Chapter 24
Future and Outlook: Where Are We, and Where Will the Spatial Information Management in Wildlife Ecology Be in 50 Years from Now?

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24.1 Looking Back

In this final chapter we briefly look back over what we have attempted in this book, and then look toward the future to discuss the outlook for overcoming the challenges we face within our fields of ecological science and in the greater application of this knowledge to enhance the prospect for a sustainable future for the biosphere. Looking back, we have tried to present a view of ecological science at the cusp of major change. The change is all around us, driven by vast improvements in computational power, analytical tools, spatial databases, economy and related governance structures within the sciences. These changes have fundamentally altered what is possible in ecological analysis and are enabling a new synthesis and applications of data and method to recast ecological theory in a spatially and temporally explicit framework. In this book we argued that ecological theory and its dissemination is lagging significantly behind advances in data acquisition and analytical methodology. This is in part because of the inertia and resistance of established procedure and theory, and secondly because of the way the sciences are currently administered and trained.

We argued that ecological systems are fundamentally sensitive to details of spatial and temporal variability, and that ecological theory and analysis must greatly expand to address this robustly; new culture is needed. We argued that landscape ecology provides a natural context for this synthesis, but only when this field itself transcends the limitations of its often ideological history to embrace a generalized, flexible, multi-scale and multi-variate theoretical and analytical framework.

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We then argued that informatics is the foundation for this framework, with special emphasis on the need for multi-scale, multi-variate, spatial databases to serve as a foundation for flexible analysis and powerful modeling. We reviewed a number of varieties of ecological data within the context of this integrated framework, noting the unique challenges and opportunities posed by GPS telemetry data on animal movement and molecular genetic data as examples. We discussed the powerful contributions to data collection and analysis enabled by modern remote sensing technology, and discussed the structure and management of ecological databases. Customized, open-source analytical software tools were identified as an area of rapid expansion and enormous opportunity. We presented a broad range of spatial and multi-variate statistical methods for analyzing animal ecology. We argued that landscape genetics, particularly when expanded into a gradient framework, provides an immense opportunity to explore the causes and consequences of population structure and for a better management maintaining genetics diversity world-wide. We presented several examples from different geographical regions and across the taxonomic spectrum of these different kinds of spatially sophisticated analysis and then discussed the prospects for integrating the best available science on spatial and temporal dynamics into natural resources management, and ended with a chapter on the integration of science and policy in animal management and conservation.

The reader must judge the degree to which we have maintained coherent connections and flow among the major examples and ideas in the book. Certainly, more thinking and assessment is necessary to fine-tune modules and visions presented here. That is what academics are good at and what universities should provide: science-based management of natural resources with an aim to achieve global sustainability. The main purpose of this chapter, however, is to look forward to where we think the changes we have argued are needed and that we have described in their initial stages will progress in the coming decades, and also how hopeful we can be about the actual prospects of effectively integrating advanced ecological monitoring and research into a truly sustainable global future.

24.2 Looking Forward

Looking forward we can anticipate several trends that we identified in this book that will continue. First, there will continue to be great advances in the collection of spatial data at fine grain over broad extents. Technological improvements have been very rapid in remote sensing and sensor networks, with new platforms being designed that will greatly expand the range of data products in terms of spectral, spatial and radiometric resolution, temporal frequency and spatial extent, and accuracy. LIDAR, RADAR and other aerial platforms, e.g. unmanned vehicles and sensors, are also improving and becoming more available for all users world-wide. This advancement will also include taxonomic species data and inventories.

The challenge for the future may be society's ability to continue the very large investments in earth observing satellite deployment in an era of increasingly limited discretionary funding and potentially declining tax revenue due to demographic changes in the populations of the United States and Europe. Some believe due to these economic and social forces that China (Russia, India, Brazil and Indonesia) may emerge as the leader of the next generation of deployment of remote sensing satellites. This remains to be seen, as China is now tied to the west, faces at least as severe demographic challenges to continued economic growth, various management and democracy challenges, plus a clear linkage with the export market economies of the United States and Europe. Despite recent failures of latest Landsat missions, it seems very likely to expect no major break in the continued deployment of more and more advanced earth observing remote sensing platforms, which will continue to provide transparent spatial and temporal data of ever higher quality and finer resolution. In turn this will continue to drive demand and progress in analytical methodology and ecological theory, as well as sustainable management dealing with the human footprint.

We also expect progress in computing power and the computationally-intensive analytical and simulation approaches that it enables to continue apace. We have higher confidence in this area, as it requires far less in terms of massive central-government investment and oversight than developing and deploying complex earth observing satellites. The advances in cloud computing and in immense remote networks of processors may provide super-computer-like computational power for anyone with a personal computer and an internet connection, allowing for in-time solutions to complex ecological optimization problems. It is important here though to push for equal access to such opportunities, and lessen the digital divide towards a truly global village view of applications, users and funding.

The major drivers of the changes to ecological theory we have discussed in this book are intimately linked to rises in computational technology. Much research that appears in 'traditional Ecology' is actually only possible due to EcoInformatics, and perhaps should be labeled as such. This has already set up a new culture, and our understanding of ecology, our universe, and ourselves within it.

We further argued that the traditional fixation on simple, equilibrium models of ecological systems is a historical legacy of the absence of powerful computing and simulation until the past several decades. This needs to be quickly reformed. The new context for modeling and analysis provided by modern computers is truly revolutionary and has led to immense changes in what questions are deemed tractable, and the sophistication and detail of ecological analysis and modeling. We argued in this book for an explicit focus on pattern–process relationships at multiple spatial scales across large extents in time and space. This was simply not even conceivable until powerful computation was coupled with extensive and fine scaled ecological data, and legally demanded, e.g. Biodiversity Convention. Together with online initiatives and opportunities, the combination of these has fundamentally altered the field of ecology, and with computational power it is expected to continue to grow at a rapid pace. Therefore, we can expect analytical and computational methodology to continue being a major driver of the advancement of ecological knowledge and the reframing of core ecological theory, all to be disseminated online for all citizens and decision-makers world-wide!

With the coupling of ever more powerful computing, with ever more extensive and detailed ecological datasets, we anticipate that many researchers will independently adopt the multi-scale spatial informatic data-cube model we presented in Chapter 6, and use it to implement the kinds of flexible, multi-scale, multi-variate space–time analyses and multi-species modeling efforts we described in Chapters 2, 4 and 6 and elsewhere in this volume. Technological advances being made as we write will enable the sequencing of entire genomes very rapidly and inexpensively. This will revolutionize landscape genetics, the study of geneflow, population fragmentation and adaptive evolution in complex and changing environments. Landscape and their resources can get optimized towards reaching best possible goals.

The generation gaps between current cutting-edge data, computing and analysis and established ecological theory might continue and perhaps expand. The rate of advance in data acquisition and computational power will likely increase, which will likely lead to further disequilibrium between established procedures and principles and the potential of currently emerging methods and datasets. On the other hand, one could argue that there will be a decrease in the dischord between orthodox ecology and the cutting edge of science. It may be argued that this dischord is at its maximum right now, as traditional modes of thought, governance and global structures, procedures of analysis and explanatory theories which were developed prior to the availability of GIS, remote sensing and computing are still dominant in the global culture of the science and its funding agencies. Over time, these advances in method and data are infiltrating orthodox ecological thought and in some cases, as described in Chapters 2 and 4, leading to major shifts in paradigms. We argue that this cultural shift from non-spatial, equilibrium paradigms of the twentieth century, to spatially and temporally explicit, nonequilibrium paradigms of the twenty-first century is the most important transition in the history of ecological thought. Once it has been accomplished then even very rapid advances in the quantity of data or improvements of the speed of computation will not lead to larger disequilibrium between established thought and emerging method. That is, once this *qualitative* change in paradigms is made, further quantitative change in data and method will not prove revolutionarily challenging and will not provoke further paradigm shifts for the foreseeable future. Therefore, we offer that the skeleton space–time–scale–pattern–process paradigm we outline in this book may emerge as the core of the ecological science of the next century. This is not a small feat, and we are very excited to see its development world-wide.

The arguments above are hopeful and optimistic. We unfortunately are less optimistic about our second theme of expected future changes. A second, although usually subsidiary, theme of this book is the potential of advances in ecological monitoring and research to guide management of the earth's natural resources and how it potentially could play an instrumental role in a global transition to a sustainable future. Earth is clearly facing the greatest mass extinction in 65 million years. Human population growth, one-sided resource exploitation, compounded with anthropogenic climate change are a potent combination driving this biodiversity crisis. It is not at all clear that the technical and theoretical advances we describe in this book will be decisively beneficial in mitigating this crisis. What is needed is massive public outcry demanding real change to environmental sustainability. There is a key role for science in this, as the public debate will not occur in earnest until the severity of the circumstances become more universally understood by the people, the media and governments. We feel that scientists have been far too timid and ineffectual in their efforts to communicate with the public and powers in charge. We feel strongly that scientists should not make policy. Politics is a process of valuation of alternative actions by the people; science ideally is knowledge of processes and conditions. While the political debate absolutely needs to be deeply informed by science, scientists should resist the desire to use science as a political tool. There is a very fine line here. Science should fully participate in all relevant key questions of this world, and always work at the core. That Earth is facing a dire biodiversity crisis is clear. That there needs to be bold and quick political action to address this is also clear. That science is the key source of knowledge to provide a basis for the political decisions that will address this crisis is also clear. The role of scientists is as communicators not as policy makers. The current view of most practicing scientists is that scientists create knowledge and knowledge will rise to the top because of its inherent value. As a result scientists generally allocate very little of their time and effort to communicating their findings to non-specialists. As a result, there is a massive disjunction in understanding of many major issues of global importance between the scientific community and the general population. This is where we feel scientists should focus their efforts with the aim of moving toward a more sustainable future. Scientists must inform the debate and provide reliable data and information. Simultaneously, there needs to be a much stronger response from the legal community and national and international governing bodies to ensure global sustainability, environmental justice and world peace.