VOLUME II
Introduction

This report presents the results of an international, cooperative effort involving scientists from extremely diverse fields of expertise. The SCOPE–ENUWAR biological analyses have sought consensus among experts, and synthesis from existing information and understanding, in order to evaluate the potential consequences to the natural environment and to human environments of the short- and long-term consequences of a large-scale nuclear war. Yet among the most common questions we are asked are: Why study these issues? Aren't the consequences of direct effects bad enough? Why worry about natural ecosystems and people in non-combatant nations when hundreds of millions of humans would die directly or shortly thereafter? Aren't there too many uncertainties in the climatic issues, making a further look at the consequences to biological systems premature?

Why, indeed? The answer is found in the endpoint of such analyses: impacts on humans and society. Our premise is that the consequences to the global human population are precisely what one should focus upon; all the rest are merely intermediary steps in making that evaluation. Projecting darkness at noon and subfreezing temperatures in July does not paint a picture which is complete enough to understand the total effects of nuclear war; humans simply would not die from a reduction in sunlight for a few weeks, and the world's human population would not likely be greatly reduced by freezing to death. The present analyses show that if substantial global climatic and other disturbances were to occur after a nuclear war, effects on the agricultural and ecological bases which support the Earth's human population would probably lead indirectly to the subsequent loss of hundreds of millions or even billions of human lives. A major conclusion of the current work on the vulnerability of human and natural systems is that the mechanism most likely to lead to the greatest consequences to humans from a nuclear war is not the blast wave, not the thermal pulse, not direct radiation, nor even fallout; rather, it is *mass starvation.*

We do not know this, however, from single analyses of the specific effects of a specified hypothetical nuclear war. Such an approach was not possible or desirable, because of the large uncertainties in the physical analyses and in nuclear war scenarios; the continuously evolving nature of the projections by the physical scientists; the complexity of interactions of possible nuclear-

war induced disturbances across the global landscape and over time; and the complexities of ecological, agricultural, and societal systems and their responses to perturbations. There will always be uncertainties in the physical projections, in part because the global atmospheric systems are so complex that they can never be perfectly predicted, in part because many of the variables in climate assessments cannot be measured at their appropriate scale, and experimentation at the global scale is not possible. Further, the exact scenario of a nuclear war could only be defined as it occurred, not in some pre-war speculation. Delaying the biological assessments until the physical uncertainties are resolved, then, is never to do them. But already it is clear that nuclear war-induced climatic perturbations are a *plausible* consequence of nuclear war.

Because of this, the present analyses are focused on characterizing the *vulnerability* of biological and human systems to the types and ranges of perturbations that could follow a large-scale nuclear war. For instance, by examining the current status and potential duration of global food supplies, we can characterize the vulnerability of the human population to global-scale disruptions in food production and distribution systems. Whereas we are not predicting that a global-scale *elimination* of these systems would necessarily follow a large-scale nuclear war, it does appear that humans have the potential through nuclear war to *disrupt* global agricultural, ecological, and societal systems on a scale unprecedented in extent or intensity.

There is a great opportunity for feedback from the biological analyses into the physical studies. For instance, many of the issues in dispute for climatic consequences involve the early, acute time period, with arguments over the intensity of initial temperature decreases. Analyses of the concomitant impacts on agricultural systems, however, indicate that even for smaller temperature decreases, the effects on regional and global agricultural productivity would still be devastating. Similar responses can be expected for many natural ecosystems if affected in their vulnerable growing seasons, or should tropical and sub-tropical systems suffer freezing or chilling. Hence, much of the dispute would seem to be irrelevant to the central issue of overriding importance: human survival. We are coming to the realization that the *duration* of climatic changes of a few degrees is more important, within limits, than how extreme the initial temperature drop would be; this indicates a clear need for longer-term analyses. How quickly temperatures would drop and the nature of their temporal patchiness might be as important as how low they drop. We do emphasize, however, that extreme temperature excursions for quite limited periods can be extremely damaging if occurring in certain regions or in the active growing season. Duration of extremes are more important for ecosystems which are not adapted to or used to experiencing such extremes. The potential reduction in precipitation in the longer-term, chronic phase following a nuclear war appears to be bio-

logically more important for many systems than the loss of incident sunlight during the acute period. The degree of spatial and temporal heterogeneity of climatic effects requires considerably more study. Different issues are key for different regions, as seen by the biological analyses thus far; e.g., Australian agricultural systems are most vulnerable to changes in precipitation; pelagic marine ecosystems are most vulnerable to prolonged decreased light inputs; many agricultural systems and tropical ecosystems are most vulnerable to low temperature excursions. Other considerations are that external radiation doses anticipated from global fallout, which have been well investigated, are not very significant with respect to inducing human and biological effects; but local fallout and internal doses, which are rarely analyzed and are poorly understood, would likely be of critical importance to millions of humans and to natural and agricultural systems after a nuclear war. These and a large number of other findings from biological considerations need to be integrated into a physical effects research program in order to make it more relevant.

Biological responses can have direct feedback to the physical processes themselves. For instance, changes in biological systems on a large scale would likely affect surface albedo. The possibility of the creation of large areas of standing dead biomass from temperature-induced impacts on tropical forests leads to the consideration of massive fires extending into the several-year time frame, potentially prolonging climatic effects; similar fires can follow from coniferous forests killed by local fallout, and by grassland, forest, and other ecosystems subject to reduced precipitation. Further, biologically mediated processes affect or control many atmospheric processes, e.g., via changes in CO_2 inputs and sinks, changes in the rates of evapotranspiration, and the global cycles of other atmospheric gases. The biological record can be instructive in evaluating previous catastrophic events, especially those which have concerned periods of weeks, months, or years of lowered temperatures with frosts occurring in the growing season. Such climatic analogs, including the Little Ice Age and volcanic events, have been inadequately investigated so far. And human-ecological interactions, such as desertification resulting from overexploitation for resources, can extend climatic effects in time and space. Clearly, the feedbacks are many, and physical analyses will be incomplete and often less relevant without their consideration.

What if it is found that there would be no nuclear war-induced climatic perturbations? There are still many global biological issues resulting from nuclear war that require careful attention. The current arsenals of strategic nuclear weapons are so large that the effects seen at Hiroshima and Nagasaki are grossly inadequate as models of a modern nuclear war. Issues such as prompt fallout, UV-B enhancement, pyrotoxins, habitat destruction, acidic fogs, elevated NO_x and HCl levels, and fire-caused high CO levels, among

many others, could affect the human and biological systems on a local or global scale. The potential for synergistic effects among these stresses is very high, but almost no work has been done in this area. Linkages of agricultural and ecological effects to impacts on human societal systems are extremely important; for example, reduced agricultural productivity from loss of fossil fuel subsidies alone could tremendously decrease world food yields, and disruption of food imports to many countries in the world could lead to large consequences even for humans far removed from the theatres of nuclear war. It is apparent that should major climatic disturbances occur, human consequences would be devastating; but the converse is not true, that minor or no climatic effects would result in only limited impacts on the global human population.

Just as the studies of nuclear war climatic effects have provided incentives to the development of general circulation models and other techniques for understanding atmospheric systems, nuclear war-induced stresses on the environment provide an ideal framework to develop the general field of stress ecology, an area greatly in need of an infusion of resources and new ideas, and an area of considerable importance in the current affairs of the citizens of the world in coping with increasing anthropogenic stresses on the environment. Indeed, one of the most amazing things evident from enumerating the consequences of nuclear war is that virtually every environmental problem we are currently confronting would be a direct result of nuclear war—only on a scale and intensity of unprecedented magnitude. The development of the next generation of ecosystem models and the assembly of extensive data bases of microcosms and whole ecosystems experimentally subjected to perturbations are exactly the areas of research needed to characterize environmental responses to large-scale stresses. It has been a quarter of a century since there was a substantial experimental effort in characterizing the effects on biological systems of nuclear war. We still draw primarily from the seminal work of Platt, Woodwell, and others in evaluating the effects of radiation on ecosystems, but few of the other nuclear war-related stresses on the environment have been treated explicitly. Yet this is the most important environmental issue ever facing humans.

The question should not be, 'Why study the biological effects?' but, rather, 'Why have we waited this long?' It is even more imperative today, since the new perspective on nuclear war is that a modern nuclear war would almost certainly export its devastation far beyond the combatant countries, particularly but not exclusively if there were major climatic impacts. The agricultural, ecological, and human vulnerabilities to perturbations on a global scale suggest that the indirect effects are likely to be much more consequential than the direct effects of the detonations themselves, and these effects would define what the post-nuclear war world would be like for the 4 billion or so immediate survivors. Understanding how different a picture of con-

sequences this is compared to the limited perspective drawn from nuclear tests and the relatively small-scale nuclear detonations on Japan can only be accomplished by understanding the vulnerability of the human support systems to the potential stresses of a modern nuclear war. It is unreasonable to expect decision-makers to develop appropriate nuclear policies when they only have an inadequate and obsolete perception of the consequences of nuclear war.