THE ECOLOGY AND MANAGEMENT OF THREATENED AND ENDANGERED SPECIES OF THE UNITED STATES

by

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A.B., Kansas Wesleyan University, 1969

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Division of Biology

KANSAS STATE UNIVERSITY
Manhattan, Kansas
1980

Approved by:

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ACKNOWLEDGMENTS

This reporter would like to acknowledge the assistance given to him by the staff of the Endangered Species Office in Washington, D.C. and its regional representatives. Thanks also go to my wife Linda who did much of the typing, and to my parents who gave much help and encouragement although they never were able to see the finished report.

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Chapter 1

INTRODUCTION

The Endangered Species Act of 1973 (Public Law 93-205, 87 Stat. 884), signed into law on December 28 of 1973, provided protection for those plants and animals which, as determined by the United States Secretaries of Interior and Commerce, were thought to be endangered or threatened with possible extinction. That law defined an endangered species as one which:

> ...is in danger of extinction throughout all or a significant portion of its range other than a species of the Class Insecta determined by the Secretary [of Interior] to constitute a pest whose protection under the provisions of this Act would present an overwhelming and overriding risk to man.

The same piece of legislation defined a threatened plant or animal as one which is "...likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."

The purpose of this report is to examine the situation of those vertebrates, arthropods, mollusks, and plants of the United States that have been determined to be endangered or threatened. Procedures used for determining which species are facing extinction are outlined as well as a review of legislation pertaining to extinction. Present management practices for some selected species are described, and current ecological thinking related to extinction along with examples is summarized.

Hopefully the reader of this report will gain a more thorough understanding of the possible role certain ecological principles might play in the process of extinction, and that this will be done in terms understandable to the layman. A more thorough familiarity of some of the plants and animals

currently endangered or threatened, management programs currently used in dealing with some of them, and possible explanations offered by students of the respective species and their situations should be gained.

Chapter 2

LEGAL AUTHORIZATION

This chapter presents federal legislation which has been passed dealing with animals and plants facing possible extinction. A large number of laws could be cited here if all major and minor actions were covered as well as all state and international actions. This chapter deals only with what is felt by this reporter to be some of the significant federal legislation passed and signed into law, and this will be done in chronological order of enactment.

One of the first pieces of significant legislation was the Lacey Act (31 Stat. 188 [1900], 18 U.S.C.§42-44 [1970]). This law, as amended, makes it unlawful to transport or receive across a state or country's border an animal or any part thereof knowingly taken in violation of a state's or foreign country's laws. Of course, threatened and endangered species fall under the protection of this law if they happen to be protected by state or international law.

The Black Bass Act (44 Stat. 576 [1926], 16 U.S.C.§851-856) was passed in 1926 and provides protection similar to the Lacey Act in that it makes it unlawful to transport fish taken illegally in one state or country to another. Steelhead trout legally taken in the Columbia River between Washington and Oregon are exempted.

Migratory birds are given federal protection through the Migratory Bird Treaty Act, as amended (40 Stat. 755 [1918], 16 U.S.C.§703-711 [1970]). A treaty with Great Britain on August 16, 1916 to protect migratory birds

and another with the United Mexican States on February 7, 1936 to protect migratory birds and game mammals forms the basis of this law which makes it unlawful to kill, take, sell, import or export migratory birds, eggs, nests, or any parts thereof except as specified by the Secretary of Interior who specifies when, where, and how it can be done. Exception is given for breeding and raising such birds for approved scientific purposes. If a given state has stricter laws governing migratory birds, it takes precedence. If federal law is stricter than a given state law, someone illegally killing such a bird is subject to a misdemeanor charge and can be fined five hundred dollars or given a maximum six month jail sentence or both if convicted. If such illegal taking is done with the intent to sell or barter, the offender is subject to being charged with a felony and, if convicted, can be fined two thousand dollars or given a maximum two year jail sentence.

The Migratory Bird Conservation Act of 1929, as amended (45 Stat. 1224 [1929], 16 U.S.C.§715 [1970]), was passed with the intention of more effectively meeting all of the obligations of the two treaties mentioned in the preceding paragraph. Especially significant in this act was the establishment of the Migratory Bird Conservation Commission with the Secretary of Interior serving as chairman and other members including the Secretaries of Commerce and Agriculture, two senators, and two representatives. This commission is authorized to approve purchase or rental of any lands or waters recommended by the Secretary of Interior as vital for protecting and preserving not only migratory birds as set forth in the two treaties but also species threatened with extinction. Purchase can also be for the purpose of developing habitat necessary for protecting and preserving the species concerned. Land cannot be removed from a power site or national forest for such purposes without prior approval from the state in which the site or

forest is located. Two hundred thousand dollars were appropriated in June of 1940 and every fiscal year thereafter for the purposes of this law. This appropriation was increased to $105,000,000 beginning with fiscal year 1962 and each of fifteen following fiscal years.

The Migratory Bird Stamp Act of 1934, as amended (48 Stat. 451 [1934], 16 U.S.C.§718-718(i) [1970]), provides that any funds left after administering the act can be used for the acquisition of migratory bird refuges. This added another legal tool for authorizing acquisition of habitat.

The Continental Congress adopted the bald eagle as the national bird in 1782. In 1940, Congress passed the Bald Eagle Act (54 Stat. 250 [1940]) giving full protection to the bird. The act, as amended (76 Stat. 1246 [1962], 16 U.S.C.§668-668(d) [1970]), also gives protection to the golden eagle. Violation of this law carries a five hundred dollar fine and/or a maximum of six months in jail. The Secretary of Interior is responsible for determining if it is compatible with the law to issue permits for the purpose of taking these two species for museums, zoos, scientific purposes, or for use in the religions of various Indian tribes. The Secretary can also give approval for the seasonal taking of golden eagles when a state governor presents sufficient evidence that they are endangering livestock. As of 1975, the southern bald eagle was listed as an endangered species (Federal Register, Vol. 40, No. 188). The northern bald eagle and golden eagle, although not listed as threatened or endangered, are still protected under the original law.

Two treaties in the 1940's and one in the early 1950's began to expand to an international audience the recognition that some species were declining in numbers. On October 12, 1940, the Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere (56 Stat. 1354) called

for the ratifying nations to explore the possibilities of establishing national parks, reserves, monuments, and wilderness preserves within which all life would be protected. These countries would also give protection to migratory bird species of economic or aesthetic value as well as to species threatened with extinction. Countries of the Western Hemisphere that were still parties to the agreement in 1975 were Argentina, Brazil, Costa Rica, Chile, the Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Mexico, Nicaragua, Panama, Peru, Trinidad, Tobago, the United States, Uruguay, and Venezuela (Department of State, 1975).

The International Convention for the Northwest Atlantic Fisheries ([1950] 1 U.S.T. & O.I.A. 477, T.I.A.S. No. 2089) on February 8, 1949, established an international commission with authority to conduct studies and observe the condition of any species of life in the North Atlantic. This commission was also given the authority to recommend seasons, size limits, catch limits, and types of fishing gear for commercial fishery use. Participating nations in 1975 still included Bulgaria, Canada, Denmark, France, the German Democratic Republic, the Federal Republic of Germany, Iceland, Italy, Japan, Norway, Poland, Portugal, Romania, Spain, the Union of Soviet Socialist Republics, the United States, and the United Kingdom.

On May 9, 1952, the United States, Canada, and Japan signed the International Convention for the High Seas Fisheries of the North Pacific Ocean Treaty ([1953] 4 U.S.T. & O.I.A. 380, T.I.A.S. No. 2786). This established a commission to guard against overexploitation of species in the North Pacific.

By means of these three preceding treaties, the attention of the world was beginning to be focused on the fact that some species which are exploited for commercial purposes could become excessively exploited. All

three treaties are still in force.

As the federal government's involvement with fish and wildlife conservation and management increased, it became necessary to form a governmental bureau to handle the involvements. The Fish and Wildlife Act of 1956, as amended (70 Stat. 1119 [1956], 16 U.S.C.§742(a)-742(d) and 742(e)-742(j) [1970]), created the U.S. Fish and Wildlife Service to be composed of a Bureau of Commercial Fisheries and a Bureau of Sport Fisheries and Wildlife. It also authorized the Fish and Wildlife Service to acquire refuge lands for the conservation and protection of all types of wildlife.

The Land and Water Conservation Fund Act of 1965, as amended (78 Stat. 897 [1964], 16 U.S.C.§460(1)-4 to 460(1)-11, [1970]), was enacted to create a fund to assist the states and federal agencies in meeting the present as well as expected recreational needs of the public. Much of this money is raised by the charging of user fees at national parks, forests, monuments, and recreational areas. One of the subpurposes for which such money can be allocated is for preserving species threatened with extinction. More about this act and its financial importance will be mentioned when later legislation is considered.

It was not until October 15, 1966, that the federal government became formally involved with threatened species per se by passage of the Endangered Species Preservation Act (80 Stat. 926 [1966]). This law acknowledged the fact that a number of native species of wildlife have been exterminated, and the purposes of the act were set forth in Section 1(a) of the law:

> The purposes of this Act are to provide a program for the conservation, protection, restoration, and propagation of selected species of native fish and wildlife, including migratory birds, that are threatened with extinction, and consolidate, restate, and modify the present authorities relating to administration by the Secretary of Interior of the National Wildlife Refuge System.

The Secretary of Interior was charged with the determination of endangered

species, and some general criteria for making such judgements were included as well as the requirement for listing such species in the Federal Register.

The act further stated that it would be the policy of the Secretaries of Interior, Agriculture, and Defense to seek to aid such native species by preserving land habitat necessary to their survival. Any land acquisition was to be done by the Secretary of Interior with funds from the Land and Water Conservation Fund Act of 1965 with a maximum amount of $750,000 per area and a maximum of fifteen million dollars for all acquisitions appropriated.

All lands and waters administered by the Secretary of Interior as wildlife refuges, areas for the protection and conservation of fish and wildlife threatened with extinction, wildlife ranges, game ranges, wildlife management areas, or waterfowl production areas were consolidated under the Secretary of Interior and given the designation of National Wildlife Refuge System. The Secretary was authorized to manage all resources and govern the uses of such areas in cooperation with state agencies if he deemed their participation necessary or useful. Any unauthorized use or removal of property from such areas can, upon conviction, result in a five hundred dollar fine and/or a maximum six months in jail.

In essence, this law authorized research on threatened species and acquisition of habitat for them. The Department of Interior estimated the administrative costs of the program at about four million dollars yearly for the succeeding five years (Senate Report 1463, 1966).

The intent of the Endangered Species Preservation Act of 1966 was broadened with the passage of the Endangered Species Conservation Act of 1969 (89 Stat. 275 [1969]). The law extended coverage to include all vertebrates plus crustaceans and mollusks, and subspecies as well as species that could be considered for possible listing in the Federal Register. The

Secretary of Interior was ordered to review the status of species or subspecies on the Federal Register listing at least every five years or whenever any interested party petitioned him with substantial evidence to do so.

The 1969 law also differed from the 1966 one in that "foreign" species and subspecies and not just species native to the United States can be considered and importation of them prevented. The Secretary can issue permits for the import of such species and subspecies as he determines necessary for scientific purposes or to avoid undue economic hardships. Economic hardship permits, however, are to be for specified quantities and periods of time, not to exceed one year. To aid in regulating illegal importation, the Secretary is authorized to designate what ports of entry fish and wildlife can enter the United States.

This law authorizes the acquisition of water as well as land habitats necessary for the survival of threatened species whereas the 1966 law had authorized only land acquisition. The funds available from the Land and Water Conservation Fund Act of 1965 for habitat acquisition were increased from $750,000 per area to $2.5 million per area and five million dollars per year. The total overall ceiling of fifteen million dollars is maintained. The Department of Interior estimated an additional $145,000 yearly administrative costs to the budget allotment (Senate Report No. 91-526, 1969). Penalties for violation of the law and subsequent conviction were increased to ten thousand dollars and/or a maximum of one year in jail.

The Marine Mammal Protection Act of 1972 (86 Stat. 1027 [1972], 16 U.S.C.§1361-1362, 1371-1384, 1401-1407 [1970]) was approved on October 21, 1972, to give protection to marine mammals. The law recognized that certain stocks of marine mammals have become depleted and called for a moratorium on the taking and importation of marine mammals and marine mammal products with certain

exceptions to be allowed as determined by a Marine Mammal Commission and Committee of Scientific Advisors on Marine Mammals as established under the act. One such exception was the taking of such marine mammals by Indians, Aleuts, or Eskimos dwelling on the coast of the North Pacific or Arctic Oceans for subsistence purposes or for purposes of creating and selling authentic articles of handicraft and clothing unless the Secretary of Commerce or Interior determined the stocks of mammals concerned to be too seriously depleted. With the passage of the Endangered Species Act of 1973, any mammal classified as endangered cannot be taken.

Regulations for issuance of permits to take such mammals are listed as well as other duties of the two above-named commissions. One million dollars per year for four years was allotted to the commission for operations.

Administration of the act is divided between the Secretaries of Commerce and Interior. Members of the order Cetacea and Pinnipedia (except walruses) are under the jurisdiction of the Secretary of Commerce while other marine mammals are under that of the Secretary of Interior.

The February 25, 1974 issue of the Federal Register (Vol. 39, No. 38) listed the following species as being covered by this act: the polar bear, sea otter, walrus, dugong, West African manatee, West Indian manatee, and the Amazonian manatee.

The Endangered Species Conservation Act of 1969 had provided funds for an international convention with the purpose of drafting a treaty to control international traffic in endangered species. The result was the Convention on International Trade in Endangered Species of Wild Fauna and Flora, held in Washington, D.C. on February 12, 1973. The convention established regulations to prevent commercial overexploitation of any species, subspecies, or geographically separate population of plant or animal. Three

appendices or lists of such organisms with differing levels of trade regulations depending upon the degree to which they were threatened and the contribution international trade makes to such threats were established. Forty-two nations, including the United States, ratified the treaty (Schreiner and Ruhr, 1974).

Appendix I includes species, subspecies, or populations threatened with extinction which are or might be affected by trade. Strict regulation of trade of these is to be observed.

Appendix II includes species, subspecies, or populations of plants and animals that, although not currently threatened with extinction, could become so if trade in them was not regulated. Also included are other species which are subject to regulation so that trade in the others listed in Appendix II can be brought under effective control. Trade in Appendix II specimens requires an export permit and no member nation can allow import of Appendix II organisms without such permit from the country of origin.

Appendix III includes species, subspecies, or populations of plants and animals which any member nation identified as being threatened by over-exploitation within its jurisdiction and requests the cooperation of other member nations in regulating trade in the organism concerned. Export permits are required.

The Federal Environmental Pesticide Control Act of 1972, as amended (P.L. 92-516, 86 Stat. 973, U.S.C.§136), prohibits the use of pesticides whenever they might present an imminent hazard to species considered endangered or threatened by the Secretary of Interior.

The Endangered Species Act of 1973 (Public Law 93-205, 87 Stat. 884 [1973]) repealed the Endangered Species Conservation Act of 1969 (except those sections dealing with the National Wildlife Refuge System. This piece of

legislation is the current and most significant law passed with regard to threatened and endangered species.

Section 1 states that the law is to be known as the Endangered Species Act of 1973. Its purpose is to "...provide for the conservation of endangered and threatened species of fish, wildlife, and plants, and for other purposes."

Section 2 acknowledges that various species of fauna and flora have become extinct and a number of others are facing possible extinction. Commitments of the United States to other countries through the migratory bird treaties with Canada and Mexico, the Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere, the International Convention for the Northwest Atlantic Fisheries, the International Convention for the High Seas Fisheries of the North Pacific Ocean, the Convention on International Trade in Endangered Species of Wild Fauna and Flora, and other international agreements are acknowledged.

> The purposes of this Act are to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species, and to take such steps as may be appropriate to achieve the purposes of the treaties and conventions [those mentioned in the above paragraph] set forth in Subsection (a) of this section.

All federal departments and agencies are ordered to cooperate and seek to use their authorities to further the purposes of the act.

Section 3 lists sixteen different definitions of terms used throughout the body of the act. The most significant of these are considered in the following paragraphs.

"Conserve," "conserving," and "conservation" were defined as meaning to use all methods and procedures necessary to remove a species from a threatened or endangered status. Such methods and procedures might include research, law enforcement, habitat acquisition, and propagation among others.

The terms "endangered" and "threatened" were defined as they were in Chapter 1 of this report.

The term "fish and wildlife" was broadened to include all vertebrates, mollusks, crustaceans, arthropods, or other invertebrates and included, as did the 1969 law, any part, product, egg, or offspring of such organisms as well as dead bodies or parts of them.

The term "species" again included both species and subspecies, but the term was broadened by this act to include geographic populations. One population along the northern part of a species'range could be endangered while another population of the same species along the southern part of the range was not. Under this law, the northern population could be classified as endangered or threatened without the southern population also being similarly classified.

"Plant" referred to any member of the plant kingdom including seeds, roots, and/or any other parts of a plant.

The term "take" was defined to mean to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct.

"Secretary" could refer to the Secretary of Interior, Commerce, or Agriculture. The Secretary of Commerce was to have jurisdiction over marine species (order Cetacea and order Pinnipedia with the exception of walruses), and the Secretary of Interior jurisdiction over all other species as well as the responsibility for the actual classification and listing of species. The Secretary of Agriculture was to be in charge of enforcing the trade regulations set forth in the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Section 4 outlines the procedures for determining and listing species

in the Federal Register as endangered or threatened. These criteria and procedures are discussed in Chapter 3 of this report. A list of endangered wildlife as well as one of threatened wildlife was called for whereas the Endangered Species Conservation Act of 1969 maintained a single listing. Any person, group, or agency was given the right to petition the Secretary of Interior to review the status of any given species.

The Secretary of Interior was given the authority to list as endangered or threatened any species that might be similar in appearance to a species already listed. This is permitted if it presents an identification problem and subsequent additional threat to the species already endangered or threatened or if it makes law enforcement more efficient.

Regulations pursuant to Section 4 were established that required all proposed listings and rulemakings to be published in the Federal Register for public comment. The Secretary of Interior was also given authority to make emergency rulings whenever a significant risk to wildlife was felt to exist without going through the normal rulemaking procedures. However, such emergency rulings were to be effective for only 120 days at which time the ruling would become invalid unless the ruling had gone through the processes required for non-emergency rulemakings in the meantime.

All proposed rulemakings published in the Federal Register were to be accompanied by the evidence on which the proposition was based. If any person felt he was adversely affected by the proposed rulemaking, he was to be given forty-five days to file comment with the Secretary who would make public in the Federal Register a summary of all such opinions.

The Secretary was authorized to issue regulations pertaining to protection and management of threatened species. This implies that the regulations regarding threatened species are somewhat more flexible than

those pertaining to endangered species.

The Secretary was authorized in Section 5 to acquire waters and/or lands felt necessary for preservation of endangered or threatened species with funds from the Land and Water Conservation Fund Act of 1965. As of 1976, more than $18.5 million of these funds had been used to purchase over 45,000 acres. During the 1976 fiscal year, an additional 4,670 acres were acquired for $5,134,000. Recovery plans (discussed in Chapter 6) have identified land for acquisition for approximately sixty other endangered or threatened species (U.S. Department of Interior, 1976).

The need for close cooperation with the states was acknowledged in Section 6. Management agreements between the Secretary of Interior and the states were designed to provide for administration and management of areas established for conservation of threatened and/or endangered species. Revenues derived from such areas were to go back to the counties in which the areas were located.

Cooperative agreements were discussed which would provide assistance to the states in establishing programs for endangered and/or threatened species. In order to be eligible for such an agreement, the state must show that it possesses the programs and authority to conserve such species. The federal government cannot provide more than two-thirds of the financial support for such a program. This figure can be increased to three-fourths if two states share a particular endangered or threatened species. Appropriations for cooperative agreements are not to exceed ten million dollars for the period ending June 30, 1977. Twenty-one such agreements had been signed by March of 1978 (Endangered Species Technical Bulletin, Vol. 3, No. 4). In cases of conflict between state and federal laws, the more restrictive apply.

Section 7 requires the Secretary to review all programs of the department and try to utilize them for furtherance of the law. Heads of all other agencies are to review their programs to be sure they do not result in additional reduction of wildlife numbers and distribution.

Foreign countries are urged to implement their own programs for conserving threatened and endangered species in Section 8. The United States pledges its cooperation and financial assistance in such endeavors. Authority is also given for implementation of the articles of the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Section 9 lists actions that are to be considered unlawful. Chief among these prohibited acts is that no person subject to the jurisdiction of the United States can take any endangered faunal species in the United States or its territorial sea, or violate any regulations the Secretary has made regarding threatened and/or endangered species. It also makes unlawful violation of any regulations promulgated by the Secretary involving plants. This includes importation or exportation of such plants, carrying or receiving them, or the sale of any such plants. Regulations covering listed species held in captivity as well as the import and export of wildlife and plants are also covered in this section.

Section 10 allows for exceptions through the issuance of permits to the actions prohibited in Section 9. In general, such permits are to be issued only for scientific purposes. Some can be issued in cases where an "undue economic hardship" might exist as a result of classifying a species as endangered or threatened. Applications for all permits are to be published in the Federal Register. If no valid adverse comments are received, the permit will be issued.

Section 11 states the civil and criminal penalties that could result

from violation of the law and subsequent conviction. Civil penalties are set at a maximum fine of ten thousand dollars per violation and criminal penalties at twenty thousand dollars and/or one year in jail. Court jurisdiction and law enforcement are also discussed. Upon recommendation of the Secretary, rewards of up to but not exceeding $2,500 can be paid to anyone supplying information that results in a conviction. Citizen suits can be brought against any person or agency (including governmental ones) to enjoin them if they are alleged to be in violation of the law.

Under the Endangered Species Act of 1973, the U.S. Fish and Wildlife's Law Enforcement Division referred 220 investigations to the Department of Justice for the fiscal year 1975. Justice declined to prosecute 70 of the cases, 29 resulted in acquittal or dismissal, and 121 resulted in convictions. Fines and costs averaged $152 per case for a total of $18,385 (U.S. Department of Interior, 1975a). For fiscal year 1976, criminal convictions numbered 46. Courts imposed total fines of $6,347 and 1,115 days of jail sentences with 970 days suspended. Civil actions numbered 112 with total penalties of $3,460 (U.S. Department of Interior, 1976).

Section 12 orders the Smithsonian Institution to prepare a list of plants threatened with extinction along with recommendations to conserve them. This report was presented to Congress in December of 1974 and the plants proposed for threatened or endangered status published in the Federal Register for public comment (Federal Register, Vol. 40, No. 127).

Section 13 amends other laws to be consistent with the Endangered Species Act of 1973. The Endangered Species Preservation Act of 1966, Marine Mammal Protection Act of 1972, Land and Water Conservation Fund Act of 1965, and Migratory Bird Conservation Act were among those amended.

The Endangered Species Conservation Act of 1969 was repealed in

Section 14.

Section 15 appropriated funds to the Department of Interior of four million, eight million, and ten million dollars for fiscal years 1974, 1975, and 1976 respectively. Corresponding figures for the Department of Commerce were two million, 1.5 million, and two million dollars. These appropriations were made in 1973, but the actual budget figures for those years varied somewhat for the Department of Interior as can be seen from Table 2.1 which outlines expenditures for years 1966-1976. This reporter made no attempt to determine actual budgetary allotments for the Department of Commerce.

In reports to the Senate, the Departments of Interior and Commerce estimated their combined total costs for the 1974-1975 fiscal year at 69.9 million dollars (Senate Report 93-412, 1973). These costs included state grants-in-aid and habitat acquisition by the Department of Interior as well as program costs for both departments.

The responsibility for coordinating all activities of the law as designated for the Department of Interior was given to the U.S. Fish and Wildlife Service. Similar authority for the Department of Commerce was delegated to the National Marine Fisheries Service.

The ninety-fifth Congress amended the Endangered Species Act of 1973 with passage of the Endangered Species Act Amendments of 1978 (Public Law 95-632, 92 Stat. 3751 [1978]). This action was primarily the result of court injunctions issued against continued construction of the Tellico Dam in Tennessee and the Grayrocks Dam in Wyoming. Construction on these projects was halted because it presented a threat to the critical habitat of two endangered species--the snail darter in the Little Tennessee River and the whooping crane on the Platte River in Nebraska. The court decisions were based in part on Section 7 of the Endangered Species Act of 1973. Chapter 6 discusses these two projects in more detail.

Table 2.1

Department of Interior Budget Breakdown, Fiscal Years 1966-1976

Fiscal Year	Dept. of Interior ($millions)[a]	Bureau of Sport Fisheries and Wildlife ($millions)[a]	Federal Endangered Species Budget ($millions)[b]	Endangered Species Budget as % of BSFW Budget
1966	1,626	76.846	0.350	0.46
1967	1,725	89.047	0.385	0.43
1968	1,965	108.757	0.554	0.51
1969	1,996	111.333	0.550	0.49
1970	1,773	123.464	0.560	0.45
1971	2,309	135.905	0.575	0.42
1972	2,612	151.014	0.825[c]	0.55
1973	2,862	158.822	4.172	2.63
1974	2,642	179.740	4.600[d]	2.56
1975	3,565	207.000	5.606	2.71
1976	3,843 (est.)	249.083 (est.)	7.374	2.96

[a]Pearson, 1976

[b]Dole, 1975

[c]Prior to 1972, the endangered species program was not a specific line item in the budget. Most of the appropriated funds for prior years were for research. In 1972, a new budget activity was established encompassing both research and technical functions.

[d]The Fish and Wildlife Service's budget structure was revised in 1974. The budget activity was expanded to include not only research and technical assistance but also law enforcement, refuge management for endangered and threatened species, planning, and program coordination. The 1973 figure has been adjusted to conform with this.

The major changes in the 1973 law dealt with Section 7. The Secretary of Interior is required to review the actions of federally funded programs to determine if they jeopardize the continued existence of any endangered or threatened species or their habitat. Following review of the program and consultation with the agency or agencies involved, the Secretary issues an opinion on what effects the program's actions might have on any endangered or threatened species involved or their habitat. He is required to suggest:

> ...those reasonable and prudent alternatives which he believes would avoid jeopardizing the continued existence of any endangered or threatened species or adversely modifying the critical habitat of such species, and which can be taken by the Federal agency or the permit or license applicant in implementing the agency action. (ibid.)

Each federal agency is required to request information from the Secretary regarding the presence of any endangered or threatened species or the proposed listing of any species for such classification within the area of their proposed program. If any such species is present, the agency must prepare a biological assessment of the effects their program might have on the species.

Once the consultation process has begun, the agency cannot enter into any contracts or agreements for construction which would interfere with the implementation of alternative measures suggested by the Secretary. This was a point which the Grayrocks Dam Project violated.

Once the Secretary's biological opinion of a proposed project is issued, the applicant may submit an application within ninety days for exemption from Section 7 regulations. All applications for exemption are submitted to a review board. The board must determine if: (1) an irresolvable conflict exists between the proposed agency action and the continued existence of an endangered or threatened species or its critical habitat; (2) the applicant has made "reasonable and responsible effort" to develop alternatives to the proposed project; (3) conducted any required biological assessments; and (4) refrained from making

any "irreversible or irretrievable commitment of resources." If the board finds that these criteria are met, a report on the exemption application along with the Secretary's views and suggestions are submitted to the Endangered Species Committee for a final determination.

The seven permanent members of this committee are the Secretaries of Interior (chairman), Agriculture, and Army, Chairman of the Council of Economic Advisors, and Administrators of the Environmental Protection Agency and the National Oceanic and Atmospheric Administration. In addition, one representative recommended by the governor of the affected state is seated on the committee.

The Endangered Species Committee shall grant an exemption if it determines that:

> (1) "there are no reasonable and prudent alternatives to the agency action;
> (2) "the benefits of such action clearly outweigh the benefits of alternative courses of action consistent with conserving the species or its critical habitat, and such action is in the public interest; and
> (3) "the action is of regional or national significance...." (ibid.)

For an exemption to be granted, at least five members of the committee must be in agreement. If an exemption is granted, the committee must also establish:

> ...such reasonable mitigation and enhancement measures, including, but not limited to, live propagation, transplantation, and habitat acquisition and improvement, as are necessary and appropriate to minimize the adverse effects of the agency action upon the endangered species, threatened species, or critical habitat concerned. (ibid.)

If the Secretary of Interior determines that extinction of a species will occur once an exemption has been granted, the committee reconsiders the exemption and either upholds or withdraws it. An agency which receives an exemption must report annually to the Council on Environmental Quality on its compliance with the committee's prescribed mitigation and enhancement measures.

Some of the other provisions of The Endangered Species Act Amendments of 1978 deal with critical habitat and recovery plans. They are both discussed in

greater detail in Chapter 6. The amendments also call for the Secretary of Interior to review the list of threatened and endangered species at least every five years. The Fish and Wildlife Service is authorized to enter into cooperative agreements with states for the conservation of threatened and endangered plants. Authorization for using money from the Land and Water Conservation Fund Act of 1965 to acquire critical habitats for such plants is provided.

Chapter 3

HISTORY, TERMINOLOGY, AND LISTING PROCEDURES

The first governmental listing of endangered United States wildlife was in 1966 when the Bureau of Sport Fisheries and Wildlife, a division of the U.S. Fish and Wildlife Service, published Rare and Endangered Fish and Wildlife of the United States. This was the result of circulating a tentative list in 1964 among persons and organizations knowledgeable of the species on the list for their revision and comments. The 1966 publication has been commonly referred to as the "red book," and it classified species as either rare, endangered, peripheral, or status undetermined. This publication should not be confused with the "red data book" published and periodically updated by the International Union for Conservation of Nature and Natural Resources (IUCN), a Swiss-based organization. The IUCN lists species worldwide while the Bureau of Sport Fisheries and Wildlife's "red book" listed only species and subspecies considered in the United States.

In 1968, the 1966 edition of the "red book" was revised with one species being deleted from the list and two undergoing a change in classification. The classification terms used were the same as for 1966.

A third revision appeared in 1973 under the title of Threatened Wildlife of the United States. The term "threatened" was substituted for both "rare" and "endangered" while "peripheral" and "status undetermined" were retained.

All three "red book" editions list only vertebrates--mammals, birds, fishes, reptiles, and amphibians. Information is presented

regarding their former and present numbers and distributions. Proposed protective measures and those already undertaken are also given.

The three Fish and Wildlife Service publications served only as an unofficial listing of species confronted with possible extinction in the United States. With the passage of the Endangered Species Preservation Act of 1966, the Federal Register became the reference for the official listing of such species. The Federal Register continues as the official list under authority of the Endangered Species Act of 1973. The listings are published at irregular intervals with any amendments to the list appearing in subsequent issues. The July 14, 1977 Federal Register (Vol. 42, No. 135) list is the basis of coverage for this report. Prior major listings in the Federal Register have been those for March 11, 1967, October 13, 1970, December 2,1970, March 30, 1972, June 4, 1973, January 4, 1974, September 26, 1975, and October 27, 1976.

The Federal Register lists prior to January 4, 1974 listed species only as "threatened with possible extinction" and did not use any of the three classifications used in the three "red book" editions. Following this date, the Federal Register lists used the classification of either "threatened" or "endangered."

The Federal Register listing for July 14, 1977 did not list all of the species listed in the "red book" editions. Of thirty mammalian, thirty-six avian, six reptilian, eleven amphibian, and fifty-five fish species listed in the 1973 "red book," the July 14, 1977 Federal Register listing included eighteen, twenty-three, four, four, and thirty of those species respectively. An updated version of the "red book" has not been published since 1973 and even though it has no official status regarding the listing of species eligible for legal protection under the Endangered Species Act of 1973, it has served

the role of providing an initial list of animals for biologists to consider for legal protection under the law.

Six classification terms have been mentioned in the preceding paragraphs. The following paragraphs define and discuss these terms and some others that have been and will be encountered in this report.

United States

This area includes the forty-eight contiguous United States, Alaska, and any immediate offshore islands containing endangered or threatened species. Hawaiian and oceanic species will not be considered. This geographical area was chosen to provide an area with a representative selection of threatened and endangered species yet one small enough to limit the number of species to be examined.

Species

The Endangered Species Act of 1973 defined this term to "...include any subspecies of fish or wildlife or plants and any other group of fish or wildlife of the same species or smaller taxa in common spatial arrangement that interbreed when mature." The entire concept of speciation will be examined in further detail in Chapter 4.

Extinct Species

An extinct species is one that has no living representatives. A similar term commonly encountered in the literature is "extirpated."

There were approximately 4,226 living mammal species and 8,684 living bird species worldwide in 1600. Of that number, thirty-six mammalian and ninety-four avian species have become extinct. Corresponding figures for the same period of time in North America are nineteen extinct species of

mammals and six extinct species of birds (Fisher, Simon, and Vincent, 1969).

Rare Species

The definition of a rare species used by the Fish and Wildlife Service is one that is not presently threatened with extinction but is "...in such small numbers throughout its range that it may be endangered if its environment worsens. Close watch of its status is necessary" (U.S. Department of Interior, 1966). This classification term was used only in the 1966 and 1968 editions of the "red book," but it is not used in any of the Federal Register listings.

Endangered Species

An endangered species was initially defined in the 1966 and 1968 "red book" editions as one whose:

> ...prospects of survival and reproduction are in immediate jeopardy. Its peril may result from one or many causes--loss of habitat or change in habitat, overexploitation, predation, competition, or disease. An endangered species must have help, or extinction will probably follow. (U.S. Department of Interior, 1966 and 1968)

This definition was not used in the 1973 "red book." With passage of the Endangered Species Act of 1973, the definition of endangered was altered somewhat to read as stated in Chapter 1. Approximately 2.5% of all mammal and bird species that have existed since 1600 have become endangered (Fisher, Simon, and Vincent, loc. cit.).

Threatened Species

This term was first used in the 1973 "red book" instead of "endangered." The Endangered Species Act of 1973 also required a listing in the Federal Register of those species considered as endangered as well as a second listing of those considered as threatened. The definition of "threatened" that will be followed in this report will be the same as that listed in Chapter 1.

Peripheral Species

A peripheral species is one whose "...occurrence in the United States is at the edge of its natural range and which is rare or endangered within the United States although not in its range as a whole. Special attention is necessary to assure retention in our Nation's fauna" (U.S. Department of Interior, 1966 and 1968). The same definition was used in the 1973 "red book" with the exception of "...threatened with extinction..." being substituted for "...rare or endangered...." This term is not used in any of the Federal Register listings now.

Status Undetermined Species

A status undetermined species is one that has been suggested as possibly being endangered but about which there is "...not enough information to determine its status. More information is needed" (ibid.). The definition was again the same in the 1973 "red book" with the exception of "...threatened with extinction..." being substituted for "...endangered...." This term is used only in unofficial listings.

The procedure for placing a species on the endangered or threatened list has undergone no major changes since 1966. Under Section 4(a) of the Endangered Species Act of 1973, the Secretary of Interior shall determine if any species is eligible for placement on the list by consideration of any of the following:

(1) "the present or threatened destruction, modification, or curtailment of its habitat or range;
(2) "overutilization for commercial sporting, scientific, or educational services;
(3) "disease or predation;
(4) "the inadequacy of existing regulatory mechanisms; or
(5) "other natural or manmade factors affecting its continued existence."

The Secretary makes decisions regarding proposed listings if the proposed

species meets any of the above criteria and also on the basis of the following:

> ...the best scientific and commercial data available to him and after consultation, as appropriate, with the affected states, interested persons and organizations, other interested Federal agencies, and, in cooperation with the Secretary of State, with the country or countries in which the species concerned is normally found or whose citizens harvest such species on the high seas.... (Public Law 93-205, 87 Stat. 87)

This obviously does not establish any objective methods for the determination of endangerment. The Endangered Species Preservation Act of 1966 provided *some* guidelines as to the sources of the "...best scientific and commercial data..." by stating the Secretary of Interior should periodically seek the "...advice and recommendation of interested persons and organizations including, but not limited to, ornithologists, ichthyologists, ecologists, herpetologists, and mammalogists." In other words, the advice and counsel of individuals and/or organizations with expertise regarding the status of species under consideration are actively sought:

> ...to date there have been devised no objective methods of classifying any particular taxon or population with regard to definitions [endangered and threatened]. Instead, the biologists of this Office must make a subjective judgement on the current status of each species and how present or planned future activities may negatively affect these species. (Opler, 1975)

Any person, group, or agency can petition the Secretary to have a species placed on the endangered or threatened list. Information supporting the proposal should be submitted to the National Marine Fisheries Service for marine species or to the Fish and Wildlife Service for all other species.

When a nomination is received, it is screened to determine if a review of the proposal is warranted. If it is determined that review by specialists is warranted, notice is published in the Federal Register and data is solicited from all relevant sources. This notice and data gathering is usually done for a period of thirty days but the time is optional. Governors of states in which the species is found must also be notified and allowed ninety days for

comment. Once all comments are received from state governors involved and relevant sources, a final decision is made whether to list the proposed species or not. If the decision is made to list the species, it is proposed in the Federal Register along with the species' common and scientific names, a summary of the facts leading to the proposal, the specific portions of the species' range where it is endangered or threatened, a summary of facts regarding any portion of the range considered to be critical habitat (see Chapter 6), and any special regulations pertaining to the proposal. Sixty days are allowed for comment. If no adverse evidence is presented during that time period, a public hearing on the proposed listing is requested.

If granted, announcement of the hearing must be published in the Federal Register. If denied, the reasons for denial must also be listed in the Federal Register. Once a hearing is granted, information is compiled, presented, and analyzed. The Secretary of Interior then determines whether the species shall be listed or not. If he decides to list it, the listing is published in the Federal Register. If it is listed as threatened rather than endangered, any special regulations concerning the species must be published at the same time. A decision not to list a species as threatened or endangered must be accompanied with a letter to the petitioner explaining the decision.

Proposals to remove a species from the threatened or endangered list or to change a particular species' classification follow the same procedures as those for adding a species. Figure 3.1 presents a diagrammatic summary of the listing process.

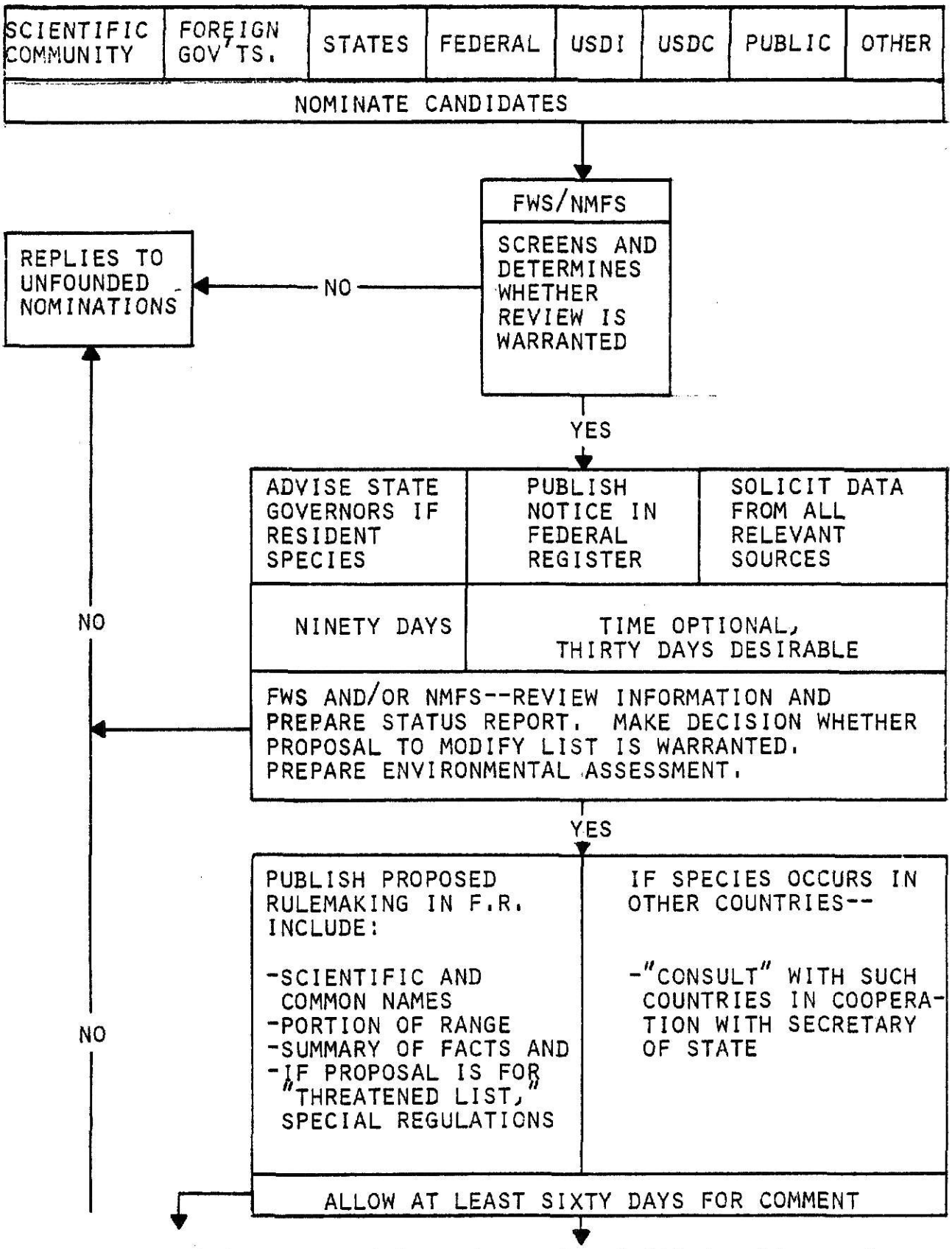

Figure 3.1. General Procedures for Modifying Lists of Threatened or Endangered Wildlife. (Used with permission of U.S. Fish and Wildlife Service, 1976)

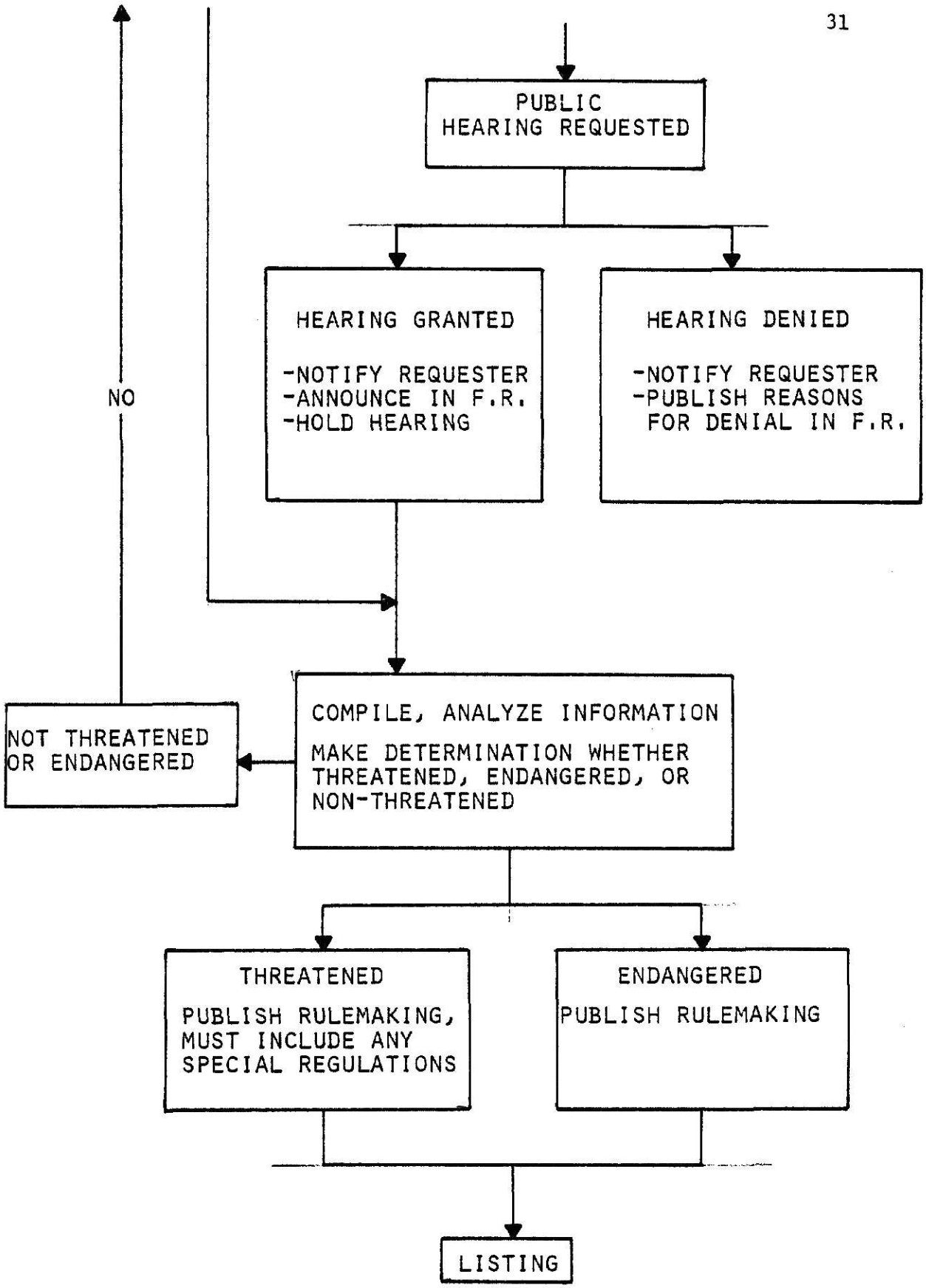

Figure 3.1. General Procedures for Modifying Lists of Threatened or Endangered Wildlife. (Used with permission of U.S. Fish and Wildlife Service, 1976)
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Chapter 4

ECOLOGICAL THEORIES RELATED TO EXTINCTION

Fisher, Simon, and Vincent (1969) listed five general causes which they felt were responsible for some of the extinctions which have occurred and for the declining populations of some of the species observed around the world. Those reasons were as follows: (1) natural evolutionary processes; (2) overhunting for the purpose of food, clothing, sport, or pest control; (3) introduced predators; (4) other introduced species that have become competitors, vectors for disease, or modifiers of the habitat; and (5) habitat disturbance or destruction.

The purpose of this chapter is to examine some of the current ecological theories dealing with population dynamics and how they apply to those causes threatening and endangering species. Theories often deal with mathematical relationships. An effort has been made to hold the mathematics at a minimum and summarize the results and predictions of the theories along with examples from nature.

Logistic Growth

A single breeding pair of animals could increase at a geometric rate to exceedingly large numbers. They, however, do not achieve their potential increase. This indicates that there must be some force opposing this increase.

By balancing these two opposing forces, the logistic equation describes how a population grows. The force that leads to adding numbers to a population by births is called the biotic potential (Chapman, 1928). Biotic potential

refers to an organism's inborn capacity to increase its numbers, i.e. the maximum rate at which it can reproduce under ideal conditions. The force which constrains the biotic potential is known as environmental resistance.

If one was to plot on a graph the relationship between the numbers of individuals in a population and the length of time required for the population to reach those numbers, the curve would be a sigmoid or S-shaped one as in Figure 4.1. An examination of the curve shows that the size of the population increases slowly at first, then increases rapidly, and finally decreases so that the number of individuals in the population levels off. This type of curve in which population size is plotted against time is known as a growth rate curve.

That the curve in Figure 4.1 levels out reflects the environmental resistance restricting unlimited growth. Whereas the biotic potential is considered to be an innate quality characteristic of a given species, environmental resistance can come from all living and/or non-living forces in the environment in which the particular species is found.

An environment does not have an unlimited ability to support ever-increasing numbers in a population. Factors such as food, living space, den or nesting materials, and predators place a limit on an environment's capacity to support a population. This limit or capacity is commonly referred to as an environment's carrying capacity for that particular population. Another way of viewing carrying capacity is to consider it as the population size at which each member of the population has the minimal amount of resources needed to maintain itself. As the population size increases, the amount of resources available to each individual decreases. The carrying capacity of the hypothetical population graphed in Figure 4.1 is denoted by K.

Carrying capacity is not a quality which is innate or characteristic to

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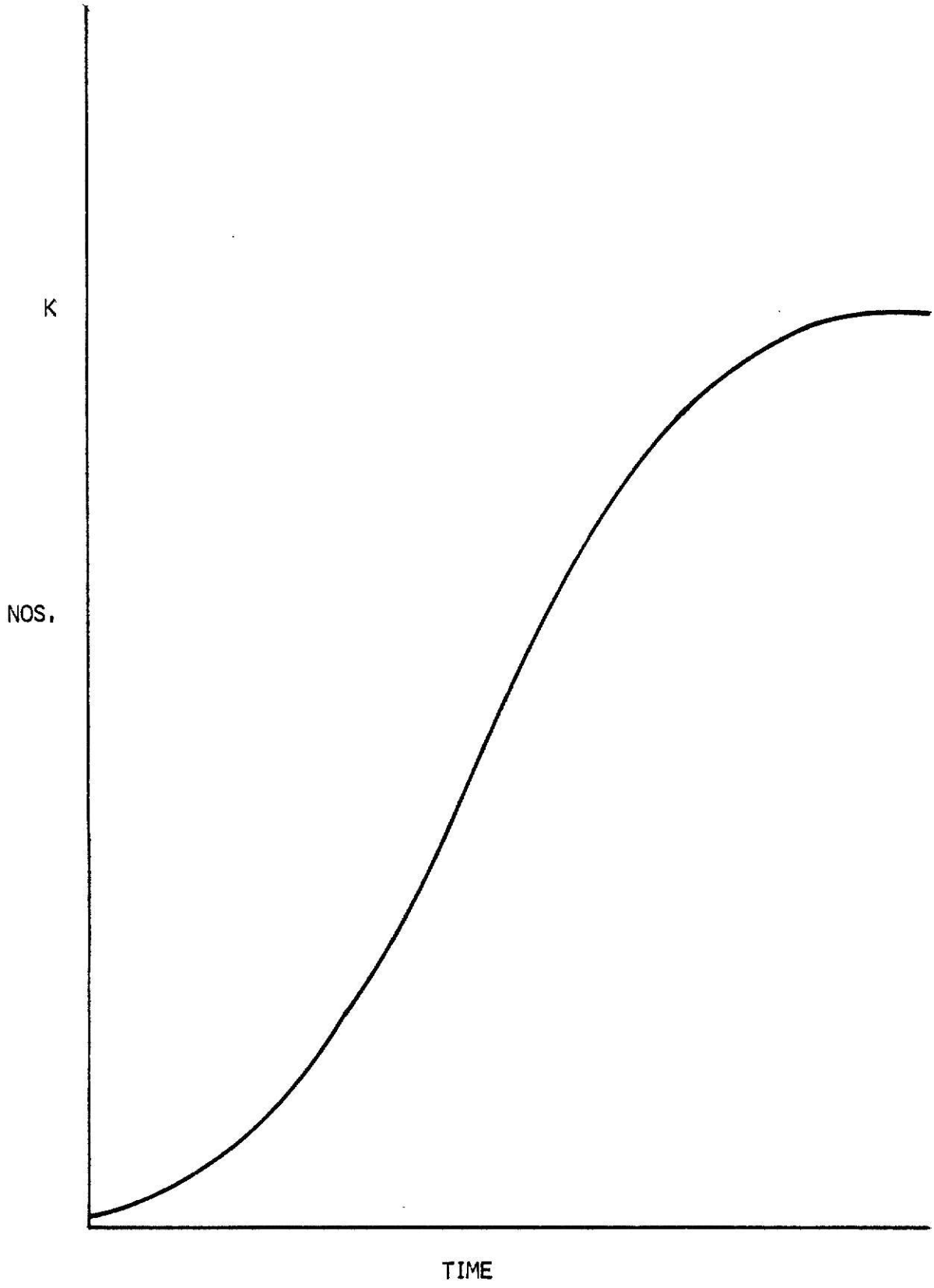

Figure 4.1. A Typical Sigmoid Curve

a given type of environment. A grassland does not have an inflexible limit to the numbers of prairie dogs it can support. The carrying capacity of a given environment is subject to change with environmental change. A given grassland might be capable of supporting a larger number of prairie dogs during a series of wet seasons than during a series of dry ones, or a southern one might support more than a northern one because of a longer growing season for the vegetation upon which they feed.

Verhulst (1838) and Pearl and Reed (1920) independently formulated a mathematical equation for population growth in a limited environment exhibiting an S-shaped growth curve. This equation was stated as follows:

$$\frac{dN}{dt} = rN\frac{(K-N)}{K} = rN(1-N/K) \qquad \text{(Equation 4.1)}$$

where dN/dt = growth rate of the population, r = the biotic potential or intrinsic growth rate for that species, N = the size of the population, and K = the carrying capacity of that given environment. This equation is known as the Verhulst-Pearl growth equation or the logistic growth equation. In words, the mathematical equation states that the growth rate of a population (dN/dt) equals the population's biotic potential (rN) times the proportion of the environment's carrying capacity still unexploited (1-N/K).

Data for a theoretical population of mule deer based on a logistic growth equation are presented in Table 4.1 (Dasmann, 1964). If the deer population numbers are plotted against time, an S-shaped curve results (Figure 4.2).

The assumptions on reproduction are listed in Table 4.1. The breeding population included only does which were two years of age, and their innate maximum rate of increase was two fawns annually. The sex ratio was assumed to be equal. The total population included bucks, does, and fawns. The annual increment ($\Delta N/\Delta t$) was determined by the difference between a given year's total

Table 4.1

Increase in a Mule Deer Population Based on a Logistic Formula (Dasmann, Wildlife Biology, 1964; Reprinted with permission of John Wiley and Sons Publishers)

Year	Breeding Population Females, N_b	Total Population, N_t	Annual Increment, $\Delta N/\Delta t$
1	1	2	2
2	1	4	2
3	2	6	4
4	3	10	5
5	5	15	9
6	8	24	11
7	12	35	16
8	18	51	17
9	26	68	16
10	34	84	11
11	42	95	4
12	48	99	1
13	50	100	0

Formula: $\Delta N/\Delta t = rN_b \frac{K-N_t}{K}$

Assumptions: (1) The carrying capacity (K) equals 100 deer; (2) the maximum rate of increase (r) is two fawns per breeding female; (3) sex ratios are equal; and (4) does produce their first fawns at two years of age and annually thereafter.

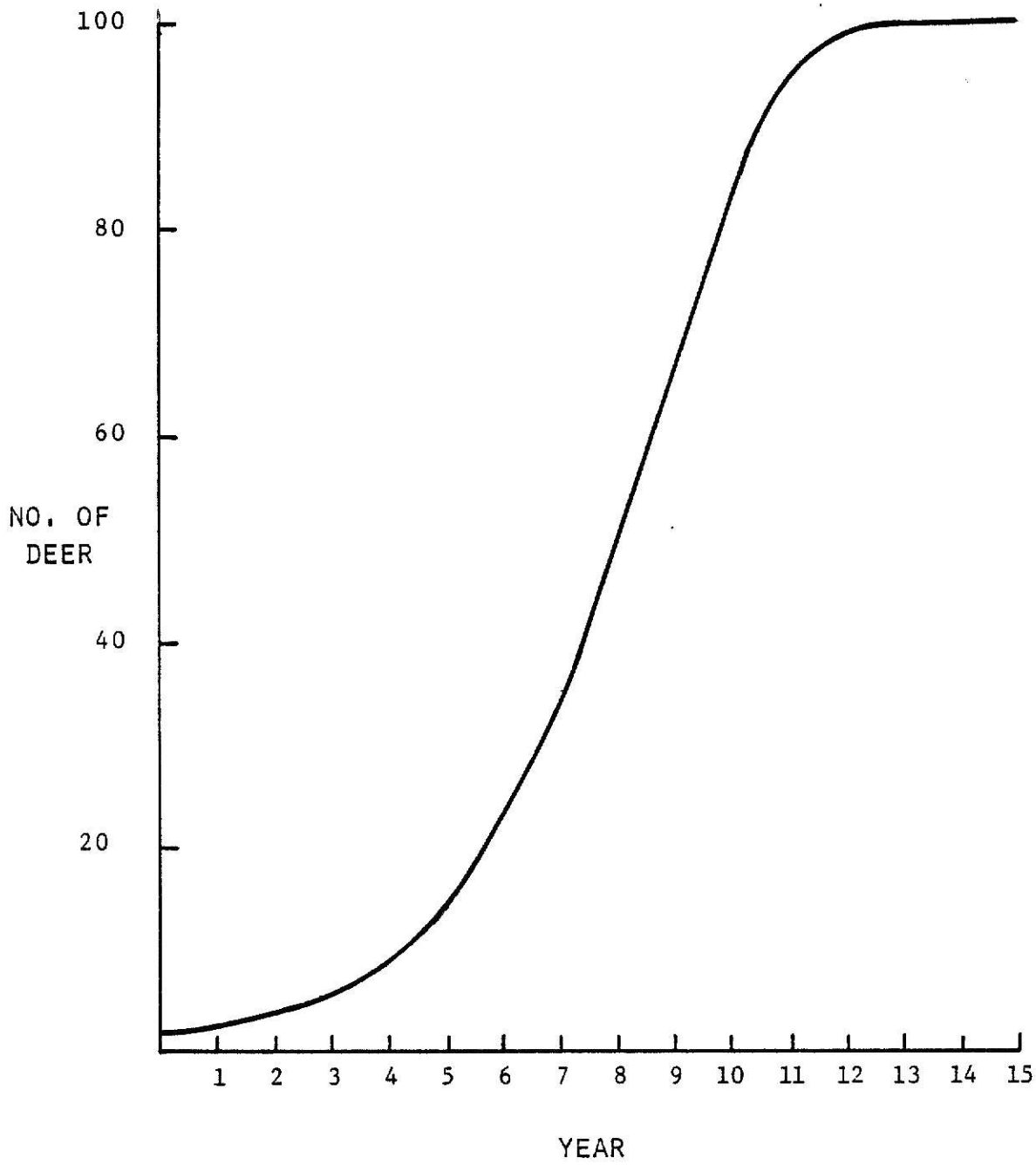

Figure 4.2. Increase in a Mule Deer Population Based on a Logistic Formula. (Dasmann, Wildlife Biology, 1964; Reprinted by permission of John Wiley and Sons, Inc.)

population and the previous year's total population. For example, the one breeding doe in year one produced two fawns of which one-half (or one) was assumed to be another doe. That doe, however, did not reproduce until it was two years of age so its first reproductive year was the third one. In year three, the original doe plus her first doe fawn each produced two fawns to give four fawns total of which two were does. The total population for year three included the original buck and doe plus a buck and doe fawn from each of the previous two years to give a total of six deer. The first two young of the doe's first doe fawn would be included for year four plus the young of the original doe for those four years to give a total of ten deer in the population.

The environmental resistance first begins to manifest itself in the fourth year. This is the first year where the population begins to deviate from its initial rapid growth. The deer have apparently reached the carrying capacity of the environment by year ten at which point the growth curve begins to flatten out.

The logistic example involving the mule deer is different from what would be observed for an organism such as yeast since only the does reproduced and did not do so until they were at least two years of age. In contrast, all yeast cells undergo reproductive cell division and do so in a much shorter period of time. This would account for some minor modifications in the shapes of their respective growth curves, but even so they would both be examples of sigmoid curves.

Use of the logistic equation in dealing with endangered species is presented in Miller and Botkin (1974) and Miller, Botkin, and Mendelssohn (1974). Using census data on the endangered whooping crane for the years 1938-1972, these authors used the logistic equation to construct a simple mathematical model of the population and make predictions from it. They

determined the mean birth rate for that thirty-five year period to be 0.20 and the mean death rate to be 0.12, leaving a 0.08 net rate of increase. They found this 0.08 figure to give larger than expected population sizes so they adjusted the death rate to 0.16 giving a net rate of increase of 0.04. This was statistically determined to be a reliable figure. This adjustment of the death rate was justified because of a high death rate during early years, which possibly altered the age structure of the population. They predicted that, if no major environmental changes were to occur, a population of fifty-one cranes in 1972 would reach seventy-six by 1982 and 114 by 1992 with a doubling time of eighteen years. They felt that current increases were due to a declining death rate which allowed an increase in the survival of adult and subadult birds. The absolute number of breeding pairs remained relatively constant in spite of a declining birth rate over the thirty-five year period studied. They felt the failure of the number of breeding pairs and annual recruitment of young to show significant increases was possibly due to limiting resources on the wintering grounds in Texas or to the present age structure (largely adults). If a large number of adults were to reach their maximum life span at nearly the same time, the population could experience a sharp decline in the future.

Smith (1966) offered the following precaution regarding the logistic equation:

> As the density increases, population growth departs from the logistic and fluctuates. This is particularly true of animals with complex life histories, where different life stages may compete with or prey upon one another, or where each stage depends upon different environmental conditions and foods. As populations grow, age structure changes, causing population curves to fluctuate. For this reason it is very dangerous to predict the future of population trends from such a curve.

Another type of basic growth curve is a J-shaped or exponential curve. This type of growth curve is similar to the sigmoid curve except that the

population size climbs upward until a sudden limiting force reduces the population size to a smaller one. The population dies off or crashes to a lower level from where it must begin growing again. This is contrasted to the sigmoid curve where the population size levels off and maintains a relatively steady size without crashing. Odum (1971) stated that, broadly speaking, the J-shaped curve may be considered "...an incomplete sigmoid curve since a sudden limiting effect is brought to bear before the self-limiting effects within the population become important."

An example of a J-shaped curve can be seen in the case of the Kaibab deer population of the Grand Canyon (Rasmussen, 1941; Dasmann, 1964). Prior to 1906, there were about four thousand deer in the population, and a number of predators such as bears, mountain lions, and wolves were also present. Competition for range came from cattle and sheep in the area. In an effort to increase the herd size, the area was declared a federal game refuge, livestock was transferred to other areas, and trapping was used to reduce the numbers of predators. The herd began to increase in numbers until it had exceeded the carrying capacity of the area. Between the years of 1906 and 1924, the Kaibab deer herd increased from four thousand to one hundred thousand animals. Between 1924 and 1930, eighty thousand deer starved to death. Another ten thousand died between 1930 and 1939. When the growth curve for this population is plotted, a J-shaped curve results as in Figure 4.3.

The sigmoid curve is probably most representative of small organisms or those with a simple life history. The J-shaped curve is probably more representative of populations which depend on a seasonal resource. The two curves may be combined or modified in a given population depending upon the species and conditions under which it lives.

However limited the logistic equation, it is fairly simple and accurate and does help interpret much actual data. More importantly, it has served as a

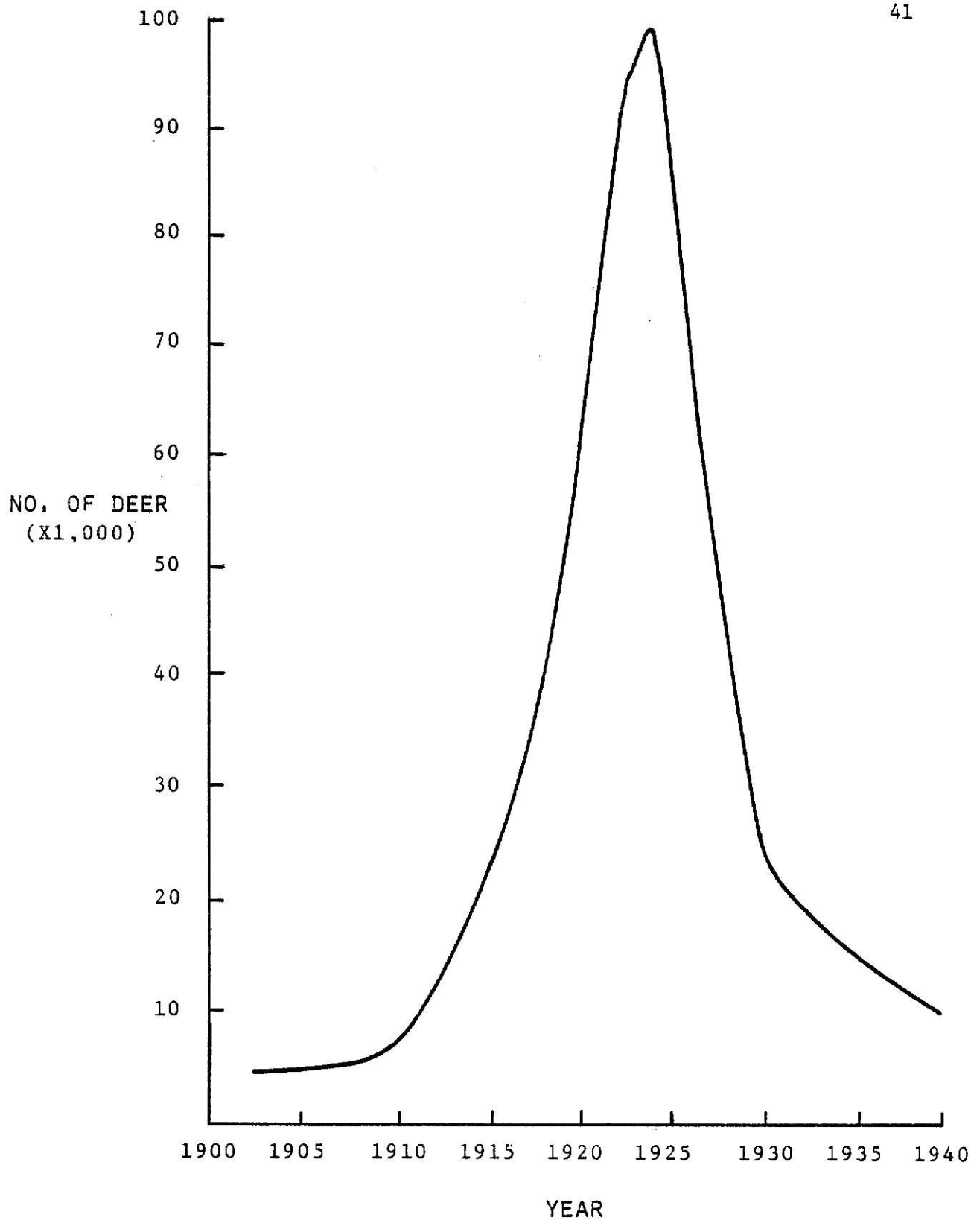

Figure 4.3. Increase in deer, Kaibab, Arizona. (Dasmann, 1964, Wildlife Biology; Reprinted by permission of John Wiley and Sons, Inc.)

basis or starting point for other theories describing growth and interactions of various populations.

Competition

Competition may be defined as the "...use or defense of a resource by one individual that reduces the availability of that resource to other individuals" (Ricklefs, 1973). Likewise, a resource can be defined as follows:

> ...a resource or object required by an organism for normal maintenance, growth, and reproduction. If the resource is scarce relative to demand, it is referred to as a limiting resource. Non-renewable resources (such as space) occur in fixed amounts and can be fully utilized; renewable resources (such as food) are produced at a fixed rate, with which the rate of exploitation attains an equilibrium. (ibid.)

Competition can occur among individuals of the same species in which case it is referred to as intraspecific competition, or it can occur between different species in which case it is referred to as interspecific competition. For example, if red wolves are competing with one another for a food source, it is an example of intraspecific competition. If, however, coyotes utilize the same food source as the red wolves, it is a case of interspecific competition.

Competitive interactions may manifest themselves in a direct or indirect manner. These are also known as interference and exploitation types of competition respectively (Park, 1954). Direct competition will be discussed first and then indirect competition.

"Direct" or interference competition often involves defense of a space. Since it would be difficult if not impossible to defend each food source or living site within a given area, the entire territory containing these resources is defended, often in an aggressive manner. This territoriality occurs most often among members of the same species. Recher and Recher (1969) observed while studying semipalmated sandpipers and western sandpipers that aggressive interactions were more numerous and intense among members of the same species than

between the two species. Some species may be territorial the year round such as the wren-tit or only during the breeding season such as the robin. The territory of some species might include only a nesting or den area while that of another might include food, nesting, roosting, watering, and protective cover such as with the California quail (Dasmann, 1968). Other species such as the endangered eastern timber wolf establish territories for the use of family or pack groups rather than for the use of a single member (Mech, 1966, 1971). Ligon (1968), reporting on the endangered red-cockaded woodpecker, observed that males feed high on the trunk as well as limbs and branches of pines while the females feed lower on the trunk. He feels this increases foraging efficiency and reduces intraspecific competition that might have adverse effects on pair bond formation.

Direct competition can also occur interspecifically. Koplin and Hoffman (1968) studied interspecific competition between two small Rocky Mountain mammals--the meadow vole and the montane vole. In areas where both species coexisted, the meadow vole inhabited both dry and wet areas surrounding ponds and streams while the montane vole occupied only dry areas. Meadow voles were trapped and removed from wet areas, and the montane voles began to move into those vacated areas. Apparently the montane voles were prevented from moving into the wet areas while the meadow voles were present.

Hansen (1962) observed direct competition for burrowing sites in Colorado between the Richardson ground squirrel and the golden-mantled ground squirrel. In areas where both species existed, the Richardson ground squirrel utilized meadow areas while the golden-mantled ground squirrel was limited to rocky areas. In situations where the Richardson ground squirrel was not found, however, the golden-mantled ground squirrel utilized both meadows and rocky areas.

Enderson (1965) and Enderson and Craig (1974) have suggested that a

possible contributing factor to the endangered status of the peregrine falcon might be competition for nesting sites. They suggested that the competition occurred with the prairie falcon in its southern range and with the gyrfalcon in its northern range.

Ligon (1970) observed aggressive encounters between red-bellied woodpeckers and endangered red-cockaded woodpeckers. These competitive interactions involved roosting sites and occurred throughout the year. He also observed competition for foraging sites between the red-cockaded and downy woodpecker. A limited number of encounters with hairy woodpeckers over foraging sites were noted, but the hairy woodpecker was an uncommon species in the area studied so no significant conclusions were drawn regarding it.

"Indirect" competition involves the exploitation of a limited common resource. A food source eaten by one individual is not available to other members of the same or different species that also feed on it. Compared to direct interference, competition by exploitation of resources expresses its effects more slowly. Reduction of a food source might not express its effect until a number of generations have gone through their reproductive cycle. As the food supply decreased relative to demand, the number of individuals reaching reproductive maturity would decline resulting in progressively smaller additions to the population via births. Over a period of time, this could result in extinction of the species or in evolutionary changes enabling it to continue its survival.

Competition with cattle and horses for grazing areas has been cited for the decline in the number of Sonoran pronghorns (Department of Interior, 1973). Similar interaction between the endangered red wolf and the coyote has also been cited as contributing to the decline of this species (ibid.).

Among endangered fishes, competition for resources has been cited as a

factor contributing to reduced population sizes. Competition from the rainbow smelt is felt to be one of the factors limiting the blue pike in Lakes Erie and Ontario (Trandahl, 1977). Another example cited is that of the long-jaw cisco in the Great Lakes and its competition from the small bloater and alewife (Department of Interior, op. cit., p. 7). Numerous other examples have been cited for desert fishes (Fisk, 1971; Pister, 1974), fishes of the American Southwest (Miller, 1961; Minckley and Deacon, 1968), and numerous trout species (Department of Interior, op. cit., pp. 16, 19, 23, 24; Langlois, 1976).

A number of laboratory experiments have studied the effects of inter-specific competition for resources (Gause, 1934; Crombie, 1947; Park, 1962). From these studies developed the idea that two species with identical ecological niches cannot occupy the same environment. This concept was known for years as "Gause's principle" (Lack, 1944). More recent work with the concept has modified it somewhat to state that no two species can coexist on a single resource that they both depend upon solely (Hardin, 1960), and it is now more commonly known as the "competitive exclusion principle."

Before proceeding further, the concept of niche should be discussed. Odum (1971) presented three different concepts of the term--spatial or habitat, trophic, and multidimensional or hypervolume. The first of these--spatial or habitat--was first treated by Grinnell (1971) who defined niche as "...the ultimate distributional unit, within which each species is held by its structural and instincting limitations...." This treatment thought of the niche in terms of where the organism was found or lived, i.e. its habitat. For example, the endangered red-cockaded woodpecker lives in southeastern pines infested with heart rot disease (Ligon, 1970; Thompson, 1971) while the endangered Attwater's prairie chicken prefers native tallgrass prairie (Lehmann, 1968).

In 1927, Charles Elton used the term *niche* in reference to the "...functional status of an organism in its community." The niche was treated by its trophic placement in a community. One organism might feed on seeds of a given perennial plant, another might obtain its energy by feeding on roots of certain annual plants, another might feed on ground dwelling birds of a certain size range, and yet another might obtain its energy by feeding on dead carcasses. For example, the endangered Everglades kite obtains its energy by feeding on the apple snail (Snyder and Snyder, 1969) while the black-footed ferret feeds primarily on prairie dogs (Henderson, Springer, and Adrian, 1969) and the California condor on carrion (Koford, 1953).

Hutchinson (1957) visualized the niche as the "...total range of conditions under which the individual (or population) lives and replaces itself." He viewed the niche as a multidimensional space within which the environment allows an organism to survive. Hutchinson's concept was one which could be mathematically measured and manipulated.

Perhaps the presentation of niche by Odum (1959) is the most useful for this report. The ecological niche of an organism "...depends not only on where it lives but also on what it does (how it transforms energy, behaves, responds to and modifies its physical and biotic environment), and how it is constrained by other organisms." He used the analogy that an organism's habitat is its "address" while the niche is its "profession."

How can species with ecological requirements so similar that they appear to be occupying the same niche exist in the same environment? Species which overlap in their ecological niches tend to differ from one another in some physiological or behavioral way. Lack's 1945 study of two British fish-eating birds provides a good example. The cormorant and the shag seem to feed on the same resource in a similar manner as both dive in search of food. However,

the shag feeds on free-swimming fish and eels in the upper waters while the cormorant dives deeper to take fish and invertebrates from the bottom.

Under the influence of decreasing interspecific competition, a species often expands its niche to marginal areas as well as optimal areas. For example, Cameron (1964) observed that meadow voles on islands often inhabited forested areas in the absence of their chief mainland competitor, the red-backed vole, which excluded it from forested areas where both voles were found.

If two species have a great amount of overlap in their niches, one or both may be forced to diverge from their normal habitats and ways in order to coexist with the other. This evolutionary divergence, however, might require an extended period of time during which the species involved cannot survive while trying to adjust. If the species does survive, it might be restricted to a marginal habitat that is limited in its area.

The case of the gray squirrel and the endangered Delmarva fox squirrel along Maryland's eastern shore is exemplary. The fox squirrel prefers small woodlots with large timber and an understory with little shrub growth as opposed to the gray squirrel which prefers large unbroken woodlands with brushy understory. Both species utilize agricultural grains found in the farmlands frequently surrounding their habitat. In areas where the two species coexist, it is observed that the Delmarva squirrel spends a large amount of time foraging on the ground while the gray squirrel is more arboreal. In its preferred habitat, the Delmarva squirrel can effectively compete with the gray squirrel. Lumbering along the Atlantic coast has removed much of the big timber preferred by the fox squirrel and left areas of dense understory. This has forced the fox squirrel into habitat preferred by the gray squirrel but marginal to its own well-being. With the fox squirrel at disproportionately lower numbers than the gray squirrel, it is placed at a competitive disadvantage (Taylor, 1973).

Lotka (1925) and Volterra (1926) took the logistic growth equation (see page 35) and modified it to include competition between two species. The logistic equation described the growth rate of a population in terms of that population's inborn ability to reproduce and unexploited resources available for its use. Considering the simplest case, what happens if another species utilizes the same resource? Under what conditions can two species coexist while competing for the same resource? Under what conditions does one species exclude a second species while competing for the same resource?

Four different competitive situations can exist under the Lotka-Volterra competition equations for two different species (species i and j) if the following information is known:

(1a) the numbers of species i alone necessary to exploit all of the resources used by species i;
(1b) the numbers of species j alone necessary to exploit all of the resources used by species j;
(2a) the numbers of species i alone necessary to exploit all of the resources used by species j; and
(2b) the numbers of species j alone necessary to exploit all of the resources used by species i.

In summary, if species i exploits resources necessary for the maintenance of species j more than it does the same resource in maintaining itself, species j will go extinct. If species j exploits a resource necessary for maintenance of species i to a greater extent than it exploits the same resource in maintaining itself, species i will go extinct. Both competing species can coexist as long as each species limits itself in resources more so than it does the other species. When one species inhibits another species growth more than its own, either species can win. Which species does win depends upon the initial proportions of the two species in relation to each other.

For the mathematically inclined, the Lotka-Volterra competition equations follow:

$$\frac{dN_1}{dt} = r_1 N_1 \frac{(K_1 - N_1 - \alpha N_2)}{K_1} \qquad \text{(Equation 4.2)}$$

$$\frac{dN_2}{dt} = r_2 N_2 \frac{(K_2 - N_2 - \beta N_1)}{K_2} \qquad \text{(Equation 4.3)}$$

where dN_1/dt and dN_2/dt equal the growth rates of species 1 and species 2 respectively, r_1 and r_2 equal the respective innate rates of increase for each species, N_1 and N_2 equal the numbers of species 1 and 2 present initially, K_1 and K_2 equal the respective carrying capacities, and α and β equal competition coefficients. The coefficient α is a characteristic of species 2 which measures its competitive inhibition per individual on species 1, and β is a similar characteristic of species 1 which measures its per individual inhibition upon species 2. The value of these coefficients is usually less than one. For example, if α equals 0.1 it means that it takes ten individuals of species 2 to have the same inhibitory effect upon species 1 that one individual of either species would have upon its own kind.

The Lotka-Volterra competition equations assume that the innate rates of increase, competition coefficients, and carrying capacities are constant values regardless of population sizes and densities. This implies that every member of species 1 is identical as is every member of species 2. This leads to linear relationships which have been criticized by Ayala (1970). Time lags are assumed not to be involved with the effects experienced by a change in population size. A final assumption is that the environment being exploited is homogeneous, i.e. the two species are assumed to be using the very same resource or resources. Another weakness of the equations is that they assume that in a stable coexistence of two species that both species are at the maximum densities they can experience at that point when in reality populations could reach a stable coexistence and not be at their maximal or

saturated population densities (Pianka, 1974). However, as with the logistic growth equation, the Lotka-Volterra equations have served as a conceptual basis for other ecological work and theories.

MacArthur and Levins (1964, 1967) and MacArthur (1972) have discussed two types of resources--continuous and discrete. Discrete resources are those that are distributed in clumps along a resource continuum. A species that utilizes discrete resources feeds on a resource base that occurs in sizes such that certain distinct sizes are available but sizes intermediate to these distinct groupings are absent. Continuous resources are those in which a preferred type or size of food is available as well as others which approximate it in size and are equally abundant and utilizable by a species. Overlap of resource utilization occurs more probably with continuous resources than with discrete ones. Theories involving discrete and continuous resources apply only to sympatric species, i.e. species whose distributions overlap.

Consider, for example, the situation with woodpeckers that select branch sizes appropriate to their body and bill sizes. The branches vary continuously from small to large. In this situation, if the woodpeckers can find enough branches of approximately the right size to be selective, then there might be three sizes of woodpeckers: a small size for small branches, a medium size for medium branches, and a large size for large branches and trunks. When branches become scarce, however, the woodpeckers have to get food from a wider range of branch sizes. Then the middle sized woodpecker gets squeezed by smaller and larger species eating off of his middle-sized branches. This squeeze may cause a local extinction.

Ground-feeding sparrows, on the other hand, eat seeds which come in discrete sizes with in-between sizes usually missing. Here we find small sparrows eating small seeds and large sparrows eating large seeds. If seeds

become scarce, however, the sparrows cannot afford to specialize and must take any kind of seed they can find. Then the best competitor is a middle-sized sparrow that has no seed to specialize on but is efficient on both the large and small seeds. This "jack-of-all-trades" can outcompete the two specialists (Fretwell, 1978).

In summary, an abundant discrete resource favors species which are specialists while a rare discrete resource favors a generalist species. An abundant continuous resource favors both specialists and generalists while a rare continuous resource favors those species which are specialists.

One implication of this discussion on resources is that species limited by discrete resources should be managed by supplying them with their resource. There are three species of sparrows--the dusky seaside, Cape Sable, and Santa Barbara--which are all endangered and seed eaters. Because of their body size, bill size, and bill shape, these birds apparently depend upon a narrow range of seed sizes and, therefore, might be considered to be limited by a discrete resource base (Fretwell, 1972). Management for the dusky seaside sparrow has been started by setting native habitat aside for the birds (Sharp, 1970).

On the other hand, species limited by continuous resources would apparently be best managed by controlling competition for the resource. Fretwell (1978) discussed the possibility of managing threatened and endangered species by controlling the population sizes of nearest or most likely competitors. He suggested that a possible management option for the endangered red-cockaded woodpecker would be the control of competition from the downy and hairy woodpeckers. The red-cockaded woodpecker is caught in a competitive squeeze between the other two species of woodpeckers. He also suggested that the management of the endangered ivory-billed woodpecker could involve control of competition from the pileated woodpecker. He noted (personal communication) that pileated

woodpeckers do not occur in Cuba or Mexico and that ivory-bills are less endangered in those places. Pileateds do occur in the southeastern United States where the ivory-bill is listed as endangered and possibly extinct. The ivory-bill may therefore be caught in a competitive squeeze of the pileated woodpecker from one side and a limited resource of large, dead trees on the other.

Predation

A second type of interaction between two species is predation. In predation, one species (the predator) benefits by capturing and consuming another species (the prey). In competition, both species are considered to inhibit each other whereas only the prey is inhibited in predator-prey interactions (Pianka, 1974). Inhibit is used in the sense of having a depressive effect upon the growth rate of the species. One might view predation as beneficial to the prey by keeping them below their particular carrying capacity and thus preserving their environmental needs. Predation on weak and unfit individuals maintains a genetic pool of the fittest individuals helping to insure future generations. The process of predation is easily observable but often difficult to measure because of factors such as disease, starvation, exposure to the elements, and emigration which can reduce population size. Thorough and accurate studies of it would probably require studying the species through several generations.

Predation, either by humans or other animals, is cited as a primary or contributing factor to the decline of several species now listed as endangered or threatened (U.S. Department of Interior, 1973). Among birds these include the heath hen, Carolina parakeet, passenger pigeon, and great auk (all extinct), Aleutian Canada goose, Everglades kite, Eskimo curlew, California condor,

whooping crane, bald eagle, and ivory-billed woodpecker. Mammals include the Morro Bay kangaroo rat, eastern timber wolf, red wolf, Mexican wolf, northern Rocky Mountain wolf, grizzly bear, Florida panther, eastern cougar, Sonoran pronghorn, and Utah prairie dog. Crocodiles and alligators are also included as well as a number of fishes which will be discussed in the next chapter.

The question of whether a predator can actually limit a prey population or even exterminate it depends on the given situation. As Lack (1966) stated:

> Only those predatory species which have not exterminated their prey survive today, hence we observe in nature only those systems which have proved sufficiently stable to persist, and many others were presumably terminated in the past by extinction.

Murie (1944) found that wolf predation upon Dall sheep lambs in Alaska was the major limiting factor for the sheep herd. Mech (1966) found wolf predation on Isle Royale kept the moose population below the density where food would be the limiting factor on the herd. Bergerud (1971) found lynx predation on caribou calves in Newfoundland to be a major limiting factor. Hornocker (1970) found in Idaho that mountain lion predation had little effect on deer and elk herds, and there has been debate as to how much of an effect removal of predators actually had on the outbreak of the Kaibab deer herd as opposed to alterations in habitat and interspecific competition (Rasmussen, 1941; Leopold, 1943; Caughley, 1970).

Man has hunted (via guns, dogs, poisoning, and trapping) wildlife for food and clothing, to protect crops and livestock (the reason many bounties have been established), for commercial trade, and for sport and curiosity. Bounties and/or indiscriminate hunting are cited as contributing factors to the decline of several species (U.S. Department of Interior, 1973). The Eskimo curlew and whooping crane have been heavily hunted for commercial purposes. The

southern sea otter has been hunted for its fur and has been blamed by abalone fishermen for raiding shellfish beds. The eastern cougar has been heavily hunted because it is considered a "pest" species, and the grizzly bear has been considered a menace to humans and livestock. The San Joaquin kit fox has been sought by varmint hunters. Koford (1953) cited shooting as a major mortality factor of the California condor. Pritchard (1976) states that "...excessive killing of individual animals..." rather than habitat destruction is responsible for the near extinction of the Florida panther. Human predation along with habitat alteration is cited for the decline of the eastern timber wolf (Mech, 1977).

Prey species confined to islands are often more susceptible to predation than mainland species. Often these prey populations have evolved in the absence of predators and therefore do not possess adaptations for escape or protection, or adequate cover for escape is limited or absent. The endangered Aleutian Canada goose inhabits a number of islands in the Aleutian Chain, and they were significantly reduced in numbers following introduction of the predatory arctic fox to the islands (Elgas, 1975). Buldir Island is one island in the chain to which the fox was not introduced because of its inaccessibility, and it is here that the major breeding population of the goose is still found. Current management practices include trapping and removal of the foxes from selected islands followed by restocking efforts from Buldir Island and captive stock (U.S. Department of Interior, 1973).

The last passenger pigeon died in captivity at the turn of this century. These birds roosted, fed, and bred by the thousands in eastern hardwood forests. They were harvested in large numbers by a variety of methods for shipment to eastern markets. How could a bird so numerous become extinct?

An answer may be found by examining a principle known as the Allee

effect (Allee et. al., 1949) which in effect says that each species has an optimum density which favors its survival. The passenger pigeon by its very numbers saturated its predators, but hunting reduced the population and diminished this saturation effect. The pigeons roosted in large number, and their nests were poorly concealed. The birds forced their flightless young from the nest to forage for food on the forest floor. This made it easy for natural predators to efficiently harvest the birds. Only when there were too many young for predators to eat them all was the population able to breed successfully.

On the other extreme, it could be that some species can exist only at low densities because f food sources or other needs are limited. Mech (1970) points out that the eastern timber wolf occurs in naturally low densities.

Some endangered species are specialized in their diets. The black-footed ferret, Everglades kite, and ivory-billed woodpecker are examples. When the food source is eliminated or overexploited, the species may decline unless alternate and suitable food sources are available. Such alternate food sources are often referred to as "buffer species." In general, the more complex a community is the more buffer species it has. John and Frank Craighead (1956) studied the changes foxes and raptors in Michigan made to alternate food sources as prey densities changed. These were all species which have maintained secure populations.

In some cases an abundant prey can be so limited by an efficient predator that intraspecific competition among the prey is reduced. This can lead to a rare species becoming more abundant than it would have been without the predation. Paine's (1956) study of the Pacific intertidal zone serves as an example. The predator was the starfish Pisaster, and the prey included seversl species of barnacles,

mussels, limpets, and chitons. One study area had all starfish removed while another was left undisturbed. The number of prey species in the starfish-free area decreased from fifteen to eight while the undisturbed area maintained its diversity. A predator that switches to the commonest suitable prey can keep all of its prey species relatively rare, which makes room through reduced competition for certain species that otherwise would be excluded. This leads to a greater diversity of prey species.

Lotka (1925) and Volterra (1926) independently made the first attempts at mathematically formulating a simple predator-prey relationship. Their work resulted in the following equations:

$$\frac{dN_1}{dt} = \text{growth rate of prey population} = r_1N_1 - PN_1N_2 \qquad \text{(Equation 4.4)}$$

$$\frac{dN_2}{dt} = \text{growth rate of predator population} = aPN_1N_2 - d_2N_2 \qquad \text{(Equation 4.5)}$$

where r_1 equals the birth rate of an individual prey, N_1 and N_2 equal the number of individuals in the prey and predator populations respectively, d_2 equals the death rate among the predator population, P equals the coefficient of predation, and a equals the predator's efficiency at converting food to energy. They assumed that no interaction exists between the prey and its food source, and that mortality among the predator population was density independent.

In summary, the equations predict that the predator-prey relationship will be oscillatory and estimate the minimum level of prey that can support a predator population as well as the maximum number of predators a prey can sustain. If the prey's reproductive rate increases or the predator's hunting efficiency decreases or both, the prey population increases and is capable of supporting a larger number of predators. If the predator's death rate increases and its predation efficiency or reproductive efficiency decreases, more prey are required

to support the predator population. If predator hunting efficiency increases, both populations are reduced. Kormondy (1976) also deduced from the equations that any factor moderately detrimental to both predator and prey leads to an increase in prey and decrease in predator.

Subsequent work by Gause (1934) and Huffaker (1958) pointed out that a predator population cannot survive when its prey is rare, and an immigration of prey must occur to maintain oscillatory patterns. Ricklefs (1973) found that time lags between prey density changes and predator responses tend to make a system less stable while environmental heterogeneity tends to stabilize it.

Rosenzweig and MacArthur (1963) presented a graphical model of predator-prey interactions based upon an equilibrium between stabilizing and unstabilizing forces. They reasoned that the maximum prey numbers would be limited by the prey's carrying capacity in the absence of predators. Likewise, they reasoned there would be a minimum prey density below which the prey population could not reproduce itself because of difficulty in finding mates. They also assumed that at any given prey density there must be some maximal predator density that can just be supported without any increase or decrease in the prey population. A final assumption was that the curve representing the prey population has a hump in it as opposed to the straight-line curve of the Lotka-Volterra model.

This model analyzes cases for inefficient, moderately efficient, and highly efficient predators. Efficient predators can capture and consume prey even when the prey density approaches rareness. The predator drives the prey to extinction as well as itself unless alternate and adequate food sources are available. This type of interaction is infrequent in nature because of prey escape tactics.

An inefficient predator cannot effectively exploit its prey until the prey approaches its carrying capacity. This produces a damped oscillation with a time lag and is probably the most common one found in nature.

A moderately efficient predator begins consuming prey at some intermediate prey density. Predator and prey oscillate indefinitely in time. This can result in the type of cyclic oscillations seen among brown lemmings and their predators (Pitelka et. al., 1955; Pitelka, 1957) which cycle about every four years and the snowshoe hare and predatory Canadian lynx (MacLulich, 1937; Elton and Nicholson, 1942) which cycle about every ten years.

Taxon Cycle

The taxon cycle, developed by Wilson (1961) and Ricklefs and Cox (1972), is a "...cycle of expansion and contraction of the geographical range and population density of a species or higher taxonomic category" (Ricklefs, 1973).

The theory states that the relative ages of island populations can be determined by their geographical distribution patterns and the amount of differentiation between island and mainland forms. Ricklefs and Cox (loc. cit.) described four stages that a population in the taxon cycle might find itself. Stage I populations are expanding or widespread over the islands, and there is little differentiation from the mainland population. Stage I species are good competitors. Stage II populations are differentiating ones that are widespread but are beginning to show differentiation among the various island populations. Stage III populations are widely differentiated and their range is becoming fragmented due to extinction of some of the populations. Stage IV populations have become endemic to one island and that population is monotypic.

As the cycle progresses, a species' vulnerability to extinction apparently increases. Ricklefs and Cox (loc. cit.) suggested that this was due

to counterevolutionary responses by resident populations on the island to the invasion of a new species. The new species expands at first because the other species are not in competition with it. As competition between the new species and those already present increases, however, the resident populations begin to evolve adaptations to deal with the new one. The new species might be driven to extinction as the resident species become more efficient competitors.

Sometimes, when the resident species no longer feel any challenge from the new species or gain no evolutionary advantage by adapting to it, they cease doing so. If the new species has not been driven to a population level too low, it might begin to build its numbers once again. Of course, the resident species might also begin their counterevolutionary adaptations again and a new cycle involving the same species will have started again.

If evolution favors rare species and if a time lag is introduced into the ecosystem, populations will continue to expand and contract. This will continue until the new species drives some of the other populations to extinction (Ricklefs, loc. cit.).

Similar cycles probably occur on the mainlands but at a slower rate. Mainland populations have been examined by Brown (1957), Darlington (1957), and Dillon (1966). Dillon defined four stages in a species' life cycle. The first stage, or neospecies, is characterized by having an expanding range and increasing numbers. The second stage, or mesospecies, begins to extensively differentiate into subspecies with stable ranges and sizeable populations. The third stage, or euspecies, is similar to the mesospecies except that subspeciation is greatly reduced. The fourth stage, or telospecies, is greatly reduced in abundance, subspeciation, and range to the point of extinction. A large number of bird and mammal examples of each stage were given in his work including the gray wolf and whooping crane.

The taxon cycle is closely associated with interspecific competition and might be found useful in dealing with any island or mainland "island" species which are threatened or endangered and influenced by such competition. By determining what phase of the taxon cycle they are in, their closeness to extinction might be able to be estimated.

Evolutionary Theory

This report does not intend to deal in detail with the subject of evolution as that could involve writing a complete textbook in itself. There are, however, certain aspects of evolutionary ecology which are felt to be pertinent to endangered and threatened species. Those which will be considered include r- and K- selection and evolution of body sizes.

r- and K-selection. In their Theory of Island Biogeography (1967), MacArthur and Wilson considered population growth in a situation where overcrowding occurs and in another one where the population is well under the carrying capacity. If fitness is defined as the genetic contribution by an individual's descendants to future generations of a population, the intrinsic rate of increase (r) for an organism in an uncrowded environment is a good measure of its fitness. Likewise, the carrying capacity (k) can be used as an index of fitness for an individual in a crowded situation.

In an environment with little or no crowding, there is very little competition for resources. This is to say that the population is well below its carrying capacity. Food is not going to limit the growth of the population so all resources can be directed toward population growth. The genotype that will be selected here is one that favors growth of the population--i.e. productivity. MacArthur and Wilson (ibid.) referred to this type of evolutionary strategy as r-selection and an organism selected for in this manner as an r-strategist.

However, populations do not expand indefinitely because as crowding begins to occur, environmental resources become limiting. For an organism to survive in this crowded condition, it must be able to replace itself even with a low amount of food and/or space. There is increased competition for food and what food is obtained must be made efficient use of, whereas r-selected organisms are not competing for food so efficient use need not be made of it. When competition for resources is high, though, large family groups cannot be supported. A genotype that favors efficient conversion of food displays K-selection and the individual is referred to as a K-strategist.

Density-dependent and density-independent factors vary in their effects on populations and natural selection. In a highly unpredictable environment, a mass catastrophe can wipe out large numbers of individuals regardless of their genetic makeup. For example, a flood or a tornado or a hurricane can kill or maim everything in its path regardless of its genotype. This type of mortality is referred to as density-independent. In contrast, an environment that is more stable or predictable in its changes will experience fewer mass catastrophes and mortality will be more a result of limited resources. This type of mortality is referred to as density-dependent.

Under density-independent mortality, a population is reduced to far below its carrying capacity and there is a minimal amount of competition for resources. The best reproductive strategy under such conditions is to put maximum effort into producing as many total offspring as soon as possible. However, in a crowded environment the population is closer to its carrying capacity and competition for resources is keener. The best strategy under these conditions is to put maximum effort and matter into offspring that will be good competitors. This usually means larger offspring, and, since larger offspring require more energy to maintain themselves, fewer can be produced.

So it is seen that r-selection favors quantity and K-selection favors quality.

One cannot simply look at an organism and classify it as an r- or K-strategist. These two types must be thought of as the two extremes on a continuum of selection. An organism can only be spoken of as being r-selected or K-selected in comparison to another organism. Most organisms fall somewhere between the extremes of the continuum. Another important point is that an organism cannot be both an absolute r- and K-strategist simultaneously. The instantaneous growth rate increases at the expense of a lowered carrying capacity and, likewise, an increase in K must be accompanied by a decrease in r.

Studies by Gadgil and Solbrig (1972) pointed out that a given species might be an r-strategist during one part of the season but a K-strategist during another part of the season. A species might also be r-selected in one part of its geographic range but K-selected in another part of it.

Pianka (1974) listed a number of correlates regarding r- and K-selection, some of which have already been discussed. These will be briefly summarized. K-selection is favored under relatively constant or predictable climates whereas less predictable or less constant ones favor r-selection. Catastrophic, density-independent, nondirected mortality favors r-selection while K-selection is favored under more directed, density-dependent mortality. Along with mortalities, one can examine types of survivorship. An r-strategist experiences a high juvenile mortality with relatively high survivorship afterwards (such as in fish and most insects). The K-strategist exhibits either a fairly constant death rate per unit time (as found in most birds) or a high juvenile survivorship and then a fairly high mortality rate after some given age (such as humans). An r-strategy favors a population size that is variable in time but well below that organism's carrying capacity. K-selected populations will be fairly constant in size over time and near the carrying capacity of the organism involved.

The community is saturated so that few if any ecological niches are left unoccupied. The life span of an r-selected organism is short, often less than one year, and both intraspecific and interspecific competition are highly variable, often with none occuring. A K-strategist has a longer life span and the two types of competition are often quite keen. K-selection leads to efficiency so selection favors development, greater competitive ability, a delayed start of reproduction, large body size, and smaller numbers of offspring/generation but a greater number of generations. The r-selected strategy favors rapid development, a high rate of increase, early reproduction, smaller body size, and larger numbers of offspring per generation but fewer (often only one) generations.

The terms r- and K-selection are somewhat misleading because they imply that a given species is genetically selected for one or the other. A better term to use is that of saying that a species is an r-strategist or a K-strategist. The use of these terms implies that a species makes use of either a productive strategy or a competitive one depending upon the type of environment in which it lives.

An examination of endangered species points out that a number appear to be K-strategists. For example, the ivory-billed woodpecker is the largest woodpecker, the whooping crane is the largest of the cranes, and the black-footed ferret is the largest of the weasel genus Mustela. K-selection favors relatively large body sizes so these examples might be considered as K-strategists when compared to other members of the appropriate taxonomic classification.

The ivory-billed woodpecker inhabits areas comprised primarily of large mature trees. Here it feeds on wood-boring larvae found immediately under the bark of those trees which have been dead for up to two years (Tanner, 1942). Destruction of such trees by logging companies in the southeastern United States

has eliminated or severely limited this necessary food source for the bird.

Whooping cranes are probably classic K-strategists (Miller and Botkin, 1974). They have a maximum longevity of thirty years or more, do not breed until five or six years of age, and a breeding pair normally has a clutch of two eggs but seldom successfully raises more than one young per year. Nesting pairs are territorial and widely scattered resulting in lower nesting densities than most birds (Miller, 1974).

The Everglades kite feeds on apple snails. Droughts, fires, and drainage of areas in the Florida Everglades have lessened the food source of this bird. Eradication programs for prairie dog towns have severely limited the habitat and food source of the black-footed ferret. These two species are probably examples of specialists utilizing a K-strategy.

Body size. As was discussed in the previous section on r- and K-selection, a number of currently endangered as well as extinct species are or were the largest species for their respective taxa. For example, the extinct great auk was the largest of the auks, the extinct passenger pigeon the largest dove-like pigeon, the endangered whooping crane is the largest crane, the California condor the largest vulture, the ivory-billed woodpecker the largest woodpecker, and the sea otter the largest of the family Mustelidae. Other examples could be cited as well as examples of species which, although they are not the largest members of their taxon, are nearly the largest. This raises the question of whether body size plays a role in the process of extinction.

Fretwell (1975) noted that species get larger in size as they grow older (see Cope's rule, page 65). He also noted that fossil records indicate that whenever a large species has gone extinct, a smaller but similar species has appeared which showed progressive size increases. He explained these

observations in terms of competition and the evolution of social systems.

As a species invades and successfully occupies a habitat, it may begin establishing dominance hierarchies and territories, and then it begins to increase in size in order to have the aggressive advantage in defending those territories. The species might also begin to evolve bright and showy colors to advertise itself and its willingness to defend the area.

As a given species increases in size for social and competitive reasons, it begins to depend on a narrower part of available resources leaving possible gaps in the resource continuum for smaller and less aggressive species to invade. If the invading species is too similar in habits or size to the large species already there, that initial species might find some immediate advantage to increasing even more in size thus making its resource base even narrower.

A widely cited principle in studying body size is Cope's rule (Cope, 1896) which states that in many phyletic lines of animals there is a tendency toward increase in size. In his paper, Cope stated:

> ...specialized types of all periods have been generally incapable of adaptation to changed conditions...of new periods...such changes have been often especially severe in their effects on species of large size, which require food in large quantities. The results have been degeneracy and extinction. On the other hand, plants and animals of unspecialized habits have survived....

The emphasis was on the idea that limitations on large size were due to ecological relationships. Later authors (Bonner, 1968; Stanley, 1973), however, believe that the structural specialization might be the limiting factor. Stanley believes that Cope's rule should be described in terms of evolving from small size rather than toward large size on the basis that all species have an optimum body size and that most species arise at sizes relatively smaller than their optimal one. As they approach this optimal size, it gives a net size increase. There would be too much adaptive discontinuity to cross in order for a large

sized taxon to arise because of the need for developmental specialization among descendants and smaller species along the way.

Observations have been made over the years that a correlation exists between size and climate. Bergmann's rule states that varieties of a species often tend to become larger as one progresses to cooler climates (Bergmann, 1847). Apparently this does not hold true for cold-blooded organisms, possibly due to delayed gonadal development. For many years the hypothesis was that animals in cold regions were larger because of surface-volume relationships (Allen, 1877) although some questions about its validity have arisen in recent years. Smith (1954) has suggested that since large organisms have longer generation times they are less subject to environmental stress produced by seasonal climate fluctuations.

Thus far correlations between size and the physical environment have been discussed, but such correlations can also be found between an organism and its relationships to other organisms. In predator-prey situations, the size of the prey might be influenced by the size of the predator as well as the presence or absence of predators. Predators at the top of a food chain are often the largest species in the chain.

Another plausible hypothesis is that of character displacement (MacArthur and Wilson, 1967). If two species occupy the same niche, competition occurs and the niche is subdivided into two niches. Evolutionary selective pressure acts to cause divergence in the two species so that they occupy similar yet slightly different niches.

Bonner (loc. cit.) identified three rates of size increase. Fast rates are those which occur in species over one to ten thousand years of time, medium rates occur within families over five to forty-five million years, and slow rates occur within taxonomic kingdoms over the entire span of organic evolution.

Bonner's "fast rate" species showed nearly equal frequency between size increase and decrease. He contended that the major reasons for fast rate changes were ecological, with competition and character displacement being the major processes involved. His "medium rate" species showed a predominant size increase. He returned to the concept of subdivision of the niche once again. There is a limit to the number of times a niche can be subdivided, and so he reasoned that a medium rate organism was more likely to encounter less competition through an increase in size than if it decreased in size and perhaps entered competition for microhabitats. Finally, he argued that for "slow rate" organisms structural changes have occurred permitting even larger sized individuals. The large size of many ruminants is thought to be due to selection for larger weapons such as horns and antlers, and this structural change has then required subsequent adjustment in body proportions to accomodate them (Ehrlich et. al., 1974). As Bonner (op. cit., p. 13) stated it, "Structure keeps pace with size and size takes advantage and exploits every change in structure." For slow rate organisms, the size changes are done by small transitional forms as a species becomes a larger species and expands to a genus and on through the rest of the taxonomic hierarchy.

Speciation

Ricklefs (1973) defined speciation as the "...separation of one population into two or more reproductively isolated independent evolutionary units." Stebbins (1971) described three general types of speciation. The first type is phyletic speciation and is the type that occurs over a long period of time. This type of speciation is difficult to document because of the long periods of time involved. The second type is primary speciation in which one species line divides into two separate lines with time. The third type is

secondary speciation. It is the opposite of primary speciation in that it involves two species evolving toward one species.

Perhaps the California condor and whooping crane are exemplary of phyletic speciation. The California condor is believed to have evolved from the slightly larger Gymnogyps amplus, and this transition is believed to have occurred at or near the end of the Pleistocene epoch some three million years ago. The whooping crane is estimated to be 3.5 million years old and an Upper Pliocene species (Fisher, Simon, and Vincent, 1969).

Brodkorb (1960) defined the longevity of bird species as follows:

> ...equal to the time necessary to replace half of the species in a fauna. For the late Pleistocene this would be the interval from the time when the avifauna was composed of equal numbers of living and extinct species until the present, when neospecies alone exist.

Brodkorb (1971) estimated the median longevity of late Pleistocene species to be 475,000 years and that of Tertiary species (which includes the Paleocene, Eocene, Oligocene, Miocene, and Pliocene epochs) to be about three million years.

Following this reasoning, the whooping crane has surpassed the median longevity of Pliocene species by 500,000 years. Does this mean that its time has come to be replaced by a new species? The Condor, well along in its median longevity and heavily hunted in the past, might have had its normal evolutionary progress toward extinction accelerated.

For primary speciation to occur, some sort of spatial separation needs to take place. In a brief and generalized form, this type of speciation involves a local interbreeding population being divided into two or more populations by a geographic barrier. Differentiation between the separated populations occurs and when the barrier is removed, the populations have become reproductively isolated and will not interbreed.

Subspecies represent populations of the same species that have become separated and undergone some morphological changes but are not reproductively isolated. If they were introduced into a common area, interbreeding would occur.

The probability of a subspecies becoming a new species is greater on a small "island" of habitat rather than on a large area of the same habitat. This is because populations in the large "mainland" area are more outbred, have a greater variety of habitats that might be successfully exploited, and chances of genetic drift are lessened. As continued alteration of habitat keeps occurring, smaller patches or islands of suitable habitat are created. This is probably one reason some of the subspecies appear on the threatened and endangered lists.

Although some of the subspecies might go on to become new species, those new species might exist in such low numbers they could not become successfully established. They could become involved in the taxon cycle and become endemic to one area or be driven to extinction.

The question has recently arisen as to whether subpopulations of the endangered Kirtland's warbler are possibly being established. Ohio State University, the Michigan Fish and Wildlife Department, members of the Kirtland's warbler recovery team, and the U.S. Fish and Wildlife's regional staff are studying the problem. The question arose over a live-trapped warbler in Ontario in 1977. If subpopulations are being established, it might account in part for the apparent loss of birds in the Bahamian wintering grounds (Endangered Species Technical Bulletin, Vol.3, No. 2).

Secondary speciation has been overshadowed somewhat in this discussion. Interbreeding has been listed for some species on the endangered list. Examples are the red wolf hybridizing with the coyote (Riley and McBride, 1972), the

Houston toad with two other toad species, and the Mexican duck with the mallard (U.S. Department of Interior, 1973).

Island Biogeography

Large islands generally support more plant and animal species than smaller ones. Although area alone accounts for most of the species diversity observed (Hamilton et. al., 1964), MacArthur and Wilson (1963, 1967) theorized that a balance between the processes of immigration and extinction might account for the diversity of some island biotas. They stated that "...area itself is correlated with environmental diversity, which exerts a more direct effect on species numbers and is a quality that has only begun to be described and measured."

Consider an island isolated at some distance from a mainland source of species. If the island is initially devoid of species, the immigration rate of new species to the island is high because of the larger number of species that are new to the island. As the number of species on the island increases, the immigration rate decreases until the species from the mainland source are present, which, of course, means that no further new immigrants are possible. The extinction rate for species on the island is low when there are few species, but it increases as the number of new species increases because of increased competition and less space for the various species to occupy. When the immigration rate equals the extinction rate, an equilibrium number of species ($\hat{S}$) exists. Figure 4.4 represents this graphically. Although the equilibrium number of species might remain constant, the actual species composition can change and does so at varying rates.

MacArthur and Wilson made a number of predictions from their theory. As the distance between an island and its species source increases, successful

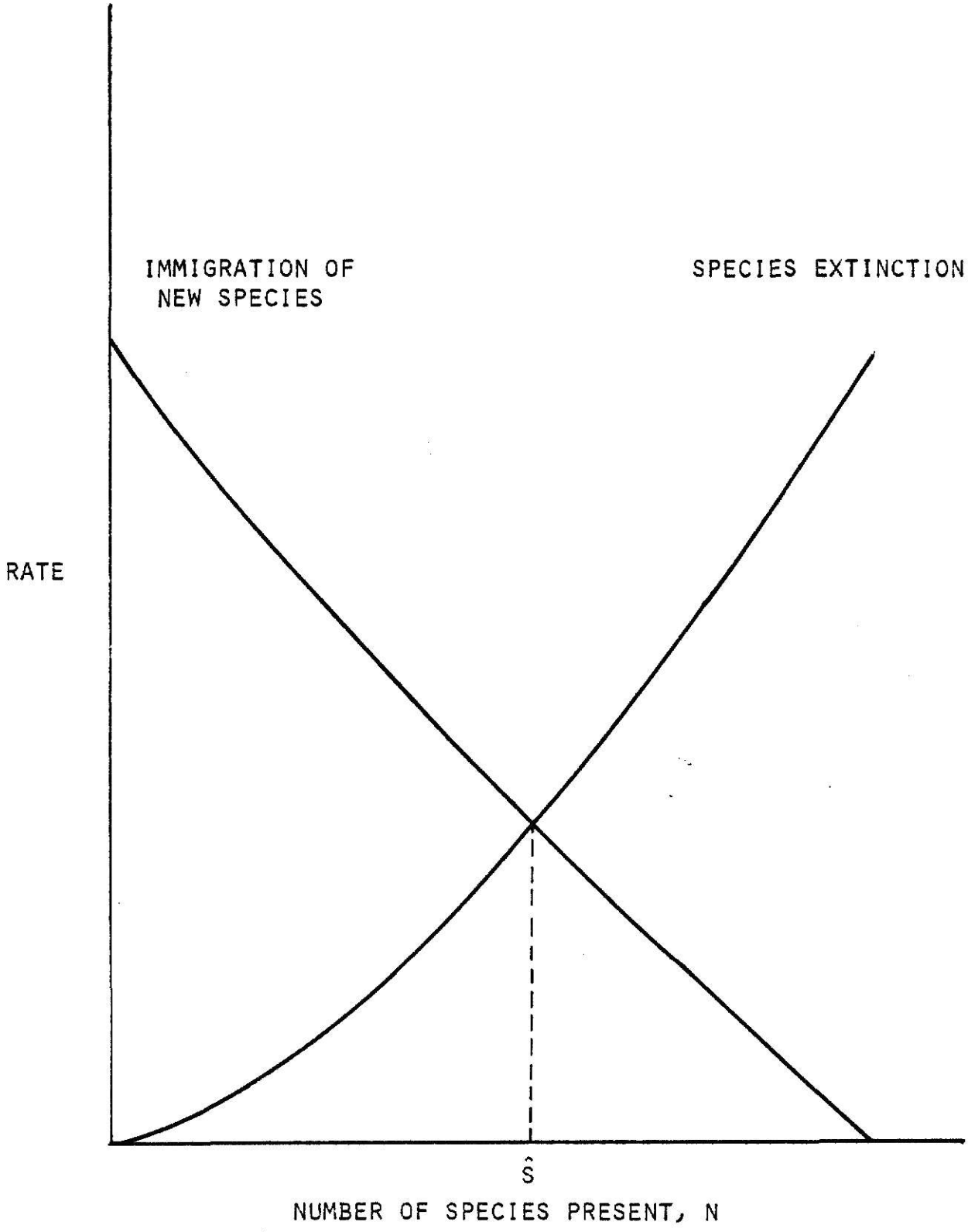

Figure 4.4. Immigration and Extinction Rate Curves for a Single Island. (MacArthur and Wilson, 1967, Theory of Island Biogeography; Reprinted by permission of Princeton University Press)

dispersal rates decrease and so do the immigration rates. Extinction rates increase with a decrease in island size because such islands support smaller and less stable populations. Simple islands with little topographic relief and with homogeneous habitat have higher extinction rates because heterogeneous habitats and topographic relief provide a greater variety of immigrating species with opportunity to successfully invade and become established. Finally, islands located close together (as in an archipelago) have higher immigration rates than scattered islands since the water barrier is reduced somewhat for mobile species such as insects and birds. Studies by Dammerman (1948) of Krakatau Island and by Simberloff and Wilson (1969) of several tiny mangrove islands in the Florida Keys support the equilibrium theory of island biogeography.

The discussion thus far has dealt with true oceanic islands, but "islands" can also occur on a mainland. Such mainland islands can involve a type of habitat separated by a topographical barrier from the next area of similar habitat. For example, a mountaintop can be considered an "island" separated by a "sea" of valleys and lowlands from the next mountaintop island. An area of habitat, a food source, or a breeding area surrounded by large areas of dissimilar makeup can constitute a possible mainland island. MacArthur (1972) noted that the major difference between oceanic and mainland islands is that oceanic islands "...are separated by a vacuum insofar as land birds or insects are concerned, whereas mainland islands are separated by other habitats filled with birds and insects."

Species on a mainland can disperse more easily to another nearby mainland island than can oceanic species on oceanic islands. A mainland species can rest in some habitat it is traversing but to try and rest while crossing the ocean could prove fatal for a species. This spillover of transient or

wide-ranging species from adjacent habitats is a major factor involved in dealing with mainland islands. Vuilleumier (1970) and Brown (1971) have conducted studies on mainland islands in the South American Andes and mountains of the American Great Basin respectively.

Diamond (1975) has made use of MacArthur and Wilson's predictions in outlining possible designs of natural preserves. Large preserves would be better than a small one or several small ones because they would have lower extinction rates and hold more species at equilibrium. If a number of disjunct non-homogeneous preserves was all that could be had in a given area, each would favor the survival of a different group of species. If there were disjunct preserves similar in habitat, they should be clumped closely together rather than scattered so as to increase immigration from one to the other. Several disjunct preserves should be grouped equal distance from each other rather than in a linear order because a linear arrangement would place the terminal areas relatively remote from each other. An even better arrangement would be if the disjunct preserves were connected by strips of protected habitat. This would allow movement of species between areas across suitable habitat rather than large areas of unsuitable habitat. Finally, Diamond suggested that preserves should be as nearly circular in shape as possible to minimize dispersal distances. Of course, the relationship between the area of a preserve and the chances of a species surviving in it would be characteristic for each species.

When one looks at threatened and endangered mainland species, some examples of possible island species can be found. The black-footed ferret lives on mainland islands composed of prairie dog towns. The size or area of these towns as well as the distance between them might be important factors to consider in attempts to restore ferret populations. Similar situations might exist for the Everglades kite which lives on a number of mainland islands

where the apple snail is found, and the endangered lizards of California that are confined to islands of suitable habitat surrounded by unsuitable habitat. Some of the species found on the offshore islands, of course, are affected by island biogeographical theory.

In the 1976 rough draft of the proposed recovery plan for the Kirtland's warbler (Kirtland's warbler recovery team, 1976), a major management proposal was to improve the habitat for the bird. They felt that the bird had withdrawn to the center of its range with isolated islands of suitable habitat surrounding it. For the years 1951, 1961, 1971, 1972, 1973, 1974, and 1975, the areas in square miles covered by the summer population were 91, 86, 27, 27, 25, 27, and 31 respectively. In comments received regarding the proposed plan, Chandler S. Robbins of the Migratory Bird and Habitat Research Laboratory in Laurel, Maryland, suggested utilizing some of the principles of island biogeography. He suggested habitat improvement begin near the center of the birds' summer range to increase the area and, as the population hopefully increased, expand it to adjacent areas of suitable habitat connected by corridors of proper habitat.

Seasonal Regulation

Species that live in a seasonal environment experience regular changes in the quality and quantity of resources they use. For example, some species migrate from one area to another with a change of seasons while others utilize different food resources with seasonal changes. Fretwell (1972) has dealt with the effects seasonal changes have upon population sizes and fluctuations.

Species that possess a generation time that approximates a seasonal cycle in length divide each generation into a birth and death period when exposed to a change in seasons. Perhaps the key point to be gained from seasonal

regulation theory for the purpose of this report is that there are actually two different carrying capacities for such populations--a winter one and a summer one. The winter population size is partly limited by the amount of summer (breeding) habitat, and winter (non-breeding) habitat places at least partial limits on the size of the breeding population. Fretwell (ibid.) states that "...factors affecting a season's births or deaths are more certainly important in determining the next season's population and may have little effect on the season's own population." He presents a mathematical treatment of determining which season is the more limiting one on the population size.

Fretwell (ibid.) cites the studies of the great tit in Marley Wood (Lack, 1966) as a species strictly limited by winter food resources. His analysis of Errington's 1957 data on muskrats suggests that prewinter survival is the regulatory phenomenon in that particular situation. Analysis of Tinkle's 1967 data on the side-blotched lizard indicates that it is regulated by density-dependent factors during the breeding season.

Miller, Botkin, and Mendelssohn (1974) constructed a mathematical model of the endangered whooping crane population of North America. The question of the carrying capacity of their winter range was given consideration when the authors stated that "...if the population continues to increase at its present rate, the carrying capacity of the wintering range could become the most immediate problem in the welfare and management of the species."

Consider the case of the Kirtland's warbler. These birds spend the summer in Michigan in stands of jack pine that are five to fifteen feet in height. Dense branches of these trees located near the ground are important features of the habitat (Radtke and Byelich, 1963). The warblers migrate south-eastward in the autumn to what is believed to be an area in the Bahamas

(Mayfield, 1972; Radabaugh, 1974).

Current management practices concern the birds' summer habitat. Preserved areas of jack pine (Mayfield, 1963), controlled burning to help the pines reseed naturally (Radtke and Byelich, loc. cit.), and studies of brown-headed cowbird parasitism of warbler nests (Mayfield, 1961) have been used to try and increase the size of the summer population. Census data of singing males on the summer range for the years 1951, 1961, 1971, 1972, 1973, 1974, and 1975 were respectively 432, 502, 201, 200, 216, 167, and 179 (Kirtland's warbler recovery team, 1976). The species tended to withdraw toward the center of its range as well.

Little has been done in regard to the winter habitat of the bird. This is probably due in part to the small amount of information known about what islands and types of habitat the birds actually occupy during the winter. A proposed major aspect of the recovery plan for this bird involves initiating surveys and studies to try and locate the wintering grounds and habitat requirements (ibid.).

Fretwell (1977) predicted that the warbler would yield one of its lowest population counts on record for the start of the 1977 breeding season. This population decline was to follow an all-time high census of a post-breeding population for 1976--1,054 birds. When he analyzed the data, it indicated that the post-breeding season population size was so high that the deaths during the winter season would lead to fewer survivors to begin breeding the following spring than would be the case if fewer birds were present in the fall. Census data for the warbler in the summer of 1977, however, showed a higher number of birds than Fretwell predicted. Fretwell suggests that in the areas where the bird winters an early freeze had resulted in an above average mortality of palm warblers, a competitor with the Kirtland's warbler. This

could have lessened any interspecific competitive restrictions.

Food Chains

A food chain describes what a given organism in a given community eats and by what it in turn is eaten. The food chain involves the flow of both energy and matter. A community is composed of numerous food chains interrelated and interconnected to form food webs. Food chains and food webs are composed of trophic levels. All organisms in a community that obtain their energy in the same manner are said to occupy the same trophic level. Trophic level classification is one of function and not species. A given species might occupy one or more trophic levels in a given chain. For example, a fox might normally feed on small rodents, but it might change its diet to include berries when the rodent density is low. Odum (1971) identified two types of food chains--grazing and detritus. The grazing food chain is the one of interest for this report.

The first trophic level or link in a grazing food chain is composed of the producers. These are the green plants and, in some cases, certain bacteria. The efficiency of plants in a given area in capturing and converting solar energy sets upper limits to long-term energy flow and biological activity in a community.

The second trophic level is composed of the herbivores or primary consumers. They obtain their energy by eating the producers. Among terrestrial organisms the insects, rodents, and hoofed mammals compose a large percentage of the herbivores.

The next trophic level is that of the carnivores or secondary consumers that feed on the herbivores. If the herbivores fed upon are relatively small (such as mice), the carnivore may be a small one such as a weasel. The weasel

can in turn be eaten by a larger carnivore such as a bobcat. In this case, the bobcat would be a tertiary consumer or a secondary carnivore.

The amount of solar energy captured and converted by green plants is not completely passed to the end of the food chain. A large amount is lost at each trophic level as heat via respiration. Only 10-20% of the energy entering a trophic level is utilizable by the next higher level. Vaughn (1972) points out that consumers at the top end of a food chain often find themselves in a precarious position. Since so much energy is lost as heat at lower trophic levels, the longer the chain is the less energy there is available for top consumers. Since the top consumer depends upon its food from trophic levels with lower productivities, it can be susceptible to starvation if food becomes limiting at lower trophic levels unless alternate food sources are available.

The endangered Florida panther and eastern cougar are examples of top consumers in a food chain that have been affected by reduction in numbers of their main prey, the white-tailed deer, which occupies the herbivorous trophic level in this particular food chain. The endangered grizzly bear, eastern timber wolf, northern Rocky Mountain wolf, gray wolf, red wolf, Mexican wolf, San Joaquin kit fox, and black-footed ferret might also be considered top consumers in their respective food chains. As one proceeds up a food chain, the numbers of individuals decrease. There are usually fewer carnivores than herbivores and fewer herbivores than producers because of the amount of energy available to each trophic level and the costs of organism maintenance. Might it be possible that some of the endangered and threatened top consumers just naturally occur in the low densities observed?

Because so much energy is lost at each trophic level, organisms found at higher trophic levels must consume prey from lower levels in quantities sufficient to support themselves. For example, X grams of fish might require

10X grams of plankton. A fish-eating bird in turn requires 10X grams of fish to maintain itself, but these 10X grams of fish were produced from 100X grams of plankton. This can lead to the concentration of certain materials as the food chain progresses. One such group of materials is chlorinated hydrocarbons (pesticides and herbicides), including DDE and DDT among others. These hydrocarbons become especially concentrated in the fatty tissue of birds. The birds may be killed if they ingest large amounts of the hydrocarbon directly in a single dose, or they may have their reproductive success lessened. This reproductive failure is the result of laying eggs with thin shells which break under the weight of an incubating adult or when disturbed.

Chlorinated hydrocarbons and their effect upon the ability to lay eggs with normal shells are cited as a major cause for the endangered status of some birds. The American and arctic peregrine falcons have been depleted by the ingestion of DDE and DDT with resultant eggshell thinning (Anderson and Hickey, 1972; Enderson and Craig, 1974; Thelander, 1976). Similar results are cited for the bald eagle (U.S. Department of Interior, 1973) and brown pelican (Anderson et. al., 1969; Anderson and Hickey, 1970).

Succession

Odum (1971) defines ecological succession in terms of three parameters. First, community development is an orderly and reasonably directional process involving changes in species structure and community processes over a period of time. For example, in the piedmont region of the southeastern United States a bare field may progressively pass through a grassland, grass-shrub, pine forest, and oak-hickory forest community, each with its associated species of plants and animals. This particular progression may take up to 150 years to occur.

Second, it is the result of modification of the environment by the

community itself although the physical environment determines pattern and rate of change as well as often placing limits on how far community development will proceed. As organisms exploit their environment, their own activities make the habitat unsuitable for their continued survival. In so doing, however, they leave an environment that is suitable for another group of organisms.

Third, succession can result in a stable ecosystem (referred to as the climax community) in which maximum biomass and symbiotic relationships among organisms are maintained. Organic matter ceases to accumulate, and a gradual balance between production and respiration in the community is achieved.

The sequence of communities that replace one another in a given area (terrestrial or aquatic) is called a sere, and the transitory communities leading to the climax community are often referred to as pioneer communities. Succession which begins with a bare habitat is referred to as primary succession. Secondary succession is that which starts on an established ecosystem which has been disturbed or altered in some way. This discussion will deal with secondary succession.

Succession occurs gradually over a period of time so that populations do not suddenly appear and then disappear. Although succession is described as a progressive change, it is often variable. Seral stages might be skipped or two stages combined into one resulting in a shorter time period before the climax stage is reached. Likewise, climatic factors such as drought might prolong a seral stage.

Succession continues until the establishment of new species no longer changes the community environment. The process does not of necessity always end in a climax community and can, in fact, regress to a previous seral stage. Factors such as fire, agricultural activities, logging, livestock, industrial

activities, or activities of the community itself can either eliminate given ecosystems or keep them in a constant state of succession. Some of these factors will be discussed in the following paragraphs.

Rodents can keep an area in a given successional stage by their burrowing and eating habits. Bond (1945) described how the feeding habits of prairie dogs maintain the open areas of grass and other moderately low vegetation they require.

The endangered masked bobwhite quail of the southwestern United States prefers areas where brush and tree growth meet open grassland. Overgrazing of the open grassland by livestock has altered the community making invasion by woody species (especially mesquite) possible and thus making it unsuitable for the masked bobwhite (Tomlinson, 1972).

Strict fire control and prevention have generally been felt to be sound management practices for forests, but it may not always be for endangered species which inhabit the forests. The absence of fires, whether man-caused or natural, allows an ecosystem to progress to its climax sere which might not be favorable to the species involved. The Kirtland's warbler and Mississippi sandhill crane are two endangered species so affected.

The Kirtland's warbler prefers nesting sites in young jack pines with low brushy undergrowth. Jack pines with such undergrowth are generally six to fifteen years old and five to twenty feet in height. As the pines mature beyond this age, they shade out the lower branches causing them to die. Fire helps keep mature jack pines to a minimum, and many young seedlings eventually become established from the cones that break open and release their seeds when heated. Controlled burnings are now being utilized as part of the bird's management (Mayfield, 1963; Radtke and Byelich, 1963).

Livestock used to have free range in the Jackson County area of

Mississippi inhabited by the Mississippi sandhill crane. The range was burned to keep it in the grassy successional sere. With the end of free range, the fires were no longer set and woody species of plants invaded the area. This eliminated many of the savanna areas where the cranes breed (Valentine and Noble, 1970).

Logging practices have affected the endangered Delmarva Peninsula fox squirrel. Trees are cut as soon as they reach marketable size. The squirrel prefers mature timber and an understory with little shrub growth. Mature trees shade out such understory growth while cutting allows light to penetrate and encourage such growth. This in turn makes it marginal habitat for the squirrel (Taylor, 1973).

The endangered (and possibly extinct) ivory-billed woodpecker depends upon wood-boring insects found in overly mature stands of timber in the southeastern United States (Tanner, 1942). Since most timber is logged as soon as it is marketable and infested overly mature trees are of no economic value, most forests are not allowed to reach this advanced stage of maturity.

Agricultural practices such as plowing and irrigation have reduced much of the prairie habitat preferred by various species. The endangered Attwater's prairie chicken of Texas prefers the naturall tallgrass prairie habitat, but disruption of this ecosystem for the growth of grain sorghums, rice, and cotton has lessened the amount of suitable habitat (U.S. Department of Interior, 1973).

The endangered red wolf of Texas and Louisiana prefers the coastal prairie areas. Prime denning areas of low sand mounds have been plowed and converted to rice fields. The planting of crops has made the area more suitable to invasion by the coyote (Riley and McBride, 1972).

The endangered San Joaquin kit fox prefers rough, dry, uncultivated

valley land with its associated plant and animal communities or rolling hills devoid of trees and brush. As irrigation projects have made much of this type of land in the San Joaquin Valley tillable with resultant urbanization, the seral stage of the ecosystem has been changed from that preferred by the fox (Morrell, 1975).

Similar clearing of bottomlands for agriculture has limited the habitat of the endangered Columbian white-tailed deer of the northwestern United States (U.S. Department of Interior, 1973).

Chapter 5

THREATENED AND ENDANGERED SPECIES

Mammals and Birds

The number of living species of mammals in the world is 4,060 (Vaughan, 1972). The estimate for North America is 350 (Zim and Hoffmeister, 1955). The current number of endangered mammals worldwide is at least 169 species and 64 subspecies, and for North America the numbers are seven species and twelve subspecies. There are fifteen threatened mammal species and four subspecies worldwide with three of the four subspecies found in North America (Federal Register, Vol. 42, No. 135). North American species comprise 8.62% of all living mammalian species in the world while the endangered species of the same area account for 4.32% of worldwide endangered species and numerous endangered subspecies.

The number of living bird species in the world is 8,580 (Peterson, 1970), and 645 of these live in the North American area (Robbins, Bruun, and Zim, 1966). Worldwide, at least 146 species and 64 subspecies are endangered while the corresponding figures for North America are ten species and fifteen subspecies with no threatened species or subspecies listed (Federal Register, loc. cit.). North America contains 7.52% of all living bird species in the world and 6.85% of worldwide endangered species. Table 5.1 summarizes the figures for birds and mammals.

The western and southeastern states have the largest number of endangered and threatened birds with the southwestern and south central states having almost as many. All geographic regions of the United States have such

Table 5.1

Numbers of Living, Endangered, Threatened, and Extinct Species and Subspecies of Birds and Mammals

Classification	Birds	Mammals
Number of living species, worldwide	8,580[b]	4,060[g]
Number of living species, North America[a]	645[c]	350[h]
Number of endangered species, worldwide	146[d]	169[d]
Number of endangered species, North America[a]	10[d]	7[d]
Number of endangered subspecies, worldwide	64[d]	64[d]
Number of endangered subspecies, North America[a]	15[d]	12[d]
Number of threatened species, worldwide	0[d]	15[d]
Number of threatened species, North America[a]	0[d]	0[d]
Number of threatened subspecies, worldwide	1[d]	4[d]
Number of threatened subspecies, North America[a]	0[d]	3[d]
Number of extinct species and subspecies combined since 1600, worldwide	36[e]	94[e]
Number of extinct species since 1600, North America[a]	3[f]	3[f]
Number of extinct subspecies since 1600, North America[a]	3[f]	16[f]

[a]Refers to the area north of Mexico

[b]Peterson, 1970

[c]Robbins, Bruun, and Zim, 1966

[d]Federal Register, Vol. 42, No. 135

[e]Fisher, Simon, and Vincent, 1969

[f]U.S. Department of Interior, 1973

[g]Vaughan, 1972

[h]Zim and Hoffmeister, 1955

birds and/or mammals that reside in that area year-round or at least for part of the year. The areas mentioned are those regions with the largest numbers of such species. Since some of these species have been used in discussing theories in Chapter 4, no further discussion of them will be presented in this chapter.

Reptiles and Amphibians

Stebbins (1954) listed the probable number of worldwide reptilian species at seven thousand. Forty-four species and eleven subspecies are currently endangered worldwide. (The American alligator is a species that is classified as threatened in parts of its range.) In the United States, three species and one subspecies are so classified. The American alligator, American crocodile, blunt-nosed leopard lizard, and San Francisco garter snake are those particular reptiles (Federal Register, Vol. 42, No. 135).

The probable number of worldwide amphibian species at present is 2,500 (Stebbins, loc. cit.). Eight species and four subspecies are currently classified as endangered worldwide, and one species is classified as threatened. In addition, all species of viviparous African toads (Nectophrynoides spp.) are also classified as endangered. In the United States, three species and one subspecies are endangered. Those particular amphibians are the desert slender salamander, Texas blind salamander, Houston toad, and Santa Cruz long-toed salamander. The Red Hills salamander is classified as threatened in the United States (Federal Register, loc. cit.).

Four of the listed reptilian and amphibian species are found in California, two in Texas, and the other three in southeastern states. Those found in California are the blunt-nosed leopard lizard, San Francisco garter snake, desert slender salamander, and Santa Cruz long-toed salamander. The two found in Texas are the Texas blind salamander and Houston toad. The south-

eastern species are the American alligator, American crocodile (Florida), and Red Hills salamander (Alabama).

People involved with endangered reptiles and amphibians generally have listed destruction or alteration of habitat as the major cause of declining numbers. Uncontrolled collecting is another frequently mentioned cause.

Vestal (1977), the California Department of Fish and Game (1972), and Bury (1971) have studied and discussed the loss of habitat for the Santa Cruz long-toed salamander. Vestal described four known breeding populations of the salamander, and three of the populations were found to be associated with temporary ponds and marshes along the coast. The loss of other satisfactory breeding areas has been due to land development, road construction, and increased recreational activities in the area. Vestal also listed indiscriminate collecting as a problem.

The situation with the blunt-nosed leopard lizard has been one of increased water in its habitat. Bury (ibid.), the California Department of Fish and Game (op. cit., p. 47), and Brode (1977) listed the habitat requirements of this lizard as sparsely vegetated plains and grassland areas. California, with its increasing demand for water, has begun importing water for agricultural purposes and many of the areas that the lizard inhabits are disappearing.

The desert slender salamander is found under limestone sheets and rocks that occur at the base of water-soaked cliffs or wherever continuous water seepage occurs (Bury, op. cit., p. 8; California Department of Fish and Game, op. cit., p. 45). Although this habitat is not presently being altered, the specialized requirements of this species place it in a position where any habitat modification could be fatal for it.

Bury (op. cit., p. 16) and the California Department of Fish and Game (op. cit., p. 49) once again cited habitat requirements as the reason the San

Francisco garter snake is endangered. Housing and road construction have destroyed much of the marshy habitat around the ponds it prefers.

The Fish and Wildlife Service's 1973 edition of the "red book" listed similar causes for the Texas blind salamander and Houston toad. The salamander requires deep wells and underground streams in caves of Harp County, Texas, while the Houston toad requires loblolly pine areas. Interbreeding with two other toad species has also resulted in the hybridization of the Houston toad according to the same reference.

The American crocodile and American alligator have both been heavily poached and limited by the amount of satisfactory habitat. Predation, especially by raccoons, on alligator hatchlings has been a problem (U.S. Department of Interior, 1973).

Theories dealing with speciation, island biogeography, predation, and r- and K- selection might be applicable to some of these species of reptiles and amphibians. Current management practices include acquisition and preservation of suitable habitat and protection under the Endangered Species Act of 1973.

Fishes

There are about twenty thousand species of fish in the world (Harder, 1975). Of that number, thirty-four species and seven subspecies are presently on the worldwide endangered list. All of the subspecies and twenty-four of the species listed as endangered are found in the United States. Of those, one species and two subspecies are classified as threatened (Federal Register, loc. cit.). The list of United States threatened and endangered fishes is composed of six darters (family Percidae, subfamily Etheostomatinae), five pupfish and three gambusia (family Cyprinodontidae), five trout (family Salmonidae, subfamily Salmoninae), and two chubs (family Cyprinidae). An examination of the geographical distribution of these fish shows that the majority are found in

Nevada, California, and Texas. Eastern species or subspecies are scattered over a number of states.

Miller (1972) listed pollution (including toxic chemicals and pesticides), damming of rivers, deforestation and overgrazing, channeling, removal of ground water, and introduction of predatory species or species with a broader ecological niche as some of the factors responsible for reducing the size of these fish populations. Minckley and Deacon (1968) cited these same factors as being responsible for the endangered status of many of the fishes of the southwestern United States.

The Flaming Gorge Reservoir on the Green River of Utah and Wyoming was impounded in November of 1962. This river is the major tributary of the Colorado River Basin. Studies following enclosure of the reservoir supported some of the speculations held by experts prior to the enclosure. Stalnaker and Holden (1973) found signifcant changes in the yearly flow and temperature pattern downstream. Vanicek (1970) found significant changes in the species composition downstream from the dam. He found that native fishes had completely disappeared for seven miles downstream and that the number of native species had been reduced for as far as sixty-five miles below the dam. Pearson, Kramer, and Franklin (1968) also found alterations in the macroinvertebrate community and concluded that in the first twenty kilometers below the dam the macroinvertebrates might never stabilize as water conditions (especially water temperature) fluctuate with release of water from the reservoir.

Another example of impoundment affecting an endangered species is that of the Tellico Dam on the Little Tennessee River and its alteration of habitat for the snail darter. This small member of the perch family was discovered in a seventeen-mile stretch of the river in 1974. It inhabits clean gravel shoals with cool, swift water of low turbidity. The food of the fish is primarily

snails which also require this type of shoals as habitat. After spawning, the larvae of the snail darter are swept downstream where they mature and then swim back upstream to spawn. The Secretary of Interior determined that closure of the Tellico Dam would destroy the shoals required for breeding by the darter and its food source of snails. He also determined it would prevent movement of the maturing darters upstream to spawn because they would be carried through the gates of the dam and concentrated below it. This heavy concentration of darters below the dam also makes them more susceptible to heavy predation (U.S. Department of Interior, 1976). Chapter 6 discusses the snail darter and its critical habitat in more detail.

Beland (1953) discussed the effect of channeling in the lower Colorado River. He felt that channeling drained adjoining backwater lakes and sloughs, eliminated vegetative cover along the streams, eliminated numerous eddies in meandering streams, increased water turbidity by increased bank erosion, and reduced the amount of spawning area. Deacon and Bunnell (1970) cited the channeling of the Tecopa Hot Springs outflow creek as the major cause for decreasing the Tecopa pupfish. Channeling to increase the creek's rate of flow destroyed breeding habitat and this, along with the introduction of the predatory mosquitofish, resulted in this pupfish's probable extinction.

The introduction of non-native (exotic) fish can affect the native fish populations by increasing hybridization, interspecific competition, or predation. Stalnaker and Holden (1975) discussed not only the effects of the Flaming Gorge Reservoir on the Green River but also the introduction of exotic species such as the channel catfish and numerous small cyprinidae which they felt resulted in increased competition for food and space. Miller (1961) reported that the number of native fish species declined progressively from seven to two while the number of exotic species increased from zero to twelve over the period from

1854 to 1955 on the lower Colorado and Gila Rivers near Yuma, Arizona. Native species decreased from eleven to zero while exotic species increased from zero to five on the Salt River of the Southwest for the period 1890-1944. Introduction of exotic species into the Southwest began with the carp in 1872, and approximately thirty-six species have been introduced since then, mostly during the period 1930-1950. Damming, pollution, change of stream or riparian vegetation, irrigation, or chemical treatment can be indirectly responsible for the success of exotics.

An examination of the desert pupfishes (genus Cyprinodon) shows some examples of the effects of introduced species. These pupfish inhabit scattered and isolated desert springs along the California-Nevada border in close proximity to the Death Valley National Monument area. As the glaciers advanced into the Southwest about fifty thousand years ago, a great amount of rain fell. As they receded thirty thousand years later, the water began to disappear until about four thousand years ago nearly all of the water suitable for fish had vanished except for some scattered volcanic hot springs and their outflow streams. It is in such waters that the desert pupfishes (there are five endangered species) are found (Bunnell, 1970; Pister, 1974). Thus, these fish have become isolated by the natural reduction in the extent of their habitat.

The Owens River pupfish was nearly driven to extinction by the introduction of the aggressively predatory black bass (genus Micropterus) (Deacon and Bunnell, op. cit., p. 15). Other introduced species that have had detrimental effects on native pupfish populationa include mollies (genus Poecilia), crayfish, bullfrogs, and mosquitofish. Mosquitofish are often stocked into areas to help control mosquito larvae, but they are also efficient predators of the young of other fish species. The mosquitofish was specifically noted as one of the reasons for the decline of the Tecopa pupfish and Warm Springs pupfish

(U.S. Department of Interior, 1973). Deacon and Bunnell (op. cit., p. 14) cited the example of seven introduced goldfish wiping out the last killifish (genus Empetrichthys) in Manse Springs, Nevada.

Another contributing factor which has affected the pupfishes has been the lowering of the water table. The Devil's Hole pupfish serves as an example. This fish is found in a single spring-fed pool in Ash Meadows, Nye County, Nevada. The spring surface lies fifty feet below the general land surface and measures 10'x70'x45'. Not all of the spring is exposed to daylight for photosynthesis to occur and thus supply food. The fish spend most of their time on a shallow, sunlit shelf (10'x20'x3') at one end of the hole. Much of the area adjacent to the spring has been developed for agricultural use, and this has necessitated irrigation. Wells drilled into the same aquifer that supplies Devil's Hole have dropped the level of the spring. Since a drop of about three feet would lower the spring level below the shelf used by the fish to spawn and feed upon, this could be a critical lowering (Deacon and Bunnell, op. cit., pp. 16-20). Minckley and Deacon (1968) cited similar reasons as one of the problems with the disappearance of the two subspecies of Empetrichthys latos (Pahrump killifish) at Manse Springs, Nevada.

Interbreeding or hybridization has been cited as one of the causes for the situation in which some of the endangered or threatened trout find themselves. Minckley (1973) noted that the endangered Arizona and Gila trout hybridized with introduced species of Salmo. Langlois (1976) cited a similar situation for the greenback cutthroat trout in Colorado.

Not all of the endangered or threatened species of fish have been covered in this discussion. Selected species have been used as examples to illustrate some of the causes experts have cited for diminishing numbers. In most cases, a combination of these causes rather than any single one is

probably responsible.

Arthropods

All of the endangered and threatened arthropods are butterflies. There are approximately 112,000 species of butterflies in the world, and eleven thousand of them are found in North America (Borror and White, 1970). Six subspecies are presently listed as endangered and two as threatened (Federal Register, loc. cit.). Six of the listed butterflies are found in California--the El Segundo blue, Smith's blue, Lange's metalmark, Lotis blue, mission blue, and San Bruno elfin. The other two subspecies--the Bahama swallowtail and Schaus swallowtail--are found in Florida. Those found in California are principally in the southern part of the state. If this area seems to have a disproportionate number of endangered and threatened species, it is believed to be because of a high degree of endemicity combined with the effects of over-population by humans (Pyle, 1976).

Once again, the major cause cited for decreasing numbers of butterflies has been the destruction or modification of habitat. The El Segundo blue inhabits the coastal sand dunes of a few southern counties in California. This butterfly's life cycle is closely associated with plants of the genus Eriogonum. Where dunes have developed, people have often introduced an exotic species of ice plant (genus Mesembryanthemum) to help hold the sand in place. It is a rapidly spreading plant that chokes out the native species of Eriogonum, apparently important for the survival of the El Segundo blue. Standard Oil of California fenced shut a two acre area of dune habitat on its property in 1975 and removed the aggressive ice plant. This area is currently the primary refuge for the El Segundo blue. The case of this butterfly also serves to point out the effects that competition between plants can have upon invertebrates (Oppewall, 1975).

Habitat for the Schaus swallowtail is preserved in the Biscayne National Monument off the coast of Florida. With the exception of natural mortality due to freezes or hurricanes, this population is felt to be maintaining itself at a steady level (Covell and Rawson, 1973).

According to Pyle (loc. cit.), four major areas of research are needed in lepidopteran conservation. First, life history studies should be continued so as to provide sound data upon which to base management decisions. Second, accelerated work in genetics and population biology should be encouraged to better understand the effects of patchy islands of habitat. Third, more information should be obtained on mortality factors other than habitat disturbance. Fourth, a more complete biogeographical survey of Lepidoptera is needed.

The listing of the eight subspecies of North American butterflies has not met with universal approval. The listing of some of the butterflies was poorly researched (Miller, 1975). Populations of the Schaus swallowtail butterfly decline and increase in a cyclic manner. Observations leading to the listing of it were taken during the years of cyclic decline. By classifying a butterfly as threatened or endangered, scientific collectors have felt they were unfairly restricted in their studies. The feeling is that habitats should be listed as threatened or endangered rather than the butterflies themselves. If the habitat is destroyed, the butterflies will go extinct despite any regulations placed on their taking. Listing of the butterflies might call more attention to the rarity of them leading to higher prices being paid for the obtaining of one. The view of extinction as a natural process by which unfit populations of butterflies are removed has also been urged by Miller to be given more attention.

Mollusks

The endangered mollusks are concentrated in the southern states,

especially Alabama, Tennessee, and Virginia. Scattered states throughout the Midwest have endangered mollusks also. Eleven naiad species are presumed to have become extinct since 1850, and nearly all were inhabitants of riffle areas in large rivers (Stansberry, 1971).

Impoundment and channeling of streams have been cited as important reasons for these diminishing mussel populations (Stein, 1972). As moving water is slowed, the mixing of the water and movement of atmospheric oxygen into it is reduced. Suspended solids carried by the moving water are able to settle to the bottom as the current slows. Many of these suspended solids are organic in nature and place an increased demand on the system for oxygen as they decompose. As carbon dioxide and other products of decomposition accumulate, the carbon dioxide combines with the water to form carbonic acid and lower the pH of the water. As the water near the bottom becomes more acidic, the ability of the mussels to exchange gases with the water is hindered and they may suffocate. If the pH is low enough, the calcium carbonate shells of the animals are frequently dissolved, and they die from a loss of their protective covering. Mussels obtain both food and oxygen by drawing water over their gills and passing it back into the immediate surroundings. If the water is not moving, much of the same water (now reduced in food and oxygen content) is filtered again. In addition, waste products are discharged into the animal's surroundings and are contained in the water which the animal draws over its gills (Stansberry, 1971, 1973).

Stansberry and Stein (1971) feel freshwater mussel preservation should concentrate on the following:

> (1) decrease harmful pollutants such as domestic sewage, industrial outfalls, and agricultural runoff;
> (2) decrease the number and extent of stream impoundments;
> (3) limit or stop stream channeling activities;
> (4) halt or reduce commercial harvesting until reduced populations increase in number;

(5) conduct continuing research programs to determine the requirements for survival of declining species; and
(6) establish sanctuaries in rivers known to have populations of rare and endangered species.

Plants

Until 1973, much of the work and public attention regarding threatened and endangered species involved animals. However, the plants began to receive attention with the passage of the Endangered Species Act of 1973.

Section 12 of that law directed the Secretary of the Smithsonian Institution as follows:

> ...to review (1) species of plants which are now or may become endangered or threatened and (2) methods of adequately conserving such species, and to report to Congress...the results of such review including recommendations for new legislation or the amendment of existing legislation.

The Report on Endangered and Threatened Plant Species of the United States was transmitted from the Smithsonian to the Congress on December 15, 1974.

The report covered all fifty states and included only native species. No introduced species, hybrids, or horticultural variations were included. Four classifications of plants were used: endangered, threatened, recently extinct, and exploited.

The report defines endangered plant species as those "...in danger of extinction throughout all or a significant portion of their ranges." This could be as the result of overexploitation, destruction or modification of habitat, disease, predation, or other unknown reasons.

Threatened plant species are defined as those that were "...likely to become endangered within the foreseeable future throughout all or a significant portion of their ranges." Plants considered as rare, very rare, or depleted are included in this classification.

Recently or possibly extinct plant species are defined as those "...no longer known to exist after repeated search of the type localities and other

known or likely places." If a species considered extinct is rediscovered, it is immediately classified as endangered until more is learned about its distribution.

Exploited species are considered by the report as those dealt in heavily by commercial dealers or actively sought by private collectors.

Little (1975) would like to make a separate classification "rare" to cover native species which, although they are well known in their own areas, nevertheless have such a limited geographical distribution that they are known only within a few counties of a state. There are an estimated one hundred species of such trees.

Only the indigenous vascular plants--angiosperms (flowering plants), gymnosperms (pines and their relatives), and pteridophytes (ferns) are considered. The Smithsonian desires that lower nonvascular plants such as the algae, fungi, lichens, mosses, and liverworts will also be studied and classified.

The Smithsonian report lists 761 species, subspecies, and varieties of vascular plants of the continental United States (including Alaska) as endangered, 1,238 as threatened, 100 as extinct, and 82 as exploited. Those listed as exploited are included in either the endangered or threatened lists. The number of endangered species for the United States is 3.8% of the total number of native plants, the threatened species are 6.1% of the total native plant species, and the 100 extinct species equal 0.5% of the total native plant species of the United States. Of the plants listed in the report, trees comprise two of those listed as extinct, eighteen of those listed as endangered, and twenty-two of those listed as threatened (Preston, 1975).

The report lists a number of causes for the endangerment of these plants. One such cause is commercial collecting and overzealous gathering of specimens by private collectors. The rarer a plant species is, the higher the price that

can be asked and received for it. Likewise, private collectors have gathered rare varieties of plants for their private collections.

More than 1,800 foreign plant species have been introduced to the continental United States. Examples of such species are the dandelion, thistle, and water hyacinth. Many of these have become aggressive and successful competitors with native species. The import of foreign species also poses the problem of introducing foreign insect pests and diseases which could be detrimental to native species.

Strip mining, clear cutting, irrigation, overgrazing, and stream channeling as well as the drainage of bogs, marshes, and swamps have reduced the numbers of some species. Lumbering has eliminated the milky camellia in eastern Texas while wild burros have overgrazed the Panamint daisy in California. Housing projects, oil shale recovery, and construction of dams, power plants, and factories might also be included. Weinberg (1975) felt that the LaFarge Dam Project in Vernon County, Wisconsin could destroy the Sullivantia plants found in the area as well as monkshood, Birds-eye primrose (Primula spp.), and Forbes' saxifrage.

Fires have destroyed or reduced the number of cacti in the chaparral areas of southern California, but, at the same time, the elimination of natural fires has had negative effects as well. Some grassland areas where natural fires are now controlled have become areas covered by trees and shrubs. This can lead to a change in soil texture and content, different competing species, varying sunlight intensity, and other effects.

Some plant species are adapted to restricted habitats. When those habitats are destroyed or modified, species there are unable to adapt to a new type of habitat before becoming extinct. French's shooting star, which is found in depressions below overhanging sandstone ledges in Arkansas and Kentucky,

is an example of such a plant (ibid.).

The Smithsonian report points out that the process of speciation must be kept in mind when considering loss of species. Some species have been lost as a result of natural speciation over a long period of time. Also, the long and slow geological and climatic changes that are constantly taking place on earth have their effect upon abundance and distribution of native and new species.

The report makes some specific recommendations for preserving threatened and endangered plant species. First, preservation of such species in their native habitat should be considered as the best method. Cultivation or artificial propogation is felt to be an unsatisfactory alternative which should only be used as a last resort when extinction is imminent. Even then, cultivation and artificial propogation should be done with the purpose of re-establishing the particular species in its native habitat.

Transplantation or artificial propagation is considered as unsatisfactory because the complete ecosystem is usually not well enough known. A plant might be transplanted, but it may fail if the new soil was not of the same texture and did not contain the same mineral proportions, percentage moisture, and other plants associated with the native habitat or the climate varied. All of the requirements of the plant are not known. Transplanting could also cause root breakage which could result in fungal or other types of infection.

The second recommendation is that threatened and endangered plant species found on federal and state lands should be mapped and given continued protection. Special efforts should be made by federal and state departments and agencies to consider such plant species and their critical habitat when reviewing environmental impact statements.

The third recommendation is that the Secretary of Interior review and publish in the Federal Register the lists of plants in the Smithsonian report.

In keeping with this recommendation and the first one, the Fish and Wildlife Service calls for information regarding the plants listed in the report and their critical habitats (Federal Register, Vol. 40, No. 127). Four plant species have officially been listed as endangered since March of 1978--the San Clemente broom, San Clemente bushmallow, San Clemente Island larkspur, and San Clemente Island Indian paintbrush (Endangered Species Technical Bulletin, Vol. 3, No. 1). April of 1978 saw the addition of ten more endangered species plus two threatened ones for the United States (Federal Register, Vol. 43, No. 81). Those listed as endangered are the Virginia birch, Contra Costa wallflower, Santa Barbara Island liveforever, hairy rattleweed, persistent trillium, Eureka evening primrose, Antioch Dunes evening primrose, Eureka dunegrass, Texas wild rice, and Furbish lousewort. The two threatened plants are Rydberg milk-vetch and northern wild monkshood.

Fourth, the Secretary of Interior is advised to make sure that commercially exploited species are given urgent protection by enforcing existing laws prohibiting removal or commercial traffic in such plants. All species of the families Cactaceae and Orchidaceae have been placed on the list of commercially exploited species.

In Chapter 2, the Convention on International Trade in Endangered Species of Wild Fauna and Flora was discussed. The fifth suggestion of the Smithsonian report is to have the Secretary of Interior submit the proposed list of threatened and endangered plant species to the Secretariat of the Convention for inclusion in Appendix III of the convention's treaty. This appendix lists plant and/or animal species which are commercially overexploited, and the member nations of the Convention have agreed to help one another in controlling traffic in such species. It also gives the Secretary authorization for acquisition of critical habitat.

The sixth suggestion calls for continued research and establishment of a program to monitor plant populations for the purpose of watching for declines or increases, changes in habitat or geographical distribution, and conditions of reproduction.

In its seventh recommendation, the Smithsonian also urges the establishment of a Registry of Endangered and Threatened Plants. This registry would serve as a central filing office for information on endangered and threatened plant species and would include maps, a specialized library, a computer, and a small staff of botanists.

The eighth recommendation is to give wide public exposure and publicity to these plant species in an effort to make the public and interested organizations aware of the need for protection and preservation.

The ninth and final recommendation states that the Smithsonian feels that no new legislative action is required. However, a review of the Endangered Species Act of 1973 is required to provide better protection for plants. They feel that this review might be necessary because: (1) the term "species" includes plant species and subspecies but not varieties; (2) the Secretary of Interior does not have authority to acquire habitat for preserving threatened or endangered plants that are not included in Appendix III of the Convention on International Trade in Endangered Species of Wild Fauna and Flora; and (3) the Endangered Species Act of 1973 does not prevent "taking" of endangered and threatened plant species in the United States.

Chapter 6

MANAGEMENT

This chapter presents some of the current practices being followed for the management of endangered and threatened species. The agencies and organizations chosen for discussion are mostly federal ones, but there are numerous state, private, and smaller agencies that are also involved.

Assorted federal agencies were questioned about their policies involving endangered and threatened species. The agencies replying were the Corps of Engineers, Federal Highway Administration, Federal Power Commission, Federal Energy Regulatory Commission, Missouri River Basin Commission, Ohio River Basin Commission, and Bureau of Land Management. The overall policy of these agencies is to consider the impact of their various programs upon endangered and threatened species as well as the habitats of such species. Federal agencies are subject to the authority of Section 7 of the Endangered Species Act of 1973.

Critical Habitat

The importance of proper habitat for the survival of certain species of plants and animals was discussed in Chapters 4 and 5. Likewise, acquisition of habitat has been seen to be a significant part of some of the legislation. Authorization for acquisition of habitat is particularly mentioned in the Migratory Bird Conservation Act, the Fish and Wildlife Act of 1956, and the Endangered Species Act of 1973.

In keeping with the intent of Sections 2 and 5 of the Endangered Species Act of 1973, the Fish and Wildlife Service and the National Marine Fisheries

Service jointly announced that they would begin proposing areas to be designated by rulemaking as areas of "critical habitat" for threatened and endangered species (Federal Register, Vol. 40, No. 78). Except in emergency situations, governors of states in which areas are proposed as critical habitat are given prior notice of ninety days for comment. Local government units whose boundaries include or are adjacent to the proposed area are also notified. The procedure for officially listing habitat as critical in the Federal Register is similar to that for listing a species as threatened or endangered.

All or any portion of a species' range can be considered in establishing critical habitat, but the following vital needs must be considered: (1) space for normal movement, growth, and normal territorial behavior; (2) habitat supplying sufficient food, water, and other nutritional requirements; (3) sufficient area for breeding, giving birth, and raising young; (4) sufficient shelter; and (5) enough habitat to supply any other unique or special biological, physical, chemical, or behavioral requirements the species might have. Critical habitat does not mean that habitat necessary for maintaining a viable minimum population but rather that which is necessary to return a species from threatened or endangered status (ibid.).

The Endangered Species Act Amendments of 1978 define critical habitat as:

> (1) "the specific areas within the geographical area occupied by the species...on which are found those physical or biological features [a] essential to the conservation of the species and [b] which may require special management considerations or protection; and
> (2) "specific areas outside the geographical area occupied by the species at the time it is listed...upon a determination by the Secretary [of Interior] that such areas are essential for the conservation of the species."

Once an area is designated by rulemaking as critical habitat, it is subject to federal and/or state regulations regarding its use which might affect the resident wildlife. For example, suppose an organization wishes to establish a summer recreation camp on a critical habitat area. If it is determined by the

Secretary of Interior that such a camp would in no way result in a further reduction in numbers or distribution of a species of sufficient magnitude to place the species concerned in a threatened or endangered status or restrict the potential of an already endangered or threatened species to expand or recover, he could give his approval for the camp. However, perhaps the road into the camp would destroy part of the critical area of a bird species' sole source of food to the point that the species could find no food and would experience a reduction in its numbers and limit its distribution to the now even smaller area where its food exists. If the Secretary judged that such reduction in numbers and distribution would lead to it becoming threatened or endangered, he could prevent construction of the road and order it constructed through another area where effects would not be so detrimental. Certain activities might be detrimental to critical habitat areas while others are not. The elimination or alteration of the detrimental activities is sought. This applies to activities by individuals, groups, private companies, and state and federal organizations. Keith Schreiner, manager of the federal endangered species' program, summed up the government's attitude toward critical habitat as follows:

> The most important point I can make about critical habitat is that in no way does it place an iron curtain around a particular area; that is, it does not create a wilderness area, inviolable sanctuary, or sealed-off refuge. Furthermore, I would stress that it does not give the Fish and Wildlife Service or any other government agency an easement on private property nor will it affect the ultimate jurisdiction regarding any public lands.
>
> ...In short, the determination of critical habitat is a means of helping all Federal agencies meet their responsibilities under the Endangered Species Act of 1973. It is a tool to help save and restore species, not a weapon to hinder economic or social progress. (Endangered Species Technical Bulletin, Vol. 1, No. 2)

Any individual, organization, private concern, state, and/or federal agency has been urged to supply any information, including maps, that they might have regarding habitats of threatened and/or endangered fauna and/or flora (Federal

Register, Vol. 40, No. 78).

The Department of Interior has proposed that critical habitat be determined for twenty-one species and nine subspecies of fish, five species and two subspecies of reptiles and amphibians, eleven species and thirteen subspecies of birds, and five species and eleven subspecies of mammals. Those species and subspecies are all classified as endangered. At the time of the notice, such information was being eagerly sought for nine high priority species: the Indiana bat, Mississippi sandhill crane, whooping crane, Florida manatee, American peregrine falcon, San Joaquin kit fox, blunt-nosed leopard lizard, California condor, and black-footed ferret. As of April, 1978, officially listed critical habitats totaled twenty-six (Endangered Species Technical Bulletin, Vol. 3, No. 4).

Critical habitat was first proposed for the Mississippi sandhill crane. A five-county land and airspace area encompassing about ten thousand acres was declared critical on June 30, 1975, under emergency provisions of the Endangered Species Act of 1973, Section 4(f) (Federal Register, Vol. 40, No. 126). In this particular case, a highway right-of-way was depleting the cranes' habitat. Emergency regulations are effective for only 120 days so a formal proposed rulemaking was made September 3, 1975 (Federal Register, Vol. 40, No. 171).

In November of 1976, the U.S. Supreme Court held that the highway construction endangering the cranes' habitat must stop. This decision marked the first time that a case involving the Endangered Species Act of 1973 had been carried to the highest court (Endangered Species Technical Bulletin, Vol. 2, No. 1).

Construction on the Tellico Dam in Tennessee by the Tennessee Valley Authority was halted by a lawsuit charging that critical habitat of the endangered snail darter would be destroyed. The Court of Appeals for the Sixth

District ruled for the opponents of the dam on January 31, 1977 (549 F.2d 1064[6th Cir., 1977]). The case was appealed to the U.S. Supreme Court by the T.V.A. who contended that the lower court's ruling, if allowed to stand, would mean the loss of about eighty million dollars already spent on the project plus additional millions in economic benefits the dam would bring to the region (Endangered Species Technical Bulletin, Vol. 2, No. 11).

The Supreme Court, by a six to three vote, upheld the decision of the lower court to halt construction of the dam (Tennessee Valley Authority vs. Hill, 46 U.S.L.W. 4673[1978]). Congress then passed the Endangered Species Act Amendments of 1978 which establishes an Endangered Species Committee authorized to determine whether certain federal programs can be exempted from requirements of the Endangered Species Act of 1973. The committee ruled in January of 1979 that continued construction of the dam must be halted. The decision hinged on two primary factors: (1) whether a reasonable alternative to the project existed, and (2) whether the project's economic benefits outweighed the costs of completing the dam. The committee determined that the benefits to be gained did not outweigh the cost of completing the project based on a committee staff report which estimated the project would cost $7.22 million annually to complete and operate as compared to $6.5 million in benefits to be gained (Endangered Species Committee Staff Report, 1979).

Construction of the Grayrocks Dam and Reservoir on the Laramie River in Wyoming was halted by a federal district court ruling for the Nebraska district in the fall of 1978 (No. CV76-L-242, [D. Neb., Oct. 2, 1978]). Plaintiffs in the case claimed construction of the dam would alter whooping crane habitat downstream, and that federal funding and approvals for the project had been granted without prior consultation with the Secretary of Interior.

The Laramie River is a tributary of the Platte River which flows across

Nebraska and provides critical habitat for the endangered whooping crane. The Platte River Valley is a resting point for the cranes on their annual migration from Texas to Canada. The birds require open and undisturbed areas of a 75-100 yard radius for roosting sites, and the sand and gravel bars of the Platte River provide such areas. With any reduction in wetland habitat elsewhere, it is feared that the Platte Valley might become the only suitable roosting habitat for the cranes in future years. Biologists of the U.S. Fish and Wildlife Service estimate there has already been a 60-65 percent loss of sandbar and wet meadow areas over the past forty years within the critical habitat area involved. A decrease in river flow caused by the Grayrocks Dam and Reservoir would lead to a reduction of downstream channel widths and possible alteration or destruction of the sandbar areas (Endangered Species Technical Bulletin, Vol. 3, No. 12).

The Grayrocks project was granted exemption from the Endangered Species Act of 1973 by the committee with the provision that the builders abide by an out-of-court settlement reached between opponents of the project and the Missouri Basin Power Project (which includes the Grayrocks Dam and Reservoir). The agreement calls for a limit to the consumptive use of water from the Laramie River and the establishment of a trust fund of $7.5 million for preservation and maintenance of whooping crane habitat (ibid.).

Critical habitat has also been proposed for a number of floral species (Federal Register, Vol. 40, No. 77). As the threatened or endangered status of these plants is officially listed, their critical habitats will also be specified.

Recovery Plan Concept

To effectively initiate a program of management to restore an endangered or threatened species to a stable population level, the Fish and Wildlife Service felt that a program dealing with the total problem was necessary. A series of different programs not united in a single objective would probably prove to be

ineffective. With this in mind, the Fish and Wildlife Service adopted the recovery plan concept as a way of dealing with such species. The Endangered Species Act Amendments of 1978 direct the Secretary of Interior to develop and implement recovery plans for all endangered and threatened species unless he finds that doing so "...will not promote the conservation of the species."

Each species is assigned a recovery team composed of four to nine members who are knowledgeable of the particular species under consideration. This group's job is to present and define the problems and needs of their assigned species, outline needed actions and management plans necessary to restore the species to a more secure population level and possibly qualify it for removal from the threatened or endangered list, set a timetable for achieving the plan's objectives, and estimate the costs of implementing the plan. The recovery plan is then submitted to the U.S. Fish and Wildlife Service for comments and final approval. After the approval of the plan, the recovery team is responsible for overseeing and updating the plan. To date there have been fifty-nine recovery teams appointed, and sixteen recovery plans have been approved (Endangered Species Technical Bulletin, Vol. 3, No. 4).

Following is a condensed example of a recovery plan. This particular one is for the California condor. The recovery team was composed of representatives from the Fish and Wildlife Service, Forest Service, Bureau of Land Management, California Department of Fish and Game, and the National Audubon Society.

Objectives:

"To maintain a minimum population of at least 50 California condors, well distributed throughout their 1974 base range with an average natality (birth rate) of at least 4 young per year, and the lowest possible annual mortality."

Condensed summary of suggested actions:

1. Supply adequate nesting conditions. This includes keeping humans and sources of excess noise controlled for at least a 1½ mile area adjacent to the nests.
2. Supply adequate roosting sites. Control all activities within ½ mile of any roosting sites.
3. Supply adequate food, perhaps including supplemental carrion. Protect

feeding areas from disturbance.

4. Protect the birds from harm by strengthened enforcement of existing laws, increasing public awareness of the birds' problems, and controlling all activities within the areas the birds frequent. (California condor recovery team, 1974)

Research

The center for research on threatened and endangered species is located at the Patuxent Wildlife Research Center near Laurel, Maryland. The original purpose of this center, established in 1965, was twofold:

(1) "...to obtain needed information on the distributional, behavioral, ecological, physiological, genetic, and pathological characteristics of threatened species in the wild so as to identify and evaluate limiting factors and find means of correcting them, and

(2) "...to maintain captive populations of these wildlife species for study and for the production of suitable stock needed to restore or bolster populations in the wild." (Erickson, 1968)

The center does not deal only with problems of threatened and endangered species. The endangered species' staff comprises only one section of the center. The staff is composed of fourteen professional scientists, seven biological technicians, and two secretaries (Erickson, 1977).

The geographic location of the center has a mild climate so most animals can be kept out-of-doors, is close to a number of experts in various disciplines, and has fifty-five acres of well-drained agricultural land surrounding it. When the center was first established, the staff hoped that several research substations could be established across the country. These substations now number nine--three in Hawaii and one each in California, Arizona, Florida, Minnesota, South Dakota, and Puerto Rico (ibid.).

The Patuxent Center is divided into three interrelated sections: ecological, propagational, and investigational laboratories that are currently involved in the study of forty-four species in varying intensity either at Patuxent or the field substations (ibid.).

The ecology section has responsibility for all of the field work for the

center. Its duties include censusing and mapping populations, investigation of ecological and behavioral characteristics of species, formulation of management plans from research data, handling of restocking of animals to the wild, and conducting follow-up studies of such restockings. This section is also responsible for gathering data on endangered and threatened species such as the California condor, masked bobwhite quail, Florida Everglades kite, ivory-billed woodpecker, dusky seaside and Cape Sable sparrows, southern bald eagle, and black-footed ferret.

The propogation section is responsible "...for developing breeding stocks and devising efficient methods of producing animals for release to bolster or restore wild populations" (Erickson, op. cit., p. 422). The rationale for captive breeding is: (1) animals that can be successfully raised in captivity should significantly exceed their normal production rates in the wild because of the reduction in natural types of mortality which are not present in captivity, and (2) maintenance of a breeding stock serves as a measure of insurance against extinction of a species by some unexpected catastrophic loss. The number of bird and mammal species with breeding stock at Patuxent now totals sixteen of which seven are endangered (Erickson, 1977).

Captive stock is obtained from the wild so as to have minimal effect on the population from which it is removed. For populations in precarious situations, preliminary trials are conducted on closely related but more abundant species. For example, Andean condors are substituted for California condors, other species of sandhill cranes for whooping cranes, and South American snail kites for Everglades kites. Nine of the sixteen species of captive stock at Patuxent are such surrogate species (ibid.). The captive breeding program is not intended to replace a species' breeding in the wild but rather to supplement it with healthy captive stock.

Success in captive propagation has been experienced with the masked bobwhite quail, Aleutian Canada goose, and whooping crane. In 1968, predictions were than within ten years "...more than 50 species, threatened and otherwise, will be under study at Patuxent, and releases to the wild will be a normal, annual event" (Erickson, 1968).

Drury (1974) has theorized that, because different populations of a species tend to vary somewhat in their genetic composition, the number of sub-populations was more important than the total population size. He felt that isolation of a relict population would encourage further specialization. Therefore, he suggested that a first step in rehabilitating such species would be to break up large populations into subpopulations but not ones of complete independence. He felt that in a breeding program variability should be deliberately promoted and natural selection of suitable phenotypes allowed to progress. Turn-over between the breeding population and the wild is also encouraged.

The laboratory investigations section is charged with the following:

> ...studies of the basic biology of threatened wildlife species. It provides analytical, diagnostic and other consultative services for the other two sections. It also undertakes less applied studies which should contribute to a more complete understanding of the nature of those animals which are less successful in perpetuating themselves." (Erickson, op. cit., pp. 426-427)

The section maintains reference materials and employs specialists in such fields as nutrition, genetics, and pathology.

These three sections coordinate all of the research on threatened and endangered species at Patuxent.

Zoos

The International Union for the Conservation of Nature and Natural Resources (IUCN) listed 291 species of mammals endangered in 1972. Since 1962, 162 of the 291 have been reported in various zoo collections (Perry, Bridgewater,

and Horseman, 1972). The value of a zoo in an endangered species program is felt to be captive propagation of such species (Conway, 1969). Current increases in the number of individuals of a given species reported by zoos do not distinguish whether increases are due to captive breeding, transfer from another zoo, or capture in the wild.

Perry, Bridgewater, and Horseman (ibid.) report eight endangered species with a population of more than one hundred of which fifty percent were captively born are located in zoos. None are native to the United States.

Bridgewater (1972) reported that 62 of 340 worldwide endangered bird species were represented in zoo collections as well as those populations found in the wild. Of the 62 species, thirty bred one or more times in captivity with 24 of the thirty doing so with any frequency. Ten of the 62 species had a population size greater than 125 with fifty percent of the population captively born and present with breeding potential at a minimum of twenty institutions. None of the ten were native to the United States. What breeding success did occur was in the Anseriformes, Galliformes, and Psittaciformes.

In 1973, there were nine species of endangered United States birds and five of mammals in North American zoos (Perry and Kibbee, 1974). The corresponding figures for 1974 were the same for birds and one more for mammals (International Zoo Yearbook, 1975). In 1975, seven endangered mammal species and five bird species were found in zoos (International Zoo Yearbook, 1976). Smith (1972) criticized zoos for not completing the annual questionnaires on endangered species that the International Zoo Yearbook supplied thus leading to incorrect accounts of such species held in captivity.

Perry, Bridgewater, and Horseman (loc. cit.) summarized their views as follows:

On the record to date, zoos have not become a significant resource in

> the preservation of rare or endangered mammals. Seven species or subspecies (no U.S. species) endangered or extinct in the wild appear to have reasonably secure captive populations with potential for reintroduction. In a few other cases, favorable trends give promise of security in the near future. While these are important contributions, their number is small by comparison with IUCN's long and growing list.

Zoos often do not possess a policy of propagating such species but only one of exhibiting them. Zoos that desire to propagate such species might not have a male and female, the animals might be immature or beyond reproductive age, or the zoos might not possess natal facilities to care for newborn animals.

In 1974, Perry and Kibbee (loc. cit.) found that of 146 zoos in the United States each one's mammal collection had an average of 3.9 individuals with an excess of females. They state that it might be necessary to establish a cropping or transplanting program of excess females so as to reduce the number of species not endangered and provide space and facilities for endangered and threatened species at zoos.

Bridgewater (loc. cit.) feels that some of the more common species in zoos should be eliminated or decreased in numbers so that more space and natal facilities are available for endangered species. In essence, zoos must choose between a program to exhibit as many different species as they can or a program to propagate diminishing species.

North American zoos are presently dealing with endangered and threatened species through the International Species Inventory System (ISIS). This organization was founded in 1973, and it is a program by which participating zoos compile data on the types and numbers of animals they have in their collections. This information is stored in a computer located at the Minnesota Zoological Garden offices. The fundamental goals of ISIS were initially to "...provide a continuing census and to collect vital statistics on wild animals held in captivity with special emphasis on exotics and endangered species" (Seals et. al., 1974).

The initial effort was to census all mammal collections. Participating zoos in the United States, Canada, and Europe numbered 110 as of March 8, 1978. The operating budget of approximately $55,000 per year is derived from individual zoos, the American Association of Zoological Parks and Aquariums, and the Office of Endangered Species (Olsen, 1978).

Information is stored on each individual specimen in a given zoo: individual identification, pedigree, place of birth or capture, sex, age, any zoo transactions involving the particular animal, hybrid status, death and autopsy information, studbook identification, marine mammal permit numbers, any quarantines undergone, endangered species permit numbers, price, and color phase. Egg data is recorded for birds.

ISIS also has the capability of storing information on physiological norms established by zoo veterinarians. Life history data can also be stored that includes behavioral data, management procedures, growth statistics, and husbandry information.

The ISIS program is dependent upon the number of zoos that participate and actively work to keep their inventory updated. If this is done, zoos can receive computer printouts of other zoos' inventories and attempt to match breeding pairs or exchange data for research purposes. ISIS records indicate that slightly over fifty percent of its members fully participate in the program at this time (ibid.).

National Wildlife Refuges

In 1903, President Theodore Roosevelt set aside an area on Florida's east coast to protect a colony of herons and pelicans that nested there. This became Pelican Island and was the first national wildlife refuge established in this country. Today, over 370 refuges totaling 32 million acres are in the

system (U.S. Department of Interior, 1975a).

The National Wildlife Refuge System is administered by the Department of Interior through the Fish and Wildlife Service. Authority to obtain refuge lands for migratory waterfowl was granted by the Migratory Bird Conservation Act of 1929. The Fish and Wildlife Act of 1956 authorized the acquisition of land for the conservation and protection of all kinds of wildlife. The Endangered Species Preservation Act of 1966 provided for refuges to protect vanishing wildlife and consolidated all of the refuges under the National Wildlife Refuge System.

All national wildlife refuges are maintained and managed:

> ...for the primary purpose of developing a national program of wildlife and ecological conservation and rehabilitation. These refuges are established for the restoration, preservation, development and management of wildlife and wildlands habitat; for the protection and preservation of endangered or threatened species and their habitat; and for the management of wildlife and wildlands to obtain the maximum benefits from this resource. (U.S. Department of Interior, 1975b)

At least 137 refuges covering 39 states encompass parts of the range of one or more endangered or threatened species of mammals, fish, birds, or reptiles. Records indicate that 44 endangered species occupy refuge lands (U.S. Department of Interior, 1976).

The Fish and Wildlife Service also administers 1,370,766.2 acres of wetlands known as waterfowl production areas. These are small marshes or potholes suitable as waterfowl habitat. They are located in the states of North Dakota, South Dakota, Minnesota, Nebraska, and Montana. Fifty-nine areas totaling 436 thousand acres and designated as coordination areas have been conveyed to various states. These are federally owned lands that the states manage for wildlife or other related uses.

Wildlife refuges do not protect mammals and birds alone. All refuges harbor a variety of plants and animals. In addition, many also contain historical

and scenic sites not to be found elsewhere. Refuges are open to visitation as are the national forests and national parks.

Many refuges cut and sell timber or hay or bring in other revenue in the course of managing the wildlife they contain. These revenues are shared with local governments.

Table 6.1 summarizes the major purposes for which refuges have been established:

Table 6.1

Management Purposes of Refuges
(U.S. Department of Interior, 1975b)

Purpose	No. of units	Acreage
Migratory birds (waterfowl)	275	4,012,797.9
Migratory birds (general)	68	4,324,884.2
Big game areas	16	7,647,624.4
National game ranges	4	2,393,801.0
National wildlife ranges	4	13,690,910.4

Sullivan and Shaffer (1975) have suggested that it might be better to preserve an area of each different type of habitat and all organisms associated with it rather than establishing an area for the preservation of one particular species. They suggested that the habitat might be classified using Kuchler's (1960) potential vegetation types for North America. They also suggested that a transition size exists for a preserve. An area less than this minimum size is more likely to act as an island while one larger than the minimum size acts as a mainland. Extinction rates would be expected to be higher in the smaller area as discussed in the theory on island biogeography in Chapter 4. They went on to suggest that an examination of the space requirements of rare, large-bodied carnivores would be a good beginning from which to determine an area's transition size.

Most of the large preserves and refuges are in the western United States. Sullivan and Shaffer also suggested that the design of preserves should include several levels of preserves encompassing as much biological diversity as possible. First and second level preserves might be designed to support large carnivore populations. Lower level preserves might be designed to serve as corridors or "stepping-stones" along which species might move. This idea of corridors and stepping-stones is somewhat similar to Diamond's (1975) thoughts on designing natural preserves which were discussed in the section on island biogeography in Chapter 4.

National Forests

There are 140 national forests in the forty-eight contiguous United States and Alaska. These forests are geographically grouped into nine regions--Northern, Rocky Mountain, Southwestern, Intermountain, California, Pacific Northwest, Eastern, Southern, and Alaska. In addition, there are two forest labs, two forest institutes, and eight forest and range experiment stations found within these forests (U.S. Department of Agriculture, 1975).

The Agricultural Appropriation Act of May 23, 1908 (35 Stat. 251, 255; 16 U.S.C.§ 553) provided that the U.S. Forest Service help enforce all laws for the protection of fish and wildlife. Management objectives regarding endangered and/or threatened species have been outlined in the Forest Service Manual. The Forest Service is to establish fish and wildlife habitat as the primary use of land that is essential to the continued survival of endangered and/or threatened species (Forest Service Manual 2603.3, September 1974, Amend. 18). Section 2613.17 of the Manual (May 1975, Amend. 22) instructs the Forest Service to cooperate with the Fish and Wildlife Service in determining critical habitats in their forests and also states that an evaluation be made by the appropriate forest

supervisor as to whether these areas ought to be set aside as threatened or endangered species' areas (Forest Service Manual 2633.4, June 1975, Amend. 23). All regional foresters are to establish minimum management plans for such species in consultation with the Fish and Wildlife Service (Forest Service Manual 2624.4, February 1975, Amend. 21).

A summary of threatened and endangered species in each of the national forest regions is summarized in Table 6.2. The species in the table group into nine endangered species of mammals, twelve endangered species of birds, three endangered species of reptiles or amphibians, and eight endangered and three threatened species of fish (Petoskey, 1976).

Table 6.2

Distribution of Endangered and Threatened Species in National Forest Regions (Petoskey, 1976)

Region	No. endangered species	No. threatened species
Northern	3	0
Rocky Mountain	2	0
Southwestern	9	1
Intermountain	4	2
California	8	2
Pacific Northwest	2	0
Eastern	-	-
Southern	11	0
North Central	4	0

In 1960, the Multiple Use-Sustained Yield Act was passed. This piece of legislation recognizes and attempts to develop in harmony all of the resources of national forests--timber, rangeland, water, recreation, and wildlife. Wildlife began to receive a greater share of attention and effort during this time.

The Rocky Mountain region has management programs dealing with the

endangered greenback cutthroat trout, American peregrine falcon, and black-footed ferret (Minow, 1976). These programs involve restocking of greenback cutthroat trout from national forest streams to streams in the Rocky Mountain National Park, surveys in the Pike National Forest of Colorado for suitable nesting sites for the American peregrine falcon, and surveys of grassland areas in the region for black-footed ferrets and management of prairie dog towns to assure maintenance of black-footed ferret habitat.

The Eastern Region has outlined management plans for three nationally endangered species. The respective species are discussed in the following three paragraphs (Forest Service, Eastern Region, 1973).

Michigan has undertaken a management program for the Kirtland's warbler which involves annual surveying and censusing of populations, controlled burning of certain jack pine stands, and controlling cowbird parasitism. The five year cost is projected at $60,000.

Missouri, Indiana, Illinois, and West Virginia have proposed management programs for the Indiana bat. This program is integrated with plans for cave management in these areas. The proposed five year budget for surveying of caves for the presence of this bat is $91,000.

Minnesota and New Hampshire have proposed a five year budget of $16,000 to study the American peregrine falcon. This money is marked for the inspection of former aeries each year during the breeding season.

Only programs involving federally listed endangered and/or threatened species for two national forest regions have been mentioned. However, individual forests also have current or proposed management programs for species that are unique to their area but not classified nationally.

National Parks

On March 1, 1872, President U.S. Grant signed a bill that created

Yellowstone National Park in northwestern Wyoming, the first of its kind anywhere in the world. Today national parks, monuments, and natural areas are administered by the National Park Service of the Department of Interior. These areas are summarized in Table 6.3.

Table 6.3

Areas Administered by the National Park Service
(U.S. Department of Interior, 1975)

Type area	No. of units	Acreage
National parks	37	15,566,855.73
National monuments	35	9,606,690.59
National preserves	2	669,550.00

The 287 areas administered by the National Park Service can be divided into four general categories: natural areas, historical areas, recreational areas, and national capital parks. This report will deal with the natural areas. A natural area "...must be an expanse or feature of land or water of such scenic and scientific value and quality as to be worthy of preservation as a national park, national monument, or national preserve" (U.S. Department of Interior, National Park Service, 1975). These areas must contain the following:

> ...one or more distinctive attributes such as forest, grassland, tundra, desert, estuary, or river systems. They may contain "windows" on the past for a view of geological history, imposing landforms such as mountains, mesas, thermal areas, and caverns, and they may be habitats of abundant or rare wildlife and plant life. (ibid.)

The Index of the National Park System and Affiliated Areas defined a national park, national monument, and national preserve as follows:

> 1. "A national park covers a large area. It contains a variety of resources and encompasses sufficient land or water to ensure adequate protection of the resources. Chosen primarily for scenic and scientific values, all the national parks but one are natural areas. [Mesa Verde National Park in Colorado is the one exception.]

2. "A national monument is intended to preserve at least one nationally significant resource. It is usually smaller than a national park and lacks its diversity of attractions. [Dinosaur National Monument in Utah is an example.]

3. "National preserve is...a new category of natural areas established primarily for the protection of certain resources. Activities such as hunting and fishing or the extraction of minerals and fuels may be permitted if they do not jeopardize the natural values." [Big Cypress in Florida and Big Thicket in Texas are examples.]

Over the years, it has been the philosophy of the national parks to protect wildlife. In 1963, an advisory committee to then Secretary of Interior Udall was headed by Aldo Leopold. Their recommendations follow:

1. The goal of managing the national parks and monuments should be to preserve, or where necessary to recreate, the ecologic scene as viewed by the first European visitors. As part of this scene, native species of wild animals should be present in maximum variety and reasonable abundance. Protection alone, which has been the core of Park Service policy, is not adequate to achieve this goal. Habitat manipulation is helpful and often essential to restore or maintain animal numbers. Likewise, populations of animals themselves must sometimes be regulated to prevent habitat damage; this is especially true of ungulates.

2. Research programs on management should be expanded and placed under the authority of the National Park Service.

3. Populations should be regulated by predation and other natural means as much as possible. Artificial means should be used only when natural ones do not suffice.

4. The Park Service should cooperate closely with state fish and game departments in managing populations that might migrate outside of the parks.

5. Excess game animals that do not migrate from the parks should be removed.

6. Harvesting of excess game animals in parks should be done by park personnel or people trained by park personnel for that service.

The Service's policy is to "...address all known endangered species and their related habitat when planning and implementing park programs. In turn, only if no adverse effect on such a species will occur, will the program be implemented in the species habitat." (Guse, 1976)

Endangered Species Program for Kansas

The state of Kansas recognizes two categories of wildlife facing possible

extinction--endangered and threatened. As defined in the Nongame and Endangered Species Conservation Act (1975 Supp., K.S.A. 32-501--32-570, L. 1975), endangered means "...any species of wildlife whose continued existence as a viable component of the state's wild fauna is determined to be in jeopardy." That term also includes any species on the official Federal Register listing of national species that might reside permanently, temporarily, or migrate through the state.

Threatened was defined by the same law to mean "...any species of wildlife which appears likely, within the foreseeable future, to become an endangered species." The same conditions regarding federally listed species still apply.

The Nongame and Endangered Species Conservation Act, passed and signed into law in 1975, made it unlawful to export any threatened or endangered species from the state or to possess, sell, or carry any such species, dead or alive, out of the state. If any pallid sturgeon is caught by hook and line, no crime will have been committed if the fish is immediately returned to the water from which it was caught.

Any violations involving a threatened species are class C misdemeanors punishable by a maximum fine of $500 and/or one month in jail. Any violations involving an endangered species are class A misdemeanors punishable by a maximum fine of $2,500 and/or one year in jail. Authority for administering and enforcing the law is vested in the Kansas Forestry, Fish, and Game Commission.

Provisions were made in the law for acquiring critical habitats, and the governor was authorized to review all programs administered by him to see that they further the intent of the law.

A species can be declared endangered or threatened because of any of the following reasons: (1) destruction or modification of habitat or range; (2) overhunting or overcollecting for any purpose; (3) disease or predation; (4) inadequate regulatory mechanisms; or (5) the presence of any natural or manmade factors

affecting continued survival of a species.

The Commission's fish and game budget for fiscal year 1976 was $6,744,244. Of that amount, $20,000 was estimated to be spent on the endangered species program (Ward, 1975).

In the summer of 1975, the Commission entered into a contract with Kansas State Teachers College at Hays to document the existence of the black-footed ferret in the state through the summer of 1977. The initial budget for the project was $2,400 (Hlavachick, 1977).

The Soil Conservation Service and the Conservation Committee of the Kansas Academy of Science published a list of fishes (1974), amphibians and reptiles (1974), mammals (1974), and birds (1975) that were declining in numbers across the state. They used six classifications: endangered, threatened, endangered in Kansas but not nationally, threatened in Kansas but not nationally, such species with peripheral populations in Kansas, and extirpated. These lists were consolidated into a booklet in March of 1974 entitled Rare and Endangered Animals of Kansas published by the Kansas State University Cooperative Extension Service.

With the passage of the Nongame and Endangered Species Conservation Act, the fish and game commission established various committees to review and make recommendations on various species. These committees have and still are reviewing the 1974-1975 lists and hope to arrive at an approved list soon.

General Management Considerations

With the passage and signing of the Endangered Species Act of 1973, threatened and endangered species were given protection by law. This means no open hunting season for any of these species.

The Fish and Wildlife Service's 1973 "red book" edition has described

protective measures that have already been taken on some of these species as well as measures that have been proposed. The principal means of managing these species has been and still is preservation, acquisition, and/or manipulation of habitat. Critical habitat is protected and acquisition of it provided for under Sections 3 and 4 of the Endangered Species Act of 1973.

Another means of management frequently mentioned has been captive propagation. This is done with the intention of maintaining a breeding stock and being able to successfully transplant or restock individuals to suitable habitat.

Basic research and data gathering on natural histories and behavioral patterns have been implemented. Without background data or reference data, the effects of a management plan are difficult to assess.

Basic research, legal protection, habitat acquisition and management, and captive breeding are the main areas of thrust in current endangered species programs. Other methods such as control of pollution (especially pesticides), predation, and competition are used but less frequently.

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APPENDIX

LIST OF SCIENTIFIC NAMES

Following are the scientific names of species mentioned in this report. The genus name is listed first followed by the species and subspecies name. The status classifications are based on the July 14, 1977 listing in the Federal Register (Vol. 42, No. 135). Status abbreviations are as follows: Ex=extinct, E=endangered, T=threatened, and S=stable (not endangered or threatened).

Common Name	Scientific Name	Status
Birds:		
Auk, great	Pinguinus impennis	Ex
Condor, Andean	Vultur gryphus	E
Condor, California	Gymnogyps californianus	E
Cormorant, great	Phalacrocorax carbo	S
Cowbird, brown-headed	Molothrus ater	S
Crane, Mississippi sandhill	Grus canadensis pulla	E
Crane, whooping	Grus americana	E
Curlew, Eskimo	Numenius borealis	E
Duck, mallard	Anas platyrhynchos	S
Duck, Mexican	Anas diazi	E
Eagle, golden	Aquila chrysaetos	S
Eagle, northern bald	Haliaeetus leucocephalus alascanus	S
Eagle, southern bald	Haliaeetus leucocephalus leucocephalus	E
Falcon, Arctic peregrine	Falco peregrinus tundrius	E
Falcon, American peregrine	Falco peregrinus anatum	E
Falcon, prairie	Falco mexicanus	S
Gyrfalcon	Falco rusticolus	S
Goose, Aleutian Canada	Branta canadensis leocopareia	E
Hen, heath	Tympanuchus cupido cupido	Ex
Kite, Everglades	Rostrhamus sociabilis plumbeus	E
Kite, South American snail		
Parakeet, Carolina	Conuropsis carolinensis carolinensis	Ex
Pelican, brown	Pelecanus occidentalis	E
Pigeon, passenger	Ectopistes migratorius	Ex
Prairie chicken, Attwater's	Tympanuchus cupido attwateri	E
Quail, California	Lophortyx californicus	S
Quail, masked bobwhite	Colinus virginianus ridgwayi	E
Robin	Turdus migratorius	S
Sandpiper, semipalmated	Ereunetes pusillus	S
Sandpiper, western	Ereunetes mauri	S

Common Name	Scientific Name	Status
Shag	Phalacrocorax aristotelis	S
Sparrow, Cape Sable	Ammospiza maritima mirabilis	E
Sparrow, dusky seaside	Ammospiza maritima nigrescens	E
Sparrow, Santa Barbara song	Melospiza melodia graminea	E
Tit, great	Parus major	S
Warbler, Kirtland's	Dendroica kirtlandii	E
Warbler, palm	Dendroica palmarum	S
Woodpecker, downy	Dendrocopos pubescens	S
Woodpecker, hairy	Dendrocopos villosus	S
Woodpecker, ivory-billed	Campephilus principalis	E
Woodpecker, pileated	Dryocopus pileatus	S
Woodpecker, red-bellied	Centurus carolinus	S
Woodpecker red cockaded	Dendrocopos borealis	E
Wren-tit	Chamaea fasciata	S
Mammals:		
Bat, Indiana	Myotis sodalis	E
Bear, grizzly	Ursus arctos horribilis	T
Bear, polar	Thalarctos maritimus	S
Cougar, eastern	Felis concolor cougar	E
Coyote	Canis latrans	S
Deer, Columbian white-tailed	Odocoileus virginianus leucurus	E
Deer, mule	Odocoileus hemionus	S
Deer, white-tailed	Odocoileus virginianus	S
Dugong	Dugong dugong	E
Elk	Cervus canadensis	S
Ferret, black-footed	Mustela nigripes	E
Fox, Arctic	Alopex lagopus	S
Fox, San Joaquin kit	Vulpes macrotis mutica	E
Ground squirrel, golden-mantled	Spermophilus lateralis	S
Ground squirrel, Richardson's	Spermophilus richardsonii	S
Hare, snowshoe	Lepus americanus	S
Lemming, brown	Lemmus trimucronatus	S
Lion, mountain	Felis concolor	S
Lynx, Bay (bobcat)	Lynx rufus	S
Lynx, Canada	Lynx canadensis	S
Manatee, Amazonian	Trichechus inunguis	E
Manatee, Floria (West Indian)	Trichechus manatus	E
Manatee, West African	Trichechus senegalensis	S
Moose	Alces alces	S
Muskrat	Ondatra zibethica	S
Otter, southern sea	Enhydra lutris nereis	E
Panther, Florida	Felis concolor coryi	E
Prairie dog, blacktail	Cynomys ludovicianus	S
Prairie dog, whitetail	Cynomys gunnisoni	S
Prairie dog, Utah	Cynomys parvidens	E
Pronghorn, Sonoran	Antilocapra americana sonoriensis	E
Rat, Morro Bay kangaroo	Dipodomys heermanni morroensis	E
Sheep, Dall	Ovis dalli	S
Squirrel, Delmarva fox	Sciurus niger cinereus	E
Squirrel, eastern gray	Sciurus carolinensis	S
Vole, meadow	Microtus pennsylvanicus	S

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THIS IS THE BEST IMAGE AVAILABLE.

Common Name	Scientific Name	Status
Vole, montane	Microtus montanus	S
Vole, red-backed	Clethrionomys spp.	S
Walrus	Odobenus rosmarus	S
Wolf, eastern timber	Canis lupus lycaon	E
Wolf, gray	Canis lupus monstrabilis	E
Wolf, Mexican	Canis lupus baileyi	E
Wolf, northern Rocky Mountain	Canis lupus irremotus	E
Wolf, red	Canis rufus	E
Reptiles:		
Alligator, American	Alligator mississippiensis	E[a], T[a]
Crocodile, American	Crocodylus acutus	E
Lizard, blunt-nosed leopard	Crotaphytus silus	E
Lizard, side-blotched	Uta stansburiana	S
Snake, San Francisco garter	Thamnophis sirtalis tetrataenia	E
Amphibians:		
Salamander, desert slender	Batrachoseps aridus	E
Salamander, Red Hills	Phaeognathus hubrichti	T
Salamander, Santa Cruz long-toed	Ambystoma macrodactylum croceum	E
Salamander, Texas blind	Typhlomolge rathbuni	E
Toad, Houston	Bufo houstonensis	E
Fish:		
Alewife	Alosa pseudoharengus	S
Bass, black	Micropterus spp.	S
Bloater, small	Coregonus hoyi	S
Carp	Cyprinus carpio	S
Catfish, channel	Ictalurus punctatus	S
Cisco, longjaw	Coregonum alpenae	E
Darter, snail	Percina tanasi	E
Goldfish	Carassius auratus	S
Killifish, Pahrump	Empetrichthys latos	E
Molly	Poecilia spp.	S
Mosquitofish	Gambusia affinis	S
Pike, blue	Stizostedion vitreum glaucum	E
Pupfish, Devil's Hole	Cyprinodon diabolis	E
Pupfish, Owen's River	Cyprinodon radiosus	E
Pupfish, Tecopa	Cyprinodon nevadensis calidae	E
Pupfish, Warm Springs	Cyprinodon nevadensis pectoralis	E
Smelt, rainbow	Osmerus esperlantus	S
Trout, Arizona	Salmo apache	T
Trout, Gila	Salmo gilae	E
Trout, greenback cutthroat	Salmo clarki stomias	E
Trout, steelhead	Salmo gairdneri	S

[a]The American alligator is classified as endangered wherever it is found in the wild except in Florida and certain areas of Georgia.Louisiana (except in Cameron, Vermillion, and Caliseau parishes), South Carolina, and Texas where it is classified as threatened.

Common Name	Scientific Name	Status
Arthropods:		
Butterfly, Bahama swallowtail	Papilio andraemon bonhotei	T
Butterfly, El Segundo blue	Shijimiaeoides battoides allyni	E
Butterfly, Lange's metalmark	Apodemia mormo langei	E
Butterfly, Lotis blue	Lycaeides argyrognomon lotis	E
Butterfly, mission blue	Icaricia icarioides missionensis	E
Butterfly, San Bruno elfin	Callophrys mossii bayensis	E
Butterfly, Schaus swallowtail	Papilio aristodemus ponceanus	T
Butterfly, Smith's blue	Shijimiaeoides enoptes smithi	E
Mollusks:		
Snail, apple	Pomacea paludosa	S
Plants:		
Birch, Virginia	Betula uber	S
Broom, San Clemente	Lotus scoparius traskiae	E
Bushmallow, San Clemente	Malacothamnus clementinus	E
Camellia, milky	Stewartia malachodendron	S
Daisy, Panamint	Enceliopsis covillei	S
Dunegrass, Eureka	Swallenia alexandrae	S
Ice-plant	Mesembryanthemum spp.	S
Larkspur, San Clemente Island	Delphinium kinkiense	E
Liveforever, Santa Barbara	Dudleya traskiae	S
Lousewort, Furbish	Pedicularis furbishiae	S
Milk-vetch, Rydberg	Astragalus perianus	S
Monkshood	Aconitum noveboracerise	S
Monkshood, northern wild	Aconitum noveboracense	S
Paintbrush, San Clemente Island Indian	Castilleja grisea	E
Pine, jack	Pinus banksiana	S
Pine, loblolly	Pinus taeda	S
Primrose, Antioch Dunes evening	Oenothera deltoides howellii	S
Primrose, birds' eye	Primula spp.	S
Primrose, Eureka evening	Oenothera avita eurekensis	S
Rattleweed, hairy	Baptisia arachnifera	S
Rice, Texas wild	Zizania texana	S
Saxifrage, Forbes'	Saxifraga forbesii	S
Shooting star, French's	Dodecatheonmedia var. frenchii	S
Sulvania	Sullivantia renifolia	S
Trillium, persistent	Trillium persistens	S
Umbrella plant	Eriogonum spp.	S
Wallflower, Contra Costa	Erysimum capitatum var. angustatum	S

THE ECOLOGY AND MANAGEMENT OF THREATENED AND ENDANGERED SPECIES OF THE UNITED STATES

by

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A.B., Kansas Wesleyan University, 1969

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Division of Biology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

ABSTRACT

This report is an objective review of the ecology of threatened and endangered species of the United States (exclusive of Hawaii) and current practices used in managing such species. Legal authorization for the management of such species is discussed by a review of some key federal laws with a section-by-section summary of the Endangered Species Act of 1973. Terminology encountered in dealing with these species as well as the procedures for having a species classified as threatened or endangered are explained. Some of the current ecological thinking dealing with extinction is summarized. Examples demonstrating these theories are drawn from both endangered and non-endangered bird and mammal species. Reasons cited by various students of other animal classes and plants for their endangerment are reviewed in Chapter 5. The final chapter discusses some of the various management practices and philosophies currently used by various government agencies and private concerns. The endangered species program for Kansas is also outlined.