Summary: Predicting Effects of Habitat Patchiness and Fragmentation—The Manager's Viewpoint

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Habitat fragmentation is the process whereby areas of homogeneous habitat are broken into a mosaic of smaller, dissimilar habitat patches. Fragmentation may occur as a consequence of natural disturbance or of management activity.

Natural landscapes, as Verner points out in the preceding summary, are mosaics of generally small vegetation patches characterized by differences in vegetation structure and composition. Natural patches also typically support relatively diverse plant assemblages of different ages and quantities of components, such as snags and dead-and-down materials. Vegetation succession in these patches has the potential to develop to "climax" conditions, which persist until the plant community is set back to an earlier successional stage by random instances of disturbance (e.g., fires, landslides, insect kills).

Land-management practices may result in planned fragmentation of the landscape into a mosaic of patches that often are larger than most natural patches, that may be converted to different vegetation compositions or structures, that have low species diversity, that are often monocultures, that are more even-aged, that do not retain natural quantities of components, and that are not retained to climax. This shift from natural to managed landscapes has generally resulted in a larger proportion of the landscape being dominated by relatively large patches of more even-aged plant communities. In forested lands, these generally are of a relatively young age, whereas in shrublands, patches often are old and decadent. Such changes in landscape have influenced communities of terrestrial vertebrates. For example, species that require large tracts of relatively unbroken forested lands have declined in number and distribution, whereas the reverse has occurred with species adapted to mixes of vegetation structure and composition with associated edges or large expanses of decadent shrubs.

Regardless of the approach selected to manage the landscape (i.e., allowing nature to take its course or adopting a plan to manage for some specific objective) assemblages of wildlife species will continue to persist. The critical questions for managers are, How many of each species should there be? And, Where will those animals reside? The public, through passage of various laws and other ways of expressing its desires (e.g., purchase of hunting licenses, founding and funding wildlife-advocacy groups), has given land managers broadly formulated answers to these questions. Laws such as the Endangered Species Act, the National Forest Management Act, and the Federal Land Policy and Management Act and their guiding regulations mandate that all species must be retained on public lands. In addition, production of animals for recreational and commercial pursuits has clearly been demanded by the public. To complicate the management situation further, the public also demands from the land other benefits that may conflict with each other and with wildlife goals—wood products, red meat, minerals, "clean" watersheds, and areas for recreation—snowmobiles, off-highway vehicles, skiing, camping, and hiking.

The challenge for managers, then, is to produce wildlife, various commodities, recreational opportunities, water, and other benefits, several of which cannot be provided simultaneously from the same parcel of land, in quantities to meet public demand. Trading off some benefits for others, even some wildlife species for others, is an inescapable consequence of decision making. Unfortunately, the public has not given managers clear directions to produce certain benefits at the expense of others, so they must continue to choose between producing spotted owls (*Strix occidentalis*) or mule deer (*Odocoileus hemionus*) or, perhaps, some commodity or suite of benefits from a unit of land.

Obviously, the only practical way to produce a desired set of wildlife is to manage habitat for these species. To effectively manage the land to produce desired numbers of wildlife, managers need information about species' requirements, including the effects of landscape fragmentation on wildlife. Further, managers need guidelines to assist them in using habitat fragmentation as a tool to produce a desired suite of wildlife.

As a manager, I had hoped that this part of the volume would include presentations on habitat fragmentation in two broad categories: (1) the impacts of fragmentation of large pieces of land on faunal elements; and (2) information that would be applicable to small-scale management activities (e.g., timber sales). Knowledge of the impacts of fragmentation on wildlife is essential for evaluating the impacts of virtually any management activity. In California, there are about 880 species of amphibians, reptiles, birds, and mammals (Laudenslayer and Grenfell 1983), not to mention the myriad species of invertebrates. Managers need to know how fragmentation will affect all of these species to ensure that they are retained as viable components of the system. And, we must have fragmentation theory translated into a

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form that can be readily applied in the development and implementation of projects that benefit wildlife. Without such information, wildlife biologists will, again, be restricted to reacting to projects proposed by other functions and to giving best-guess recommendations.

Chapters in this part give much information about the impacts of fragmentation on wildlife. Unfortunately, of seven such studies, five were restricted to the effects of fragmentation on birds. This phenomenon probably should be expected, because the majority of terrestrial vertebrate species in many localities are birds—in California, for example, 62% of all terrestrial vertebrate species are birds—and the field of avian habitat relationships appears to be more advanced than that for other taxa. Two studies, however, treat taxa in addition to birds. Murphy and Wilcox (Chapter 41) examined effects of fragmentation on butterflies and birds, and Rosenberg and Raphael (Chapter 38) looked at fragmentation relative to all classes of terrestrial vertebrates.

All of the chapters on birds are concerned with forested habitats, including western riparian (Dobkin and Wilcox, Chapter 42), and urban woodlots (Gotfryd and Hansell, Chapter 46), as well as those of Europe (Haila, Chapter 45; McLellan et al., Chapter 44) and eastern North America (McLellan et al.; Temple, Chapter 43). This distribution points out the need to look at other systems in addition to forests, including grasslands, shrublands, woodlands, and deserts.

The chapters by Seagle (Chapter 40) and by Urban and Shugart (Chapter 39) present models that help to explain the effects of habitat fragmentation and may have application for predicting consequences of management actions. Seagle presents a model "to simulate the effects of landscapes of various sizes." His model allows colonization of landscapes by up to 150 hypothetical species, depending on habitat characteristics exhibited by the landscapes, and then simulates the effects of different patches of habitat on the species that colonize the land. Urban and Shugart present a model "to simulate demographic processes of natality, dispersal, and mortality as these might occur in a mosaic of habitat patches." Both of these approaches may be useful for simulating the cumulative effects of management actions on a land unit.

Only one study, that by Temple (Chapter 43), gives information that may be directly applicable to small-scale management questions. Temple discusses the concept of the core area of a patch in contrast to the entire area of the patch. He presents information suggesting that the core area explains differences in avifaunas more accurately than total patch area does. This concept will be exceedingly useful to managers, as it should provide more accurate predictions of the effects of management activities on wildlife and a rough guide to estimating the effective size of a patch.

Where do we go from here? Researchers can address several concerns about future habitat fragmentation. For example: (1) When is a habitat island not a habitat island? (2) When must we provide ecological reserves, as opposed to managed landscapes? (3) What guidelines can managers use when designing a habitat mosaic that will produce wildlife as well as other benefits? (4) How can managers appropriately evaluate the impacts of fragmentation on wildlife and other resources?

In my opinion, question (1) above is a very major concern. Much of the theoretical basis of habitat fragmentation is predicated on MacArthur and Wilson's (1967) theory of island biogeography. This theory is based on the idea that islands are surrounded by areas uninhabitable by species which colonize the islands. This assumption is applicable to terrestrial species on oceanic islands, but is a patch of old-growth forest an island if it is surrounded by pole-sized timber? Or do the old-growth and pole-sized timber areas together constitute an island? The answer, of course, depends on the species of interest. Much more research is needed to assist managers in making correct decisions about such questions.

Much of the conservation literature (see Soulé and Wilcox 1980; Frankel and Soulé 1981) advocates the retention of ecological reserves—large tracts of lands that are relatively homogeneous in plant composition and structure—to ensure the perpetuation of a desired set of biological attributes. Although this approach is necessary and will help conserve biotic elements, I question whether enough lands can be put aside to effectively meet all conservation objectives. Because the vast majority of lands in most areas will be under some form of management, and because even reserves may require management to ensure retention of the characteristics they are intended to preserve, a reserve system will not necessarily free us from the need for techniques that will produce wildlife as a consequence of resource management. Thus, research is needed to develop guidelines for large- and small-scale management projects.

Land-management activities are based on guidelines designed to meet certain objectives. Guidelines often have been designed to produce certain kinds of wildlife with little thought given to the entire faunal assemblage. For example, for years managers have attempted to provide large amounts of edge in the belief that edge would be beneficial to wildlife. More recently, however, managers have learned that large amounts of edge will not provide suitable habitat for some species; thus, this guideline alone will not meet all wildlife needs. Managers need guidelines that will ensure the retention of the entire faunal assemblage. The methods that Harris (1984) proposed to integrate principles of island biogeography into forest management should help solve some of these problems. Future research should build on this work to develop more precise methods and to extend guidelines to ecosystems other than forests.

Finally, we still have a need for continued work to evaluate the effects of fragmentation on wildlife in habitats other than forests. Gaps in our knowledge of such habitats are great, especially for amphibians, reptiles, and mammals in grasslands, deserts, shrublands, and woodlands. And, perhaps of greater concern is the utter lack of information about invertebrate communities. In most cases, we even lack information regarding local invertebrate faunal composition, so it is not surprising that we know almost nothing about the effects of habitat fragmentation on these taxa.

In conclusion, the understanding of habitat fragmentation has come a long way in the past 20 years or so, but in terms of management applications, we have just glimpsed the tip of the iceberg. Habitat fragmentation is and will continue to be an important concern to land managers, but it is hoped that better guidelines will soon be available to ameliorate its effects.

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