CLIMATIC CHANGE IN THE NATIONAL PARKS, WILDLIFE REFUGES AND OTHER DEPARTMENT OF INTERIOR LANDS IN THE UNITED STATES

Prepared by

Department of the Interior

May, 1997

Global Change and Department of the Interior Public Resources: A Summary.

Importance of DOI Lands

- Encompass large areas and wide range of landscapes and ecosystems throughout the United States and Territories
- Contain important natural resources used by the American public and vital to the economy through grazing, agriculture, mining, recreation, and tourism
- Protect unique and nearly pristine biological features, including rare species of plants, fish and wildlife, and unique ecosystems

Existing Stresses on Resources Exacerbated by Climate Change

- Increased development, and recreational and economic use demands
- Habitat fragmentation, especially in surrounding landscapes
- Air and water pollution
- Exotic species invasions
- Altered disturbance and hydrologic regimes
- Increased intensity of wildfire and other disturbances

Additional Potential Impacts of Climate Change

- Direct effects of sea-level rise on coastal DOI lands and melting of glaciers in mountain ecosystems.
- Increased intensity and frequencies of disturbances such as fire, floods, droughts, and hurricanes
- Accelerated spread of exotic species and disease
- Accelerated habitat and biodiversity loss
- Changes to fundamental ecosystem processes

Management Implications

- Develop tools and policies for managing frequencies and intensities of disturbance
- Expand efforts to curtail and mitigate exotic species and diseases
- Emphasize ecosystem approaches and actively enhance corridors and linkages
- Develop Adaptive Management policies
- Expand biological inventory, monitoring and research

May 12, 1997

Climatic Change in the National Parks, Wildlife Refuges and Other DOI Lands

Background

This document presents a brief overview of the lands and natural resources managed by the Department of the Interior (DOI) and of the human-induced stresses that impact these resources. With this as a framework, we overlay the predicted impacts of climate change on these lands and give some examples of resources vulnerable to these impacts. Given the current range of predictions regarding climatic changes, we conclude with some general implications for managing these public lands.

Although the magnitude and timing of potential climate change in parks, refuges, and other public lands is uncertain, generally accepted views on climate change effects at regional and global scales have been provided by The World Meteorological Organization/Intergovernmental Panel on Global Change (Watson et al. 1996). In brief, CO_2 levels have risen ~30% above pre-industrial (since 1860) levels, causing a mean surface temperature increase of 0.3-0.6 degrees C. With projected levels of increased emissions, global surface temperatures may rise 2 degrees C on average by 2100. The greatest changes in temperature are expected to occur in higher latitudes, (Peterson and Johnson 1995, Keeling et al. 1996). Eustatic sea-level has risen 10-25 cm in the last 100 years, and will likely rise another 15-95 cm (mid-range 50 cm) by 2100 (Watson et al. 1996). Vegetation simulation models, such as the Mapped Atmospheric-Plant-Soil-System (MAPSS; Neilson 1993) biogeographic model, suggest that vegetation may change significantly through out the nation under a double-CO_2 scenario (Fig. 1).

The climate changes that may take place over the next 100 years are of the same magnitude as the changes which occurred over thousands of years during the Pleistocene Era (Watson et al. 1996). The climate that has helped shape the vegetation and wildlife and other characteristics of the DOI lands is expected to shift, while the boundaries of the natural protected areas (parks, refuges, wilderness areas and other DOI lands) remain fixed. Some of these areas may be changed such that they are no longer capable of providing the habitat or environment or other functions for which they were originally established. Also, some lands may change in such a way as to enhance economic benefits and human values. However, it appears the basic vulnerability of DOI lands under these climatic conditions may be characterized by species that fail to migrate, fail to adapt, migrate to a less-protected environment, or are otherwise placed at a competitive disadvantage..

Our ability to assess potential vulnerabilities of specific DOI lands to predicted changes has been hampered by: (1) poor resolution, bias, and uncertainty of general circulation models and global vegetation simulations; (2) poor understanding of two-way interactions between atmospheric and land surface processes at local and regional scales; and (3) insufficient information on landscape- and ecosystem-scale changes on plants, animals, and ecosystem processes. Despite these uncertainties, there is strong agreement that natural systems are more vulnerable to climate change than cultivated/urbanized ones (OTA 1993). Furthermore, patterns of response to global change variables suggest that global change may affect DOI ecosystems through: sea-level rise and glacier retreat, altered disturbance frequency and intensity, accelerated spread of exotic species and diseases, accelerated habitat loss and loss of biodiversity, increased CO_2 and abnormal changes in the rates of ecosystem processes.

1. Current Resources and Stressors

National parks, national wildlife refuges and other public lands managed by the DOI protect a wide range of landscapes and ecosystems including mountains, deserts, grasslands, coniferous forests, deciduous forests, floodplains, wetlands and coastal areas (Fig. 2). These lands contain natural resources, wilderness, wildlife, and recreational opportunities for America and the world.

Whereas some DOI lands function as large ecosystems, others are heavily influenced by human activities and multiple stresses. Over 80% of the total land area in the National Wildlife Refuge System, over 50% of the land area in the National Park Service, and over 30% of the land area of the Bureau of Land Management is found in Alaska. Most of the state of Alaska is comprised of federal lands dominated by pristine boreal forest, tundra and coastal ecosystems.

In the northern Great Lake States some of the more pristine areas still retain much of their pre-settlement character and serve as havens for wildlife and wilderness recreation (e.g., Isle Royale National Park, Seney National Wildlife Refuge). Other ecosystems in the eastern and southern U.S. are still recovering from extensive logging during the past century and some are developing into mature forests. Parks and refuges along the Atlantic coast (e.g., Assateague and Cape Hatteras National Seashores, Chincoteague and Cape May National Wildlife Refuges) protect valuable coastal resources such as highly productive estuaries, which serve as the breeding and feeding grounds for a wide range of marine life, including economically important fish and shellfish. In addition, the coastal barriers provide valuable habitat to many songbirds, sea turtles, and other wildlife. The barrier islands also protect the coastline of the eastern U.S. from the effects of storm surges and severe weather.

Cypress and bottomland hardwood forests on DOI lands are a critical interface between terrestrial and aquatic systems. Hurricanes threaten some areas of the Gulf and Atlantic Coasts nearly every year, and mangrove and some hardwood forests of southeastern national parks (Everglades, Biscayne and Virgin Islands) have not recovered from recent hurricanes which destroyed vegetation, wildlife habitat, and park facilities.

Stressors common to nearly all DOI lands include: increased development in and adjacent to federal lands, increased recreational use, altered disturbance and hydrologic regimes (natural fire, flooding), grazing by livestock or concentrations of protected wildlife, habitat fragmentation at landscape scales which is often intensified at boundaries, air pollution, and exotic species invasion. Most DOI lands are embedded in diverse mosaics of heavily modified areas (e.g., cities, towns, roads, and areas used for agriculture, grazing, or forestry). Most of the major rivers and streams in the US contain dams and reservoirs for water supplies and hydroelectric power. As a result, the reduced magnitude and frequency of floods has greatly impacted native riparian vegetation, facilitating the spread and persistence of exotic species (e.g., tamarisk and Russian olive trees, warm-water fishes; (OTA 1993). Logging has converted most of the forestland outside of national parks in the lower 48 states to younger age classes, while agricultural practices and urban development have reduced functional wetland and riparian habitat. The existence of old-growth forests in Olympic National Park adjacent to thousands of acres of recent clearcuts clearly illustrates the vital role parks play in protecting natural systems from human impacts. More than 90% of California wetlands have been lost, making wildlife refuges and other protected areas critical for protecting migratory waterfowl and other species (USGS 1996). As urban areas encroach on wildlands, many forest ecosystems now have lower fire occurrence and increased fuel accumulation compared to the past few centuries due to fire exclusion.

Many ecological processes have been altered by land-use practices. For example, the Chesapeake Bay, the Nation's largest estuary, has experienced serious environmental degradation during the last century. The major environmental stresses in the region are from humans, linked to land use and highly populated urban areas. Coral reef ecosystems are threatened by nutrient enrichment from sewage and agriculture, over fishing, and stress from high sedimentation caused by deforestation, agriculture, vessel traffic, and coastal runoff (Jameson 1995). Over 40% of the plant species in Hawaii Volcano National Park are exotic species introduced by humans (Loope and Mueller-Dombois 1989). Nearly all DOI ecosystems are impacted to some degree by exotic plants and animals, visitor use developments, and recreational impacts.

2. Additional Impacts Imposed by Climate Change and Selected Examples of Vulnerabilities

Climate change poses additional stresses to DOI and surrounding lands. Although there is considerable uncertainty in current predictions, particularly at the regional and landscape scales, evidence suggests that human-induced climate change will affect DOI ecosystems through: sea-level rise and glacier retreat, altered disturbance frequency and intensity, accelerated spread of exotic species and diseases, accelerated habitat loss and loss of biodiversity, and abnormal changes in the rates of ecosystem processes.

a. Sea-level Rise and Glacier Retreat

Direct climate change effects on DOI ecosystems are sea-level rise and the retreat (melting) of glaciers. Sea-level rise is caused by changes in precipitation, temperature rise, and the indirect effects of higher levels of atmospheric CO_2 (Ellison 1996). Field and modeling research on gulf coastal wetland systems, parks, and refuges from Texas to Florida show that sea-level rise has impacted the health, distribution, and loss of marsh and forest communities (Doyle 1997). Regional models predict that sea level rise, increased tidal range and saltwater intrusion over the next century will result in the landward encroachment of aquatic ecosystems: low lying hardwood and pine forest communities will be replaced by marsh habitat and significant acreage of marsh will be replaced by open water.

The change in distribution and abundance of coastal habitat on DOI lands will involve a loss of functional habitat for wildlife and recreation in some areas and the possible creation of new opportunities in other areas. For example, relative sea-level increases, associated with local subsidence, hydrologic alteration, sedimentation deficits and other factors, threaten productive wetlands in wildlife refuges (e.g., Sabine, Bayou Sauvage) of southern Louisiana, where coastal marshes are eroding at the rate of 70 km^2 per year (Figs. 3 and 4). Although not solely the result of eustatic sea-level rise, the submergence of the Louisiana coast provides and excellent physical model of how seal-level rise related to global change would impact other areas. Gulf coastal forests of Florida's Big Bend, Central, and Key regions composed of slash pine and cabbage palms have experienced diebacks in recent decades from saltwater encroachment of increased tides and surges (Ross et al. 1992, Perry and Williams 1996, Doyle 1997). Predicted changes in coastal habitat along Apalachee Bay in northwest Florida at St. Marks National Wildlife Refuge based on a land elevation model indicates a nominal loss/gain of marsh as a result of upslope migration and a net loss of coastal forest habitat in connection with the increase in sea-level (Doyle 1997). Simulations of south Florida landscape changes indicate that a complex of federal lands will undergo vast shoreline digressions and habitat conversion that will reduce available land cover and habitat function under sea-level rise projections of 15-95 cm by the year 2100 (Doyle 1997).

Even a small increase in temperature will result in reduced areas of glacial ice, dramatically changing the nature of some alpine ecosystems. Long-term monitoring data from several Northwestern parks, including North Cascades National Park, which contains over half of the glaciers in the continental U.S., and Glacier National Park, show that glaciers have retreated significantly during the warmer climate of the twentieth century (Fig. 5).

b. Change in Disturbance Frequency and Intensity

Fire is an important component in many natural ecosystems. Fire suppression activities of the past 50-100 years (Ferry et al. 1995), has set the stage for extreme wildfires and rapid vegetation change during the next century. If fires are more common in the future, they initially could be larger and more intense, altering ecosystem structure and incurring increased costs for fire management and human safety. Patterns of succession may be atypical and species distributions may be less predictable given altered disturbance patterns, a rapidly changing climate, and competition from exotic species (see below). Insect and disease outbreaks may become more common in forests, killing more trees and further increasing the potential for wildfires. For example, fruit tree leaf roller infestations in southern baldcypress forests have become more common in forests that are stressed by subsidence in southern Louisiana (Goyer 1997). Repeated defoliation results in mortality of baldcypress saplings.

The greatest concern to southeastern coastal areas related to climate change is the prediction that storms will increase in intensity. Modeling studies suggest that increasing sea-surface temperatures increase the intensity of hurricanes (Emanual 1987). Recent examples in Everglades National Park, Florida and in the Virgin Islands illustrate the effects of hurricanes on coastal systems. The possibility of long-term changes in large-scale atmospheric circulation (e.g., the El Nino Southern Oscillation) could result in more frequent high-intensity storms that would degrade the coastal barrier, leading to the loss of vulnerable estuarine areas and increased destruction of property and public facilities. A hindcast simulation of hurricanes from 1886-1989 indicated that the periodicity and trajectories of a few intense storms accounted for most of the impact on modern day mangrove forests across south Florida (Doyle and Girod 1997). When storms are very intense, vegetation and hydrological systems can be sufficiently modified to cause a permanent shift from forested intertidal (mangrove) ecosystems to barren intertidal or subtidal mudflats (Ellison 1996). Barrier islands that protect coastal ecosystems and urban areas will also become more degraded if storm intensity increases. The size of Louisiana's barrier islands has already decreased by 55% over the past century and a variety of methods have been used to slow the rate of erosion; increased storm frequency and intensity will accelerate this rate of land loss, exposing wetlands on DOI lands to storm damage (Williams et.al 1997)

c. Accelerated Spread of Exotic Species And Diseases

A long-term change in climate may shift the competitive balance among plant species, with a warmer climate encouraging the growth of more drought-tolerant conifers and weedy species. Exotic plants, for example warm season and cold season grasses, are becoming adapted to a wide range of habitats on most DOI lands. Aside from replacement of native plant species, some of the grasses, such as Johnson grass, are noxious weeds and toxic to livestock and wildlife. There is increasing concern that many of the species are becoming adapted to a wider range of habitats outside their native country. Many scientists associate the range expansion of Chinese tallow tree in the southern U.S. with temperature rise. In addition, large inland bodies of water such as the Great Lakes, Lake Mead, Lake Powell, and the Salton Sea may have significant shifts in fish populations, with those species tolerant of warmer temperatures and more saline conditions better able to survive. Often these fishes are exotic species.

In the Intermountain West, where the Bureau of Land Management manages large tracts of public land, the invasion of exotic annual grasses threatens the integrity of many native shrub grassland ecosystems, which increases the frequency and intensity of wildfires. Along the Snake River in the Birds of Prey National Conservation Area, much of land has been converted from a native shrub grassland to an exotic annual grassland through a series of repeated wildfires (Fig. 6). A rapidly changing climate may further aggravate the problem where the exotic annual grasses mature and dry out earlier than the native grasses and are thus more easily ignited and susceptible to fire. The effect of increased CO_2 would likely change the competitive relationships of some range ecosystems in favor of some exotic grasses (Smith et al. 1987).

d. Accelerated Habitat Loss and Loss of Biodiversity

Competition for water between humans and natural systems is already high and may intensify with the added stress of accelerated climatic change. About 53% of the pre-settlement wetland area in the lower 48 states has been lost or converted to other uses (USGS 1996). Climate change is expected to accelerate the loss of wetlands and the biodiversity associated with them via the mechanisms discussed earlier (Watson et al. 1996). Wetland plant and animal communities along the shores of the Great Lakes (e.g., Indiana Dunes National Lakeshore, Ottawa National Wildlife Refuge) are closely related to groundwater hydrology, and will be altered if temperature increases and precipitation decreases. Wetlands on more-protected DOI lands will become increasingly important as refugia even as they are also altered and stressed by climate change. Coral reefs are extremely susceptible to additional stresses of climate change (including sea-level rise, increased sea-surface temperature and ultra-violet radiation effects) and their alteration is expected to greatly affect coastal fisheries and biodiversity (Watson et al. 1996). A recent change in the Northwest is a rapid increase in regeneration of forest communities at high elevations, thereby displacing meadows, altering wildlife habitat and potentially reducing recreational opportunities in popular parks such as Mt. Rainier (Fig. 7). The open forest areas of the forest-tundra ecotone in Rocky Mountain National Park are showing significant growth which is filling in canopy gaps and shading out tundra communities.

e. Species Distribution Changes and Local Extinctions

The climate changes that may take place over the next 100 years are about the same magnitude as the changes in the Pleistocene Era, which occurred over thousands of years (Watson et al. 1996). Thus, similar changes in species distribution are predicted, and local extinction may occur for those species that fail to migrate, fail to adapt, migrate to a less-protected environment, or are otherwise placed at a competitive disadvantage. Changes in species' distributions will be observed first at the limits of their current ranges (Stohlgren and Bachand 1997). For example, in a warmer climate, eastern white pine may become extinct at the southern limit of its distribution. In addition, increased stream temperatures, combined with higher atmospheric inputs of nitrogen, will alter the distribution and abundance of fish and other aquatic species in this region. Migration routes of caribou and waterfowl (e.g., in Denali and Gates of the Arctic National Parks and in Arctic National Wildlife Refuge) may be altered in response to habitat changes due to early snowmelt. Whales and seals may also shift their migration routes in response to ocean temperature changes and decreased extent of the Bering Sea ice. The distribution and abundance of salmon, which are sensitive to changes in water temperature, will almost certainly change in southern Alaska (Glacier Bay, Katmai, and Wrangell-St. Elias National Parks and Preserves) in a warmer climate with potential positive and negative effects on local fisheries. We know that bird species distributions are affected by temperature regulation and climatic adaptation (e.g., Martin 1997), but we do not know which species are most vulnerable upon migration from more-protected DOI lands or habitats, to less-protected lands and habitats.

Because unique habitats are imperiled, rare and threatened species associated with them are also a major concern. Species endangerment patterns in the U.S. reflect highly fragmented landscapes and habitats (Fig. 8) (Flather, et al. 1994). It is likely that climate change, land use change, and disruption of natural disturbance regimes will accelerate the local extinction of many species, but monitoring programs are few and predictive models at appropriate spatial scales are non-existent.

f. Changes in the Rate of Ecosystem Processes

A rapidly changing climate along with an increase in extreme weather events likely will affect ecosystem processes such as productivity, nutrient cycling, disturbance, herbivory, competition, and hydrologic processes. For example, a warmer, drier climate may result in less productive rangelands on millions of acres of land, thereby reducing their ecological and economic viability. In a drier climate, deep-rooted sagebrush will persist but not spread in grasslands; in a wetter climate, sagebrush will tend to replace grasslands, thereby reducing forage for cattle and some mammal and bird species. Lower soil moisture in some densely-stocked forests may produce sufficient stress to induce more frequent attacks by insect pests such as spruce budworm and fungal diseases in some species. Northern latitudes are predicted to have the greatest rates of temperature change (Watson et al. 1996). Some of the more northern forests, where organic matter tends to accumulate in soils, may produce an undesirable feedback where increased decomposition and altered nutrient cycling in a warmer climate results in a further increase in emissions of carbon dioxide to the atmosphere. Field experiments and observational studies are showing a change in the structure and composition of tundra plant communities in Alaska.

Some potential effects of climate change (e.g. extended growing seasons, enhanced rates of plant growth) will alter the structure of federally protected ecosystems. For example, tree growth may be enhanced by increased temperature and atmospheric CO_2 at the forest-tundra ecotone in mountain parks. However, this may have negative effects for many understory plant and animal species that require open, patchy habitats, cover or light penetration through the canopy. (Chapin and Shaver 1996, Keeling et al. 1996).

3. Implications for Management

DOI land managers are confronted with the difficult challenge of maintaining natural populations and ecosystems with very limited information and a host of uncertainties that may not be resolved for many years. Based on the current state of knowledge, there are five basic strategies for addressing the effects of global change on natural ecosystems.

a. Maintain or Restore Natural Disturbance Frequencies and Intensities

In forest ecosystems, it may be possible to modify fuel loadings with fuel treatments (e.g., prescribed burning) to reduce the intensity of future ignitions particularly in areas with the potential for large fires which may also present significant resource loss and ecosystem changes. Recent changes in USDA Forest Service and DOI fire management policy emphasize restoration of the natural role of fire in the ecosystem. This new policy will help resource managers address the difficult task of using fire as an ecological process in areas with differing land management objectives, and enable better preparation for fire-related impacts associated with extreme weather conditions and climate change. In dammed hydrologic systems, prescribed floods, like the one in the Grand Canyon in the early spring of 1996, should be used routinely to rejuvenate floodplains and aquatic and riparian habitats (Collier et al. 1997).

b. Enhance Migration Corridors and Use an Ecosystem Approach

If populations of sensitive plant and wildlife species limited to parks and refuges are displaced because of climate change, managers may seek to establish buffer zones and migration corridors (pathways that allow safe movement of species from one location to another) to continue to protect these sensitive resources to ensure long-term survival. Conflicts over natural resources among federal agencies, state agencies and local residents are already common and could become more common in the future if distributions of plants, wildlife and fish are altered. In many areas, it will be especially important to develop conservation strategies at large spatial scales that overcome or bypass barriers such as roads, cities, croplands, fragmented habitat, and other physical and biological obstacles. This means that federal agencies will need to cooperate increasingly with state and local governments and all other stakeholders and work to resolve these complex issues from a broad ecosystem perspective.

c. Increase Exotic Species Mitigation Efforts

The reestablishment of native species by improving the competitive advantage is a key approach to the mitigation of exotic species. Increased emphasis on developing biological controls and technologies which integrate biological, chemical and physical control technologies is needed. The selected application of fire is one important management tool that may be used effectively along with efforts to reduce the viability and spread of exotic species. Warmer stream temperatures, exacerbated by dams and water diversions, which can increase the competitive advantage of exotic fishes over native fishes, may be influenced by riparian vegetation that provides a protective cover from sunlight. Efforts to lessen disturbance, and nitrogen inputs, (including atmospheric deposition), should be considered to curb the establishment of exotic plants, particularly exotic grasses, which benefit from increased disturbance, and nitrogen inputs from air pollution. Mitigation efforts must be increased, and shifts from native to exotic species, and increases in native and exotic pathogens, must be carefully monitored.

d. Develop an Adaptive Management Philosophy

Despite the inherent uncertainties of climate change, land managers must view climate change as an additional stress to DOI and surrounding lands. Human activities have created ecological "islands" in a sea of contrasting land uses and management objectives. The public lands, which serve a wide range of public needs, also provide the setting for the study and practice of new adaptive ecosystem management concepts. Adaptive management is a management concept in which ecosystem responses to management actions are carefully monitored and evaluated and used to revise and direct future management approaches. These concepts are likely to provide the practical understanding for resource managers to be able to adapt and/or mitigate the impacts of future climatic change and other environmental stressors. For example, managing small tracts of lands (e.g., parks and refuges) for pre-settlement plant and animal communities may become increasingly difficult and impractical if temperature and precipitation changes force new plant and animal communities to be formed within these protected areas. Efforts should be made by federal agencies to increase the functionality and adaptability of their lands by working with other agencies and private landholders to protect habitat and wildlife on the boundaries of parks, wildlife refuges, and other DOI lands. Recent land acquisitions, conservation easements and water-allocation agreements associated with Everglades National Park are a good example of this approach.

e. Expand Natural Resource Inventory, Monitoring, and Research Activities

Successful natural resource management requires an integrated, science-based ecosystem inventory, monitoring, and research program. The DOI public lands, parks, refuges, and wilderness areas provide a wide range of natural laboratories well suited for studying the impacts of various stresses on ecosystems for testing and developing adaptive management strategies. Evaluating the biological and socio-economic effects of multiple stresses on DOI ecosystems demands a long-term commitment to interdisciplinary science. Within DOI lands, highly fragmented habitats (e.g., wetlands, tallgrass prairie), areas of high native diversity, sensitive habitats and those with distinct or endemic species assemblages deserve immediate attention. Rare and threatened native species also deserve special attention, especially in relation to altered disturbance regimes, climate change, and displacement by exotic species. Emerging climate change research programs in the DOI are using combinations of field observations, experimental manipulations, and predictive models to characterize ecosystem response to climate change and to develop management strategies for an uncertain future. The uncertainties associated with climate change present the Department with a significant challenge, and its greatest opportunity to preserve and protect some of America's most valued natural resources.

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MAPSS Simulated Vegetation Distribution

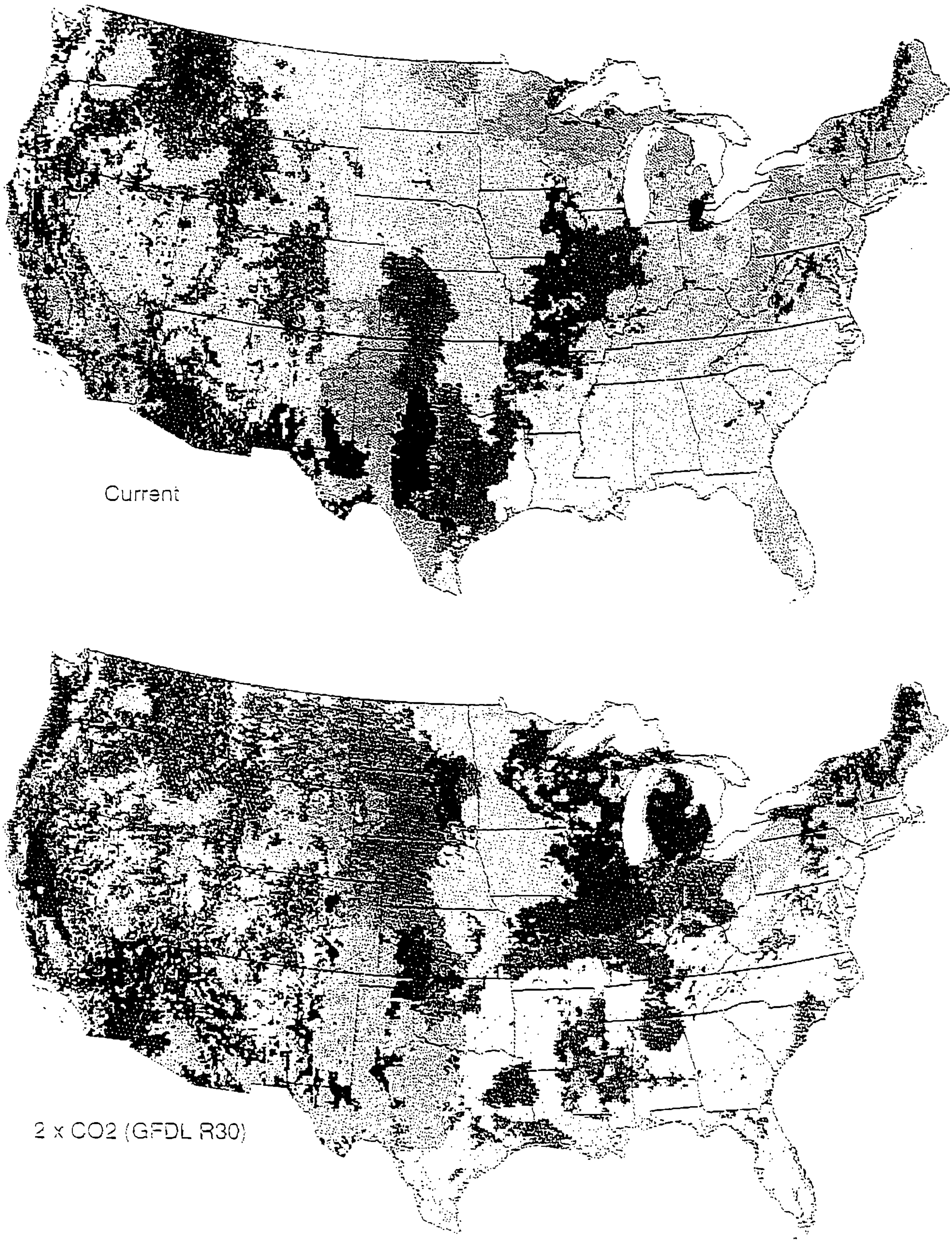

Figure 1. Distribution of different potential vegetation types within the United States as simulated by Mapped Atmospheric-Plant-Soil-System (MAPSS) biogeographic model. Note Changes in vegetation between current condition and a doubled-CO_2 climatic scenario. Ecosystems are predicted to change dramatically on most federal lands in the continental United States.

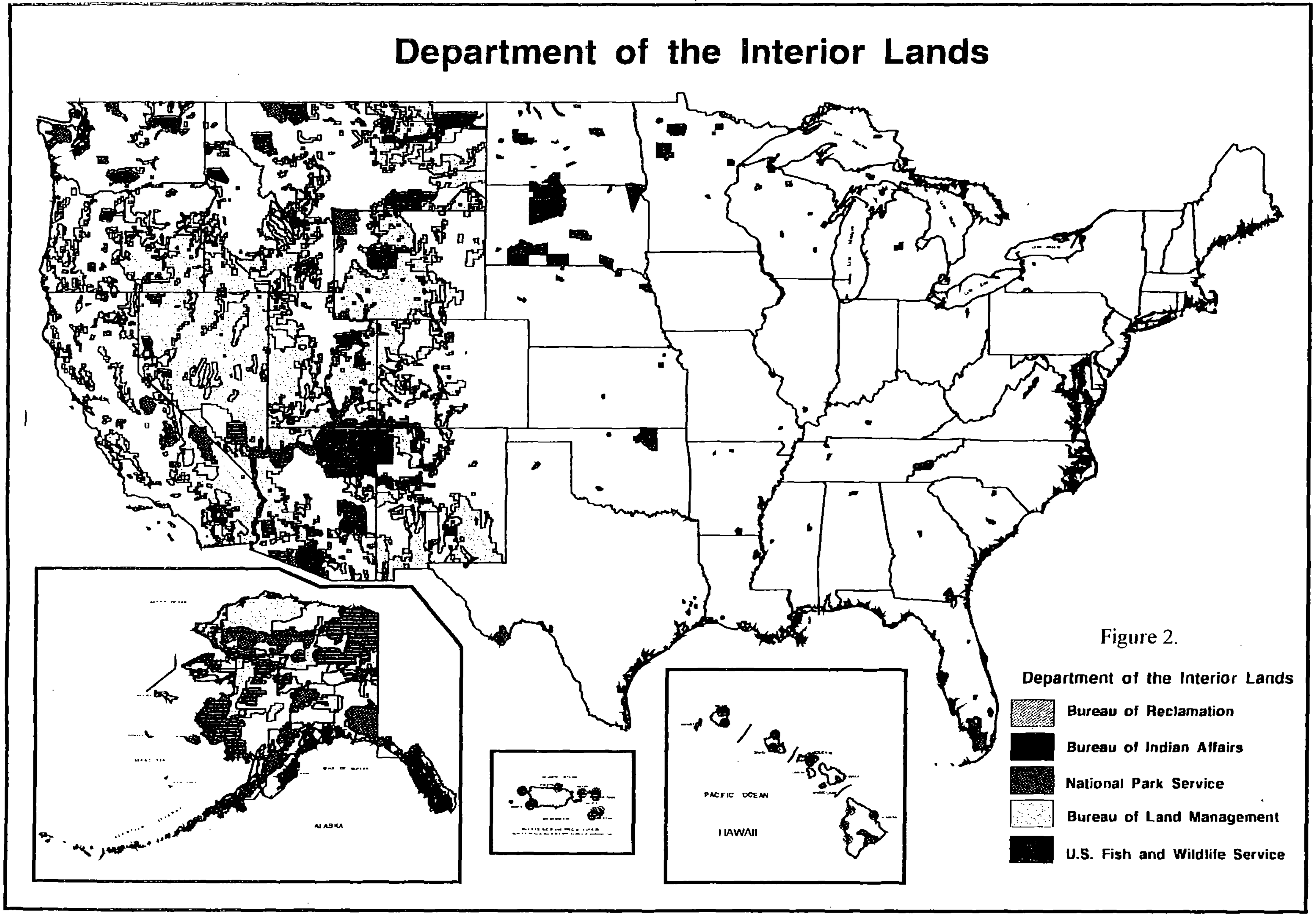
Department of the Interior Lands
ALASKA
PACIFIC OCEAN
HAWAII
Department of the Interior Lands
Bureau of Reclamation
Bureau of Indian Affairs
National Park Service
Bureau of Land Management
U.S. Fish and Wildlife Service

Figure 2.

LAND LOSS IN THE LOUISIANA COASTAL ZONE 1955/56 - 1978

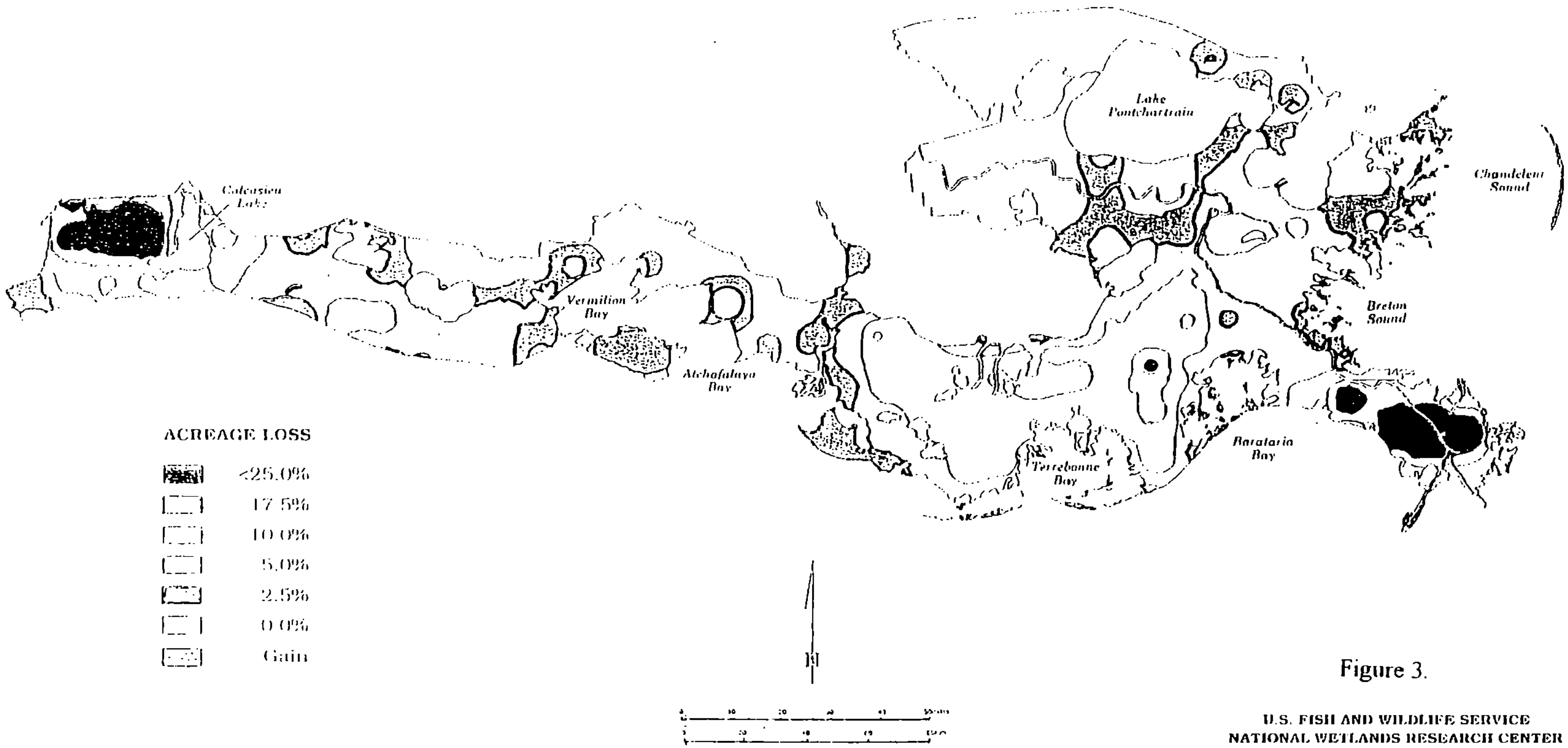

Figure 3.

U.S. FISH AND WILDLIFE SERVICE
NATIONAL WETLANDS RESEARCH CENTER
and
LOUISIANA DEPARTMENT OF NATURAL RESOURCES
COASTAL MANAGEMENT DIVISION

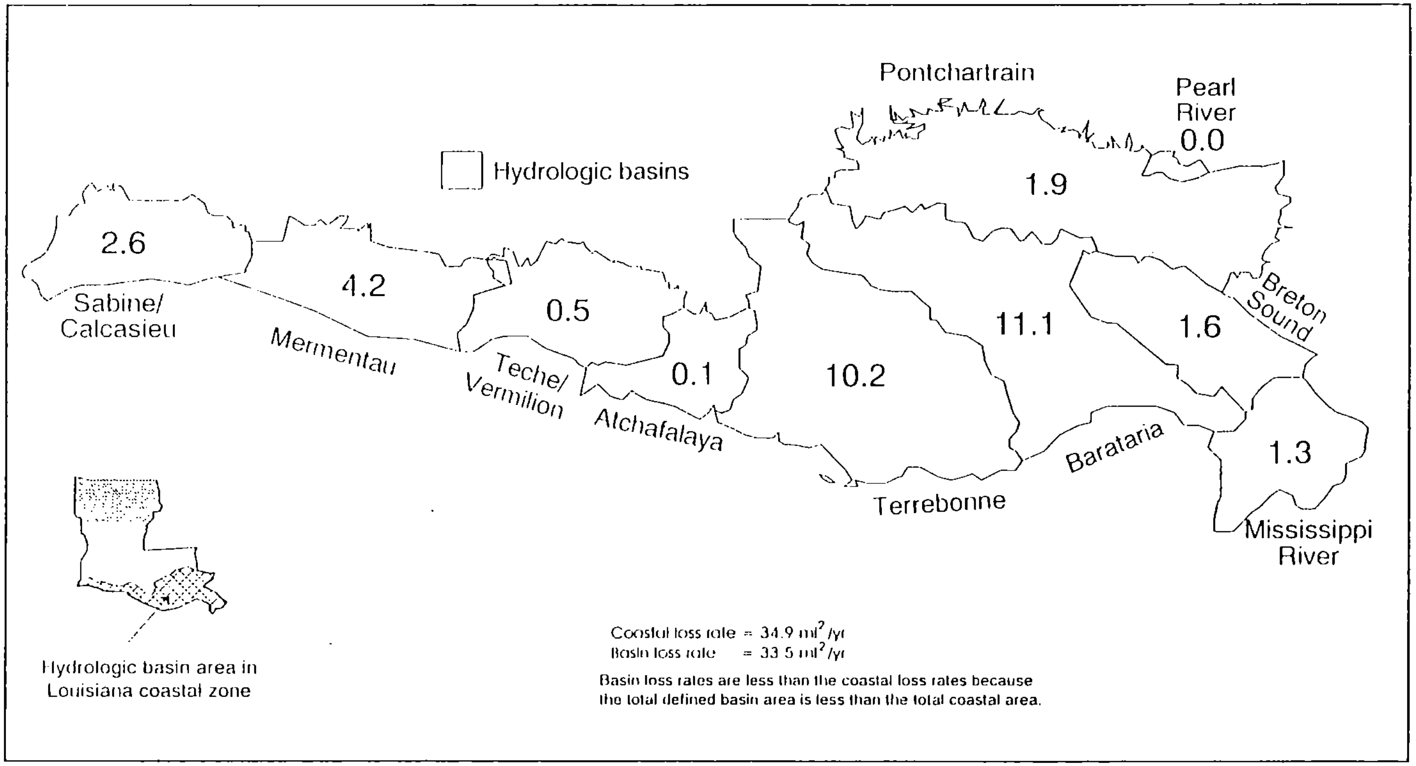

Figure 4. 1978-90 loss rates for coastal hydrologic basins (sq. mi/yr) and total coastal Louisiana.

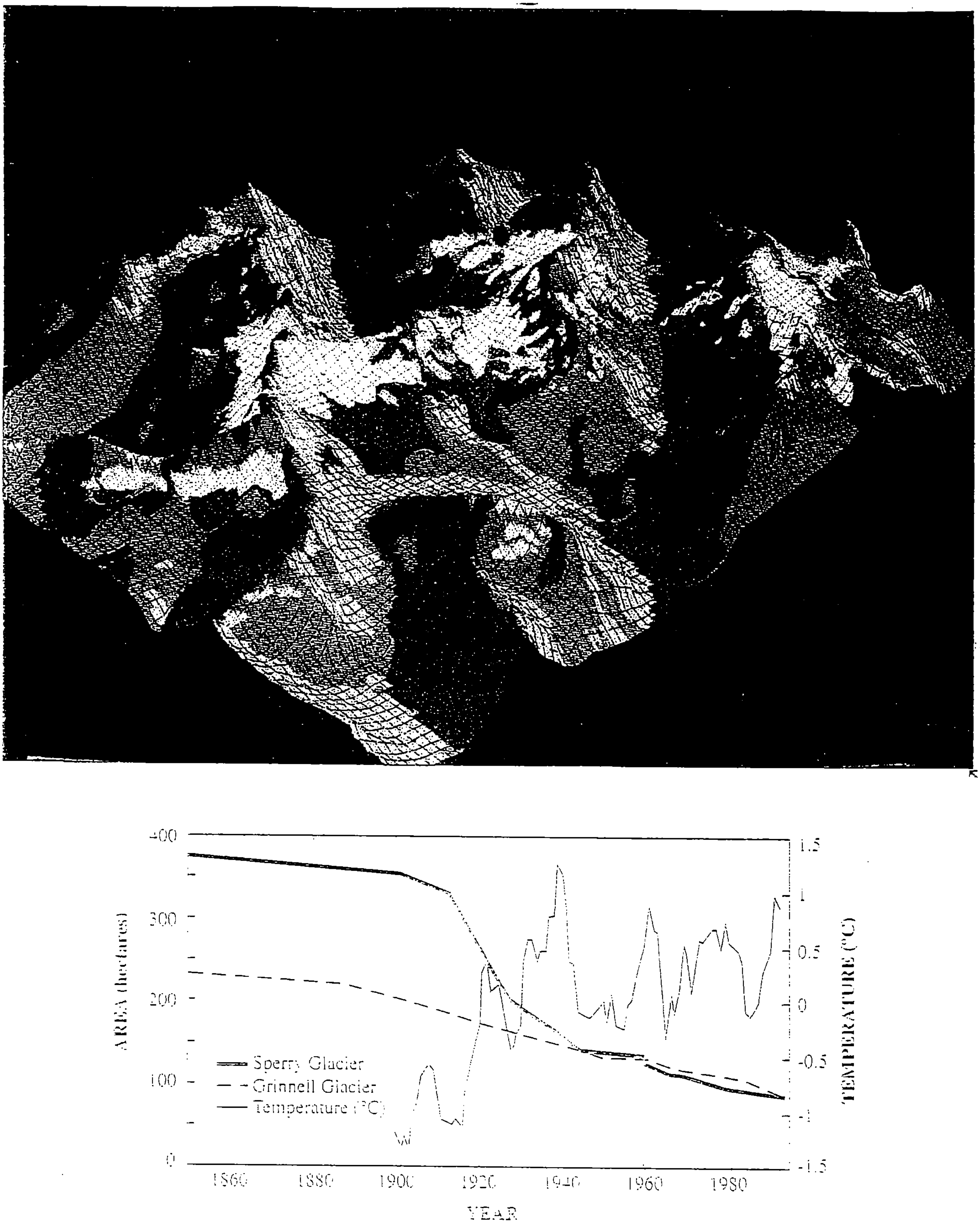

Figure 5. A geographic information system representation of glacier shrinkage from 1850 to 1993 in Glacier National Park. Yellow areas reflect current area of each glacier. Red and orange represent the previous extent of glaciers at various times in the past. Glacier area is strongly correlated with temperature, and further shrinkage could eliminate may alpine glaciers by 2030.

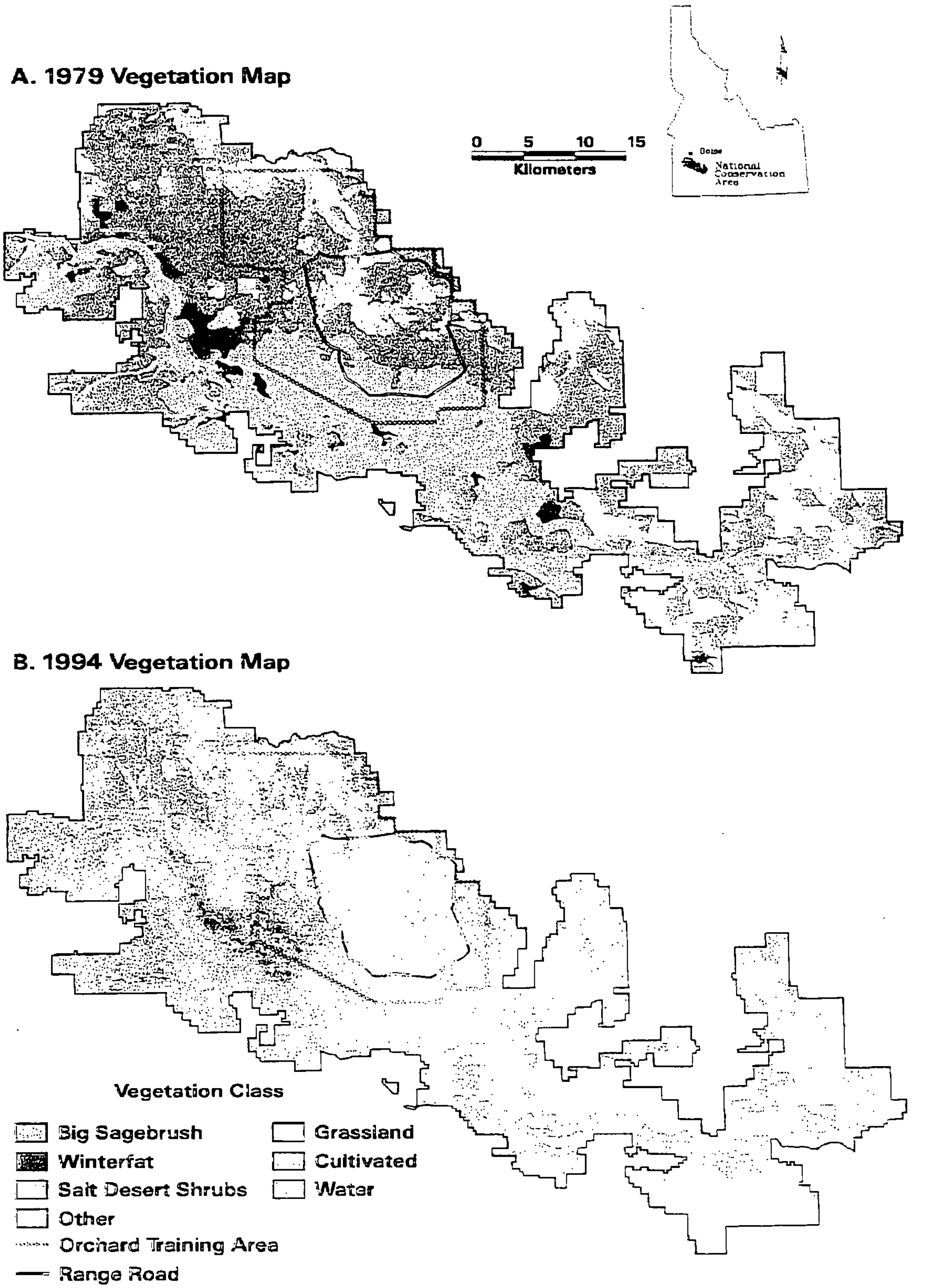

Figure 6. Vegetation changes in the Snake River Birds of Prey National Conservation Area from 1979 to 1994. Native shrubs and grasses have decreased substantially and exotic annual grasses have increased in dominance in a relatively short period of time. Changes in habitat may affect populations of birds and other wildlife.

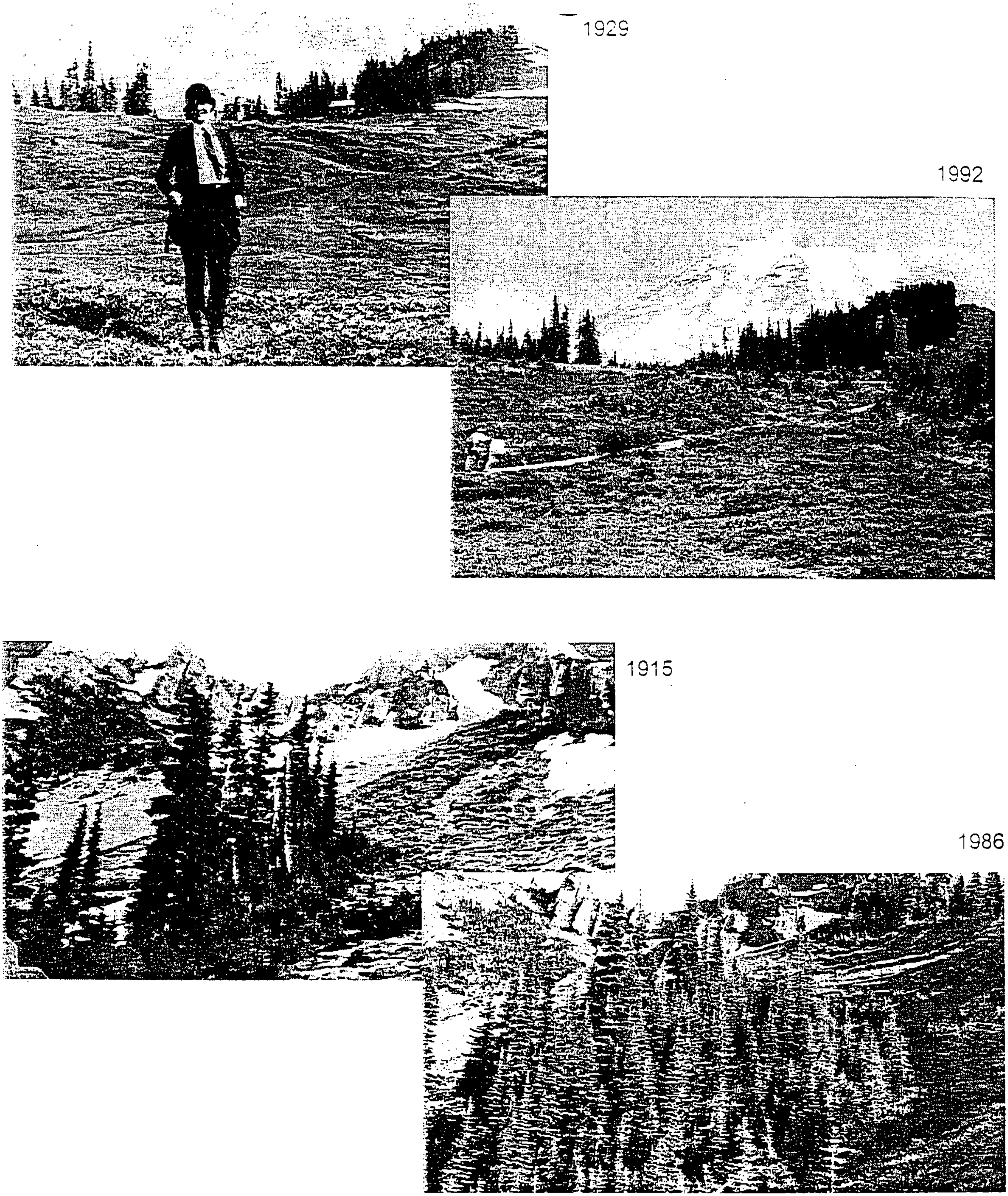

Figure 7. Paired photos of sites in Mt. Ranier (above) and Olympic National Park (below), showing recent tree establishment associated with a warmer, drier climate.

Figure 8. Regions of species endangerment in the conterminous US, based on numbers of endangered species by counties grouped according to similar climate, physiography, soils, vegetation, and land use.