A Species in Crisis

Conservation Biology and the Black-Footed Ferret. ULYSSES S. SEAL, E. TOM THORNE, MICHAEL A. BOGAN, and STANLEY H. ANDERSON, Eds. Yale University Press, New Haven, CT, 1989. xviii, 302 pp., illus. $40.

The recent history of the black-footed ferret is probably one of the best known stories in modern conservation. It has many of the characteristics of a good story, but also many that effectively illustrate the evolving sciences in conservation biology. The species was once widespread over much of the North American Midwest and largely dependent upon prairie dog colonies for food and shelter. Loss of the prairie habitat and systematic efforts to remove the prairie dogs led to its decline, and it was believed to be extinct until the chance rediscovery of a colony in Wyoming in 1981. Subsequent studies failed to locate further colonies, and it was agreed that a captive colony should be established as a safeguard for the species. Unfortunately, just as this initiative got under way an outbreak of canine distemper led to the death of all the captive animals and most of the remaining wild population. An effort to capture all the remaining ferrets was agreed on, and by the end of 1986 there were 18 wild-caught ferrets in captivity—probably all that remained of the species. Since then, captive management has resulted in a more secure population of over 150 animals, but only after the intensive application of systematic, molecular, population, and reproductive biology, not to mention over 2 million dollars.

This book arose from a meeting held in 1985, before the captive population was established, and its content reflects the concerns prevailing at that time. As Seal makes clear in the introductory section, the 19 chapters do not attempt a comprehensive treatment of conservation biology. Habitat management, disease control, nutrition, behavior, and other relevant topics are omitted because the critical need was to safeguard the species. First, successful reproduction was essential, and six chapters describe factors involved in natural and artificial reproduction, including the emerging technologies of embryo transfer and cryopreservation of gametes. Almost nothing was known of the basic biology of the black-footed ferret, and it was necessary to know much more. The morphological and molecular systematic studies by Anderson and by O'Brien *et al.* indicated that both polecats and other ferrets were sufficiently closely related to the black-footed ferret to serve as models, and most of the detail on reproduction is about these species. Of more general interest is a review of embryo technology by Wildt and Goodrowe, which presents some intriguing possibilities for the future but emphasizes that these were unlikely to be immediately useful for the black-footed ferret.

The book is very much a book of the crisis, and the chapters that will stand the test of time are those that address more general issues in the management of critically endangered species. A lesson to be learned throughout the sections on population biology and management is that species rescue is considerably more likely and less traumatic (for both the animals and the decision-makers) when the populations to be drawn on are in the thousands rather than in the tens or even hundreds. Demographic and genetic problems as well as more general extinction models are dealt with in detail in chapters by Ballou, Harris *et al.*, and Lacy and Clark. Much classical population biology theory, derived from models assuming infinite population size, has little relevance to small populations, where chance plays a major role, and new methods are needed. Brussard and Gilpin present a simple simulation model of colony extinction and recolonization and conclude that long-term management of the species will require multiple reserves with managed migration of individuals. Most of the chapters on population biology, and the management plan by Ballou and Oakleaf, suggest that reasonable goals for maintenance of genetic variability and demographic stability can be achieved if the population is expanded rapidly to a size of about 250 and a reintroduction program then initiated. Certainly during the gestation of the book the program has moved toward meeting these goals.

Another respect in which we clearly need to refine our skills is the making of decisions at moments of crisis when almost everything is uncertain. Emotions can run high, and the tendency may be to postpone action for fear of doing something disastrous. In the business and commercial world such situations are also common, and Maguire shows how decision theory can be applied just as well to conservation issues. There are differences, though, in the aims of conservation and of commerce; in the latter optimization is appropriate, but in conservation planning a course of action that is least likely to do irrevocable damage may be preferable.

The subject matter of this book is very broad, but its focus is narrow: a particular species at a particular time and place. While the specific applications will go out of date, the principles will become more and more significant as we face the same situation with more and more species. Many other works in conservation biology are felt to be too theoretical and hard to apply to specific cases. This is not so here. This is a practical book including chapters by leading theoreticians, and the authors and editors do an excellent job of taking general principles and applying them to a species about which very little was known.

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Ecological Prediction

Biological Invasions. A Global Perspective. J. A. DRAKE *et al.*, Eds. Published for the Scientific Committee on Problems of the Environment, International Council of Scientific Unions, by Wiley, New York, 1989. xxiv, 525 pp. $146. SCOPE, 37.

This book is the culmination of an almost decade-long investigation of biological invasions sponsored by the International Council of Scientific Unions' Scientific Committee on the Problems of the Environment (SCOPE). It has significant redundancies with earlier volumes produced by regionally based SCOPE studies of invasion (see Ted Case's review of three of these in *Science* **236**, 1000 [1987]), but it is the most comprehensive. It is thus the best single book of the series for a personal library or for a graduate seminar. A central theme of this final volume is predictability—which species will fail to establish themselves in a new biogeographic region and which will succeed and with what consequences—and it is this topic I single out for review.

Biological invasions have been the ecological problem of the second half of the current millennium. Driven primarily by the movement of Western humans over the planet, exotic invaders have been the single greatest cause of species extinction, and certainly the major nexus between economics and ecology. Thus the intellectual focus of the SCOPE exercise was defined at the outset with two simple, seemingly straightforward questions: What are the factors that

determine whether a species will be an invader or not? and What are the site properties that determine whether an ecological system will be relatively prone to, or resistant to, invasion? Answers to these questions would be invaluable to efforts to prevent invasion and to control invasive species.

Each chapter grapples with one or both of these questions from the standpoint of the expertise of its authors. Some chapters focus on the taxon or the biogeographical origin of the invader, others on the character or community structure of the invaded system. Some chapters are conceptual; some stress models. Unfortunately, in chapter after chapter failure to answer the key questions is variously acknowledged. There are complaints that insufficient information has been collected concerning failed invasions or introductions. There are references to the inherent complexity of ecology. Some think that the timing, location, and initial population size of the invading propagule are important considerations. Brown sees an unbridged gulf between academic ecologists who are satisfied with generalities and applied ecologists who must manage on a case-by-case basis.

Nonetheless, many authors remain hopeful. Ehrlich is pleased that we have some generalities about invasion, viz., that mammals are more likely invaders than monophageous arthropods but do not necessarily have less serious effects. And in their concluding chapter, Mooney and Drake also remain optimistic: in a section headed "good intentions are not enough," they comment that "as our understanding of biological systems becomes more complete we should be able to reduce the probability that an intentional introduction will have an adverse effect."

I find this ambiguity unsettling; the participants in this thorough study have reached a conclusion they seem unwilling to accept. Population biology has always had difficulties with prediction, even for the simplest single-species systems within undisturbed environments. The problem of predicting invasion success stretches its capacities beyond the breaking point. Species X of ecological system Y is to invade ecological system Z—will it succeed? A major misconception is that species X has intrinsic properties or factors independent of its resident ecological context (system Y). Also, we must understand that we have never characterized any ecological system, Y or Z, at the level of species-species interactions; that is, we cannot predict the dynamics of an undisturbed Y or Z. In any case, X invading system Z is a complete unknown. We have no knowledge of the coupling parameters between X and Z, and we are also ignorant of the nonequilibrium dynamics that will result from the initial growth of X in Z.

To underscore this fundamental ignorance concerning invasion, I and others have shown that we cannot predict, from summary statistics alone, species-invasion success for differential-equation systems modeled on a computer. The same is true for well-characterized *Drosophila* species in laboratory ecosystems. Though field ecologists are right to be suspicious of the "successes" of such models, they should not let the lessons of the limits and failures of these models be lost on them: we are never going to have a scheme to predict the success of invading species.

Given that we must renounce our quest for case-by-case predictability, what should we do? There is pattern in the data we possess on invasions. The next efforts in the study of invasion should be self-consciously statistical, with an emphasis on characterizing the probability distribution of outcomes for classes of invasions. But for this we will need the raw data on-line in computer databases accessible to all researchers.

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New View of the Ionosphere

The Earth's Ionosphere. Plasma Physics and Electrodynamics. MICHAEL C. KELLEY, with contributions from Rodney A. Heelis. Academic Press, San Diego, CA, 1989. xii, 487 pp., illus. $89.95. International Geophysics Series, vol. 43.

Known for decades as an electromagnetically active layer of the atmosphere with dramatic effects on human radio communications, the ionosphere has in more recent times been investigated with incoherent scatter radars and scientific satellites. This has resulted in a new view of the ionsophere as the "battleground between the earth's neutral atmosphere and the sun's fully ionized atmosphere," in which large-scale atmospheric flows and the solar wind vie for influence and control. In this new view, the emphasis has shifted from the causes and structure of the ionosphere to its dynamical behavior in response to various forms of energy input and dissipation.

This book represents an effort to synthesize these new thrusts of ionospheric research into the plasma physics and electrodynamics of magnetized, partially ionized gases in relative motion. It is written on the level of a literature review but includes a tutorial introduction and is suitable for graduate students (though no end-of-chapter problems are provided).

The struggle between atmosphere and solar wind unfolds across a region that is demarcated by altitude as much as by latitude, the solar wind dominating at higher latitudes and altitudes. The region considered for this book extends from the equator to the poles but in altitude is limited to the region between 90 and 2000 kilometers. The chapter organization is by latitudinal region, with chapters on electrodynamics and plasma physics for low- and for high-latitude regions. Appendixes provide discussions of measurement techniques and reference data that will be useful shortcuts for the newcomer to this field. The tutorial sections, which outline the gross nature of the electrodynamic interaction between the solar wind and ionosphere, are among the most physically satisfying and lucid I have seen. The treatment of the magnetosphere as a region through which solar wind motions are communicated to the ionosphere is cursory, but commensurate with the emphasis of this volume.

The sections on equatorial ionospheric dynamics proceed from a physical description of the equatorial dynamo driven by atmospheric motions to accounts of the formation of dynamic structures by hydrodynamic large-scale instabilities, such as ionization "fingers" formed by variants of the Rayleigh Taylor instability, and of the short-scale phenomena such as the gradient drift instability. Throughout these sections, and the rest of the book, a nice balance is struck between descriptions based on first-principle derivation and actual observations, at times of active perturbation experiments designed to make ionospheric motions visible.

The high-latitude region may be usefully defined in terms of the dominance of solar- and magnetospheric-driven flows of the ionospheric plasma. Similar patterns are seen in the neutral winds as well, albeit without the high degree of variability seen in the plasma flow. Ample attention is given to observations of plasma flow, which are used to illustrate the features thought to dominate the global convection within the polar regions. The inference of magnetic "field-aligned current" systems is outlined; but disappointingly, the fundamental role of plasma flow shear in generating such currents is lightly treated so that the flow and field-aligned current patterns are poorly related to each other.

A chapter is devoted to the effects of horizontal and vertical transport of plasma within the ionosphere. The local effects of features such as convection stagnations or supersonic flow channels are outlined (notably absent here is the Post-Rosenbluth low-