

Measurement of Background Gamma Radiation in the Northern Marshall Islands

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Significance

67 nuclear tests were conducted on two atolls in the northern Marshall Islands between 1946 and 1958. These tests produced radioactive fallout, which even today gives rise to radiation measurable above naturally occurring background levels. Rather than obtain new data, recent estimates of contamination levels in the northern Marshall Islands use measurements made decades ago to calculate present radiation levels. In contrast, we report on timely measurements on three different atolls, and provide detailed fits and simulated maps across several islands, including the islands of Bikini and Rongelap. Bikini and Rongelap Islands are of particular interest as they are relevant to the discussion of human resettlement.

Introduction

- The United States conducted 67 nuclear weapons tests in the northern Marshall Islands (RMI) from 1946-1958, resulting in severe radioactive contamination of inhabited atolls, including Bikini, Enewetak, and Rongelap.
- Communities living on islands in these atolls were exposed to high levels of radioactive fallout, resulting in severe health complications, many of which persist today.
- Exposed populations were evacuated, primarily to Majuro and Ebeye—two small, barren islands in the southern Marshall Islands.
- Subsequent remediation and resettlement efforts have been largely unsuccessful, including disastrous premature attempts to resettle Rongelap and Bikini, and the conversion of Runit Island, in Enewetak Atoll, into an unstable nuclear waste repository.
- Resettlement remains hugely important because Majuro and Ebeye are extremely overcrowded, and evacuated communities desire nothing more than to return to their home islands.
- Resettlement hinges upon ensuring the islands are radiologically safe for human habitation.
- Previous studies have modeled background radiation levels on the islands based on old data and assumptions about the half-life of Cesium-137, which is the major source of background radiation on the islands, accounting for ~90% of all gamma radiation attributable to the nuclear testing.
- By contrast, this study reports empirical measurements of external gamma radiation on six contaminated islands.
- This study is the first step in determining whether the contaminated islands are safe for habitation.

Materials and Methods

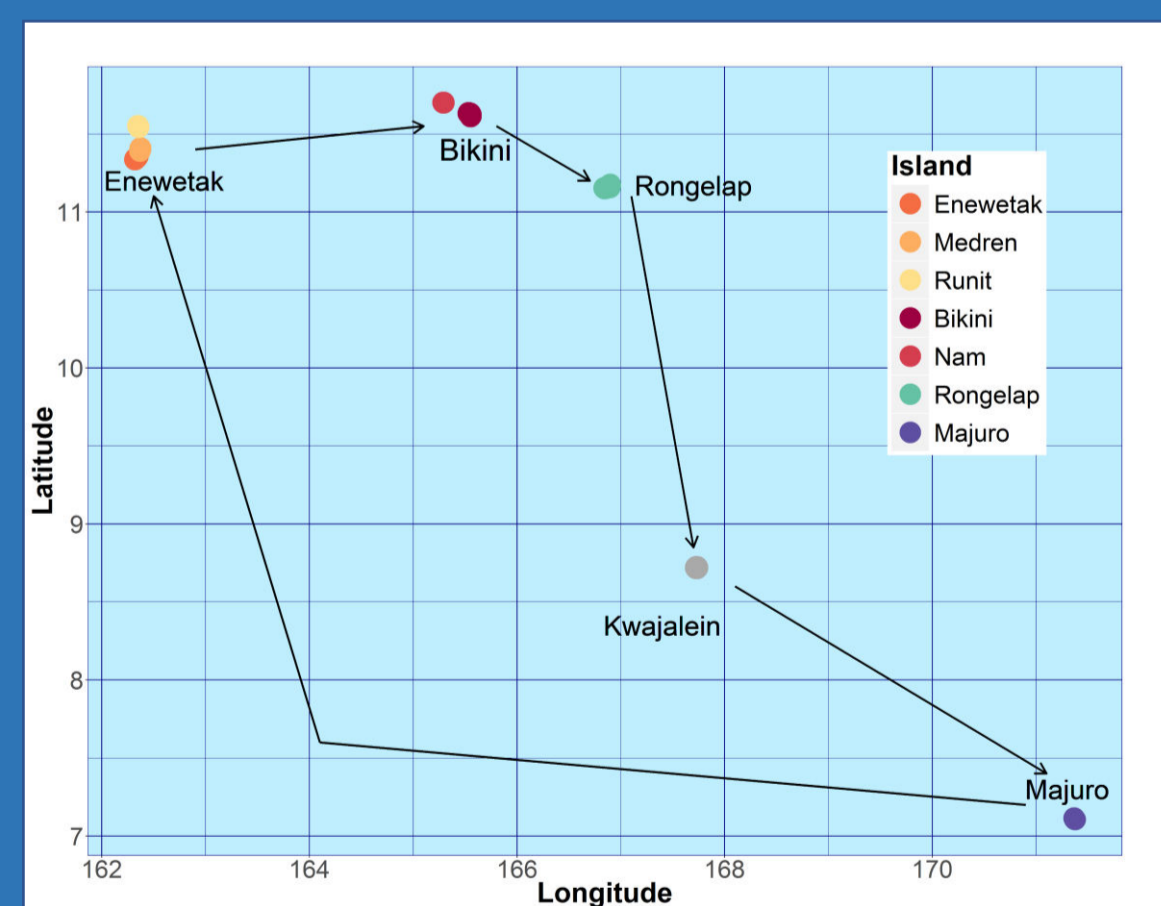


Figure 1: Simplified map of research team's trajectory. Only visited atolls are shown.

- External gamma radiation was measured on six contaminated islands throughout three atolls (fig. 1). As a control, measurements were taken on Majuro, the inhabited capital of the Marshall Islands, which was unexposed to nuclear contamination. Data were also collected in Central Park in New York City, as an additional point of comparison.
- To access the islands, the research team chartered a scuba diving boat and sailed more than 1,600 kilometers over a two-week period in August 2015 (fig. 1, fig.2).
- Gamma radiation was measured with two independent sets of Ludlum model 44–20 Gamma scintillators, connected to and operated by Ludlum model 2241–2 survey meters.
- Data were collected by two teams of two researchers. Per pair, one member read out the Ludlum results, while the other recorded the value and the associated GPS location (fig. 3).
- Data were compared to controls and standards. Empirical measurements were interpolated to create predictive maps of background gamma radiation values across the island extents.



Figure 2: The expedition vessel.



Figure 3: Researchers taking a point measurement on Runit Island.

Results

Data Characterization

- There is significant variation in radiation levels across the islands (figs. 4 & 5, tbl. 1.).
- The distribution of radiation levels on all islands was found to be non-normal (Shapiro-Wilk, $p < 0.05$ in all cases; fig. 4). Thus, non-parametric statistical tests were used to analyze the data.
- Radiation levels tend to drop-off with proximity to the coast, though a hot spot was observed on the coast of Enewetak (fig. 5).

Comparison Across Islands

- Mean gamma radiation levels on Bikini island are significantly elevated relative to levels observed on all other islands ($p < 0.01$).
- Mean gamma radiation levels on Rongelap and Runit Islands, in Rongelap Atoll; and Bikini and Nam Islands, in Bikini Atoll are significantly elevated relative to observed levels on the control island, Majuro ($p < 0.01$, fig. 4).
- Radiation levels on Enewetak and Medren Islands, on Medren Atoll are not significantly elevated relative to the control island ($p > 0.05$, fig. 4).
- These results are consistent with the islands' differing histories of exposure and clean-up efforts.

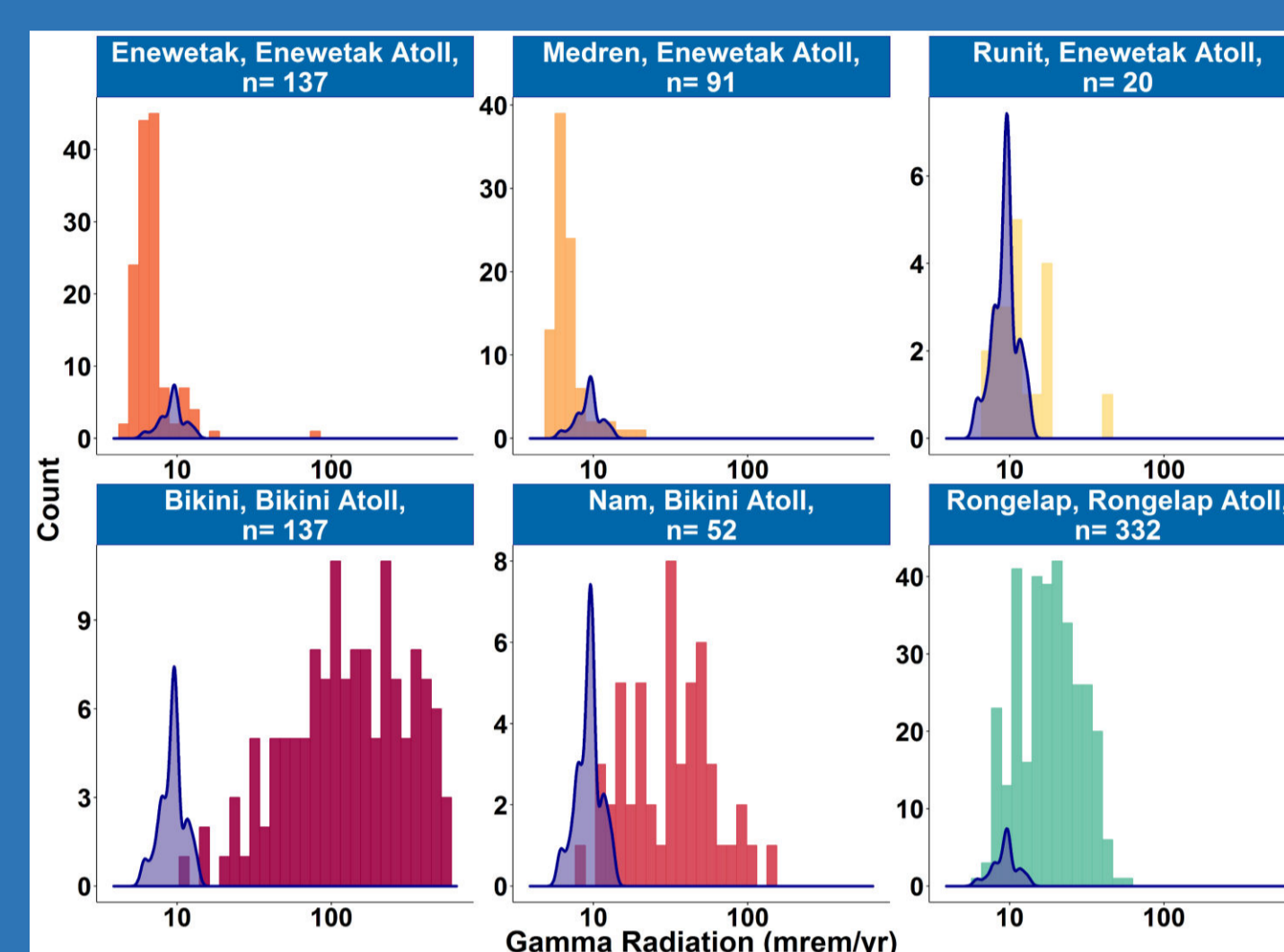


Figure 4: Measured gamma radiation levels on each island (log scale). The purple curve represents the fitted distribution of measured radiation levels on the control island, Majuro. The y-axis differs across islands to account for varying radiation levels.

Atoll	Island	N	Min.	1st Qu.	Median	Mean	3rd Qu.	Max
Bikini	Bikini	137	10.5	70.1	137	184	265	648
Bikini	Nam	52	7.88	19.3	32.4	38.4	49.5	143
Enewetak	Enewetak	137	4.38	6.13	6.13	7.47	7.01	84.1
Enewetak	Medren	91	5.26	6.13	6.13	7.08	7.01	21.9
Enewetak	Runit	20	7.01	9.20	10.5	13.1	16.0	42.9
Rongelap	Rongelap	332	6.13	12.3	18.4	19.8	25.4	55.2
Majuro*	Majuro	19	6.13	8.32	9.64	9.45	9.64	13.1

Table 1: Non-parametric summary statistics by island. * Majuro is the background control.

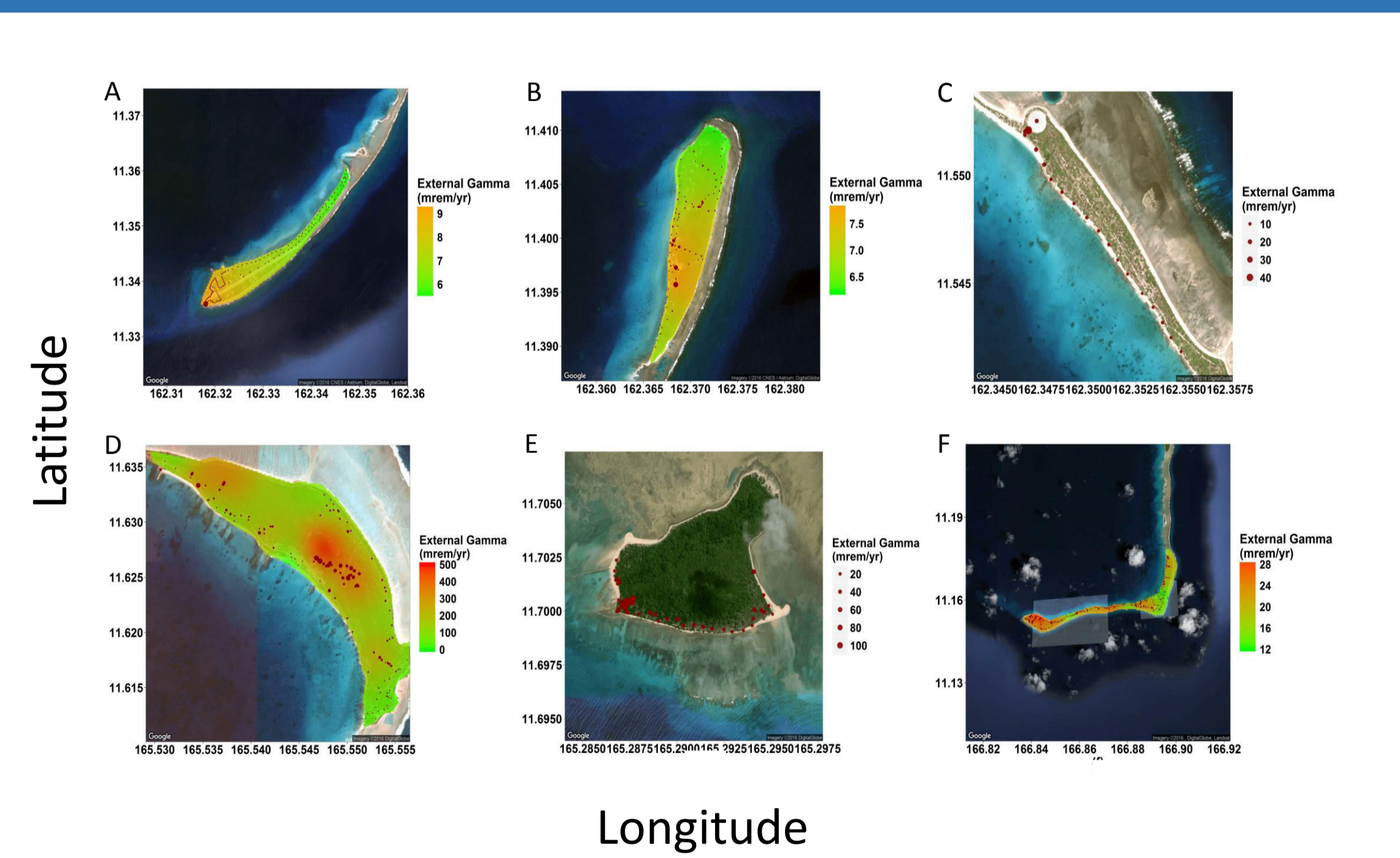


Figure 5: Measured and interpolated external gamma radiation levels on each island (mrem/y). (A) Enewetak, Enewetak Atoll (n=137); (B) Medren, Enewetak Atoll (n=91); (C) Runit, Enewetak Atoll (n=20); (D) Bikini, Bikini Atoll (n=137); (E) Nam, Bikini Atoll (n=52); (F) Rongelap, Rongelap Atoll (n=336).

Comparison to Standards

- The US and RMI have set a standard for safe habitation: The maximally exposed person shall not receive a cumulative effective dose greater than 100 mrem/y above background.
- Mean external gamma radiation levels on Bikini are significantly higher than the standard ($p < 0.01$, figs. 6 & 7).
- On all other islands, external gamma radiation is significantly below the standard ($p < 0.01$, figs. 6 & 7). However, the standard is in terms of cumulative dose. Thus, to determine whether these islands are safe, additional exposure pathways must be assessed.

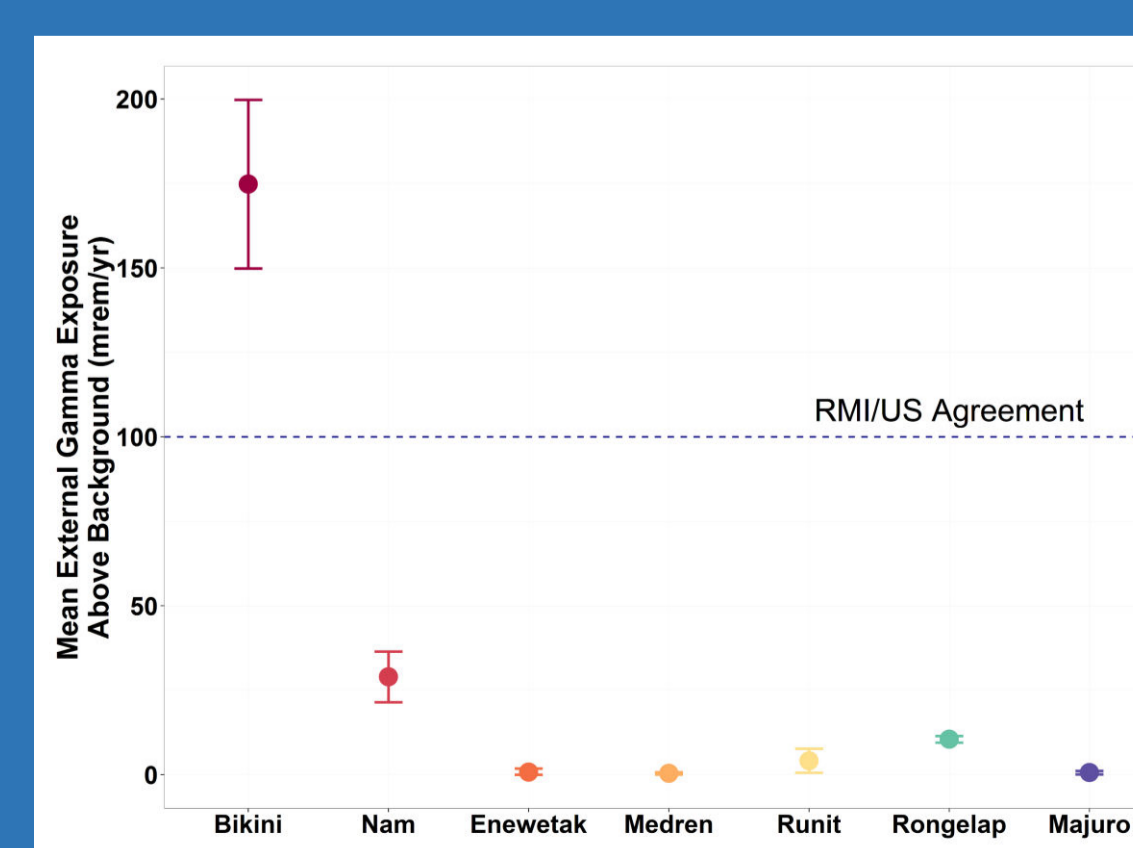


Figure 6: Adjusted external gamma radiation compared with the standard for safe habitation (100 mrem/y). Error bars represent ± 1 SD.

Results (Cont'd)

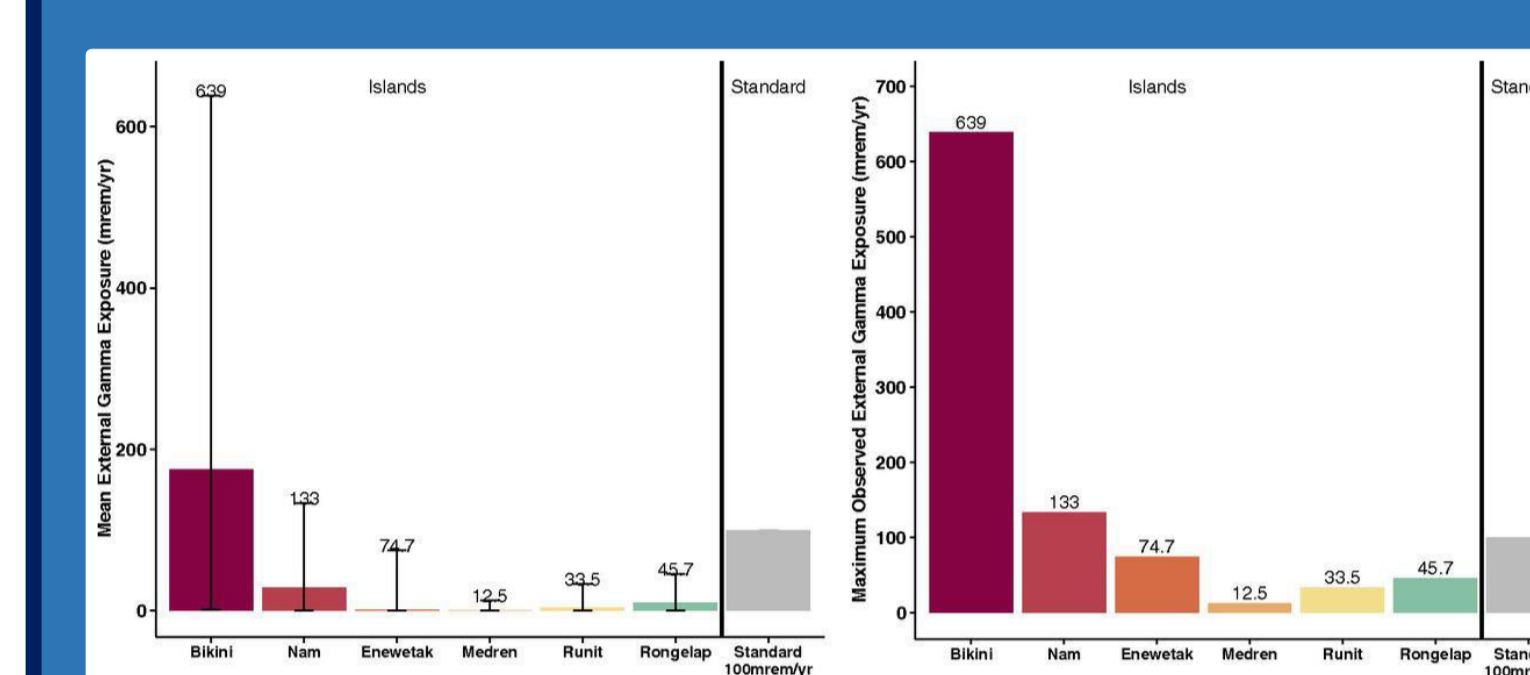


Figure 6: Mean and maximum background-adjusted external gamma radiation compared to the standard for safe habitation (100 mrem/y). Left: Range of observed values with bar height representing the mean. Right: maximum observed values.

Comparison to Central Park

- External gamma radiation levels in Central Park were found significantly elevated relative to all islands except Bikini ($p < 0.01$).
- This is because background radiation is much higher in New York than the Marshall Islands, and particularly elevated in Central Park due to large quantities of Manhattan Schist present there.
- Safety standards are set in terms of elevated exposure relative to background, and this comparison does not adequately reflect the cumulative dose of individuals living in either area.
- A detector sensitivity analysis was also conducted in Central Park. Measurements of the distribution for single-point measurements were found to be normally distributed, with a standard deviation of ~10%.

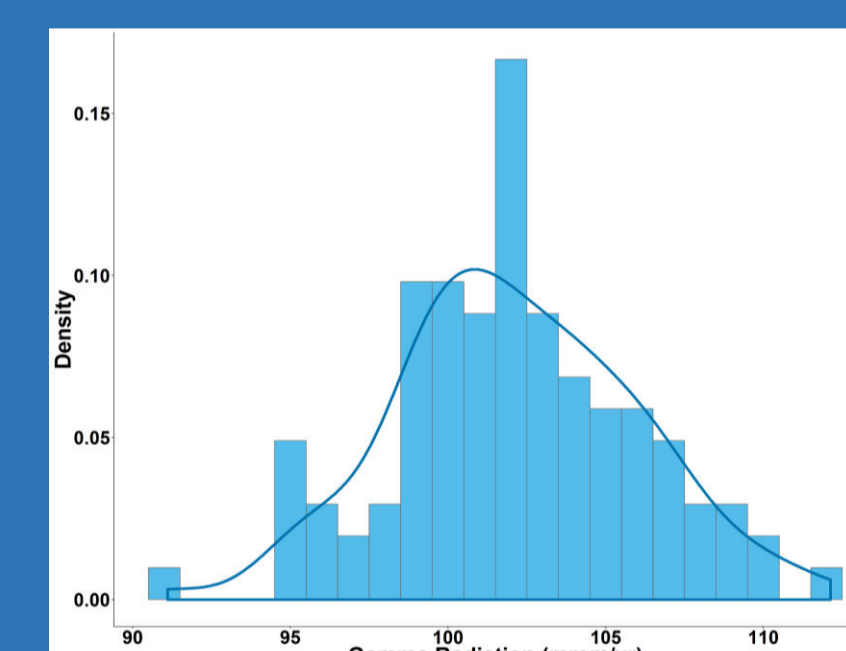


Figure 7: Distribution of external gamma radiation assessed during a single location sensitivity test in Central Park (N = 100).

Conclusions & Next Steps

- Our finding suggests that Bikini Island exceeds the standard agreed upon by the US/RMI and may not be safe for habitation (fig. 6, table 2).
- External gamma radiation levels on islands in Enewetak and Rongelap Atolls are well below the standard.
- However, additional exposure pathways must be measured to make a conclusion as to whether these islands are safe for habitation.
- The K1 Project Research team returned to the Marshall Islands in May 2017 to measure radiation levels in foods that are central to the Marshallese diet, including breadfruit, pandanus, and fish. In addition, the team collected measurements of soil and water.
- Analysis of these samples, in conjunction with the research presented here, should produce an accurate, empirically based assessment of the radiological safety of the contaminated islands.



Members of the community in Enewetak living with uncertainty as to whether their island is safe for habitation.

Key References

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