Figures

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Figures for Chapter 1, Executive Summary

Figure 1.1. Map showing the geographic distribution in the United States of SAP 4.4 case studies.

Figures for Chapter 2, Introduction

Figure 2.1. Annual mean temperature anomalies 1901–2003. *Red shades indicate warming over the period and blue shades indicate cooling over the period. Data courtesy* [*NOAA's National Climatic Data Center*](). *Regions are: (1) Northeast, (2) Southeast, (3) Central, (4) South, (5) East North Central, (6) West North Central, (7) Southwest, (8) West, (9) Northwest, (10) Alaska,(11) Hawaii.*

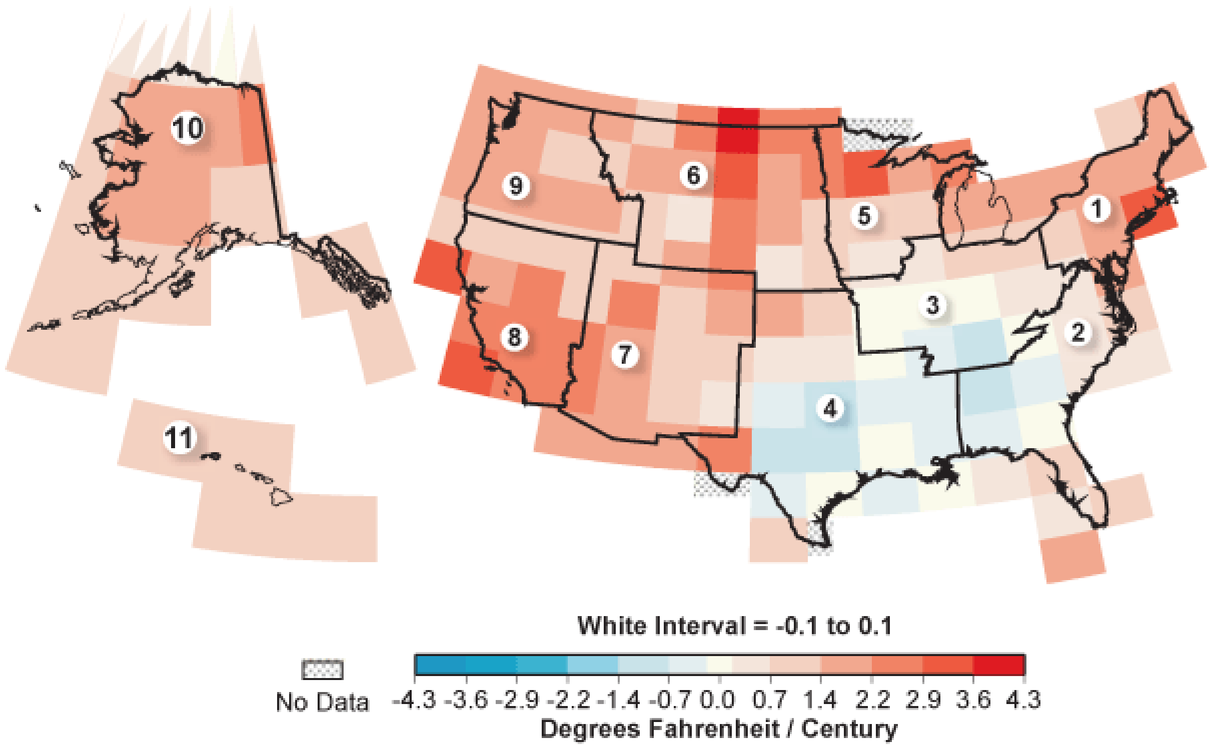


Figure 2.2. Annual precipitation anomalies 1895–2003. *Green shades indicate a trend towards wetter conditions over the period, and brown shades indicate a trend towards dryer conditions. Data courtesy [NOAA's National Climatic Data Center](). Regions are: (1) Northeast, (2) Southeast, (3) Central, (4) South, (5) East North Central, (6) West North Central, (7) Southwest, (8) West, (9) Northwest, (10) Alaska,(11) Hawaii.*

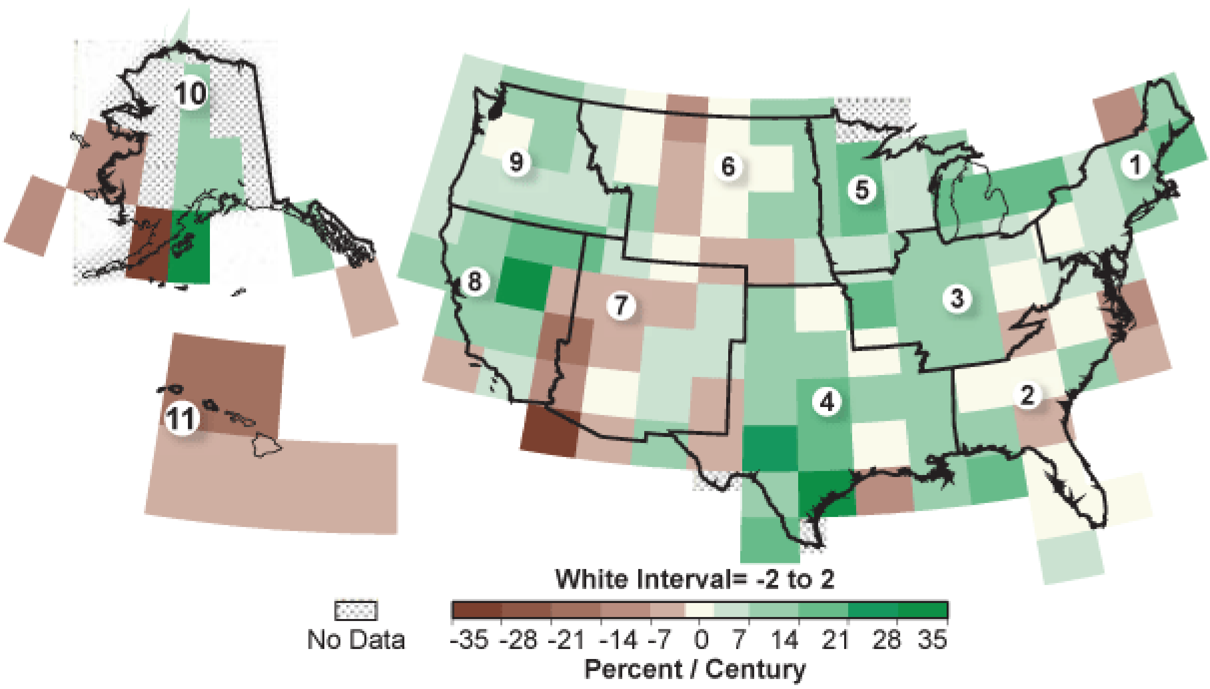
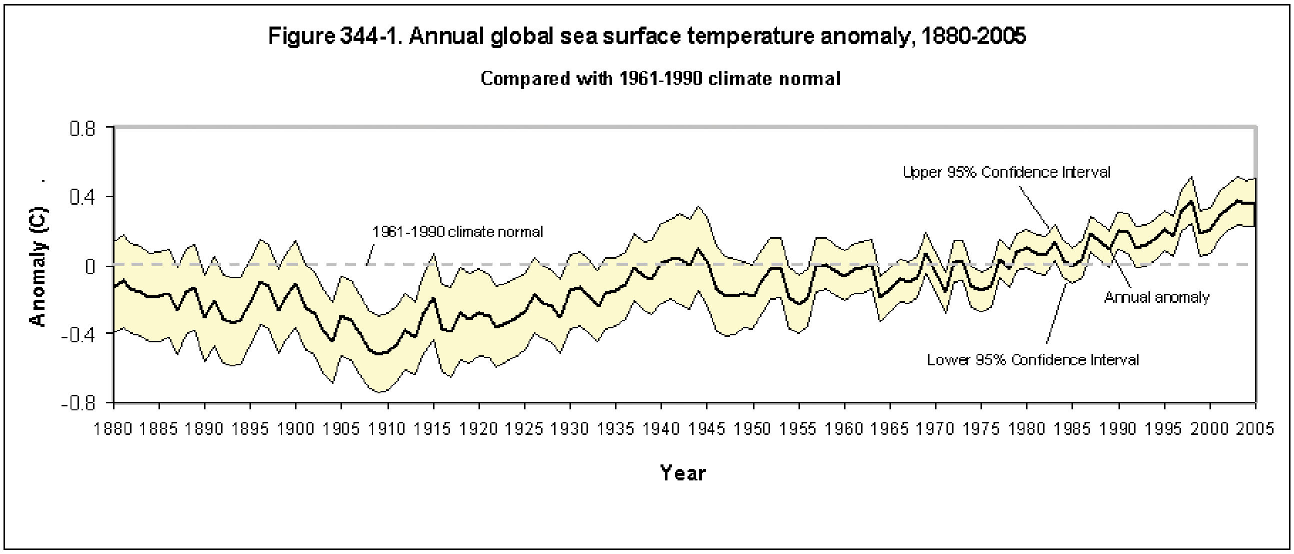


Figure 2.3. Annual global sea surface temperature anomaly, 1880–2005, compared with 1961–1990 climate normal (U.S. Environmental Protection Agency, 2007).



Figures for Chapter 3, National Forests

Figure 3.1. Timeline of National Forest System formation and the legislative influences on the mission of the national forests.

Figure 3.2. Jurisdiction and organizational levels within the National Forest System.

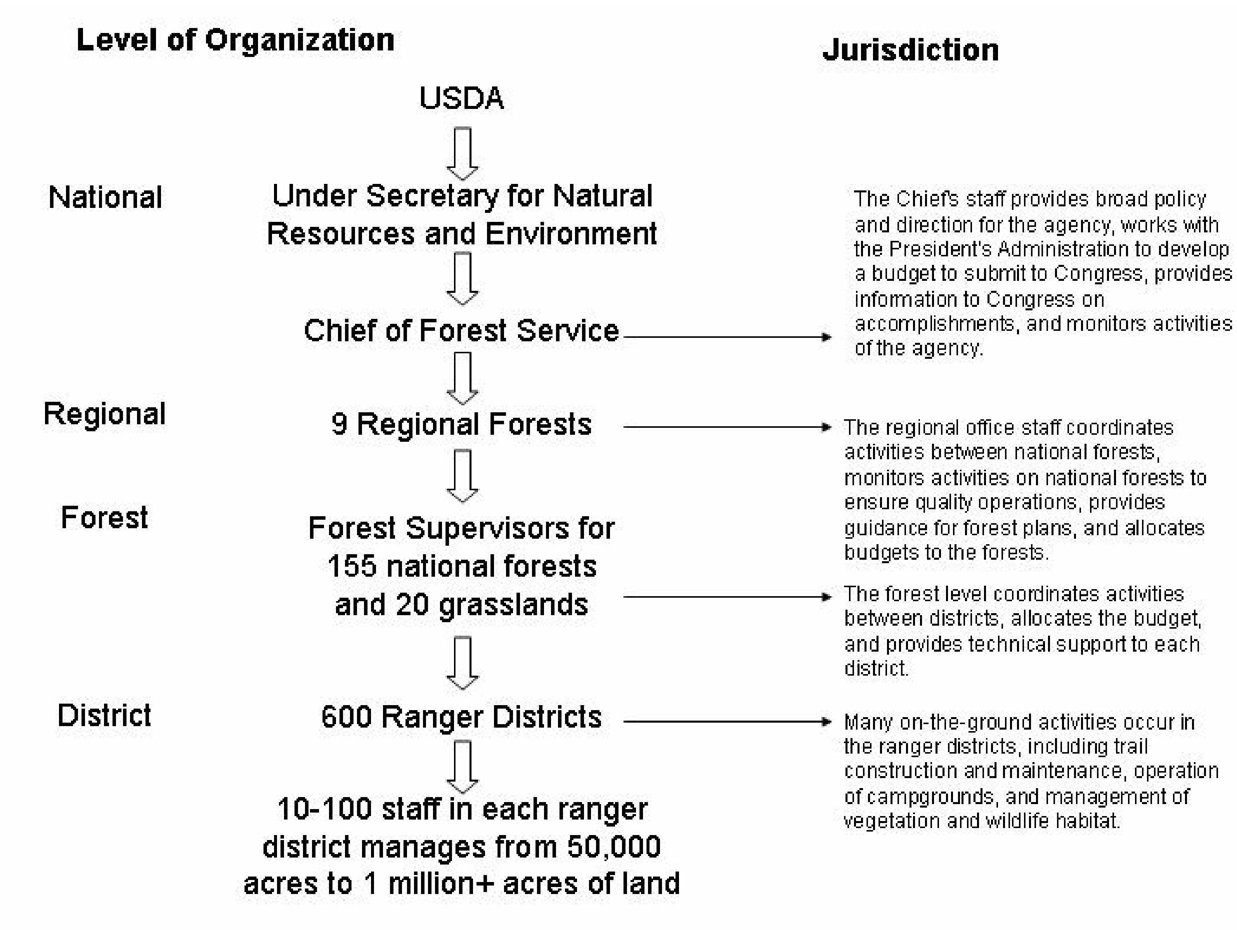


Figure 3.3. One hundred fifty-five National Forests and 20 National Grasslands across the United States provide a multitude of goods and ecosystems services, including biodiversity (USDA Forest Service Geodata Clearinghouse, 2007).

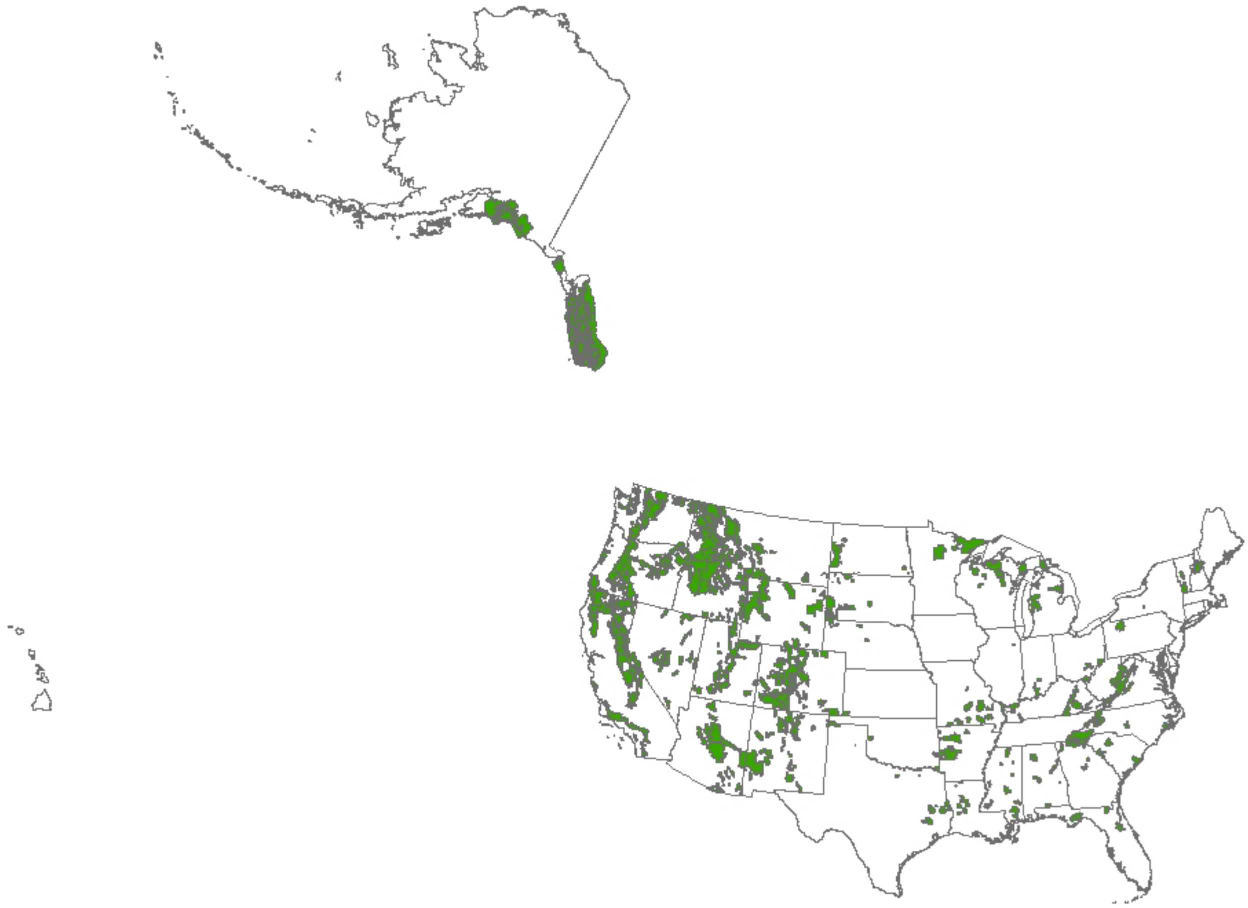


Figure 3.4. Historical harvest levels and grazing across the National Forests (USDA FS Forest Management; Mitchell, 2000).

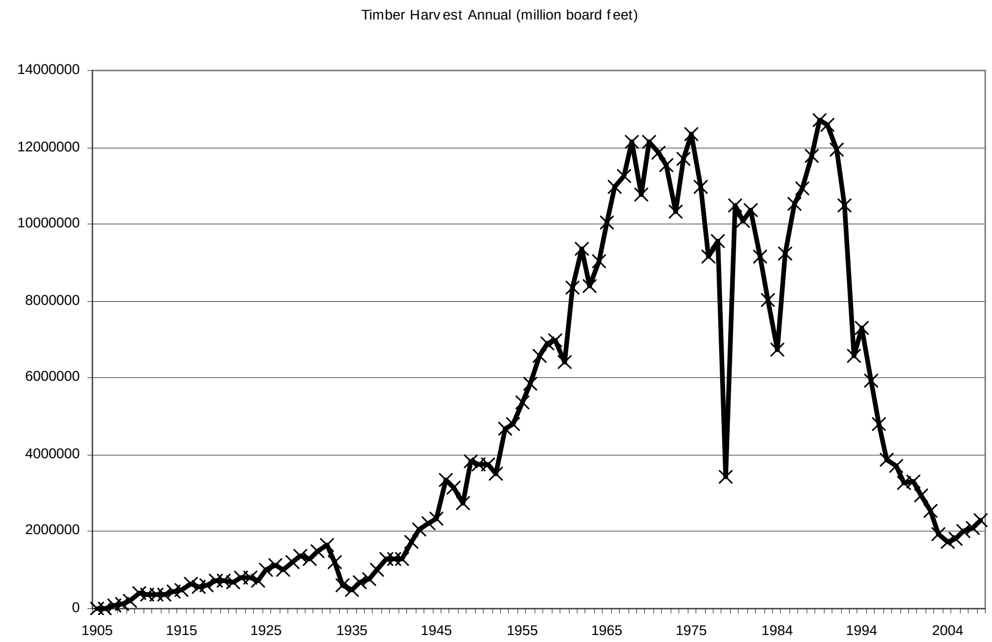


Figure 3.5. Wildland Urban Interface across the United States (Radeloff et al., 2005).

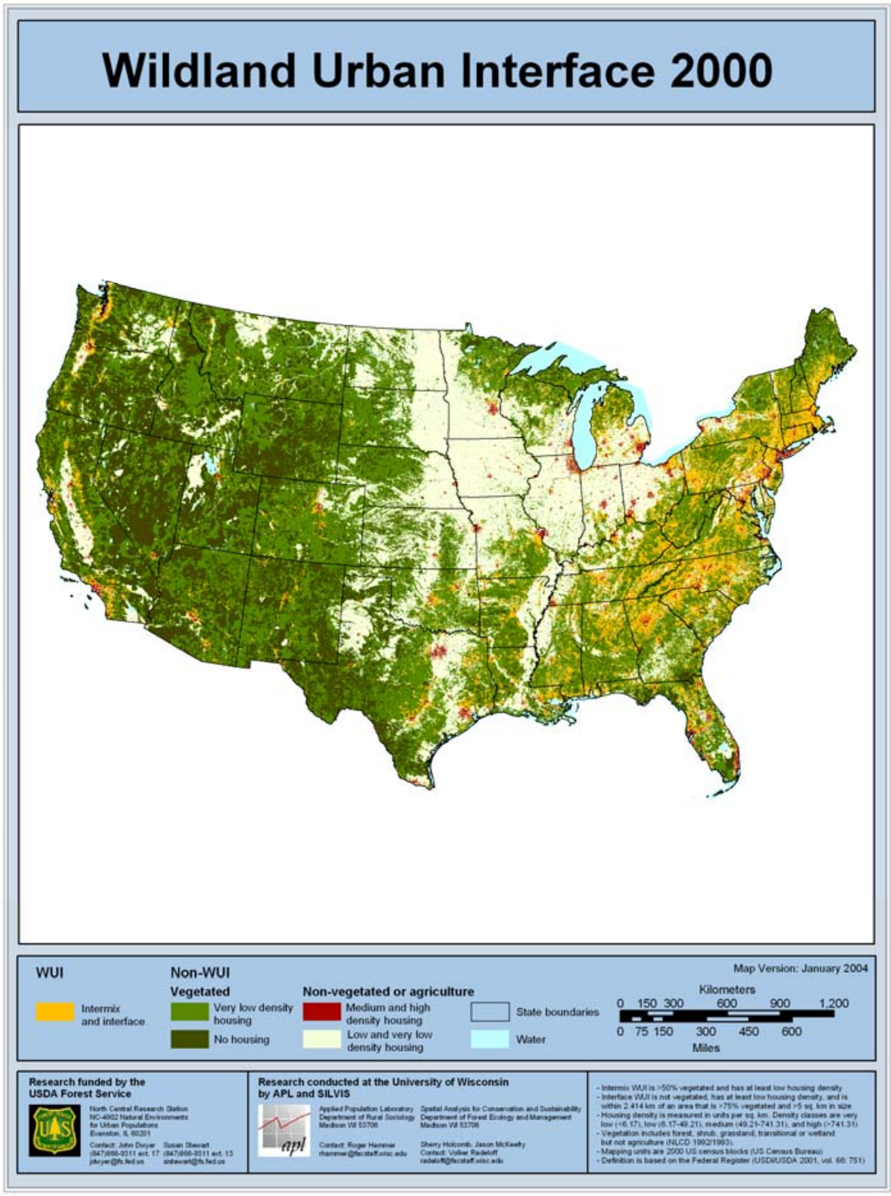


Figure 3.6. Influence of non-native earthworms on eastern forest floor dynamics (Frelich *et al.*, 2006). Forest floor and plant community at base of trees before (a, left-hand photo) and after (b) European earthworm invasion in a sugar maple-dominated forest on the Chippewa National Forest, Minnesota, USA. Photo credit: Dave Hansen, University of Minnesota Agricultural Experimental Station.

Figure 3.7. Conceptual model of the relative time scales for disturbance vs. climatic change alone to alter ecosystems. Times are approximate. From McKenzie *et al.* (2004).

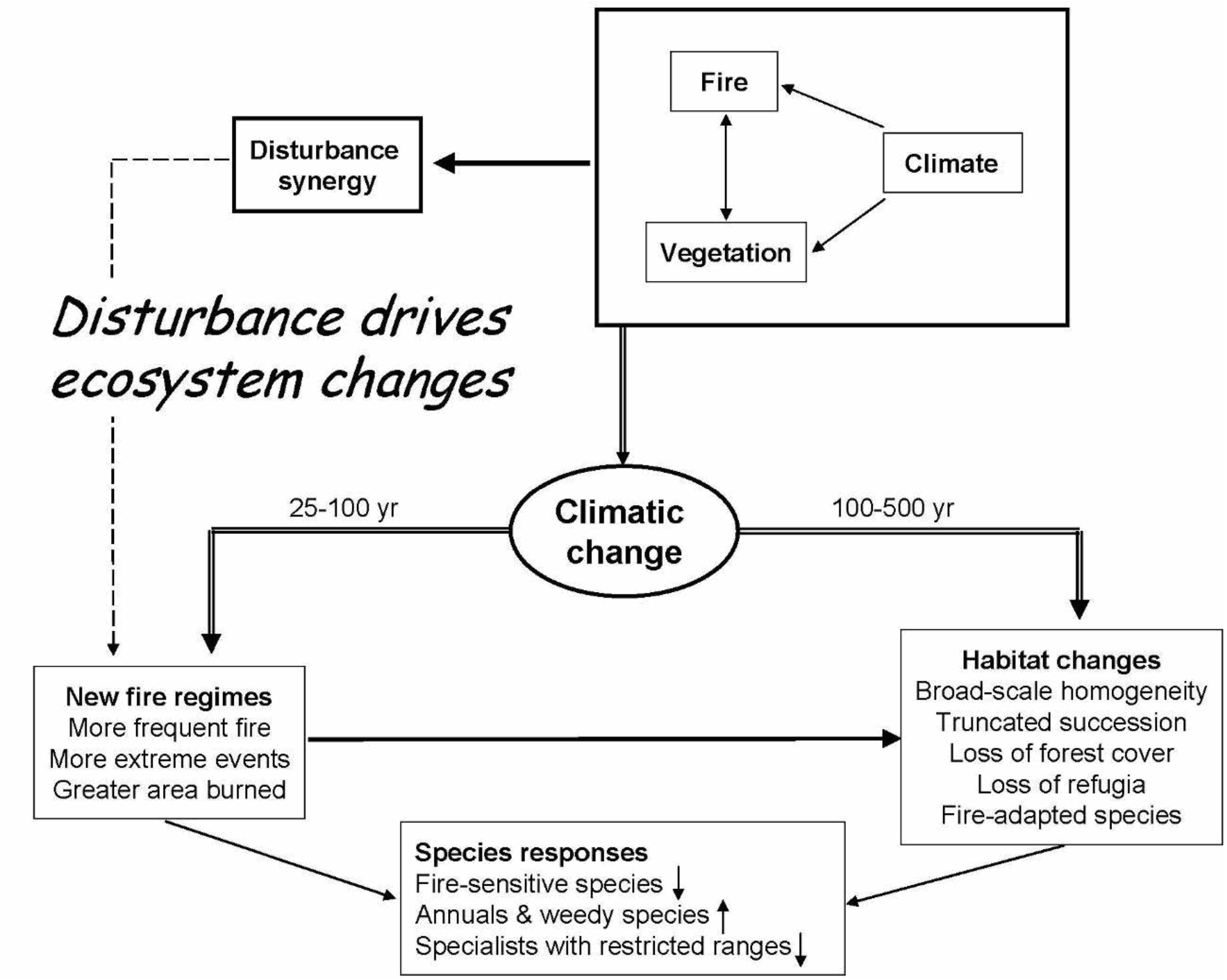


Figure 3.8. Stress complex in pinyon-juniper woodlands of the American Southwest. Adapted from McKenzie *et al.* (2004).

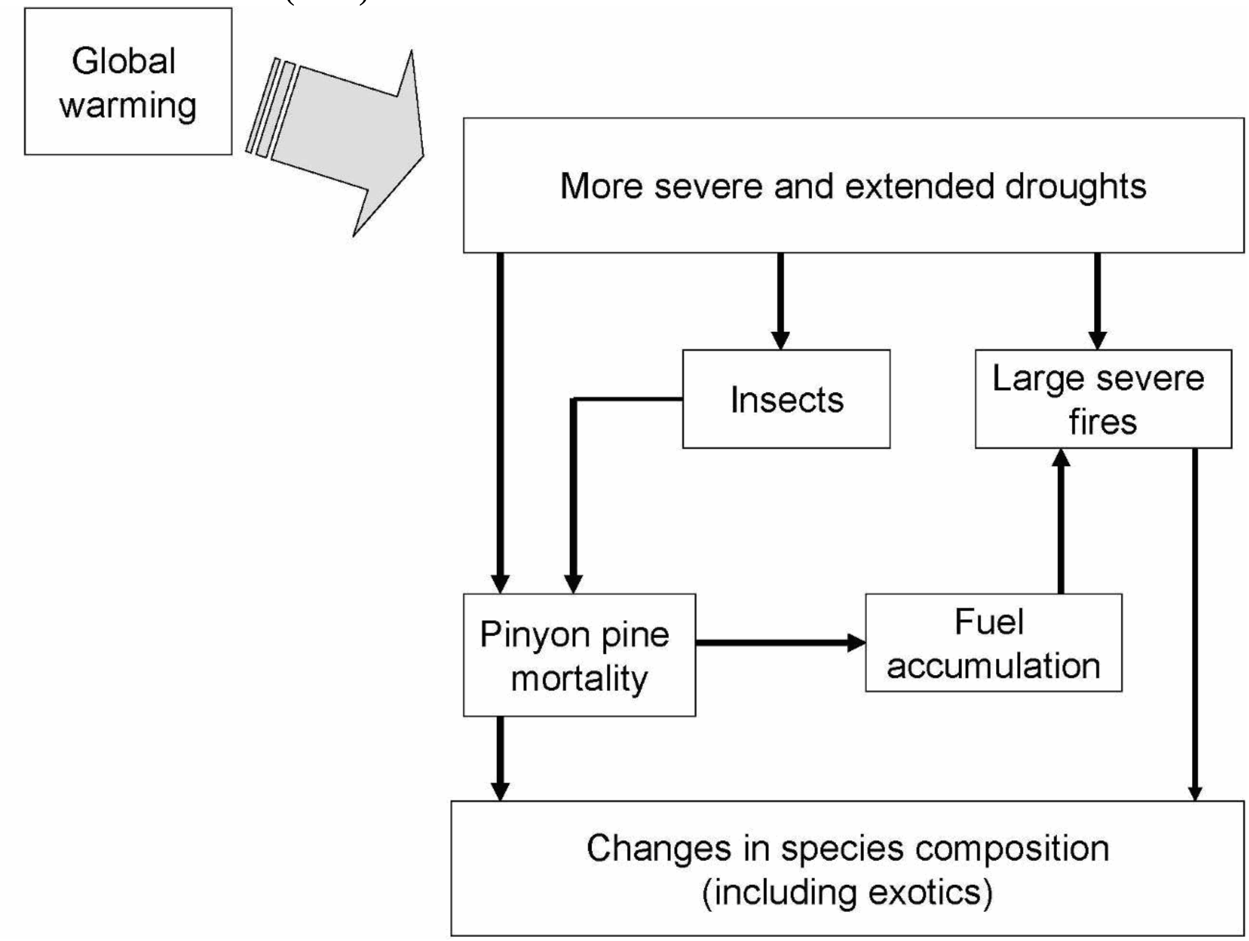


Figure 3.9. Stress complex in Sierra Nevada and southern Californian mixed-conifer forests. From McKenzie, Peterson, and Littell (In Press).

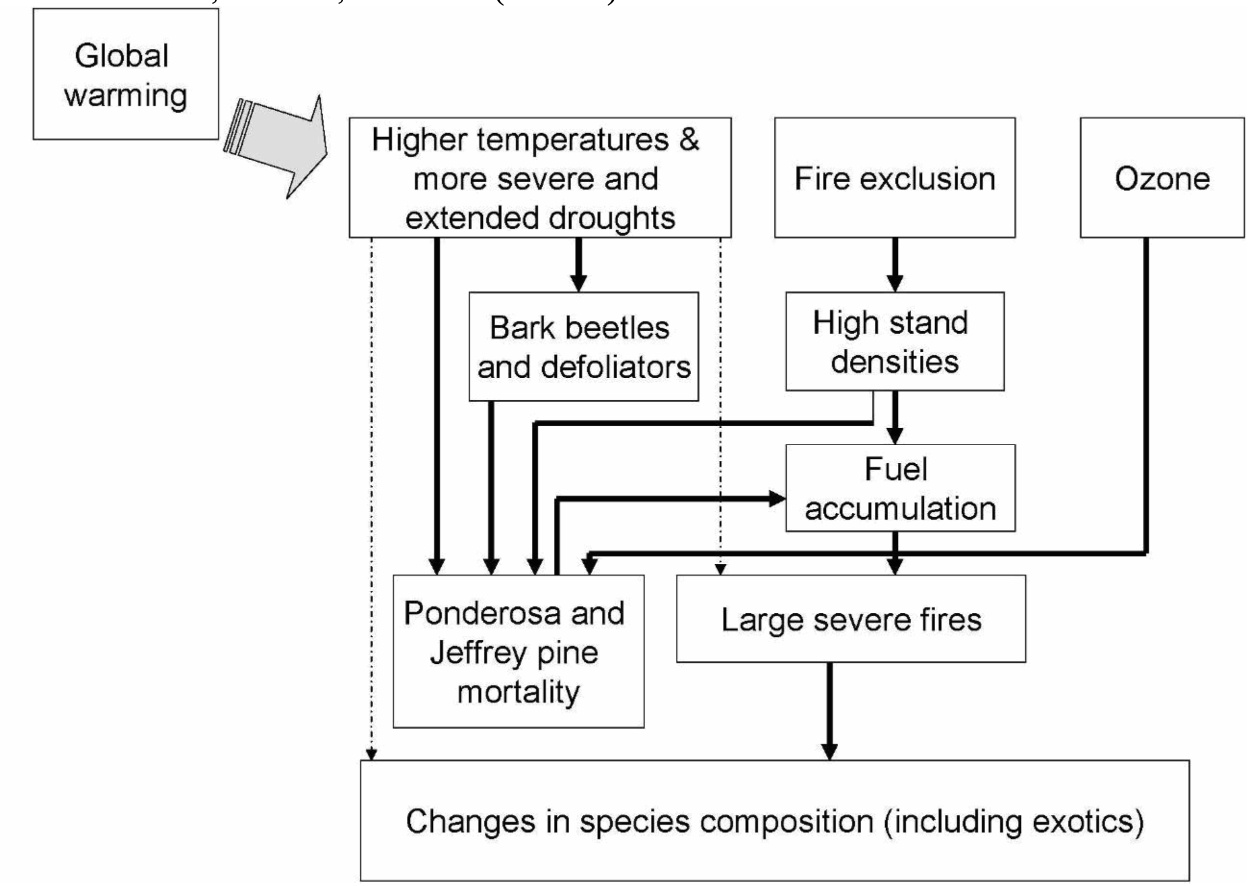


Figure 3.10. Stress complex in interior (BC and USA) lodgepole pine forests. From McKenzie, Peterson, and Littell (In Press).

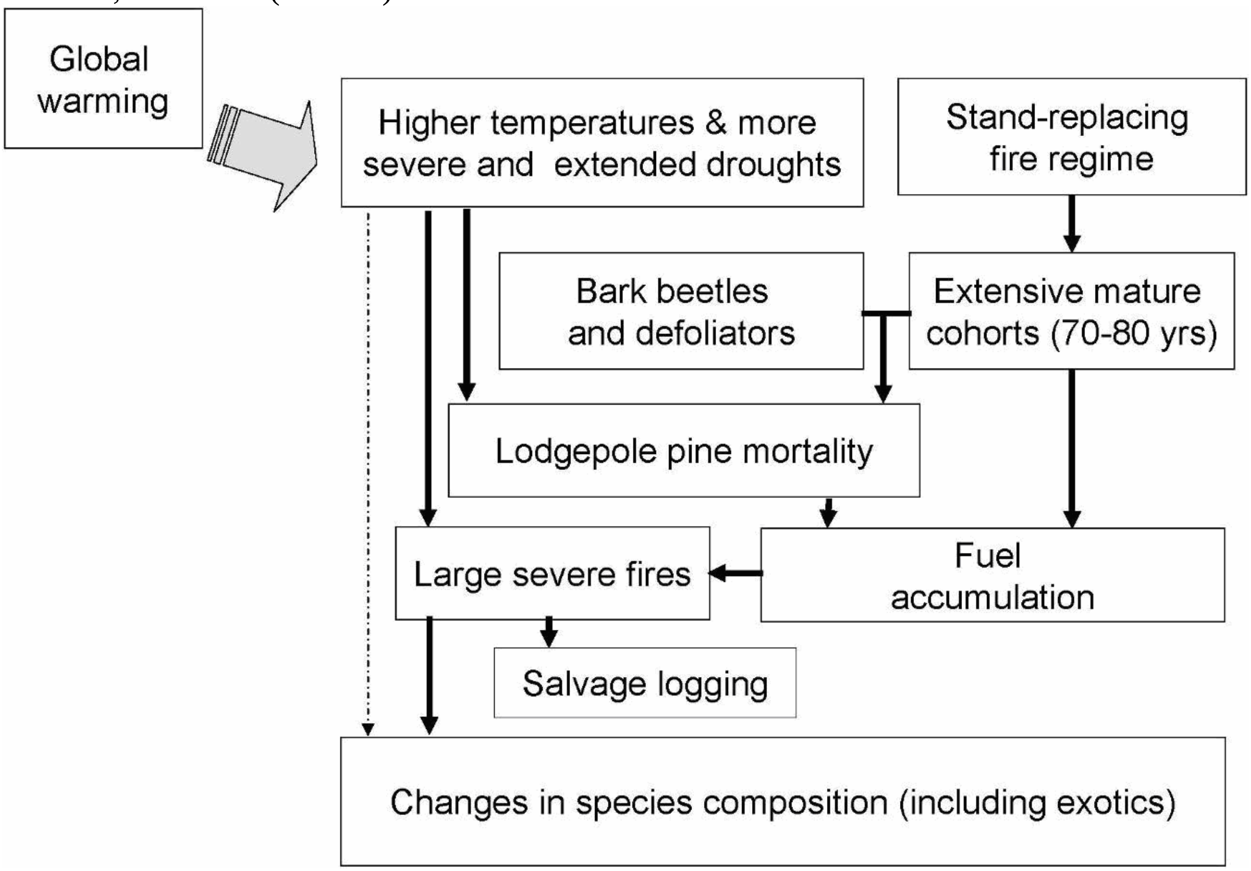


Figure 3.11. Stress complex in the interior and coastal forests of Alaska. From McKenzie, Peterson, and Littell (In Press).

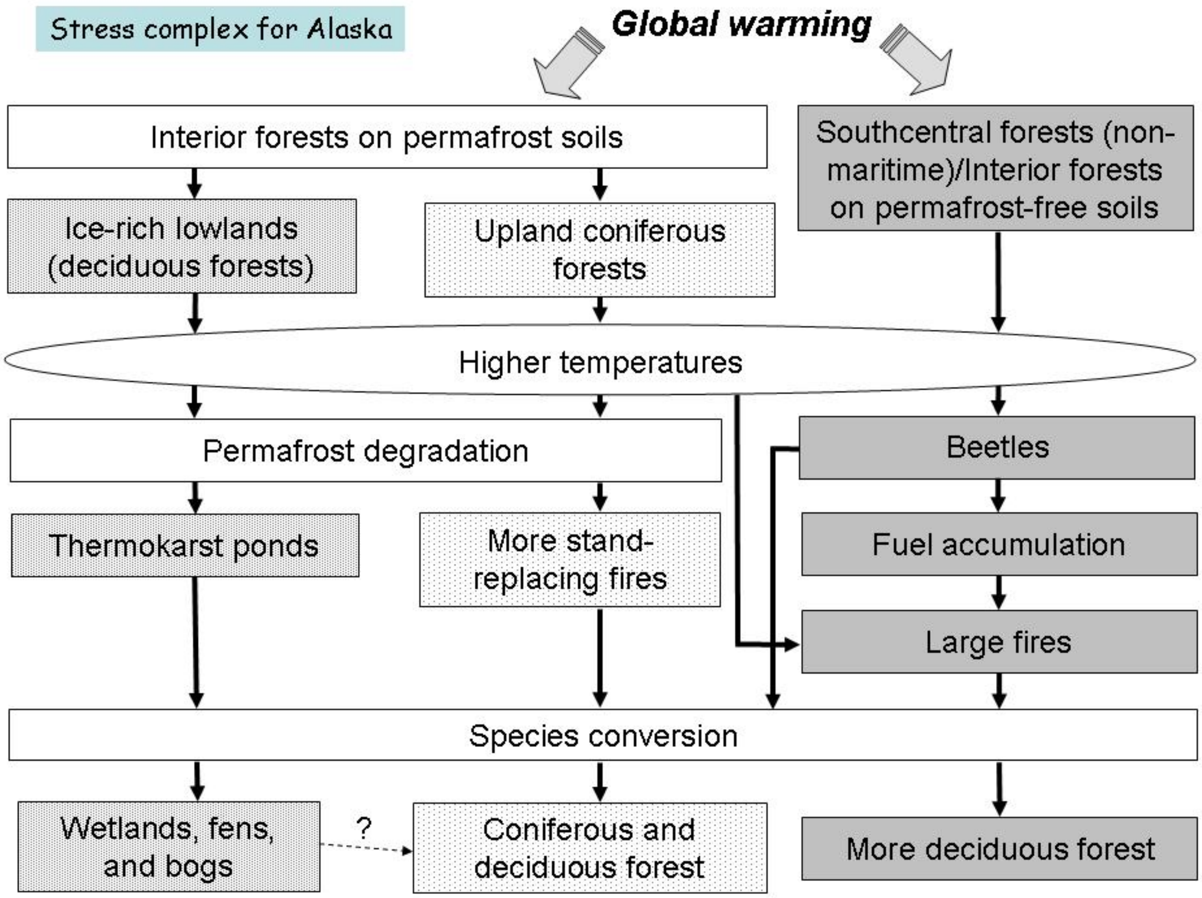


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Figure 3.12. Anticipatory and reactive adaptation for natural and human systems (IPCC, 2001).

		Anticipatory	Reactive
Natural Systems			• Changes in length of growing season • Changes in ecosystem composition • Wetland migration
Human Systems	*Private*	• Purchase of insurance • Construction of house on stilts • Redesign of oil-rigs	• Changes in farm practices • Changes in insurance premiums • Purchase of air-conditioning
	Public	• Early-warning systems • New building codes, design standards • Incentives for relocation	• Compensatory payments, subsidies • Enforcement of building codes • Beach nourishment

Figure 3.13. Map and location of the Tahoe National Forest, within California (a) and the Forest boundaries (b) (USDA Forest Service, 2007a; USDA Forest Service, 2007b).

a)

b)


Tahoe NF
District Boundary
Major Road
Pacific Crest Trail
Ranger Station
Visitor Center
Sierraville
Sierraville District
Camptonville
Yuba River District
Truckee
Big Bend
Truckee District
Nevada City
American River District
Foresthill

Figure 3.14. Thinned stands for fuel reduction and resilience management, part of the Herger-Feinstein Quincy Library Pilot Project. Photo courtesy of Tahoe National Forest.

Figure 3.15. Former salmon habitat (rivers marked in bold black) of the Sierra Nevada. Tahoe National Forest (TNF) rivers are scheduled to have salmon restored to them in current national forest planning. Adaptive approaches suggest that future waters may be too warm on the TNF for salmon to survive, and thus, restoration may be inappropriate to begin. Map adapted from (Sierra Nevada Ecosystem Project Science Team, 1996).

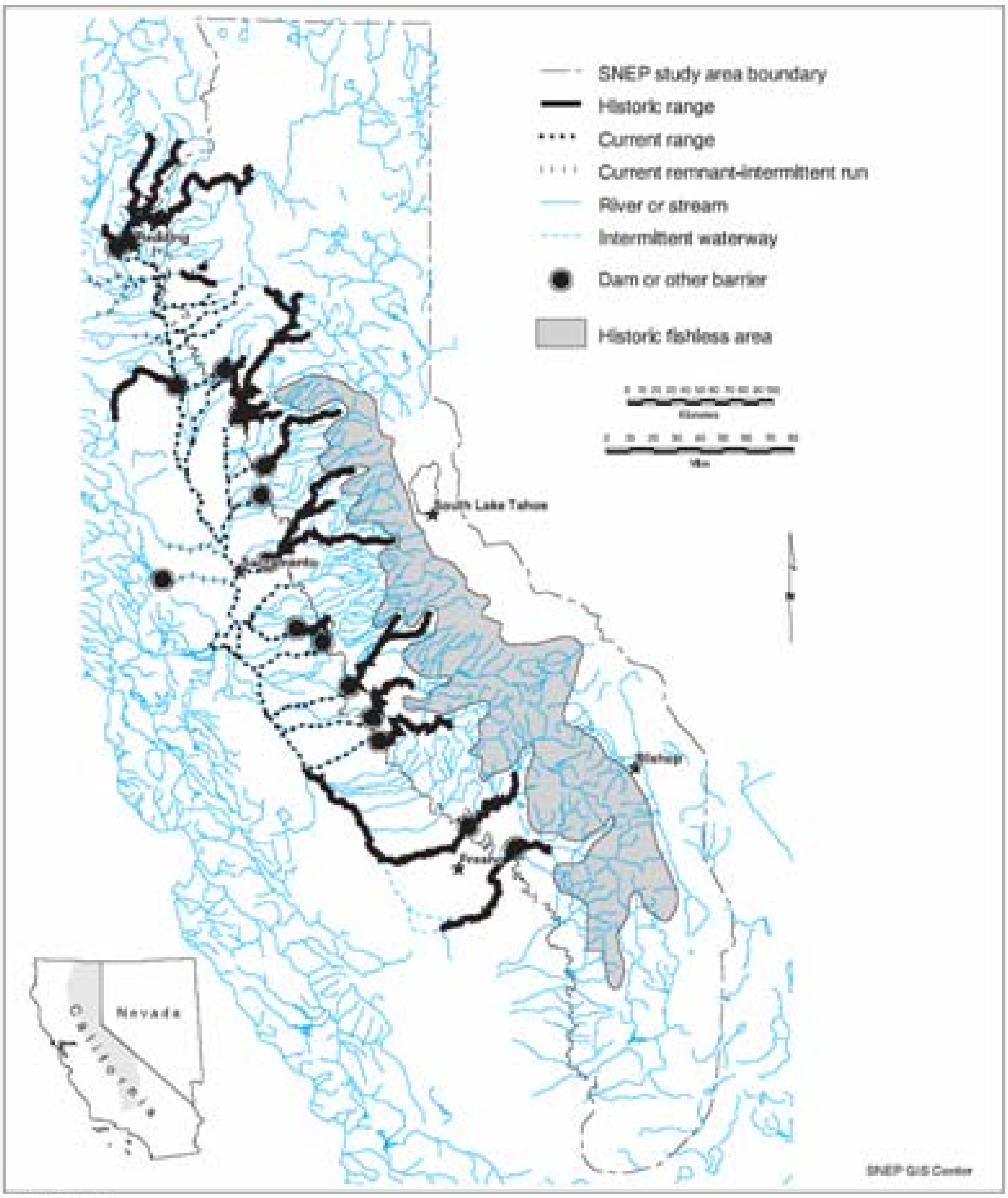


FIGURE 33.1

Figure 3.16. Olympic Peninsula land ownership and Northwest Forest Plan allocation map. Olympic National Forest contains lands (dark boundary) with different land use mandates and regulations. These include adaptive management areas, late-successional reserves, and Wilderness areas. Map courtesy of Robert Norheim, Climate Impacts Group, University of Washington.

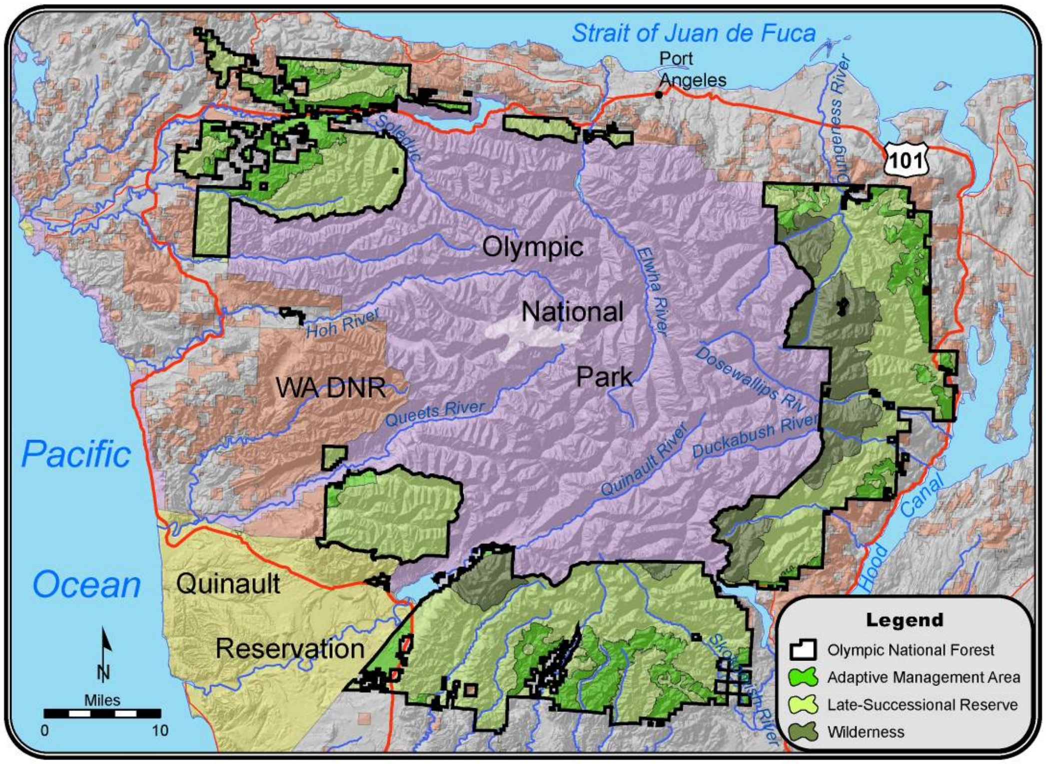
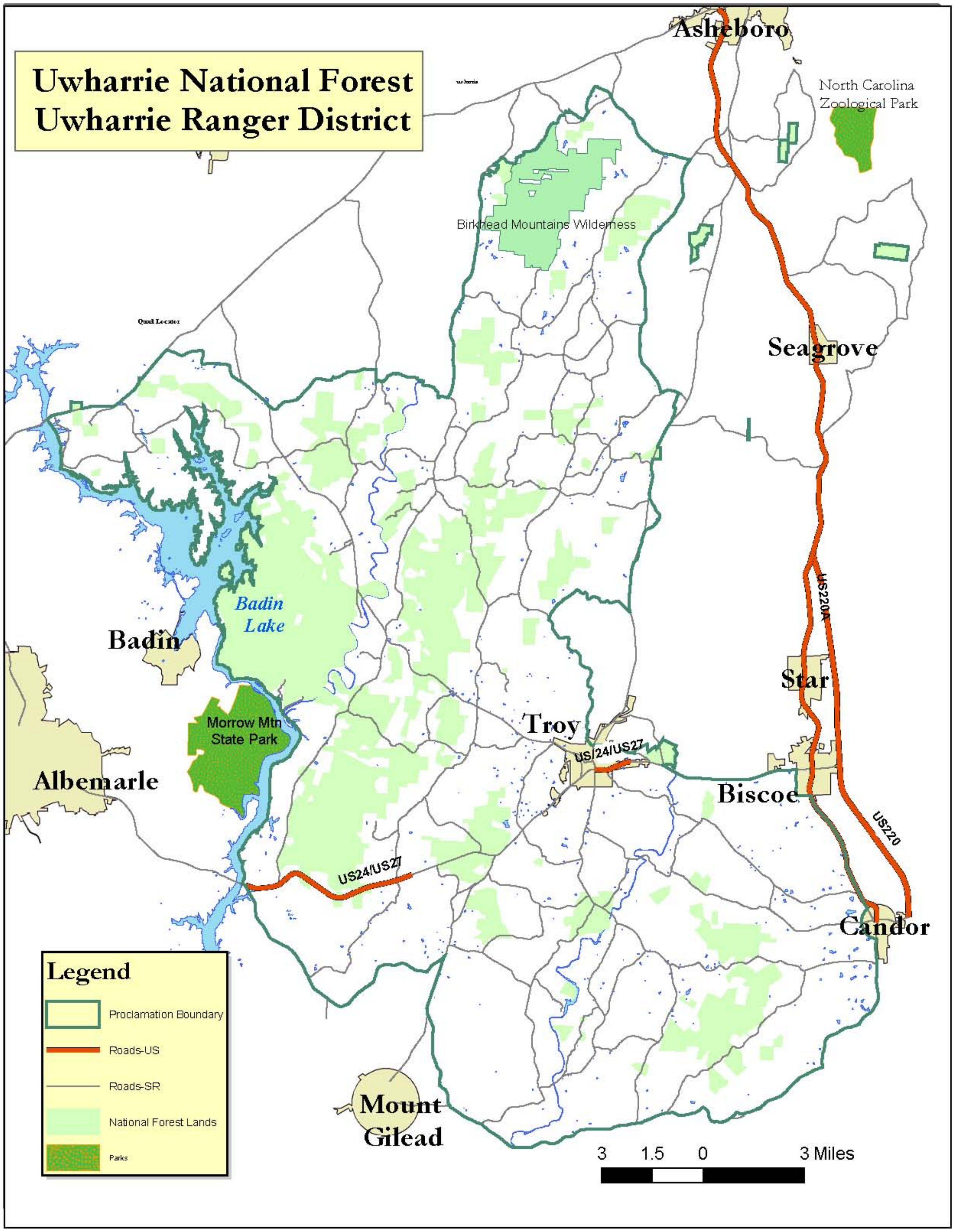


Figure 3.17. Olympic National Forest is charged with mitigating the legacy of 20th century timber harvest. Landscape fragmentation and extensive road networks (upper left) are consequences of this legacy that influence strategies for adaptation to climate change. The old-growth forest dependent northern spotted owl (upper right) is one focus of the NWFP, which prescribes forest practices but does not address climatic change. Changes in the timing and intensity of runoff expected with climate change are likely to interact with this legacy to have negative impacts on unmaintained roads (lower left) that in turn will impact water quality for five threatened or endangered species of anadromous and resident fish. Photo Credits: All photos courtesy Olympic National Forest.

Figure 3.18. Map of the Uwharrie National Forest in North Carolina (USDA Forest Service, 2007c).



Figures for Chapter 4, National Parks

Figure 4.1. Photograph looking up from the Colorado River at the Grand Canyon, courtesy of Jeffrey Lovich, USGS.

Figure 4.2. Everglades National Park, Photo courtesy of National Park Service; photo by Rodney Cammauf.

Figure 4.3. Photograph of Joshua tree in Joshua Tree National Park. Photo courtesy of National Park Service.

Figure 4.4. Historical timeline of the National Park Service. Adapted from the National Park Service (2007a).

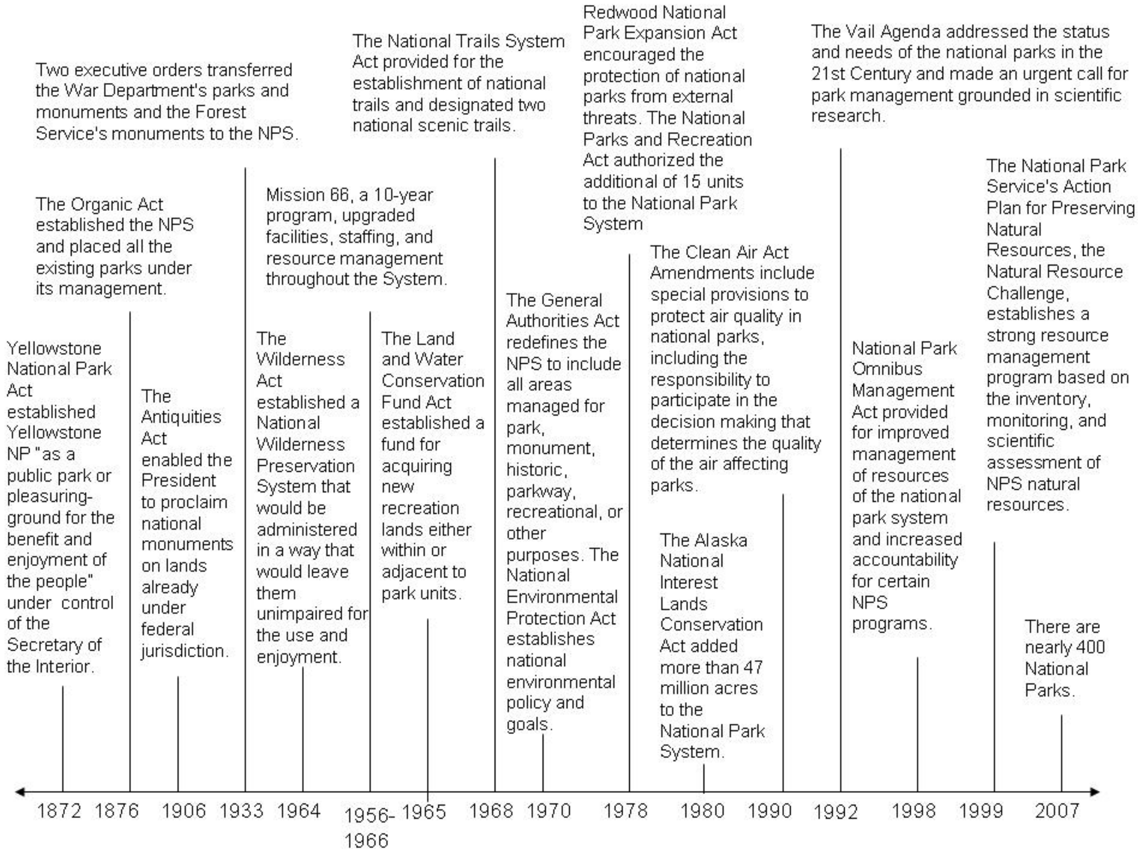


Figure 4.5. Organizational chart of National Park Service. Adapted from the National Park Service (2007b).

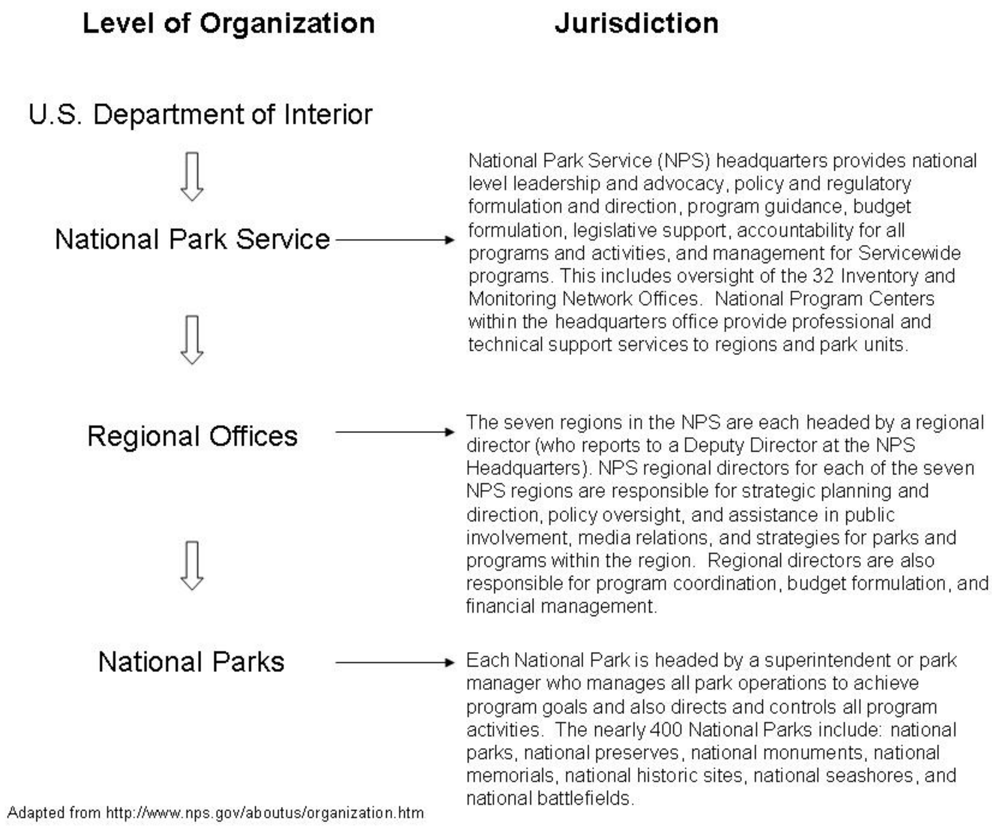


Figure 4.6. Map of the National Park System. Data courtesy of National Park Service, Harpers Ferry Center (2007).

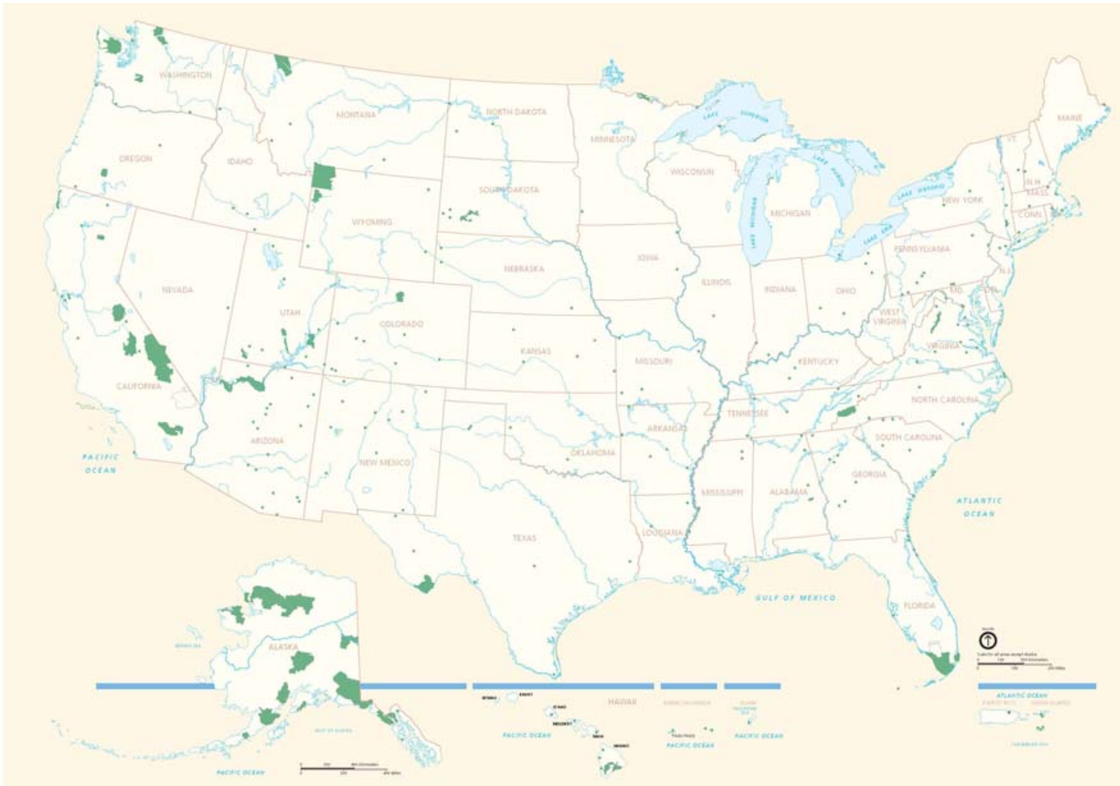


Figure 4.7. Kemp's Ridley hatchlings heading for the water at a hatchling release. Photo courtesy National Park Service, Padre Island National Seashore.

Figure 4.8. Scenario planning is appropriate for systems in which there is a lot of uncertainty that is not controllable. In other cases optimal control, hedging, or adaptive management may be appropriate responses. Reprinted from Peterson, Cumming, and Carpenter (2003).

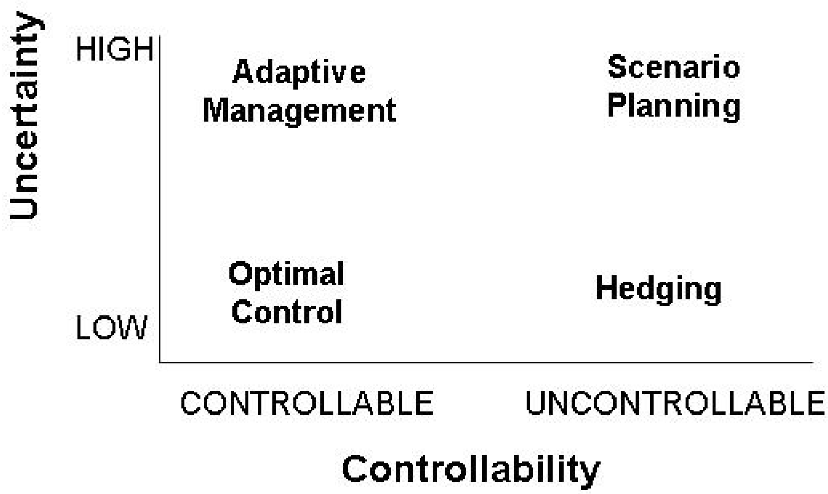


Figure 4.9. Photos of Arapahoe Glacier in 1898 and 2004 (NSIDC/WDC for Glaciology, Boulder, Compiler, 2006).

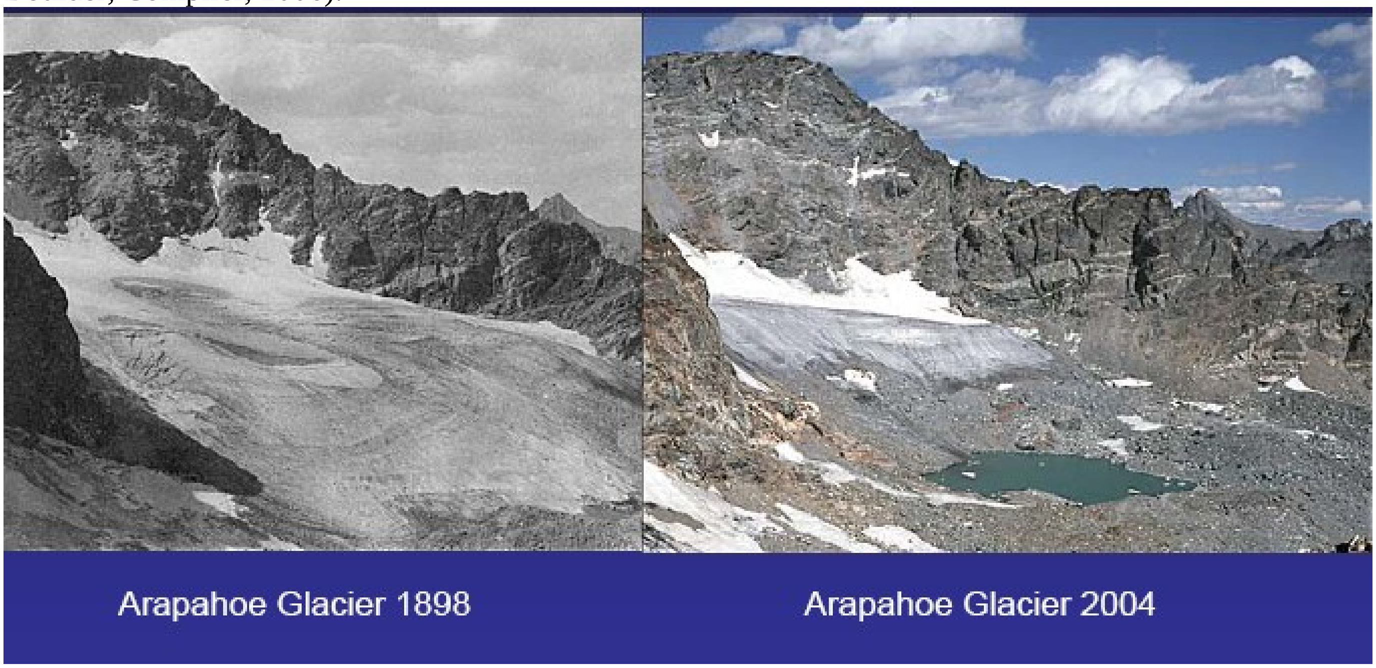


Figure 4.10. Photo pair of Rowe Glacier, with permissions, NSIDC and leachfam website (Lee, 1916; Leach, 1994).

Figures for Chapter 5, National Wildlife Refuges

Figure 5.1. Structure of the NWRS. Adapted from Fischman (2003), Refuge Administration Act (1966), and FWS Regulations – CFR 50.

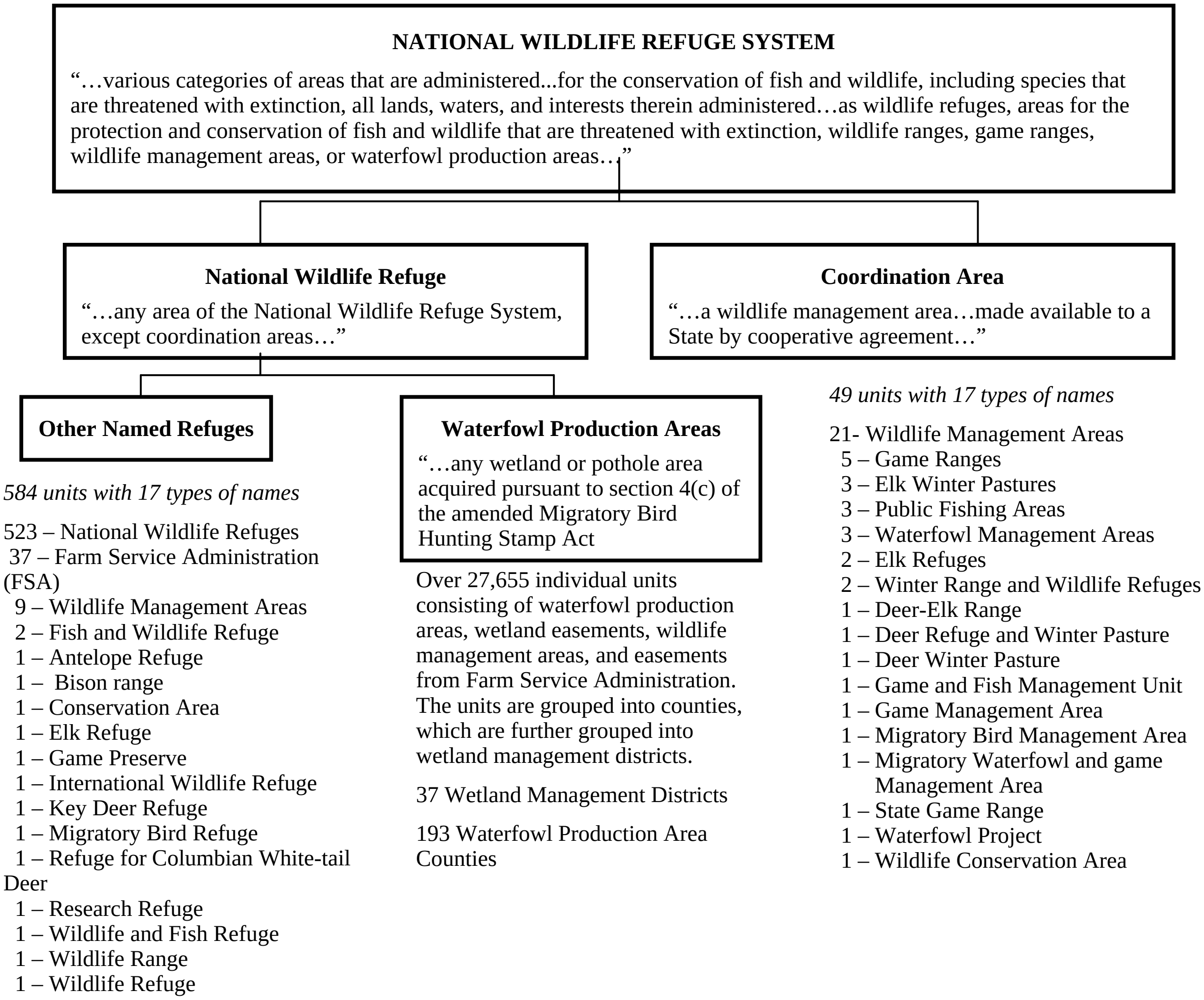


Figure 5.2. The National Wildlife Refuge System. Adapted from Pidgorna (2007).

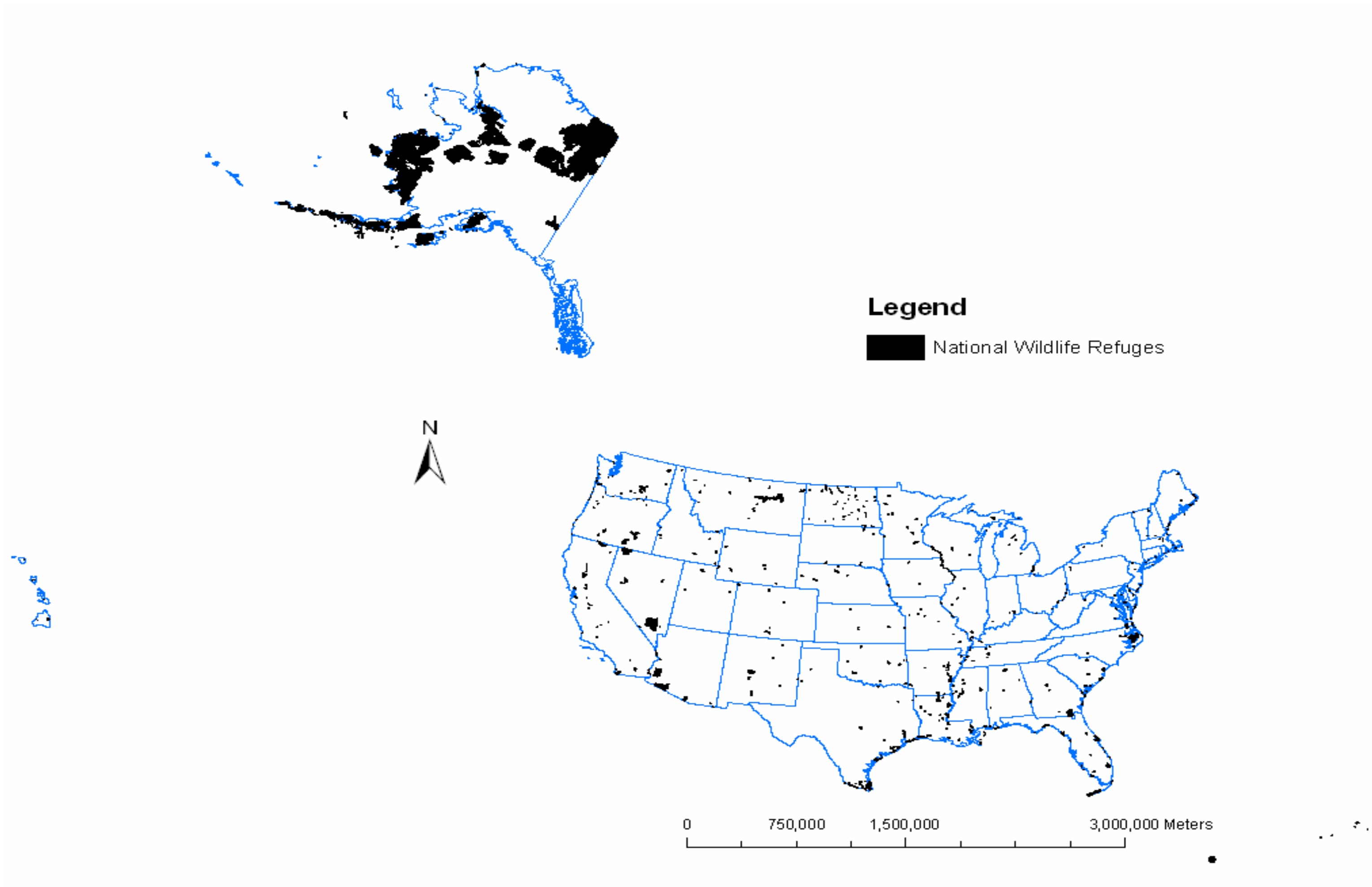


Figure 5.3. Organizational chart (U.S. Fish and Wildlife Service, 2007a).

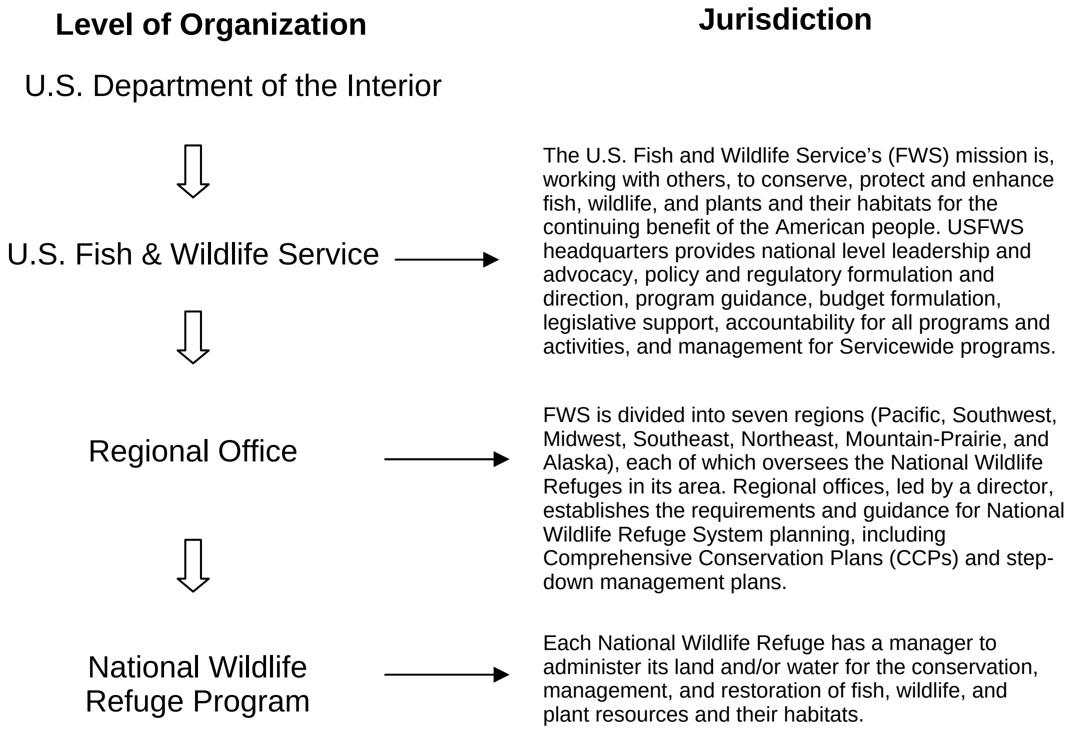


Figure 5.4. Timeline of milestone events of the NWRS (U.S. Fish and Wildlife Service, 2007d).

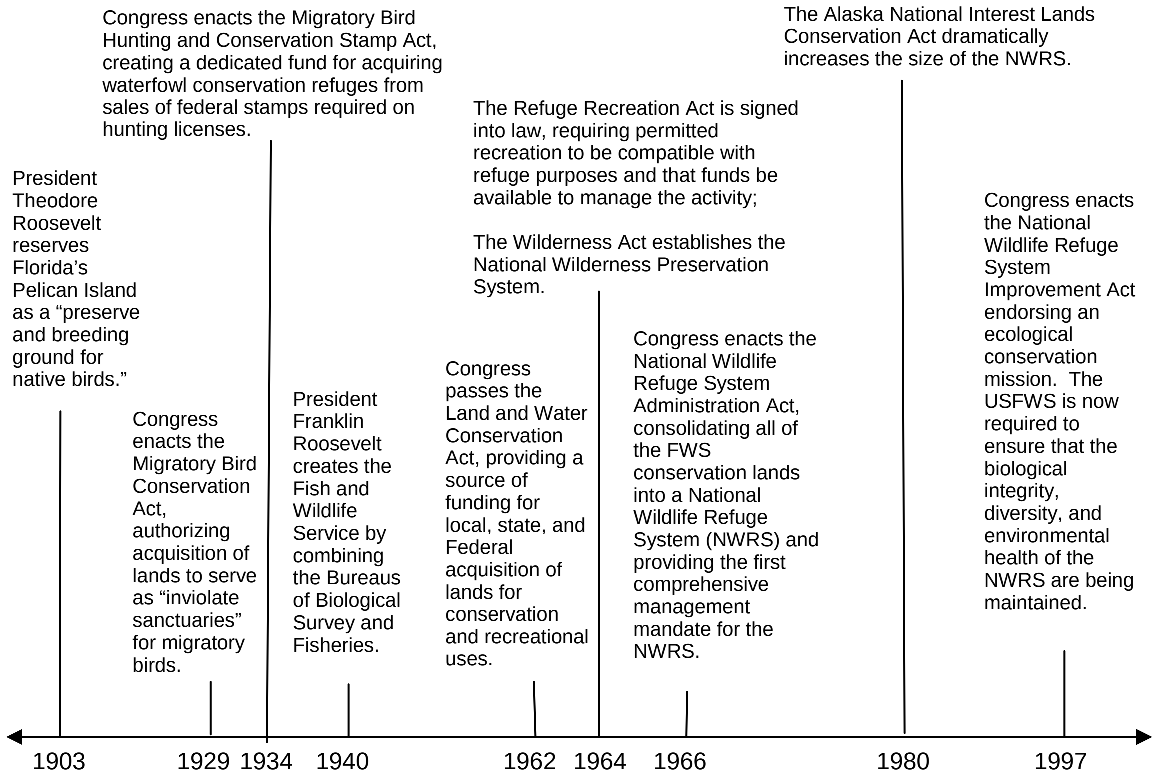


Figure 5.5. Blackwater National Wildlife Refuge, Chesapeake Bay, Maryland. Current land areas and potential inundation due to climate change (Larsen *et al.*, 2004b).

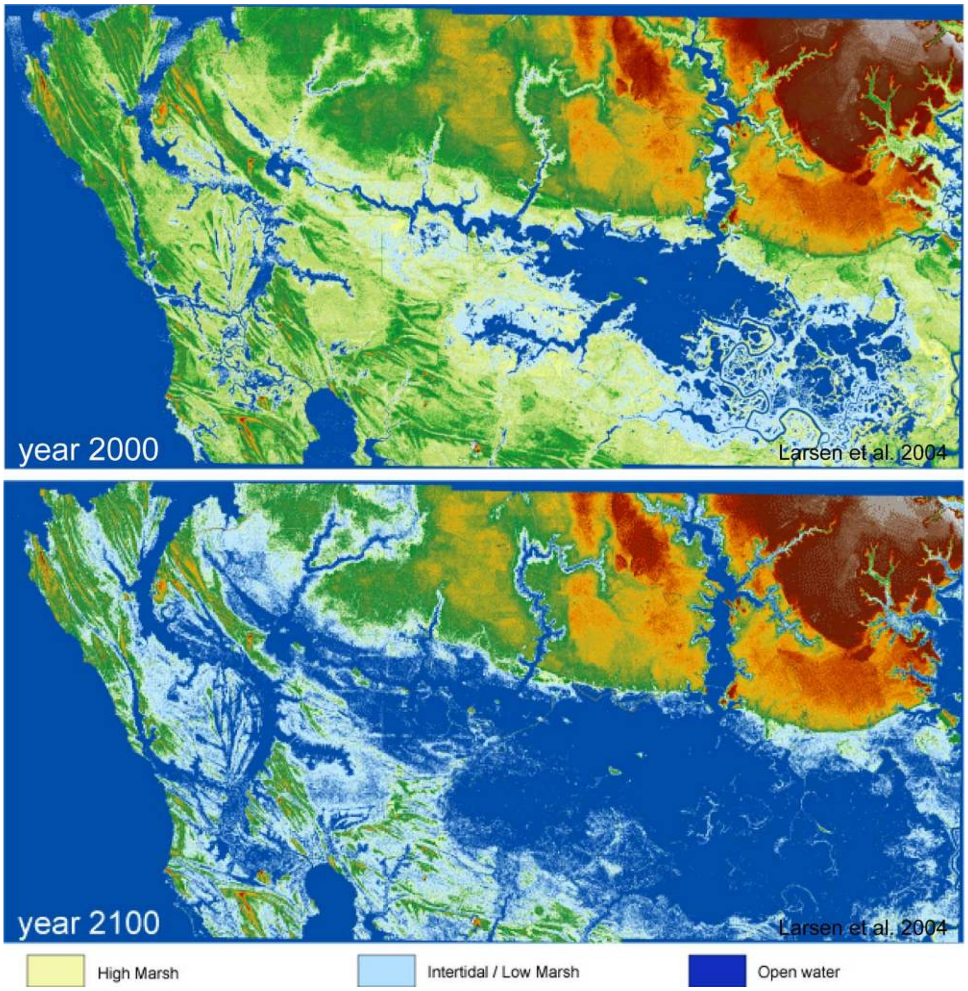
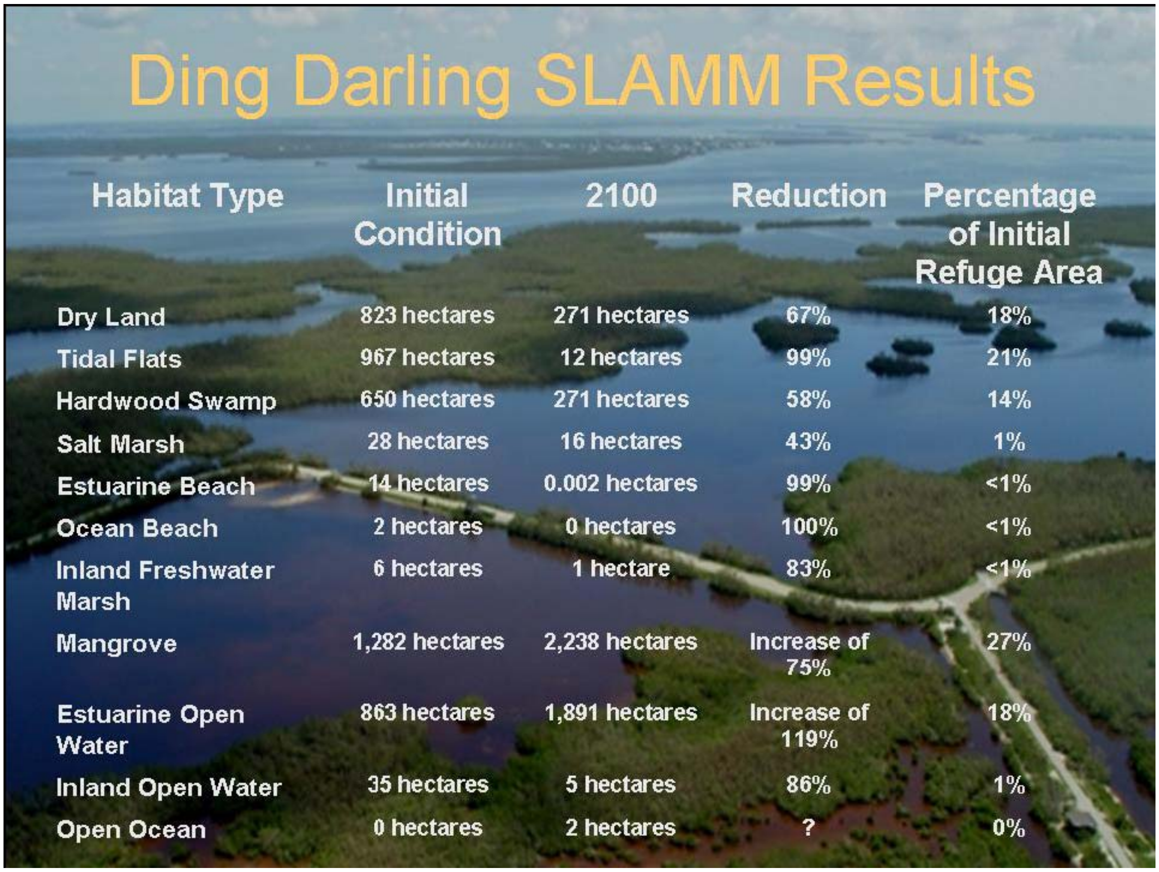


Figure 5.6. Results of the Sea Level Affecting Marshes Model (SLAMM) for Ding Darling National Wildlife Refuge. Source: USFWS unpublished data (McMahon, Undated, 2007).



Ding Darling SLAMM Results

Habitat Type	Initial Condition	2100	Reduction	Percentage of Initial Refuge Area
Dry Land	823 hectares	271 hectares	67%	18%
Tidal Flats	967 hectares	12 hectares	99%	21%
Hardwood Swamp	650 hectares	271 hectares	58%	14%
Salt Marsh	28 hectares	16 hectares	43%	1%
Estuarine Beach	14 hectares	0.002 hectares	99%	<1%
Ocean Beach	2 hectares	0 hectares	100%	<1%
Inland Freshwater Marsh	6 hectares	1 hectare	83%	<1%
Mangrove	1,282 hectares	2,238 hectares	Increase of 75%	27%
Estuarine Open Water	863 hectares	1,891 hectares	Increase of 119%	18%
Inland Open Water	35 hectares	5 hectares	86%	1%
Open Ocean	0 hectares	2 hectares	?	0%

Figure 5.7. Ecoregions of North America (Level 1) (U.S. Environmental Protection Agency, 2007).

Figure 5.8. Potential climate change vegetation shifts across North America. A. Vegetation 1990. B. Projected vegetation 2100, HadCM3 general circulation model, IPCC (2000) SRES A2 emissions scenario. C. Projected change as fraction of ecoregion area. D. Potential refugia (Gonzalez, Neilson, and Drapek, 2005).

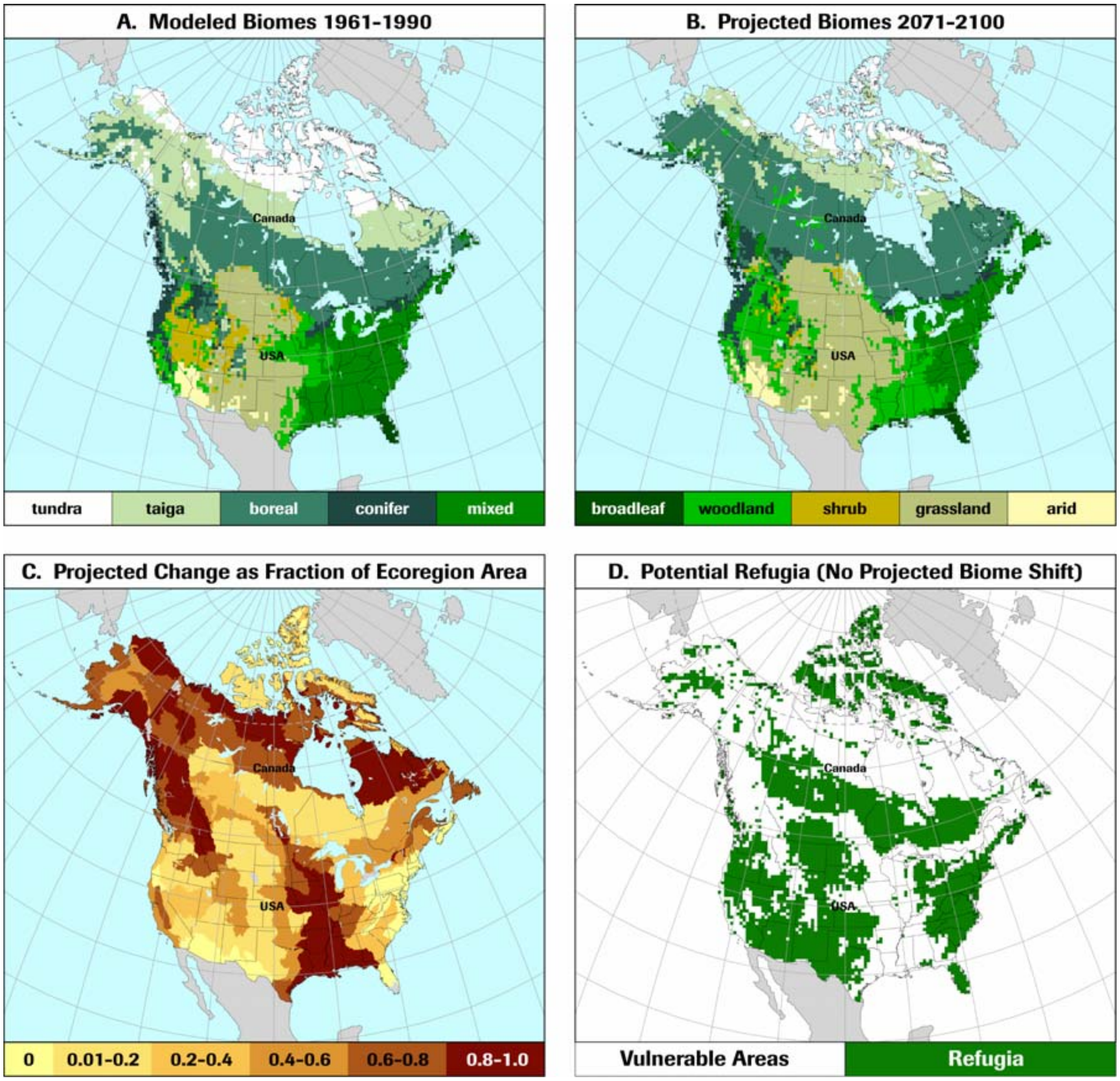
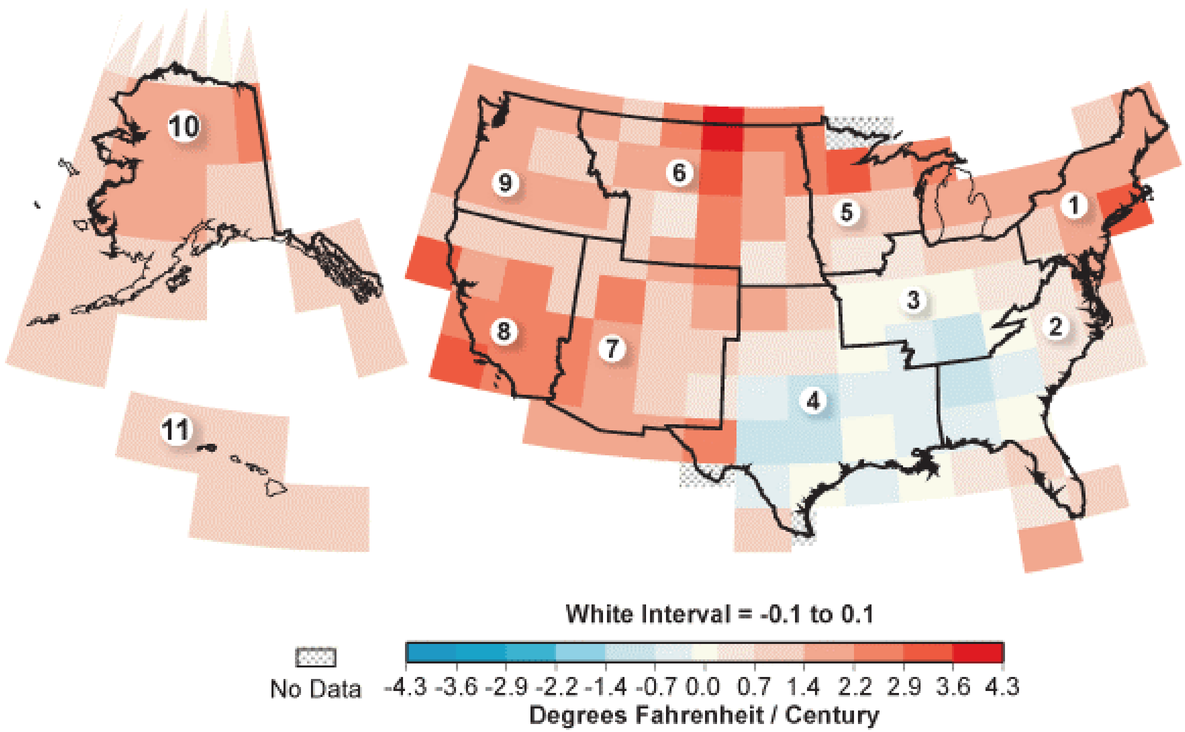


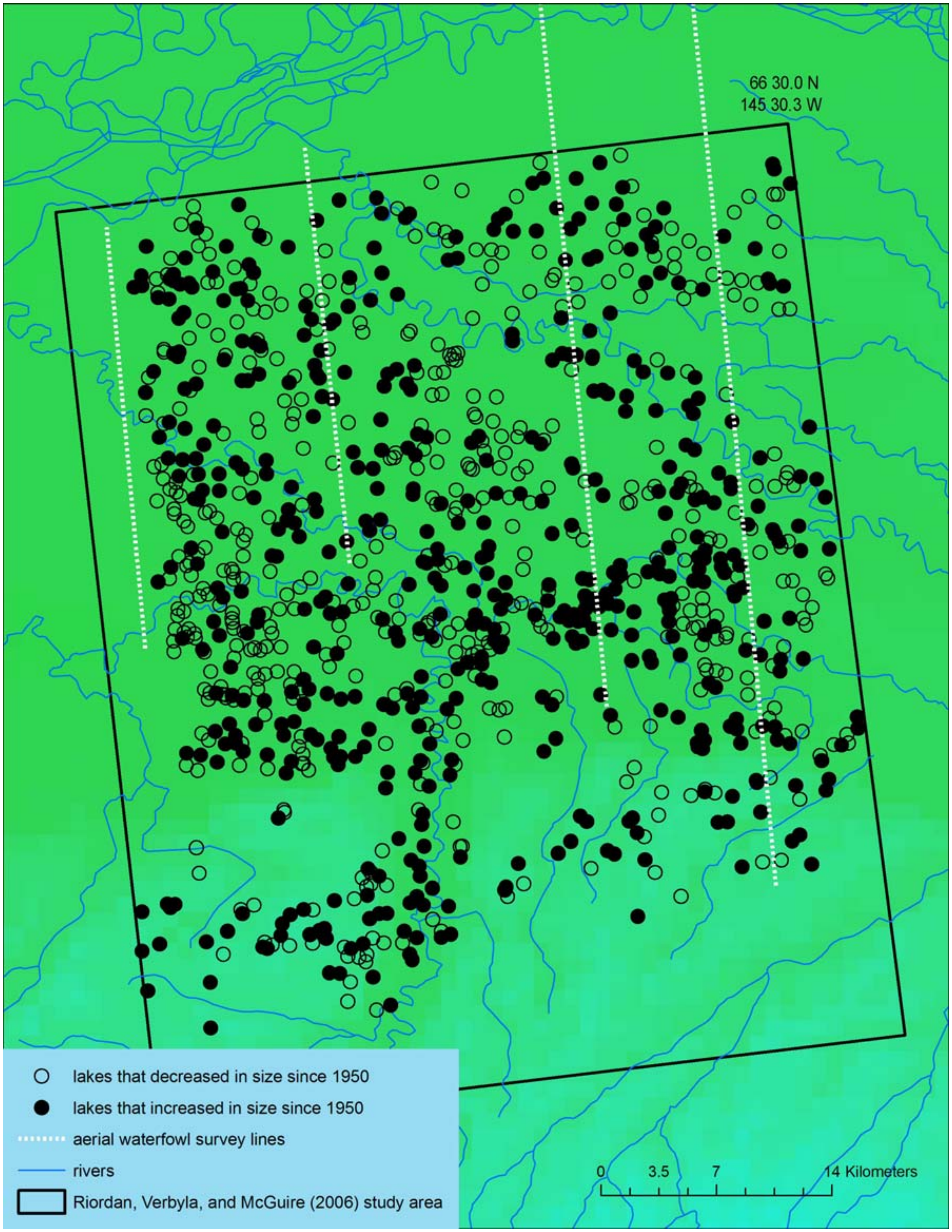
Figure 5.9. Annual mean temperature trends 1901–2003. Note warming in northern two-thirds of Central Flyway and cooling in southern third of the flyway. Data are from NOAA National Climatic Data Center (2006).



1 **Figure 5.10.** Central Flyway Waterfowl Migration Corridor (U.S. Fish and Wildlife Service,
2 2007b).

3
4

Figure 5.11. Heterogeneity in closed-basin lakes with increasing and decreasing surface area, 1950–2000, Yukon Flats NWR, Alaska. Net reduction in lake area was 18% with the area of 566 lakes decreasing, 364 lakes increasing, and 462 lakes remaining stable. Adapted from Riordan, Verbyla, and McGuire (2006).



Figures for Chapter 6, Wild and Scenic Rivers

Figure 6.1. Photo of Snake River below Hell's Canyon Dam. Photograph compliments of Marshall McComb, Fox Creek Land Trust.

Figure 6.2. Wild and Scenic Rivers in the United States. Data from USGS, National Atlas of the United States (2005).

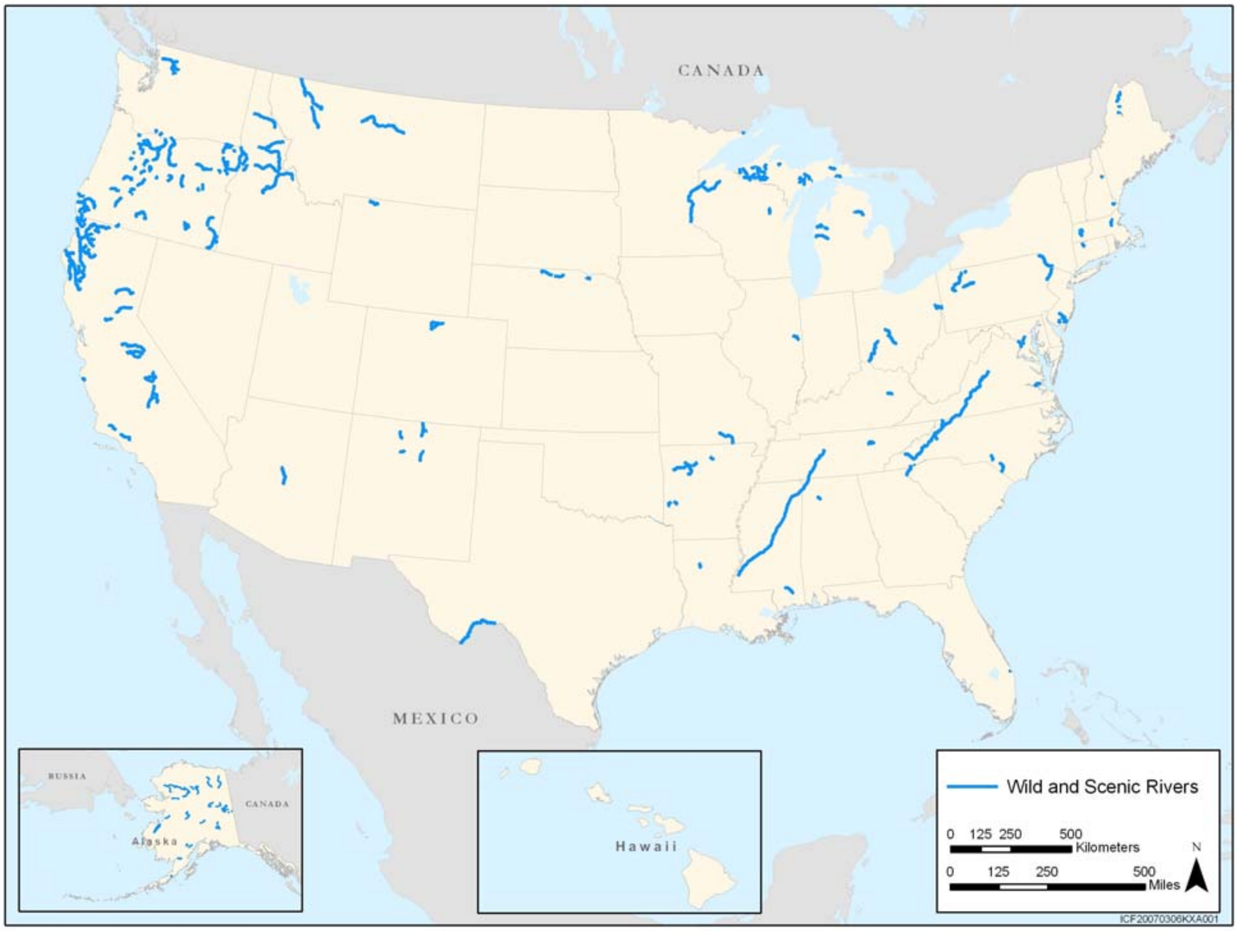


Figure 6.3. Selected milestones in the evolution of the Wild and Scenic Rivers system. Adapted from National Wild and Scenic Rivers System website (2007a).

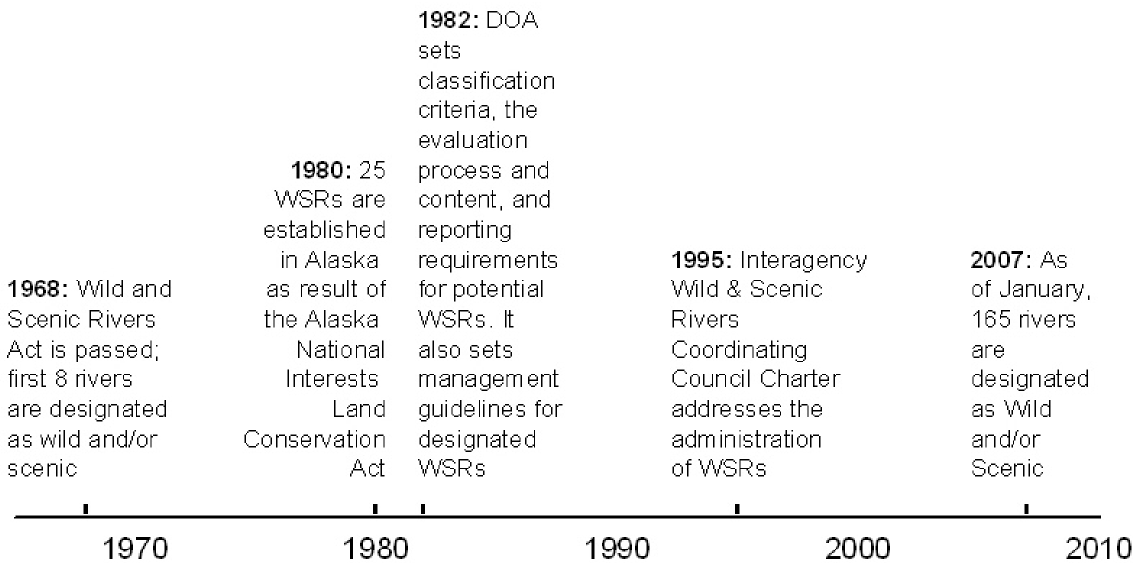


Figure 6.4. Conditions and factors affecting the future conditions of Wild and Scenic Rivers.

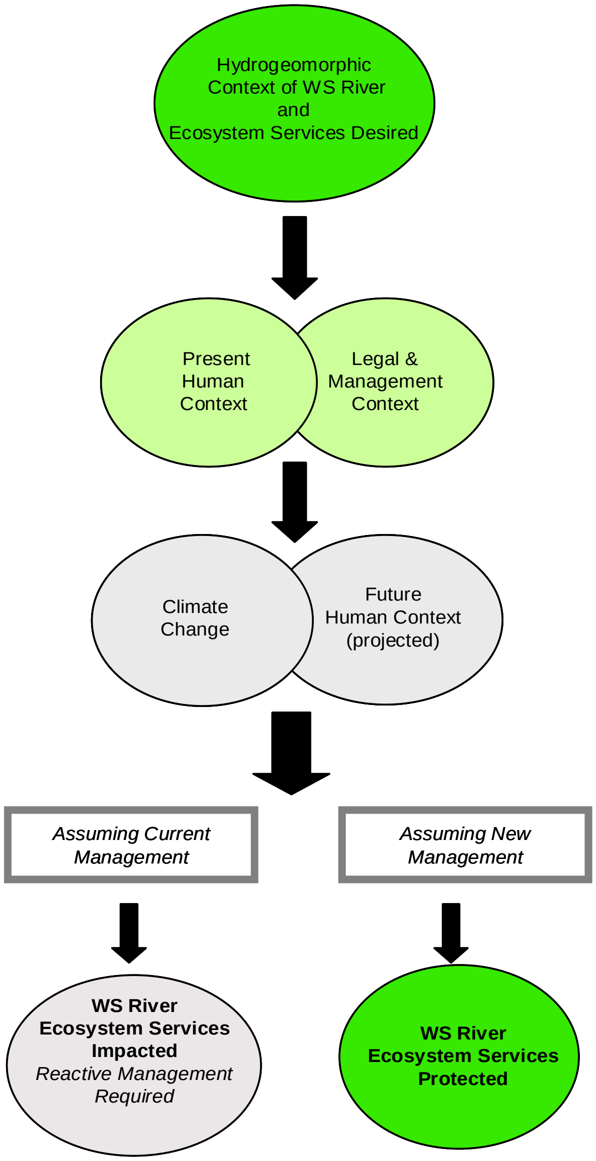


Figure 6.5. Illustration of natural flow regimes from four unregulated streams in the United States, (a) the upper Colorado River (CO), (b) Satilla Creek (GA), (c) Augusta Creek (MI), and (d) Sycamore Creek (AZ). For each the year of record is given on the x-axis, the day of the water year (October 1 – September 30) on the y-axis, and the 24-hour average daily streamflow on the z-axis (Poff and Ward, 1990).

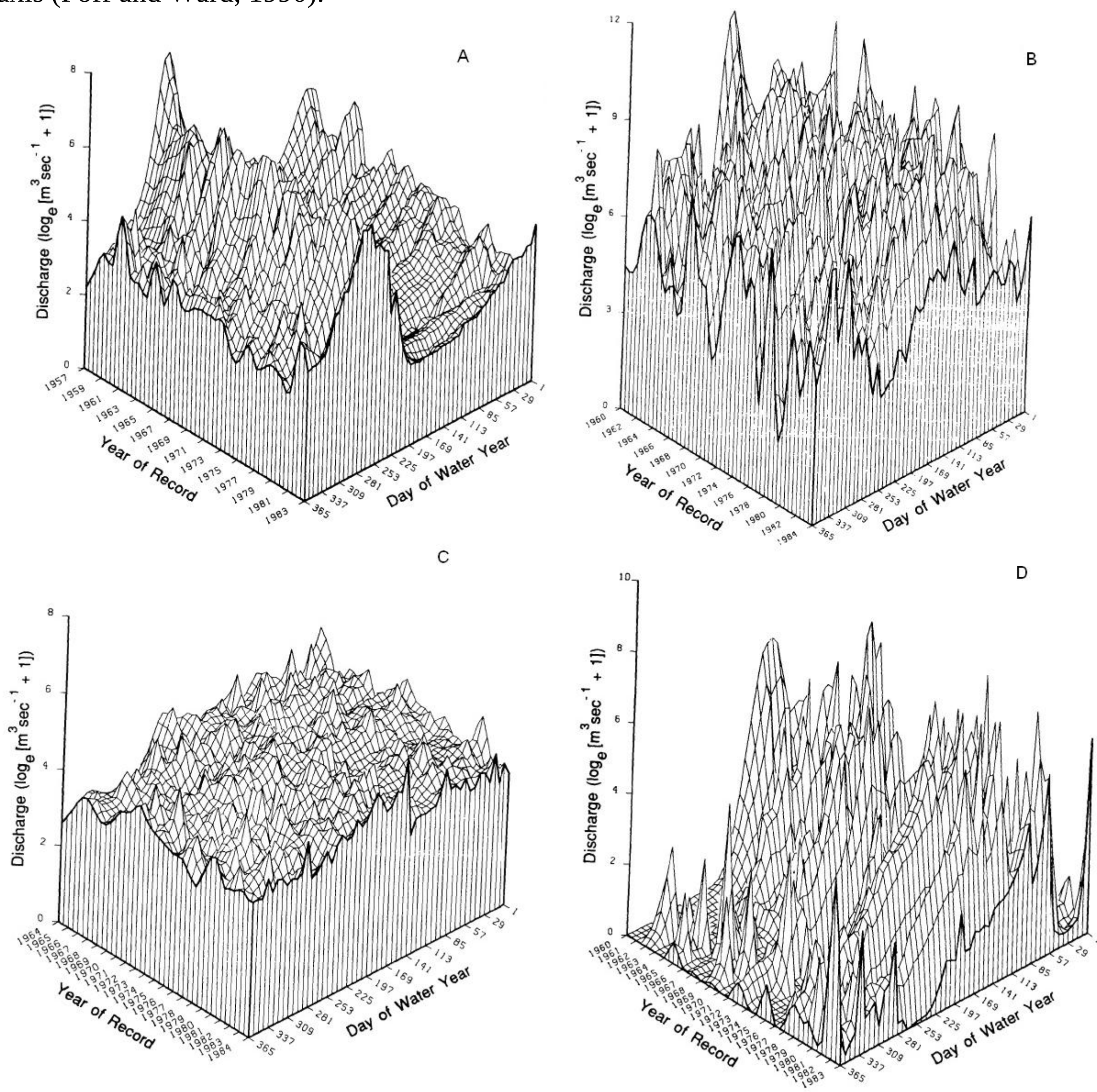


Figure 6.6. Trends in water withdrawals by water-use category. As the population has grown, water has been increasingly withdrawn for public use since 1950 as indicated by total withdrawals (blue line). Water withdrawn for power production and water for irrigation represent largest use followed by water for industrial uses then public supply. From Hutson *et al.* (2004).

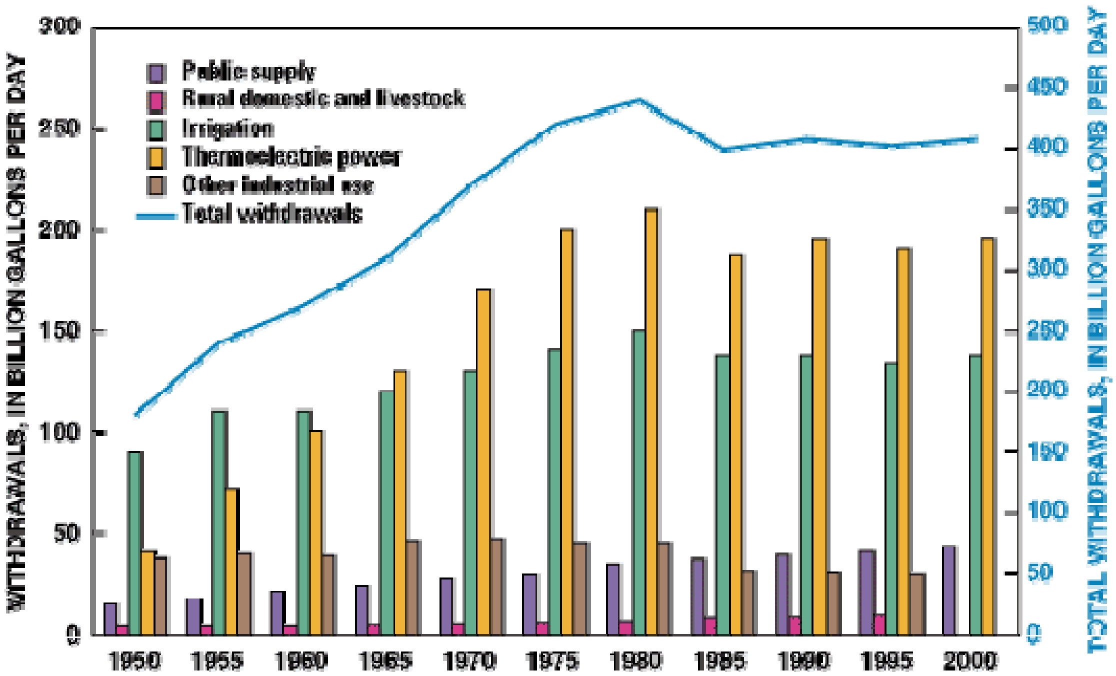


Figure 6.7. Changes in monthly average river flows on the Delaware River, in the Upper Delaware Scenic and Recreational River segment. Lowered flows in December–July result from upstream depletions for New York City water supply. Increased flows result from upstream reservoir releases during summer months for the purpose of controlling salinity levels in the lower Delaware. Figure based on data provided by USGS (2007).

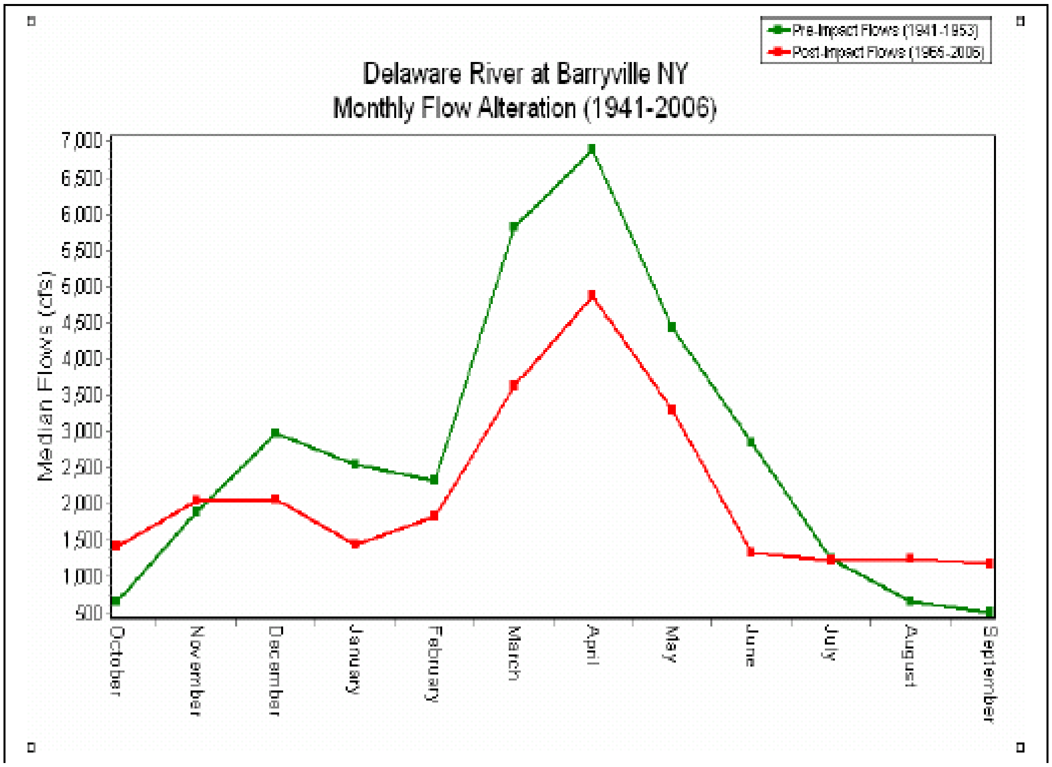


Figure 6.8. Location of dams and WSRs in the United States. Data from USGS, National Atlas of the United States (U.S. Geological Survey, 2005; 2006a).

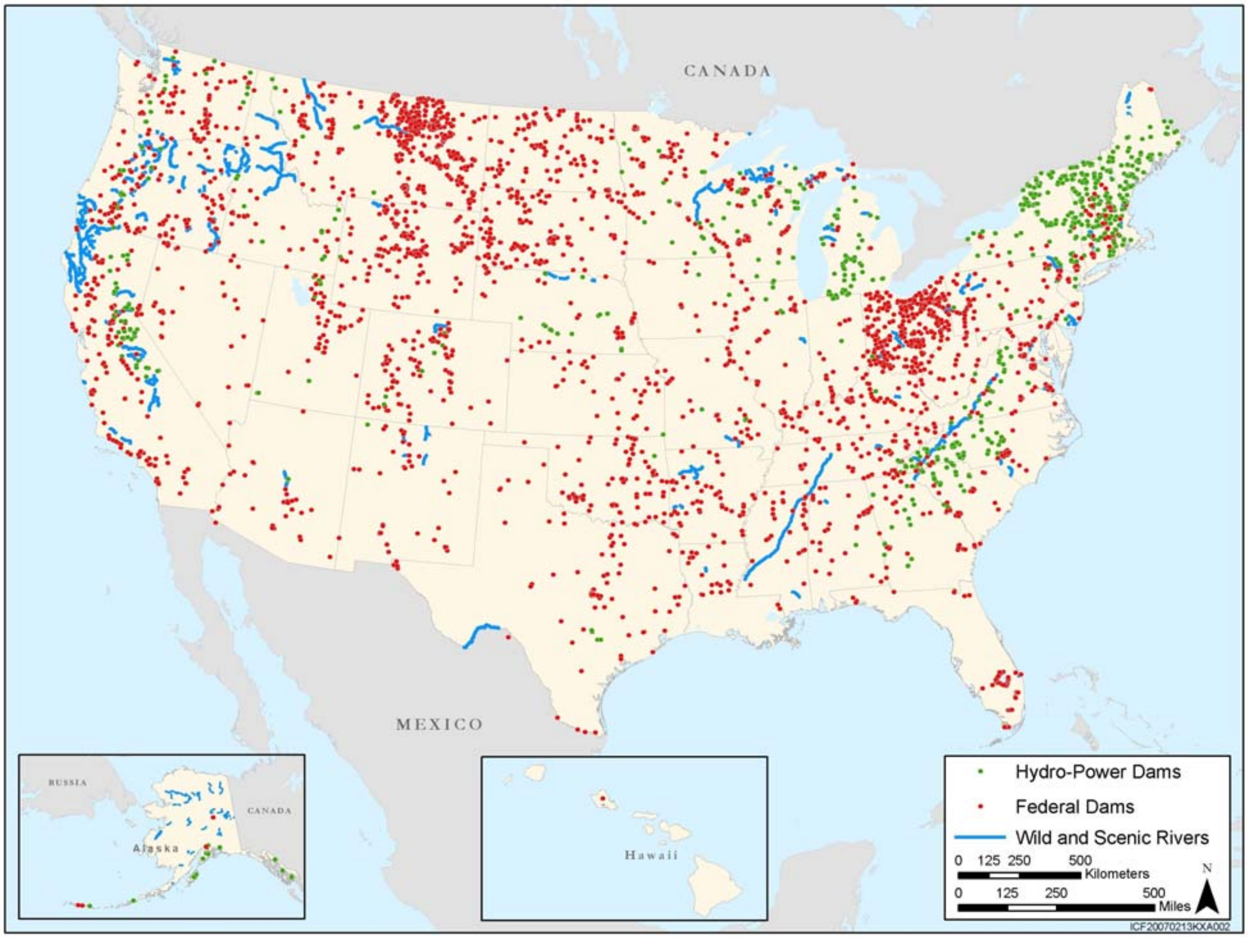


Figure 6.9. Photo of scientists standing on the bed of an urban stream whose channel has been incised more than 5 m due inadequate storm water control. Incision occurred on the time scale of a decade but the bank sediments exposed near the bed are marine deposits laid down during the Miocene epoch. Photograph courtesy of Margaret Palmer.

Figure 6.10. Organization of the WSR system. Adapted from National Wild and Scenic Rivers System website (2007a).

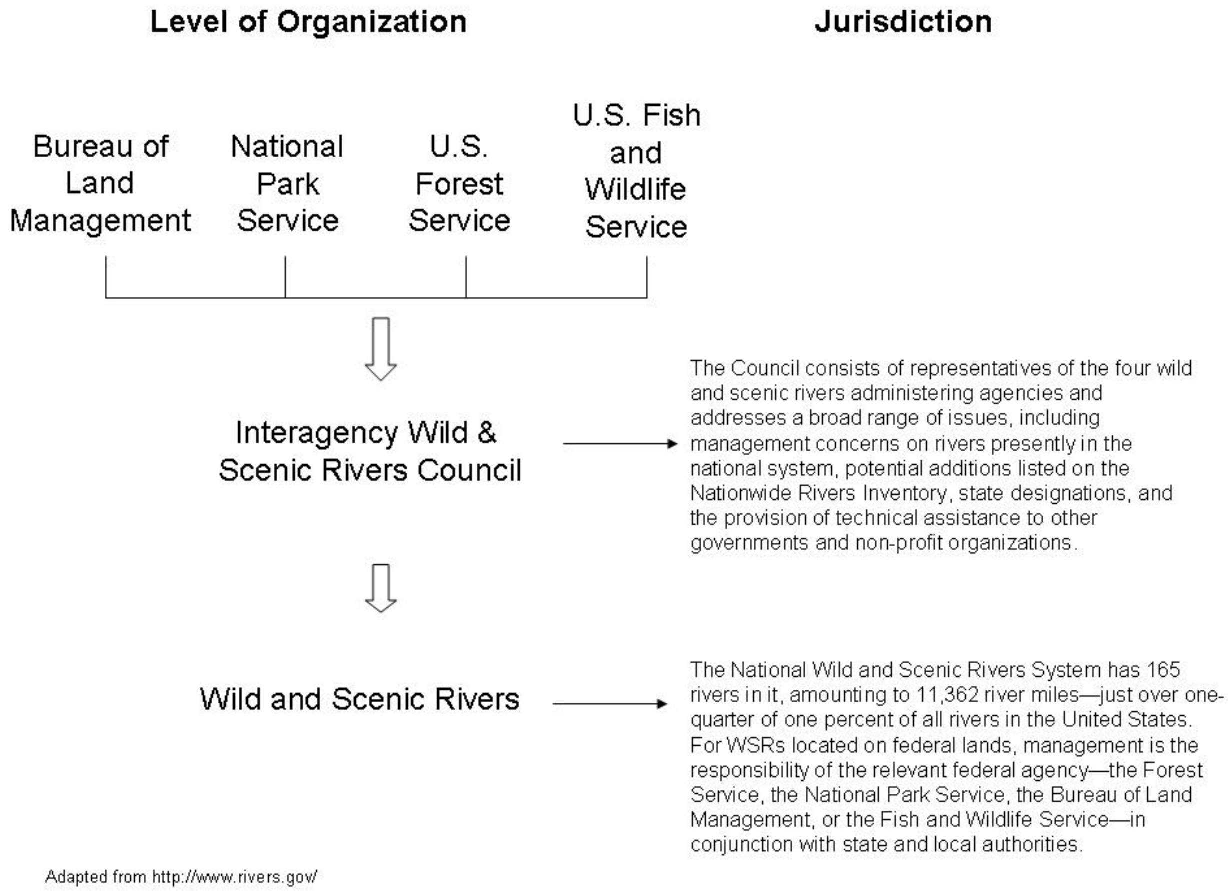
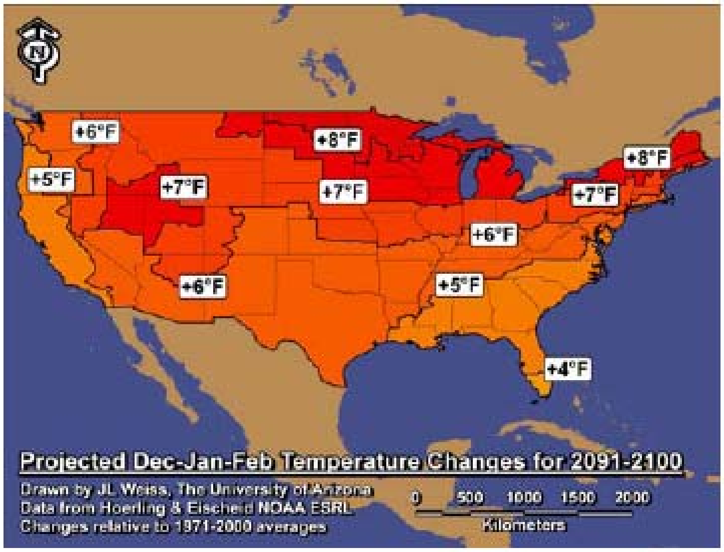
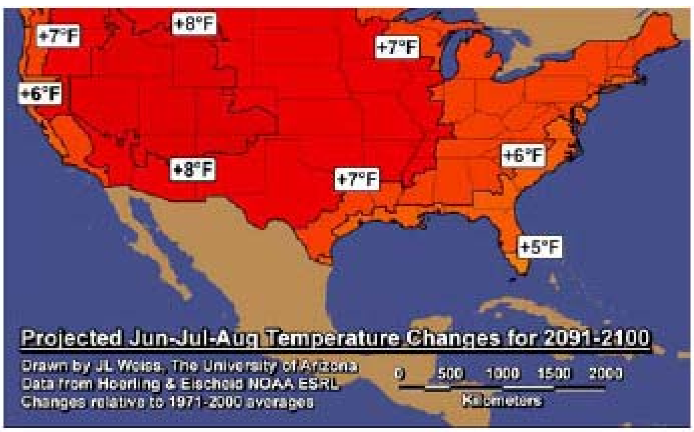


Figure 6.11. Farmington WSR. Photo compliments of the Farmington River Watershed Association.

Figure 6.12. Projected temperature changes for 2091-2100 (University of Arizona, Environmental Studies Laboratory, 2007).*

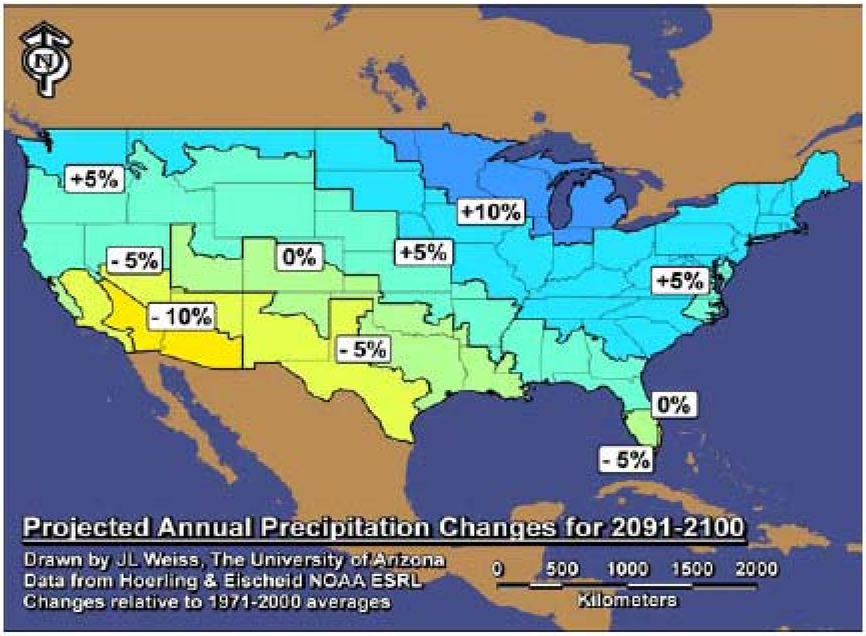




(www.geo.arizona.edu/dgesl/research/regional/projected_US_climate_change.htm

* Note: This figure is provisional, based on securing permission to reprint.

Figure 6.13. Projected annual precipitation changes for 2091-2100 (University of Arizona, Environmental Studies Laboratory, 2007).



* Note: This figure is provisional, based on securing permission to reprint.

Figure 6.14. Median, over 12 climate models, of the percent changes in runoff from United States water resources regions for 2041–2060 relative to 1901–1970. More than 66% of models agree on the sign of change for areas shown in color; diagonal hatching indicates greater than 90% agreement. Recomputed from data of Milly, Dunne, and Vecchia (2005) by Dr. P.C.D. Milly, USGS.

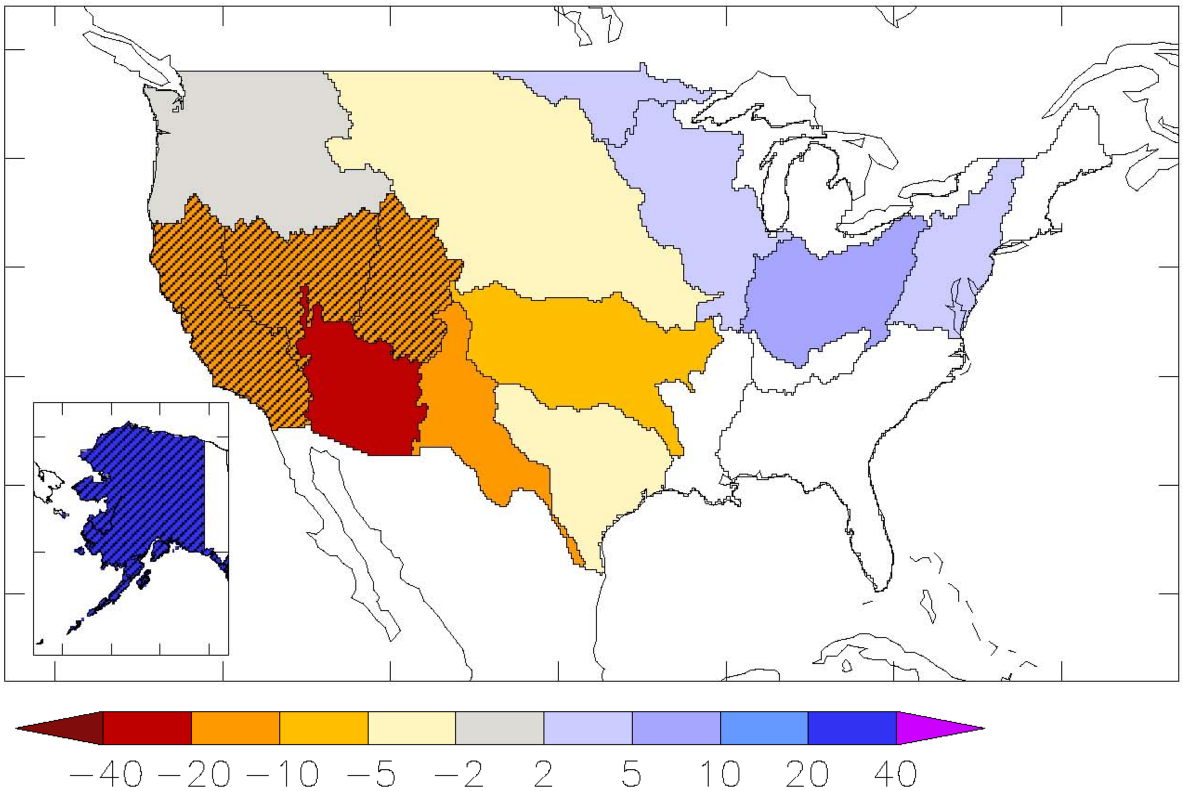


Figure 6.15. Photo of snowmelt in WSR during winter-spring flows. Photo courtesy of National Park Service, Lake Clark National Park & Preserve.

Figure 6.16. Earlier onset of spring snowmelt pulse in river runoff from 1948–2000. Shading indicates magnitude of the trend expressed as the change (days) in timing over the period. Larger symbols indicate statistically significant trends at the 90% confidence level. From Stewart, Cayan, and Dettinger (2005).

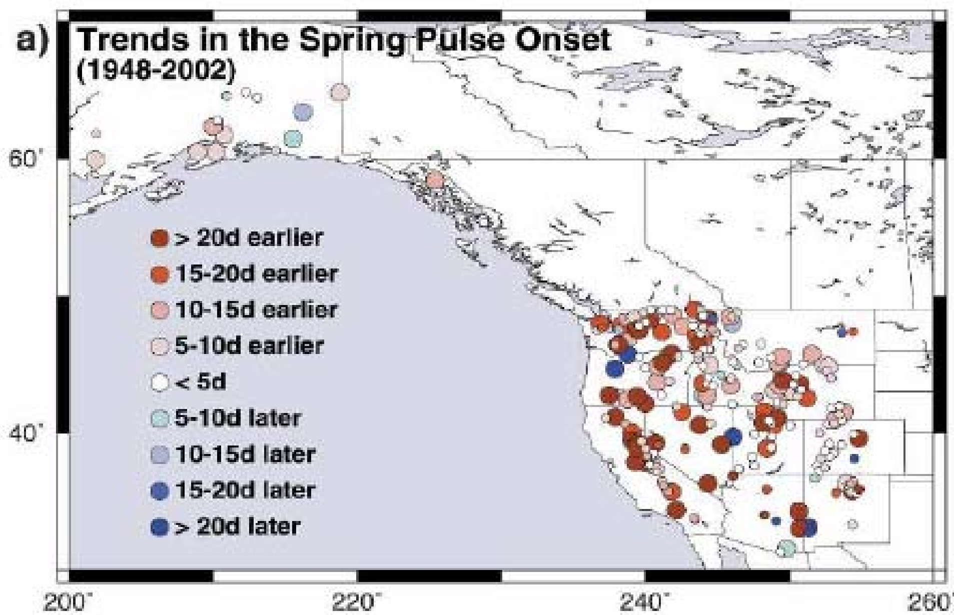


Figure 6.17. Very rapid increases (1–4 hours) in water temperature (temperature "spikes") in urban streams north of Washington D.C. have been found to follow local rain storms. *Top graph:* dark line shows stream discharge that spikes just after a rainfall in watersheds with large amounts of impervious cover; gray line shows temperature surges that increase 2–7ºC above pre-rain levels and above streams in undeveloped watersheds in the region. There is no temperature buffering effect that is typical in wildlands where rain soaks into soil, moves into groundwater, and laterally into streams. *Bottom graph:* shows that the number of temperature surges into a stream increases with the amount of impervious cover. From Nelson and Palmer (2007).

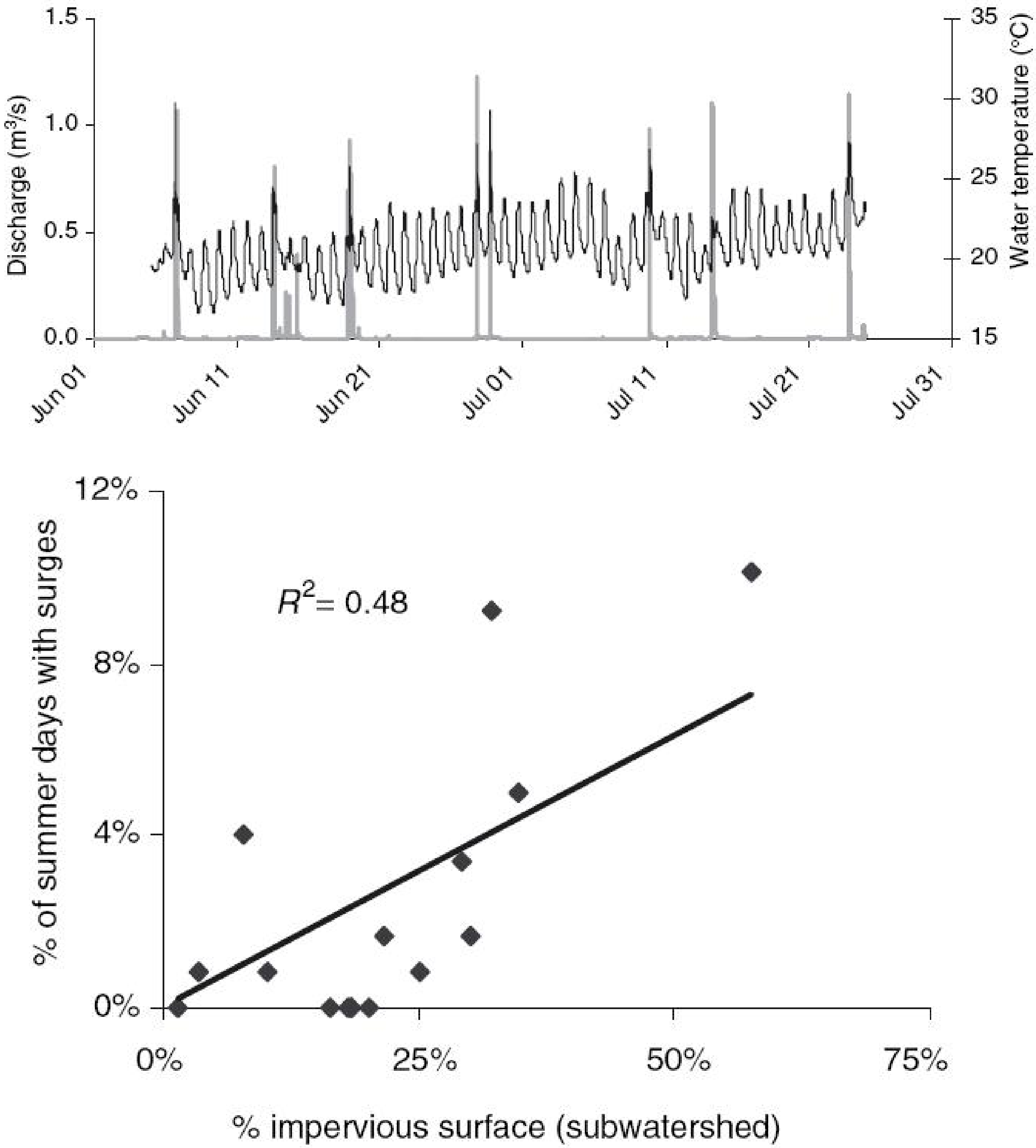


Figure 6.18. Water stress projected for the 2050s based on withdrawals-to-availability ratio, where availability corresponds to annual river discharge (combined surface runoff and groundwater recharge). From Alcamo, Flörke, and Märker (2007).

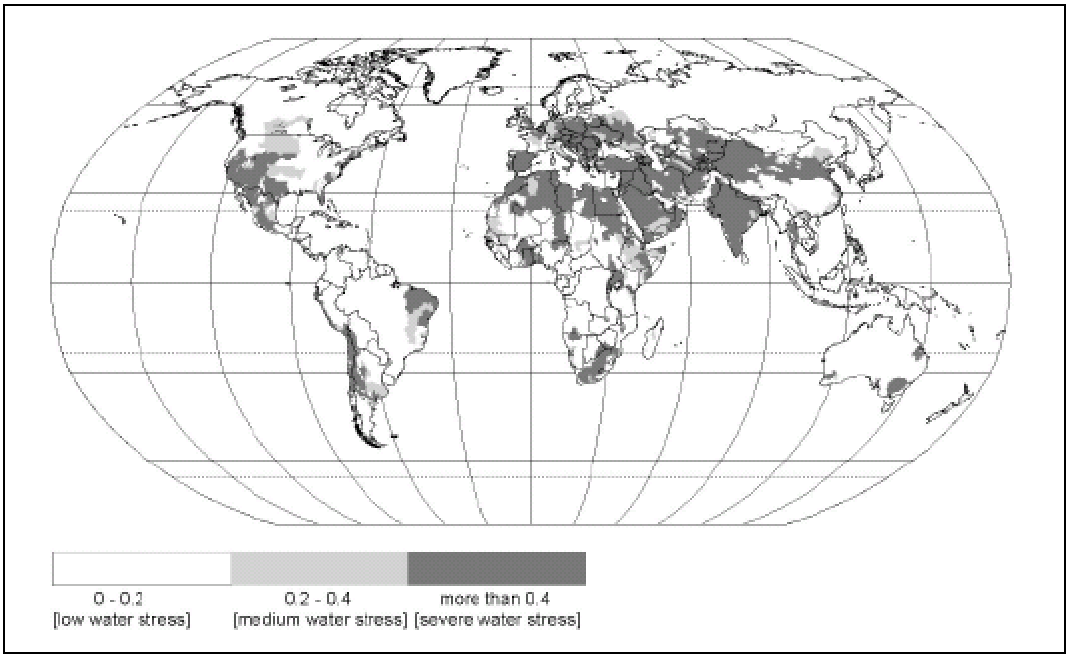


Figure 6.19. The Wild and Scenic portions of the Wekiva River. Data from USGS, National Atlas of the United States (2005).

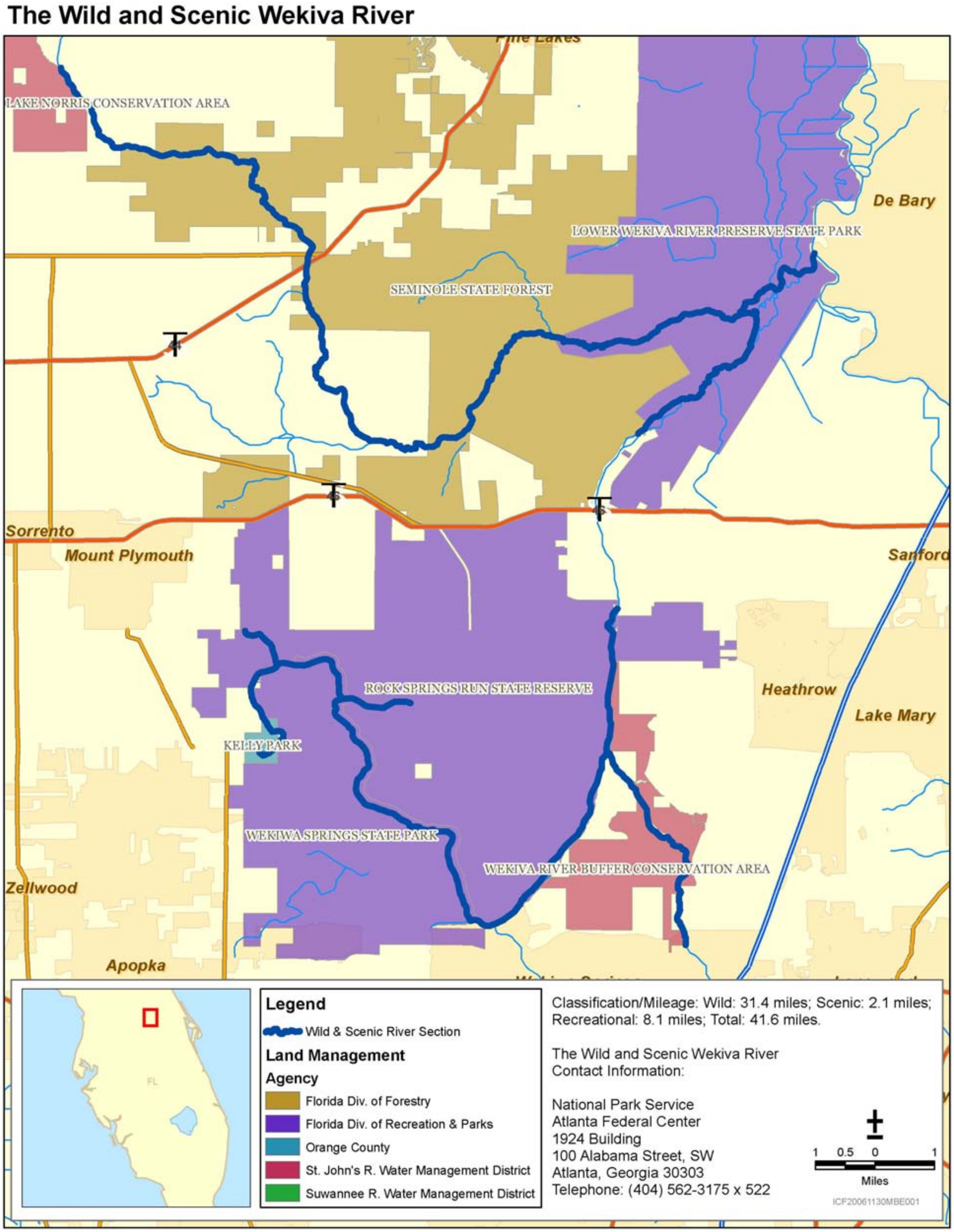


Figure 6.20. The Wild and Scenic portions of the Rio Grande WSR in New Mexico. Data from USGS, National Atlas of the United States (2005).

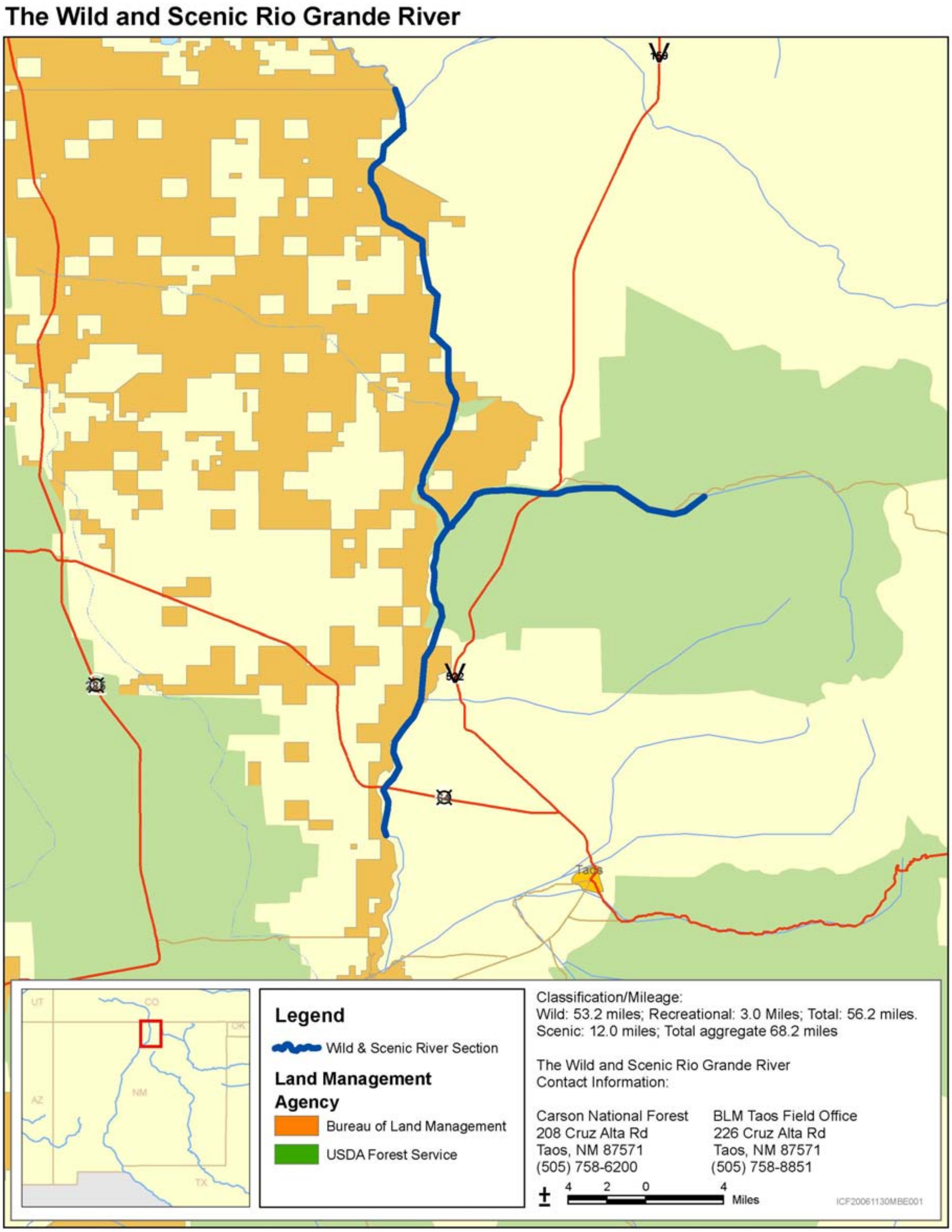


Figure 6.21. The Wild and Scenic portions of the Rio Grande WSR in Texas. Data from USGS, National Atlas of the United States (2005).

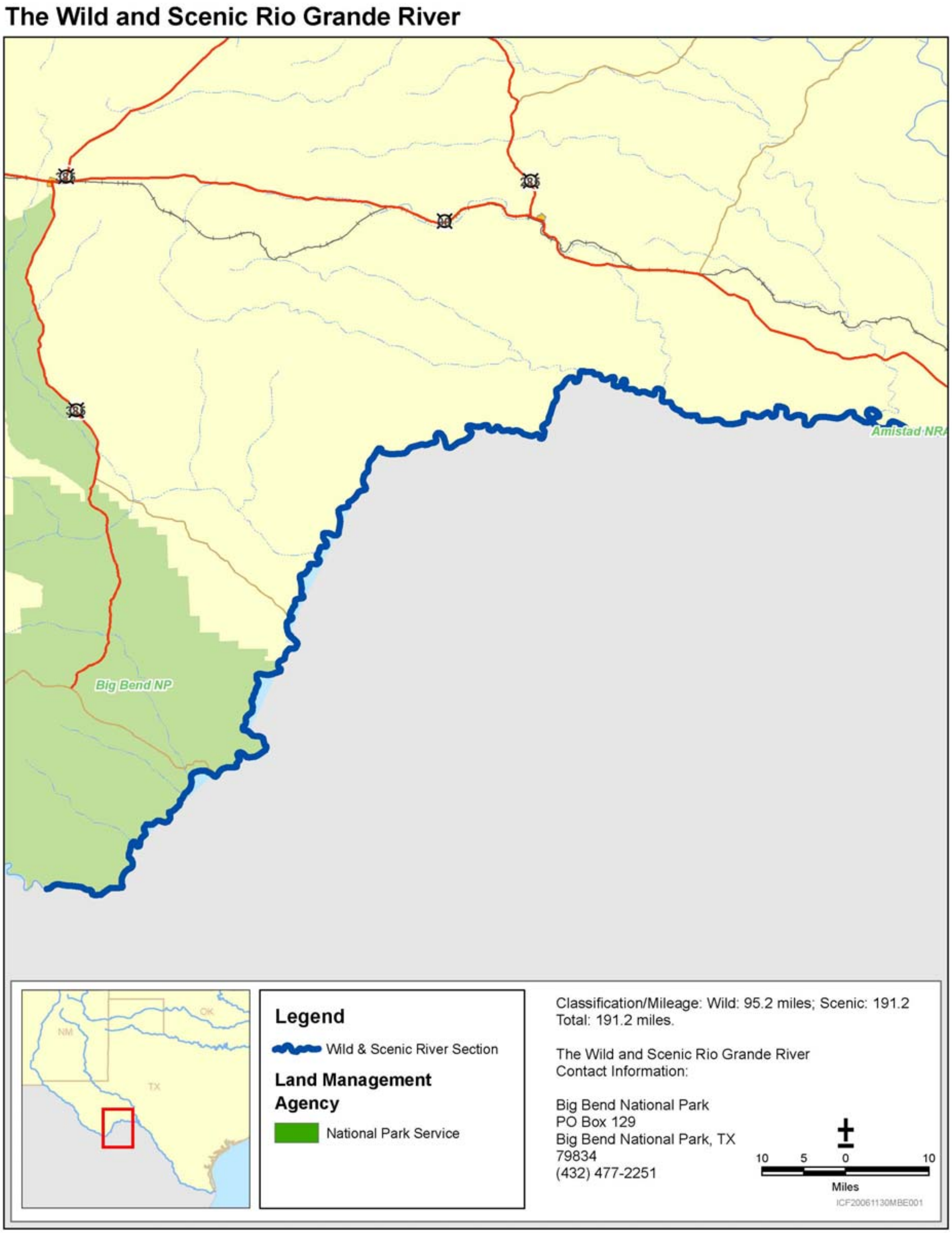
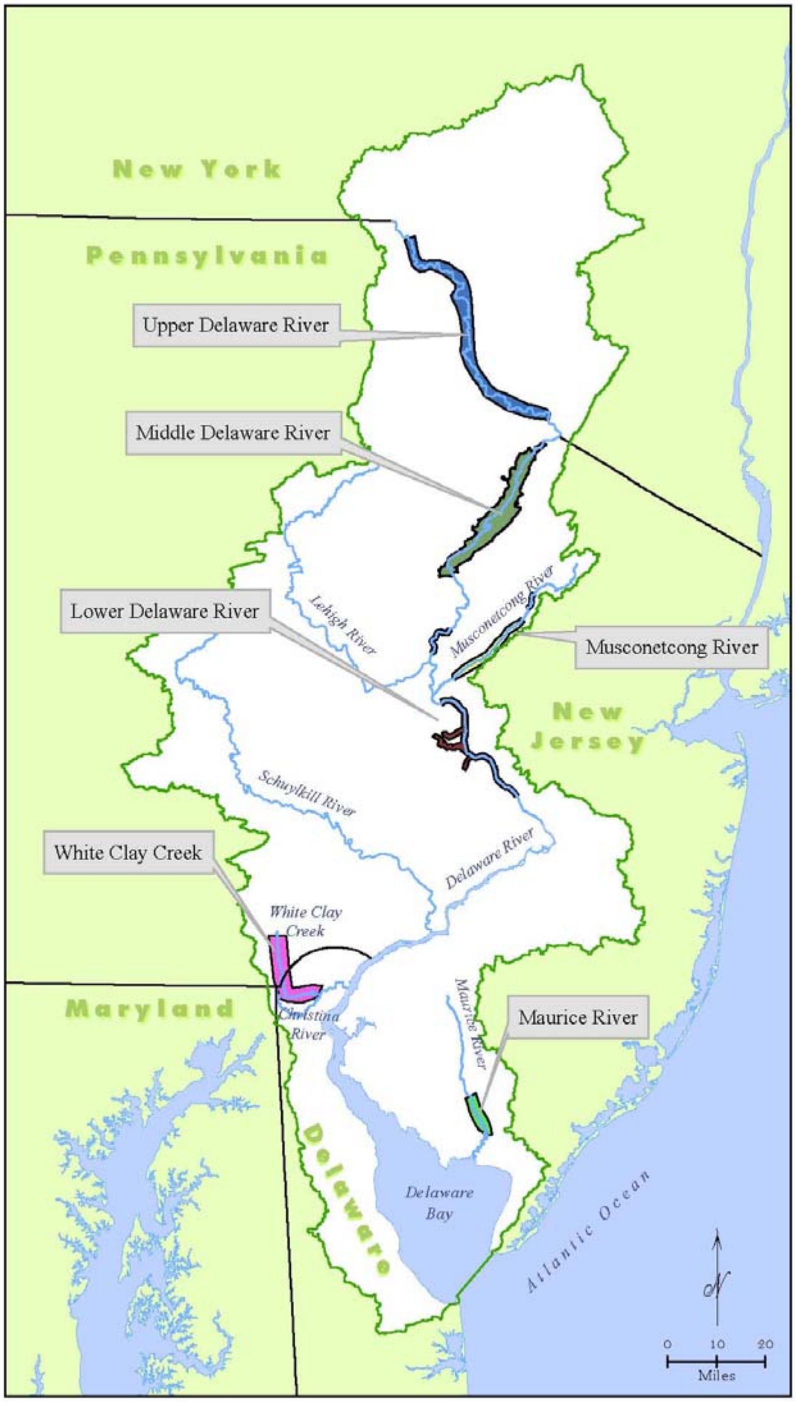


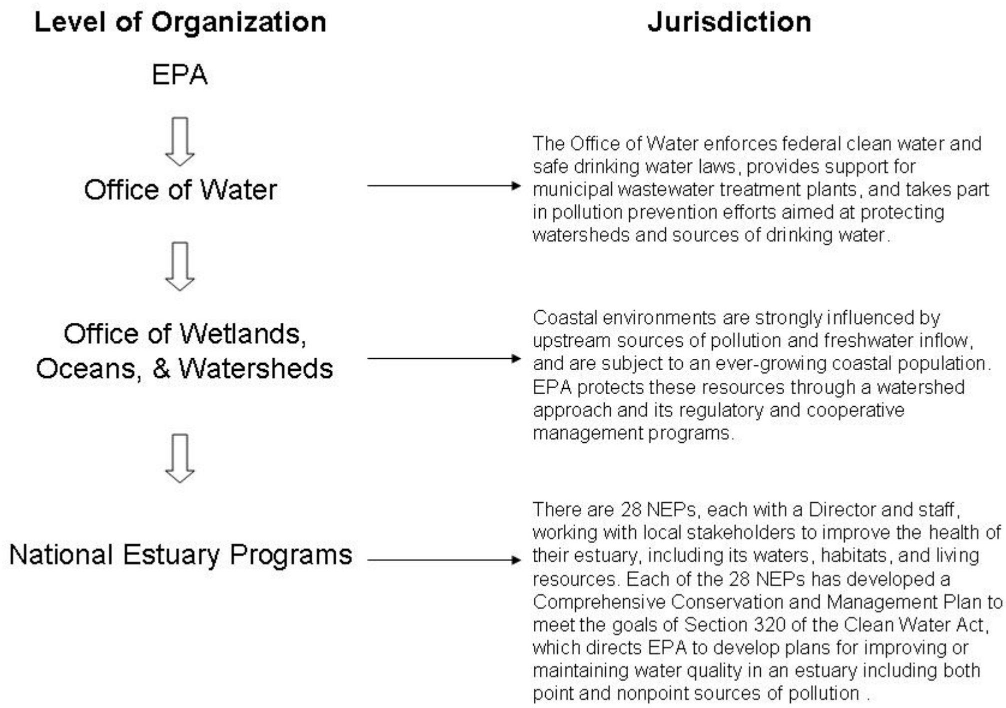
Figure 6.22. Dams and diversions along the Rio Grande (Middle Rio Grande Bosque Initiative, 2007).

Figure 6.23. Map of Wild and Scenic stretches in the Delaware River basin. Courtesy of Delaware River Basin Commission (Delaware River Basin Commission, 2007).



Figures for Chapter 7, National Estuaries

Figure 7.1. Organization of the NEP system (U.S. Environmental Protection Agency, 2007b).



Adapted from http://www.epa.gov/water/org_chart/index.htm#

Figure 7.2. Timeline of National Estuaries Program formation (U.S. Environmental Protection Agency, 2007a).

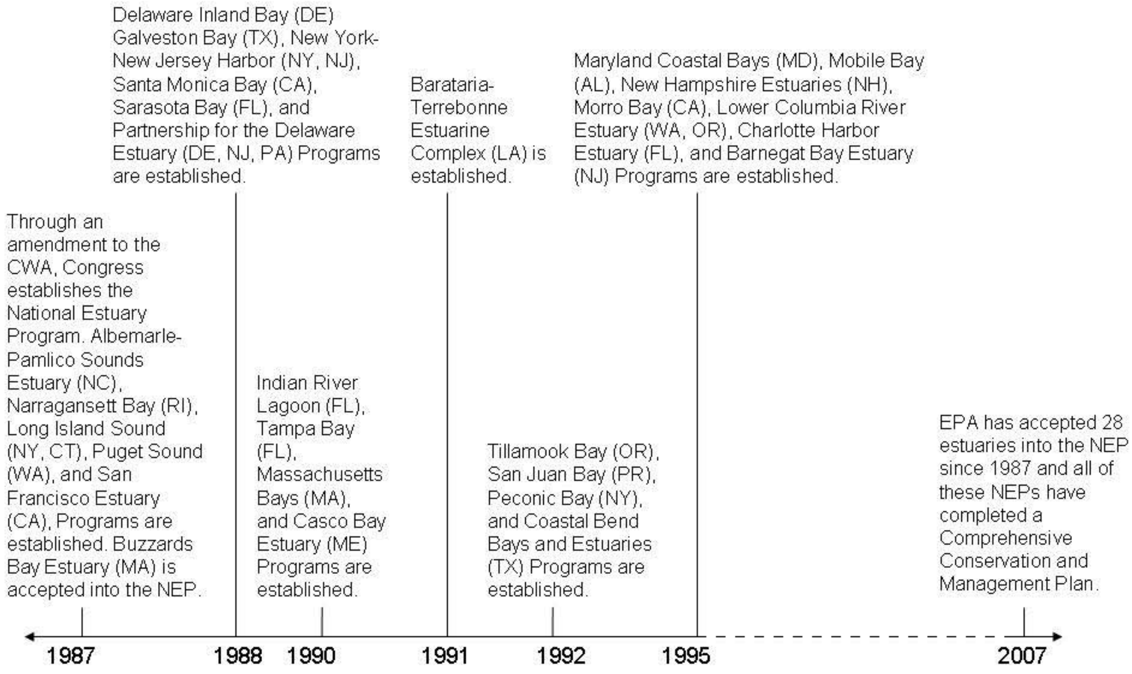
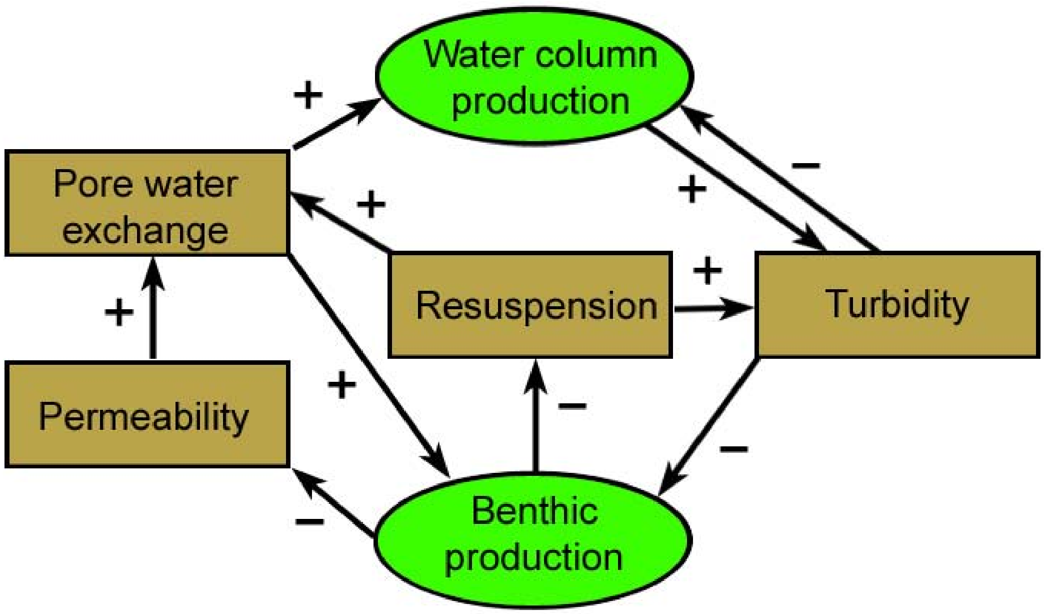


Figure 7.3. The Albermarle-Pamlico National Estuary Program region (Albemarle-Pamlico National Estuary Program, 2007).

Figure 7.4. Feedbacks between nutrient and sediment exchange and primary production in the benthos and water column. A plus symbol indicates enhancement and a minus symbol suppression.



Figures for Chapter 8, Marine Protected Areas

Figure 8.1. Locations of the 14 MPAs that compose the National Marine Sanctuary System (National Marine Sanctuary Program, 2006c).

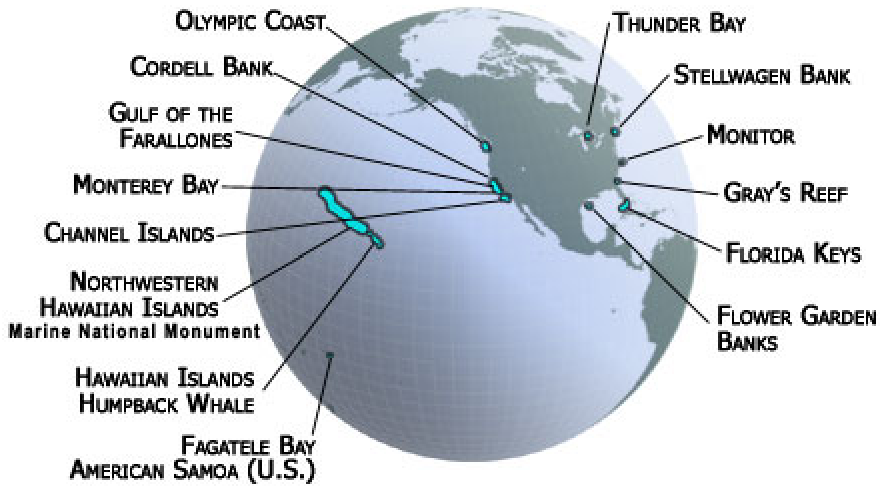


Figure 8.2. Timeline of the designation of the national marine sanctuaries in the National Marine Sanctuary Program (National Marine Sanctuary Program, 2006a).

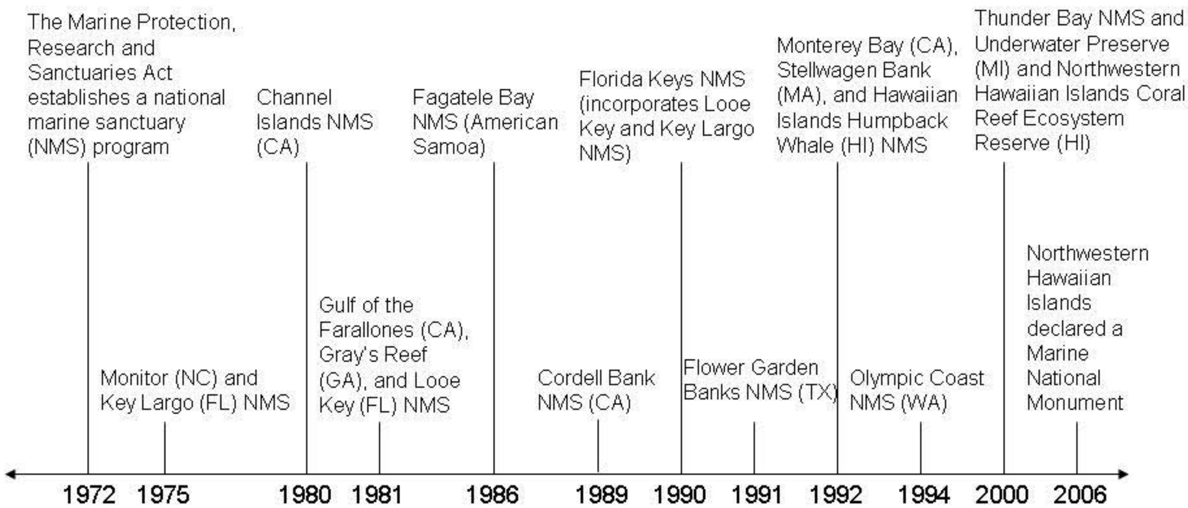


Figure 8.3. Map of the Florida Keys National Marine Sanctuary. The 1990 designation did not include the Tortugas Ecological Reserve located at the western end of the sanctuary, which was implemented in 2001. The Key Largo NMS corresponded to the Existing Management Area (EMA) just offshore of the John Pennekamp Coral Reef State Park; the Looe Key NMS corresponded to the EMA surrounding the Looe Key Sanctuary Preservation Area and Research Only Area (National Oceanic and Atmospheric Administration, 2007d).

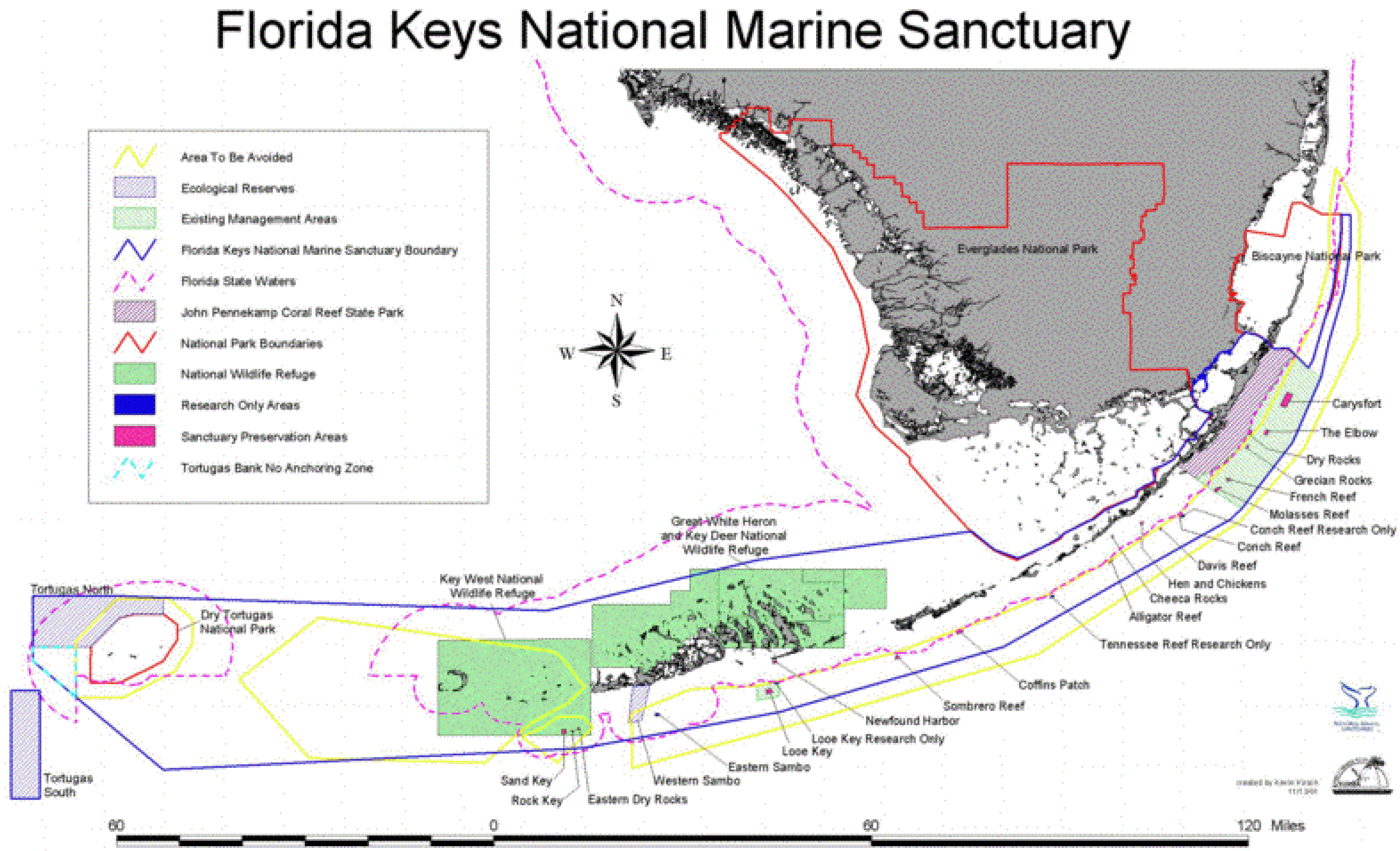


Figure 8.4. Organizational chart of the National Marine Sanctuary Program (NOAA National Ocean Service, 2006).

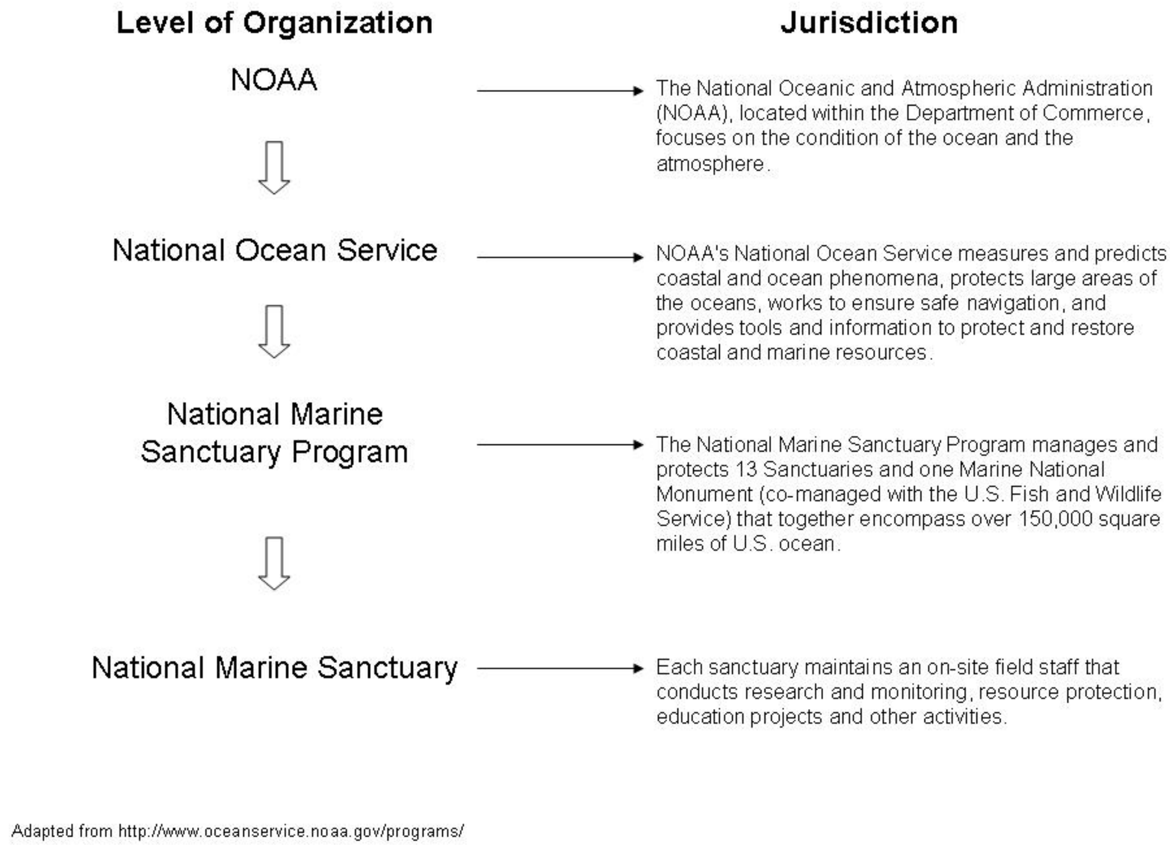


Figure 8.5. Total observed change in coral cover (%) across the Caribbean basin over the past 25 years (Gardner *et al.*, 2003). A. Coral cover (%) 1977-2001. Annual estimates (▲) are weighted means with 95% bootstrap confidence intervals. Also shown are unweighted estimates (●), unweighted mean coral cover with the Florida Keys Coral Reef Monitoring Project (1996-2001) omitted (x), and the number of studies each year (○). B. Year-on-year rate of change (mean ΔN ± SE) in coral cover (%) for all sites reporting two consecutive years of data 1975-2000 (●) and the number of studies for each two-year period (○).

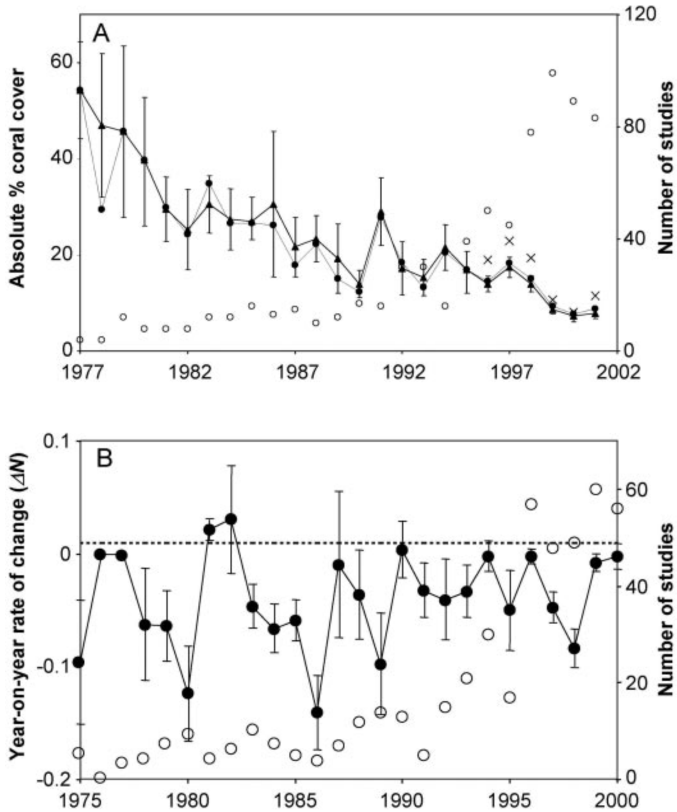


Figure 8.6. Map of the Great Barrier Reef Marine Park showing the adjacent catchment in Queensland. Modified from Haynes (2001) and courtesy of the Great Barrier Reef Marine Park Authority.

Figure 8.7. Sea surface temperature (SST) projections for the Great Barrier Reef (GBR) (Lough, 2007).

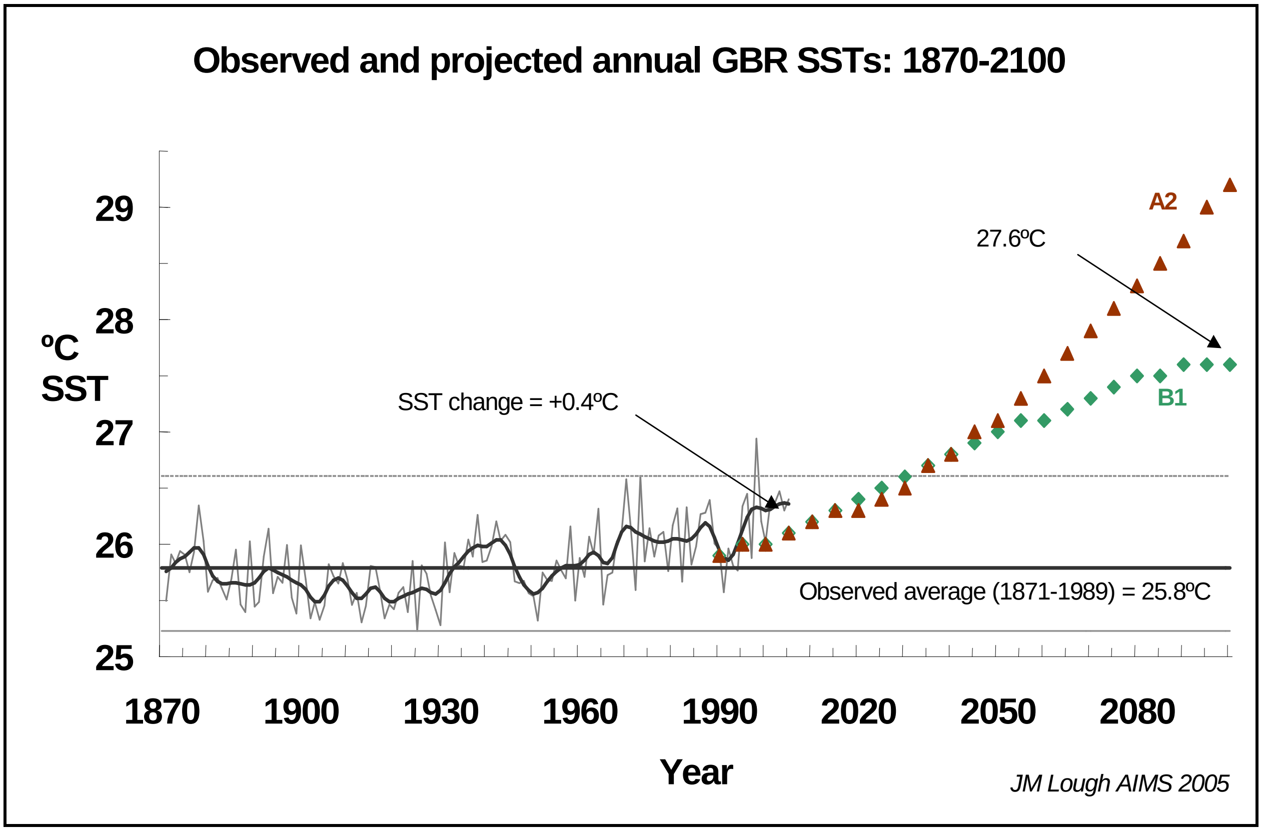


Figure 8.8. Endemic species from the Hawaiian Islands. A. Masked angelfish, *Genicanthus personatus* (Photo: J. Watt), B. Rice coral, *Montipora capitata*, and finger coral, *Porites compressa* (photo: C. Hunter), C. Hawaiian hermit crab, *Calcinus laurentae* (photo: S. Godwin), D. Red alga, *Acrosymphtyon brainardii* (photo: P. Vroom).

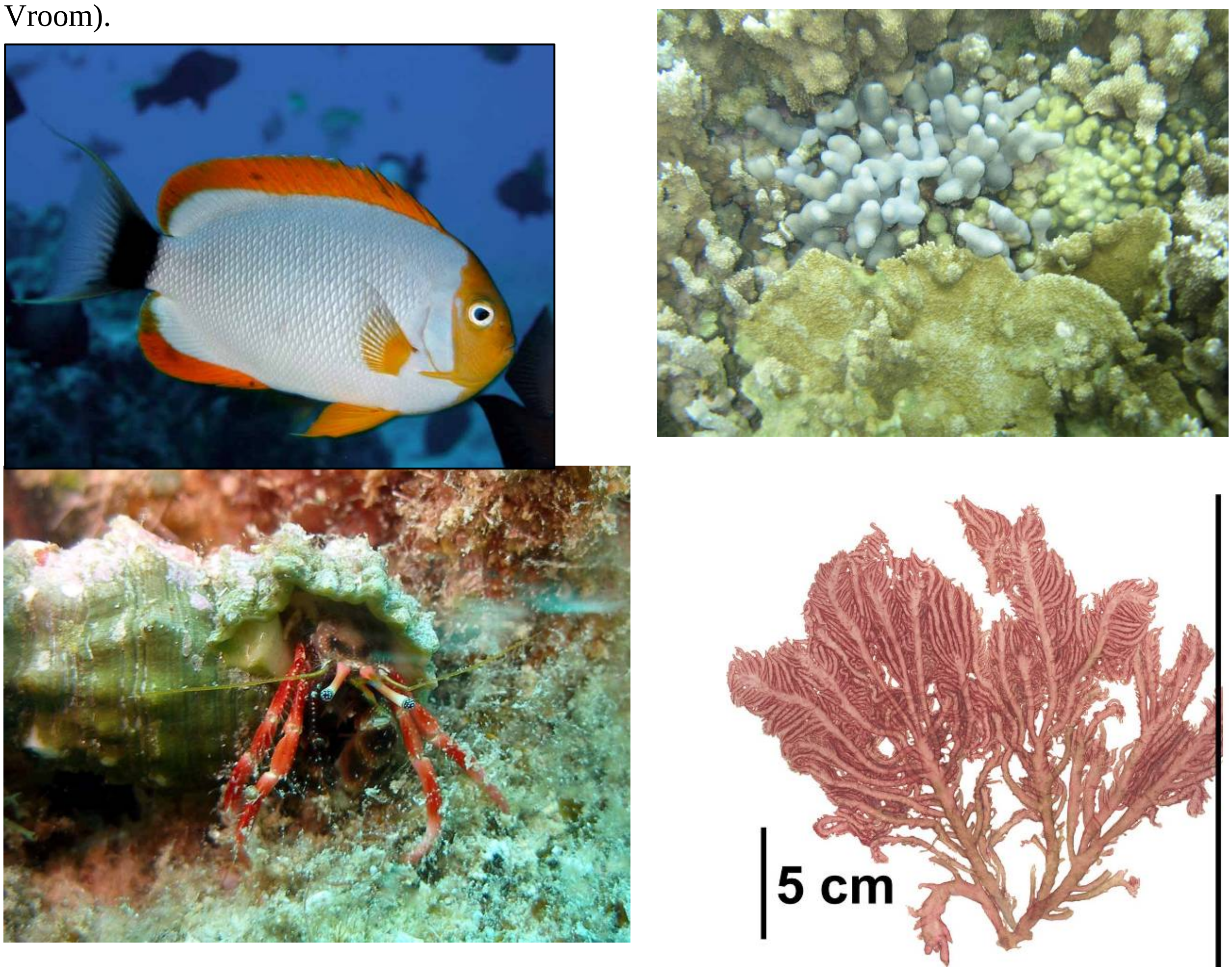


Figure 8.9. a) NOAA Pathfinder SST anomaly composite during summer 2002 period of NWHI elevated temperatures, July 28–August 29. b) NASA/JPL Quikscat winds (wind stress overlayed by wind vector arrows) composite during summer 2002 period of increasing SSTs, July 16–August 13. The Hawaii Exclusive Economic Zone (EEZ) is indicated with a heavy black line; all island shorelines in the archipelago are also plotted (adapted from Hoeke et al., 2006).

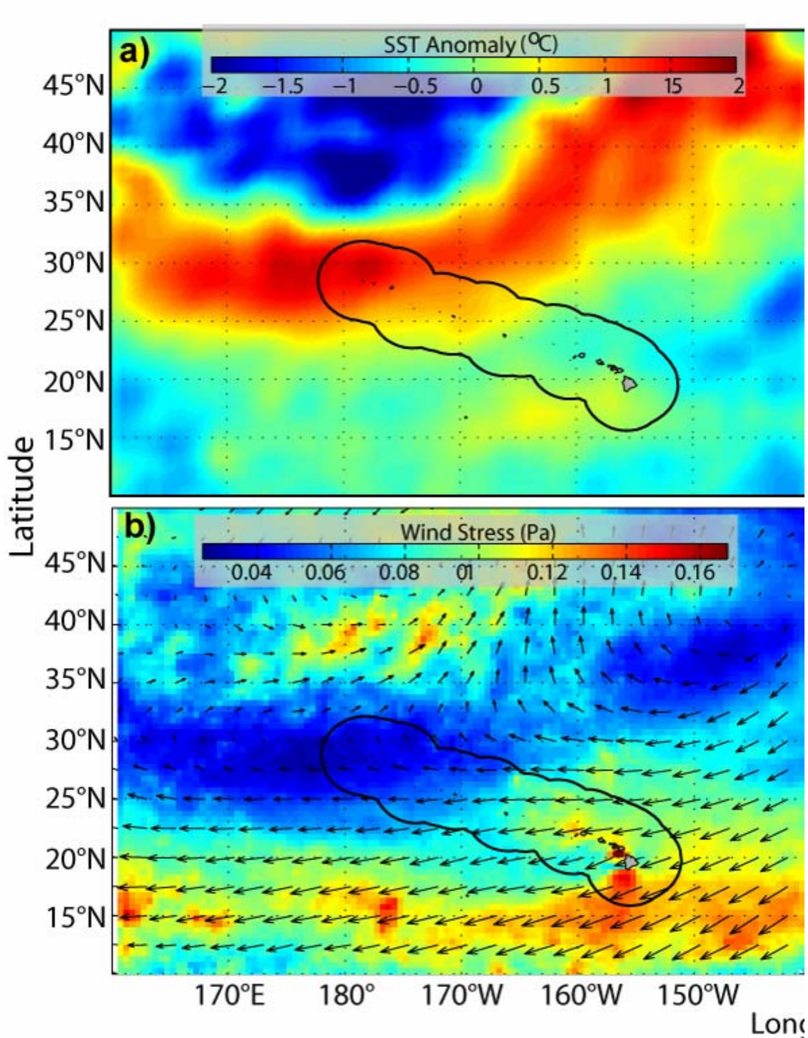
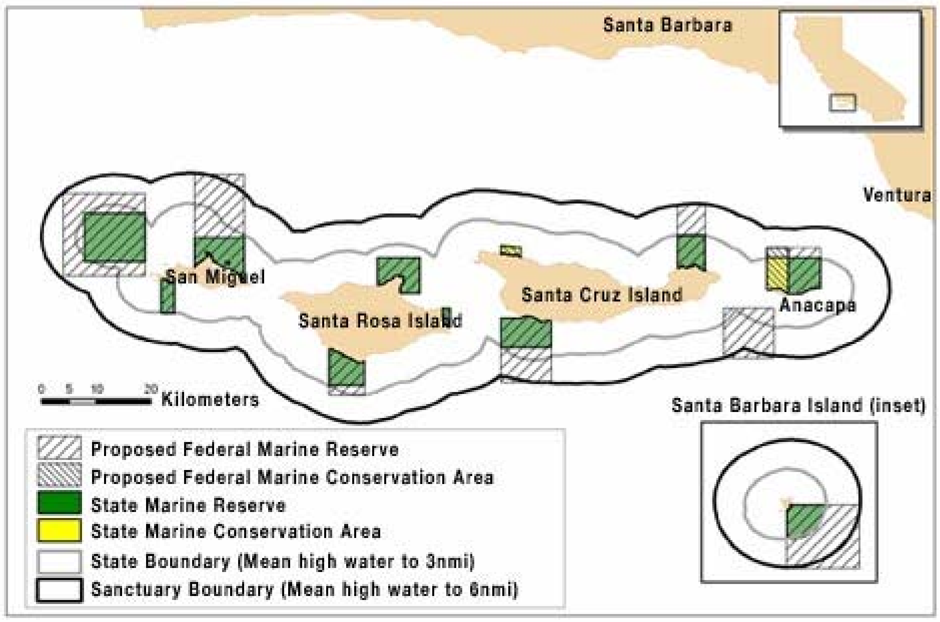


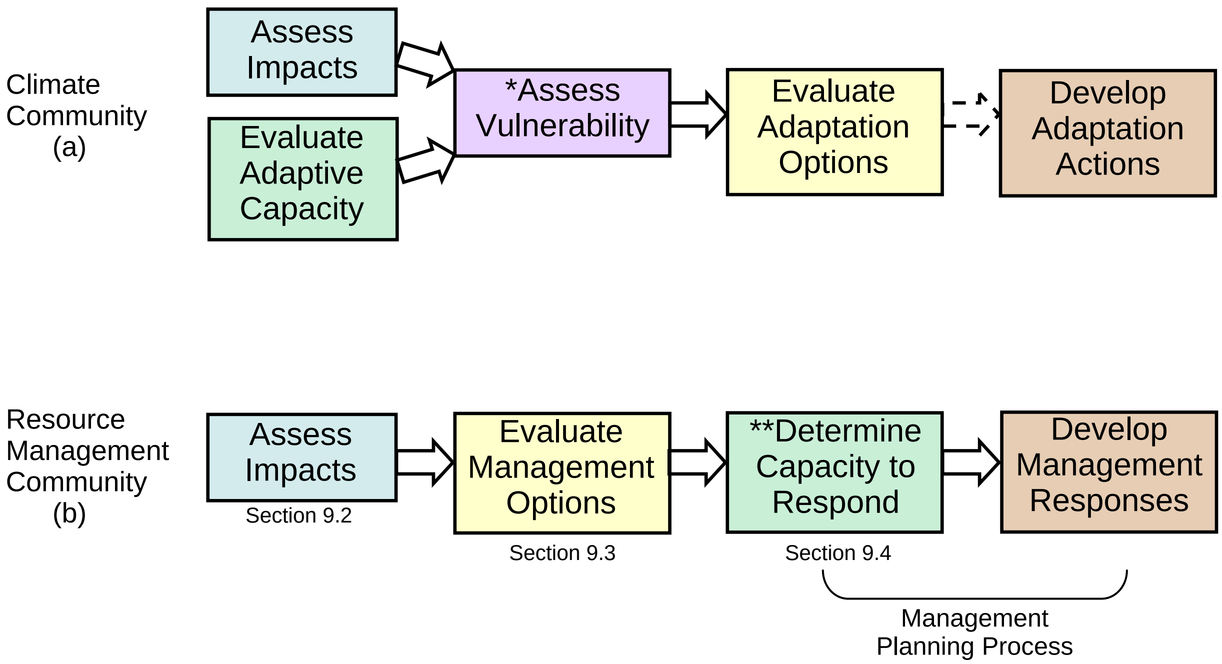
Figure 8.10. Map of the Channel Islands National Marine Sanctuary showing the location of existing state and proposed federal marine reserves and marine conservation areas (Channel Islands National Marine Sanctuary, 2007).



NOAA's preferred alternative for marine zones in the Sanctuary.

Figures for Chapter 9, Synthesis and Conclusions

Figure 9.1. Two conceptual models for describing different processes used by (a) the resource management community and (b) the climate community to support adaptation decision making. Colors are used to represent similar elements of the different processes.



*Vulnerability is the sum of projected impacts and adaptive capacity; this step is done by managers when they evaluate the projected impacts and their capacity to respond during their planning process
**Assessing the capacity to respond in the management community is equivalent to assessing adaptive capacity in the climate community

Figure 9.2. The process of adaptive management.