1

Introduction

Martin G. Raphael and Bruce G. Marcot

Conservation and restoration of biological diversity are often-stated objectives of land management. Doubtless, most natural resource managers will say they are achieving those objectives. But how can this be determined? The term "biological diversity" has been given many definitions (see Baydack and Campa 1999 for a listing of 19 alternatives), and most of these emphasize the variety of life and its processes. Much of this variety pertains to various aspects of species—their presence, distribution, occurrence within ecological communities, gene pool diversity, ecological functions, and other parameters—about which we know little, if anything for most species.

What's in This Book

The authors of this book describe a variety of approaches that move natural resource management toward the goal of achieving biological conservation, particularly species conservation. Natural resource managers usually focus on conservation practices that address only the larger and better-known taxa. This book focuses on the rare or little-known taxa, particularly species.

What is meant by "rare" or "little known"? Figure 1.1 illustrates the set of species the authors are addressing. Consider a large planning area and the assemblage of species that occur there (denoted as set A). Among those species are those that are rare (set B; as described in chap. 3) and those that are little known (set D; as described in chap. 4). One might wish to focus on

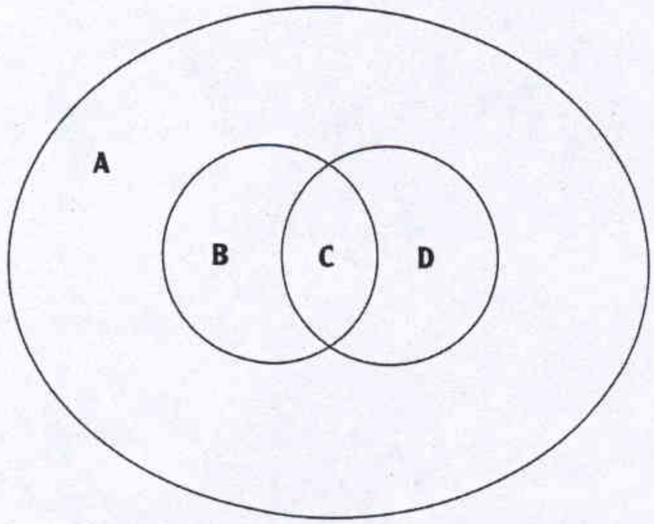


Figure 1.1. The species "universe." Set A represents all species in a given planning area. Set B represents all species in A that are rare. Set D represents all species in A that are little known. The area of overlap between sets B and D (labeled as C) is the set of species that are both rare and little known. The union of sets B and D is the set of species that are rare or little known.

the set of rare species, which might be at risk due to their small population size and increased vulnerability to disturbance. But one must not ignore the little-known species, because many of these, if we did know more about them, also might prove to be at risk because they are rare or because they are also vulnerable to changes in their environment. Conceptually, it is the combined sets of species B and D that define the group of species we call rare or little known. And perhaps the more vulnerable subset of these species are those that are both rare *and* little known (species set C; discussed in chap. 5).

The authors of this book evaluate how well various conservation approaches provide for rare or little-known species, either directly or indirectly. A few conservation strategies are fairly well aimed at providing for such species, but most focus on other aspects of biological diversity and conserve such species at best opportunistically or incidentally. For these strategies, the bottom line for conserving such species is largely that "it depends" on how the strategies are specified and implemented. The authors discuss the legal, biological, sociological, political, administrative, and economic dimensions by which conservation strategies can be gauged, to help managers determine which strategy or combination of strategies would best meet their goals and objectives. There are no fixed, single, or easy answers.

This book focuses primarily on terrestrial ecosystems and rare or little-known species associated with those systems. However, rarity concepts surely extend to aquatic, riparian, and wetland systems, and the authors provide some examples from these ecosystems when relevant to overall objectives. It is outside the scope of this book, however, to provide detailed discussions of river (fish) and marine issues.

This work was also prompted by the need to provide information on alternative approaches that could complement single-species assessment and management. Taking a strictly species-specific approach has proven difficult and expensive, particularly the collection of basic inventory data (Molina et al. 2006). Alternative ways of managing multiple species, including those rare or little-known, as well as ecological systems under scientifically credible approaches might help complement species-specific approaches currently in use.

How can rare or little-known species be managed effectively? There are many possible approaches to conceptualizing, assessing, managing, and monitoring rare or little-known species. In this book, the authors provide a classification of such approaches, offer a summary of the theoretical and conceptual foundations of each approach, evaluate each approach's efficacy in conserving rare or little-known species, and review how each has been used in assessments, management plans, and monitoring activities. The goal is to give land managers access to this diverse literature and to provide them with the basic information they need to select those approaches that best suit their conservation objectives and ecological context.

The book suggests an overall procedure by which management approaches can be identified (fig. 1.2). This entails first describing the legal, social, economic, administrative, political, and ecological requirements and considerations for the management question (discussed here and in chap. 2). The next step is to articulate the overall social, economic, and ecological management goals (chap. 2) and then to identify the rare or little-known species to address (chaps. 3, 4, and 5). Then one conducts a risk assessment that identifies key threats to the species and system factors and possible management sideboards (chaps. 6, 7, and 8). From this assessment, one can identify the management approach or combination of approaches that best addresses the specific risk factors (chaps. 6, 7, and 8), and then evaluate the approaches for their social, economic, ecological, and administrative application (chaps. 8, 9, 10, and 11). A final selection of approaches is made (chap. 12), and a program to monitor and evaluate success of meeting the goals is implemented (chaps. 11 and 12). Results of monitoring can

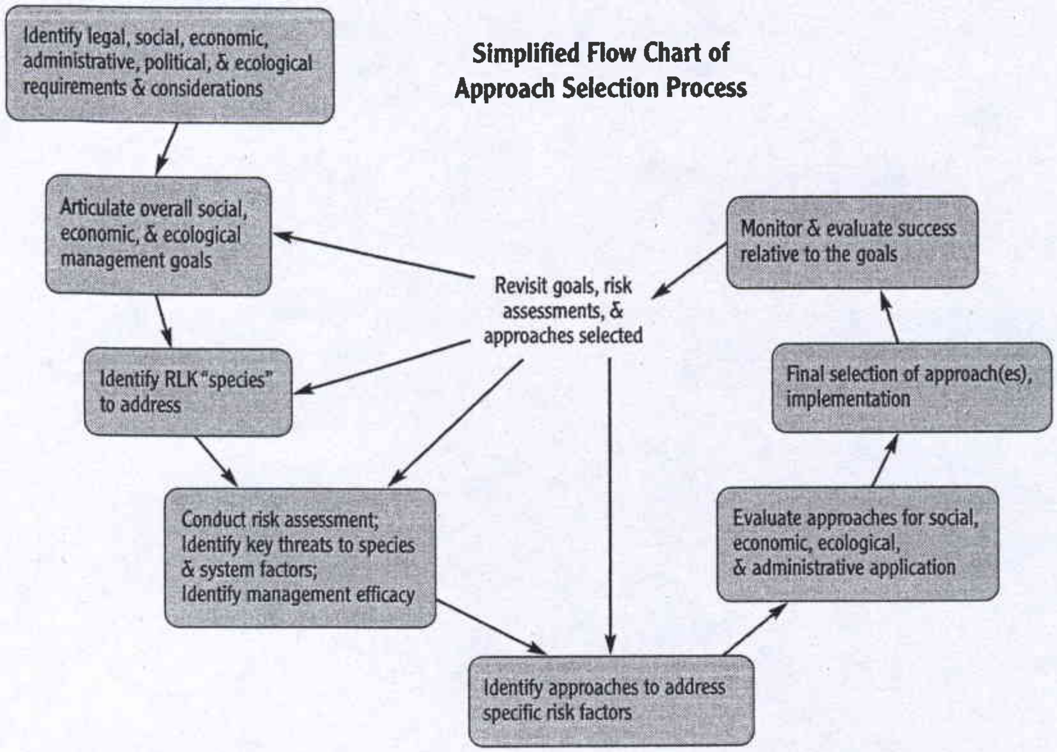


Figure 1.2. Flow chart of the process for selecting and testing alternatives to conservation of rare or little-known species as discussed in this book. A fuller version of this process with explanation of each step is presented in chapter 12.

be used to revisit the goals, the species selected, the risk assessment, and the set of approaches selected. In the end, our objective is to provide a thorough scientific evaluation of approaches and management options for conserving rare or little-known terrestrial species.

Why Should Land Managers Care about Conserving Rare or Little-Known Species?

Land managers should be concerned about rare or little-known species for ethical, ecological, and legal reasons.

Rare or Little-Known Species Contribute to Biodiversity

The reasons may mirror the many practical and ethical reasons given for conserving nature itself—preserving potential future sources of drugs and pharmaceuticals, protecting native pollinators of our food plants, "saving all the pieces" to ensure that the system works, acknowledging the "existence value" of other life forms on Earth, and so on. Bolger (2001) pointed out that, although we do not fully understand how biological diversity provides for ecological functions in ecosystems, assuring some level of redundancy in species and their functions, and protecting species that have particularly salient functions ("keystones"), are probably important for maintaining system stability. Until we learn more, Bolger noted, it is prudent to protect all species lest we sacrifice some unknown critical function. This book provides examples of critical functions and the ecological roles of rare or little-known species.

Conservation science is concerned, in part, with anticipating how natural or human-caused disturbance affects the pattern of commonness and rarity among the biota of a given area (Lubchenco et al. 1991; also see chap. 3). The concept of rarity has several definitions in common usage (see chap. 3), but in the lexicon of conservation biology, "rarity" is most simply defined based on the distribution and abundance of a species (Gaston 1994). However, for many taxa we lack basic information on distribution and abundance (Brown and Roughgarden 1990; Flather and Sieg 2000) from which to judge rarity and basic information on life history and ecology. The authors here refer to these species collectively as "little known." Although it is most certainly true that many little-known species are also rare, there are many examples of little-known species that are likely quite common, such as soil and forest canopy arthropods. As Flather and Sieg discuss in chapter 3, there are different kinds of rarity that may have differing kinds of management implications. Something could be (1) locally common but endemic or highly restricted in spatial distribution, (2) widespread but rare everywhere, (3) a locally rare population of a species that is common elsewhere (i.e., at the edge of the range or an outlying population in a metapopulation, or (4) genetically or behaviorally distinctive.

Rare or Little-Known Species Can Play Key Ecological Roles

Rare or little-known species help provide for productive and diverse ecosystems from which humans can sustainably use renewable natural resources. This is particularly true with native organisms whose roles may be to stave off unwanted invasions by nonnative species; some rare or little-known native organisms provide such ecological services. Rare or little-known species may contribute significantly to the maintenance of ecosystem function (Andrén et al. 1995; Borrvall et al. 2000; Cottingham et al. 2001; Lyons and Schwartz 2001; Lyons et al. 2005), thereby helping to provide the goods and services that humans derive from ecosystems (Chapin et al. 1998).

An example is the set of soil microspiders ("micryphantids" of the family Araneae) that collectively occur in abundance, that consist of many poorly known, undescribed, or possibly rare species, and that are likely important invertebrate predators at a very fine scale. Overall, soil microspiders contribute to the balance of soil food webs and maintenance of nutrient pools, and thus to productivity of soils that in turn provide ecosystem services of growing food crops of commercial interest to people (Mansour and Heimbach 1993). In another example, empirical studies have demonstrated how rare broadleaved plant species can control the abundance of dominant grasses by governing ecosystem processes (Boeken and Shachak 2006). In a review of how biodiversity can affect ecosystem functioning, Hooper et al. (2005) noted in general that even relatively rare species such as keystone predators can strongly influence energy and material flows through an ecosystem.

Likewise, referring to invertebrates, Black (2002, 3) wrote:

> Though endangered invertebrates are unlikely to determine the fate of a large ecological system, as a group they may have a large effect. Often, endangered invertebrates are specialists that perform vital ecosystem functions such as pollination or the recycling of nutrients. . . . Endangered species also may play a linchpin role in small, specialized systems such as caves, oceanic islands, or some pollinator–plant relationships.
>
> . . . [S]ome endangered species might also provide useful products—such as new defenses against diseases or tools for studying various ecosystem or organismal processes—as well as direct material benefits.

Such beneficial ecological roles are played by organisms that are tiny and hidden in soil, forest canopies, and other places difficult to study. Wilson (1987) tells us it is the "little things that run the world." Most of these little things, and some of the big things, are effectively invisible to science but may play major roles in keeping ecosystems healthy and diverse. Wilson argues that some invertebrates (e.g., ants and termites) can have enormous abundances and impacts on overall community energetics. He estimates that the global biomass of ants alone substantially exceeds that of all vertebrates combined, yet the number of management-oriented ant and termite experts and studies is tiny. Patrick (1997, 17) noted that "terrestrial ecosystems are dependent on a high diversity of macro- and microscopic organisms" and their ecological functions.

In some cases, increasing rarity of a species, such as caused by anthropogenic stressors, might sacrifice the ecological roles of such species. McConkey and Drake (2006) discovered this with pteropodid fruit bats (flying foxes) on islands of the South Pacific Ocean, where the bats' role in seed dispersal declined as the bats became scarcer. In such cases, a rare species that otherwise plays an important ecological role, such as dispersal of large seeds by fruit bats, may reach a threshold of "functional extinction" before it reaches numerical extinction.

Such ecological significance of rare or little-known species may not be evident except in changing systems or systems under stress. On this, Andrén et al. (1995, 141) wrote: "It is possible that the major importance of biodiversity for ecosystem processes is not apparent under relatively stable conditions, but that diversity is imperative for an ecosystem's response to stress or major environmental changes, such as climatic change, without any loss of ecosystem function. Perhaps rare species become important when conditions change."

One example is the rare polylepis tree (*Polylepis weberbaueri*) of family Rosaceae, which occurs at 2000 to 4500 m elevation in the Andes Mountains of South America, including in Ecuador. Much of the high-elevation woodlands of the altiplano plateau of Ecuador have been eliminated for agriculture, leaving only remnant pockets of this rare polylepis woodland. These pockets are now increasingly critical habitat for a variety of high-elevation birds, including giant conebill (*Oreomanes fraseri*), rufous antpitta (*Grallaria rufula*), and red-rumped bush-tyrant (*Cnemarchus erythropygius*).

Rare or Little-known Species Can Have Evolutionary Significance

Over evolutionary time, species that are rare and that are closely tied to specific environments may become the basis for unexpected adaptive radiation when environmental conditions change. Regional climate changes likely spurred great speciation events in the Amazon (antbirds), coastal

Australia (treecreepers), and central Africa (many primates, squirrels, and small carnivores). Also, rare founder populations on oceanic islands and continental habitat islands can become the basis for evolution of locally endemic taxa. For instance, the Hawaiian Islands contain local avian endemics, including subspecies such as the Hawaiian owl (*Asio flammeus sandwichensis*), species such as the Hawaiian crow (*Corvus hawaiiensis*), genera such as the Hawaiian goose (*Branta sandvicensis*), and even subfamilies such as Drepanidinae (Hawaiian honeycreepers); the origins of such local endemics were likely rare immigrant founders.

Another reason why rare or little-known species may be of conservation interest pertains to extinction risk. All other things being equal, rare species are more apt to be lost from the regional or local species pool than are common species (Pimm et al. 1988; Johnson 1998).

Rare or Little-Known Species Are Conserved by Some Legal Regulations

Land managers may also care about conserving biodiversity because they must adhere to pertinent legal or regulatory provisions. However, such provisions in many countries do not target rare or little-known species per se, but rather address conservation of listed threatened or endangered species or more general biodiversity goals (see chap. 2). Examples include the United States' Endangered Species Act, Canada's Species at Risk Act, and Australia's Environment Protection and Biodiversity Conservation Act of 1999 under which individual states and territories provided further specifications, such as New South Wales' Threatened Species Conservation Amendment Bill of 2006.

Also relevant to rare species conservation in Australia are the Regional Forest Agreements (RFAs), which establish processes and consequences of the recent extensive redistribution of public forest lands into many new conservation reserves. This redistribution was based largely on modeled habitat requirements of threatened species and the public desire to represent all vegetation communities within the Australian conservation reserve system. The RFAs also specify management prescriptions for all threatened species in commercial forestry operations. The RFAs are based on a collage of state and commonwealth legislation, such as the Forestry and National Park Estate Act of 1998 (Rod Kavanagh, pers. comm.).

In another example, India's National Wildlife Protection Act of 1972 covers major fauna (vertebrates and some insects) and very few plant species, but it does not cover rare, little-known, or endangered species per se. The 2006 amendment creates a National Tiger Conservation Authority that specifically calls for conservation of the tiger as a flagship and endangered species. India's Biodiversity Act of 2002 does address conservation of endangered species likely on the verge of extinction. Also, India's Environmental Protection Act defines and provides protection for sensitive sites, and like most other countries, India follows regulations under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) to prohibit illegal international trafficking of listed species (Ashish Kumar, P. K. Mathur, pers. comm.).

In some other countries there is either no specific law or regulation comparable to these acts, or legislation is less directly related to protection of rare or little-known species. For instance, Argentina has no endangered species act but instead has National and Provincial Natural Monument Laws to protect some particular endangered species (Ana Trejo, pers. comm.). The People's Republic of China has no national endangered species act; instead, there are lists of wild fauna and flora afforded "special state protection" that were promulgated and approved by the Chinese State Council in 1988. This provides some measure of protection of biota when proposing activities that might arguably impact them. China also has a new Environmental Impact Assessment (EIA) law that requires an EIA for a government "plan" (analogous to a "programmatic EIS" in the United States), but this requirement has yet to be fleshed out in specific regulations. The EIA law also requires an EIA for any construction project, and this dimension has been fleshed out in regulations, although there seems to be little guidance on rare and little-known species (G. Gordon Davis, pers. comm.).

Rare or Little-Known Species Can Be Targets for Conservation in Planning

Finally, as motivated by the foregoing concerns, some legal or regulatory provisions (e.g., the U.S. Endangered Species Act; the Canadian Species at Risk Act) require land-managing agencies to explicitly consider rare or little-known species in their resource planning activities. The basic problem with managing for rare or little-known species is that rarity itself imposes risks to viable, persistent populations, and lack of knowledge imposes uncertainties regarding the necessary conditions for such species. More-over, the number of species that qualify as rare or little known can be quite large, further complicating the management problem.

For example, in the interior Columbia basin, U.S., Marcot et al. (1997) estimated that 22% of all bird species were either "irregular" or "rare" in occurrence in that region (fig. 1.3). Also, of a total 43,825 estimated species of fungi, lichens, bryophytes, vascular plants, mollusks, arthropods, and vertebrates expected to occur in that region, they found 60% were little known and had insufficient information for scientists to judge their occurrence in the planning area. Given inherent extinction risks, information constraints, and the sheer number of species that may be classified as rare or little known, it is easy to understand why the management issue can be overwhelming. If so many species are unknown and undescribed, or at best poorly studied, how do we know we are conserving biological diversity? How do we go about setting management practices to achieve the conservation of biological diversity?

Knowledge Is Increasing

Scientific knowledge on rare or little-known species has been increasing, but disproportionately more so for taxa that are easier to locate and study. As an example, the number of papers published each decade in all journals of the Ecological Society of America (ESA) since its inception in the 1940s has increased overall, with the greatest recent increases since the 1980s being studies on bryophytes, bacteria, fungi, and ferns (fig. 1.4a), vascular plants (fig. 1.4b), and invertebrates, fishes, and birds (fig. 1.4c).

However, the *proportions* of all ESA papers published on only vascular plants, fishes, and birds have increased; whereas the proportions published on all other taxa have not. This may be explained in part by the emergence of other, taxa-specific publications (particularly on invertebrates, fungi, lichens, and bryophytes) that might have drawn potential papers away from ESA journals. But it appears that scientific knowledge of many of the other taxonomic groups of rare or little-known taxa is not keeping pace with that on vascular plants and vertebrates. A consequence of this imbalance will be a widening gap in knowledge between these taxonomic groups. In addition, taxon experts, especially systematists, are not being trained and hired by agencies or universities/museums at even a replacement rate (Wheeler and Cracraft 1997).

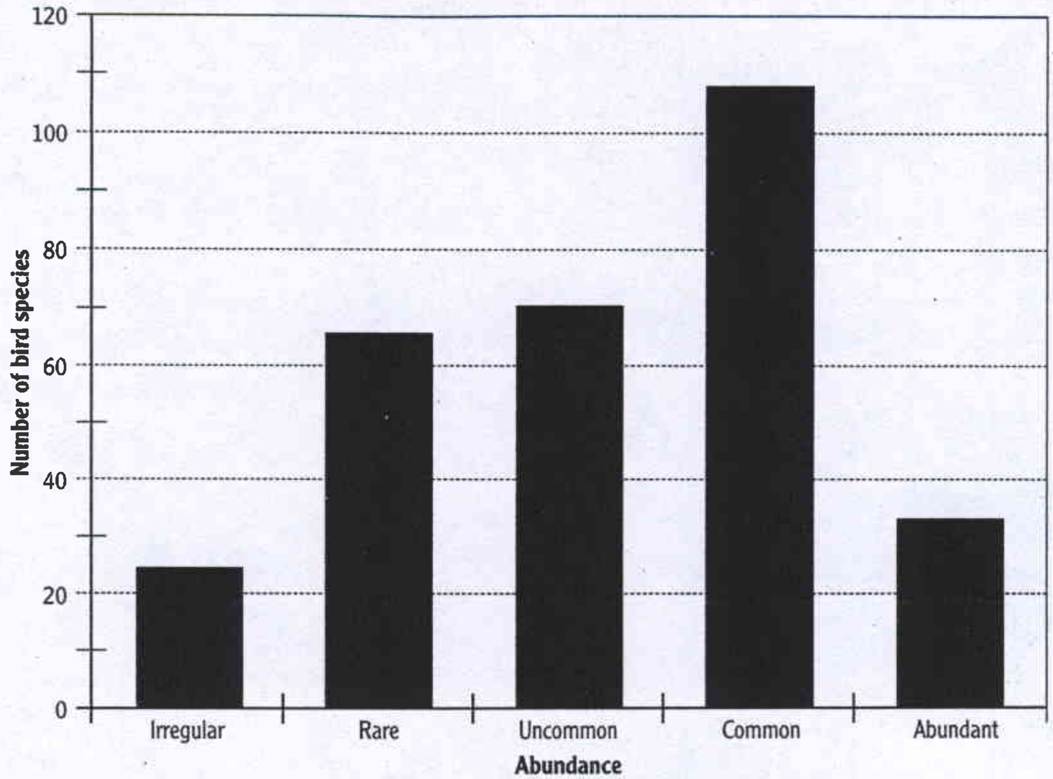
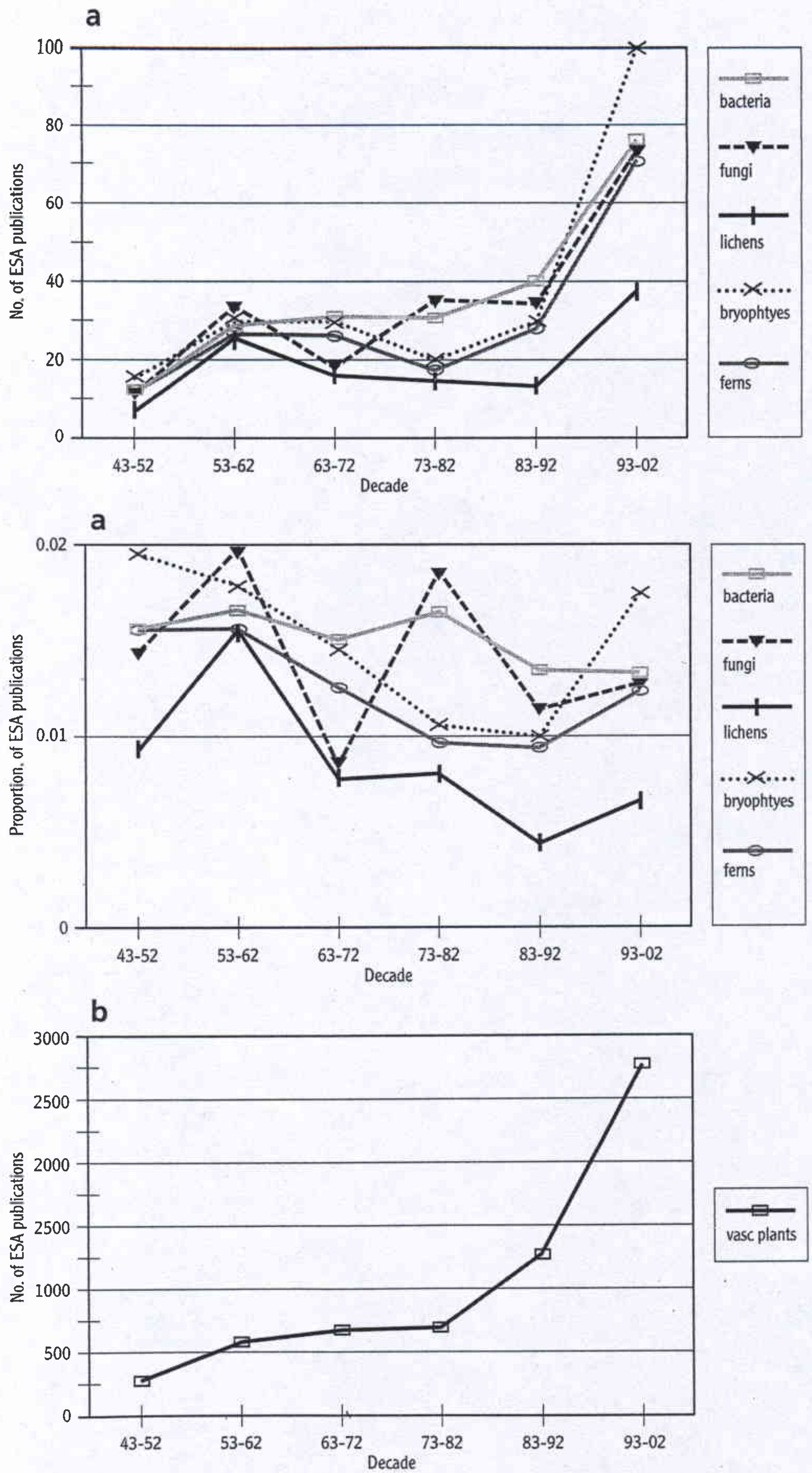


Figure 1.3. Number of bird species in the interior U.S. Columbia River basin by abundance class. *Source*: Marcot et al. 1998.

Another way to view amount of, and change in, knowledge is on a per capita (per species) basis. Dividing the total number of ESA publications (fig. 1.4d) by the globally known number of species per taxon (see chap. 4) reveals that most publications per capita are on known vertebrates and known bacteria and fewest on known fungi and known invertebrates. When considering high-end estimates of numbers of species (described plus unknown), fewest publications per taxon are on invertebrates, bacteria, and fungi. These taxa are in need of much basic taxonomic, biological, and ecological work.

Conclusion

Rare or little-known species are, by their nature of being scarce or poorly understood, often not explicitly included in conservation and natural resource planning. Although still incomplete, there is growing scientific evidence that many rare or little-known species may play key ecological roles in the function, structure, and composition of some ecological com-



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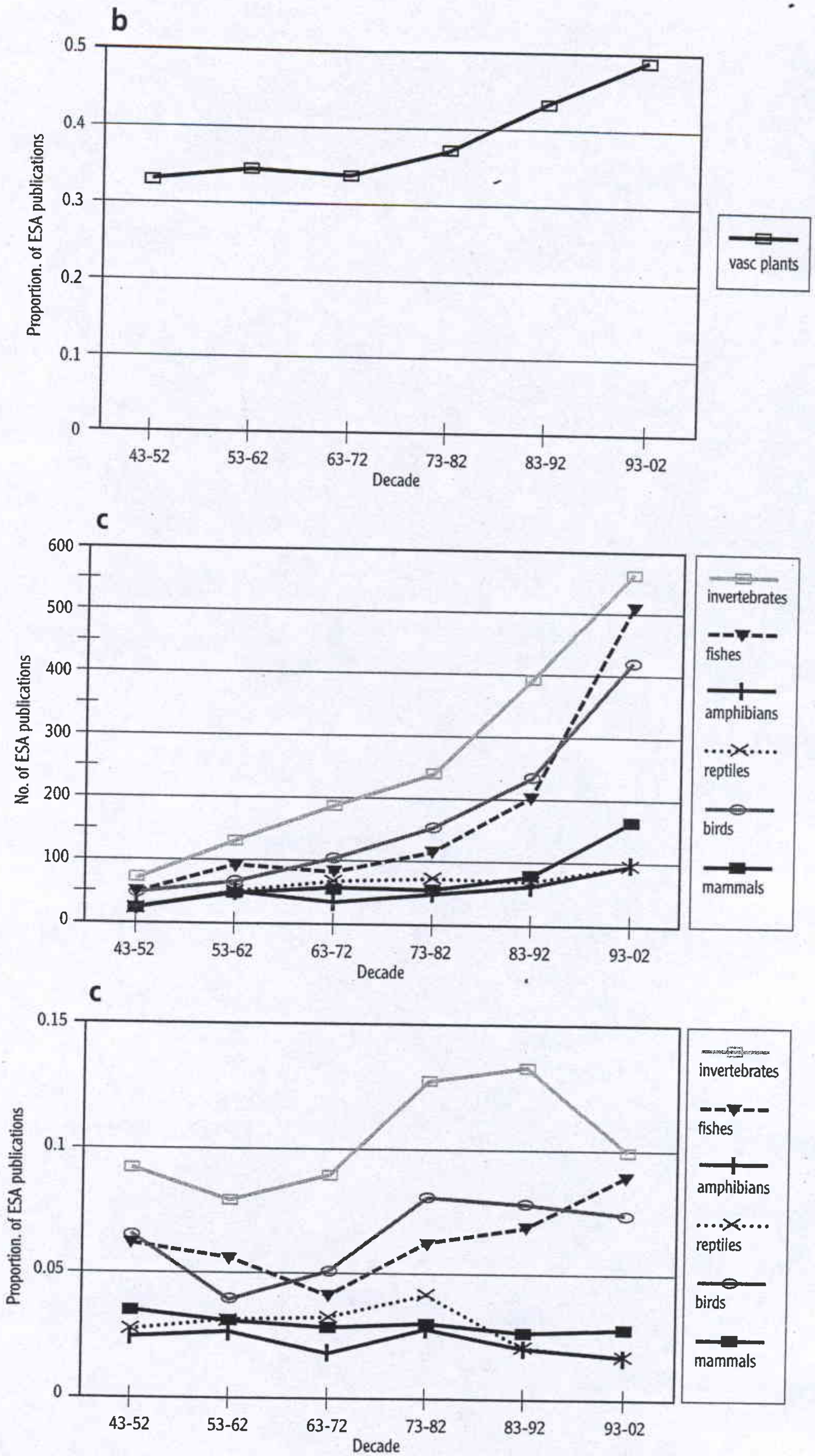

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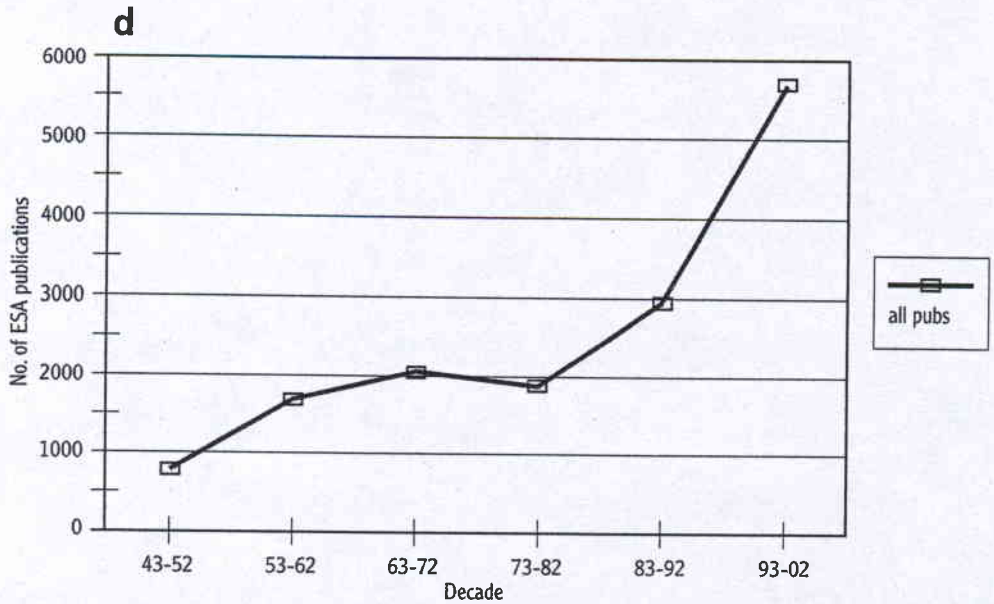

Figure 1.4. Number and proportion of publications by the Ecological Society of America on various taxonomic groups (a–c) and on all topics (d).

munities and could be important for long-term evolutionary potential. To conserve and restore the breadth of natural biodiversity, resource managers could include attention on rare or little-known species and their ecological functions, as well as on the more usual charismatic or better-known species and processes.

This book describes and evaluates a variety of management approaches and practical considerations for conserving rare or little-known species in terrestrial ecosystems. This focus is unique for two reasons. First, although there are many books and articles on conservation of rare species, most deal with conserving large and well-known species. However, in most ecosystems the vast majority of species consists of rare or little-known species that have received paltry or incomplete coverage in the conservation biology literature (e.g., fungi, lichens, mollusks, bryophytes, nonshowy soil arthropods). These taxa have many unique attributes that make their detection, identification, and quantification extremely difficult. Given the significant ecosystem functions that at least some of these taxa perform, it is important to include them in comprehensive conservation efforts. Yet the inherent uncertainty in their poorly understood ecologies and natural histories makes their conservation on a species-by-species approach difficult to infeasible.

A major focus of the book thus addresses their unique attributes and provides detailed descriptions of conservation approaches that can be considered and evaluated for effectiveness in meeting specific conservation goals. Second, the book emphasizes the practical considerations that land managers face in developing and implementing conservation strategies to deal with rare or little-known species. These include integration of social, economic, and biological goals as well as practical matters of costs, personnel, and dealing with uncertainty and risks in decision making.

References

Andrén, O., J. Bengtsson, and M. Clarholm. 1995. Biodiversity and species redundancy among litter decomposers. Pp. 141–51 in *The significance and regulation of soil biodiversity*, ed. H. P. Collins, G. P. Robertson, and M. J. Klug. Dordrecht: Kluwer.

Baydack, R. K., and H. Campa III. 1999. Setting the context. Pp. 3–16 in *Practical approaches to the conservation of biological diversity*, ed. R. K Baydack, H. Campa III, and J. B. Haufler. Washington, DC: Island Press.

Black, S. H. 2002. Director's message. *Xerces News* (Summer): 3–4.

Boeken, B., and M. Shachak. 2006. Linking community and ecosystem processes: The role of minor species. *Ecosystems* 9 (1): 119–27.

Bolger, T. 2001. The functional value of species biodiversity: A review. *Biology and Environment: Proceedings of the Royal Irish Academy* 101B (3): 199–224.

Borrvall, C., B. Ebenman, and T. Jonsson. 2000. Biodiversity lessens the risk of cascading extinction in model food webs. *Ecology Letters* 3:131–36.

Brown, J. H., and J. Roughgarden. 1990. Ecology for a changing earth. *Ecological Society Bulletin* 71:173–88.

Chapin, F. S., O. E. Sala, I. C. Burke, J. P. Grime, D. U. Hooper, W. K. Lauenroth, A. Lombard, et al. 1998. Ecosystem consequences of changing biodiversity. *BioScience* 48:45–52.

Cottingham, K. L., B. L. Brown, and J. T. Lennon. 2001. Biodiversity may regulate the temporal variability of ecological systems. *Ecology Letters* 4:72–85.

Flather, C. H., and C. H. Sieg. 2000. Applicability of Montreal Process Criterion 1—conservation of biological diversity—to rangeland sustainability. *International Journal of Sustainable Development and World Ecology* 7:81–96.

Gaston, K. J. 1994. *Rarity*. London, UK: Chapman and Hall.

Hooper, D. U., F. S. Chapin, J. J. Ewel, A. Hector, P. Inchausti, S. Lavorel, J. H. Lawton, et al. 2005. Effects of biodiversity on ecosystem functioning: A consensus of current knowledge. *Ecological Monographs* 75 (1): 3–35.

Johnson, C. N. 1998. Species extinction and the relationship between distribution and abundance. *Nature* 394:272–74.

Lubchenco, J., A. M. Olson, L. B. Brubaker, S. R. Carpenter, M. M. Holland, S. P. Hubbell, S. A. Levin, et al. 1991. The sustainable biosphere initiative: An ecological research agenda. *Ecology* 72:318–25.

Lyons, K. G., and M. W. Schwartz. 2001. Rare species loss alters ecosystem function: Invasion resistance. *Ecology Letters* 4:358–65.

Lyons, K. G., C. A. Brigham, B. H. Traut, and M. W. Schwartz. 2005. Rare species and ecosystem functioning. *Conservation Biology* 19 (4): 1019–24.

Mansour, F., and U. Heimbach. 1993. Evaluation of lycosid, micryphantid and linyphi-

id spiders as predators of *Rhopalosiphum padi* (Hom.: Aphididae) and their functional response to prey density: Laboratory experiments. *Entomophaga* 38:79–87.
Marcot, B. G., M. A. Castellano, J. A. Christy, L. K. Croft, J. F. Lehmkuhl, R. H. Naney, K. Nelson, et al. 1997. Terrestrial ecology assessment. Pp. 1497–1713 in *An assessment of ecosystem components in the interior Columbia basin and portions of the Klamath and Great basins*, ed. T. M. Quigley and S. J. Arbelbide. Vol. 3. USDA Forest Service General Technical Report PNW-GTR-405. USDA Forest Service Pacific Northwest Research Station, Portland, OR.
McConkey, K. R., and D. R. Drake. 2006. Flying foxes cease to function as seed dispersers long before they become rare. *Ecology* 87 (2): 271–76.
Molina, R., B. G. Marcot, and R. Lesher. 2006. Protecting rare, old-growth forest associated species under the Survey and Manage guidelines of the Northwest Forest Plan. *Conservation Biology* 20 (2): 306–18.
Patrick, R. 1997. Biodiversity: Why is it important? Pp. 15–24 in *Biodiversity II: Understanding and protecting our biological resources*, ed. M. L. Reaka-Kudla, D. E. Wilson, and E. O. Wilson. Washington, DC: Joseph Henry Press.
Pimm, S. L., H. L. Jones, and J. Diamond. 1988. On the risk of extinction. *American Naturalist* 132:757–85.
Wheeler, Q. D., and J. Cracraft. 1997. Taxonomic preparedness: Are we ready to meet the biodiversity challenge? Pp. 435–46 in *Biodiversity II: Understanding and protecting our biological resources*, ed. M. L. Reaka-Kudla, D. E. Wilson, and E. O. Wilson. Washington, DC: Joseph Henry Press.
Wilson, E. O. 1987. The little things that run the world (the importance and conservation of invertebrates). *Conservation Biology* 1 (4): 344–46.

Conservation *of* Rare *or* Little-Known Species

Biological, Social, and Economic Considerations

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