, 31(1), 1998, pp. 1–32.
19. On Micronesian history, see D. Hanlon, *Remaking Micronesia: Discourses over Development in a Pacific Territory, 1944-1982* (Honolulu, HI: University of Hawai'i Press, 1998) and R. Rogers, *Destiny's Landfall: A History of Guam* (Honolulu, HI: University of Hawai'i Press, 1995). On the state of exception see Giorgio Agamben's *State of Exception* (Chicago, IL: University of Chicago Press, 2005) which addresses how sovereign power declares a state of emergency to transcend the rule of law. This radioactive contamination of the entire planet ushers in an unprecedented era of what Achille Mbembe in another context terms 'necropower,' 'where sovereignty consists fundamentally in the exercise of a power outside the law (*ab legibus solutus*) and where "peace" is more likely to take on the face of a "war without end."' A. Mbembe, 'Necropolitics', *Public Culture*, 15(1), 2003, pp. 11–40, p. 23.

20. Micronesia is the size of continental US, so combined with the EEZ and 3.9 billion acres of submarine land and resources this triples the territorial US (National Academy of Sciences, 1989), p. 1. UNCLOS and its importance to reconfiguring the Pacific as an Americanized space is explored in DeLoughrey, *Routes and Roots*.
21. E. Margolis, 'The Hydrogen Bomb Experiments and International Law', *The Yale Law Journal*, 64(5), 1955, pp. 629–47, p. 630.
22. Margolis, 'The Hydrogen Bomb', p. 631.
23. Margolis, 'The Hydrogen Bomb', p. 634.
24. P. Boyer, *By the Bomb's Early Light: American Thought and Culture at the Dawn of the Atomic Age* (Chapel Hill, NC: University of North Carolina Press, 1994), p. 92.
25. Boyer, *Bomb's Early Light*, p. 90. For more on the impact on Bikini, see Boyer, *Bomb's Early Light*; S. Firth, *Nuclear Playground* (Honolulu, HI: University of Hawai'i Press, 1987); J. Niedenthal, *For the Good of Mankind: a History of the People of Bikini and Their Islands* (Majuro, Marshall Islands: Bravo Publishers, 2001); R. Stone, *Radio Bikini* (Robert Stone Productions, 1988); J. Dibblin, *Day of Two Suns: Nuclear Testing and the Pacific Islanders* (London: Virago, 1988); T. Teaiwa, 'Bikinis and Other s/pacific n/oceans', *The Contemporary Pacific*, 6, 1994; and J. Weisgall, *Operation Crossroads: The Atomic Tests at Bikini Atoll* (Annapolis, MD: Naval Institute Press, 1994).
26. See Grove, *Green Imperialism*.
27. *Operation Ivy* (United States Air Force Lookout Mountain Laboratory, Air Photographic Charting Service, Hollywood, California, 1952).
28. Quoted in Boyer, *Bomb's Early Light*, p. 91.
29. M. Stephenson and J. Weal, *Nuclear Dictionary* (London: Longman, 1985), p. 79; R. Jungk, *Brighter than a Thousand Suns: A Personal History of the Atomic Scientists* (New York: Harcourt Brace, 1958), p. 310.
30. On *Bravo* see Dibblin's *Day of Two Suns*, Firth's *Nuclear Playground*, D. O'Rourke's *Half-Life* (O'Rourke and Associates Filmmakers Pty, 1986), H. Barker, *Bravo for the Marshallese: Regaining Control in a Post-Nuclear, Post-Colonial World* (Belmont, CA: Wadsworth, 2004), and B. Johnston and H. Barker, *Consequential Damages of Nuclear War: The Rongelap Report* (Walnut Creek, CA: Left Coast Press, 2008).
31. Johnston and Barker, *Consequential Damages*, pp. 18–19.
32. My emphasis. *Military Effects Studies on Operation Castle* (United States Air Force Lookout Mountain Laboratory, Air Photographic Charting Service, Hollywood, California, 1954).
33. *Operation Castle Commander's Report* (Lookout Mountain Laboratory, US Air Force, Hollywood, California, 1954), <<http://www.archive.org/details/CastleCommandersReport1954>>.
34. Jungk, *Thousand Suns*, p. 310.
35. Margolis, 'The Hydrogen Bomb', p. 637.
36. C. Kwa, 'Radiation Ecology, Systems Ecology and the Management of the Environment', in Michael Shortland (ed.), *Science and Nature* (Oxford: British Society for the History of Science, 1993), pp. 213–49, p. 215.
37. On antinuclear activism in the Pacific, see Firth, *Nuclear Playground*, Teaiwa, 'Microwomen: US Colonialism and Micronesian Women Activists', in D. Rubenstein (ed.), *Pacific History: Papers from the 8th Pacific History Association Conference* (Mangilao, Guam: University of Guam and Micronesian Area Research Center, 1992).
38. My emphasis. H. Odum and E. Odum, 'Trophic Structure and Productivity of a Windward Coral Reef Community on Eniwetok Atoll', *Ecological Monographs*, 25(3), 1955, pp. 291–320. See also V. Kuletz's discussion of the Odums, *The Tainted Desert: Environmental Ruin in the American West* (New York: Routledge, 1998), p. 249. Biologist Lauren Donaldson found in the irradiated Pacific atolls 'an unparalleled opportunity to study the role of trace elements' in the environment (quoted in Klinge, 'Atomic Waters', p. 11).
39. F. Golley, *A History of the Ecosystem Concept in Ecology* (New Haven, CT: Yale University Press, 1993), p. 105.

40. See for instance S. Bocking, 'Ecosystems', S. Kirsch, 'Ecologists and the Experimental Landscape: The Nature of Science at the US Department of Energy's Savannah River Site', *cultural geographies*, 14(4), 2007, pp. 485–510.
41. Hagen, *An Entangled Bank*, p. 105.
42. Hagen, *An Entangled Bank*, pp. 104, 105.
43. Kwa, 'Radiation Ecology', p. 213.
44. H. Odum, 'Preface', in H. Odum and R. Pigeon (eds), *A Tropical Rain Forest: A Study of Irradiation and Ecology at El Verde, Puerto Rico* (Oak Ridge, TN: United States Atomic Energy Commission, National Technical Information Service, 1970), p. x.
45. H. Odum, 'Introduction to Section F', in H. Odum and R. Pigeon (eds), *A Tropical Rain Forest: A Study of Irradiation and Ecology at El Verde, Puerto Rico* (Oak Ridge, TN: United States Atomic Energy Commission, Division of Technical Information, 1970), pp. F1–F7, C–17. See also A. Lugo, 'H.T. Odum and the Luquillo Experimental Forest', *Ecological Modelling*, 178, 2004, pp. 65–74.
46. P. Taylor, 'Technocratic Optimism, H.T. Odum, and the Partial Transformation of Ecological Metaphor after World War II', *The Journal of the History of Biology*, 21(2), 1998, p. 229. See also Kuletz, *The Tainted Desert*, pp. 248–58.
47. H. Odum, 'The Stability of the World Strontium Cycle', *Science*, 114(2964), 1951, pp. 407–11, p. 407.
48. Kwa, 'Radiation Ecology', p. 213.
49. Golley, *The Ecosystem Concept*, p. 74.
50. Hagen, *An Entangled Bank*, p. 112.
51. My emphasis, E. Odum, 'Ecology and the Atomic Age', *ASB Bulletin*, 4(2), 1957, pp. 27–9, p. 28.
52. S. Kingsland, *The Evolution of American Ecology 1890-2000* (Baltimore, MD: Johns Hopkins University Press, 2005), p. 185.
53. W. Churchill, 'Geographic of Sacrifice: The Radioactive Colonization of Native North America', in W. Churchill (ed.), *Struggle for the Land: Native North American Resistance to Genocide, Ecocide and Colonization* (San Francisco, CA: City Lights Books, 2002), pp. 239–91, p. 239.
54. G. Mitman, *The State of Nature: Ecology, Community, and American Social Thought, 1900-1950* (Chicago, IL: University of Chicago Press, 1992), p. 209.
55. G. Beer, 'The Island and the Aeroplane: The Case of Virginia Woolf', in Homi Bhabha (ed.), *Nation and Narration* (London: Routledge, 1990), pp. 265–90, p. 265.
56. See DeLoughrey, *Routes and Roots*.
57. *Operation Greenhouse* (Lookout Mountain Laboratory, US Air Force, Hollywood, California, 1951), <<http://www.archive.org/details/OperationGreenhouse1951>>.
58. D. Cosgrove, *Apollo's Eye: A Cartographic Genealogy of the Earth in the Western Imagination* (Baltimore, MD: Johns Hopkins University Press, 2001), p. 2.
59. D. Cosgrove and W. Fox, *Photography and Flight* (London: Reaktion Books Ltd, 2010), p. 59.
60. Cosgrove, *Apollo's Eye*.
61. Waldheim quoted in P. Adey, *Aerial Life: Spaces, Mobilities, Affects* (Oxford: Wiley-Blackwell Publications, 2010), p. 10.
62. C. Kaplan, 'Mobility and War: The Cosmic View of US "Air Power"', *Environment and Planning A*, 38, 2006, pp. 395–407; P. Adey, *Aerial Life*. My thanks to Mimi Sheller for her references on aerial vision.
63. Cosgrove, *Apollo's Eye*, pp. 242–3.
64. Matthew Farish has an interesting argument about the decentralization of the American city in response to fears of nuclear attack that might be suggestively placed in a dialogue with the highly focalized space of the atomic test island. M. Farish, 'Disaster and Decentralization: American Cities and the Cold War', *cultural geographies*, 10(2), 2003, pp. 125–48.
65. Cosgrove, *Apollo's Eye*, p. 26.
66. Cosgrove, *Apollo's Eye*, p. 236.
67. Cosgrove, *Apollo's Eye*, p. 242.
68. Quoted in S. Sontag, *Regarding the Pain of Others* (New York: Farrar, 2003), p. 66.

69. *Hollywood's Top Secret Film Studio, Radio Bikini*. As one AEC film observed, 'one of the most important and dramatic elements in the dropping of the bomb is the photographic element' (quoted in Stone, *Radio Bikini*).
70. P. Virilio, *War and Cinema: The Logistics of Perception* (London: Verso, 1989), p. 4.
71. G. Baldacchino, 'Islands, Island Studies', *Island Studies Journal*, 1(1), 2006, pp. 3–18, p. 5.
72. As I discuss in *Routes and Roots*, functionalism, which is based on studying how individual parts fit the body of the whole community, is tied very closely to the bounded island concept and ecosystem ecology.
73. My emphasis, K.R. Howe, *The Quest for Origins: Who First Discovered and Settled New Zealand and the Pacific Islands* (Harmondsworth: Penguin Books, 2003), p. 23.
74. J. Fabian, *Time and the Other: How Anthropology Makes its Object* (New York: Columbia University Press, 2002).
75. D. Livingstone, *Putting Science in its Place: Geographies of Scientific Knowledge* (Chicago, IL: University of Chicago Press, 2003), p. 180.
76. Teaiwa, 'Bikinis', p. 90.
77. Teaiwa, 'Bikinis', p. 89.
78. P. Ricoeur, *The Rule of Metaphor: The Creation of Meaning in Language* (London: Routledge, 2003), p. 34.
79. Ricoeur, *The Rule of Metaphor*, p. 110.
80. Ricoeur, *The Rule of Metaphor*, p. 147.
81. *Nuclear Test Film – Operation Sandstone – Navy* (Department of Energy, 1948), <<http://www.archive.org/details/gov.doe.0800003>>.
82. *Nuclear Exiles* (National Geographic Society, 1987). See the work of Nathan Atkinson, 'Newsreels as Domestic Propaganda: Visual Rhetoric at the Dawn of the Cold War', *Rhetoric and Public Affairs*, 14(1), 2011, pp. 70–101, who demonstrates the control and sanitization of images of the Bikinians.
83. T. Teaiwa, 'Reading Paul Gauguin's *Noa Noa* with Epeli Hau'ofa's *Kisses in the Nederends*: Militourism, Feminism, and "Polynesian" Body', in Vilsoni Hereniko and Rob Wilson (eds), *Inside Out: Literature, Cultural Politics and Identity in the New Pacific* (Lanham, MD: Rowman and Littlefield, 2001), pp. 249–69.
84. Turning to geology, oceanography, and histories of voyaging, Diaz and Kauanui have argued against colonial models of island isolation to demonstrate that the 'Pacific is on the move,' understood in terms of tectonics, human migration, and a growing field of scholarship in V. Diaz and J. Kauanui, 'Native Pacific Cultural Studies on the Edge', *The Contemporary Pacific*, 13(2), 2001, pp. 315–42, p. 317.
85. S. Shigematsu and K. Camacho, *Militarized Currents: Toward a Decolonized Future in Asia and the Pacific* (Minneapolis, MN: University of Minnesota Press, 2010), p. xv.
86. Johnston and Barker, *Consequential Damages*, p. 196. Mbembe's description of the necropolitics of the colony are relevant here: 'the colonies are zones in which war and disorder, internal and external, figures of the political, stand side by side or alternate with each other.' They are 'the location par excellence where the controls and guarantees of judicial order can be suspended – the zone where the violence of the state of exception is deemed to operate in the service of "civilization."' Mbembe, 'Necropolitics', p. 24.
87. Johnston and Barker, *Consequential Damages*, p. 96. Merril Eisenbud, an AEC scientist later observed: 'There are many unanswered questions about the circumstances of the 1954 fallout. It is strange that no formal investigation was ever conducted. There have been reports that the device was exploded despite an adverse meteorological forecast. It has not been explained why an evacuation capability was not standing by, as had been recommended, or why there was not immediate action to evaluate the matter when the task force learned (seven hours after the explosion) that the AEC Health & Safety Laboratory recording instrument on Rongerik was off scale. There was also an unexplained interval of many days before the fallout was announced to the public.' Oral history interview, <http://www.hss.energy.gov/healthsafety/ohre/roadmap/achre/chap12_3.htm>.
88. See Barker, *Bravo for the Marshallese*, and Johnston and Barker, *Consequential Damages*, p. 28.
89. R. Conard, *Medical Survey of Rongelap and Utirik People Three Years after Exposure to Radioactive Fallout* (Upton, NY: Brookhaven National Laboratory, 1958), quoted in G. Johnson, *Collision Course*

- at Kwajalein: *Marshall Islanders in the Shadow of the Bomb* (Honolulu, HI: Pacific Concerns Resource Center, 1984), p. 13.
90. Quoted in B. Johnston, ‘“More Like Us than Mice”: Radiation Experiments with Indigenous Peoples’, in B. Johnston (ed.), *Half-Lives & Half-Truths: Confronting the Radioactive Legacy of the Cold War* (Santa Fe, NM: School for Advanced Research Press, 2007), p. 25.
91. Mbembe, ‘Necropolis’, p. 24.
92. The Department of Energy (formerly the AEC) Advisory Commission on Radiation Experiments determined in 1995 that the AEC did conduct a few non-therapeutic tests on the Marshallese but as they had no access to materials that were later declassified, they stated that there was no evidence of deliberate exposure or experimentation. See Johnston and Barker, *Consequential Damages*, pp. 30–1 and the ruling here: <http://www.hss.energy.gov/healthsafety/ohre/roadmap/achre/chap12_3.html>.
93. Johnston and Barker, *Consequential Damages*, p. 231.
94. Johnston and Barker, *Consequential Damages*, p. 156.
95. Johnston and Barker summarizing comments made by the AEC in response to complaint letters from the Rongelapese, *Consequential Damages*, p. 24.
96. See Johnston, ‘More Like Us Than Mice’, p. 40.
97. Johnston and Barker, *Consequential Damages*, pp. 119–21.
98. Johnston and Barker, *Consequential Damages*, p. 19.
99. See Johnston and Barker, *Consequential Damages*, pp. 153–6, and ACHRE <http://www.hss.energy.gov/healthsafety/ohre/roadmap/achre/chap12_3.html>.
100. ACHRE <http://www.hss.energy.gov/healthsafety/ohre/roadmap/achre/chap12_3.html>. L. Smith, *Decolonizing Methodologies: Research and Indigenous Peoples* (London: Zed Books, 2006), p. 1.
101. Johnston and Barker, *Consequential Damages*, p. 139.
102. See B. Johnston, ‘Half-Lives, Half-Truths, and Other Radioactive Legacies of the Cold War’.
103. See DeLoughrey, *Routes and Roots*.
104. Golley, *The Ecosystem Concept*, p. 3.
105. US Atomic Energy Commission Official Memorandum, 1 August 1968, <<http://www.hss.doe.gov/Healthsafety/IHS/marshall/collection/ihp/.../B34.PDF>>.
106. See R. Boyd, ‘Metaphor and Theory Change: What is “Metaphor” a Metaphor for?’, in A. Ortony (ed.), *Metaphor and Thought* (Cambridge: Cambridge University Press, 1979), pp. 356–408, and T. Kuhn, ‘Metaphor in Science’, in A. Ortony (ed.), *Metaphor and Thought* (Cambridge: Cambridge University Press, 1979), pp. 409–19.
107. B. Latour, ‘Give Me a Laboratory and I will Raise the World’, in M. Mulkay and K. Knorr-Cetina (eds), *Science Observed: Perspectives on the Study of Science* (London: SAGE, 1983), p. 17.
108. C. Geertz, *Interpretation of Cultures* (New York: Basic, 1973), p. 22.
109. Firth, *Nuclear Playground*, p. 3.
110. Welsome, *Plutonium Files*, p. 299.
111. Caufield, *Multiple Exposures*, p. 132.
112. See K. Spalding et al., ‘Forensics: Age Written in Teeth by Nuclear Tests’, *Nature*, 437(7057), 2005, pp. 333–4.
113. J. Masco, *The Nuclear Borderlands: The Manhattan Project in Post-Cold War New Mexico* (Princeton, NJ: Princeton University Press, 2006), p. 27.
114. See Godfrey Balacchino’s important collection of the same title *A World of Islands* (Malta: Agenda Publishers, 2007).

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