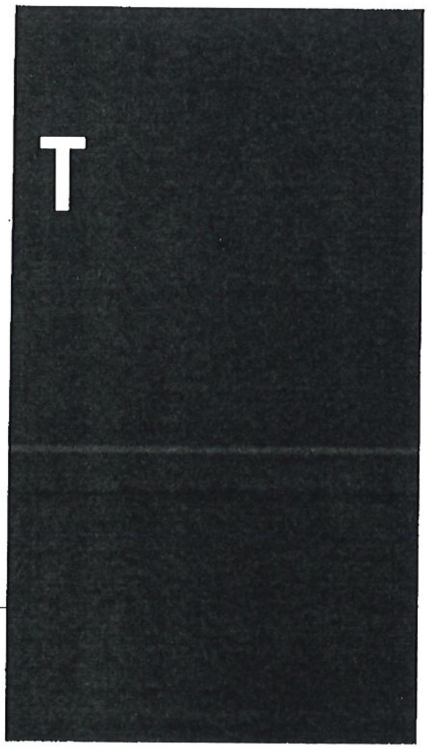
The Biological Consequences of Nuclear War

Initiating National Case Studies

By Mark A. Harwell and Ann C. Freeman

For most of the past four decades, the scientific understanding of the consequences of nuclear war was dominated by the experiences of Hiroshima and Nagasaki.[1] A potential modern nuclear war was largely considered to be just a collection of Hiroshimas, each independently resulting in human casualties locally from blast, burns, and radiation. Effects on the environment in Japan were trivial compared to direct effects on people near each detonation, and it was not until 1975 that the first serious study on global environmental effects was undertaken.[2] However, that study failed to recognize the critical indirect effects that could follow the global atmospheric changes and other large-scale physical stresses induced by multiple nuclear detonations. Only in the last few years have these issues been identified[3] and studied carefully. The first volume of the study by the Scientific Committee on Problems of the Environment (SCOPE) on the environmental consequences of nuclear war (ENUWAR),[4] updated at a 1987 Bangkok workshop and a more recent Moscow workshop, constitutes the standard reference that examines and documents the global-scale physical environmental stresses that could follow a major nuclear war.

While recognizing that uncertainties remain in the projections of physical effects, ENUWAR scientists expanded the assessments to include potential consequences for the Earth's biological systems including the global ecology, agri-



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cultural productivity, and associated impacts on the human population (for effects on population see Figure 1 on this page).[5] The authors of the second volume of the ENUWAR study took the approach of examining the vulnerabilities of the global biology to the types of physical stresses predicted and thus did not limit their evaluations to any single scenario.

The physical stresses were classified according to their biological relevancy, with emphasis on the following:

- acute climatic changes, consisting of abrupt onset of brief periods of chilling or freezing temperatures and sharp reductions in sunlight, lasting for a period of weeks to months;
- chronic climatic changes, with temporal and spatially averaged temperature reductions of a few degrees below normal for at least one growing season and perhaps several, with associated reductions in sunlight (5 to 20 percent) and precipitation (25 to 50 percent);
- stratospheric ozone depletions that could increase ultraviolet-B (UV-B) radiation at the Earth's surface by a factor of 2 or more;
- local and global fallout of radionuclides produced by nuclear detonations; and
- other physical stresses such as air pollution and wildfires.

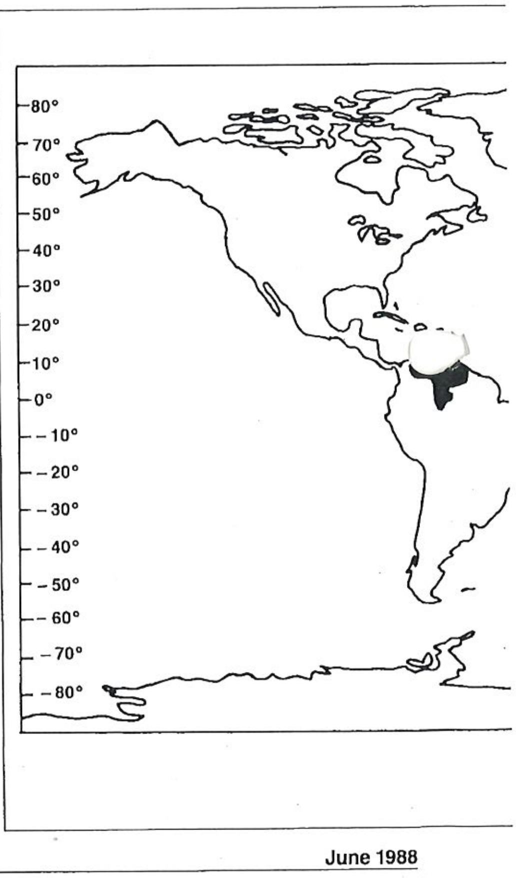
Global Issues and Effects

The conclusions from the biological studies were clear: the potential indirect effects of a large-scale nuclear war could greatly exceed the direct effects, and the substantial majority of the human population would be at risk of global famine resulting from severe reductions in agricultural productivity throughout at least the Northern Hemisphere. Ecological effects would be unprecedented in intensity and scale, and disruptions in energy subsidies to agriculture, such as loss of fertilizers and pesticides, could exacerbate the agricultural effects. The potential for secondary ecological effects and synergisms, as well as important feedbacks with societal responses to nuclear war, is great; however, these issues have not been examined in depth. This stark picture of nuclear famine on a global scale was reaffirmed at the Bangkok workshop, even in light of the so-called "nuclear autumn" scenario,[6] and most recently at the Moscow workshop. As agricultural systems in particular are very sensitive to the types of physical stresses discussed in the ENUWAR physical effects report, the uncertainties in these effects at the intensity of current projections are not significant for the biological conclusions.

The ENUWAR biological studies are different from the physical studies in several regards. First, the experimental data base for the biological effects of nuclear war is lacking, and governments provide very little funding for such studies. Those studies that have been conducted have focused on ecological effects of radiation at exposure levels that could occur only very near nuclear detonations,[7] severely limiting the applicability of these experiments. Biological responses to stress are functions of the scale and intensity of the stresses, yet no ecosystems-level experiments have been conducted using nuclear-war-projected climatic changes. Second, modeling the responses of the biosphere to global stresses is in its infancy, unlike the substantial effort on global climate models. Also, the diversity and complexity of biological systems worldwide, and their intricate feedbacks with human systems, make ecological generalizations difficult. Consequently, estimating the potential effects of nuclear war on biological systems requires a suite of different methodologies, which include: historical analogues, such as 1816, the "year without a summer," for effects of extreme weather episodes during a growing season; statistical models, also based on historical data but for normal relationships, such as that between average temperature and growing season length; physiological data and models, derived from controlled field and laboratory experiments on plant and animal responses to temperature, light, and other environmental conditions; simulation modeling of ecosystems and agricultural crop productivity, used to test for sensitivity to chronic climate effects; and expert judgment, drawing upon specialists in many different types of ecological and agricultural systems.

Based on this suite of approaches, the global-scale assessments were conducted and uncertainties identified. Certain scientific issues were identified as critical:

- issues of scale—the vulnerabilities of ecological and agricultural systems, the processes controlling recovery, and the stresses themselves can only be described with attention to the time and spatial scales (for example, a temperature prediction, daily averaged over a general circulation model grid scale of about 5 × 5 degrees longitude and latitude, that temperatures would remain at 5° C can still allow subfreezing temperatures to occur locally and for brief periods of time);
- importance of variances versus averages—biologically relevant stresses are likely to be excursions from normal



conditions, such as brief episodes of low temperatures or reductions in frequency of precipitation events, rather than simple reductions in average conditions;

- physical/biological interface issues—the previous two items have considerable implications for the types of information biologists need from physical scientists (see Thomas Ackerman and Wendell Cropper, Jr., page 31).
- focus on primary effects rather than secondary effects—ecological responses to stress involve a myriad of indirect, secondary effects, such as those on food webs, loss of critical species, and pest outbreaks,[8] and the actual effects for these issues, which have not been addressed in the context of nuclear war, are likely to be more severe, and ...ve more synergistic responses than predicted; and
- vulnerability of agricultural production and food availability—of all the ecological systems examined, agriculture was consistently the most sensitive to the physical stresses and societal disruptions projected to occur following a nuclear war.

The single area in which the biological consequences of nuclear war need to be modified since publication of the ENUWAR study is the effects of increased UV-B radiation associated with depletion of stratospheric ozone. At the Moscow workshop new results indicated that long-term ozone depletions of 50 percent or more are feasible (see R. P. Turco and G. S. Golitsyn, page 8), and UV-B levels could increase by a factor of 5 or more. New summaries of the biological effects of enhanced UV-B radiation[9] suggest damage to many marine phytoplankton, zooplankton, and larval fish populations in response to increases of UV-B radiation of only 10 to 50 percent, with potential alterations in marine biological diversity, pelagic community structure, and fisheries yields. Extrapolations to a fivefold increase are uncertain, but severe global-scale effects on marine ecosystems, as well as on agricultural systems, are plausible. Improved assessment of biological effects from nuclear-war-induced UV-B radiation requires serious attention.

Objectives of Case Studies

Although the biological picture that has emerged through the ENUWAR study represents a strong consensus in the international scientific community, substantial uncertainties remain. ENUWAR scientists recognized that to reduce uncertainties would entail considerable experimental research or new model development, for which funds are not presently available, or a focus on improving local data bases and local knowledge of specific regions. Consequently, the ENUWAR project has initiated a series of national-level case studies with two primary objectives.

One goal is to reduce the remaining scientific uncertainties in understanding the effects of nuclear war by using much more detailed data on ecological, agricultural, and human systems available

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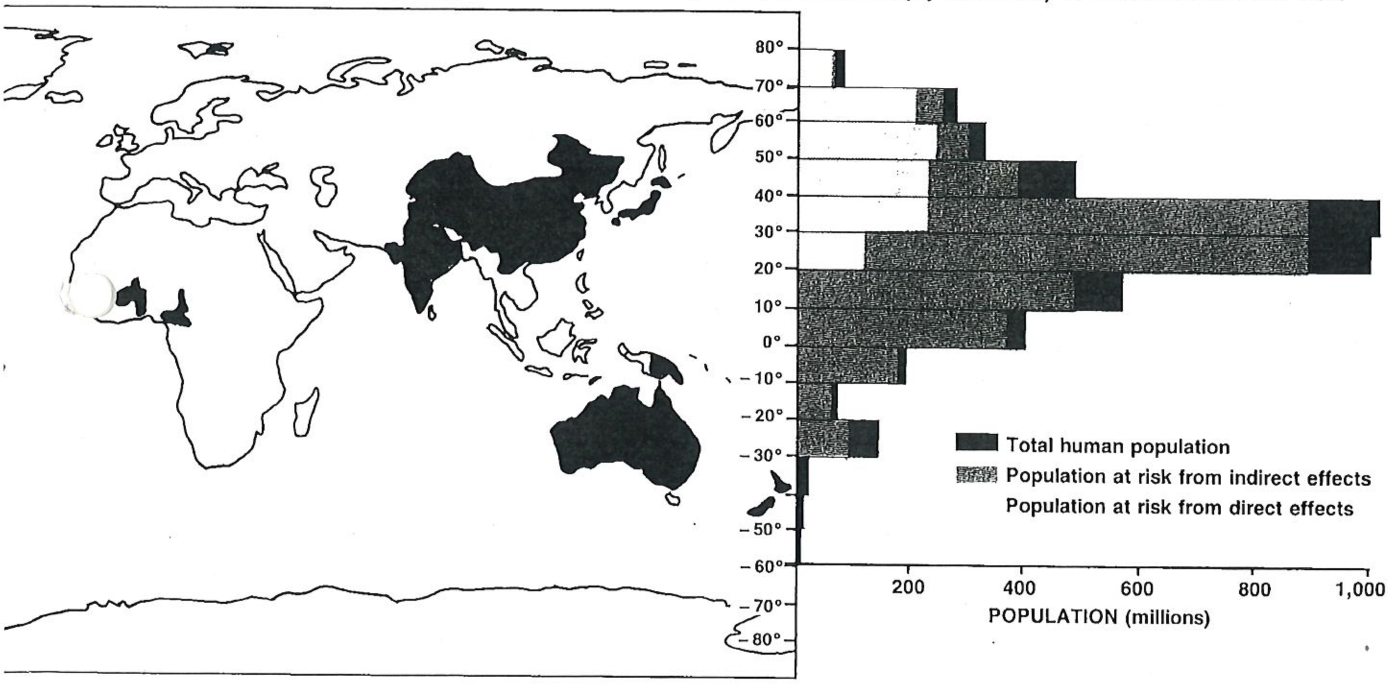
FIGURE 1. Proposed case study regions and estimated global populations (by latitudes) at risk from nuclear war.



Notes: Shading represents proposed case study regions. The figure on populations potentially affected by direct and indirect effects of nuclear war is adapted from M. A. Harwell and T. C. Hutchinson, *Environmental Consequences of Nuclear War: Volume 2—Ecological and Agricultural Effects*, SCOPE 28 (Chichester and New York: John Wiley & Sons, 1985).

at the national level and by drawing upon scientists with broad expertise in specific national conditions. Thus, the overall scientific understanding will be advanced significantly beyond what was possible in the global study.

Second, even though uncertainties still exist, the basic new picture of nuclear war effects has become well established through the ENUWAR study. Consequently, a major task is for this scientific information to be widely incorporated into the thinking of policy analysts and decision makers throughout the world, especially since the message is most important to non-nuclear countries. The most effective way to accomplish that task is by conducting studies on specific countries so that their leaders, and the leaders of similar countries, can relate much better to the effects in the context of their own conditions rather than just hemispheric averages. Actively involving the highest levels of the scientific communities in each country considerably aids in reaching policy leaders. A secondary benefit is that the national case studies have direct relevance to current environmental stresses that are experienced globally but whose effects occur at the local or national scale, such as climate change or the effects of UV-B radiation on the vulnerable agricultural systems of countries such as India, China, and sub-Saharan Africa.[10]

To facilitate the case studies, ENUWAR scientists will convene technical workshops with in-country scientists to provide each country with projections of the physical effects of a U.S.-Soviet nuclear war on the environment of the specific nation studied. They will also provide: for certain countries, such as Japan, additional specific scenarios of nuclear detonations on those countries; methodologies, models, and other analytical tools so that the in-country scientists can assess the effects of nuclear war on their country's ecological, agricultural, and human systems; technical and logistical assistance in preparing scientific and popular reports; and assistance in acquiring support for each study.

All nations chosen for case studies would likely be noncombatants, so that indirect effects would not be masked by direct effects; are major population centers or are representative of a class of countries that collectively have substantial populations; have major scientific communities that could be drawn upon to conduct the studies; and have an in-country scientist willing to coordinate the study with the potential for research funding.

The countries or regions that were selected for initiating studies are sub-Saharan Africa, Australia, the People's Republic of China, India, Japan, and Venezuela. Each has very different agricultural, ecological, and human systems, and assessment of the physical and climatic effects following a nuclear war will be nation-specific and even local-region-specific. Thus, each case study will focus on the specific effects of nuclear war on the country's ecological, agricultural, and human systems that are most pertinent.

Each case study will produce a detailed technical report describing the complete project, its approaches, results, and conclusions; a brief technical summary of that larger technical document, and a short version written for educated nonscientists, especially policymakers, that describes the essence of the study and its findings. A summary technical book will also be produced based on the technical reports for synthesis and integration across studies and for extrapolation to global implications. The current status of each of the studies follows.

- ***Sub-Saharan Africa.*** Commitments for participation in the ENUWAR African case study have been made by the directors of scientific research in Cameroon, Benin, Togo, and Burkina Faso; additional countries from East and southern Africa will be added. Coordination will be through the Semi-Arid Food Grain Research and Development Program of the Organization of African Unity, and collaborations are also being explored with the International Crop Research Institute for Semi-Arid Tropics, the International Institute of Tropical Agriculture, the International Livestock Center for Africa, the Regional Agro-Meteorological Organization, and other organizations. Emphasis will be on agricultural effects on staple crops and livestock, especially from reductions in precipitation associated with monsoon inhibition and from disruptions in imports of food, energy, pharmaceuticals, and other essential commodities. Ecological effects will also be studied.
- ***Australia.*** The case study in Australia is affiliated with the Australia Academy of Sciences and will be coordinated by the climate-agriculture research unit at Australian National University. The study is expected to include effects on New Zealand and Papua New Guinea as well and thus includes attention to societal effects (see Wren Green, page 28). Particular emphasis will be on using the extensive data base and modeling capabilities to examine current climate variability and agricultural impacts and for relating general circulation model results to local weather conditions. (These methodologies will also be applied to the other case studies.)
- ***People's Republic of China.*** The national case study in China is spon-