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Research, part of a Special Feature on Scenarios of global ecosystem services

Synthesis of the Storylines

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ABSTRACT. This paper outlines the qualitative components (the storylines) of the Millennium Ecosystem Assessment (MA) scenarios. Drawing on a mixture of expert knowledge, experience, and published literature, we have explored plausible consequences of four trajectories for human development. The storylines have been designed to draw out both benefits and risks for ecosystems and human well-being in all four trajectories with enough richness of detail to allow readers to immerse themselves in the world of the scenario. Only a summarized version of the storylines is presented here; readers are encouraged to read the more detailed versions (MA 2005). Together with the quantitative models (Alcamo et al. 2005) the storylines provide a base from which others can consider implications for policy and practice in more depth, adding their own interpretations, experience, and imagination. This is the purpose of the following papers in this volume.

Key Words: *adaptive governance; economic development; ecosystem services; environmental management; environmental technology; futures; poverty reduction; regime shifts; resilience; scenarios; urbanization*

INTRODUCTION

The Millennium Ecosystem Assessment (MA) Scenarios were developed to explore possible future changes in the provision of life-supporting services to humans from the world's ecosystems (Carpenter et al. 2006). These uncertainties arise in several ways. Although our understanding of ecosystems is improving, we know from the past that human modification of ecosystems can cause unexpected feedbacks that can intensify human impact and result in unintended outcomes (e.g., the emergence of diseases due to the decline of a key species). Past experience has also shown that ecosystems can appear to be changing slowly while building toward large and rapid changes that result in the system moving to a fundamentally different state (e.g., rapid overtaking of grasslands by woody weeds as a result of changes in fire regimes, or rapid emergence of algal blooms in lakes once nutrient levels pass a threshold). These and other examples indicate that there are potential impacts of human actions that have yet to be identified and understood (Bennett et al. 2003, Peterson et al. 2003, Carpenter et al. 2006). Further uncertainty surrounds the responses of people to environmental and social challenges, because people constantly learn and change the rules that they apply to decision making, depending on the extent of their knowledge and the nature of their values and beliefs at the time.

This paper deals with the use of scenario storylines, which draw on both quantitative exploration of future change (Alcamo et al. 2005) and expert judgment and imagination where current knowledge does not allow robust quantitative models to be developed (MA 2005). These storylines are plausible, provocative, and relevant thought-pieces about how the future might unfold. They are not forecasts, projections, predictions, or recommendations, because we recognize that many of the major challenges of the future are unknowable. By offering insight into possible uncertainties and the consequences of current and possible future actions, we hope to illuminate key issues that might otherwise be either missed or dismissed, and to widen perspectives and support more informed decision making in situations of uncertainty.

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DEVELOPMENT AND QUALITATIVE USE OF THE SCENARIOS

The introduction to this volume (Carpenter et al. 2006) outlined the rationale for the approach taken in developing MA scenarios. The scenarios were constructed around alternative pathways of human development identified by key decision makers and user groups (Carpenter et al. 2006). The scenario development team drew on a detailed analysis of past trends in major drivers of change performed by the Conditions and Trends and Policy Responses Working Groups of the MA. A discussion of these drivers can be found in MA (2005) and Nelson et al. (2006).

Two broad uncertainties underpinned many concerns about the future. These were: (1) the degree to which social and political institutions become more or less connected globally or more or less disaggregated regionally and locally than they are now; and (2) the extent to which decision makers in these institutions adopt proactive vs. reactive policies and practices with respect to managing ecosystems and their relationships with societies' needs and aspirations (Carpenter et al. 2006).

Within the discussion with the interviewees, and drawing on commentaries in the literature and media, we identified four further clusters of beliefs about the future that correspond to competing philosophies of development (MA 2005). "Global Orchestration" builds on the thinking of some influential international financial institutions that for several decades have advocated trade liberalization and free markets as the key ingredients for improving human welfare worldwide (e.g., Williamson 2000). In this scenario, decision makers go further by addressing a wider range of global public goods, including education, health, and institutional arrangements. "Order from Strength" was deliberately more optimistic than previous global disaster scenarios such as "Mad Max" (Costanza 2000) or "Barbarism" (Raskin et al. 2002). It acknowledged the views of those who feel that strong national security is essential, a view that is prominent in several national administrations in both the developing and developed world at present. "Adapting Mosaic" was based on arguments made by many ecologists and environmentalists that better outcomes for humans and ecosystems require closer attention to local learning about ecosystems and our roles in them. Rather than postulate major changes in people's environmental sensitivity, which has already been explored by previous global scenarios (e.g., Raskin et al. 2002), we built on the existing trends in many countries of devolving responsibility for environmental decision making to communities and growing disillusionment with the role of global and national institutions in environmental management. "TechnoGarden" brought together existing strong confidence in technology and human ingenuity in some sectors (Hawken et al. 2000, McDonough and Braungart 2002) with emerging recognition of the economic value of ecosystem services and efforts to capture that value in economic markets. It explores a world driven toward better environmental management by economic and technocratic development.

Previous global scenarios have dealt with ecological processes superficially, if at all (Cumming et al. 2005, 2006). We know from the past century of research on social–ecological interactions that both beneficial and adverse consequences of social–ecological interactions occur due to complex interactions of trends and discrete events. Social–ecological change is often surprising, because cumulative changes are often unnoticed until a period of relatively rapid change precedes a substantial impact or reorganization (MA 2005. Scheffer and Carpenter 2003). The risks and opportunities for human–environmental interactions in the future that we wanted to explore were not the obvious ones that involve making the same mistakes that were made in the past. Rather, we wanted to demonstrate to readers how a set of seemingly reasonable decisions made with the intention of improving the welfare of at least part of society could, if made at inappropriate scales or without due attention to unapparent ecological changes, produce surprises that could reduce or negate the welfare gains. Our main purpose in doing this was to illustrate the steps that could be taken to avoid or prepare for possible negative outcomes.

THE STORYLINES IN SUMMARY

Here we present key elements of the storylines. Exploring issues of this complexity cannot be done in short, simple stories, so we encourage readers to read the longer storylines to gain greater understanding of how and why the outcomes were expected to occur (Cork et al. 2005). Figure 1 and Table 1 also allow you to explore further details, especially with respect to how urban and rural areas and richer and poorer countries and regions might differ under the four scenarios.

The Global Orchestration scenario (globally connected, environmentally reactive) (Fig. 1) depicts a globally connected society in which policy reforms that focus on global trade and economic liberalization are used to reshape economies and governance, emphasizing the creation of markets that allow equitable participation access to goods and services. These policies, in combination with large investments in global public health and education, achieve economic growth and lift many people out of poverty into an expanding global middle class. Supra-national institutions in this scenario are well placed to deal with global environmental problems such as climate change and declining fisheries. However, environmental problems are considered only after they become apparent, making people vulnerable to surprises arising from delayed action, and threatening the fundamental goal of improving the well-being of all people.

Growing economies, expansion of education, and growth of the middle class lead to demand for cleaner cities, less pollution, and a more beautiful environment. Rising income levels bring about changes in global consumption patterns, boosting demand for provisioning ecosystem services, including agricultural products such as meat, fish, and vegetables. Demand for these ecosystem services leads to increasing conversion of forests into crops and pasture, leading to declines in supporting, regulating, and cultural ecosystem services. These problems are remote from most people, because they live in urban areas, and receive only limited attention. Global economic expansion expropriates or degrades many of the ecosystem services poor people once depended upon for their survival. An increasing number of people are impacted by the loss of basic ecosystem services essential for human life, requiring substantial governmental, business, and individual investments to mitigate and adapt to these losses. In some regions, wealth is sufficient to achieve satisfactory results, but in others it is not. Although risks seem manageable in some places, in other places there are sudden, unexpected losses as ecosystems cross thresholds and degrade irreversibly. Loss of potable water supplies, crop failures, floods, species invasions, and outbreaks of environmental pathogens increase in frequency.

The Order from Strength scenario (globally disconnected, environmentally reactive) (Fig. 1) represents a regionalized and fragmented world, concerned primarily with security and order, emphasizing regional markets, and paying little attention to common goods. Nations look after their own interests as the best defense against economic insecurity, and the movement of goods, people, and information is strongly regulated. The role of government expands as oil companies, water systems, and other strategic businesses are either nationalized or subjected to more state oversight. Trade is restricted, large amounts of money are invested in security systems, technological change slows, and global inequality grows. Agreements on global climate change, international fisheries, and the trade in endangered species are only weakly and haphazardly implemented, resulting in degradation of the global commons. Local problems often go unresolved, especially in poorer regions, but major problems are handled by rapid disaster relief when they threaten the well-being of the wealthy. Many powerful regions and countries minimize their own local problems, including pollution and natural resource-intensive industries, by shifting burdens to other places, increasing the gap between rich and poor both within and between countries.

Ecosystem services become less resilient and more variable in Order from Strength. Border control and low levels of trade tend to restrict the number of invasions by exotic species, but successful invaders have much greater impacts on vulnerable ecosystems. Conservation reserves persist within fixed boundaries, but climate and land use change around them, leading to the unintended declines and loss of many species. Conditions for crops are often suboptimal, and the ability of societies to import alternative foods is diminished by trade barriers. As a result, there are frequent shortages of food and water, particularly in poor regions.

In the Adapting Mosaic scenario (globally disconnected initially, environmentally proactive) (Fig. 1), political and economic activity focuses on regional institutions and ecosystems. This scenario sees the rise of local ecological identity, development of ecosystem management strategies, and the strengthening of local institutions. Investments in human and social capital are geared toward improving knowledge about ecosystem functioning and management. There is optimism that we can learn, but humility toward ecosystems that promotes the maintenance of regulating and

Fig. 1. Pictorial representation of some elements of the storylines. Please click on any rectangular picture below to obtain further details about that scenario. We thank Pille Bunnell for the artwork in Fig. 1, which she created in consultation with Steve Carpenter and Elena Bennett.

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supporting ecosystem services. There is variation among nations and regions in styles and success of governance, including management of ecosystem services. Many regions explore actively adaptive management, investigating alternatives through experimentation. Others employ bureaucratically rigid methods to optimize ecosystem performance. Some areas thrive, whereas others develop severe inequality or experience ecological degradation. Initially, restrictions on trade in goods and products are increased, as regions compete with one another, but barriers for information nearly disappear because of improving and cheaper communication technologies.

Eventually, the focus on local governance leads to some failures in managing global environmental problems, including climate change, declining marine fisheries, and persistent organic pollutants. Communities realize that global and regional problems are inter-connected, and they begin to develop networks that share effective solutions among communities, regions, and nations. Successes are especially common where there is mutual benefit from coordination, such as along river valleys. As learning accumulates, provision of many ecosystem services improves, and a variety of social and environmental problems—ranging from urban poverty to agricultural water pollution—are addressed.

The TechnoGarden scenario (globally connected, environmentally proactive) (Fig. 1) depicts a globally connected world relying strongly on technology and highly managed, often engineered, ecosystems. Overall efficiency of ecosystem service provision improves, but is shadowed by the risks inherent in large-scale, human-made solutions and rigid control of ecosystems. Technology and market-oriented institutional reform are designed to benefit both the economy and the environment. Property rights are extended to ecosystem services, requiring people to pay for pollution they create, and paying people for providing ecosystem services through actions such as preservation of watersheds. Investment in learning, information, and green technology, including ecological engineering, increases and is accompanied by a significant focus on economic development and education. In response to a variety of problems in global agriculture, there is a worldwide reduction of agricultural subsidies and trade barriers, agriculture diversifies as farms produce a variety of ecological services rather than simply maximizing food production, and there is growth of new markets for ecosystem services such as trade in carbon storage. Gradually, environmental entrepreneurship expands, resulting in companies and cooperatives providing reliable ecosystem services to cities, towns, and individual property owners. Rapidly increasing capacity for innovation in developing nations, together with trade in ecosystem services and enhanced uptake of technology due to rising income levels, lifts many of the world's poor into a global middle class.

Not every problem, however, has succumbed to technological innovation. The reliability of ecosystem services, especially in urban areas, is increasingly critical and difficult to ensure. Technological solutions themselves sometimes create new problems and vulnerabilities as supporting ecosystem services, like nutrient cycling, are unintentionally reduced. The costs of managing the environment are continually rising. Environmental breakdowns that impact large numbers of people become more common. The challenge for the future will be to learn how to organize social–ecological systems so that ecosystem services are maintained without taxing society's ability to implement solutions to novel, emergent problems.

VARIATION IN ENVIRONMENTAL AND SOCIAL OUTCOMES BY 2050

None of the scenarios represent utopia. All show improvements as well as declines for various aspects of ecosystem services and human well-

Table 1. Defining characteristics of the four scenarios

	Global Orchestration	Order from Strength	Adapting Mosaic	TechnoGarden
Dominant Approach for Sustainability	Sustainable development, economic growth, public goods	Reserves, parks, national-level policies, conservation	Local–regional co-management, common-property institutions	Green-technology, eco-efficiency, tradable ecological property rights
Economic Approach	Fair Trade (reduction of tariff boundaries), with enhancement of global public goods	Regional trade blocs, mercantilism	Integration of local rules regulates trade; local non-market rights	Global reduction of tariff boundaries, fairly free movement of goods, capital, and people, global markets in ecological property
Social Policy Foci	Improve world; global public health; global education	Security and protection	Local communities linked to global communities; local equity important	Technical expertise valued; follow opportunity; competition; openness
Dominant social organizations	Trans-national companies (Companies that spread seamlessly across many countries); global NGO and multi-lateral organizations	Multi-national companies (Companies that consist of loose alliances of largely separate franchises in different countries)	Local co-operatives, global partnerships and collaborations established as local groupings recognize the need to share experiences and solutions	Trans-national, professional associations, NGOs

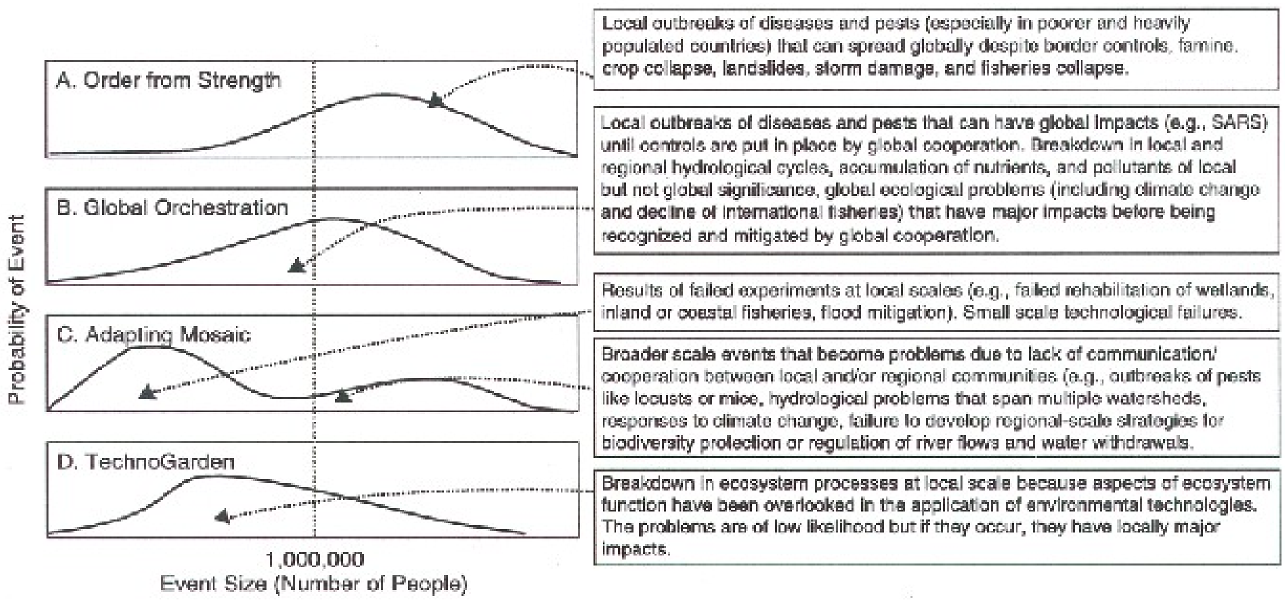
being. However, each scenario has its own pattern of improvements and decline. In all scenarios, there is potential to overlook linked social and ecological processes that work across scales of space and time. Good policies would acknowledge and prepare for these different risks, and ideal policies would contain elements of all four trajectories.

In a globally connected but environmentally reactive world (Global Orchestration), institutions exist that could deal with global environmental issues such as global climate change, or large-scale national issues such as salinization of landscapes. However, such problems often could be well advanced and difficult to reverse in time to avert disaster for two reasons. Firstly, institutions involving local communities who are in touch in real time with ecosystem change are likely to be relatively poorly developed. Consequently, we think it unlikely that the impacts of extreme events could be contained in terms of the area and the numbers of people they affect (Fig. 2). Secondly, there would be lower investment in understanding and monitoring the processes by which small-scale processes aggregate to become larger-scale problems. In balance, good luck could see moderate improvements in human well-being in this scenario, but there are also significant chances of major environmental problems affecting a million or more people (Fig. 2).

Please note that Fig. 2 represents the perceptions of the scenario writing team about impacts of extreme events. These relationships are open to interpretation, and we encourage readers to draw their own inferences.

Strong control of borders and movements of people and other organisms could have benefits for some aspects of environmental management (such as pests and diseases) in a globally compartmentalized, environmentally reactive world (Order from Strength). We could not, however, see the world avoiding major environmental problems for even a

Fig. 2. Types of plausible extreme events across scenarios. The x-axis is the magnitude of the disturbance of ecosystem services, measured by the number of people affected. The y-axis is the likelihood of an extreme ecosystem event of a given magnitude. Source: MA 2005.



few decades if wealthy countries focus primarily on protecting their own resources and there are strong barriers to cooperative detection of, and action on, emerging global environmental threats (Fig. 2). Poorer individuals, regions, or nations, would be forced to focus on economic and physical survival before environmental management, even though the resulting loss of ecosystem services undermines economic growth and human well-being generally. The wealthy not only face the risks of environmental problems developing unnoticed in their own part of the world, but they also face risks from problems arising in poorer regions and nations that spread regionally or globally. Examples include increased risks from major flooding, land movements, dust, and other forms of air pollution, and the spread of pests and diseases, including human pathogens. Although these outcomes seem obvious, writing the scenarios alerted us to how easily the world could find itself forced into a downward spiral of ecological degradation, diminished capacity to cope, and reduced human well-being, even though very few people or their leaders would want these outcomes.

The strong focus on understanding and managing local-scale social–ecological processes in the globally compartmentalized but environmentally proactive world (Adapting Mosaic) could produce substantial ecological and economic outcomes. The storyline, however, also explored how the social forces that allow local institutions to gather strength and authority could also erect barriers to communication between localities that compete with one another for better environmental outcomes (e.g., to facilitate entry to green markets) and how this could diminish the ability to detect ecological problems arising from processes that aggregate across landscapes and regions. Thus, new challenges akin to salinization or global climate change might grow to dangerous proportions before being identified and action taken. The dangers we see in this trajectory, therefore, are at two scales: impacts affecting a few people to hundreds of thousands of people in highly populated countries caused by failed experiments and lack of communication and cooperation at local and regional scales; and larger-scale impacts, such as collapses of international fisheries from ineffective global cooperation (Fig. 2).

In a globally connected and environmentally proactive world (TechnoGarden), we think that market forces could drive increased understanding of environmental risks and opportunities. This scenario explores the beliefs that ecological technologies will be fairly successful, produce few major unexpected breakdowns of ecosystem services, and become key tools for meeting social and economic objectives, yet detect and deal with ecological problems early. Many experts think that these assumptions are plausible, if optimistic, some making the case that massive improvements in efficiency are possible even with current technology (e.g., Hawken et al. 2000, Mol and Sonnenfeld 2000). Early detection and effective repair technology would likely confine ecological problems in this scenario to local scales affecting relatively few people (Fig. 2). The risks in this trajectory are that technology does not develop fast enough (Jacobs 1991) or that the ability of humans to manipulate ecosystems outstrips our ability to make wise decisions (Holling and Meffe 1996). These risks are much lower with respect to fast (short-term) processes, that affect the functioning of ecosystems over days, weeks, and months, than to slower (longer-term) processes that determine the persistence of ecosystems over years, decades, and centuries.

DEALING WITH ALTERNATIVE OUTCOMES WITHIN SCENARIOS

A major challenge in writing the storylines was encompassing the range of possible answers to the questions raised by users, without making the storylines too complex and unreadable. The literature shows that much of what we have learned about ecology came as surprises initially (Bennett et al. 2003), so the range of plausible ecological changes and the timing of those changes in the future is large. In the future, it is likely that human intervention in ecological systems will produce even more surprises, as it has in the past with respect to, for example, the bioaccumulation of toxins in food webs (Woodwell 1967), the creation of the ozone hole (Crutzen 1995), and the degradation of land and water by accumulation of nutrients applied initially to improve the fertility of agricultural systems (Cottingham et al. 2000, Carpenter et al. 2001). Interactions among social, economic, and environmental variables can, in the extreme, produce major environmental disasters such as flood damage, famine, wars, and even collapses of whole societies (Diamond 2005).

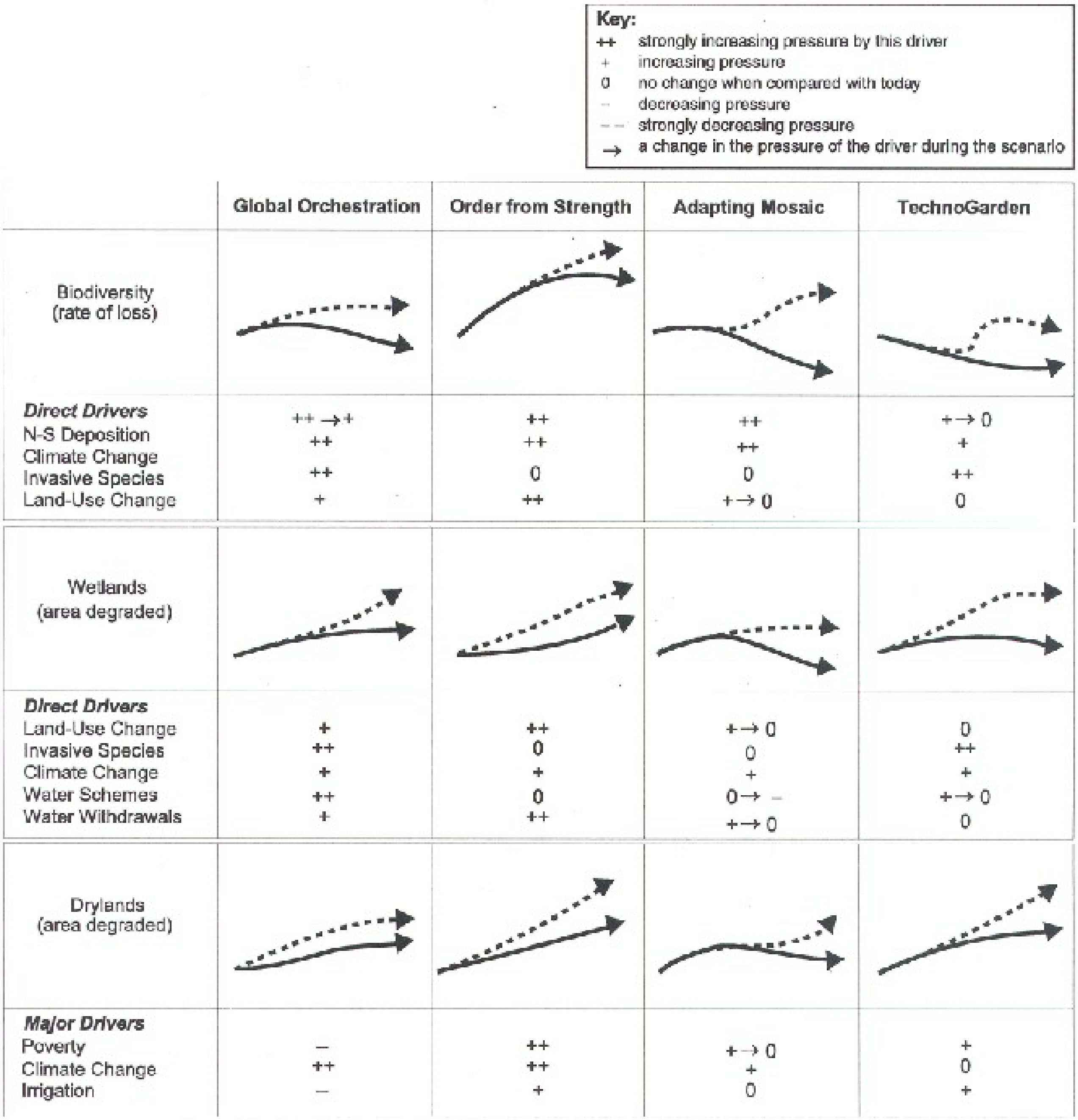
Rather than considering such extreme events in one or another scenario, and implying an unintentional ranking or distracting readers from the messages about subtle and potentially overlooked risks and benefits that are embedded in even the most optimistic outcomes, we considered the probabilities of extreme events in each scenario (Carpenter et al. 2006; Fig. 2). Another approach to dealing with variable outcomes within scenarios was to consider best and worst cases for a range of major issues (Cork et al. 2005). Some of these are summarized in the following sections.

Biodiversity

In all four scenarios, we expect to see some continuing decline in biodiversity. In the best case for the two environmentally proactive scenarios, TechnoGarden and Adapting Mosaic, however, we expect the rate of biodiversity loss to reduce steadily over the next 45 years (Fig. 3). This optimistic expectation was based on concerted and effective actions to reduce land-use change, reverse habitat simplification, reduce impacts of invasive species, and encourage enhanced ecosystem function and production of ecosystem services. The big risks for Adapting Mosaic are failed experiments and climate change, which might increase the rate of biodiversity loss beyond the control of poorly developed mechanisms for developing and implementing broad-scale solutions (Fig. 3). TechnoGarden carries the risk of technological failures that could lead, for example, to outbreaks of new pests and diseases threatening biodiversity. Such problems might see abrupt increases in biodiversity loss, followed by stabilization through rapid development and application of techno-environmental solutions (Fig. 3).

Land-conversion pressures are much more significant in Global Orchestration because of the scale of development of agriculture, but in the optimistic case, investment now to address already recognized declines in biodiversity reaps benefits by around 2020 (Fig. 3). The pessimistic outcome is less extreme than in TechnoGarden and Adapting Mosaic because it is assumed that wealth is available

Fig. 3. Postulated implications of the four scenarios for biodiversity loss, wetland degradation, and desertification over the period 2000–2050. Solid lines indicate the best case, dashed lines the worst case envisaged for each scenario. The row below the arrows for each issue contains a qualitative indication of changes in the relevant drivers (see Key for explanation of the symbols).



to address problems after they have emerged. A worse outcome for this scenario would see it turn into Order from Strength.

Without a focus on cooperation to improve the well-being of poorer countries, an Order from Strength world is likely to see the highest rates of land conversion and eutrophication, particularly in poorer countries, and devastating effects of invasive species (even though rates of introduction might be reduced through border control) that would see both habitats simplified and species reduced in numbers and viability (Fig. 3). Despite the very different optimistic cases for these two environmentally reactive scenarios, both face serious risks of inability to deal quickly enough with climate change (Fig. 3).

Wetlands

We expect wetland degradation in the next 45 years to be influenced strongly by withdrawal of water and the need to expand agriculture and water storage under the influence of population growth, and by invasive species and climate change (Fig. 3). The best outcomes are expected in the Globally disconnected but environmentally proactive Adapting Mosaic, because in the best case, we expect the scale of water storage developments to be limited because of the environmentally sympathetic approach to farming, and we think rates of land conversion and water withdrawal would be lower than in other scenarios (Fig. 3). The relatively high population pressure in this scenario, however, means that these benefits are not achieved until around 2020 in the best case and might not be achieved until much later if experiments fail, and learning and network development are slow.

Perversely, the next best scenario in the short term (best case) is the globally disconnected environmentally reactive Order from Strength. This is also because of limited development of irrigation and water storage schemes (Alcamo et al. 2005) and land conversion for agriculture, but in this case the limits are caused by poor economic growth and coordination. In this scenario, however, the worst case is more likely—i.e., that development of irrigation and water storage schemes and land conversion will proceed, leading to massive increases in area of wetlands being degraded (Fig. 3).

The best case scenarios for both Adapting Mosaic and Order from Strength assume a degree of trading with other regions and countries (the disconnections relate mainly to ability to cooperate and plan strategically at larger scales), but breakdown in trade contributes to the worst case scenarios in both cases.

In both globally connected scenarios, economic growth is initially accompanied by degradation of wetlands. Expenditure on mitigation after the fact in Global Orchestration produces the best case, whereas failure to react fast enough produces uncontrollable degradation in the worst case (Fig. 3). The proactive environmental policies of TechnoGarden include successful use of environmental technologies to improve water-use efficiency and protect and enhance wetlands by around 2030 in the best case. In the worst case, technologies fail and wetlands are replaced because their ecosystem services are provided by alternative technologies.

In the most optimistic versions of Order from Strength and Adapting Mosaic, there would be relatively low risks of invasive species because of the low levels of global trade and movements of people. Climate change is expected to become significant in the second half of the period (Alcamo et al. 2005) for all scenarios, causing a rise in sea level that leads to loss of coastal wetlands such as estuaries or tidal flats and deltas. This effect is most pronounced in Global Orchestration, Order from Strength, and Adapting Mosaic, where it might even overcompensate for the effects of learning. The effect is not so strong in TechnoGarden, thus further allowing for the leveling or turnaround of the trends of loss of the first 20 years of the century.

Drylands

Dryland degradation occurs becaue of both characteristics of a region (especially climate and water availability) and the pressure that is put on the environment by human activities. The MA modeling suggested that, globally, changes in arid areas as a result of climate change are relatively small until 2020 (MA 2005). Thus, in the short term, the pressures play a more significant role. This leads to different risks within the four scenarios.

The best case for Global Orchestration would see a significant decrease in material poverty, which could minimize dryland degradation (Fig. 4). In the worst case, however, reduction in poverty is not great enough and degradation could continue at a similar pace to what we see today. In the short term, the other three scenarios see limited relief of poverty and degradation is expected to continue at close to current rates.

In the longer term, chances appear for reduced degradation in TechnoGarden and Adapting Mosaic. In the best case for TechnoGarden, this comes from technological progress bringing about new methods for production in dryland areas. In the worst case, however, these technologies are not available to the marginalized people who need them. The best case for Adapting Mosaic sees improvement of local knowledge and property rights for better managing agriculture and ecosystem services by around 2020. The worst case sees failed experiments, and failure to adapt skills and practices quickly enough to deal with major changes in climate (Fig. 4).

Order from Strength sees the strongest degradation throughout the whole period, and the present trend might even increase because of climate change and further institutional failures.

Human Well-being

The broad trends expected in elements of human well-being (Fig. 4) hide many details about the very different ways in which these trends are achieved in the different scenarios (for a more detailed discussion, see Butler and Oluoch-Kosura 2006).

For all measures, Order from Strength is expected to produce the worst outcomes, in both the best and worst cases. This is because environmental degradation further reduces basic resources, living conditions, health status, and freedom of choice, especially (but not only) for people in poorer countries. The strong focus on national security inhibits efforts to improve global equity and, ironically, enhances the likelihood of major conflicts. Even in the most optimistic case, we envisage some decline from present levels of well-being.

Improvements in well-being in Global Orchestration flow largely from the investment in manufactured capital (technological innovation for production and for ecosystem repair) on a global scale, with less investment in human capital (education about most things is a high priority, but learning about the environment is not) and natural capital. If policies for reducing global inequalities succeed, then health, security, and freedom of choice outcomes should follow. Two critical uncertainties in this scenario, however, are the speed with which successful policies for accelerating the development of poor countries can be the applied, and whether wealth from investment in manufactured capital can be applied to improving human–ecosystem interrelationships to improve overall well-being.

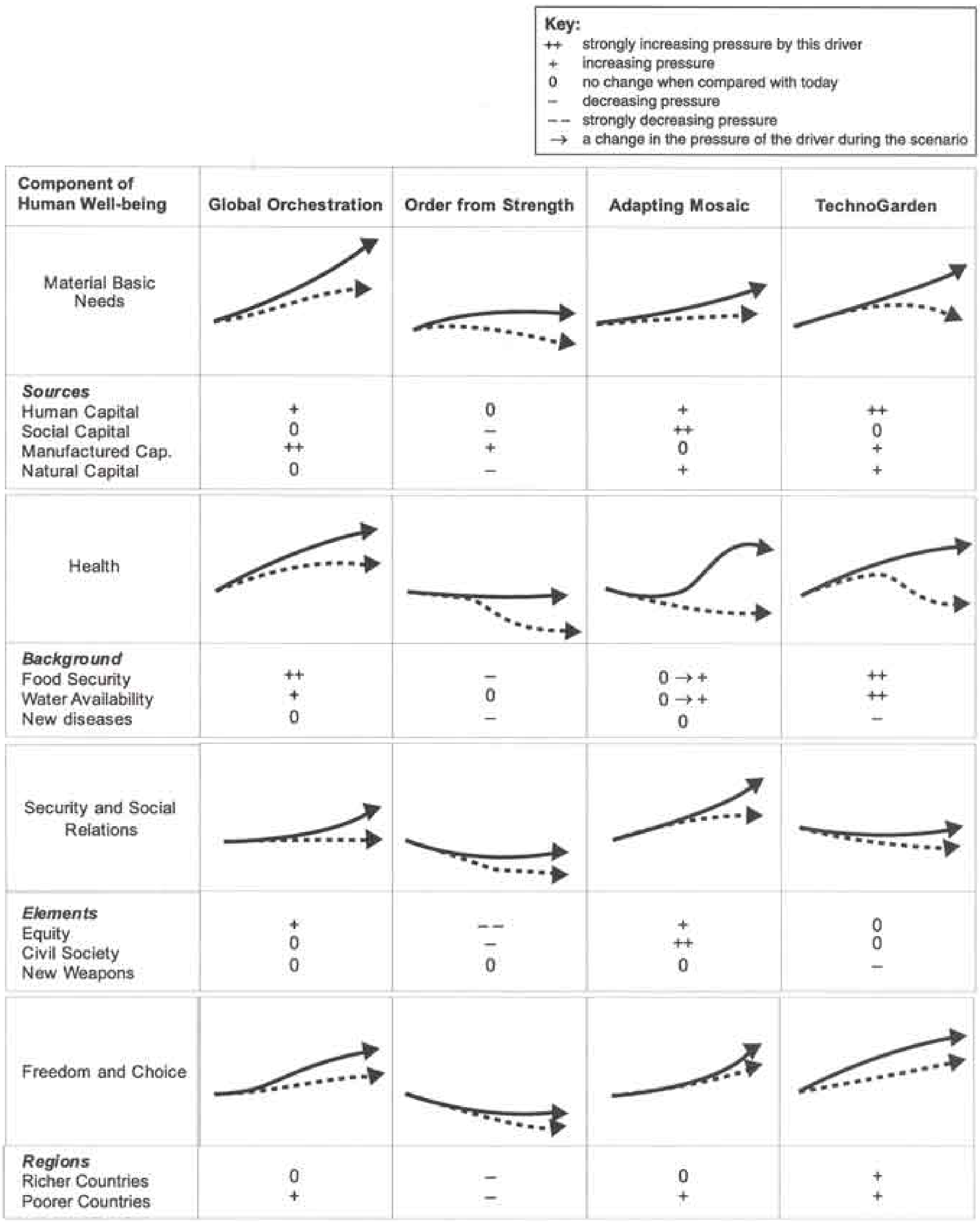
The two ecologically proactive scenarios differ in the routes adopted to improve human well-being. TechnoGarden builds manufactured and natural capital from accumulated human capital (learning, tightly targeted as ecosystem management) and uses natural capital to provide financial and other benefits to humans. Adapting Mosaic puts major emphasis on the development of social and human capital through learning and development of cooperative networks. Health benefits from better environmental management are likely in both of these scenarios. Risks of disease spread are lower in TechnoGarden because of strong global institutions, but the introduction of new bio-technologies brings with it a risk of the occurrence of new diseases.

Adapting Mosaic sees the strongest investment in social capital and the strengthening of civil societies. Some risk exists if the conflicts that accompany the redistribution of political power persist over time and hinder the development of social networks. In contrast, TechnoGarden sees a world in which the new means and methods for managing ecosystems and ecosystem services are owned by an elite group of scientists, engineers, and business people, leading to losses of informal and local knowledge. On the other hand, new social relationships may emerge as information is shared. This scenario carries both the greatest potential for developing new biological weapons and the greatest capacity of global cooperation to regulate the use of such technologies.

CONCLUSIONS

The scenarios developed by the MA Scenarios Working Group were based on a mixture of inference from quantitative modeling, based on past trends, and imagination, based on experience and expert judgement. Our two most important general

Fig. 4. Postulated implications of the four scenarios for the ability of ecosystems to meet human needs for well-being over the period 2000–2050. Solid lines indicate the best case, dashed lines the worst case envisaged for each scenario. The row below the arrows for each issue contains a qualitative indication of changes in aspects of the component of well-being (see Key for explanation of the symbols).



conclusions were: (1) that global cooperation to deal with social and environmental challenges would lead to better outcomes than lack of cooperation; and (2) that proactive environmental policies would lead to lower risks of major environmental problems affecting many people than reactive policies would (see also Carpenter et al. 2006). However, we recognized that national and international events will mean that ideal policies are not always possible at all times and that, even with cooperation and proactivity, well-intentioned decision making could cause unintended and undesirable outcomes. We tried to draw out some cautionary tales about ways in which the full range of development trajectories could have both positive and negative outcomes.

Reactivity in environmental policy can arise in many ways, but two major ones are: (1) belief that ecosystems are robust (resilient) and that ecological and social systems are not close to critical thresholds of change; and (2) insulation of elite decision makers from environmental and social change in time and or space.

Although ecology cannot yet give definitive answers to the question of ecosystem resilience for all ecosystems, evidence of the importance of ecosystem resilience and of what happens when resilience is ignored is accumulating. From the work of many ecologists and social scientists, we drew lessons about the ways in which changes in society and in ecosystems can feed back on one another to catch decision makers off guard if they are focusing on the wrong scales of time and space. In thinking about what lessons ecology has for future decision makers, we had to admit, humbly, that although the types of challenges that arise in the future could be similar to ones that have arisen in the past, there will certainly be surprises in the details. Preparation for the future, therefore, must be about preparing for a range of environmental possibilities in the context of a range of national and international policy situations.

Societies in which the elites are insulated from environmental and social changes (e.g., gated communities in most of the world's major cities or decision making by central governments vs. local communities) face the risk of problems reaching unmanageable levels before real action is taken (Diamond 2005). In our scenarios, we make the point that proactive environmental policies and connections and cooperation among regions and nations potentially increase ability to detect and react to change rapidly and constructively, but we suggest ways in which blindness to emerging challenges could still be a problem.

We have explored how major change in people's actions could occur because of chains of events that are potentially being put in place today. In the course of writing the scenarios, we have seen the world change in ways that suggested one or another of the scenarios unfolding at different times and different places. We avoided contemplating widespread changes in people's core values toward environmental management, and we equally avoided contemplating massive disasters such as world wars. Both are possible, and the world could see much brighter or much bleaker futures than we have explored. In the more detailed scenarios (Cork et al. 2005), and to a lesser extent here, we have compared across scenarios the potential for conflicts to emerge.

The purpose of scenario development is not to predict the future, but to stimulate thinking about the possibilities. Therefore, we encourage readers to make their own interpretations and extract their own lessons about future challenges and their implications for decision making.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol11/iss2/art11/responses/

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