VOLUME II
Executive Summary

The potential consequences to the global environment of a nuclear war have been the focus of several studies in the four decades since the first detonations of nuclear weapons in Japan. During this time, the *potential consequences* that would ensue from a modern nuclear war have increased dramatically, and the combination of much larger yields and much greater numbers of nuclear warheads could now result in a large-scale nuclear war having little in common with the relatively limited experiences of Hiroshima and Nagasaki. Simultaneously, the projections of the magnitude of impacts from a nuclear war have also increased steadily; however, the *perception of the consequences* of a large-scale nuclear war consistently have lagged behind the reality. New global-scale phenomena continue to be identified, even up to the present, and there remains a concern that decision-makers are operating with obsolete analyses and basing their policies on a foundation of misunderstanding of the total consequences of nuclear war.

The SCOPE–ENUWAR project had as one of its objectives the development of a comprehensive understanding of the nature of a post-nuclear war world, based on the full range of available information and models. Volume I of the ENUWAR report presented the bases for estimating potential effects on the physical environment, including possible climatic disturbances as well as fallout, UV-B, air pollutants, and other effects. The present volume takes up where the first left off, by specifically considering the potential consequences of such physical and chemical stresses on biological systems and on the ultimate endpoint of concern, i.e., effects on the global human population.

The approach taken in the biological analyses was to synthesize current understanding of the responses of ecological and agricultural systems to perturbations, relying on the expertise of over 200 scientists from over 30 countries around the Earth. Much of the synthesis took place in the context of a series of workshops that addressed specific issues; other work included conducting simulation modelling and performing detailed calculations of potential effects on the human populations of representative countries. We do not present the evaluation of a single nuclear war scenario as estimated by a single methodology; rather, a suite of methodologies were drawn upon collectively to develop an image of the aftermath of a large-scale nuclear war. The range of possible nuclear war scenarios is great; the estimates from the

physical scientists of potential climatic consequences are not yet certain and continue to evolve with time. Those estimates are complex in their spatial and temporal distribution over the Earth, and the global landscape is covered by extremely complex ecological, agricultural, and human systems that react to perturbations in complex manners. For these reasons, the present volume investigates the vulnerability of these systems to the types of perturbations possible after a nuclear war, offering readers the opportunity to form their own specific projections of biological and human consequences by providing calculations of vulnerabilities to benchmark assumptions.

Nevertheless, many conclusions are evident from considering these vulnerabilities to nuclear war perturbations. These include:

- Natural ecosystems are vulnerable to extreme climatic disturbances, with differential vulnerability depending on the ecosystem type, location, and season of effects. Temperature effects would be dominant for terrestrial ecosystems in the Northern Hemisphere and in the tropics and sub-tropics; light reductions would be most important for oceanic ecosystems; precipitation effects would be more important to grasslands and many Southern Hemisphere ecosystems.
- The potential for synergistic responses and propagation of effects through ecosystems implies much greater impacts than can be understood by addressing perturbations in isolation. For example, increased exposure to UV-B and to mixtures of air pollutants and radiation, while not crucially harmful for any one stress, might collectively be very detrimental or lethal to sensitive systems because of synergistic interactions.
- Fires as a direct consequence of a major nuclear exchange could consume large areas of natural ecosystems, but fire-vulnerable ecosystems are generally adapted to survive or regenerate via a post-fire succession. Other direct effects of nuclear detonations on ecological systems would be limited in extent or effect.
- The recovery of natural ecosystems from the climatic stresses postulated for an acute phase following following a major nuclear war would depend on normal adaptations to disturbance, such as through presence of spores, seed banks, seedling banks, vegetative growth, and coppicing. For some systems, the initial damage could be very great and recovery very slow, with full recovery to the pre-disturbed state being unlikely. Human-ecosystem interactions could act to retard ecological recovery.
- Because of limitations in the amounts of utilizable energy, natural ecosystems cannot replace agricultural systems in supporting the majority of humans on Earth, even if those natural ecosystems were not to suffer any impacts from nuclear war.

- Consequently, human populations are highly vulnerable to disruptions in agricultural systems.
- Agricultural systems are very sensitive to climatic and societal disturbances occurring on regional to global scales, with reductions in or even total loss of crop yields possible in response to many of the potential stresses. These conclusions consistently follow from a suite of approaches to evaluating vulnerabilities, including historical precedents, statistical analyses, physiological and mechanistic relationships, simulation modelling, and reliance on expert judgment.
- The vulnerabilities of agricultural productivity to climatic perturbations are a function of a number of different factors, any one of which could be limiting. These factors include: insufficient integrated thermal time for crops over the growing season; shortening of the growing season by reduction in a frost-free period in response to average temperature reductions; increasing of the time required for crop maturation in response to reduced temperatures; the combination of the latter two factors to result in insufficient time for crops to mature prior to onset of killing cold temperatures; insufficient integrated time of sunlight over the growing season for crop maturation; insufficient precipitation for crop yields to remain at high levels; and the occurrence of brief episodic events of chilling or freezing temperatures at critical times during the growing season.
- Potential disruptions in agricultural productivity and/or in exchange of food across national boundaries in the aftermath of a large-scale nuclear war are factors to which the human population is highly vulnerable. Vulnerability is manifested in the quantities and duration of food stores existing at any point in time, such that loss of the continued agricultural productivity or imports that maintain food levels would lead to depletion of food stores for much of the world's human population in a time period before it is likely that agricultural productivity could be resumed.
- Under such a situation, the majority of the world's population is at risk of starvation in the aftermath of a nuclear war. Risk is therefore exported from combatant countries to non-combatant countries, especially those dependent on others for food and energy subsidies and those whose food stores are small relative to the population.
- The high sensitivity of agricultural systems to even relatively small alterations in climatic conditions indicates that many of the unresolved issues among the physical scientists are less important, since even their lower estimates of many effects could be devastating to agricultural production and thereby to human populations on regional or wider scales.

- Longer-term climatic disturbances, if they were to occur, would be at least as important to human survival as the acute, early extremes of temperature and light reductions, suggesting that much greater attention should be given to those issues. Similarly, much greater attention is needed to resolve uncertainties in precipitation reduction estimates, since many of the agricultural systems are water-limited, and reduced precipitation can significantly reduce total production.
- Factors related to the possibility and rates of redevelopment of an agricultural base for the human population would have much influence on the long-term consequences to the human population. Interactions with societal factors would be very important.
- Global fallout is not likely to result in major ecological, agricultural, or human effects, as compared to effects of other global disturbances. Local fallout, on the other hand, could be highly consequential to natural and agricultural systems and to humans; however, the extent of coverage of lethal levels of local fallout and the levels of internal doses to humans from such fallout are inadequately characterized.
- Human populations are highly vulnerable to possible societal disruptions within combatant and non-combatant countries after a large-scale nuclear war, such as in the consequent problems of distribution of food and other limited resources among the immediate survivors. This is an area requiring a level of serious scientific investigation that has not yet been brought to bear on these issues.

As a part of the SCOPE–ENUWAR project, a workshop was held in Hiroshima, Japan, in order for the scientists to gain a fuller appreciation of the human consequences of nuclear detonations. The considerations listed above indicate that as devastating as the Japanese atomic bombings were, as consequential to their victims even to the present day, and as important to the development of the 20th Century, they cannot provide a sense of what the global aftermath of a modern nuclear war could be like. Hiroshima today is a thriving, dynamic city reborn from complete devastation by interactions and support from the outside world; after a large-scale nuclear war, there would be essentially no outside world, and qualitatively new global-scale effects would occur that could devastate not just an urban population but the entirety of humanity. Although issues remain to be resolved, the information in this volume demonstrates some of the great vulnerabilities of agricultural, ecological, and societal support systems to the potential direct and indirect consequences of nuclear war. This demonstration of global frailties mandates the formulation of new global perspectives on avoiding the aftermath of nuclear war.