VIII CONCLUDING REMARKS

Regime shifts are among the most exciting research frontiers in ecology. They bring long-term and spatially-extensive ecological research together with theory, modeling and statistical approaches that are at the forefront of ecology today. Regime shifts, like many important topics of ecological research, demand a synthetic approach. Thus there are tremendous opportunities for small interdisciplinary teams to make crucial advances in the understanding of regime shifts.

Regime shifts are also a key topic in applied ecology. Ecosystem management is devoted to maintaining desirable ecosystem regimes, avoiding transitions to undesirable ecosystem regimes, and inventing new ways to adapt to novel ecosystem regimes. Thus regime shifts are crossroads of ecology and management.

The choice between globally-stable and multiple-attractor models of ecosystems is a key dilemma (Fig. 52). We generally have limited information about potential attractors and the state of the ecosystem. This uncertainty is depicted by the large and shifting balls and thick, fuzzy topography of the ball-and-cup diagram labeled "observations" in Fig. 52. Because the data are limited, many different inferences are plausible, and the various models have diverse implications for management decisions. Two simple extremes are shown (Fig. 52). An analyst may favor a linear model of global stability, which implies that resilience is infinite. It may further be assumed that

the desired ecosystem state (position of the ball) can be attained by controlling the position of the ecosystem through continued exogenous pressure (grey arrow). Alternatively, an analyst may conclude that there are multiple attractors, although they are not very well defined, and that the ecosystem could be managed by increasing resilience of the desired attractor, even if we are uncertain about its characteristics. The variability, or at least some of it, may be due to the intrinsic dynamics of the ecosystem, and may even be essential for building resilience.

A central message of this Excellence in Ecology book is that alternate attractors are difficult to discern yet cannot be neglected by ecologists. Fundamental work on regime shifts and alternate attractors will lead to important new insights about ecosystem change. In management, practices that ignore the possibility of regime shifts risk unpleasant surprises. A narrow focus on controlling and stabilizing ecosystem dynamics may increase the risk of crossing thresholds, while diminishing variance that is necessary for estimating where the thresholds lie.

Intensive control of ecosystems seems to increase frequency of regime shifts and perhaps promote the emergence of novel regimes. Why? Are there ways to increase ecosystem resilience, and reduce the frequency of unwanted regime shifts? How do management and ecological regime shifts interact? How do management practices change the resilience of ecosystems? Can management institutions invent better ways to address ecosystem regime shifts before they occur? These are among the most important questions facing ecology today. Yet, in a sense they are old

questions, because people have encountered ecosystem regime shifts at many times in the past.

Humanity's search for an ideal environment has meandered over time, and has never approached a stable condition. While the details differ among cultures, biogeographic regions, and eras of history, there have always been tensions between exploitation and nurturing of ecosystems, and between controlling and inventive styles of management. Control provides security, but it also leads to dependency. Control gets easier as systems are simplified, but simplification creates fragility and vulnerability. When ecological regimes change and old management systems break down, the future depends on innovative new approaches. Innovation arises from multiple human perspectives, heterogeneous landscapes, diverse biotic communities, and modular ecosystems. People nurture these seeds of creativity by instinct, even as they strive for greater predictability and control. So we move from one to the other – from control to innovation, simplification to diversification, efficiency to creativity, breakdown to renewal – seeking a point of balance that is not attainable. Instead, we find endless change, an ongoing dance with nature which sustains us and inspires us. Regime shifts are part of the dance, the big changes in rhythm that seem to transform everything. If we understand that surprises are coming, we are more likely to adapt and dance onward.

Figure

Figure 52. Observations provide uncertain information about ecosystem state (circles) and potential regimes (curves). Two possible inferences and management actions are shown for maintaining desired ecosystem conditions. Noisy data might support the idea that the system is globally stable and controllable (left), or the idea that the system has multiple attractors (right). If there are multiple attractors, it may be possible to increase resilience of a desirable attractor. (Original)