Appendix 1: Site Descriptions

H.J. Andrews Experimental Forest (AND) [USFS, LTER]

http://andrewsforest.oregonstate.edu/

The H.J. Andrews Experimental Forest (AND) was established as an Experimental Forest in 1948 with a focus on research to support forest management and timber production. The emphasis shifted to basic ecosystem research when the site participated in the International Biological Program in the 1970s. In 1980, AND became one of the first LTER sites. The site is located in the western Cascade Range of Oregon in the 15,800-acre (6,400-ha) drainage basin of Lookout Creek, a tributary of Blue River and the McKenzie River. Elevation ranges from 1,350 feet (410 m) to 5,340 feet (1,630 m). Broadly representative of the rugged mountainous landscape of the Pacific Northwest, the Andrews Forest contains excellent examples of the region's conifer forests and associated wildlife and stream ecosystems (figure A1-1).

The climate is cool and wet in winter and warm and dry in summer. Precipitation falls mainly as rain at low elevations and as snow at upper elevations. Soils are primarily Inceptisols, with local areas of Alfisols and Spodosols derived from mainly andesite volcanic bedrock. Surface horizons are commonly loamy but may be stony at depth and shallow on steep slopes. Douglas-fir/western hemlock forest dominates at lower elevations and Pacific silver fir forest at upper elevations. Forest age classes include 150- and 500-year-old stands developed after wildfire and plantations dominated by Douglas-fir that were established after clearcutting since 1950.

Research focus: Since its establishment as an Experimental Forest, the AND has been a site of intensive and extensive research on—

- watershed processes;
- forest ecology, especially structure, composition, and function of old-growth Douglas-fir forests and plantation;
- forest-stream interactions;
- biological diversity;
- processes, rates, and controls on nutrient and carbon cycling; and
- history and effects of natural and management disturbance processes (figure 9-14).

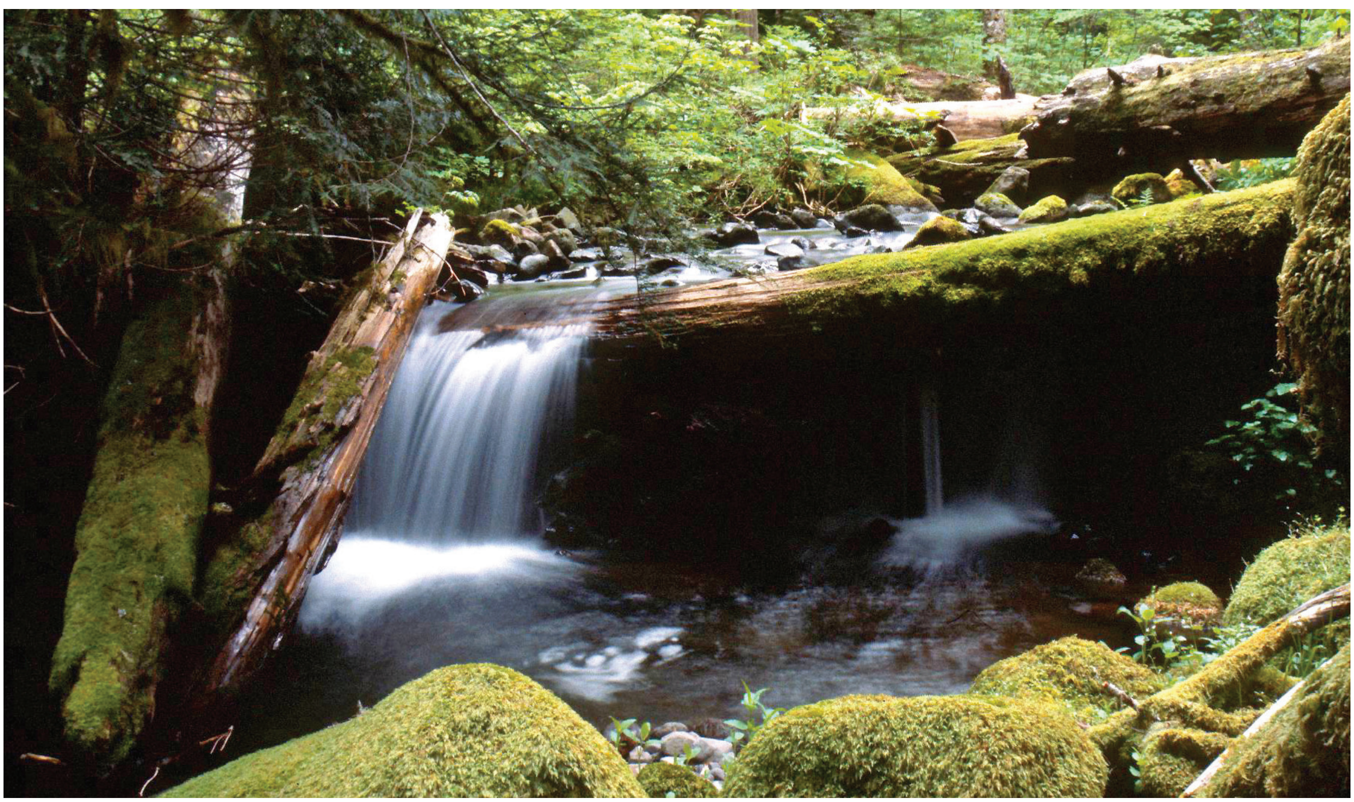


Figure A1-1. The H.J. Andrews Experimental Forest (AND) consists of streams embedded within mountainous coniferous forests. Forest of Douglas fir and western hemlock dominates most of the site, giving way to Pacific silver fir forest at upper elevations. (Photo from AND photo gallery; http://andrewsforest.oregonstate.edu.)

The central question currently guiding AND studies is "How do land use, natural disturbances, and climate variability affect three key ecosystem properties: carbon dynamics, biodiversity, and hydrology?"

Long-term research example: Studies of carbon cycling over the past two decades have revealed that Pacific Northwest forests have exceptional potential for carbon sequestration. The decomposition of logs (downed tree boles) is an important facet of the carbon balance in these forested systems. The first 20 years of a 200-year log decomposition study shows that decomposition depends on the tree species (figure A1-2). During the initial decomposition phase, which was largely the first 4 years, decomposition rates of four common species were similar. As decomposition proceeded, the rates were faster for Pacific silver fir (ABAM) and western hemlock (TSHE) compared with Douglas-fir (PSME) and western red cedar (THPL). The heartwood of the two latter species is decay resistant with THPL being particularly resistant.

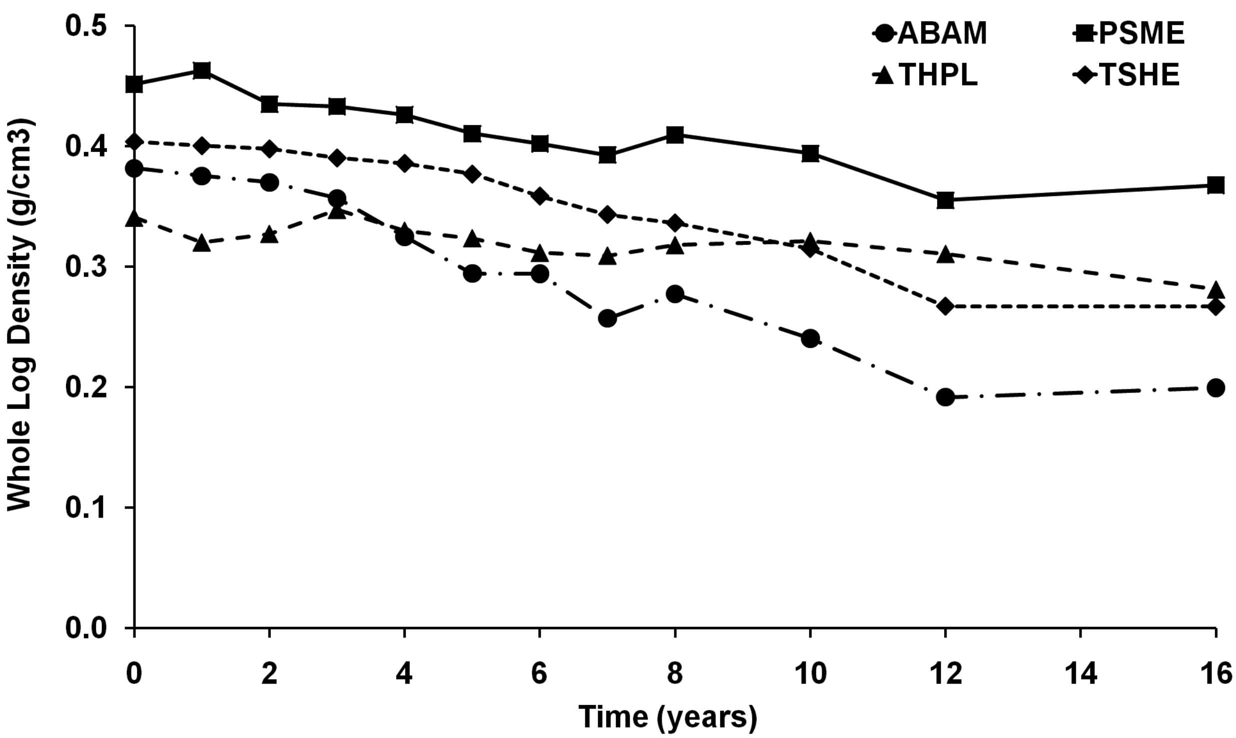


Figure A1-2. Mean density of wood and bark for logs of four species of trees common at the H.J. Andrews Experimental Forest (AND) (details in Harmon 1992). Decomposition rates of the four species were similar for the first 4 years. As decomposition proceeded, rates were faster for Pacific silver fir (ABAM) and western hemlock (TSHE), compared with Douglas fir (PSME) and western red cedar (THPL). The heartwood of the two latter species is decay resistant (Mark Harmon, unpublished data).

Arctic (ARC) [LTER]

http://ecosystems.mbl.edu/ARC/

The Arctic (ARC) LTER site was established in 1987 to understand and predict the effects of environmental change on the ecology of tundra, streams, and lakes. The site is located in the northern foothills of the Brooks Range, Alaska. The region consists of diverse vegetation and animals adapted to the frigid, dry, and windy climate (figure A1-3). Plants are low-growing (no trees) and carry out photosynthesis in a very short growing season. Tussock tundra is the dominant vegetation, but there are extensive areas of wet sedge tundra, drier heath tundra on ridge tops, and river-bottom willow communities. Permafrost (permanently frozen subsoil) is continuous. The streams in the area make up the headwaters of the Kuparuk River, and oligotrophic (low-nutrient) lakes of various ages are abundant.

Research focus: The long-term goal of ARC is to gain an understanding of controls on structure and function of arctic ecosystems through long-term monitoring and surveys of natural variation of ecosystem characteristics, experimental manipulation of ecosystems for years and decades, and synthesis of results and predictive modeling at ecosystem and watershed scales. Effects of global change on arctic systems are of particular importance for the following reasons:

- Global change is predicted to warm the Arctic sooner and more extensively than the rest of the Earth. Several decade-long experiments in heating and nutrient addition are underway in four types of tundra plant communities.
- Arctic soils contain large amounts of organic carbon, enough to double the atmospheric concentration if this carbon were to be oxidized to carbon dioxide when permafrost thaws. Climate warming and human activities in the future will change the water cycle with impacts on permafrost dynamics: too much water will slow down the decomposition of organic matter, whereas too little water will drastically reduce plant growth.

Figure A1-3. The Arctic Long Term Ecological Research (ARC LTER) site is in northern Alaska and has the goal of understanding effects of environmental change on tundra, streams, and lakes. (Photo from ARC photo gallery.)

Long-term research example: Fertilization with nitrogen (10 g/m²/y) and phosphorus (5 g/m²/y) results in a shift in species dominance from a grass-like sedge *(Eriophorum vaginatum)* to a shrub species *(Betula nana)* within 6 years (figure A1-4). *Betula* (dwarf birch) plants also increased in biomass on control plots without fertilization, but not until 11 years later after a decade of warm summers. Woody shrubs are increasing and herbaceous species are being lost throughout the Arctic, likely as a result of warmer temperatures that increase nutrient supply in the soil that favors taller, woody species (Bret-Harte et al. 2001, 2002).

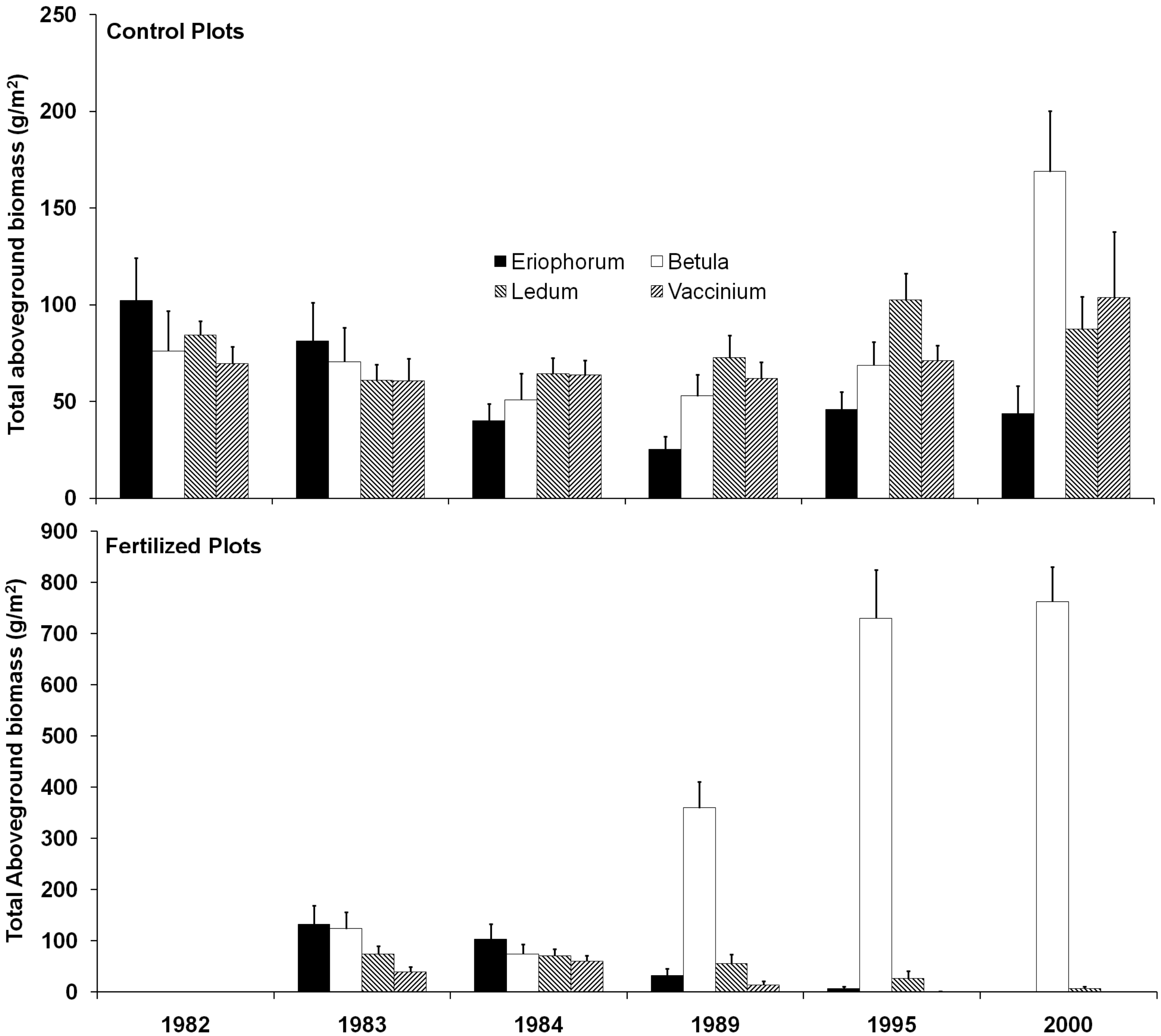


Figure A1-4. Aboveground biomass for four major species in moist acidic tussock experimental plots at the Arctic LTER. Fertilization with nitrogen and phosphorous shifts species dominance from sedges to shrubs within 6 years (updated from Shaver et al. 2001). Data are available at http://ecosystems.mbl.edu/ARC.

Baltimore Ecosystem Study (BES) [USFS, LTER]

http://www.beslter.org/

The Baltimore Ecosystem Study (BES) was established as an LTER site in 1997 to investigate metropolitan Baltimore as an ecological system. The BES conducts research and educational activities in Baltimore City and the surrounding counties (figure A1-5). The project focuses on several watersheds to organize research both spatially and functionally. For example, the Gwynns Falls Watershed encompasses 17,150 hectares and drains into the Chesapeake Bay. The watershed includes agricultural lands, recently suburbanized areas, established suburbs, and dense urban areas having residential, commercial, and open spaces.

Vegetation of the watershed has changed from predominantly forest before European settlement to primarily herbaceous today. There are no original stands of forest in the Baltimore area, although a reference second-growth forested watershed was established in a park in Baltimore County. Research on stream restoration is centered in the Minebank Run catchment. A study of the ecological effects of residential neighborhood greening and restoration is being conducted in a 364-ha storm drain catchment in Baltimore City. A permanent eddy flux tower is located in Baltimore County.

Research focus: The program brings together biological, physical, and social scientists, who collect new data and synthesize existing information to determine how the ecological and built components of Baltimore function and how they are expected to change over long periods. Research aims to provide an integrated understanding of Baltimore as a social-ecological system using several frameworks to support comparative and quantitative urban studies:

- spatial patch dynamics of biophysical and social factors,
- the watershed as an integrative tool, and
- the human ecosystem framework

Figure A1-5. The Baltimore Ecosystem Study Long Term Ecological Research (BES LTER) covers the urban Baltimore, MD, and surrounding areas. (Photo from BES photo gallery.)

These frameworks build on empirical research investigating urban biota, nutrient and energy budgets, and ecological footprints of cities, as well as biotic classifications aimed at urban planning. These frameworks support investigations of—

- the structure and change of the urban ecosystem,
- the fluxes of matter, energy, capital, and population in the metropolis, and
- how ecological information affects the quality of the local and regional environments

These data streams are designed to answer questions about the feedback between social characteristics and actions and ecological patterns and processes. Insights gained from BES research are embodied in regular dialog with Baltimore City, Baltimore County, and State of Maryland decisionmakers and environmental managers. BES approaches and insights have been used in after-school and regular academic curricula in public and private schools in the Baltimore region.

Long-term research example: BES research showed that nitrate concentrations in streams draining agricultural fields are higher than in streams draining urban and suburban areas, with lowest concentrations found in streams draining forests (figure A1-6). Interactions between climate variability and urbanization affect nitrogen losses from streams (Kaushal et al. 2008). These results are important because the mosaic of agricultural, residential, and forested land use is very dynamic in time and space, and there is great concern about nitrogen delivery to the Chesapeake Bay (Shields et al. 2008). The results raise questions in terms of balancing concerns about nitrogen with interest in other ecosystem services provided by agriculture in the landscape.

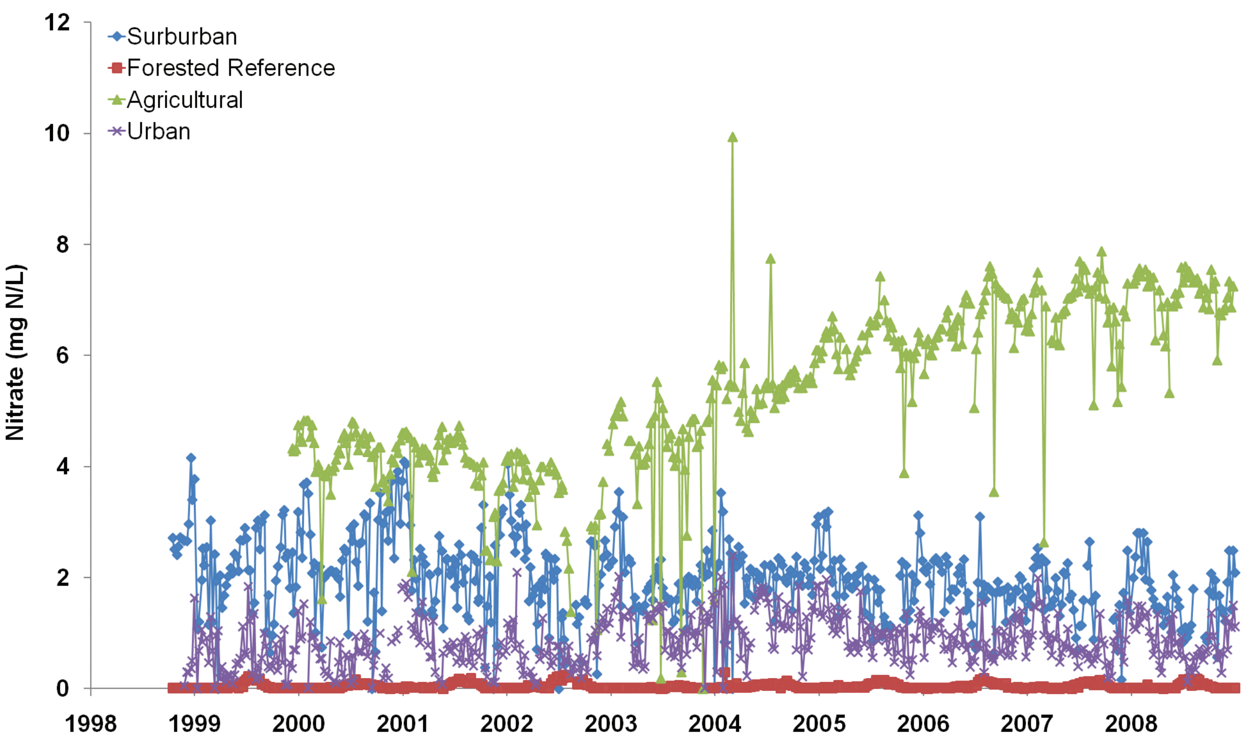


Figure A1-6. At the Baltimore Ecosystem Study (BES), nitrate concentrations in streams from agricultural fields are higher than in urban and suburban areas. Data from 1998-2001 in Groffman et al. (2004). All data are available at http://beslter.org/frame7-page_1.html.

Bent Creek Experimental Forest (BEN) [USFS]

http://www.srs.fs.usda.gov/bentcreek/

The 2,550-ha Bent Creek Experimental Forest (BEN) is the oldest experimental forest in the Eastern U.S., dating to 1916 when the USDA Forest Service acquired much of the Pisgah Forest. Located in the southern Appalachian Mountains, BEN is found on two land type associations: the intermountain valley (Asheville Basin) and the upper-elevation mountain highlands. Asheville Basin soils are Ultisols, and the vegetation is subxeric oak and hickory stands. Dry-site ericaceous shrubs, such as mountain laurel, dominate many forest understories. Mountain highlands soils are Inceptisols that are usually low in fertility. The highlands are forested with oaks and hickories on slopes and ridges. Cove hardwoods, including yellow-poplar and northern red oak, are found on more mesic sites. Rhododendron thickets are common on gently sloping aspects and in drainages. White, shortleaf, Virginia, and pitch pine are common associates.

Research focus. Much of what is known about regeneration and management of southern Appalachian hardwoods stems from research by the Bent Creek staff. Investigations at BEN focus on problems of ecological classification of upland forest ecosystems, forest dynamics, response to silvicultural treatments, and wildlife-habitat relationships. The BEN has an active outreach program that includes a wide array of silvicultural demonstrations and technical training programs.

Blacks Mountain Experimental Forest (BLA) [USFS]

http://www.fs.fed.us/psw/ef/blacks_mountain/

Blacks Mountain Experimental Forest (BLA), in Lassen County, California, was originally designated in 1934 as the Pacific Southwest Station's principal site for management studies of the interior ponderosa pine type. BLA contains about 10,600 acres ranging in elevation from 1,676 m to 2,103 m. Most of the forest is dominated by ponderosa and Jeffrey pine, with white fir and incense-cedar becoming more common at higher elevations. Locally known as "eastside pine," this forest type covers about 2.3 million acres, nearly 14 percent of the total available commercial forest area in California. The forest type also extends south into Baja California and north through eastern Oregon and Washington into central British Columbia.

Research focus. Research at BLA includes an insect-risk rating system to identify large, old ponderosa pines at risk of being killed by the western pine beetle. A 50-year record of stand development has quantified the increase in stand density of white fir and the increased mortality of large, old ponderosa pines found in interior ponderosa pine forests throughout the West in the absence of periodic wildfire (Dolph et al. 1995). In 1933 and 1934, the BLA was completely inventoried on a 1-ha grid. Timber type maps and inventories were updated following harvests. Computerized stem maps for a 20-year period and inventories for a 50-year period are available on 20-acre parcels. A.A. Hasel (1938) conducted research on sampling error in timber surveys at BLA. His seminal work had wide influence on forest inventory methods and is still highly regarded.

Long-term research example. High structural diversity forests (figure A1-7, top) maintain features such as the presence of large, old trees and snags, multiple canopy layers with dense clumps of smaller trees, and many small gaps in the canopy. Low structural diversity forests (figure A1-7, bottom) maintain a single layer of an evenly spaced and continuous canopy and a relatively homogeneous size distribution and spacing of trees.

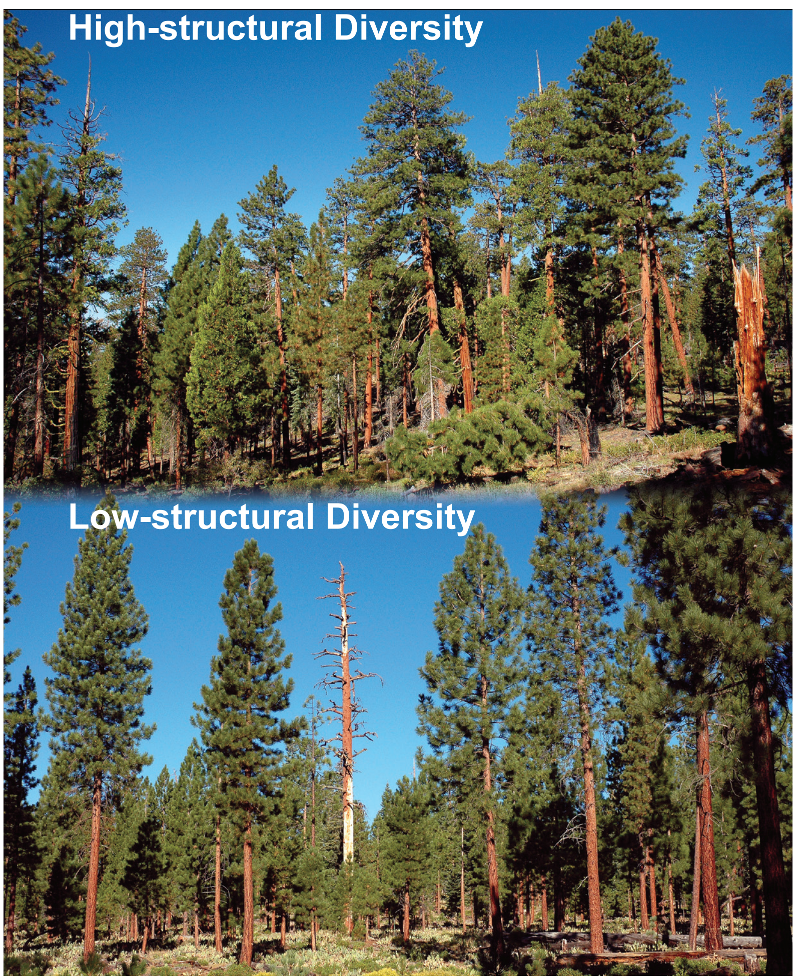


Figure A1-7. The Blacks Mountain Experimental Forest (BLA USFS) has both high- and low-structural diversity forests. (Photo by Todd Hamilton.)

Bonanza Creek Experimental Forest (BNZ) [USFS, LTER]

http://www.lter.uaf.edu/

The Bonanza Creek (BNZ) LTER program was established in 1987 to examine the interactions between climate and disturbance and their effects on ecosystem processes in the boreal forests of interior Alaska. BNZ research is concentrated at two sites near Fairbanks, Alaska. The Bonanza Creek Experimental Forest (BCEF) includes the Tanana River floodplains, upland forests, and wetlands. The Caribou Poker Creeks Research Watershed (CPCRW) is a network of upland forested watersheds (figure A1-8).

Interior Alaska has a continental climate with long cold winters and short warm summers. Permafrost is common in the area, often on north-facing slopes, lowlands, and valley bottoms. Low sun angles create dramatic differences in north-facing and south-facing slopes. The sun stays above the horizon for nearly 22 hours on the summer solstice, but for less than 4 hours on the winter solstice.

Research focus. The BNZ program focuses on improving understanding of the long-term consequences of changing climate and disturbance regimes on the Alaskan boreal forest (figure 9-4). Staff study the dynamics of change in several steps:

- Climate sensitivity of physical and biological processes to temporal variation in the environment, which defines the limits of resilience to climate change
- Changes in the successional dynamics caused by changes in climate and disturbance regime, which define the points in the adaptive cycle of disturbance and recovery at which ecosystems are most vulnerable to change
- Threshold changes that are likely to cause the boreal forest to function in a qualitatively new way
- Integration and synthesis of these modes of climate response across multiple temporal and spatial scales and exploration of their societal consequences

Figure A1-8. The Bonanza Creek Long Term Ecological Research (BNZ USFS/LTER) studies boreal forests of interior Alaska. Here, a fire burns on the Tanana Flats. (Photo by Teresa Hollingsworth.)

The research design combines long-term observations and experiments with short-term process studies to identify ecological changes and to document controls over ecosystem processes and successional dynamics in three landscape units: floodplains, uplands, and wetlands. Plot-level studies are extended to larger spatial scales (watersheds, regions, and the State of Alaska) using modeling and remote sensing.

Long-term research example. Bud burst in an aspen forest on the south-facing slope of Chena Ridge now happens 2 days earlier than in the mid 1970s (figure A1-9). This change in phenology is likely a result of a warming trend in spring temperatures in Alaska during the past several decades and has implications for plant production and the timing of plant-animal interactions in the boreal forest.

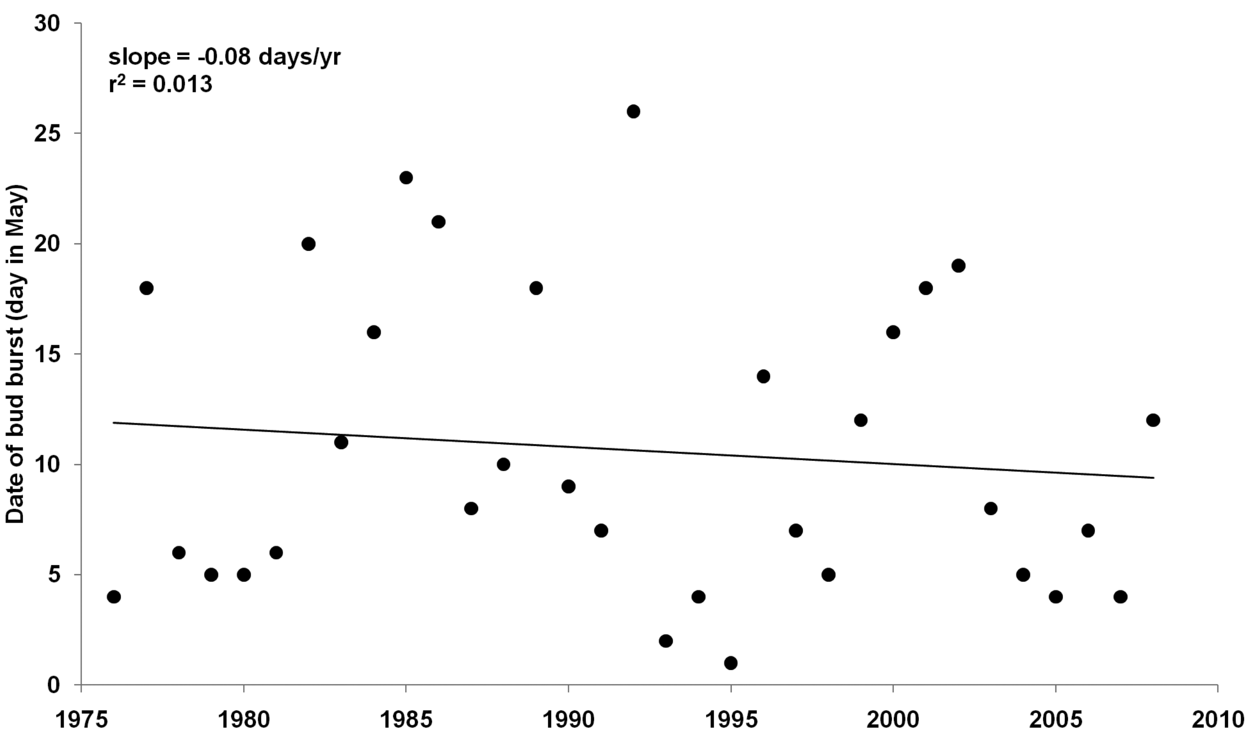


Figure A1-9. Bud burst is now occurring 2 days earlier than in the mid-1970s in an aspen forest at the Bonanza Creek Experimental Forest (BNZ). Data and methods are available at http://www.lter.uaf.edu/data_detail.cfm?datafile_pkey=300.

California Current Ecosystem (CCE) [LTER]

http://cce.lternet.edu/

The pelagic ocean California Current Ecosystem (CCE) site was established as an LTER site in 2004 to understand the processes that govern dynamics of the productive coastal upwelling biomes found along the eastern margins of all major ocean basins. The CCE site encompasses 193,000 km^2 of California coastal waters extending from San Diego northward beyond the major upwelling site at Point Conception and from the shoreline to approximately 500 km offshore (figure A1-10).

The ocean circulation system in which the CCE site is embedded, called the California Current System, is part of the clockwise circulation pattern of the North Pacific Ocean. This system modifies weather patterns and the hydrologic cycle of much of the Western United States and plays a vital role in the economy of numerous coastal communities. The ecosystem sustains active fisheries of a variety of finfish and shellfish and provides essential habitat for many invertebrates, marine mammals, seabirds, and kelp forests.

Research focus. Sixty years of climate and ecosystem observations by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) program have characterized ecosystem variability on multiple time and space scales and help form the foundation for

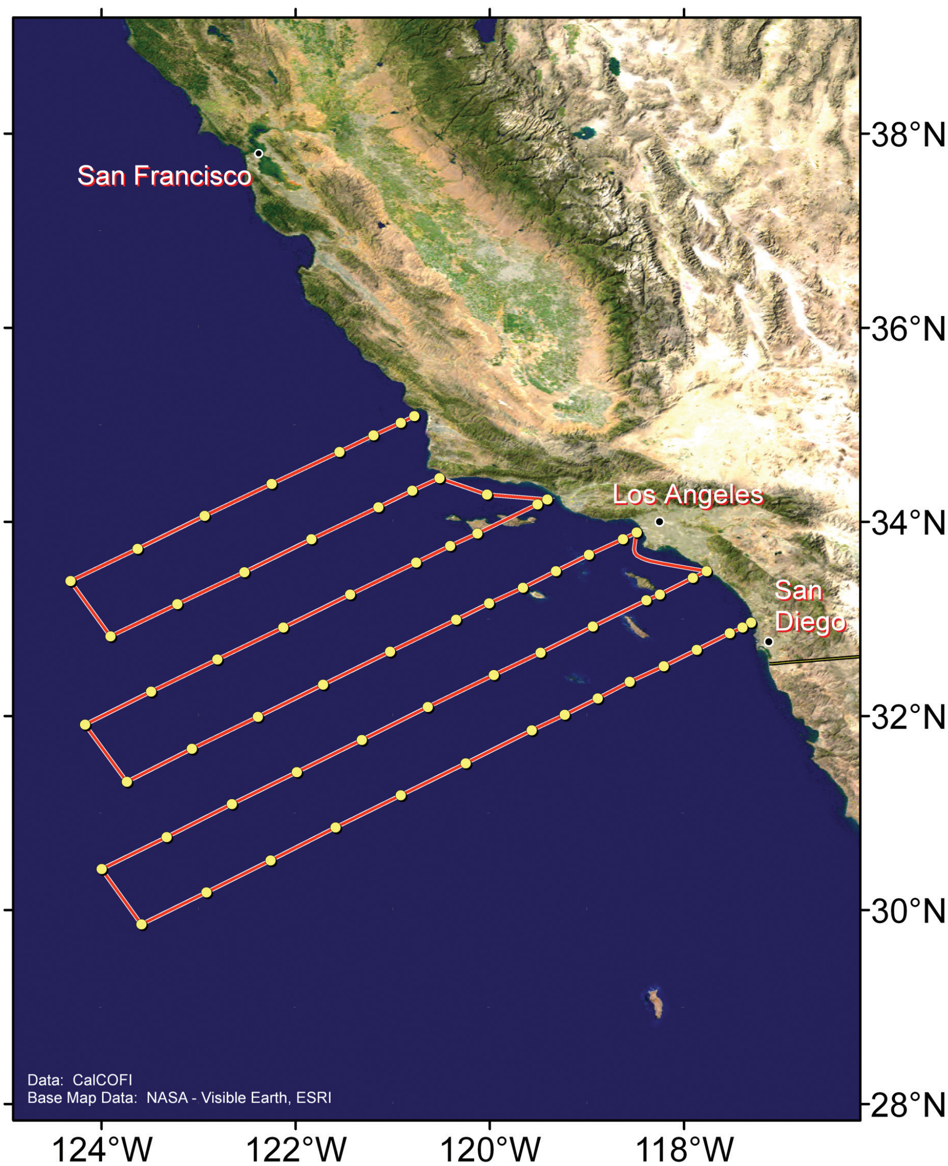


Figure A1-10. The California Current Ecosystem Long Term Ecological Research (CCE LTER) studies pelagic systems off the coast of California. The sampling grid builds on the transect lines of CalCOFI, currently consisting of six tracks extending from nearshore to offshore, along which shipboard observations are made quarterly at 66 stations. Image by Thomas J. Moore. (Base map imagery source: NASA Visible Earth/ESRI.)

CCE research. The CCE site seeks to understand how multiple scales of climate forcing lead to altered structure and dynamics of the pelagic ecosystem and how ocean productivity and biodiversity may change in the future.

The water column food web is markedly affected by physical ocean characteristics such as variations in upwelling, turbulent mixing, density stratification, and ocean circulation. This linkage to the physical environment is particularly apparent for planktonic organisms near the base of the food web (figures 3-2, 3-6). The CCE study site encompasses diverse planktonic communities in different physical environments, ranging from upwelling-dominated assemblages to stably stratified offshore assemblages typical of the subtropical gyres. The CCE group uses the spatial variability in plankton assemblages in different parts of the study site as an analog of how a single region may change over time.

Long-term research example. The ocean environment has changed in the California Current ecosystem over the past 5 1/2 decades, including a relatively abrupt ecosystem shift in the mid 1970s that resulted in an increase in average water column stratification in the CCE region (figure A1-11a), as well as a warming over the broader Northeast Pacific reflected in the Pacific Decadal Oscillation Index (figure A1-11b). Zooplankton showed a marked increase in biomass of the euphausiid (krill) *Nyctiphanes simplex* and a tendency for more outbreaks of the rare doliolid *Doliolum denticulatum* (figure A1-11c, d). Conversely, a group of salp species that predominated in the cool phase of the California Current disappeared locally (figure A1-11e). Whether or not reciprocal ecosystem changes occurred following the La Niña cooling of 1999 remains in question.

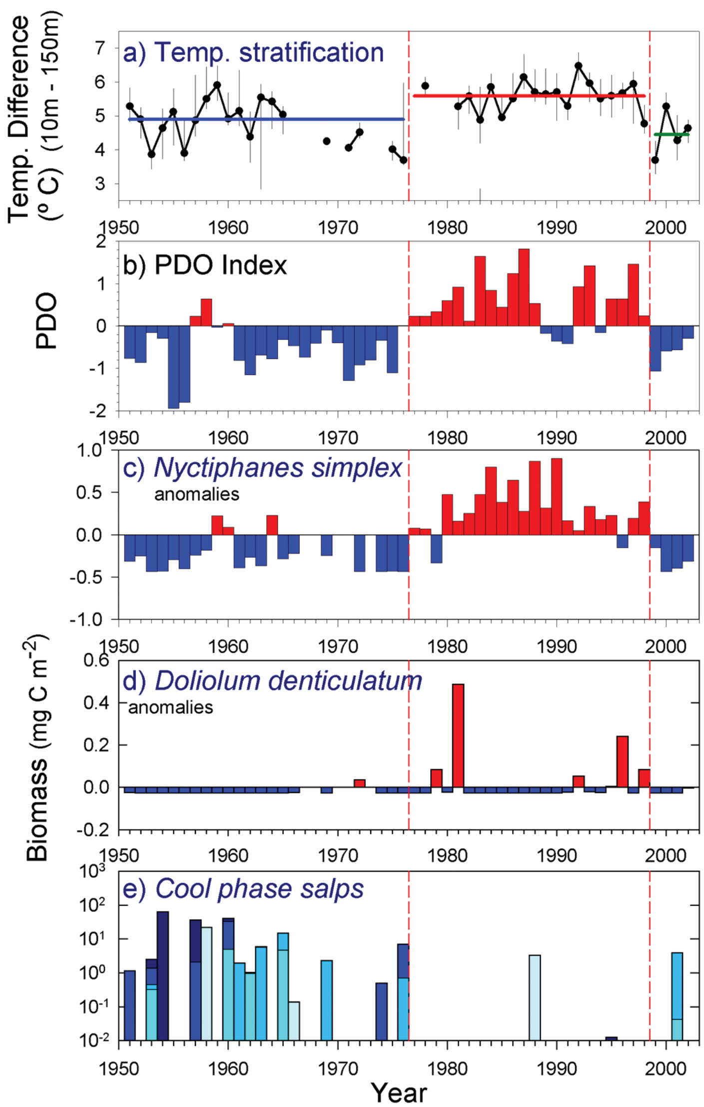


Figure A1-11. Altered (a) ocean temperature stratification and (b) the Pacific Decadal Oscillation (PDO) are resulting in (c-e) low-frequency changes in the California Current Ecosystem (CCE) zooplankton assemblage (Ohman and Venrick 2003). Reprinted with permission from The Oceanography Society.

Cascade Head Experimental Forest (CHE) [USFS]

http://www.fsl.orst.edu/chef/

The 11,890-acre Cascade Head Experimental Forest (CHE) was established in 1934 for scientific study of coastal Sitka spruce/western hemlock forests found along the Oregon Coast. In 1974, Congress established the 9,670-acre Cascade Head Scenic Research Area (SRA) that included the western half of the experimental forest, several prairie headlands, the Salmon River estuary to the south, and contiguous private lands. In 1980, the entire area was designated a Biosphere Reserve as part of the United Nations Biosphere Reserve system.

Sitka spruce and western hemlock dominate the forest from the coastal edge to 3 to 4 km inland. At this point, Sitka spruce begins to drop out and Douglas-fir density increases. Western hemlock is found throughout the forest. Some of the highest growth rates and greatest volumes per hectare for any temperate forest in the world are reported for this area. Soils, derived primarily from tuffaceous siltstones, are fine textured, moderately well drained, and very deep (more than 1 m). Soils under forest stands are fertile, rich in organic matter, and contain high levels of nitrogen.

Proximity to the Pacific Ocean results in a moderate and very wet climate. Heavy rains and gale-force winds blowing off the ocean are common in late fall and winter. Extensive blowdown and wind-pruning of trees are evidence of these severe storms (figure A1-12).

Research focus. The primary research goals of CHE and SRA are—

- to encourage scientific study while promoting a sensitive relationship between humans and their environment,
- to promote scientific understanding of how forest and wetland ecosystems relate to human use, disturbance and coastal biodiversity, and
- to provide educational and research opportunities to students and scientists from a variety of agencies and institutions.

Figure A1-12. The Cascade Head Experimental Forest (CHE USFS) occurs in the coastal Sitka spruce-western hemlock forests along the Oregon coast. Research evaluates effects of natural disturbances, such as windstorms, that occur regularly at the site. (Photo by Sarah Greene.)

Caspar Creek Experimental Watershed (CSP) [USFS]

http://www.fs.fed.us/psw/ef/caspar_creek/

Caspar Creek (CSP) is the site of long-term research on the effects of timber harvest on streamflow, water quality, sedimentation, and aquatic life in the rainfall-dominated, forested watersheds of the northern coast of California. CSP was established in 1961 as a cooperative effort between the California Department of Forestry (CDF) and the USDA Forest Service's Pacific Southwest Research station (PSW). Study basins include the North Fork (473 ha) and the South Fork (424 ha), each with nested sub-basins.

Conditions are typical of the redwood-dominated areas of California (figure A1-13). Winters are mild and wet, while summers are moderately cool and dry. About 95 percent of the average annual precipitation of 1,200 mm falls from October through April. Summer coastal fog is common. Snow is rare, and rainfall intensities are low. The principal soils are well-drained loams to very gravelly sandy clay loams, 1 to 2 m in depth, and derived from weathered graywacke sandstone and shale of the Coastal Belt of the Franciscan Assemblage of early Cenozoic age. Soils have high hydraulic conductivities. Subsurface stormflow is rapid, producing saturated areas of only limited extent and duration.

The second-growth mixed conifer forest includes coast redwood *(Sequoia sempervirens),* Douglas-fir *(Pseudotsuga menziesii),* western hemlock *(Tsuga heterophylla),* grand fir *(Abies grandis),* and tanoak *(Lithocarpus densiflorus)*.

Research focus. Basin-scale treatment-control experiments in CSP have been used to study the effects of forest practices on watershed processes (Ziemer 1998). In the first experiment, the North Fork served as the control while two-thirds of the stand volume of the South Fork was selectively harvested and tractor-yarded from 1971 to 1973. Erosion was monitored on hillslope plots, while runoff, suspended sediment, and accumulated bed material were measured at the outlet weirs (Rice et al. 1979). From 1989 to 1991, about 37

Figure A1-13. North Fork Caspar Creek (foreground), 15-17 years after portions of the watershed were clear-cut logged. Part of the Caspar Creek Experimental Watershed (CSP USFS), the area is dominated by second-growth mixed conifer forest. (Photo from USFS archives.)

percent of the North Fork watershed was harvested (Lewis et al. 2001). This study pioneered methods for automatically collecting suspended sediment samples based on real-time flow measurements and allowed development of methods for continuous estimation of suspended sediment loads using turbidity records (Lewis and Eads 2001). These records may be the most temporally and spatially detailed of suspended sediment collected.

Long-term research example. Departures from pretreatment regressions relating storm event loads from two clearcut tributaries (CAR and EAG) to event loads in untreated control watersheds illustrate trends in sediment production after logging (figure A1-14). After initial harvesting, watershed EAG was burned (year 1) and herbicided (year 3) to control brush regrowth, and both watersheds were thinned at year 11. During the pretreatment period, departures are regression residuals and average to zero as expected. After harvesting, an abrupt increase in loads is accompanied by an increase in variance, and a second period of increased loads is associated with thinning of regrowth. While the magnitude of response differs between the two watersheds, the temporal pattern of variation is similar, reflecting the same sequence of treatments and storms.

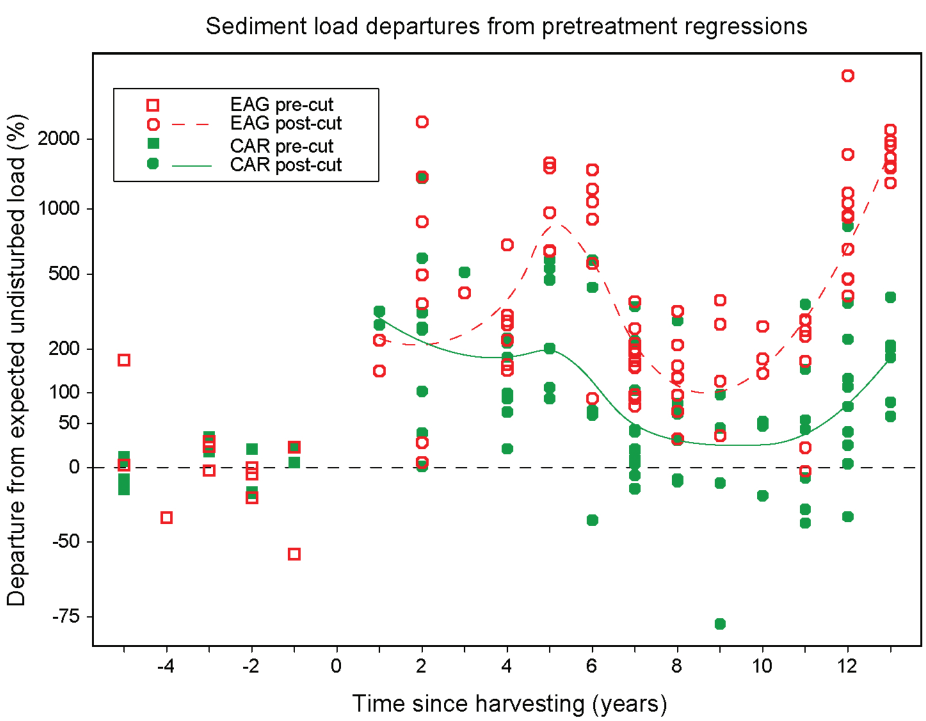


Figure A1-14. Sediment loads as a departure from pretreatment values at Caspar Creek Experimental Watershed (CSP). After harvesting, load values and variability increase for two watersheds (Jack Lewis, unpublished data).

Cedar Creek Ecosystem Science Reserve (CDR) [LTER]

http://www.cbs.umn.edu/cedarcreek

Cedar Creek Ecosystem Science Reserve (CDR) was established in 1940 and was funded as an LTER site starting in 1982 to improve understanding of the processes that govern the dynamics and functioning of ecosystems located along the boundary between prairie and forests. This region has a continental climate with cold winters and hot summers. Much of the site is covered in wetlands, including white cedar *(Thuja occidentalis)* and ash swamps, acid bogs, wet meadows, and marshes. Upland areas consist of variety of habitat types, including—

- savanna areas with a sparse canopy of burr oak *(Quercus macrocarpa),*
- prairie openings largely dominated by little bluestem *(Schizachyrium scoparium),*
- dry oak woods dominated by pin oaks *(Quercus ellipsoidalis),*
- smaller stands of hardwood forests with a large component of basswood *(Tilia americana)* and sugar maple *(Acer sacharrum),* and
- white pine *(Pinus strobus).*

Research focus. CDR research examines the population, community, and ecosystem impacts of human-driven environmental changes (figure 3-7). Research focuses on the causes and consequences of biodiversity. Following a severe drought in 1989, plant diversity had a stabilizing effect on productivity (Tilman 1996). Experiments were then established to test hypotheses about diversity effects and the underlying mechanisms (figure A1-15). A related experiment (BioCON) was established to study interactions between species diversity and elevated levels of atmospheric CO_2 and nitrogen deposition.

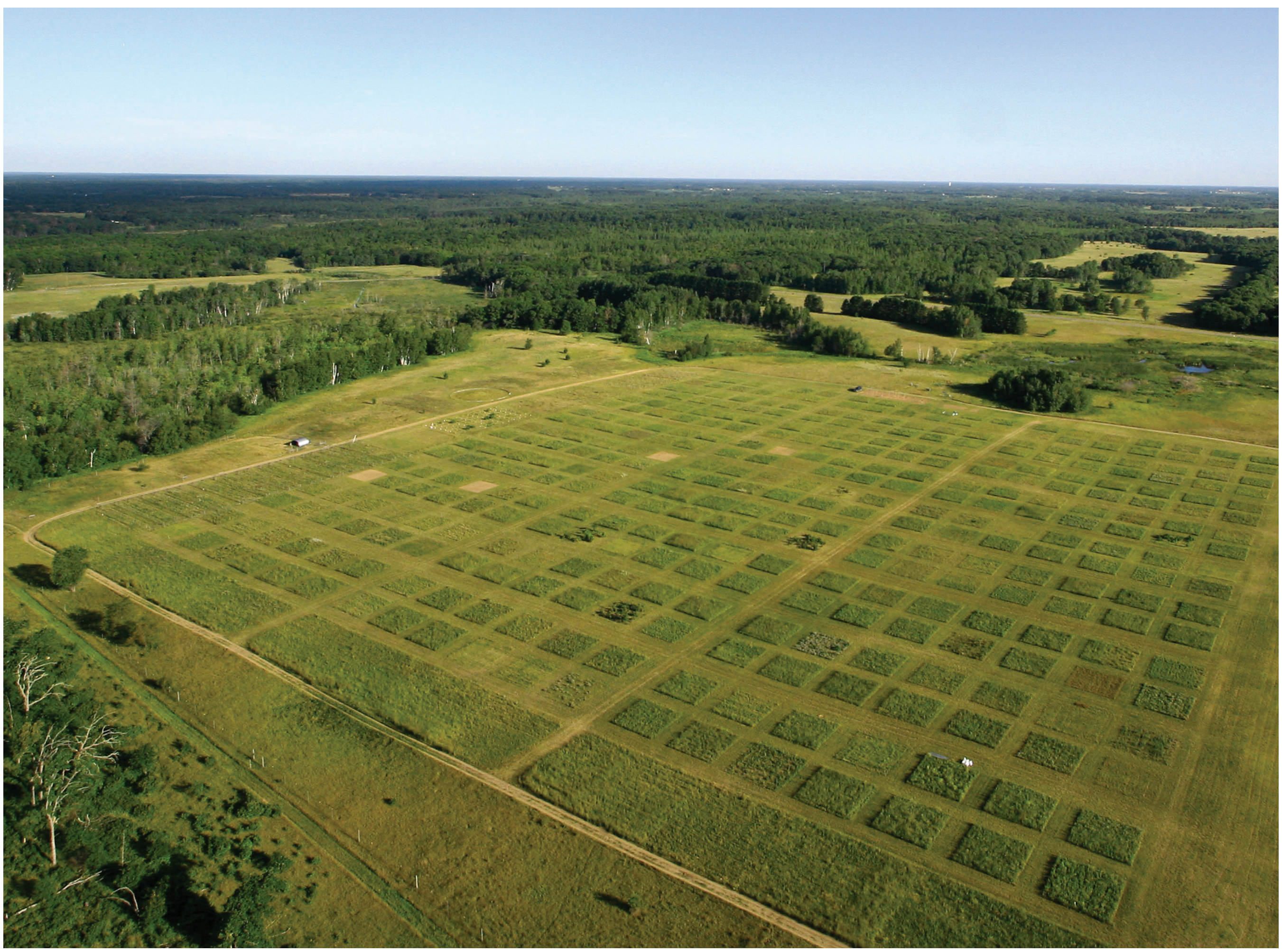


Figure A1-15. Experiments at the Cedar Creek Long Term Ecological Research (CDR LTER) in central Minnesota are designed to study the causes and consequences of biodiversity. (Photo by David Tilman.)

Long-term research example. Changes in ecosystem properties as affected by both broad-scale climate effects (drought) and landscape-scale effects on species are illustrated by data from CDR. Aboveground biomass decreased during the 1987-1988 drought, yet is generally increasing through time and more than doubled between 1991 and 2004 (figure A1-16, top). This increase is mainly due to an increase in legumes (e.g., *Lathyrus venosus*; veiny pea) caused by decreased deer herbivory. Plant species richness also decreased during the drought with recovery by 1993 (figure A1-16, bottom). The loss of species following 1991 was in response to fragmentation caused by nitrogen addition to adjacent plots. These results are important to our understanding of system response as temperatures increase with global warming, and landscape fragmentation occurs with landuse change.

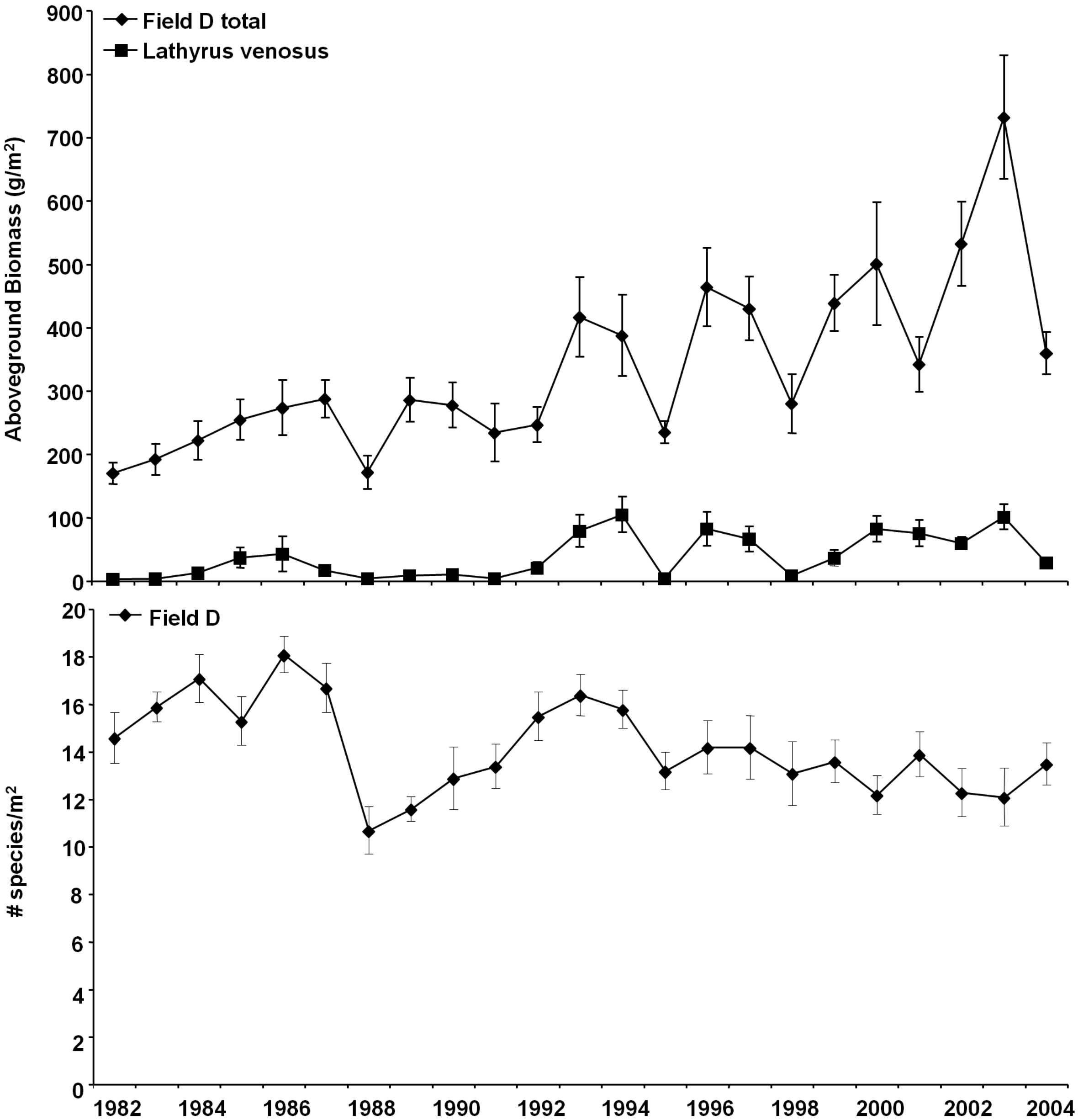


Figure A1-16. Drought responses at the Cedar Creek Ecosystem Science Reserve (CDR): top, aboveground biomass increases through time as a result of decreasing deer herbivory and an increase in legumes (*L. venosus*). Bottom, species richness decreases with landscape fragmentation (David Tilman, unpublished data).

Central Arizona-Phoenix (CAP) [LTER]

http://caplter.asu.edu/

The Central Arizona-Phoenix (CAP) site was established as part of the LTER Network in 1997 to study human interactions with the environment in central Arizona and the Phoenix metropolitan area. The study area is in a 6,400 km^2 area where two major desert tributaries of the Colorado River (the Salt and the Gila) converge. The basin once supported a vast expanse of lowland Sonoran desert and riparian systems and now houses the Nation's fifth-largest city (figure A1-17). The study area contains some of the fastest-growing municipalities in the United States, enabling researchers to study the effects of rapid urbanization on an arid ecosystem.

As agriculture and, increasingly, desert lands give way to homes and businesses, natural habitats are severely modified with significant ramifications for native plant and animal species. Water quality and quantity issues are pressing, and air quality remains a critical problem due to ozone pollution and high levels of particulate matter. Other stressors include drought and the urban heat island effect, which has raised nighttime minimum temperatures by 5 °C.

Figure A1-17. Central Arizona-Phoenix Long Term Ecological Research (CAP LTER) studies urban ecosystems and their effects on the surrounding desert. (Photo from CAP photo gallery.)

Research focus. CAP researchers are examining the function and structure of the urban ecosystem, the feedbacks between human decisions and ecological processes, and the effects of urbanization on surrounding desert land. Land-use change is viewed as a major driver of ecological patterns and processes at multiple scales (figure 9-19). Research also seeks to understand the responses, both human and ecological, that accompany changes in ecological conditions and multiple feedbacks in the system that lead to further change.

CAP has four main objectives:

- To advance ecological understanding through development of ecological theory
- To understand the structure and function of the urban ecosystem
- To develop ecological scenarios that can be used to guide future development of urban environments while sustaining ecological and societal values and to engage decision makers in this process through deliberate knowledge exchange
- To involve the public in the research effort through dissemination of information via the media, public outreach, and educational initiatives

Long-term research example. The Phoenix metropolis arose from its agricultural beginnings over the course of around 100 years. Documenting this change in coarse land-use categories involved compilation of data from air photos, satellite images, and on-the-ground land categorization. Settlement began in the late 1800s, and by 1912 irrigated agriculture surrounded small, isolated towns (figure A1-18). Whereas early land conversion was from desert to agriculture and agriculture to urban, in more recent years direct desert to urban conversion has become prevalent. Expansion of agricultural lands continued until 1975. The most dramatic land change began in the 1950s, when urban areas increased in size and began to coalesce. By 2000, much of central Arizona was urban with infilling of housing and buildings that continues today. These changes, and the legacies of former land use, are important determinants of present-day ecological pattern and process. Trends of land change seen in central Arizona through time and space are typical of smaller cities in the Southwestern United States.

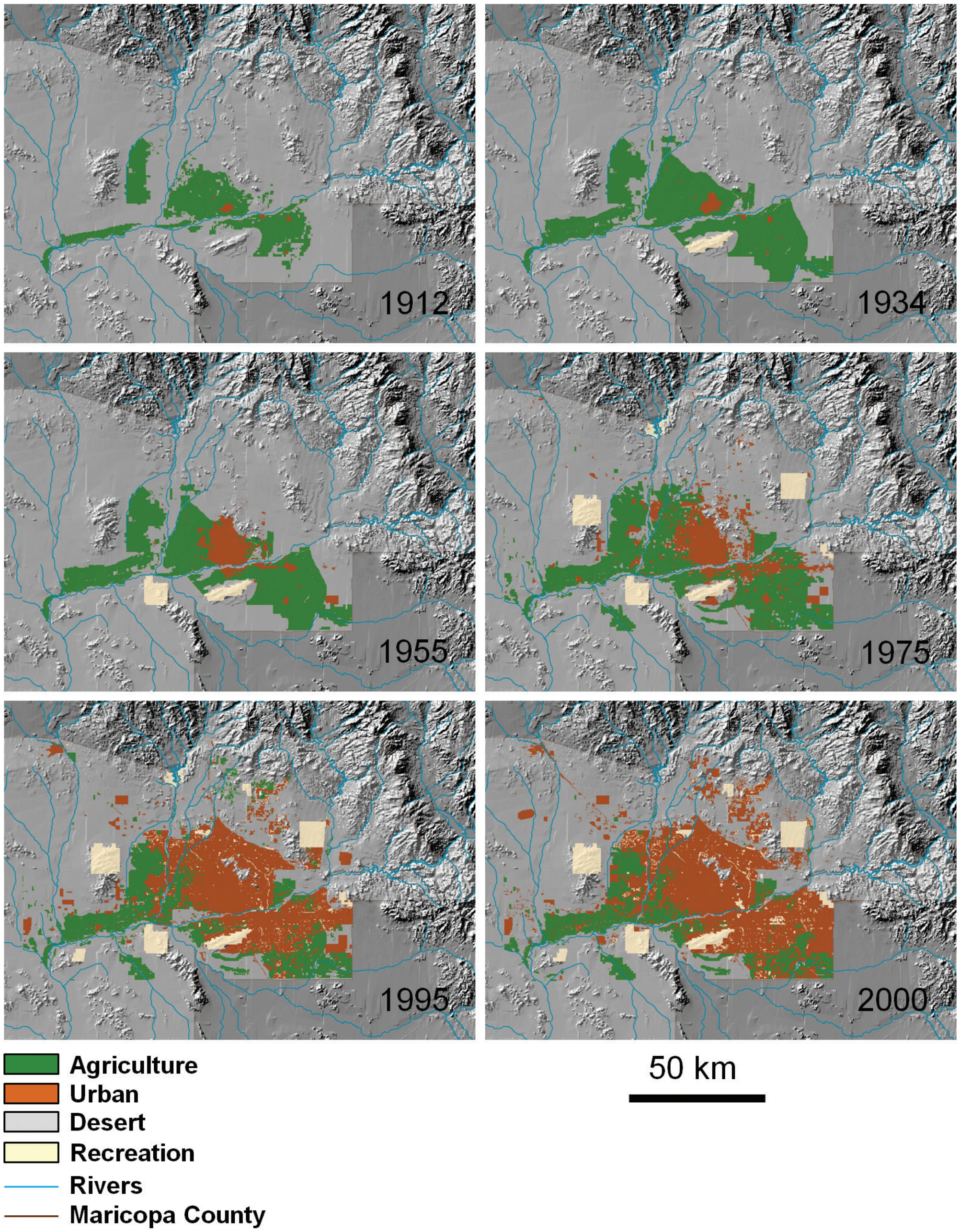


Figure A1-18. The Phoenix area shifted from predominantly desert to agricultural land in the early 1900s. A major shift from agricultural land to urbanization occurred after 1950. More recently, desert is being converted to urban areas (Knowles-Yanez et al. 1999). Reprinted with permission from Central Arizona-Phoenix LTER.

Coweeta (CWT) [USFS, LTER]

http://coweeta.ecology.uga.edu/

The Coweeta Hydrologic Laboratory (CWT), a USDA Forest Service Research Station, was established in 1934 as a testing ground for certain theories in forest hydrology; it was established as an LTER site in 1980. The site is located in the Nantahala Mountain Range of western North Carolina, and consists of two adjacent east-facing, bowl-shaped basins. Coweeta Basin (1,626 ha) is the primary site for watershed experimentation, and Dryman Fork Basin (559 ha) is held in reserve for future studies.

The climate is humid subtropical at the lowest elevations and marine humid temperate at the higher elevations. Winters and summers are mild; there is little snowfall, and summer days with temperatures exceeding 30 ºC are rare. Rainfall is evenly distributed throughout the year, with considerable spatial variability related to elevation and latitude. Precipitation generally increases about 5 percent per 100 m of elevation gain along an east-west axis. The dominant vegetation is temperate deciduous forest (figure A1-19), although the intermixing of "northern" and "southern" taxa results in one of the most biodiverse regions of North America.

Figure A1-19. Temperate deciduous forest is the dominant vegetation at the Coweeta Long Term Ecological Research (CWT USFS/LTER) site in western North Carolina. (Photo from CWT photo gallery.)

Research focus. CWT research has contributed to the growing understanding of how human practices can influence forest and stream ecosystems at numerous scales. For example, bottom-up effects of nutrient enrichment in a detritus-based ecosystem can stimulate whole-community production and cause large changes in carbon balance and consumer productivity. These changes have important implications for the contemporary die-off of eastern hemlock *(Tsuga canadensis)* from the infestation by the hemlock woolly adelgid *(Adelges tsugae)*. The CWT LTER project has achieved an understanding of complex interactions between environmental gradients, disturbance, and land use that underpin the transformation of the Old South into the "New South" in ways that can accommodate the growing demand on research to provide solutions for environment and society.

Long-term research example. Research from CWT shows the importance of monitoring large numbers of individual trees and of measuring trees over long periods. Individual trees have been measured over time to estimate growth (figure A1-20). Both red maple and white pine trees show wide variation in growth of the basal area of the trunk through time. Some trees grow very little from one year to the next, whereas other trees of the same species located nearby show high growth rates. Thus, growth rates may be related to fine-scale variation in environmental conditions (such as soil properties) and within-species genetic variability rather than broad-scale climatic conditions.

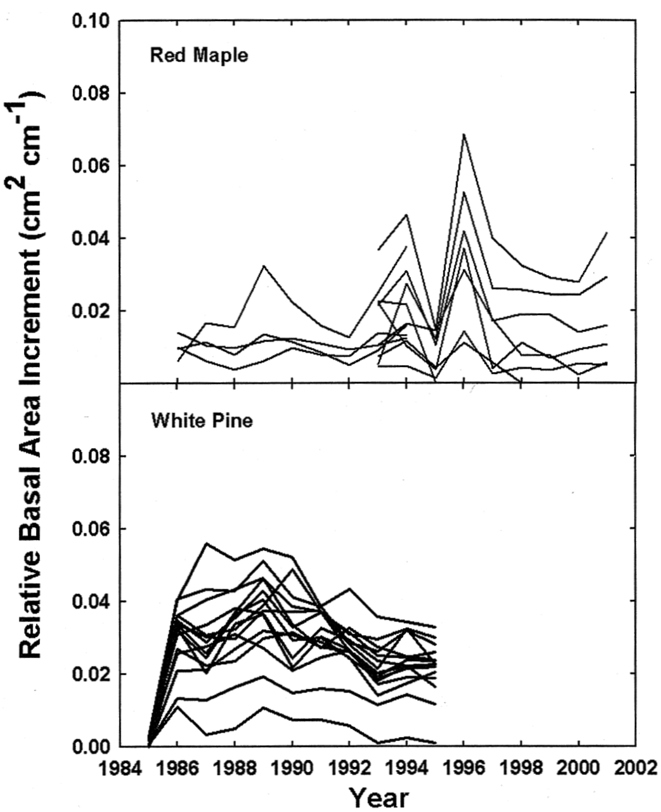


Figure A1-20. The relative basal area increment (cm^2 tree growth per cm tree diameter) of two selected species at Coweeta (CWT). Each connected line represents a single tree over the measurement period. The deciduous red maple *(Acer rubrum)* and the evergreen white pine *(Pinus strobus)* exhibit wide variation of relative basal area increment between trees (Kloeppel et al. 2003). Reprinted with permission from Oxford University Press.

Crossett Experimental Forest (CRO) [USFS]

http://www.srs.fs.usda.gov

In 1934, the Crossett Experimental Forest (CRO) was established as the first USDA Forest Service branch research station in the South. The CRO supports research on forest management in second-growth loblolly and shortleaf pine stands for forest managers and landowners. The research mission is to develop and evaluate low-cost silvicultural techniques and management alternatives suitable for natural stands on private, non-industrial timberlands in the Mid South. Research is conducted in the following major areas:

- Establishment, development, and growth of forest reproduction
- Stand dynamics, including growth, yield, regulation, and site quality
- Rehabilitation of understocked loblolly and shortleaf pine stands

Long-term data sets. Long-term data sets are available that include stand dynamics and development, annual seedfall data, trends in stand structure and timber volume in a comparative study of different silvicultural practices in southern pines, and trends in stand structure and timber volume in a long-term demonstration of the uneven-aged selection method in southern pines.

Eastern Oregon Agricultural Research Center (EOA) [USDA-ARS]

http://oregonstate.edu/dept/EOARC/

The mission of the Eastern Oregon Agricultural Research Center (EOA) is to provide the scientific basis for sound land and livestock management in eastern Oregon. The beginnings of EOA date to 1911, when the Harney Branch Station was established. After about 20 years, it became clear that the area was not suited to row crops, and the focus shifted to forage and livestock production. During the late 1930s, the U.S. Department of the Interior established the 6,475-ha Squaw Butte Range Livestock Station west of Burns, OR. In 1944, the Harney and Squaw Butte stations were merged, and 260 hectares of flood meadow was purchased by Oregon State University.

The climate is characterized by a short growing season with an average of 65 days between killing frosts. Soils range from sandy loams to heavy clays with a mosaic of areas with high salinity and alkalinity. Major plant communities are sagebrush steppe (basin big sagebrush, Wyoming big sagebrush, mountain big sagebrush, low sagebrush, and black sagebrush) and western juniper woodlands (figure A1-21). These communities are characterized by woody species in the canopy and by grasses, such as bluebunch wheatgrass, basin wildrye, Idaho fescue, Sandberg's bluegrass and needlegrasses, which dominate the understory. Invasive annual grasses, such as cheatgrass and medusahead, are invading many sagebrush steppe communities.

Research focus. EOA research builds on a rich history dating from the 1940s. The first objective is to improve understanding of rangeland, riparian, and meadow ecosystems in the northern Great Basin. Within this objective is an emphasis on juniper encroachment, prescribed fire, native seed production, productivity, and carbon sequestration. The second objective is to provide information to develop restoration strategies under forage and livestock management systems. The third objective is to produce management tools and provide information and technology transfer to aid in the restoration and management of public and private rangeland ecosystems dominated or threatened by weed invasion.

Long-term research example. Western juniper woodlands are cut to restore shrub and herbaceous productivity and composition in the northern Great Basin. This study assessed successional dynamics for 12 years following juniper cutting. Total biomass, cover, and density of understory species increased ($p < 0.001$) in cut plots over time and were greater ($p < 0.001$) in cut areas compared to woodland controls (figure A1-22). In the sixth year after cutting (1997), debris and canopy locations were dominated by annual grasses. By 2003, perennial grass biomass was two times greater than annual grass in these zones. Shrub cover and density increased ($p < 0.05$) between 1997 and 2003 in the cut treatment. Densities of perennial grasses have remained stable at 10 plants/m^2 since 1997. These results show that removal of juniper can be an effective long-term management tool to increase perennial grasses in the northern Great Basin.

Figure A1-21. The Eastern Oregon Agricultural Research Center (EOA USDA-ARS) is located in sagebrush steppe and western juniper woodlands. (Photo by Jon Bates.)

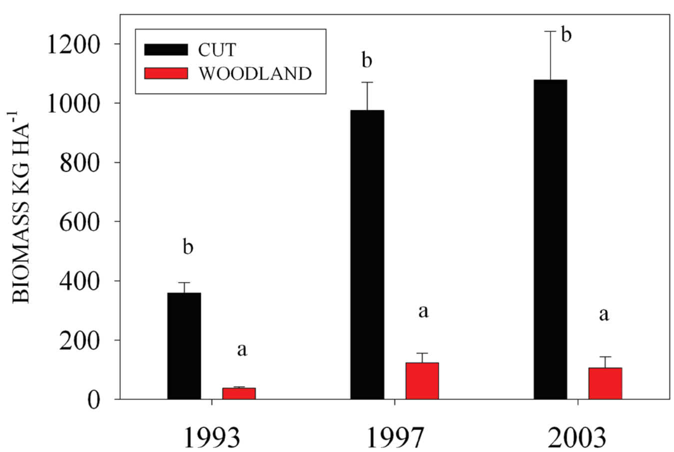


Figure A1-22. Understory biomass was 10 times greater following cutting of juniper (black) controlled with an uncut juniper woodland (red) (modified from Bates et al. 2005). Different lowercase letters indicate significant differences between treatments within a year ($p < 0.01$).

Fernow Experimental Forest (FER) [USFS]

http://www.fs.fed.us/ne/parsons/

The Fernow Experimental Forest (FER) was established in 1934 in West Virginia within the Allegheny Mountain section of the unglaciated Allegheny Plateau. The FER forests were heavily cut over between 1905 and 1911. The current, mostly second-growth, vegetation is classified as a mixed mesophytic forest type (figure A1-23). Characteristic overstory species include northern red oak *(Quercus rubra),* yellow-poplar *(Liriodendron tulipifera),* American beech *(Fagus grandifolia),* black cherry *(Prunus serotina),* sugar maple *(Acer saccharum),* and red maple *(A. rubrum).* Overall diversity of vascular plant species is high, and wildlife is typical of the central Appalachians.

Elevation ranges from 533 to 1,112 m, and slopes are generally steep. The climate is characterized as cool and rainy with precipitation evenly distributed throughout the year. Soils are mostly of the Calvin and Dekalb series, which originated from rocky materials (loamy-skeletal, mixed mesic Typic Dystrudepts).

Research focus. Both silvicultural and hydrologic research are focuses. Silvicultural research addresses questions relating to regenerating, growing, tending, and harvesting trees and stands of mixed hardwoods. Watershed research addresses questions about hydrology and water use by forests, as well as forest management effects on water and soil resources, and about the development of best management practices. The FER has been in the forefront of acid deposition and nitrogen saturation research, conducting a whole-watershed acidification study since 1989. The FER serves as a template for examining wildlife-habitat relationships in managed forests. Recent efforts focus on the role of both natural and anthropogenic forest disturbance as positive and negative influences for sensitive species, due to the presence of the endangered Indiana bat *(Myotis sodalis)* and running buffalo clover *(Trifolium stoloniferum).*

Figure A1-23. The Fernow Experimental Forest (FER USFS) is located in mixed hardwood forests of the Appalachian Mountains. (Photo from FER photo gallery.)

Long-term research example: Big Springs Cave at the FER is a winter hibernacula for the endangered Indiana Bat. Winter bat surveys have been conducted periodically since the early 1950s (figure A1-24). Number of bats was low until 1986, when human entry into the cave was prevented. Numbers have increased considerably and remained stable for the past two decades (C. Stihler, unpublished data), despite forest harvesting activity conducted annually since 1949. Recent research investigates the Indiana bat's day use of live trees and snags for roosting and their foraging habitat.

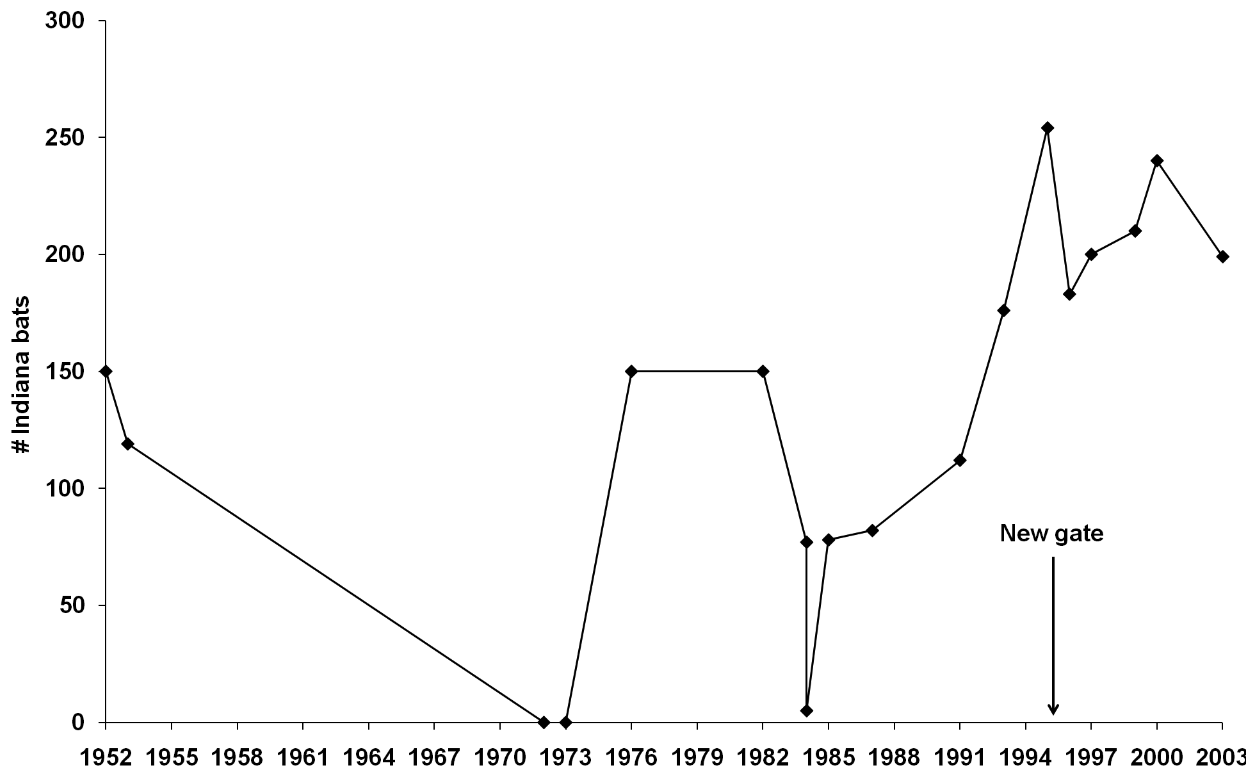


Figure A1-24. Research on hibernating Indiana bats, an endangered species, has been conducted on Fernow Experimental Forest (FER) since 1952. Bat numbers increased and have remained stable following the exclusion of humans from the cave in 1986 (C. Stihler, unpublished data).

Florida Coastal Everglades (FCE) [LTER]

http://fcelter.fiu.edu/

The Florida Coastal Everglades (FCE) LTER site was established in 2000 to determine how population- and ecosystem-level dynamics of the coastal Everglades landscape are controlled by water source, water residence time, and local biotic processes and their relative importance. The FCE is located in south Florida, where a rapidly growing human population of over 6 million live in close proximity to—and in surprising dependence on—the Florida Everglades. The FCE site is entirely within the boundaries of Everglades National Park, the third largest wilderness in the continental United States (figure A1-25). The park covers approximately 6,110 km^2 and is part of the greater Everglades ecosystem, which extends north to Lake Okeechobee and the Kissimmee River.

Figure A1-25. Sampling in the mangrove forest at the Florida Coastal Everglades Long Term Ecological Research (FCE LTER) (Shark River Slough, SRS6). (Photo by Victor Rivera-Monroy.)

The elevation gradient in the Everglades is very small, but significant: Water flows to the estuaries from an elevation of about 2 m at the northern boundary of the park. Because the coastal Everglades cover a large area that is, in effect, topographically flat, it is susceptible to dramatic changes in response to sea level rise. Hurricanes and storms are common, and add “pulse” disturbance features to the slow “press” of rising sea level.

Research focus. FCE research focuses on population and ecosystem dynamics in the oligohaline regions of Taylor Slough and Shark River Slough, where freshwater and estuarine ecosystems meet to form ecotones. Researchers are investigating the hydrologic, climatological, and human drivers that affect oligohaline ecotone dynamics, as well as the processes that regulate biophysical inputs to the ecotone from upstream freshwater Everglades marshes and the estuary proper.

Over the last century, human activity has dramatically altered the Everglades, reducing it to half its original extent and compartmentalizing the remaining system with over 2,500 km of canals and levees. Over 95 percent of the people living in south Florida obtain their drinking water from the shallow Biscayne aquifer, which is recharged in near real time by the Everglades. A primary focus of the Everglades Restoration Project is to return the existing Everglades to a healthy and stable state so that it can continue to provide critical ecosystem services to human populations.

Long-term research example: At the FCE site, total nitrogen (TN) concentration has decreased while total phosphorus (TP) concentration shows no trend with time for two mangrove sites along the Taylor River in the southern Everglades (figure A1-26). High daily and seasonal variability make it difficult to determine directional changes unless many years of data are available. These data demonstrate that phosphorus, the limiting nutrient in the Everglades and downstream Florida Bay, has not increased; yet nitrogen concentrations have decreased in spite of suggestions that freshwater Everglades wetlands are a source of increasing nitrogen in marine ecosystems.

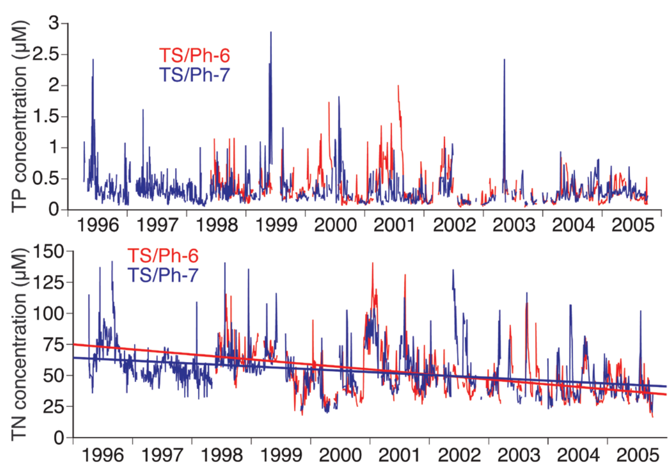


Figure A1-26. (Top) Phosphorous has not changed through time and (bottom) nitrogen has decreased at the Florida Coastal Everglades (FCE) site. (Redrawn from Childers et al. 2006.) Data available at http://fcelter.fiu.edu/data/.

Fort Keogh Livestock and Range Research Laboratory (FTK) [USDA-ARS]

http://ars.usda.gov/

Fort Keogh (FTK) is a USDA Agricultural Research Service facility located west of Miles City, MT. The site was established by Congress as an Army Calvary post on July 22, 1876, approximately 1 month after the Battle of the Little Bighorn. In 1924, Congress transferred FTK to the U.S. Department of Agriculture for agricultural research. Regional topography ranges from rolling hills to badlands with small intersecting streams. The potential natural vegetation is a grama-needlegrass-wheatgrass *(Bouteloua-Stipa-Agropyron)* northern mixed-grass prairie.

FTK currently consists of about 22,700 ha with 20,600 ha of native rangeland, 1,000 ha of seeded dryland pasture, 400 ha of irrigated pasture, and 300 ha of irrigated cropland (figure A1-27). The FTK experimental breeding cow herd consists of about 250 Line 1 Herefords, the oldest and purest line of Herefords in the world; 500 CGC's, a composite gene combination herd consisting of 50 percent Red Angus, 25 percent Tarentaise, and 25 percent Charolais; and 750 mixed-breed cows.

Research focus. The broad mission of FTK is to develop ecologically and economically sustainable range livestock production systems in the face of periodic drought. Current research focuses on developing strategies and decision tools to proactively manage livestock grazing, fire, and drought impacts on the structure and function of mixed-grass prairie while improving animal productivity. In addition, researchers are advancing management strategies to restore rangelands degraded by weeds and to inhibit weed invasions. FTK is also building understanding of the relationships between soil biota and native plants, which should lead to methods benefitting restoration ecology technology.

Figure A1-27. The Fort Keogh Livestock and Range Research Laboratory (FTK USDA-ARS) is located in northern mixed-grass prairie near Miles City, MT. (Photo by Aaron Roth.)

Fraser Experimental Forest (FRA) [USFS]

http://www.fs.fed.us/rm/fraser/

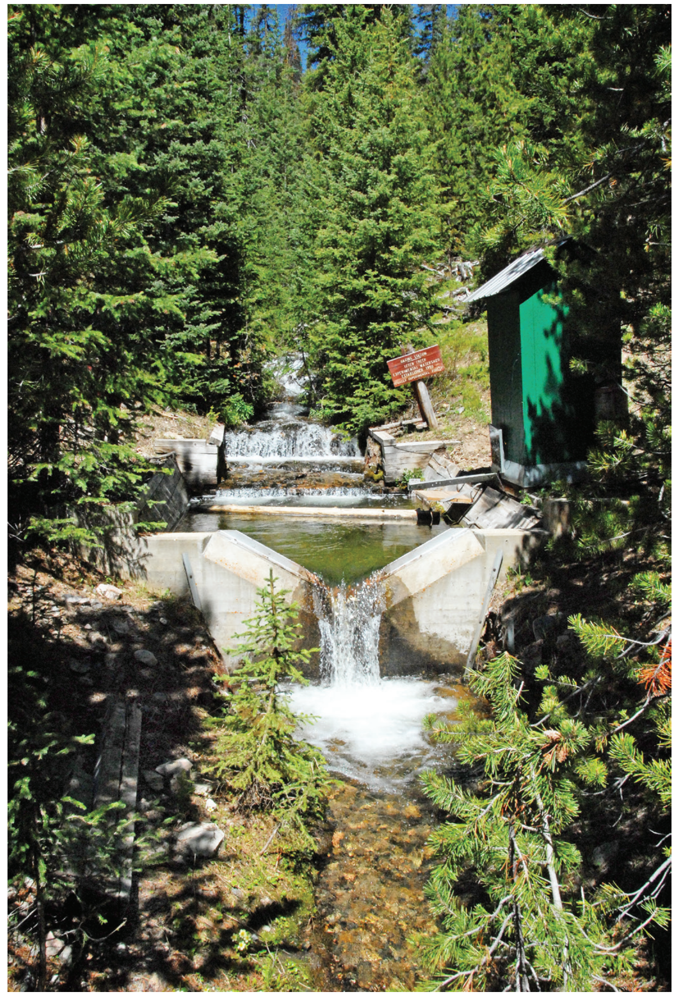


Figure A1-28. The Fraser Experimental Forest (FRA USFS) is located in subalpine coniferous forests of the central Rocky Mountains. (Photo from FRA photo gallery.)

The Fraser Experimental Forest (FRA) was established in 1937 in high-elevation subalpine coniferous forests located about 80 km west of Denver, CO. FRA includes subalpine forests and alpine tundra typical of the central Rocky Mountains (figure A1-28). In the forested areas below timberline, Engelmann spruce *(Picea engelmannii)* and subalpine fir *(Abies lasiocarpa)* are predominant trees at higher elevations, on north slopes, and along streams; lodgepole pine *(Pinus contorta* var. *latifolia)* is the predominant tree at lower elevations and on drier upper slopes.

The majority of the forest began natural regeneration after a stand-replacing fire in 1685. Pockets of older trees exist in draws and at higher elevations. The flat, low-elevation portion of the forest was logged in the early 1900s.

Overall, the climate is cool and humid with long, cold winters and short, cool summers. Frost and snowfall can occur any month of the year. Nearly two-thirds of the precipitation falls as snow from October to May, and about half of the precipitation is lost as runoff with peak flow in the second week of June. Elevation varies from 2,680 to 3,900 m, and about one-third of FRA is above timberline at 3,350 m.

Research focus. The FRA studies effects of management practices on water yield and quality. Long-term study plots were established in both lodgepole pine and Engelmann spruce, and seven watersheds have been monitored for streamflow, climate, and snow; some records now go back more than 60 years. Snow depth and water content are collected on five watersheds, with records dating to 1941 for one watershed. Current research addresses questions about links among forests, riparian areas, and streams in order to better understand mechanisms important in water balance, watershed chemistry, nutrient cycling, and ecosystem carbon storage. The current outbreak of mountain pine bark beetle has shifted focus to impacts of widespread disturbance in subalpine forests on changes in water yield, nutrient cycling, soil processes, sedimentation, and riparian structure.

Long-term studies. Most of the hydrological and silvicultural practices used in managing subalpine forests in the central Rocky Mountains are derived from research done at FRA. Improvements in understanding the factors that control snow distribution and water yield across heterogeneous landscapes have been incorporated into water yield models. Studies of tree water use and ecophysiology have provided a better understanding of the growth dynamics of forests and transpiration water loss; and these dynamics have been incorporated into models to predict the effects of changing climate on forest production and carbon storage. Long-term studies of manipulated forest stands indicate that recovery requires substantially longer than originally hypothesized.

Aquatic and terrestrial biogeochemistry have been studied in manipulated and control catchments, providing a greater understanding of the processes that control stream water quality. Long-term data sets of stream and precipitation chemistry are extremely valuable given the potential for increases in anthropogenic emissions in coming decades.

Georgia Coastal Ecosystems (GCE) [LTER]

http://gce-lter.marsci.uga.edu/

The Georgia Coastal Ecosystems (GCE) LTER program began in 2000 along the central Georgia coast. The study domain encompasses three adjacent sounds (Altamaha, Doboy, and Sapelo) and includes upland (mainland, barrier islands, marsh hammocks), intertidal (fresh, brackish, and salt marsh), and submerged (river, estuary, continental shelf) habitats (figure A1-29). Vegetation is representative of the southeastern coast and includes salt marshes (dominated by salt marsh cord grass, *Spartina alterniflora,* and black needle rush, *Juncus roemerianus*) and maritime forest (dominated by live oak, *Quercus virginiana*) that grade into brackish and fresh marshes and floodplain bald cypress forest.

Patterns and processes in this complex landscape vary spatially within and between sites and temporally on multiple scales (tidal, diurnal, seasonal, and inter-annual). Overlain on these spatial and temporal variations are long-term trends caused by climate change, sea level rise, and human alterations of the landscape (figure 9-3). These long-term trends are manifested in many ways, including changes in water quality, river discharge, runoff, and tidal inundation patterns throughout the estuarine landscape.

Research focus. GCE study sites are distributed along an onshore-offshore gradient across the domain span the full range from tidal fresh to tidal marine habitats. Project objectives are—

- to document long-term patterns of environmental forcing to the coastal zone,
- to link environmental forcing to observed spatial and temporal patterns of biogeochemical processes, primary production, community dynamics, decomposition, and disturbance,
- to investigate underlying mechanisms by which environmental gradients vary longitudinally (freshwater-saltwater) and laterally (upland-subtidal) to drive ecosystem change, and
- to explore the relative importance of larval transport and the conditions of the adult environment for a number of species in determining community and genetic structure across the landscape.

Long-term research example. The Altamaha River is the largest source of fresh water to the GCE domain and provides a natural gradient of freshwater inflow. It drains a watershed of 36,700 km^2 that is relatively undeveloped. Estimates of nitrogen input to the watershed show an increase since 1954 with a peak in 1974 (figure A1-30). Fertilizer tends to be the most important input of nitrogen to the watershed, although net food and feed import increased in importance to become the dominant source by 2002.

Figure A1-29. The Georgia Coastal Ecosystems Long Term Ecological Research site (GCE LTER) consists of upland, intertidal, and submerged habitats. (Photo by Wade Sheldon.)

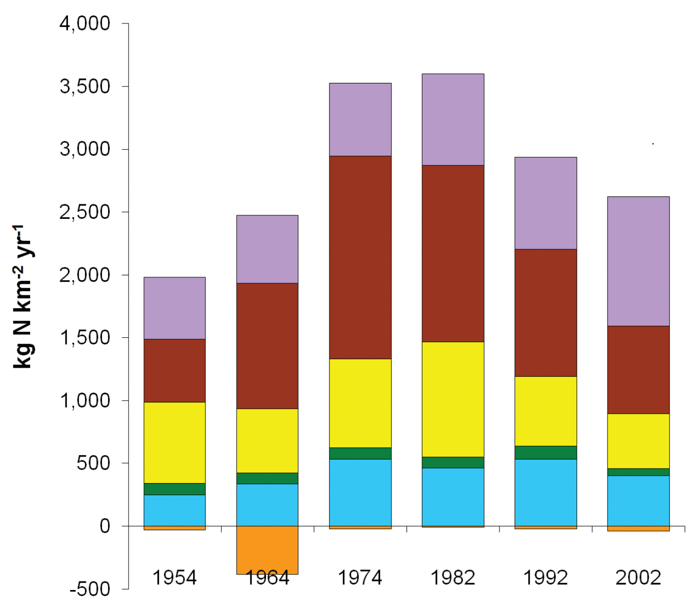


Figure A1-30. Nitrogen inputs to the Altamaha River watershed, over time, in the Georgia Coastal Ecosystems (GCE) site: net food and feed import (lavender), fertilizer input (maroon), biological nitrogen fixation in agricultural lands (yellow), biological nitrogen fixation in forest lands (green), net atmospheric nitrogen deposition (teal), and non-food export (orange). (Redrawn from Schaefer and Alber 2007.)

Glacier Lakes (GLA) [USFS]

http://www.fs.fed.us/rmrs/experimental-forests/glacier-lake-ecosystem-experiments-site/

The Glacier Lakes Ecosystem Experiments Site (GLA) was established in the late 1980s to conduct aquatic and terrestrial studies in high elevation alpine and subalpine ecosystems. The GLA is located at 3,200 to 3,500 m elevation in the Snowy Range in the Medicine Bow Mountains of southeastern Wyoming. The GLA is a 760-ha wilderness-like watershed in complex mountainous terrain containing small alpine to subalpine catchments that include persistent snowfields, glacial cirque lakes, first and second order streams, wetlands, and forest (figure A1-31). The environment is harsh with a short growing season, high winds, and low temperatures.

Figure A1-31. The Glacier Lakes Ecosystem Experiments Site (GLA USFS) includes Lost Lake, a glacial cirque basin along the Snowy Range ridge. (Photo by Robert Musselman.)

Dominant landscape types are alpine, subalpine meadow, Engelmann spruce/subalpine fir forest, shrub, krummholz (wind-deformed conifer trees), exposed bedrock, and scree. Included are old-growth forests with trees more than 700 years old. Most aquatic research is conducted at two adjacent alpine lakes (East and West Glacier Lakes) with similar surface area and depth but differing in catchment area, inflow patterns, turnover rates, stratification, snow cover, deposition of nutrients, water chemistry, and aquatic biota.

Research focus. Current research includes studies of long-term trends in deposition, effects of nitrogen deposition on subalpine meadow and on riparian systems, effects of winter recreation on air quality, the cycling of nitrogen through riparian ecosystems, the dynamics of disturbance in subalpine ecosystems, and the development and testing of techniques for monitoring of Air Quality Related Values (AQRVs) in wilderness ecosystems.

Long-term research example. Research and monitoring are determining the amount of air pollutants deposited in alpine and subalpine ecosystems and the effect of this deposition on the terrestrial and aquatic system components. At West Glacier Lake, nitrogen deposition in precipitation has been variable since 1987, with most deposition occurring from nitrate rather than ammonium (figure A1-32). On average, both nitrate and ammonium concentrations have increased starting in 1989, although these results need to be used with caution because only 2 early years (1987-1988) are available for comparison.

The GLA is a remote area and is considered to be relatively pristine with low amounts of deposition. Thus, these systems are highly sensitive to climate change, air pollutants, and chemical deposition. Long-term physical, chemical, and biological monitoring are needed to determine impacts of changes in atmospheric chemistry on these ecosystems.

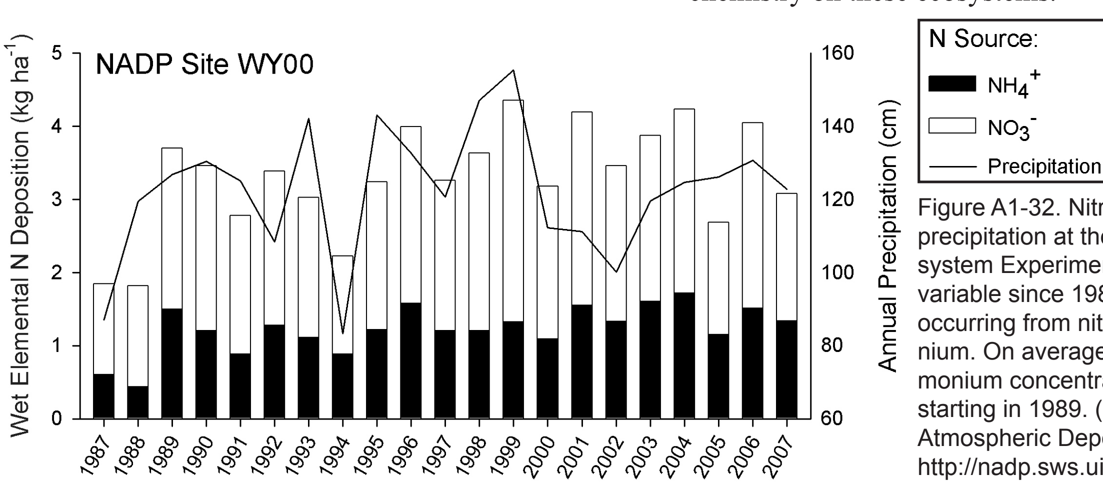


Figure A1-32. Nitrogen deposition in precipitation at the Glacier Lakes Ecosystem Experiments Site (GLA) has been variable since 1987, with most deposition occurring from nitrate rather than ammonium. On average, both nitrate and ammonium concentrations have increased starting in 1989. (Data from National Atmospheric Deposition Program, 2007, http://nadp.sws.uiuc.edu/.)

Grassland, Soil and Water Research Laboratory (GSW) [USDA-ARS]

http://ars.usda.gov/

The Blacklands Experimental Watershed (GSW) was established in 1937 near Riesel, Texas. This experimental watershed facility later became part of the USDA-ARS Grassland, Soil and Water Research Laboratory (GSW). The initial purpose of this watershed and the other two original ARS watersheds (in Coshocton, OH, and Hastings, NE) was to collect hydrologic data (precipitation, percolation, evaporation, runoff, etc.), and to evaluate the hydrologic and soil erosion response of watersheds to agricultural land management practices. The GSW currently contains 340 ha of federally owned and operated land in the heart of the Texas Blackland Prairie, a 4.45 million ha region of fertile agricultural land extending from San Antonio north to the Red River. Present day agricultural use in the region consists of cattle production on pasture and rangeland and corn, wheat, grain sorghum, and oat production.

The Texas Blackland Prairie is known for its Houston Black clay soils, which are commonly recognized as classic Vertisols. Formed from weakly consolidated calcareous clays and marls, these soils are very deep and moderately well drained. The GSW contains several small tracts of remnant (never-plowed) tallgrass prairie dominated by warm-season perennial grasses, including little bluestem and Indian grass, but which also support a diverse mixture of perennial forb species absent from intensively managed grasslands (figure A1-33).

Research focus. Traditionally, research at GSW focused on quantifying hydrologic and soil erosion processes affected by land management. Early research established the soil erosion reduction of conservation practices (terraces, grassed waterways, contour farming, etc.) which provided much of the scientific basis for the American conservation farming revolution. The importance of soil-water phases to temporal runoff patterns in Vertisols was also established. Little runoff occurs in the "dry" soil-water phase, but substantial surface runoff and lateral subsurface return flow occur in the "saturated" phase. This temporal pattern drives the shrink/swell behavior and soil crack formation of Vertisols, which has important implications for the ecology, agriculture, and infrastructure of the region (figure A1-34). Research is also examining the potential effects of changes in rainfall patterns caused by climate change. Rain-exclusion shelters are being used to study effects of altered timing and quantity of precipitation events on forage production and plant species composition on remnant prairies.

Figure A1-33. Remnant tallgrass prairie at the Grassland, Soil and Water Research Laboratory (GSW USDA-ARS) in the Texas Blackland Prairie. (Photo by R. Daren Harmel.)

Figure A1-34. Shrink-swell behavior of Vertisols at the Grassland, Soil and Water Research Laboratory (GSW) results in formation of cracks in the soil, with consequences for ecosystem dynamics, agricultural management, and building and road foundations. (Photo by R. Daren Harmel.)

Grazinglands Research Laboratory (GRL) [USDA-ARS]

http://ars.usda.gov/

The USDA-ARS Grazinglands Research Laboratory (GRL) was established in 1948 on a former U.S. Cavalry remount station. The GRL is located about 45 km west of Oklahoma City, OK, within the central Rolling Red Prairie geomorphic province. The 2,711 ha of land are planted in a variety of forages including: native prairie (1,214 ha), wheat (365 ha), improved grass varieties (809 ha), and numerous experimental plots of cool- and warm-season perennial and annual grasses and legumes (figure A1-35). The most common soil types on GRL are silty-clay loams on crests and side slopes of hills that developed on the Permian-age Dog Creek shale formation. Distribution of precipitation is generally bimodal with peaks in April-May and September-October. Moderate to severe droughts are common and can persist for several years. The frost-free growing season varies from 179 to 249 days, averaging 219 days.

The GRL is near the transition zone between tallgrass prairie to the east and mixed-grass prairie to the west. The prevailing native vegetation is defined as southern tallgrass prairie, often reaching 1 to 3 m in height. Depending on growing conditions, 60 to 90 percent of annual herbaceous production is by warm-season tallgrasses (big bluestem *[Andropogon gerardii],* indiangrass *[Sorghastrum nutans],* and switchgrass *[Panicum virgatum]*), and the mixed-grass little bluestem *(Schizachyrium scoparium)*. The most common perennial cool-season grasses include western wheatgrass *(Elymus smithii),* Canada wildrye *(Elymus canadensis),* and Scribner's panicum *(Panicum oligosanthes)*. Farming within the region is largely dryland with conventional tillage practices the norm, but interest in conservation tillage is increasing.

Research focus. The primary focus of the GRL is control of stocking rate and timing of grazing, use of complementary farmed forages to enhance livestock production, application of prescribed spring burns to control woody species, and control of broadleaf weeds with herbicides.

Long-term studies. Species composition and productivity of southern tallgrass prairie vary in response to management and precipitation. As the dominant tallgrasses and mixed-grasses decline in response to disturbance, they are replaced by less common components of the plant community or invasive perennial grasses. This shift is impermanent, and species composition will generally return to a tallgrass-dominated state with increased precipitation or reduced grazing pressure.

Figure A1-35. Developing integrated crop, forage, and livestock systems under variable climate, energy, and market conditions is a focus of the Grazinglands Research Laboratory (GRL USDA-ARS) near Oklahoma City, OK. (Photo by Michael Brown.)

Harrison Experimental Forest (HAR) [USFS]

http://www.srs.fs.usda.gov/

The Harrison Experimental Forest (HAR) was established in 1934 as a research site for studies of reforestation methods and wood preservation treatments. The forest is located near the Gulf of Mexico in the DeSoto Ranger District of the DeSoto National Forest. The HAR comprises 1,662 ha of forest with soils and topography representative of the longleaf pine forest type that once covered about 12.5 million ha across the Southeastern United States (figure A1-36).

Soils are mostly well-drained, fine-sandy loams of the Ruston and Mclaurin series. Overall, the soils are low in cation-exchange capacity, organic matter, and nutrients and are similar to the lateritic soils of the tropics. The climate is temperate-humid subtropical with precipitation distributed relatively uniformly throughout the year.

Research focus. The mission at the HAR is to provide scientific understanding of the effects of genetics, environment, and their interactions on the function and management of southern forest ecosystems. Species comparisons among the southern pines planted on the HAR as early as the 1950s-1960s have demonstrated species differences in growth trajectories and stand dynamics. Some of the earliest genetic information on longleaf and loblolly pines was generated from plantings consisting of hundreds of control-pollinated families and thousands of trees established by HAR scientists. The HAR has a large collection of southern pine genotypes that serve as a source of germplasm for genetic experiments as well as for gene conservation. Research on the biology and genetics of the southern pine/fusiform rust pathosystem has been conducted. DNA markers are being used to help incorporate blight resistance into the American chestnut, aiding the effort to reestablish this species.

Long-term research. Early research concentrated on southern pine regeneration studies, as well as investigation of various wood preservatives. In 1954, the Southern Institute of Forest Genetics (SIFG) was established shortly after the South-wide Southern Pine Seed Source Study (SSPSSS) was initiated. This study includes 130 individual field experiments at 60 locations (including the HAR) ranging from Texas to Missouri in the west and from Florida to Pennsylvania and New Jersey in the east. These experiments tested growth and survival of 103 seed sources for four major southern pine species. Currently a database is being developed which contains records for 165,696 trees.

Figure A1-36. A longleaf pine and saw palmetto site in the Harrison Experimental Forest (HAR USFS). (Photo from HAR photo gallery.)

Harvard Forest (HFR) [LTER]

http://harvardforest.fas.harvard.edu/

The Harvard Forest (HFR) was established as an LTER site in 1988 to understand historical and modern changes in the landscape of New England and the Northeastern United States resulting from human and natural disturbance processes and to apply this information to the conservation and management of forest ecosystems. Founded in 1907, the HFR is Harvard University's center for field research and education in ecology and conservation. Harvard Forest is one of the oldest and most intensively studied landscapes in North America.

The HFR is located in Petersham, Massachusetts, 65 miles west of Boston. Elevation ranges from 210 to 420 meters. Precipitation is distributed evenly throughout the year. A persistent snow pack forms in most years. Hurricane wind damage at the F1 level (Fujita scale) occurs on average every 20 years. Habitats are typical of central New England and include northern, transition, and central forest types; marshes, hardwood swamps, and conifer bogs; forest plantations; and a 70-acre pond (figure A1-37). At the height of agricultural development (1830-1850), approximately 75 percent of the land was cleared for cultivation or pasture (Foster and Aber 2004).

Figure A1-37. Transition hardwood forests with stone walls from the agricultural past are an important part of landscapes of the Harvard Forest (HFR LTER). (Photo by David R. Foster.)

Research focus. An important goal of HFR research is to examine the drivers of landscape change for human populations and for the diverse natural ecosystems of the Northeast. Drivers range from microbes to moose, invasive plants to exotic insects, hurricanes to forest harvesting, and global climate change to regional land use. Their consequences are explored through paleological and historical studies, regional studies, long-term measurements, modeling, and controlled experimental manipulations—several of which are entering their third decade.

Long-term research example. Changes in forest structure (figure A1-38, top) and composition (figure A1-38, bottom) in southwestern New Hampshire from the early 1900s to 2000 show the forest's response to the 1938 hurricane. The original old-growth forest was composed of widely spaced, but massive, white pine and hemlock, which were nearly all blown down by the storm. A young and dense stand of hemlock, beech, red maple, and birch has been undergoing a process of thinning in density and gradual increase in basal area over the past 70 years. White pine was essentially eliminated from the stand by the storm.

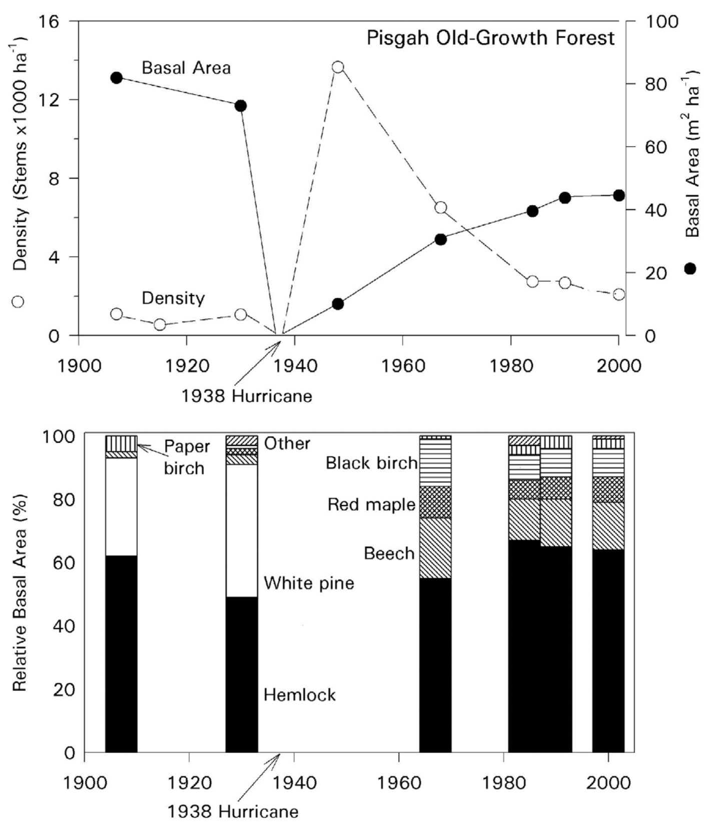


Figure A1-38. Change in density (top) and basal area (bottom) of trees before and after the 1938 hurricane at the Harvard Forest (HFR) (Foster et al. 2004). Reprinted with permission from Yale University Press.

Hubbard Brook Ecosystem Study (HBR) [USFS, LTER]

http://www.hubbardbrook.org/

The Hubbard Brook Ecosystem Study (HBR) was established in 1955 as a center for hydrologic research in New England. The site is located within the White Mountain National Forest in central New Hampshire. The HBR is a 3,160-ha, bowl-shaped valley ranging from 222 to 1,015 m in elevation.

The site is entirely forested, mainly with deciduous northern hardwoods: sugar maple *(Acer saccharum),* American beech *(Fagus grandifolia),* and yellow birch *(Betula alleghaniensis)* (figure A1-39). Red spruce *(Picea rubens),* balsam fir *(Abies balsamea),* and mountain paper birch *(Betula papyrifera* var. *cordifolia)* are abundant at higher elevations and on rock outcrops. Pin cherry *(Prunus pensylvanica),* a shade intolerant species, dominates all sites for the first decade following a major forest disturbance. Logging operations, which ended around 1915-1917, removed large portions of the conifers and allowed growth of better quality, more accessible hardwoods. The present second-growth forest is composed of about 80 to 90 percent hardwoods and 10 to 20 percent conifers.

Research focus. Research at the HBR includes studies of mountain ranges, rivers, lakes, and wetlands that provide habitat for many wildlife species, including moose, pine marten, Canada lynx, song birds, peregrine falcons, and bald eagles (figure 3-4). Critical environmental issues are land development and disturbance, air pollution, climate change, introduced species, water supply and quality, and carbon management.

The small watershed ecosystem approach to nutrient cycling was pioneered at HBR (Bormann and Likens 1985). This method uses the forest ecosystem as a living laboratory in which scientists conduct experiments on an entire watershed and monitor resulting long-term changes in streamflow, nutrient cycling, forest growth, and habitat (figure 5-3). Whole-ecosystem manipulations conducted at HBR include experiments that simulate forest management practices, such as forest clear-cutting, strip cutting, herbicide application and nutrient cation additions, and that provide a scientific basis for improved forest management.

Figure A1-39. The Hubbard Brook Ecosystem Study (HBR USFS/LTER) was established to study hydrologic processes in the northern hardwood forests of the northeastern United States. (Photo from Hubbard Brook Research Foundation.)

Long-term research example: The increase in chloride concentrations at the northeast inlet (green) and Mirror Lake outlet (blue) (figure A1-40) are caused primarily by runoff of road salt used to de-ice Interstate 93, which runs north-south through central New Hampshire (Rosenberry et al. 1999, Kaushal et al. 2005, Likens and Buso 2010). Much of the road salt is transported to Mirror Lake by the northeast inlet stream, which provides only a small portion (2 percent) of the stream flow to the lake but about 30-50 percent of all chloride. Chloride concentrations at the northeast inlet began to increase in 1970 when I-93 opened despite the installation of an earthen diversion dam. The decrease in concentrations in 1995-1996 was likely due to dilution from higher than average precipitation. After 2000, further declines resulted from installation of a plastic liner adjacent to the highway to divert contaminated runoff away from the lake. Chloride concentrations in the lake outlet, unlike those in the northeast inlet, have continued to increase due to increases in the use of salt on local roads which intersect the west and northwest inlets to the lake and contribute 47 percent of the water inflow.

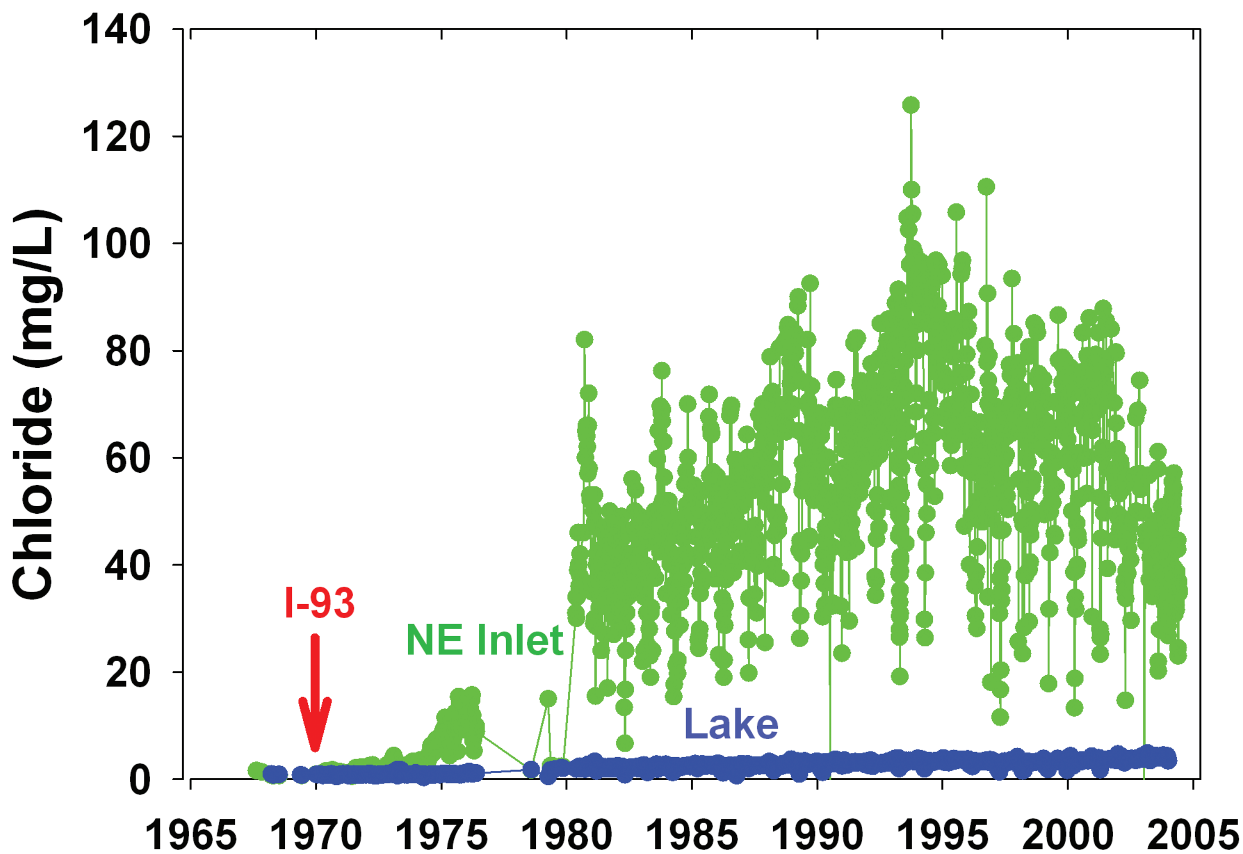


Figure A1-40. The increase in chloride concentrations at the northeast inlet (green) and Mirror Lake outlet (blue) are caused primarily by runoff of road salt used to de-ice Interstate 93, which runs north-south through central New Hampshire near the Hubbard Brook Ecosystem Study (HBR). Change in chloride concentrations through time reflect human activities. (Redrawn from Kaushal et al. 2005; Likens and Buso 2010.)

Jornada (JRN) (USDA-ARS, LTER)

http://jornada-www.nmsu.edu/

The Jornada Basin (JRN) LTER program was established in 1982 to quantify the key factors and processes controlling ecosystem dynamics and patterns in Chihuahuan Desert landscapes. The study site includes the 78,000-ha Jornada Experimental Range operated by the USDA Agricultural Research Service and the 22,000-ha Chihuahuan Desert Rangeland Research Center (CDRRC) operated by New Mexico State University. Data have been collected since 1915, and vegetation records date to the mid-1800s. The JRN is located 37 km north of Las Cruces, NM.

Livestock grazing was historically the predominant landuse in the region, although urbanization has been increasing (figure 9-20). Annual precipitation is low (avg 26 cm/y) and seasonally variable with 52 percent of rain occurring in summer. Extreme droughts are a recurrent climatic phenomenon with profound influence on the vegetation (figure 9-11). Five major plant communities can be found that differ in their degree of desertification: upland grasslands dominated by black grama *(Bouteloua eriopoda)* (figure A1-41 top), lowland grasslands dominated by tobosa *(Pleuraphis mutica)* and burrograss *(Schleropogon brevifolius),* and a series of desertified shrublands, including tarbush *(Flourensia cernua)* on lower piedmont slopes, creosotebush *(Larrea tridentata)* on upper piedmont slopes and bajadas, and honey mesquite *(Prosopis glandulosa)* on the sandy basin floor (figure A1-41 bottom).

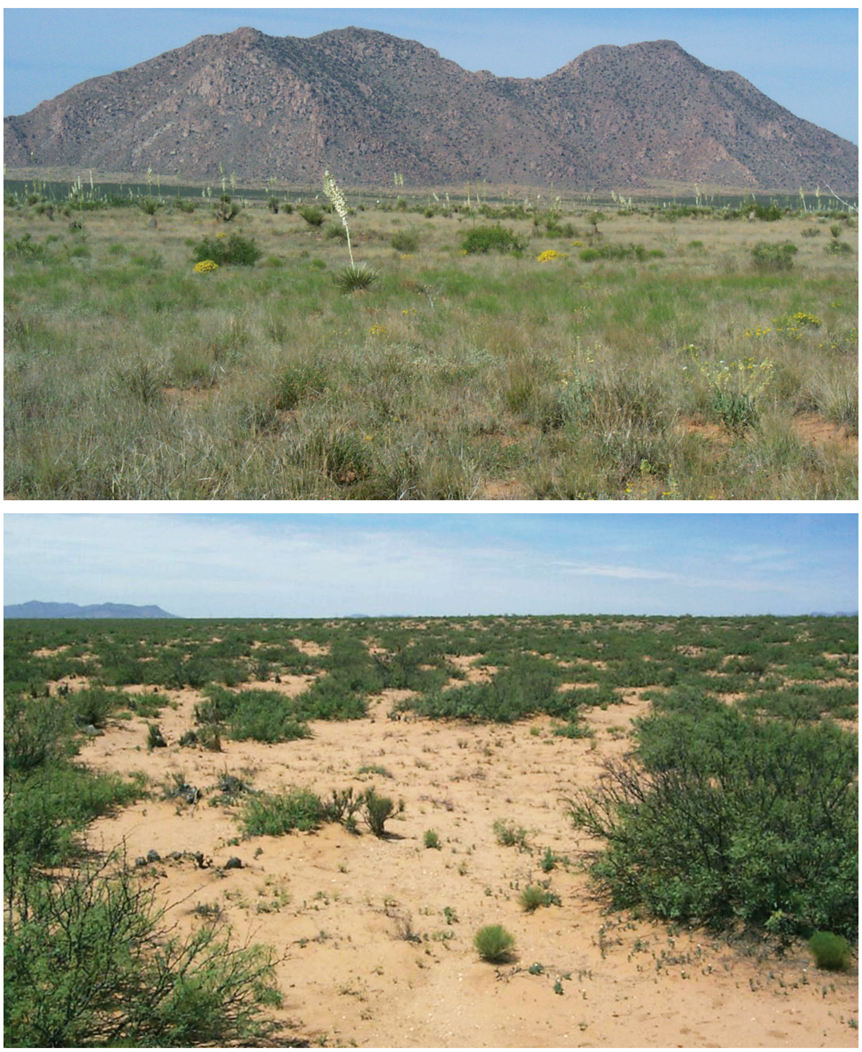


Figure A1-41. The Jornada Basin site (JRN USDA-ARS/LTER) was historically dominated by perennial grasslands (top), though most of the site is now dominated by shrublands such as honey mesquite (bottom). (Photo from JRN photo gallery.)

Research focus. Significant advances in understanding the causes and consequences of desertification have been made at specific spatial scales and for certain environmental conditions (Schlesinger et al. 1990). More recently, the JRN has been investigating the role of spatial and temporal variation in ecosystem properties and processes to desertification dynamics (figure 4-1) and the potential for grass recovery (figure 9-18) (Peters et al. 2004, 2006). Researchers are particularly interested in evaluating how processes interact across a range of scales and under different conditions to drive desertification dynamics and to regulate the conservation of biological resources.

Long-term research example. In general, the amount of area at the JRN dominated by grasslands has decreased from about 80 percent in 1858 to less than 8 percent in 1998, whereas the area dominated by shrubs has increased (figure A1-42). Although the drought of the 1950s has often been implicated as a major driver in the loss of grasses, most of the site was already dominated by shrubs by 1915. Extreme drought and livestock overgrazing in the late 1800s to early 1900s likely led to this shift from grasslands to shrublands at the landscape scale (Fredrickson et al. 1998). Small areas of remnant grasslands remain in 1998; these are often the locations farthest from shrublands early in the 20th century (Yao et al. 2006).

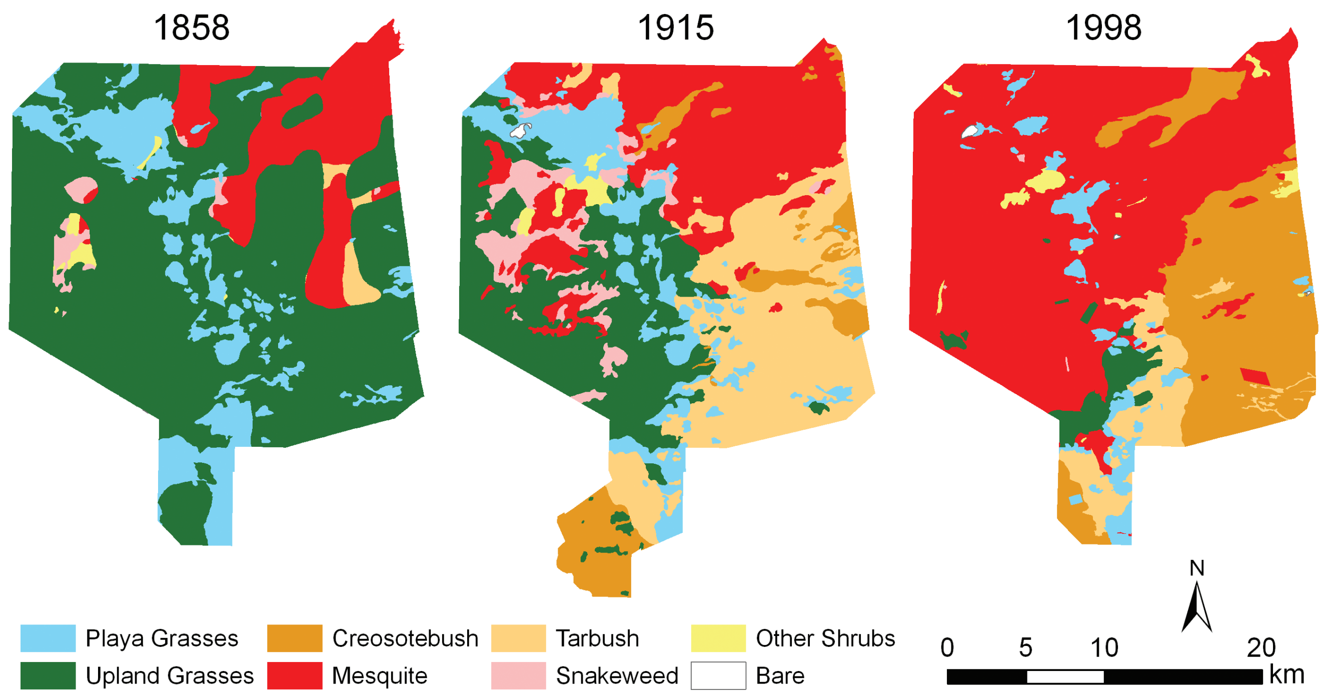


Figure A1-42. Historical maps show that about 80 percent of the Jornada Basin site (JRN) was dominated by perennial grasslands (green, blue) in 1858 but only 8 percent grassland in 1998. Even by 1915, the site was dominated mostly by shrubs (red, tan, brown). (Maps for 1915 and 1998 redrawn from Gibbens et al. 2005.)

Kellogg Biological Station (KBS) [LTER]

http://lter.kbs.msu.edu/

The Kellogg Biological Station (KBS) joined the LTER Network in 1988 to represent intensive row-crop ecosystems, a dominant land use in the U.S. Midwest. KBS consists of 1,600 ha of cropping systems, successional communities, wetlands, and lakes in southwest Michigan. This is in the northeastern portion of the U.S. cornbelt. Land use around KBS ranges from urban (Kalamazoo) to rural. Vegetation ranges from cultivated and early successional old fields to older growth eastern deciduous forest. Aquatic habitats include more than 200 bodies of water within 50 km spanning a wide range of morphometry, geochemistry, and trophic state.

Cropping systems in the area and at KBS are typical of the U.S. cornbelt. Annual crops include corn *(Zea mays),* soybeans *(Glycine max),* and wheat *(Triticum aestivum).* Perennial systems include forage crops such as alfalfa *(Medicago sativa)* and biofuel crops such as hybrid poplar (*Populus* sp.) and switchgrass *(Panicum virgatum)* (figure A1-43). Annual rainfall is evenly distributed seasonally with about half falling as snow. Cropping systems both respond to and influence climate and, in aggregate, play a large role in regional to global biogeochemical cycles. These systems can influence greenhouse gas concentrations in the atmosphere and largely determine nitrate and phosphorus inputs to aquatic systems. Cropping systems also have a large influence on biodiversity and other ecological attributes at local to landscape scales.

Research focus. By understanding how cropping systems function, agronomic management can be adjusted to better utilize biological resources to control pests, provide nitrogen, and build soil fertility, thereby making agriculture more profitable while providing environmental benefits. As such, the goal of KBS research is to develop an improved understanding of ecological interactions underlying the productivity of intensively managed annual and perennial field crops, including corn, soybean, and wheat rotations as well as forage crops such as alfalfa and biofuel crops such as hybrid poplars and switchgrass. Contrasts with unmanaged forest and successional (old field) sites provide important points of comparison for gauging the effects of intensive management on the ecology of organisms in modern field crop ecosystems. An organizing question for KBS research concerns the role of biodiversity in agricultural landscapes and, in particular, the functional significance of diversity with respect to ecosystem function.

Figure A1-43. The Kellogg Biological Station (KBS LTER) studies ecological interactions underlying the productivity and environmental performance of field, forage, and biofuel crops in heterogeneous landscapes. (Photo from KBS photo gallery.)

Long-term research example. As more than half of the conterminous U.S. land base is used for agriculture, relatively minor changes in soil carbon storage or greenhouse gas production from crop fields can have enormous impact when played out over millions of hectares. Field crop agriculture plays a key role in greenhouse gas emissions through practices such as nitrogen fertilizer application and soil tillage. Nitrous oxide (N_2O) and methane (CH_4) are especially important greenhouse gases influenced by agriculture. Methane uptake—the removal of CH_4 from the atmosphere by soil microbes—is inhibited by agriculture (figure A1-44, top, gray bars) to a fraction of that in mature forest (figure A1-44, top, black bars). When the forest is cleared for agriculture, methane uptake is suppressed, allowing more methane to accumulate in the atmosphere than prior to clearing. In contrast, N_2O production is stimulated by agricultural treatments (figure A1-44, bottom), providing a direct source of this greenhouse gas to the atmosphere. Neither change is desirable from a climate-change perspective, but both may be mitigated by appropriate agricultural management, an active area of research at KBS. In these experiments, annual crops were managed as conventional cropping systems, as no-till systems, as low-chemical-input systems, or as organic systems (no fertilizer or manure). Midsuccessional systems were either never tilled (Mid NT) or historically tilled (Early and Mid HT) before establishment.

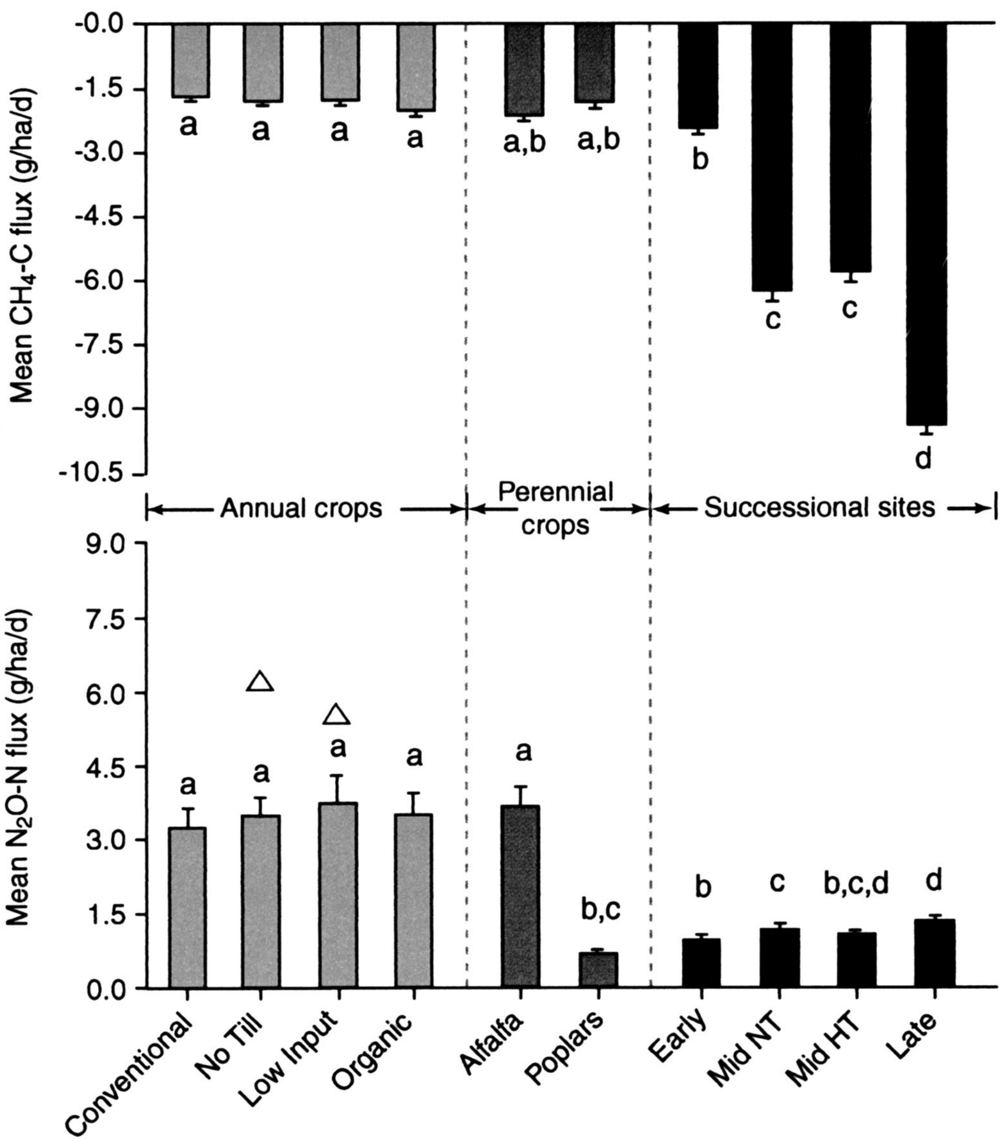


Figure A1-44. Methane oxidation and nitrous oxide production in different cropping systems at the Kellogg Biological Station (KBS) (Robertson et al. 2000). Fluxes were measured over the 1991-1999 period. Methane uptake inhibited by agriculture is indicated by the gray bars at the top of the figure. The black bars at the top represent methane uptake in mature forest. The bottom portion shows N_2O production as stimulated by agricultural treatments. There are no significant differences ($p < 0.05$) among bars that share the same letter. Triangles indicate average fluxes when the single day of anomalously high fluxes in the no-till and low-input systems in 1999 and 1991, respectively, is included. Reprinted with permission from AAAS.

Konza Prairie Biological Station (KNZ) [LTER]

http://www.konza.ksu.edu/

The Konza Prairie (KNZ) LTER program began in 1982 with a focus on fire, grazing, and climatic variability as three key drivers that affect ecological pattern and process in tallgrass prairies worldwide. The focal site for the KNZ program is the 3,487-ha Konza Prairie Biological Station (KPBS) (figure A1-45), a C_4-dominated grassland with a continental climate characterized by warm, wet summers and dry, cold winters.

KPBS is located in the Flint Hills region of northeastern Kansas, an area of steep slopes overlain by shallow limestone soils unsuitable for cultivation. These soils overlay as many as 10 distinct layers of alternating limestone and shale, contributing to the complex subsurface hydrology of the region. Because mean annual precipitation is sufficient to support woodland or savanna vegetation, periodic drought, fire, and grazing are important in maintaining the grassland. The vegetation is primarily (over 90 percent) native tallgrass prairie dominated by perennial C_4 grasses, such as *Andropogon gerardii, Sorghastrum nutans, Panicum virgatum,* and *A. scoparius.* Numerous subdominant grasses, forbs, and woody species contribute to its high floristic diversity. Gallery forests dominated by *Quercus* spp. and *Celtis occidentalis* grow along major stream courses.

Research focus. The KNZ program addresses major abiotic drivers (climate and fire) as well as the numerous biotic interactions (herbivory, competition, mutualism, predation) that shape mesic grassland ecosystems (figure 9-12). The KNZ program features long-term studies and experiments including a replicated watershed-level experiment, in place since 1977, which explicitly incorporates the major factors influencing mesic grasslands in a long-term experimental setting.

Figure A1-45. Konza Prairie Biological Station (KNZ LTER) is located in northeastern Kansas. Vegetation is tallgrass prairie on steep slopes unsuitable for cultivation. Fire is an important management tool to maintain grassland and limit invasion by woody plants. (Photo by Alan K. Knapp.)

Long-term research example. Woody plants have increased through time at the KNZ. GIS (geographic information system) representation has been used to show gallery forest expansion, digitized from aerial photographs from 1939, 1950, 1969, 1985, and 2002. From 1939 to 2002, the extent of the gallery forest increased from 162 ha to 274 ha (figure A1-46). Major drainage boundaries at the Konza Prairie Biological Station are outlined in black in figure A1-46; some of the major streams are outlined in blue. Both fire and livestock grazing are important in limiting woody plant expansion.

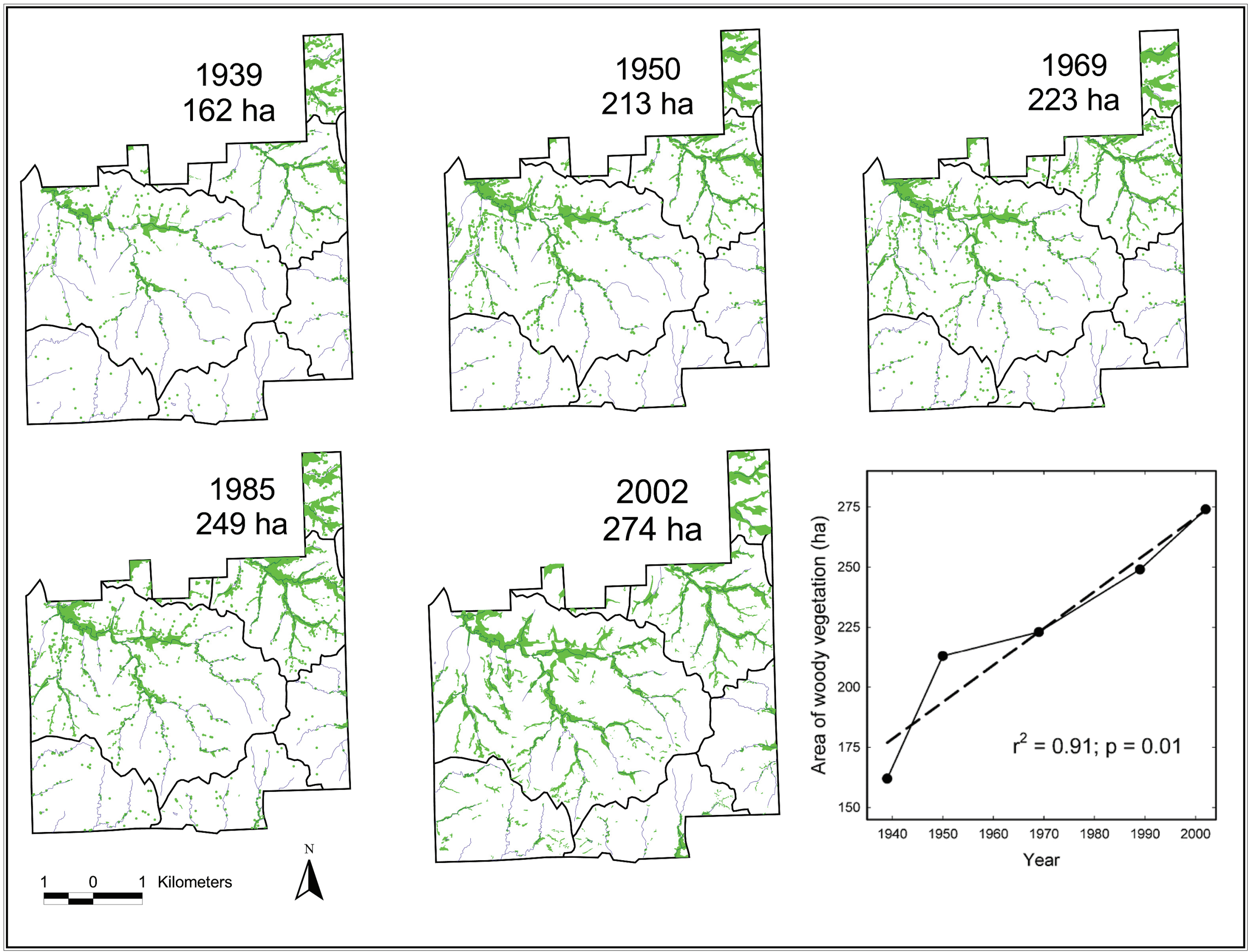


Figure A1-46. Gallery forests increased from 1939 to 2002 at the Konza Prairie Biological Station (KNZ) (Briggs et al. 2005; updated from Knight et al. 1994). Both fire and grazing are critical in maintaining grasslands and limiting woody plant expansion in tallgrass prairie. Reprinted with permission from the American Institute of Biological Sciences.

Loch Vale Watershed (LVW) [USGS]

http://www.nrel.colostate.edu/projects/lvws

Loch Vale Watershed (LVW) is a 660-ha alpine/subalpine catchment located entirely within Rocky Mountain National Park in Colorado. Biogeochemical, hydrologic, and biological information has been collected from Loch Vale since 1983. Because Loch Vale is located in a national park, it has minimal disturbances directly caused by humans. Climate is characterized by long, cold winters and a short growing season of 3-4 months. More than 65 percent of annual precipitation comes as snow between November and June. Approximately 75 percent of precipitation is lost as discharge. The western boundary of the watershed is the continental divide; streams drain northeast. The two main tributaries in Loch Vale, Andrews Creek and Icy Brook, join above The Loch which is the lowest of four lakes in the watershed. The Loch is below treeline, and Sky Pond, Glass Lake, and Andrews Tarn are alpine tarns.

Eleven percent of the catchment is tundra, located primarily on ridgetops (figure A1-47). Old-growth Engelmann spruce/subalpine fir forest is located on the valley bottom and makes up only 6 percent of the land cover. Alpine soils support plant communities largely dominated by lichen, herbaceous vegetation, grasses, and low shrubs. Tundra and wetland soils have pH values around 4.5, while forest soils have pH values between 3.8 and 4.0. Base saturation is greater than 40 percent.

Research focus. Research explores questions related to the role of climate and atmospheric deposition, primarily of nitrogen, in influencing biogeochemical fluxes. Research also explores alpine and subalpine ecosystem dynamics, including vegetation, soil, and water. Paleolimnological research conducted in Sky Pond has yielded insight into changes over time related to climate since deglaciation and into atmospheric deposition of nitrogen, metals, and persistent organic compounds. The overall program objectives are to share results and information on real and potential threats to natural alpine and subalpine resources with the public; scientific community; and air, water, and land managers and to offer a program of graduate education and research that develops future scientists and knowledgeable resource managers.

Figure A1-47. The Loch Vale Watershed (LVW USFS) is an alpine/subalpine site located in Rocky Mountain Park northwest of Denver, CO. More than 80 percent of Loch Vale is made up of exposed bedrock, talus, or glacier. (Photo by David M. Swift.)

Luquillo Experimental Forest (LUQ) [USFS, LTER]

http://luq.lternet.edu/

The Luquillo Experimental Forest (LUQ) was established as an LTER site in 1988 to study tropical forests and streams in Puerto Rico. Research in this area dates back over 100 years, with LUQ being one of the most intensively studied tropical forests in the world. The site is located in the Luquillo Mountains, which harbor the largest area of primary forests and the most pristine rivers in Puerto Rico.

Climate is subtropical maritime moderated by trade winds that maintain relatively constant air temperatures year round. Rainfall is in excess of 100 mm each month, although there are periods of lower rainfall between February and April and higher rainfall in September. Severe hurricanes occur on average every 60 years. These hurricanes and other storms dramatically change forest conditions (figure A1-48; see also figures 9-2, 9-8, 9-9, and 9-10). Drought (less than 100 mm/month) recurs on decadal scales.

Dominant soils are deep, highly weathered and leached clays with low pH and base saturation less than 35 percent at 1.25 m. Soil oxygen decreases with increasing elevation, from 21 percent in aerated soils to anaerobic soils in the highest elevation forests. The vegetation is evergreen broadleaf subtropical forest. The 240 tree species form different forest types with different species composition, structure, and dominance with elevation.

Research focus. The goal of the LUQ is to understand the long-term dynamics of tropical forest and stream ecosystems characterized by a variety of natural and human disturbances, rapid processing of organic material, and high habitat and species diversity. Natural disturbance includes hurricanes, landslides, floods, and droughts (Brokaw et al. 2012). The impact of hurricanes is large, but the organisms are generally resistant and resilient to these storms. The LTER program also studies land-water interactions to understand the role of terrestrial vegetation and land cover on stream fauna and functioning and to determine the capacity of streams to deliver ecological services to urban populations. Human disturbance includes changes in land use and land cover, changes in the atmosphere and climate, and introduction of alien species. Forest cover on the island was reduced to about 5 percent in 1950, but with industrialization and abandonment of agriculture, forests have since recovered.

Figure A1-48. The Luquillo Experimental Forest (LUQ USFS/LTER) in Puerto Rico is an evergreen broadleaf subtropical forest influenced by hurricanes and other storms. (Photo by Jerry Bauer.)

Long-term research example. Litterfall and fruitfall show the effects of multiple hurricanes (figure A1-49). In 1989, Hurricane Hugo struck the site (the first major hurricane since 1932), and afterwards several other hurricanes also affected LUQ. Litterfall (red line) peaks during hurricanes, declines sharply as trees releaf, and soon recovers to prestorm levels. During this recovery, fruit production (black bars) is low, forcing frugivores to move to other locations. Recovery, a measure of resilience, was different for different hurricane events. Hurricane Hugo had the highest pulse of litterfall and the longest period for recovery of fruitfall.

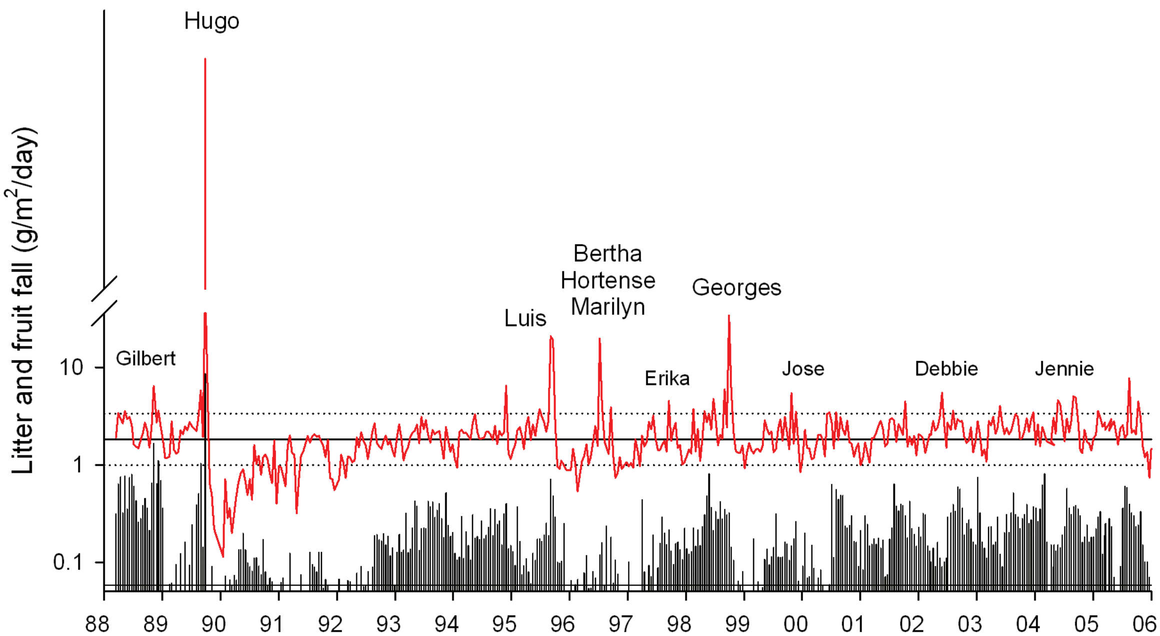


Figure A1-49. Litterfall (red line) and fruitfall during and following multiple hurricanes at the Luquillo Experimental Forest (LUQ). Horizontal solid and dotted lines are mean pre-Hurricane Hugo litterfall rate ± 95 percent CI. Litterfall peaks during hurricanes and declines through time, whereas fruit production (black bars) is low during recovery. (Updated from Scatena et al. 1996.)

Marcell Experimental Forest (MAR) [USFS]

http://nrs.fs.fed.us/ef/locations/mn/marcell/

The Marcell Experimental Forest (MAR) was established to study the ecology and hydrology of lowland watersheds that include peatland, riparian, and upland forests. The MAR is a 1,123-ha tract 40 km north of Grand Rapids, MN. The climate is subhumid continental, with wide and rapid diurnal and seasonal temperature fluctuations. Mineral soils are derived from glacial processes that occurred during the Wisconsin Glaciation, which ended about 10,000 years ago. Organic soil properties reflect peatland hydrology, vegetation, and biogeochemical processes (figure A1-50).

Vegetation varies across the site depending on forest management practices and soil properties. Canopy vegetation in uplands consists of aspen (*Populus tremuloides*, *P. grandidentata*); northern hardwoods; and conifers including white (*Pinus strobus*), red (*Pinus resinosa*), and jack pines (*Pinus banksiana*), balsam fir (*Abies balsamea*), and white spruce (*Picea glauca*). Forested peatlands consist of black spruce (*Picea mariana*), eastern larch (*Larix* sp.), and white cedar (*Thuja occidentalis*).

Research focus. Monitoring of streamflow, weather, and water table elevation began during 1960 and continues to the present. Six watersheds were instrumented to study hydrology. Over the past five decades, watersheds have also been used to study nutrient biogeochemistry, mercury cycling, trace gas emissions, peatlands ecology, and effects of climate change. Effects of timber harvest, prescribed burning, forest fertilization, herbicide use, cattle grazing, and atmospheric deposition on water yield and quality are also studied using large-scale watershed manipulations. These studies provide data that has been used to develop and evaluate Best Management Practices for forest and water resources in lowland watersheds.

Figure A1-50. Marcell Experimental Forest (MAR USFS) is a peatland site in Minnesota where hydrologic studies are conducted. (Photo by E. S. Verry.)

Long-term research example. Groundwater recharge rates have been calculated using long-term measurements of groundwater table elevation (figure A1-51). When snow accumulates on the land surface, ground water recharge ceases during winter and the water table drops due to aquifer drainage. When groundwater table recession during winter is compared to periods of recharge due to rainfall or snowmelt, ground water recharge can be calculated (Nichols and Verry 2001). When recharge values are combined with measurements of streamflow, soil water moisture, and precipitation, the data can be used to define the types and magnitude of hydrological processes that control the storage and transport of water and the implications for water and forest management throughout the region.

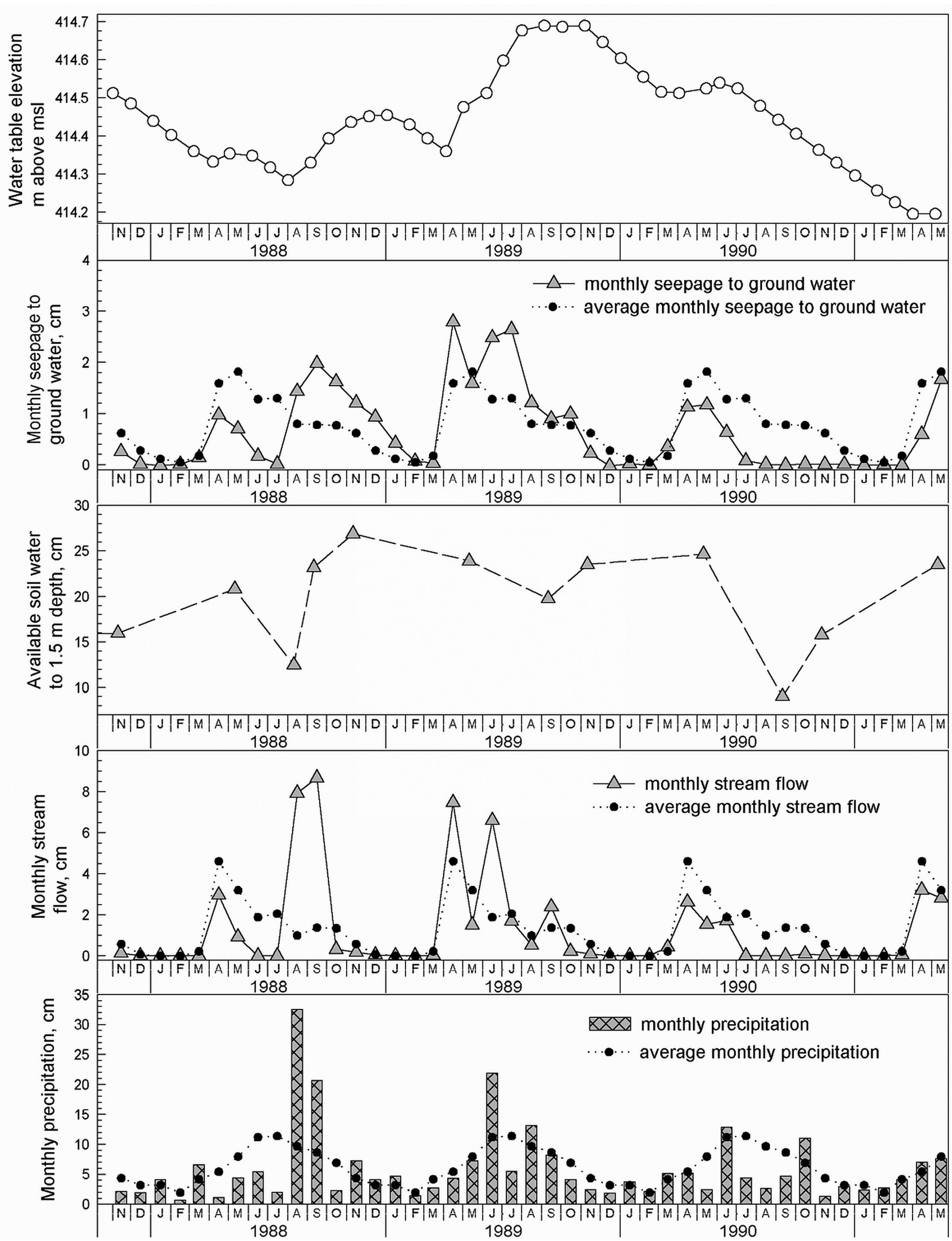


Figure A1-51. At the Marcell Experimental Forest (MAR), various components of hydrological processes are monitored, including ground water recharge (calculated from water table elevation), available soil moisture, streamflow, and precipitation (from watershed 2 during 1988-1990) (Nichols and Verry 2001). Reprinted with permission from Elsevier.

McMurdo Dry Valleys (MCM) [LTER]

http://www.mcmlter.org/

The McMurdo Dry Valleys (MCM) was established as an LTER site in 1993 to study the aquatic and terrestrial ecosystems in an ice-free region of Antarctica. The site is adjacent to McMurdo Sound, 3,500 km south of New Zealand. The area is characterized by a strong solar cycle with continuous sunlight persisting for about half the year followed by 24-hour darkness of polar night. The dry valleys are a mosaic of perennially ice-covered closed-basin lakes, ephemeral streams, bare soils, and glaciers (figure A1-52). A hydrological continuum exists in the dry valleys, beginning with glaciers and ending in closed-basin lakes. Glaciers cover about one-third of the dry valleys. These large reservoirs of water are released through melting and are the only significant source of water to the ephemeral streams and ice-covered lakes. Soils account for the majority of the valley surface area and are generally poorly developed, coarse textured, and high in soluble salts. Soils also support low rates of biological activity by dominant microorganisms.

The most complex life forms are small invertebrates. The majority of soils support up to three invertebrate taxa (tardigrades, rotifers, nematodes), but there are regions, in contrast to lower latitude ecosystems, that completely lack soil invertebrates. Aeolian transport is thought to play an important role in the dispersion of soil organisms in the dry valleys.

Research focus. The overall objectives of MCM are to understand the influence of climate legacies on the structure and function of the dry valley ecosystem and to determine the role that contemporary material transport has in structuring this ecosystem.

Long-term research example. Regional climate cooling over the 1990s resulted in alterations of soil invertebrate communities, including changes in diversity and abundance. The abundance of the dominant nematode species, *Scottnema lindsayae,* declined by 114 individuals per kilogram of soil per year at Lake Hoare and by 508 individuals per kilogram of soil per year at Lake Fryxell (Barrett et al. 2008) (figure A1-53). Given the low diversity and long generation times, these declines in population represent important shifts in the diversity, life cycles, trophic relationships, and functioning of dry valley soils.

Figure A1-52. McMurdo Dry Valleys (MCM LTER) is located in the ice-free region of Antarctica and consists of a mosaic of closed-basin lakes, ephemeral streams, bare soils, and glaciers. (Photo by Kathy Welch.)

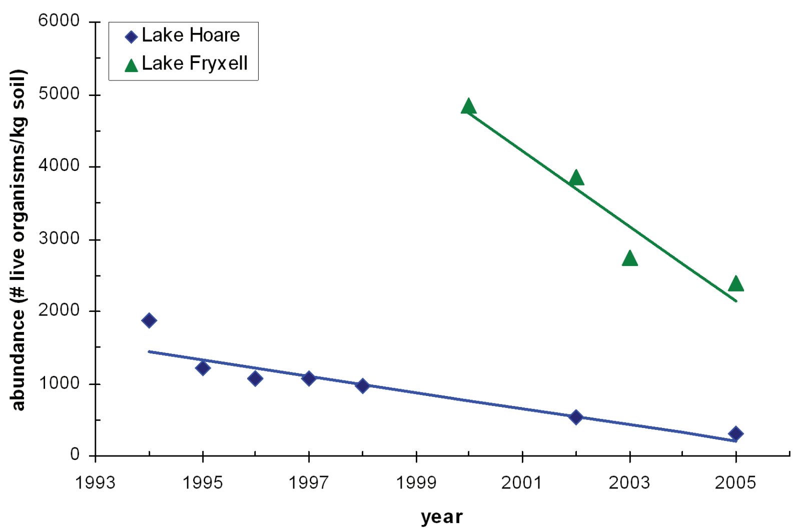


Figure A1-53. Decline in populations of the dominant animal, the nematode *Scottnema lindsayae*, at two lakes in Taylor Valley at the McMurdo Dry Valleys (MCM): Lake Hoare and Lake Fryxell. (Redrawn from Barrett et al. 2008.)

Moorea Coral Reef (MCR) [LTER]

http://mcr.lternet.edu/

The Moorea Coral Reef (MCR) LTER program was established in 2004 to provide a greater understanding of the physical and biological processes that modulate coral reef ecosystem function, shape community structure and diversity, and determine the abundance and dynamics of constituent populations. The site is a complex of coral reefs and lagoons that surround the island of Moorea in French Polynesia in the South Pacific (figure A1-54).

Moorea is a small (perimeter about 60 km) volcanic island 20 km west of Tahiti. Major coral reef types (fringing reef, lagoon patch reefs, back reef, barrier reef, and fore reef) are easily accessible to researchers. Reefs are dominated by massive *(Porites),* branching *(Pocillopora, Acropora),* and encrusting *(Montipora)* coral that are periodically disturbed by cyclones (1982, 1991, 2010), outbreaks of crown-of-thorns sea stars that consume coral (1991, 2008) (figure 9-17), and coral bleaching events (1991, 1994, 2002, 2003). Like coral reefs worldwide, reefs in Moorea are highly vulnerable to ocean warming and ocean acidification.

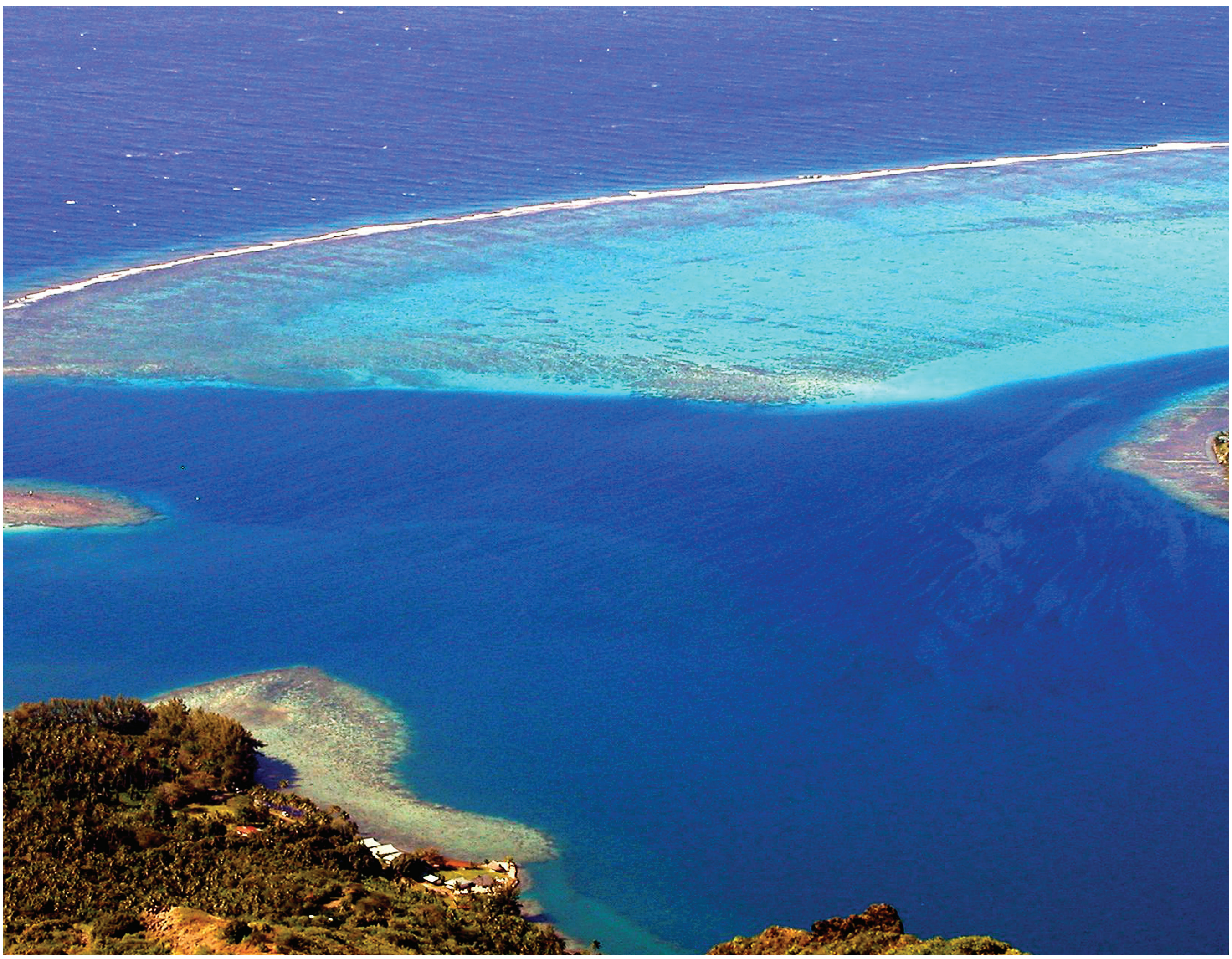


Figure A1-54. The Moorea Coral Reef (MCR LTER) site is a complex of coral reefs and lagoons surrounding the island of Moorea in French Polynesia. (Photo from MCR photo gallery.)

Research focus. The MCR research program focuses on improving understanding of the long-term consequences of disturbance and changing climate regimes on coral reef ecosystems. Principal scientific goals include—

- elucidating the mechanistic basis of oceanographic effects on coral reefs,
- evaluating mechanisms and effects of climate forcing,
- examining how species interactions affect growth, survivorship, and dynamics of corals and other associated organisms,
- exploring food web relationships and nutrient dynamics, and
- understanding the ecological controls and functional significance of biodiversity.

Long-term research example. Long-term data at MCR have challenged longstanding ideas that population dynamics of coral reef fishes can be driven by a highly variable supply of larval colonists that typically is not sufficient to saturate resources. Time series data by MCR researchers reveal a strong influence of habitat limitation on the population size of adult three-spot dascyllus *(Dascyllus trimaculatus).* The density of adult-stage dascyllus tripled over a 14-year period, which represents about two or three complete population turnovers of this fish species (figure A1-55 top) despite order-of-magnitude fluctuations in larval settlement from year to year that had no systematic trend (not shown). Increases in adult fish densities mirrored increases in abundance of the giant sea anemone *Heteractis magnifica* (figure A1-55 bottom), which functions as the settlement habitat for larval colonists and subsequently as nursery habitat for juvenile three-spot dascyllus. Fluctuations in settlement are strongly filtered by density-dependent mortality in the juvenile phase of sea anemones (Schmitt and Holbrook 2000, 2007), which results from competition with predators for space (Holbrook and Schmitt 2002, Schmitt et al. 2009).

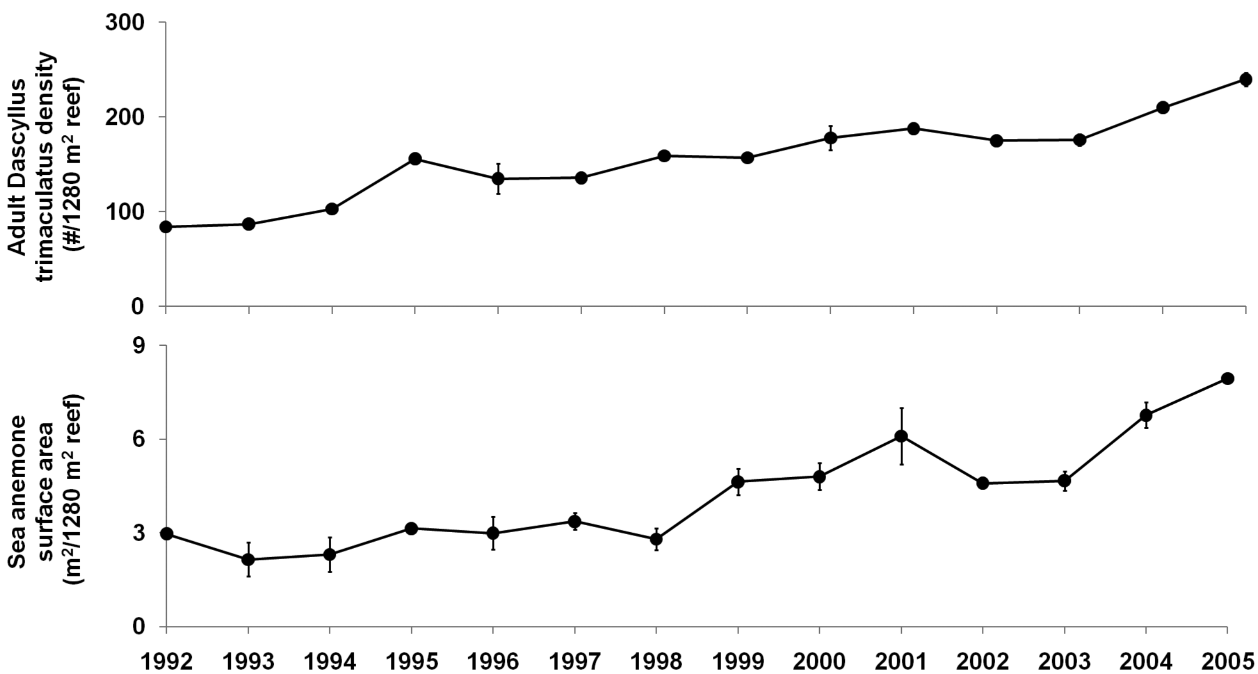


Figure A1-55. Adult abundances of a coral reef fish *(Dascyllus trimaculatus)* at Moorea Coral Reef (MCR) smoothly tripled over 2-3 population turnovers (top), closely tracking the pattern in abundance of the sea anemone *Heteractis magnifica* (bottom), which is the settlement and juvenile habitat for *D. trimaculatus* (R. Schmitt and S. Holbrook, unpublished data).

Niwot Ridge Research Area (NWT) [USFS, LTER]

http://culter.colorado.edu/NWT/

The Niwot Ridge (NWT) LTER program was established in 1980 to study ecological and hydrological processes in high-elevation areas in the Colorado Front Range of the Rocky Mountains. Research began at the site in the 1940s with the return of World War II veterans having extensive experience in cold-region logistics. Snowfall accounts for more than 80 percent of precipitation.

Subalpine forest can be found on the lower, gentler eastern slopes, whereas the higher, more rugged western portions of the ridge are nearly unvegetated (figure A1-56). Subalpine meadows and patches of krummholz sometimes are found in the abrupt transition between forest and tundra. The major research area is the Saddle, with its western half being a snow accumulation area (up to 10 m in some years) and its eastern half remaining free of snow for most of the winter. The interactions among wind, snow, and high topographic relief result in a mosaic of moisture availability to tundra plants with resulting effects on vegetation. The Saddle is characterized by different vegetation communities, including fellfield, dry meadow, moist meadow, shrub tundra, wet meadow, and snowbed.

Research focus. The goal of NWT research is to understand the causes of and ecosystem responses to climate change in high-elevation, seasonally snow-covered catchments. Changes in abundance and species composition of the native flora and fauna of these mountain ecosystems are potential bellwethers of global change. A suite of short- and long-term experiments are being conducted to better understand how alpine tundra and lakes respond to changes in climate and nutrient loading.

Figure A1-56. Niwot Ridge Research Area (NWT USFS/LTER) is located in the Rocky Mountains and ranges from subalpine forest to tundra. (Photo by Steven Schmidt.)

Long-term research example. The mountain glaciers of the world have been recognized as potentially sensitive indicators of environmental change. Because glaciers contain so little ice mass by comparison to the volume they accumulate from snowfall and lose to snow and ice-melt, glaciers of the Rockies may be particularly sensitive to environmental change. Estimates of the mass balance (accumulation minus melt of snow and ice over the year) on Arikaree Glacier have been made since 1981. Earlier studies from 1965 to 1974 extend these observations and make them the most comprehensive and continuous record for any of the small glaciers in the Front Range of the Rockies.

Since 1968, the annual net balance (NB) has been negative in 25 years and positive in 12 years, with 6 of those 12 years coming from the first decade (1968-1977) when the glacier experienced an accumulated gain of about 10 cm water equivalent (figure A1-57). From 1977 to 2000, most years show a negative NB with a total loss of about 13 cm water equivalent despite an increase in October -March precipitation. Further, the rate of loss since 1977 has accelerated by almost 2.5 cm/y. The drought years of 2001-2002 had winter precipitation only 65-70 percent of average, the lowest in 30 years of record. Such low volumes of snow accumulation, with relatively warm summers, resulted in a loss of 550 cm water equivalent. Since 2002, NB shows some recovery, but only back to the accelerating decline of the late 20th Century.

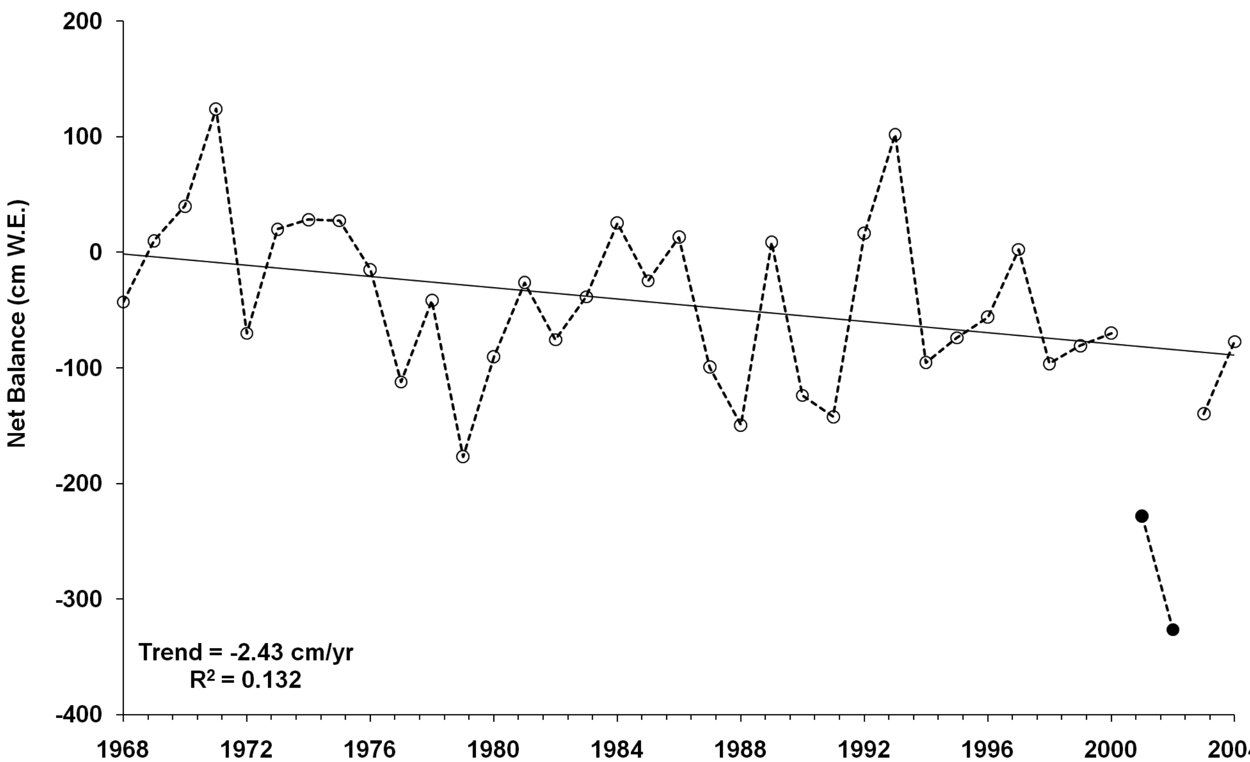


Figure A1-57. Arikaree Glacier at Niwot Ridge Research Area (NWT) has been losing mass (NB equals accumulation of mass minus melt of snow and ice) since 1965. The drought years of 2001-2002 are clearly evident in the loss of NB (T.N. Caine, in preparation).

North Temperate Lakes (NTL) [LTER]

http://lter.limnology.wisc.edu/

The North Temperate Lakes (NTL) LTER program was established in 1981 to understand the ecology of lakes in relation to relevant atmospheric, geochemical, landscape, and human processes. The NTL site comprises two geographically distinct regions: the Northern Highlands Lake District (NHLD) and the Yahara Lake District (YLD). These districts lie in formerly glaciated terrain of Wisconsin (figure A1-58). Lakes are the focal landforms of both regions, providing unique habitats, ecosystem services, and foci of human activity. The NHLD, one of the most lake-rich regions of the world, is largely forested and sparsely settled. Outdoor recreation centered on the 7,600 lakes of the region is a mainstay of the economy. The YLD is an agricultural, but urbanizing, landscape with scattered remnants of presettlement ecosystems. The diverse economy involves service industries, emerging technologies, some light industry, State government, and the State's flagship university. Ecological research began in the YLD in the 1880s and in the NHLD in the 1920s.

Research focus. The NTL's overarching research question is "How do biophysical setting, climate, and changing land use and cover interact to shape lake characteristics and dynamics over time (past, present, and future)?" Long-term research provides an opportunity to study natural and human disturbances through analysis of regional variability, historic data, and both episodic and chronic events. Whole-lake experiments are being used to understand how lakes respond to particular environmental changes (figure 4-3).

Long-term research example. Long-term observations of the phosphorus cycle and water clarity have revealed changes in water quality of Lake Mendota (Carpenter et al. 2007). Trends in dissolved reactive (mostly inorganic) phosphorus (DRP) in the surface waters reflect low sewage effluent inputs of phosphorus from upstream communities in the lake's watershed prior to 1945 (figure A1-59, top). Lake DRP concentrations increased dramatically due to an increase in effluent phosphorus inputs immediately after World War II. Following sewage effluent diversion from the lake in 1971, DRP concentrations remained high because of the increasing importance of agricultural and urban nonpoint source pollution. Variability in DRP concentrations since 1971 reflects periods of low and high inputs of phosphorus in runoff.

Figure A1-58. North Temperate Lakes Long Term Ecological Research (NTL LTER) consists of lakes in two lake districts in Wisconsin that differ in habitats, ecosystem services, and foci of human activity. (Photo from NTL photo gallery.)

Even though phosphorus concentrations stabilized at a higher level after 1950, water clarity (as measured by Secchi disk transparency) became highly variable (figure A1-59, bottom) as a result of changing levels of nutrients and herbivory (Lathrop et al. 1996). Intervals of high water clarity (deep Secchi depth) demonstrate the role of *Daphnia* (water fleas) in grazing the early spring phytoplankton in Lake Mendota. Throughout the early 1900s and from the late 1970s through the mid-1980s when planktivorous fish were abundant, predation on the larger-bodied *D. pulicaria* prevented their development early in spring. As a result, phytoplankton densities remained high with water clarity being relatively poor until around late May, when the smaller-bodied *D. galeata mendotae* with its higher temperature requirements for growth would clear the phytoplankton. In years when planktivorous fish were less abundant (1960s through the mid-1970s and since the late 1980s), *D. pulicaria* populations increased rapidly after iceout as reflected in the wide range of Secchi readings during the spring turnover period. Thus, the "clear water phase"—a common occurrence in eutrophic lakes—was initiated in Lake Mendota.

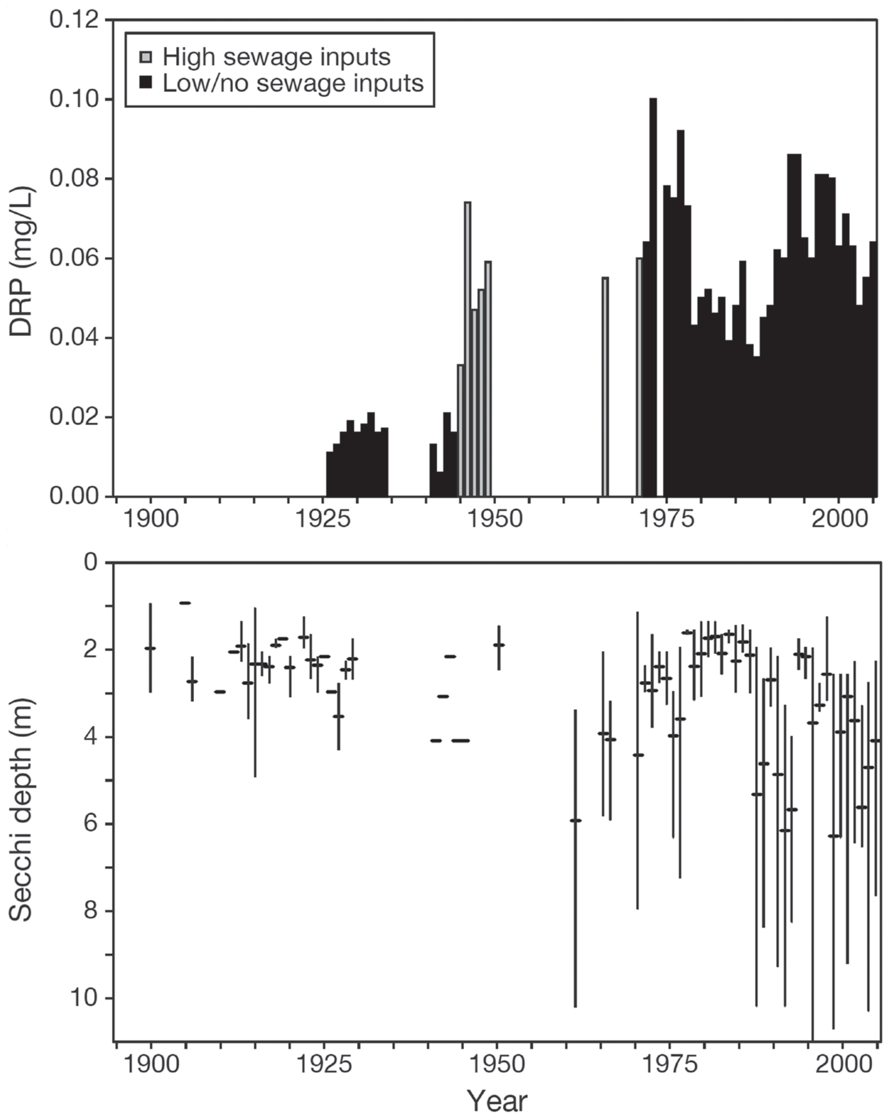


Figure A1-59. Long-term observations of the phosphorous cycle and water clarity in Lake Mendota (NTL) show both human influences and biotic interactions (Carpenter et al. 2007). Annual DRP averages were computed from the previous October through September if six or more months in a given year had concentration data. Spring turnover is defined as the period from ice out to May 10 prior to thermal stratification. For a given year, the short horizontal bar is the average of all spring turnover Secchi disk readings, and the thin vertical line is the range if more than one reading was taken. All readings were converted to 20-cm black-white disk readings. Data sources and conversion factors are described in Lathrop (1992). Reprinted with permission from the American Institute of Biological Sciences.

Palmer Station, Antarctica (PAL) [LTER]

http://pal.lternet.edu/

The Palmer, Antarctica (PAL), site joined the LTER in 1990 as the first marine pelagic site in the network. PAL is situated on the south coast of Anvers Island on the western Antarctic Peninsula. The site encompasses a larger region with several circumpolar pelagic habitats, including the continental shelf within the marginal ice zone covered seasonally by sea ice and the open ocean beyond the continental shelf break, as well as a nearshore zone influenced by glacial meltwater (Ducklow et al. 2007) (figure A1-60). Within the nearshore zone are small islands that have become deglaciated in the last few centuries.

Figure A1-60. The Palmer Station (PAL LTER) is a marine pelagic site off the western Antarctic Peninsula. Several species of penguins are studied in the nearshore zone. (Photo by Hugh Ducklow.)

Seabirds, including penguins, giant petrels, brown and south polar skuas, and other species, inhabit these islands along with mosses and two species of vascular plants. The nearshore waters abound in large marine mammals including seals (leopard, fur, crabeater, elephant, and Weddell), orcas, humpback whales, and minke whales. Palmer Station is occupied by humans year-round, but most scientific activity is concentrated in the Austral spring and summer.

Research focus. The primary goals of PAL are—

- to understand the dynamics of the Antarctic marine ecosystem as it is forced by interannual variations in sea ice,
- to document and predict ecosystem responses to rapid climate change, and
- to promote understanding of, and familiarity with, the Antarctic environment, climate change, and polar research.

There are two PAL fieldwork components: nearshore/seasonal and regional/annual. The nearshore work includes local oceanographic sampling in the water column (to depths of 50-100 m) and bird observations on nearby island breeding sites (figure 4-2), as well as experimental studies in the laboratory focusing on rate measurements of bacteria, phytoplankton, and krill metabolic and growth processes. Regional-scale sampling on the PAL Hydrographic Grid has been conducted every January since 1993. The extensive, whole-water-column survey data are aimed at documenting and analyzing the response of the pelagic ecosystem to climate variability and teleconnections, regional warming, and uncovering the mechanisms of the responses.

Long-term research example. Several sources of evidence show that warmer temperatures are influencing multiple facets of the Antarctic pelagic system (Vaughn et al. 2003, Ducklow et al. 2007). Long-term (1944-2005) temperatures at 65°12'S, 64°16'W show a mean winter (June through August) warming rate of 0.98 °C per decade (http://www.antarctica.ac.uk/met/data.html). At Palmer Station (64°46'S, 64°16'W), the mean winter warming rate is over 1 °C per decade, about five times the global average (figure A1-61).

Winter sea-ice duration (total annual days of sea-ice coverage) in the vicinity of Palmer Station is decreasing because autumn sea-ice advance is occurring later, while spring-summer sea-ice retreat is occurring earlier, shortening the winter sea-ice season by about 31 days per decade (Stammerjohn et al. 2008a). Smoothed standardized deviations (monthly anomalies divided by total standard deviations) of monthly sea-ice extent in the Palmer LTER study region is related to the Southern Oscillation Index (SOI) from 1979 to 2009 (Stammerjohn et al. 2008b). Negative SOI values indicate El Niño episodes in which positive sea-ice anomalies tend to occur (figure 3-1).

The prolonged period of La Niña (positive SOI) conditions (persistent and strong northwesterly winds) from 1998 to 2001 triggered the increased heat content delivered to the shelf water. The warming and changes in atmospheric circulation have resulted in increased transport of heat onto the continental shelf adjacent to the peninsula, as indicated by heat content of ocean water on the shelf, which has been shown to be linearly related to the ocean heat flux and shows a steady increase since 1993. This heat increase is sufficient to drive uniform warming of an approximately 300 m thick layer by 0.7°C.

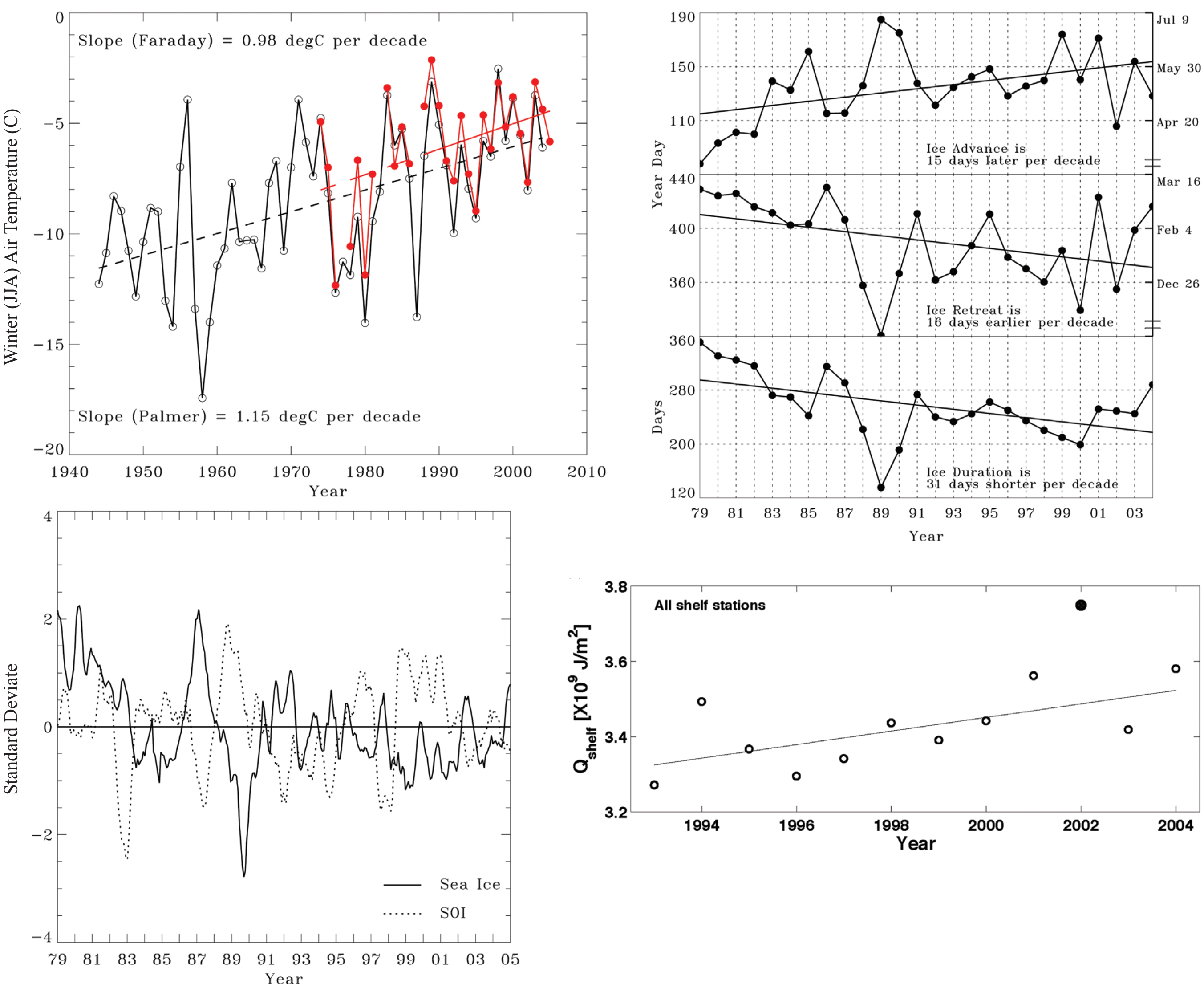


Figure A1-61. Top left: winter air temperature at two stations—black, Faraday/Vernadsky Stations (65°2'S, 64°6'W); red, Palmer Station (64°46'S, 64°16'W). Top right: autumn sea-ice advance, spring-summer sea-ice retreat, and winter sea-ice duration in the vicinity of Palmer and Faraday/Vernadsky Stations. Bottom left: smoothed standardized deviations (monthly anomalies divided by total standard deviations) of monthly sea ice extent in the Palmer Station Long Term Ecological Research (PAL LTER) study region and the Southern Oscillation Index (SOI). Bottom right: heat content of ocean water on shelf. (Figure derived from Stammerjohn et al. 2008a, 2008b.)

Plum Island Ecosystems (PIE) [LTER]

http://ecosystems.mbl.edu/PIE/

The Plum Island Ecosystems (PIE) LTER was established in 1998 with the goal of developing a predictive understanding of the long-term responses of watershed and estuarine ecosystems to changes in climate, land use, and sea level and to apply this knowledge to the management and development of policy that aims to protect the natural resources of the coastal zone. The coupled watersheds and estuary of Plum Island Sound are located near the Boston metropolitan region of northeastern Massachusetts. The Ipswich River (400 km^2) and Parker River (200 km^2) basins lie entirely within the Seaboard Lowland section of the New England physiographic province. The low relief of the basin is responsible for a large expanse of wetlands.

The estuary contains salt marsh dominated by smooth cordgrass *(Spartina alterniflora)* and marsh hay *(Spartina patens),* fresh marsh dominated by cattail *(Typha),* intertidal flats, and open-water tidal creeks and bays (figure A1-62). Species diversity is low, with half the number of fish species in areas south of Cape Cod. Plum Island Sound estuary supports productive commercial and recreational soft-shell clam and striped bass fisheries. Watershed land use composition in 2001 was approximately 46 percent forest, 34 percent urban/suburban, 10 percent agriculture, and 10 percent wetland and water.

Research focus. Research at PIE focuses on how inputs of organic matter and nutrients from land, ocean, and marshes interact with external drivers (climate, land use, river discharge, sea level) to determine the spatial patterns of estuarine productivity and trophic structure.

Figure A1-62. Plum Island Ecosystems (PIE LTER) consists of watershed and estuarine systems located near Boston in northeastern Massachusetts. (Photo from PIE photo gallery.)

Long-term research example. Nutrient-rich runoff from the terrestrial environment is one of the major factors leading to estuaries being among the most productive ecosystems on Earth. Nutrient inputs described on an areal basis, such as those used to describe fertilizer application rates on farms (measured, for example, as kg/ha of estuary), are often as high as the most intensively fertilized agricultural crops. However, excessive nutrient inputs can lead to estuarine eutrophication, a process that can lead to algal blooms, anoxia, and fish kills. Eutrophication is perhaps the most prevalent problem facing estuaries worldwide.

At PIE, nutrient inputs (loads of nitrogen and phosphorous) from the Ipswich River are substantially higher than from the Parker, primarily because the watershed is much larger (figure A1-63). Similar yields are likely due to efficient nutrient retention in the Ipswich River watershed (figure A1-63). This long-term dataset shows that nutrient load and yield from year to year have substantial variability that is not due to differences in nutrient inputs to the watershed, but rather is entirely attributed to variation in precipitation and water runoff. Nutrients accumulate during low-discharge years and then are flushed into the estuary during higher discharge years. This 4- to 5-fold difference in nutrient export between wet and dry years has a major influence on estuarine productivity.

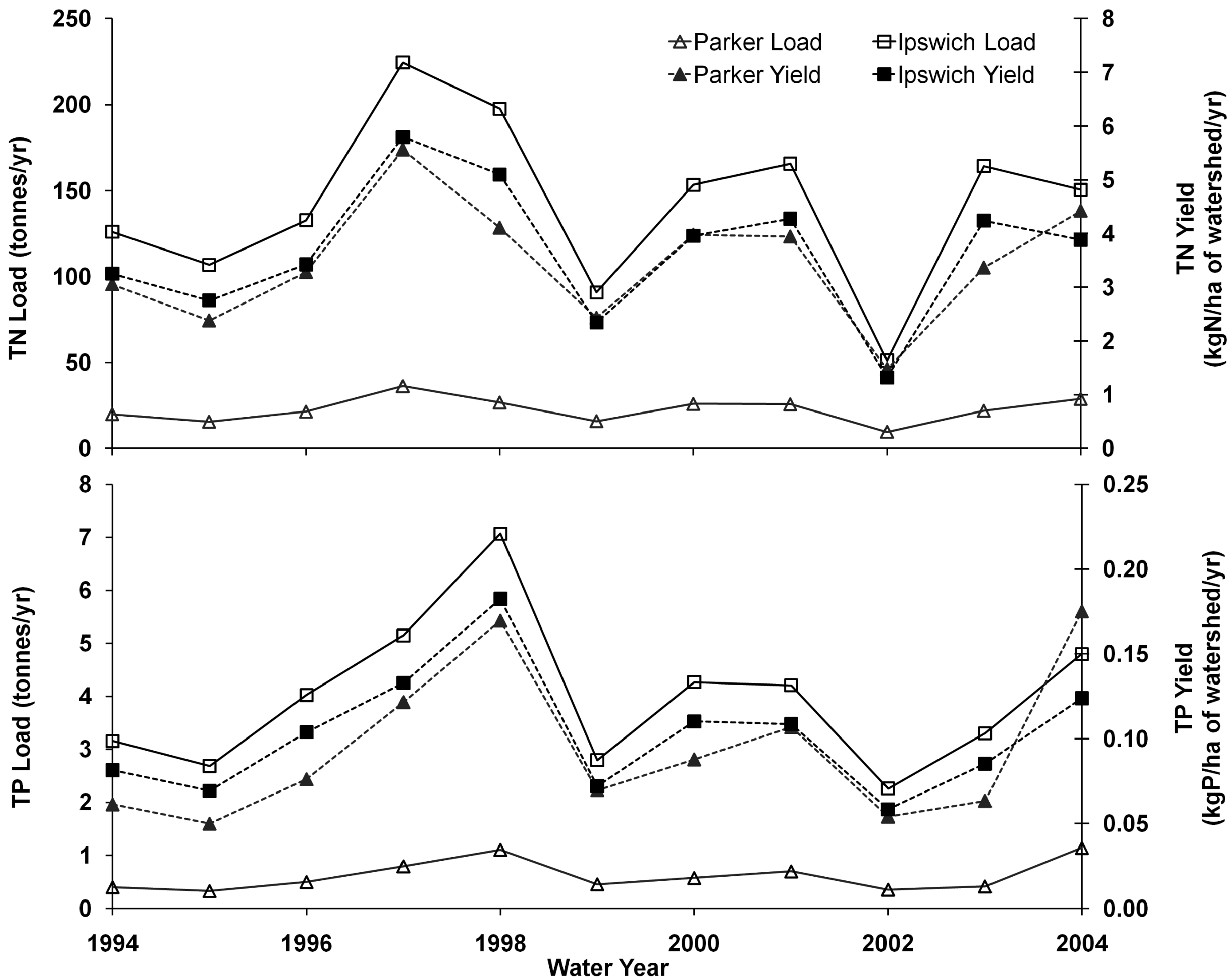


Figure A1-63. Substantial annual variability in nutrient load and yield in two rivers attributed to variations in precipitation and water runoff. Nutrient inputs from the Ipswich River are substantially higher than those from the Parker, primarily because the watershed is so much larger. Similar yields are likely due to efficient nutrient retention in the Ipswich River watershed. (See Williams et al. [2004] for methods.) Data are available at http://ecosystems.mbl.edu/PIE.

Priest River Experimental Forest (PRI) [USFS]

http://forest.moscowfsl.wsu.edu/ef/pref/

Established in 1911, the Priest River Experimental Forest (PRI) in northern Idaho contains approximately 2,758 ha (6,368 acres) of mountainous conifer forest, with small areas of talus and alpine grassland. Approximately 90 percent of the area is mountainous. Climate is transitional between a northern Pacific coastal type and a continental type. About two-thirds of PRI is covered in mixed conifer forest more than 100 years old, resulting from a fire in about 1860 (figure A1-64). The other third is nonstocked areas or is in young timber on harvest units and burn areas. Habitat is best described as complex because of the extremely rapid changes in aspect and in wetness/dryness of sites. Plant species diversity is high because of the number of different, intimately intermixed habitat types.

Research focus. Research focuses on the factors influencing forest fire, hydrology, silviculture, forest ecology, insects, and diseases of Rocky Mountain conifers. Projects have evaluated adaptability of native conifers to climate change, compared strategies for restoration of western white pine *(Pinus monticola),* compared mechanical site preparation as an alternative to prescribed fire, and evaluated the effects of wildfire and management activities on soil productivity and sediment transport. There have also been extensive studies of allometric functions, vertical trends in leaf mass per area, leaf turnover, and leaf area index. Recent work includes analyses of sap flow, nocturnal transpiration, isotopic mass balance of soil water, and hyperspectral remote sensing.

Figure A1-64. Priest River Experimental Forest (PRI USFS) is located in mountainous coniferous forest in northern Idaho. The office/laboratory building is in the center with the weather station at right. (Photo by Bob Denner.)

Reynolds Creek Experimental Watershed (RCE) [USDA-ARS]

http://ars.usda.gov/

The Reynolds Creek Experimental Watershed (RCE) was established nearly 50 years ago to address critical water issues on western rangelands. The RCE watershed (239 km^2) is located on rangeland in the north flank of the Owyhee Mountains about 80 km southwest of Boise, ID (figure A1-65). Primary land use is livestock grazing with some irrigated fields along the creek at the lower elevations and timber harvesting at higher elevations. Semi-arid sagebrush communities typical of the Great Basin are found at lower elevations, while aspen and Douglas-fir stands increase with elevation on deep soils.

Research focus. Research on the watershed has changed focus over the past 40 years, starting with monitoring and describing hydrologic processes and, over the decades, migrating toward development of computer-based tools to address critical water supply, water quality, and rangeland management problems. These tools are developed in an environment of intense monitoring and field experimentation. Currently, there are 104 data collection sites in the RCE measuring environmental parameters such as streamflow, snow depth, precipitation, soil water, and temperature. Specific research projects include the following:

- Studies of pre- and post-fire hydrology to evaluate the hydrologic impacts of juniper invasion and juniper removal and to evaluate prescribed-fire impacts on other vegetation, soil, and animal resources. Results show that erosion is reduced after juniper removal and recovery of grasses.
- Research on snow accumulation and snowmelt dynamics in mountainous terrain, working with USDA Natural Resources Conservation Service on use of snowmelt modeling tools to improve streamflow forecasting.
- Evaluation of telemetry tracking collars to determine how prescribed fire treatments for juniper and brush control affect cattle distribution and activity patterns.

Figure A1-65. Reynolds Creek Experimental Watershed (RCE USFS) is located in southwestern Idaho and includes Great Basin rangeland at low elevations with aspen and Douglas fir communities at higher elevations. Streamflow is measured using a drop-box weir. (Photo from RCE photo gallery.)

Santa Barbara Coastal (SBC) [LTER]

http://sbc.lternet.edu/

The Santa Barbara Coastal (SBC) LTER was established as an LTER site in 2000 to understand the linkages among ecosystems at the land-ocean margin. The principal study site is the semi-arid Santa Barbara coastal region, which includes steep watersheds, small estuaries, sandy beaches, and the neritic and pelagic waters of the Santa Barbara Channel and the habitats encompassed within it (figure A1-66).

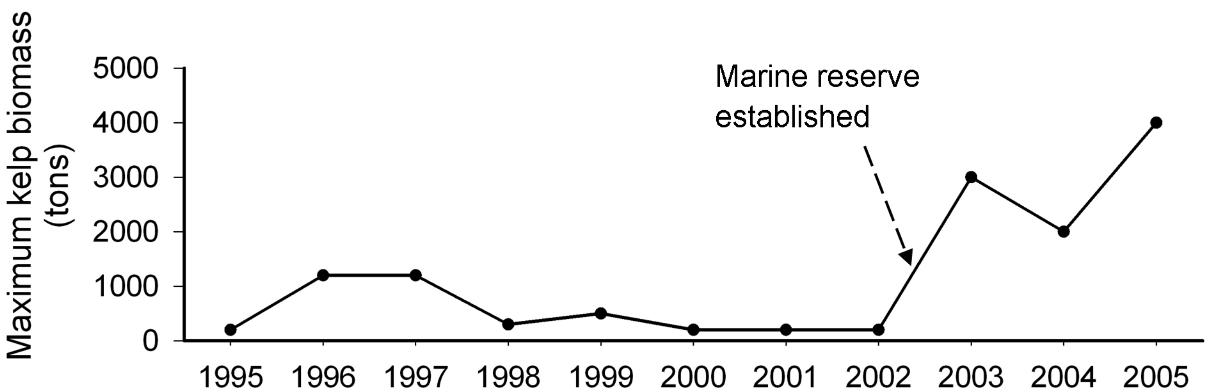
One of the more notable habitats is shallow rocky reefs dominated by giant kelp *(Macrocystis pyrifera)* forests. The rapid growth and high turnover of giant kelp result in very high rates of primary production and make these underwater forests one of the most productive systems on Earth. The characteristic three-dimensional structure of giant kelp, coupled with its extremely high productivity, enables kelp forests to provide food and habitat for a diversity of algae, invertebrates, fishes, birds, and marine mammals, many of which are ecologically and economically important.

Research focus. The focus of SBC research is developing a predictive understanding of the structural and functional responses of giant kelp forest ecosystems to environmental forcing from land and sea. The amount of nutrients and organic matter delivered to these forests varies in response to short- and long-term changes in drivers such as climate, ocean conditions, and land use. Variation in the supply of these commodities interacts with physical disturbance to influence the abundance and species composition of the forest inhabitants and the ecological services that they provide. Although there is increasing concern about the effects of human activities on coastal watersheds and near-shore marine environments, there have been few long-term studies of the linkages among the coastal ocean, shallow near-shore reef, and terrestrial habitats. SBC studies these effects of oceanic and coastal watersheds on kelp forests in the Santa Barbara Channel (figures 4-5, 4-6, 9-15).

Figure A1-66. Santa Barbara Coastal (SBC LTER) in a SPOT image of the Santa Barbara coast showing kelp forests in shallow water. © CNES 2006, distributed by Terra Image USA.

Long-term research example. The giant kelp is the world's largest alga; it forms dense forests in many regions of the world. Giant kelp plays a very important ecological role in providing food and shelter to a diverse assemblage of animals, many of which are fished. Giant kelp itself is harvested for use in a wide variety of food and industrial products. A marine reserve system was established in 2002 in the waters surrounding the California Channel Islands at the SBC site to protect kelp forests and other valued marine habitats and species from commercial and recreational harvesting.

The biomass of kelp showed a 20-fold increase in the reserve off Santa Rosa Island shortly after it was established (figure A1-67, top), suggesting that restrictions on harvesting kelp and the predators of animals that eat kelp have an immediate effect on kelp populations. However, a longer term view of the kelp population reveals that the increase in biomass following the establishment of the reserve was quite small, compared with what has occurred at this site over the last 50 years (figure A1-67, bottom). This example illustrates the need for long-term data when evaluating the effectiveness of conservation efforts designed to enhance species such as giant kelp whose abundance fluctuates greatly from year to year.



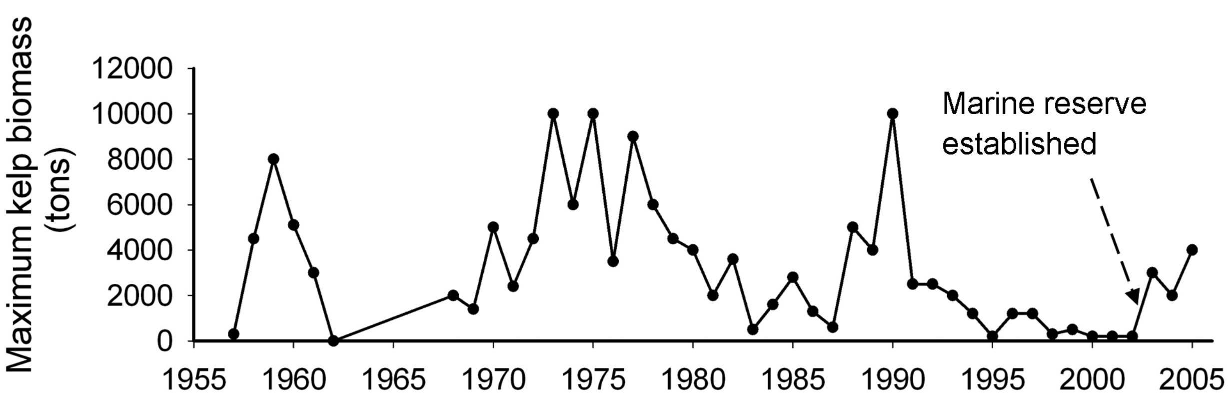


Figure A1-67. Kelp biomass increased following the establishment of a marine reserve (top), but this increase is within the natural variability in kelp biomass over the past 50 years at the Santa Barbara Coastal (SBC) (bottom). (Data available at http://sbc.lternet.edu/data/index.html.)

Santa Rita Experimental Range (SRE) [University of Arizona]

http://cals.arizona.edu/SRER/

The Santa Rita Experimental Range (SRE) was established in 1902 as the first in a series of U.S. Department of Agriculture facilities dedicated to understanding the ecology of arid environments and to developing methods for sustainable livestock grazing. Located on the western flank of the Santa Rita Mountains (45 km south of Tucson, AZ), the 21,500-ha SRE includes variation in elevation (900-1,450 m), precipitation (28-45 cm/y, about half occurring from July to September), and mean annual temperature (16-19 ºC). Thirty-two soil series are delineated as 24 mapping units. Plant communities include Sonoran desertscrub, semidesert grassland, and oak woodland with major transitions through time (figure A1-68). The flora includes 468 species, with greatest representation from the Poaceae (81 species), Asteraceae (72 species), and Fabaceae (61 species).

Research Focus. The SRE facilitates research activities in the tradition of a natural history field station. Early accomplishments included the first systematic estimates in the United States of livestock carrying capacity based on ANPP and the first use of repeat photography to record changes in vegetation. The program grew to include investigations in small mammal biology, soil moisture dynamics, and the effects of fire, as well as research in grazing management and restoration of arid landscapes degraded by drought and overgrazing. Current research includes ecosystem biogeochemistry related to carbon sequestration, co-evolution of plants and pollinators, and adaptive management of livestock grazing in a variable environment.

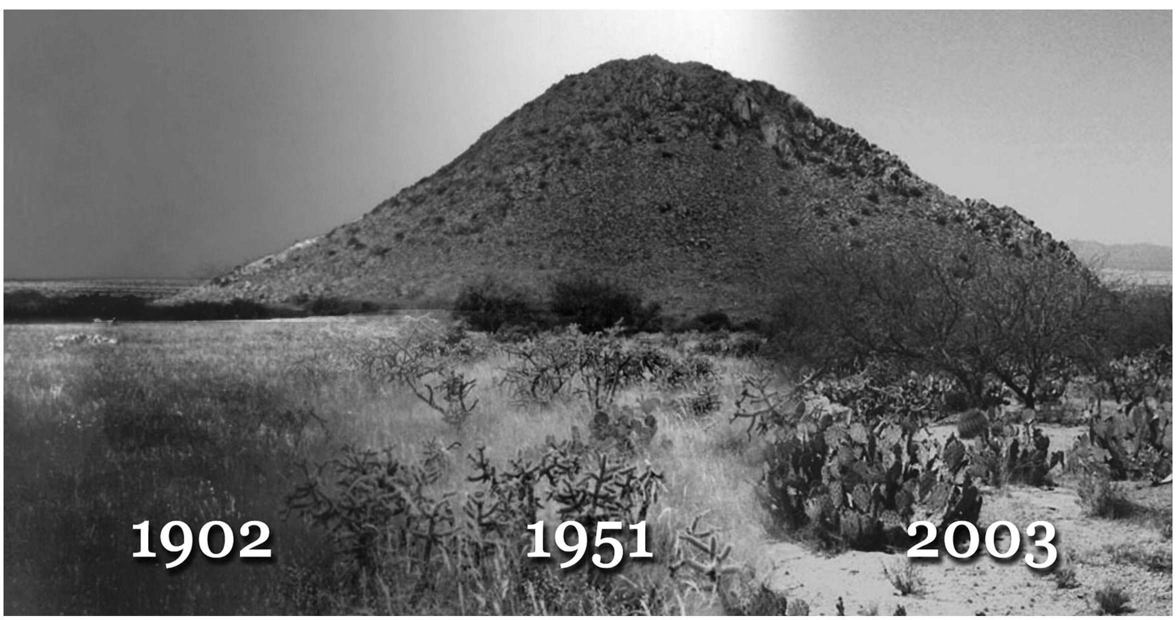


Figure A1-68. Santa Rita Experimental Range (SRE UA) near Tucson, AZ, is representative of Sonoran desert scrub vegetation. Repeat photography (available from http://ag.arizona.edu/SRER/photos.html) is used to record changes in vegetation. (Photo montage by Robert Wu.)

Santee Experimental Forest (SAN) [USFS]

http://www.srs.fs.usda.gov/charleston/

The Santee Experimental Forest (SAN) was established in 1937 in the forested landscape of the southeastern Atlantic Coastal Plain. Located in Berkley County, SC, the SAN encompasses some of the earliest colonized lands in the United States. Much of the uplands was cleared for agriculture, and the bottomlands were used for rice and indigo cultivation (figure A1-69). The SAN encompasses 2,469 ha, containing all the major forest types in the lower coastal plain occurring on three general land types: sandy ridges, broad flats, and floodplains. The dominant forest cover is mixed pine-hardwood and loblolly pine *(Pinus taeda)* stands with bottomland hardwoods occupying the riparian zones. Soils developed in marine sediments and fluvial deposits at elevations between 4 and 13 m above sea level. Climate is warm-temperate, and about 40 percent of rainfall occurs from June to August. Snowfall and ice storms are extremely rare. Tropical storms are a common hazard between August and October.

Despite the long land use history and repeat disturbance by hurricanes, the composition and productivity of the forest suggests dynamic and resilient ecosystems. Approximately 70 percent of the SAN is included in the Habitat Management Area for the red cockaded woodpecker, a federally listed endangered species. While much of the southeastern coastal landscape is being fragmented and developed, the SAN serves as an important reference for understanding ecosystem processes in a suburbanizing landscape.

Figure A1-69. Santee Experimental Forest (SAN USFS) in South Carolina was established in the forested landscape of the southeast Atlantic coastal plain. (Photo from SAN photo gallery.)

Research focus. Research traditionally focused on silviculture and prescribed fire effects. Studies have encompassed many aspects of silviculture, including harvesting, regeneration, thinning, and fertilization. Studies have also been conducted to assess the effects of prescribed fire on forest growth and composition and soil properties. With the establishment of four gauged watersheds in the 1960s, the fire and silviculture research could be conducted at a larger spatial scale. However, long-term silvicultural studies ended as a result of Hurricane Hugo. Ongoing research involves forest succession following hurricane disturbance, forest hydrology, carbon and nutrient cycling, and wildlife. The paired first-order watersheds are being used to assess effects of fuel management treatments in stands characteristic of post-hurricane regeneration. The SAN also serves as a platform for evaluating biogeochemical and hydrologic models.

Long-term research example. Measurements of streamflow (outflow) from a weir show similar trends to patterns in rainfall (figure A1-70). The data gap in 1982-1990 is partly attributed to Hurricane Hugo in 1989.

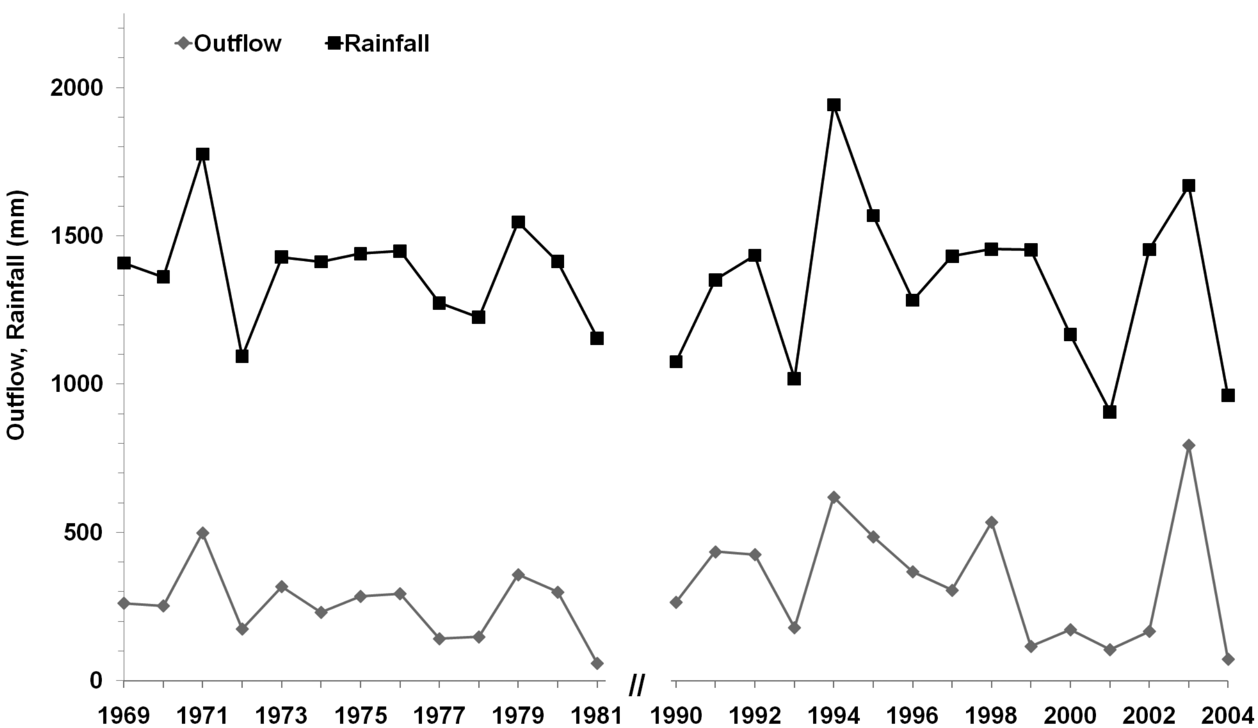


Figure A1-70. Streamflow measured as outflow from a weir follows a similar pattern as rainfall at the SAN. Data from http://www.fsl.orst.edu/hydrodb/.

Sevilleta (SEV) [LTER]

http://sev.lternet.edu/

The Sevilleta (SEV) was established as an LTER site in 1988 on the Sevilleta National Wildlife Refuge (U.S. Department of the Interior, Fish & Wildlife Service) to assess the effects of climate change, nitrogen deposition, and severe and prolonged wet and dry years on community and ecosystem processes at a biome transition zone. The site is located 80 km south of Albuquerque, NM. The climate is characterized by an abundance of sunshine, a wide range between day and night temperatures, and low relative humidity. Sixty percent of annual rainfall occurs during the summer monsoon from July through September. Extreme droughts occur on about a 50-year cycle. Cattle grazing has been excluded from the SEV since 1973.

Dominant plant species representing different biomes include *Bouteloua eropioda* (black grama) and *Larrea tridentata* (creosote bush) from the Chihuahuan Desert (figure A1-71), *Juniperus monosperma* (one-seed juniper) and *Pinus edulis* (piñon pine) from higher elevations, and *Bouteloua gracilis* (blue grama) from the shortgrass steppe in the Great Plains.

Figure A1-71. The Sevilleta Long Term Ecological Research (SEV LTER) site encompasses the transition between four major biomes, including the transition zone between Chihuahuan Desert shrubland (foreground) and grassland (background). (Photo by Robert R. Parmenter.)

Research focus. Studies at the SEV are linked by an overarching theme: how abiotic drivers and constraints affect dynamics and stability in aridland populations, communities, and ecosystems (Collins et al. 2008). Studies are conducted on soil structure and development, soil carbon and nitrogen pools and fluxes, vegetation patch structure and species interactions, and the role of consumers among habitats and especially across the grassland-to-shrubland transition zone.

Long-term research example. Species richness and cover are variable for functional groups at two transitional locations dominated by species from different biomes (figure A1-72). At both sites—Deep Well (Chihuahuan Desert-Shortgrass steppe site) and Five Points (Chihuahuan Desert shrubland-Chihuahuan Desert grassland site)—cover of grasses, richness of forbs, and total cover and richness are increasing through time. These changes may reflect the cessation of grazing in the 1970s, which favors grasses combined with increased fire frequency, which limits shrubs and increases forb species richness.

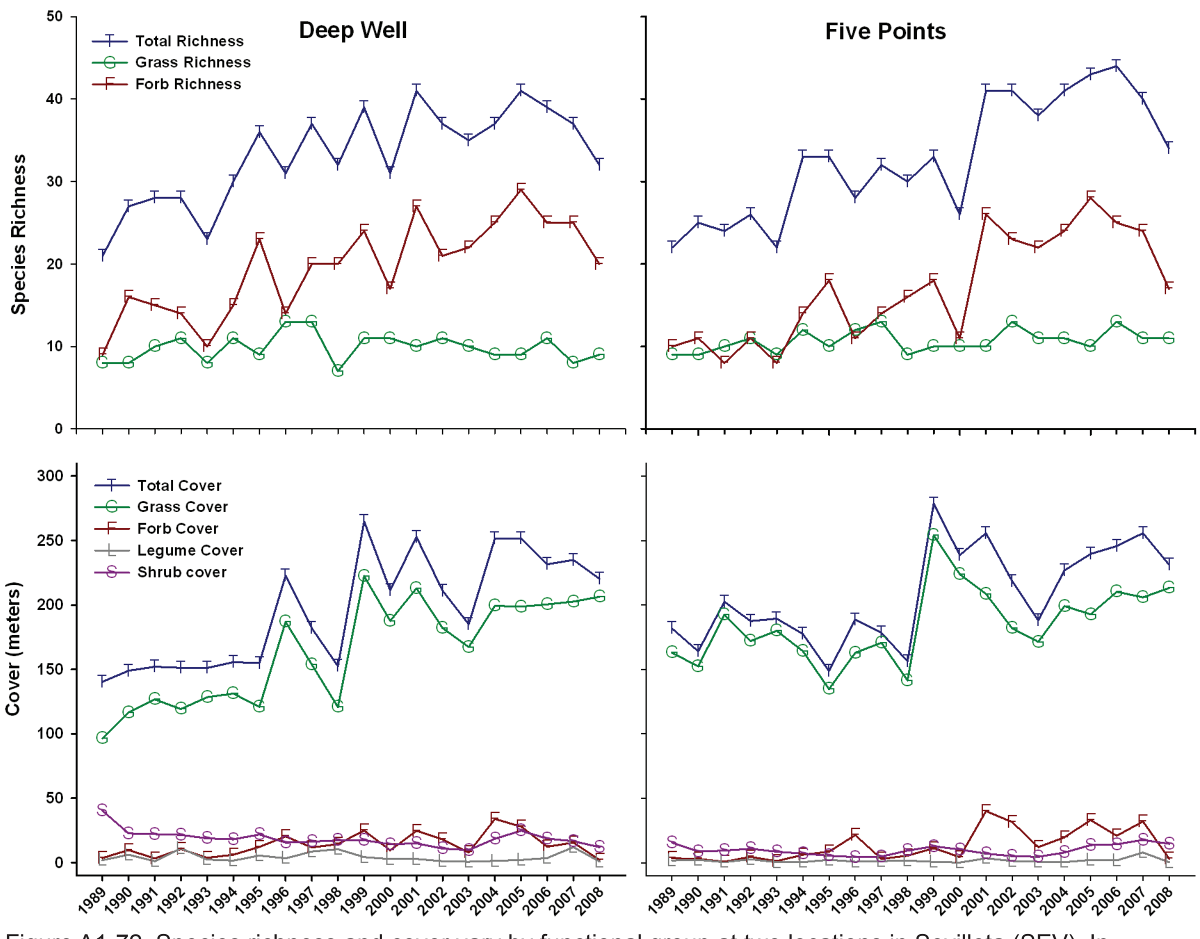


Figure A1-72. Species richness and cover vary by functional group at two locations in Sevilleta (SEV). Increases in grass cover and shrub richness result in an increase in total cover and richness at both locations (Collins and Xia, unpublished data).

Shortgrass Steppe (SGS) [USDA-ARS, LTER]

http://www.sgslter.colostate.edu/

The Shortgrass Steppe (SGS) was established as an LTER site in 1982 to study how climate, natural disturbance, physiography, and human activities influence communities of plants and animals; how they drive cycling and storage of carbon, nitrogen, and methane; and ultimately how the shortgrass steppe ecosystem responds. Studies are conducted on the USDA-ARS Central Plains Experimental Range and the Pawnee National Grasslands of the USDA Forest Service.

Topography is gently rolling with broad valleys and ephemeral streams. Soils are principally derived from alluvium and wind-reworked sediments eroded from local sedimentary rock formations and the nearby Rocky Mountains. Climate is typical of mid-continental semiarid temperate zones, but is somewhat drier because of a strong rain shadow effect of the Rocky Mountains. Approximately 70 percent of the precipitation falls during the April-September growing season. The ecosystem is dominated by short grasses (64 percent), succulents (21 percent), and dwarf shrubs (8 percent) (figure A1-73). Blue grama *(Bouteloua gracilis)* predominates and contributes 60 to 80 percent of plant cover, biomass, and net primary productivity. The disturbance regime includes a number of types of disturbances (figures 9-7 and 9-16).

Figure A1-73. Shortgrass steppe vegetation is dominated by warm season grasses at the Shortgrass Steppe (SGS) USDA-ARS/LTER site. (Photo by Amy A. Yackel Adams.)

Research focus. The mission of the SGS is to investigate the inter-relationships among climate, natural disturbance, physiography, and human use on ecosystem structure and function (figure 5-2). Located on the western edge of the central Great Plains, the shortgrass steppe is characteristic of North American grasslands with its long history of grazing by large herbivores and periodic drought. Over time, intense selection by grazing and drought has created an ecosystem that is well adapted to both, with low-standing vegetation and below-ground concentration of biological activity and organic matter. Currently, grazing by domestic livestock is the primary use of native grassland, which occupies about 60 percent of the shortgrass steppe.

Long-term research example. By 1920, much of the SGS area was settled by homesteaders who planted crops, such as corn, that are typical of wetter areas. During periods of drought, repeated crop failures led to widespread abandonment of fields; land purchases by the Federal Government resulted in the two parts of the SGS site.

A number of studies were conducted in the mid-1900s to evaluate recovery patterns on old fields. These studies showed four stages of succession dominated by different species groups (figure A1-74). The final, "climax," stage was predicted to occur 25 to more than 50 years after abandonment and represents a traditional Clementsian model. However, an alternative model was proposed in the 1970s in which the subdominant grass stage lasts indefinitely as an alternative state of the system (figure A1-74). More recent results from the SGS using 13 fields with similar soils and length of time following abandonment (53 years) found high variability in cover of shortgrasses (12-88 percent; figure A1-74) (Coffin et al. 1996). Only two fields (11 and 12) had high shortgrass cover similar to predictions from the Clementsian model, and only two (4 and 8) had low shortgrass cover similar to the alternative states model. Most fields had intermediate values that did not fit either model. High variability in recovery of shortgrasses after large disturbances led to an alternative view of the role of disturbance, one that focuses on interactions between individual plants and their environment, including disturbance characteristics, in determining recovery rates and patterns (Peters et al. 2008, 2011).

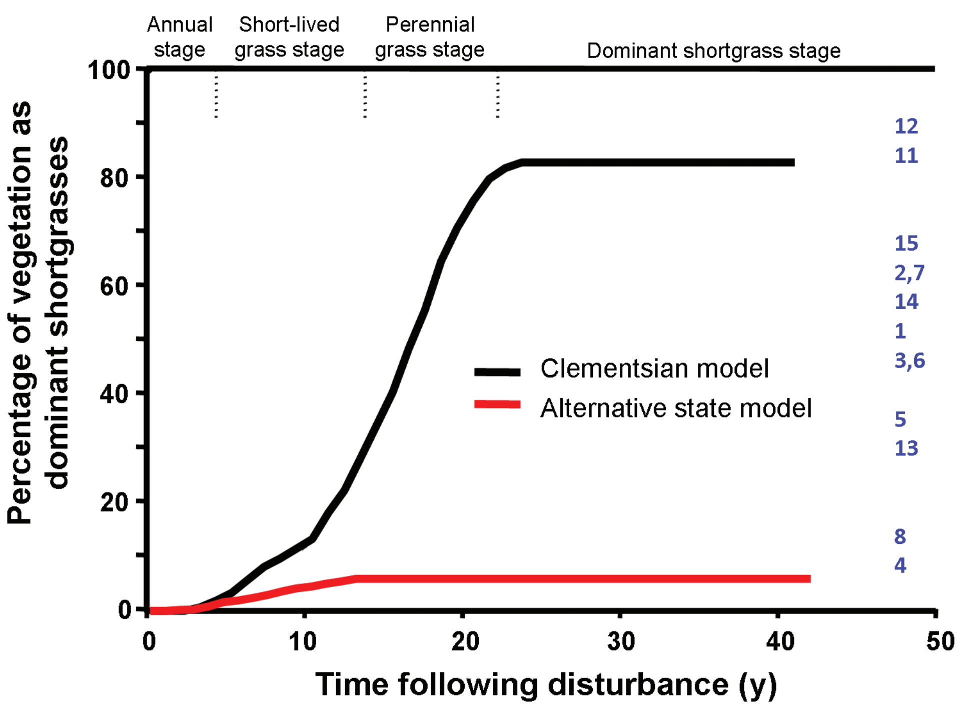


Figure A1-74. Comparison of predictions of shortgrass cover through time for two old-field models of succession (Clementsian model in black, alternative state model in red) and actual shortgrass cover found on 13 fields sampled 53 years following abandonment at the Shortgrass Steppe (SGS) site (blue numbers). (Redrawn from Coffin et al. 1996.)

Southern Plains Range Research Station (SPR) [USDA-ARS]

http://www.ars.usda.gov/

The Southern Plains Range Research Station (SPR) was established in 1913 at Woodward, OK. The predominant native vegetation is southern mixed-grass prairie dominated by sand sagebrush *(Artemisia filifolia)*. Perennial grasses (short, mid, and tall) are the major complement to sagebrush. Blue grama *(Bouteloua gracilis)* and sand dropseed *(Sporobolus cryptandrus)* provide much of the basal cover and forage production.

Precipitation is unimodal with a peak in May. Moderate to severe droughts lasting several years is a feature of the climate. Temperatures range from a high of 46 ^{o}C to a low of -28 ^{o}C with an average daily high temperature of 21 ^{o}C and an average low of 8 ^{o}C. The frost-free growing season varies from 155 days to 243 days and averages 201 days.

Deep sandy soils (loamy sands and sands) on hilly landscapes without well-defined surface drainages are common. Faster infiltration and less water loss to evaporation make sandy soils more efficient than finer textured soils in supplying water to perennial plants.

The wind erosion potential of soils is high on disturbed or cultivated areas. Most soils prone to wind erosion have largely been reseeded to native and introduced warm-season grasses.

Research focus. The mission of the SPR is to develop and transfer innovative production practices based on fundamental ecological principles and to breed, select, and release improved plant germplasm to enhance sustainable forage and livestock production. Major range management practices include controlling stocking rate and season of use, using complementary forages, and controlling sand sagebrush, which is believed to increase in density as grazing pressure increases. However, canopy cover by sand sagebrush showed no major trend over 40 years under moderate grazing or in enclosures protected from livestock.

Tallahatchie Experimental Forest (TAL) [USFS]

http://www.srs.fs.usda.gov/

The 1,416-ha Tallahatchie Experimental Forest (TAL), located in the Holly Springs National Forest near Oxford, MS, was established in 1950 to study relationships between mixed pine and hardwood forests, flooding, and soil erosion. The TAL was established following the severe erosion and flooding that came after extensive forest clearing in the upper Coastal Plain during the early 20th century. The region's hilly upland soils exhibited some of the greatest erosion rates recorded in North America.

The TAL is typical of the upper Coastal Plain of the Mid South. Much of the northern portion lies within the bottomland forest adjacent to the Little Tallahatchie River. The central and southern portion is hilly terrain drained by a number of small forested streams. Slopes range from 15 to 30 percent, and relief within these small headwater basins varies between 30 to 40 m. Soils consist of predominantly Coastal Plain sandy loams and smaller amounts of silt loams. Forest cover is 55- to 65-year-old mixed shortleaf pine and hardwood (white and red oaks and hickories), which have been only minimally disturbed since establishment.

Climate is hot, humid summers and fairly mild winters with occasional ice storms and small amounts of snow. Annual precipitation averages over 1,300 mm and is evenly distributed through the year. The growing season lasts about 218 days. Brief, high-intensity convective storms can occur throughout the year but are more common in spring and summer. Most winter precipitation results from less intense, cyclonic weather fronts. Soil temperatures rarely fall below freezing.

Research focus. Past research focused on how different vegetation types (for example, old field, poorly stocked forests, overstocked forests) and silvicultural methods affect surface runoff and sediment yields. This knowledge contributed to the success of the Yazoo-Little Tallahatchie Project, a Federal reforestation and soil stabilization program from 1949 to 1985 throughout the upper Coastal Plain of northern Mississippi.

The TAL provides a unique variety of mixed pine-hardwood forest conditions within which management disturbances have been very limited, natural wildfire has been suppressed, and prescribed burning has been carefully controlled. Recent investigations have studied—

- how plant and bird communities respond to varying fire regimes,
- how tree species composition varies with fire frequency,
- how avian community structure and nest success are affected by prescribed burning, and
- how cool-season prescribed fire affects herbaceous, understory, and overstory vegetation.

Virginia Coast Reserve (VCR) [LTER]

http://www.vcrlter.virginia.edu/

The Virginia Coast Reserve (VCR) LTER program was established in 1987 to examine how long-term changes in climate (storms, temperature), sea level, and land use affect the dynamics and biotic structure of coastal barrier systems and the services they provide. The VCR extends over 110 km on the Eastern Shore of Virginia from the Maryland border to the mouth of the Chesapeake Bay and is characteristic of coastal barrier ecosystems along much of the Atlantic and Gulf Coasts (figure A1-75).

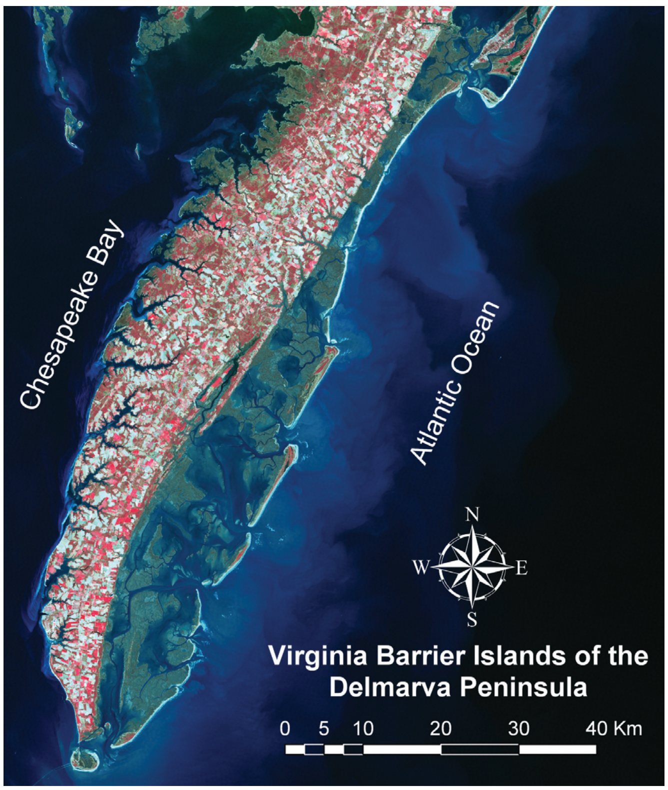


Figure A1-75. The Virginia Coast Reserve (VCR LTER) barrier island/lagoon system extends 110 km along the Atlantic shore of the Delmarva Peninsula. Sandy and dynamic barrier islands are backed by salt marshes and shallow lagoons and separated from one another by deep inlets. (Image from NASA Enhanced Thematic Mapper, 2001.)

The reserve comprises an extremely dynamic landscape that includes an assemblage of 14 barrier islands, shallow lagoons with extensive mudflats, tidal marshes, and mainland watersheds. It is one of the few remaining undisturbed coastal barrier landscapes in the Nation. The shallow seaward slope of the landscape (less than 0.1 percent) makes this a particularly sensitive location for studying responses of intertidal marshes to sea-level rise. The islands of the VCR are among the most dynamic in the United States; lateral accretion and erosion rates are as high as 13 m/y, highest along the Mid Atlantic Seaboard (figure 9-5).

At the turn of the last century, the barrier island and lagoon system supported one of the most prosperous farming- and fishing-based communities in the country. Towns on the islands were abandoned after the Great Storm of 1933, and the scallop fishery collapsed with the loss of seagrass around the same time. The VCR LTER program is now working with collaborators to restore seagrass to the region.

Research focus. Current research focuses on whether changing land use will affect water quality in VCR coastal bays and the recolonization of the seagrass as the foundation species, whether marshes can keep pace with one of the highest recorded rates of sea-level rise on the Atlantic Coast, and whether spatial variations in species and community distribution patterns on the islands can be used to predict areas vulnerable to change. Research is organized around three synthetic questions:

- How do long-term drivers of change (climate, rising sea level, land-use change) and short-term disturbance events interact to alter ecosystem dynamics and state change, and how is their effect modified by internal processes and feedbacks at the local scale?
- How do fluxes of organisms and materials across the landscape influence ecosystem dynamics and state change?
- In the future, what will be the structure of the landscape and what processes will drive ecological state change?

Walker Branch Watershed (WBW) [U.S. Department of Energy]

http://walkerbranch.ornl.gov

Walker Branch Watershed (WBW) was established in 1967 to quantify land-water interactions in a forested landscape. The WBW is located about 40 km west of Knoxville in the Ridge and Valley Geophysical Province of eastern Tennessee. WBW is a 97.5-ha forested watershed that resides within the U.S. Department of Energy Oak Ridge National Environmental Research Park, which encompasses over 8,000 ha of protected and mostly forested land devoted to research and education in the environmental sciences (figure A1-76).

Figure A1-76. Walker Branch Watershed (WBW DOE) near Knoxville, TN, is located in eastern deciduous forest. Stream studies are a prominent part of the site and research. (Photo by Brian Roberts.)

The climate is typical of the humid southern Appalachian region with little seasonality in rainfall. The vegetation is primarily chestnut oak *(Quercus prinus),* white oak *(Quercus alba),* tulip poplar *(Liriodendron tulipfera),* and red maple *(Acer rubrum),* which together account for about 70 percent of the total basal area. Hickory (*Carya* spp.) and shortleaf pine *(Pinus echinata)* were historically important minor components, but insect infestations have greatly reduced their abundance. The forest is of mixed age; the watershed was primarily in subsistence agriculture and open woodland prior to acquisition by the U.S. Government in 1942.

The soils are primarily Ultisols with small areas of Inceptisols in alluvial areas adjacent to streams. Soils are generally well drained, with high infiltration capacity, and are acidic (pH 4.2-4.6) and low in exchangeable bases, nitrogen, and phosphorus (Johnson and Van Hook 1989).

Research focus. The WBW project has three primary objectives:

- Provide base-line values for unpolluted natural waters within an urbanizing landscape.
- Contribute to our knowledge of cycling and loss of chemical elements in forest ecosystems.
- Enable development of models for predicting the effects of human activities on the landscape (especially climate change, atmospheric deposition, and air quality).

Long-term measurements include atmospheric inputs and stream outputs of water and chemicals, soil chemistry surveys, and forest vegetation inventories. Stream studies continue to be a prominent component of WBW research, particularly the role of stream processes in controlling stream nutrient concentrations and catchment outputs. Several studies have investigated nitrogen cycling and retention using tracer ^{15}N addition experiments (for example, the Lotic Intersite Nitrogen Experiment—LINX; see chapter 10). Whole-stream rates of metabolism (gross primary production, ecosystem respiration) have been measured continuously since 2004.

Long-term research example. The climate at WBW has been warming over the past 40 years (figure A1-77, top). Warming is higher during winter, with average air temperatures for January-March increasing at a rate of 0.72 ˚C/y, about twice the rate of annual temperatures. Annual precipitation and runoff are highly variable with no significant trends. There are no significant trends in wet nitrogen deposition and dissolved inorganic nitrogen (DIN) output, and nitrogen retention in the catchment is very high (DIN outputs are about 5 percent of wet nitrogen inputs).

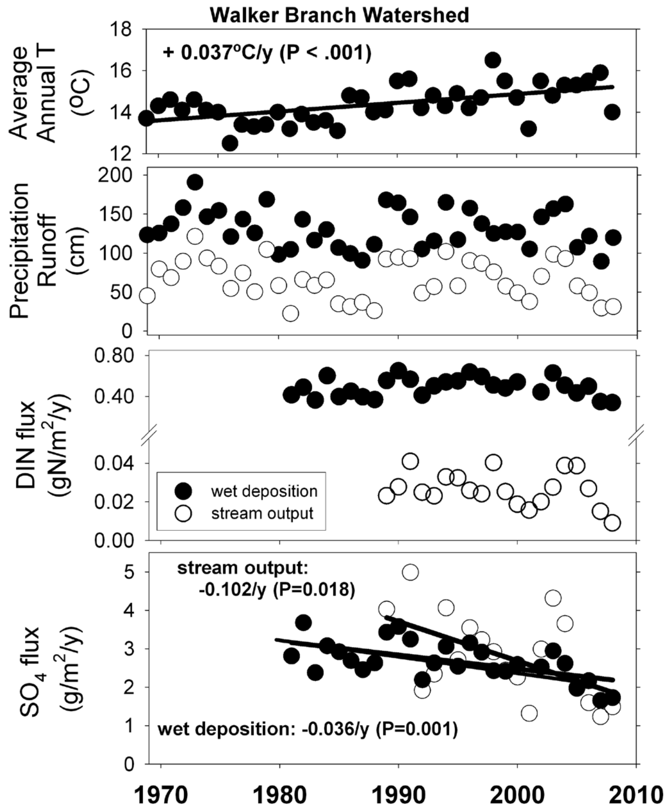


Figure A1-77. Long-term trends in climate, hydrology, and nitrogen and SO4 flux at Walker Branch Watershed (WBW). (Redrawn from Mullholland, 2004, unpublished data). Runoff values are for the East and West Fork catchments combined. Nitrogen and SO_4 flux values are for the West Fork catchment only.

Recently initiated measurements of total dissolved nitrogen (TDN) indicate that TDN output is about twice DIN output. Previous studies indicate that total retention is about 95 percent of inputs. This high rate of nitrogen retention is likely the result of increasing forest biomass and dominance by oaks. Wet SO_4 deposition input and stream SO_4 output are declining. Although stream SO_4 outputs are similar to wet deposition inputs, studies of dry SO_4 deposition in the WBW indicate that total deposition is about twice wet deposition (Tilden Meyers, unpublished data), indicating that SO_4 retention is about 50 percent. The high interannual variability in stream SO_4 output appears to be the result of a strong positive correlation between SO_4 concentration and stream discharge ($r^2 = 0.54$) and interannual variability in stream discharge.

Walnut Gulch Experimental Watershed (WGE) [USDA-ARS]

http://www.tucson.ars.ag.gov/

The Walnut Gulch Experimental Watershed (WGE) was established in the early 1950s to develop knowledge and technology for conserving water and soil in semiarid lands. The watershed is representative of brush- and grass-covered rangeland found in the transition zone between the Chihuahuan and Sonoran Deserts (figure A1-78). Shrubs dominate the lower two-thirds of WGE, including creosotebush (*Larrea divaricata*), whitethorn Acacia (*Acacia constricta*), mariola (*Parthenium incanum*), and tarbush (*Flourensia Cernua*). Grass species dominate the upper third, including black grama (*Bouteloua eriopoda*), sideoats grama (*Bouteloua curtipendula*), three-awn (*Aristida* sp.), and Lehmann lovegrass (*Eragrostis lehmanniana*). Soils are mostly well-drained, calcareous, gravelly loams with large percentages of rock and gravel at the surface. Soil surface rock fragment cover (erosion pavement) can range from nearly 0 percent on shallow slopes to over 70 percent on very steep slopes.

The WGE encompasses 150 square kilometers in southeastern Arizona surrounding the historical town of Tombstone. The precipitation regime is dominated by the North American Monsoon. More than 60 percent of the total annual precipitation comes during July, August, and September, and about 30 percent comes during the 6 months of October through March. Virtually all runoff is generated by summer thunderstorms, and peak flow rates vary greatly with area and year. Cattle grazing is the primary land use, with mining, limited urbanization, and recreation making up the remainder.

Research focus. WGE is the most highly instrumented semiarid experimental watershed in the world and serves as a model for conducting watershed hydrology studies. The critical research issues in the WGE and semiarid rangelands include livestock grazing, water management, erosion control, urbanization, rangeland carbon budget, rangeland rehabilitation, fire, desertification and non-native plant invasion.

Current research focuses on—

- hydrologic processes, climate variability, and water resources for semiarid watershed management, and
- soil erosion, sediment yield, conservation structures, and decision-support systems for sustainable land management.

The anticipated products include—

- better technologies and strategies to manage water, soil, and carbon resources,
- a hydrology and erosion model for rangeland applications, and
- decision-support tools for public land managers.

Figure A1-78. Walnut Gulch Experimental Watershed (WGE USDA-ARS) in Arizona contains both shrublands and grasslands as part of the semiarid landscape. (Photo from USDA-ARS, Southwest Watershed Research Center.)

Wind River Experimental Forest (WIN) [USFS]

http://www.fs.fed.us/pnw/exforests/wind-river/

The Wind River Experimental Forest (WIN) is located in the southwestern Washington Cascades amidst a north-south trending valley bisected by the Wind River. Though the WIN was not established until 1932, USDA Forest Service research in the area began in 1908. The 4,200-ha area comprises two divisions, Trout Creek and Panther Creek. Elevations range between 330 m and 1,300 m. The soils are primarily volcanic in origin.

The nearby Columbia River Gorge affects the Wind River valley's climate, contributing to strong winds year round and cool, wet weather in winter. Precipitation falls as rain or snow during fall, winter, and spring. Summers are warm and dry. Cold air draining into the valley can bring frost almost any time of the year.

WIN is best known for its old-growth forests—more than 400 years in age—of Douglas-fir and western hemlock. Other tree species in the forest include western red cedar, Pacific silver fir, grand fir, and noble fir. Understory trees include Pacific yew, vine maple, Pacific dogwood, and red alder. Younger forests include stands that were established after fires in the late 1840s or the 1902 Yacolt Burn. Numerous plantations were established following timber harvest into the late 1980s.

Research focus. The earliest research focused on how to prevent and control wildfires, how to best regenerate burned and cutover lands, and how to grow seedlings to revegetate thousands of hectares of forest denuded by fire and timber harvesting. The Wind River Arboretum was established in 1912 to study the local success and growth of 150 tree species from all over the world. Permanent growth and yield plots, spacing studies, pruning, fertilization, thinning, and autecology studies provided knowledge on the management and silviculture of Douglas-fir/western hemlock forests in the Pacific Northwest prior to World War II.

In the early 1980s, more ecosystem-oriented studies were conducted, including pollutant monitoring, nutrient cycling, decay of coarse woody debris, and forest gap dynamics. WIN also became one of two focal sites for the Old-Growth Program, whose objectives were defining old-growth Douglas-fir forests, identifying wildlife species associated with these forests, and determining their biological requirements and ecological relationships. In 1994, an 87-meter-tall construction crane was installed in the old-growth forest to study processes operating at the interfaces among vegetation, the atmosphere, and the forest floor (figure A1-79).

Figure A1-79. Wind River Experimental Forest (WIN USFS) in southeastern Washington is dominated by old-growth forests of Douglas fir and western hemlock. A canopy crane constructed in 1994 allows processes to be studied at the interfaces among vegetation, atmosphere, and the forest floor. (Photo from Wind River Canopy Crane Research Facility Image Archive.)

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Appendix 2. Average (standard error) maximum, mean, and minimum air temperature and annual precipitation at each site

(Sites are grouped by ecosystem type. See Appendix 26 for length of record for each station at a site.)

Site code	Air temperature			Precipitation
	Maximum	Mean	Minimum	
	°C			*cm*
Alpine and arctic				
ARC	-3.7(0.3)	-8.5(0.3)	-14.0(0.4)	32.71(2.1)
GLA	2.2(0.2)*	-0.8(0.2)*	-3.9(0.2)	131.51(9.9)
LVW	6.7(0.2)*	1.5(0.1)	-3.0(0.1)	102.88(3.8)
MCM	-14.2(0.3)	-17.9(0.2)	-21.4(0.3)*	1.38(0.3)*
NWT	7.7(0.2)*	1.8(0.1)*	-4.2(0.1)	68.69(2.1)*
Aridlands				
EOA	15.0(0.1)	7.7(0.1)*	0.4(0.1)*	28.24(1.1)
JRN	24.8(0.1)	14.8(0.1)	4.7(0.1)	26.00(1.0)
RCE	16.4(0.1)*	8.9(0.1)*	1.6(0.1)*	26.80(1.2)
SEV	23.4(0.1)	14.2(0.1)*	5.0(0.1)*	24.37(0.9)
SRE	24.7(0.1)	17.9(0.1)	11.1(0.1)	56.23(1.9)
WGE	25.3(0.1)*	17.5(0.1)*	9.7(0.1)*	35.76(1.0)
Coastal				
CCE	21.2(0.1)	17.5(0.1)*	13.7(0.1)*	25.77(1.2)
FCE	29.4(0.1)	23.9(0.1)*	18.1(0.2)*	140.90(4.8)
GCE	25.8(0.1)	20.5(0.1)	15.1(0.1)	131.19(3.0)
MCR		25.9(0.2)*		209.62(11.8)
PAL	0.8(0.1)	-2.0(0.2)*	-4.0(0.2)*	69.02(3.8)
PIE	15.5(0.1)	9.9(0.1)*	4.3(0.1)*	110.03(2.3)*
SBC	21.6(0.1)	15.8(0.1)*	10.0(0.1)*	43.67(2.7)
VCR	19.7(0.1)*	14.5(0.1)*	9.3(0.1)*	109.71(2.6)
Eastern forests				
BEN	19.7(0.1)	12.9(0.1)*	6.0(0.1)*	121.79(3.0)
CRO	24.3(0.1)*	17.4(0.1)*	10.5(0.1)*	138.60(3.7)
CWT	20.0(0.1)	12.7(0.1)*	5.5(0.1)*	180.33(3.7)
FER	16.9(0.1)*	10.3(0.1)*	3.7(0.1)	127.70(2.3)
HAR	25.6(0.1)	19.7(0.1)*	13.8(0.1)*	176.16(4.4)
HBR	12.0(0.1)*	6.5(0.1)*	1.1(0.1)*	124.32(3.5)
HFR	13.2(0.1)*	7.5(0.1)*	1.8(0.1)*	111.35(3.1)*
LUQ	27.0(0.2)	24.5(0.1)	21.9(0.1)	350.57(15.2)
MAR	10.8(0.1)	4.2(0.1)*	-2.3(0.1)*	66.58(1.3)*
NTL	10.8(0.1)	4.5(0.1)	-1.9(0.1)	79.28(1.3)

Appendix 2. Average (standard error) maximum, mean, and minimum air temperature and annual precipitation at each site—*Continued*

Site code	Air temperature			Precipitation
	Maximum	Mean	Minimum	
	ºC			*cm*
SAN	25.2(0.1)*	18.4(0.1)	11.5(0.1)*	138.25(6.9)
TAL	22.8(0.1)	16.5(0.1)*	10.3(0.1)*	139.96(3.0)*
WBW	20.6(0.1)*	14.4(0.1)*	8.2(0.1)	139.19(3.4)
Temperate grasslands and savannas				
CDR	11.6(0.1)	5.7(0.1)	-0.2(0.1)	69.36(1.1)*
FTK	14.6(0.2)	7.8(0.1)*	1.0(0.1)*	34.05(1.1)
GRL	22.5(0.1)*	15.7(0.1)	8.8(0.1)*	77.01(2.2)*
GSW	25.5(0.2)	19.5(0.1)	13.4(0.1)	90.68(3.0)*
KBS	15.2(0.1)*	9.5(0.1)*	3.8(0.1)*	91.39(2.0)*
KNZ	19.7(0.1)	13.0(0.1)	6.3(0.1)	84.74(2.0)
SGS	17.3(0.2)	9.1(0.1)*	0.8(0.2)*	32.28(1.1)
SPR	22.9(0.1)	15.3(0.1)	7.6(0.1)*	63.30(1.8)
Urban				
BES	18.5(0.1)*	13.1(0.1)	7.7(0.1)	104.66(2.3)
CAP	31.0(0.1)*	21.2(0.1)*	11.3(0.1)*	19.32(0.9)
Western forests				
AND	14.3(0.1)	9.3(0.1)	4.4(0.1)	225.62(5.8)
BLA				
BNZ	3.4(0.4)	-1.3(0.4)	-5.6(0.4)	
CHE	15.0(0.1)*	10.5(0.1)*	5.9(0.1)*	247.19(5.1)
CSP	15.9(0.1)	11.5(0.1)	7.1(0.1)	102.15(3.1)
FRA	13.1(0.2)	6.1(0.1)	-0.9(0.1)*	41.89(1.4)
PRI	13.4(0.1)	6.7(0.1)*	0.1(0.1)*	78.91(1.4)
WIN	15.3(0.1)*	9.0(0.1)	2.6(0.1)*	239.31(6.8)

* Slope is significant ($p < 0.05$) for regression of each variable against time.

Appendix 3. Average (standard error) ice duration, sea level, streamflow, water clarity, and water temperature for sites with data

(Sites are grouped by ecosystem type. See Appendix 26 for length of record for each station at a site.)

Site code	Ice duration *days/year*	Sea level[1] *m*	Streamflow *L/s*	Water clarity *m*	Water temperature *°C*
Alpine and arctic					
ARC	260 (2)		2827.7 (211.5)	4.6 (0.15)	11.0 (0.3)
LVW			165.5 (6.9)		3.7 (0.1)
MCM			749.3 (133.3)		4.0 (0.4)
NWT	267 (4)		166.7 (6.6)		
Aridlands					
RCE			549.6 (69.0)		
WGE			14.1 (1.9)		
Coastal					
CCE		-0.08 (0.01)*		14.2 (0.36)*	17.1 (0.1)*
FCE		-0.07 (0.01)*	3108.0 (549.7)*	1.6 (0.09)	26.2 (0.1)*
GCE		-0.07 (0.01)*	377247.3 (15712.8)		21.4 (0.2)
MCR		-0.001 (0.01)*			
PAL	215(10)				
PIE		-0.06 (0.01)*	1089.9 (42.2)		
SBC		-0.03 (0.004)*	122.2 (26.3)		15.9 (0.1)*
VCR		-0.13 (0.01)*		0.7 (0.04)	
Eastern forests					
BEN			47849.9 (1582.6)		
CWT			4.0 (0.1)		
FER			5.9 (0.2)		
HBR	132 (2)*		3.8 (0.1)		
LUQ		-0.01 (0.01)*	1573.7 (61.0)		
MAR			0.5 (0.03)		
NTL	104 (2)*		141.6 (8.8)*	6.3 (0.13)	13.8 (0.1)*
SAN			41.4 (7.8)*		
WBW			11.4 (0.7)		

Appendix 3. Average (standard error) ice duration, sea level, streamflow, water clarity, and water temperature for sites with data—*Continued*

Site code	Ice duration *days/year*	Sea level[1] *m*	Streamflow *L/s*	Water clarity *m*	Water temperature *°C*
Temperate grasslands and savannas					
GSW			2.9 (0.3)		
KBS	73 (3)		25620.4 (773.0)*		
KNZ			64.7 (10.1)		
Urban					
BES		-0.11 (0.01)*	1160.6 (68.6)		
CAP			27654.4 (2442.5)		
Western forests					
AND			25.7 (0.9)		5.9 (0.1)
BNZ			43.9 (3.0)		
CSP			77.7 (8.5)		10.7 (0.2)
FRA			56.6 (3.1)		
PRI			48302.2 (1487.0)		

[1]Annual mean sea level is defined as the annual arithmetic means of hourly heights relative to the National Tidal Datum Epoch (i.e., the most recent mean sea level datum established by CO-OPS—currently the mean sea level 1983-2001).

* indicates significant slope ($p < 0.05$) for regression of each variable against time.

Appendix 4. Regression coefficients and R^2 values for nine climatic variables for which linear regression against time is significant ($p < 0.05$)

(Sites are grouped by ecosystem type. See Appendix 26 for length of record for each station at a site.)

Site code	Variable	Slope	Y-intercept[1]	R^2
Alpine and arctic				
GLA	Maximum air temperature	0.07	1.6	0.3
	Mean air temperature	0.07	-1.4	0.3
LVW	Maximum air temperature	-0.07	7.5	0.3
MCM	Minimum air temperature	-0.11	-20.1	0.3
	Precipitation	0.21	-0.01	0.4
NWT	Maximum air temperature	0.04	6.5	0.3
	Mean air temperature	0.02	1.2	0.1
	Precipitation	-0.49	86.4	0.2
Aridlands				
EOA	Mean air temperature	0.01	7.3	0.2
	Minimum air temperature	0.02	-0.4	0.2
RCE	Maximum air temperature	0.03	15.7	0.2
	Mean air temperature	0.03	8.2	0.3
	Minimum air temperature	0.03	0.7	0.3
SEV	Mean air temperature	-0.01	14.5	0.1
	Minimum air temperature	-0.01	5.3	0.04
WGE	Maximum air temperature	0.01	24.8	0.05
	Mean air temperature	0.01	16.9	0.2
	Minimum air temperature	0.01	9.0	0.3
Coastal				
CCE	Mean air temperature	0.02	16.8	0.3
	Minimum air temperature	0.03	12.7	0.4
	Sea level	0.002	-0.2	0.8
	Water clarity	-0.11	17.0	0.3
	Water temperature	0.01	16.6	0.2
FCE	Mean air temperature	0.02	23.2	0.4
	Minimum air temperature	0.04	17.1	0.3
	Sea level	0.002	-0.2	0.9
	Streamflow	110.58	564.7	0.2
	Water temperature	-0.03	26.5	0.4
GCE	Sea level	0.003	-0.2	0.8
MCR	Mean air temperature	0.08	24.7	0.6
	Sea level	0.003	-0.04	0.5
PAL	Mean air temperature	0.06	-3.2	0.3
	Minimum air temperature	0.08	-4.9	0.3

Appendix 4. Regression coefficients and R^2 values for nine climatic variables for which linear regression against time is significant ($p < 0.05$)—*Continued*

Site code	Variable	Slope	Y-intercept[1]	R^2
PIE	Mean air temperature	-0.01	10.2	0.05
	Minimum air temperature	-0.01	5.0	0.2
	Precipitation	0.36	87.6	0.3
	Sea level	0.003	-0.2	0.9
SBC	Mean air temperature	0.01	15.2	0.2
	Minimum air temperature	0.02	8.7	0.4
	Sea level	0.001	-0.1	0.3
	Water temperature	0.02	15.5	0.2
VCR	Maximum air temperature	0.02	19.2	0.2
	Mean air temperature	0.03	13.7	0.4
	Minimum air temperature	0.04	8.3	0.5
	Sea level	0.004	-0.3	0.9
Eastern forests				
BEN	Mean air temperature	0.01	12.6	0.1
	Minimum air temperature	0.03	5.3	0.3
CRO	Maximum air temperature	-0.02	25.2	0.3
	Mean air temperature	-0.02	18.2	0.4
	Minimum air temperature	-0.02	11.2	0.2
CWT	Mean air temperature	0.01	12.3	0.1
	Minimum air temperature	0.02	4.9	0.2
FER	Maximum air temperature	-0.02	17.8	0.2
	Mean air temperature	-0.01	10.6	0.1
HAR	Mean air temperature	0.01	19.4	0.1
	Minimum air temperature	0.02	13.3	0.2
HBR	Ice duration	-0.45	140.6	0.2
	Maximum air temperature	0.02	11.5	0.1
	Mean air temperature	0.03	5.8	0.3
	Minimum air temperature	0.03	0.2	0.4
HFR	Maximum air temperature	0.03	12.5	0.3
	Mean air temperature	0.03	6.7	0.4
	Minimum air temperature	0.04	0.8	0.4
	Precipitation	0.59	97.8	0.1
LUQ	Sea level	0.002	-0.1	0.4
MAR	Mean air temperature	0.02	3.4	0.2
	Minimum air temperature	0.03	-3.6	0.3
	Precipitation	0.20	57.0	0.2
NTL	Ice duration	-0.19	117.9	0.2
	Streamflow	2.29	102.7	0.2
	Water temperature	0.06	13.0	0.4
SAN	Maximum air temperature	-0.01	25.7	0.1
	Minimum air temperature	-0.01	11.9	0.1
	Streamflow	4.89	13.5	0.7

Appendix 4. Regression coefficients and R^2 values for nine climatic variables for which linear regression against time is significant ($p < 0.05$)—*Continued*

Site code	Variable	Slope	Y-intercept[1]	R^2
TAL	Mean air temperature	-0.01	17.3	0.1
	Minimum air temperature	-0.02	11.6	0.2
	Precipitation	0.24	123.2	0.1
WBW	Maximum air temperature	0.02	20.0	0.1
	Mean air temperature	0.01	14.0	0.1
Temperate grasslands and savannas				
CDR	Precipitation	0.05	65.1	0.03
FTK	Mean air temperature	0.01	7.3	0.1
	Minimum air temperature	0.02	0.4	0.1
GRL	Maximum air temperature	-0.01	23.1	0.1
	Minimum air temperature	0.02	8.0	0.2
	Precipitation	0.19	68.8	0.1
GSW	Precipitation	0.30	79.9	0.1
KBS	Maximum air temperature	0.02	14.4	0.2
	Mean air temperature	0.02	8.7	0.2
	Minimum air temperature	0.02	3.0	0.2
	Precipitation	0.38	75.2	0.2
	Streamflow	122.12	20,810.5	0.2
SGS	Mean air temperature	0.02	8.3	0.2
	Minimum air temperature	0.04	-0.6	0.3
SPR	Minimum air temperature	0.01	7.1	0.1
Urban				
BES	Maximum air temperature	0.01	18.2	0.1
	Sea level	0.003	-0.3	0.9
CAP	Maximum air temperature	0.01	30.3	0.2
	Mean air temperature	0.02	20.0	0.5
	Minimum air temperature	0.03	9.7	0.5
Western forests				
CHE	Maximum air temperature	0.01	14.7	0.1
	Mean air temperature	0.01	10.1	0.1
	Minimum air temperature	0.01	5.5	0.2
FRA	Minimum air temperature	-0.03	0.01	0.4
PRI	Mean air temperature	0.01	6.4	0.05
	Minimum air temperature	0.01	-0.7	0.2
WIN	Maximum air temperature	-0.02	15.9	0.1
	Minimum air temperature	0.01	2.3	0.1

[1] Y-intercept was calculated for the first year of a dataset, which contains records of one variable over time for one site.

Appendix 5. Annual average (standard error) nitrogen (as nitrate) from various sources at sites with data

(Sites are grouped by ecosystem type. See Appendix 27 for length of record for each station at a site.)

Site code	Precipitation (concentration) *mg/L*	Wet deposition *kg/ha*	Coastal water *μM/L*	Lake *mg/L*	Stream *mg/L*
Alpine and arctic					
ARC	0.06 (0.02)	0.17 (0.01)			0.03 (0.01)*
GLA	0.17 (0.01)	2.00 (0.11)			
LVW	0.17 (0.01)*	1.73 (0.06)			0.28 (0.02)*
MCM				0.14 (0.01)	
NWT	0.21 (0.01)*	3.70 (0.27)*		0.21 (0.01)*	
Aridlands					
JRN	0.42 (0.04)	0.03 (0.002)			
RCE	0.12 (0.01)	0.29 (0.02)			
WGE	0.24 (0.01)	0.85 (0.09)			
Coastal					
CCE			0.2 (0.02)		
FCE	0.12 (0.004)	1.75 (0.08)*	0.3 (0.05)*		
PAL			4.4 (0.15)		
PIE	0.24 (0.01)*	2.64 (0.08)			0.02 (0.001)
SBC			0.4 (0.11)		
VCR	0.23 (0.02)	2.69 (0.19)	0.8 (0.16)		
Eastern forests					
BEN	0.13 (0.01)	2.12 (0.16)			
CRO	0.17 (0.01)	2.33 (0.07)			
CWT	0.15 (0.004)*	2.59 (0.08)*			
FER	0.33 (0.01)*	4.19 (0.18)*			0.78 (0.02)*
HBR	0.28 (0.01)*	3.33 (0.11)*			0.16 (0.02)*
HFR	0.28 (0.01)*	3.46 (0.14)			
LUQ	0.06 (0.004)	1.91 (0.13)			0.14 (0.01)
MAR	0.23 (0.01)*	1.76 (0.05)*			
NTL	0.25 (0.01)*	1.97 (0.09)*		0.01 (0.001)	

Appendix 5. Annual average (standard error) nitrogen (as nitrate) from various sources at sites with data—*Continued*

Site code	Precipitation (concentration) *mg/L*	Wet deposition *kg/ha*	Coastal water *µM/L*	Lake *mg/L*	Stream *mg/L*
SAN	0.17 (0.01)	1.95 (0.08)			
TAL	0.17 (0.01)	2.38 (0.10)			
WBW	0.23 (0.01)*	2.96 (0.10)			0.02 (0.001)
Temperate grasslands and savannas					
CDR	0.29 (0.01)	2.13 (0.18)			
GRL	0.23 (0.01)	2.09 (0.06)			
KBS	0.40 (0.01)*	3.62 (0.14)*			1.11 (0.02)
KNZ	0.28 (0.01)	2.38 (0.08)			0.002 (0.0002)*
SGS	0.32 (0.01)	1.03 (0.05)			
Urban					
BES	0.29 (0.01)*	3.33 (0.16)*			1.98 (0.08)*
CAP	0.66 (0.07)	0.76 (0.15)			0.02 (0.01)*
Western forests					
AND	0.03 (0.001)	0.62 (0.02)			0.001 (0.0001)
BLA	0.06 (0.01)*	0.46 (0.03)			
BNZ	0.03 (0.002)	0.11 (0.01)			
CSP	0.05 (0.003)*	0.47 (0.04)			
FRA	0.21 (0.01)*	3.70 (0.27)*			
PRI	0.09 (0.01)	0.69 (0.05)			

* indicates significant slopes ($p < 0.05$) for regression of each variable against time.

Appendix 6. Regression coefficients and R^2 values for nitrogen (as nitrate) from various sources for which linear regression against time is significant ($p < 0.05$)

(Sites are grouped by ecosystem type. See Appendix 27 for length of record for each station at a site.)

Site code	Source	Slope	Y-intercept[1]	R^2
Alpine and arctic				
ARC	Stream	0.003	0.001	0.4
LVW	Precipitation (concentration)	0.002	0.15	0.2
	Stream	0.009	0.20	0.5
NWT	Lake	0.005	0.15	0.4
	Precipitation (concentration)	0.003	0.17	0.2
	Wet deposition	0.103	2.35	0.3
Coastal				
FCE	Coastal water	0.055	0.12	0.8
	Wet deposition	0.026	1.31	0.3
PIE	Precipitation (concentration)	-0.002	0.27	0.2
Eastern forests				
CWT	Precipitation (concentration)	-0.001	0.17	0.2
	Wet deposition	-0.028	3.07	0.3
FER	Precipitation (concentration)	-0.006	0.43	0.6
FER	Stream	-0.006	0.87	0.2
	Wet deposition	-0.086	5.58	0.6
HBR	Precipitation (concentration)	-0.005	0.36	0.5
	Stream	-0.007	0.31	0.4
	Wet deposition	-0.048	4.14	0.5
HFR	Precipitation (concentration)	-0.006	0.37	0.5
MAR	Precipitation (concentration)	-0.002	0.26	0.2
	Wet deposition	-0.017	2.04	0.3
NTL	Precipitation (concentration)	-0.003	0.29	0.4
	Wet deposition	-0.032	2.47	0.3
WBW	Precipitation (concentration)	-0.002	0.26	0.3
Temperate grasslands and savannas				
KBS	Precipitation (concentration)	-0.005	0.48	0.5
	Wet deposition	-0.062	4.62	0.6
KNZ	Stream	0.0001	0.001	0.3
Urban				
BES	Precipitation (concentration)	-0.007	0.38	0.7
	Stream	-0.073	2.39	0.7
	Wet deposition	-0.084	4.13	0.5
CAP	Stream	0.005	-0.02	0.4

Appendix 6. Regression coefficients and R^2 values for nitrogen (as nitrate) from various sources for which linear regression against time is significant ($p < 0.05$)—*Continued*

Site code	Source	Slope	Y-intercept[1]	R^2
Western forests				
BLA	Precipitation (concentration)	-0.007	0.10	0.5
CSP	Precipitation (concentration)	-0.001	0.06	0.2
FRA	Precipitation (concentration)	0.003	0.17	0.2
	Wet deposition	0.103	2.35	0.3

[1] Y-intercept was calculated for the first year of a dataset, which contains records of one variable over time for one site.

Appendix 7. Annual average (standard error) nitrogen (as ammonium) from various sources at sites with data

(Sites are grouped by ecosystem type. See Appendix 27 for length of record for each station at a site.)

Site code	Precipitation (concentration) *mg/L*	Wet deposition *kg/ha*	Coastal water *µM/L*	Lake *mg/L*	Stream *mg/L*
Alpine and arctic					
ARC	0.08 (0.02)	0.10 (0.01)			0.006 (0.001)*
GLA	0.10 (0.01)*	1.20 (0.08)*			
LVW	0.12 (0.01)*	1.19 (0.06)*			0.014 (0.002)*
MCM				0.01 (0.002)	
NWT	0.11 (0.01)*	1.99 (0.19)*		0.03 (0.004)	
Aridlands					
JRN	0.51 (0.04)*	0.03 (0.002)			
RCE	0.15 (0.01)*	0.38 (0.04)*			
WGE	0.23 (0.02)	0.79 (0.09)			
Coastal					
FCE	0.08 (0.01)	1.24 (0.11)*	5 (1.2)*		
PAL			2 (0.4)		
PIE	0.12 (0.004)*	1.28 (0.06)*			0.002 (0.0002)
SBC			1 (0.1)		
VCR	0.24 (0.07)	2.59 (0.67)	3 (0.5)		
Eastern forests					
BEN	0.11 (0.01)*	1.83 (0.16)*			
CRO	0.20 (0.01)	2.67 (0.18)			
CWT	0.11 (0.005)	1.89 (0.09)			
FER	0.17 (0.005)	2.24 (0.08)			
HBR	0.13 (0.005)	1.57 (0.07)			0.013 (0.001)*
HFR	0.14 (0.01)	1.72 (0.09)			
LUQ	0.03 (0.002)	0.78 (0.07)			0.022 (0.005)*
MAR	0.28 (0.01)	2.10 (0.08)			
NTL	0.27 (0.01)	2.08 (0.11)		0.03 (0.002)	
SAN	0.11 (0.01)*	1.19 (0.07)*			

Appendix 7. Annual average (standard error) nitrogen (as ammonium) from various sources at sites with data—*Continued*

Site code	Precipitation (concentration) *mg/L*	Wet deposition *kg/ha*	Coastal water *µM/L*	Lake *mg/L*	Stream *mg/L*
TAL	0.14 (0.01)	1.97 (0.14)			
WBW	0.15 (0.01)	1.94 (0.09)			0.003 (0.0003)
Temperate grasslands and savannas					
CDR	0.45 (0.02)	3.31 (0.28)			
GRL	0.23 (0.01)*	2.05 (0.08)			
KBS	0.35 (0.01)	3.19 (0.11)			0.017 (0.001)
KNZ	0.31 (0.01)*	2.59 (0.12)*			0.009 (0.002)*
SGS	0.48 (0.02)*	1.53 (0.08)			
Urban					
BES	0.19 (0.01)	2.19 (0.10)			
CAP	0.97 (0.14)	1.07 (0.21)			0.018 (0.003)
Western forests					
AND	0.02 (0.001)	0.33 (0.02)			0.009 (0.001)
BLA	0.04 (0.005)	0.35 (0.04)			
BNZ	0.02 (0.005)				
CSP	0.04 (0.003)	0.34 (0.03)			
FRA	0.11 (0.01)*	1.99 (0.19)*			
PRI	0.10 (0.005)	0.76 (0.02)			

* indicates significant slopes ($p < 0.05$) for regression of each variable against time.

Appendix 8. Regression coefficients and R^2 values for nitrogen (as ammonium) from various sources for which linear regression against time is significant ($p < 0.05$)

(Sites are grouped by ecosystem type. See Appendix 27 for length of record for each station at a site.)

Site code	Source	Slope	Y-intercept[1]	R^2
Alpine and arctic				
ARC	Stream	-0.001	0.01	0.3
GLA	Precipitation (concentration)	0.003	0.07	0.4
	Wet deposition	0.037	0.75	0.5
LVW	Precipitation (concentration)	0.004	0.07	0.6
	Stream	-0.001	0.02	0.4
	Wet deposition	0.027	0.83	0.4
NWT	Precipitation (concentration)	0.003	0.07	0.2
	Wet deposition	0.075	1.02	0.3
Aridlands				
JRN	Precipitation (concentration)	0.020	0.25	0.7
RCE	Precipitation (concentration)	0.004	0.10	0.2
	Wet deposition	0.010	0.25	0.2
Coastal				
FCE	Coastal water	1.325	0.60	0.7
	Wet deposition	0.032	0.70	0.3
PIE	Precipitation (concentration)	0.002	0.09	0.3
	Wet deposition	0.025	0.94	0.5
Eastern forests				
BEN	Precipitation (concentration)	0.002	0.08	0.3
	Wet deposition	0.055	1.15	0.2
HBR	Stream	-0.0004	0.02	0.4
LUQ	Stream	-0.002	0.04	0.3
SAN	Precipitation (concentration)	0.003	0.06	0.6
	Wet deposition	0.032	0.76	0.5
Temperate grasslands and savannas				
GRL	Precipitation (concentration)	0.003	0.18	0.2
KNZ	Precipitation (concentration)	0.005	0.24	0.4
	Stream	0.002	-0.01	0.6
	Wet deposition	0.051	1.85	0.4
SGS	Precipitation (concentration)	0.008	0.35	0.3
Western forests				
FRA	Precipitation (concentration)	0.003	0.07	0.2
	Wet deposition	0.075	1.02	0.3

[1] Y-intercept was calculated for the first year of a dataset, which contains records of one variable over time for one site.

Appendix 9. Annual average (standard error) sulfur (as sulfate) from various sources at sites with data

(Sites are grouped by ecosystem type. See Appendix 27 for length of record for each station at a site.)

Site code	Precipitation (concentration) *mg/L*	Wet deposition *kg/ha*	Lake *mg/L*	Stream *mg/L*
Alpine and arctic				
ARC	0.08 (0.01)*			
GLA	0.18 (0.01)*	2.15 (0.10)		
LVW	0.18 (0.01)*	1.80 (0.10)*		0.7 (0.03)*
MCM			58 (2.83)	
NWT	0.18 (0.01)*	3.18 (0.17)	2 (0.19)*	
Aridlands				
JRN	0.60 (0.05)	0.04 (0.003)*		
RCE	0.12 (0.01)*	0.30 (0.03)		
WGE	0.24 (0.02)	0.82 (0.09)		
Coastal				
FCE	0.24 (0.004)	3.55 (0.13)*		
PIE	0.60 (0.03)*	6.59 (0.28)*		
VCR	0.62 (0.06)	4.71 (0.52)		
Eastern forests				
BEN	0.38 (0.02)	6.29 (0.45)		
CRO	0.35 (0.01)*	4.81 (0.18)		
CWT	0.40 (0.02)*	6.85 (0.33)*		
FER	0.81 (0.04)*	10.47 (0.60)*		1.5 (0.03)
HBR	0.51 (0.03)*	6.19 (0.32)*		1.8 (0.04)*
HFR	0.51 (0.03)*	6.30 (0.30)*		
LUQ	0.26 (0.01)	8.22 (0.47)		0.7 (0.03)
MAR	0.32 (0.02)*	2.45 (0.14)*		
NTL	0.38 (0.02)*	2.99 (0.22)*	1 (0.03)*	
SAN	0.44 (0.01)	4.95 (0.19)		
TAL	0.33 (0.01)*	4.69 (0.19)*		
WBW	0.69 (0.02)*	8.96 (0.33)*		0.8 (0.02)
Temperate grasslands and savannas				
CDR	0.36 (0.01)	2.63 (0.19)		
GRL	0.37 (0.01)	3.42 (0.12)*		
KBS	0.77 (0.04)*	7.05 (0.46)*		6.6 (0.05)
KNZ	0.41 (0.01)*	3.42 (0.15)*		
SGS	0.33 (0.02)*	1.07 (0.08)*		
Urban				
BES	0.67 (0.03)*	7.28 (0.35)*		8.6 (0.21)
CAP	0.89 (0.27)	5.07 (2.28)		22.6 (2.01)*

Appendix 9. Annual average (standard error) sulfur (as sulfate) from various sources at sites with data—*Continued*

Site code	Precipitation (concentration) *mg/L*	Wet deposition *kg/ha*	Lake *mg/L*	Stream *mg/L*
Western forests				
AND	0.06 (0.002)*	1.20 (0.05)		0.1 (0.003)
BLA	0.05 (0.005)	0.39 (0.04)		
BNZ	0.06 (0.004)	0.23 (0.02)		
CSP	0.08 (0.005)*	0.75 (0.07)*		
FRA	0.18 (0.01)*	3.18 (0.17)		
PRI	0.07 (0.005)	0.54 (0.02)		

* indicates significant slopes ($p < 0.05$) for regression of each variable against time.

Appendix 10. Regression coefficients and R^2 values for sulfur (sulfate) from various sources for which linear regression against time is significant ($p < 0.05$)

(Sites are grouped by ecosystem type. See Appendix 27 for length of record for each station at a site.)

Site code	Source	Slope	Y-intercept[1]	R^2
Alpine and arctic				
ARC	Precipitation (concentration)	-0.007	0.1	0.3
GLA	Precipitation (concentration)	-0.002	0.2	0.3
LVW	Precipitation (concentration)	-0.003	0.2	0.5
	Stream	0.018	0.6	0.4
	Wet deposition	-0.046	2.4	0.5
NWT	Lake	0.091	1.0	0.5
	Precipitation (concentration)	-0.004	0.2	0.6
Aridlands				
JRN	Wet deposition	-0.001	0.1	0.4
RCE	Precipitation (concentration)	-0.003	0.2	0.2
Coastal				
FCE	Wet deposition	0.037	2.9	0.2
PIE	Precipitation (concentration)	-0.015	0.8	0.6
	Wet deposition	-0.127	8.4	0.5
Eastern forests				
CRO	Precipitation (concentration)	-0.003	0.4	0.2
CWT	Precipitation (concentration)	-0.007	0.5	0.4
	Wet deposition	-0.158	9.6	0.6
FER	Precipitation (concentration)	-0.022	1.2	0.7
	Wet deposition	-0.293	15.2	0.6
HBR	Precipitation (concentration)	-0.015	0.8	0.8
	Stream	-0.022	2.2	0.9
	Wet deposition	-0.157	8.8	0.7
HFR	Precipitation (concentration)	-0.017	0.8	0.7
	Wet deposition	-0.135	8.3	0.4
MAR	Precipitation (concentration)	-0.009	0.5	0.7
	Wet deposition	-0.075	3.7	0.7
NTL	Lake	-0.016	1.2	0.7
	Precipitation (concentration)	-0.013	0.6	0.8
	Wet deposition	-0.120	4.8	0.7
TAL	Precipitation (concentration)	-0.005	0.4	0.4
	Wet deposition	-0.050	5.4	0.2
WBW	Precipitation (concentration)	-0.013	0.9	0.7
	Wet deposition	-0.120	10.8	0.3

Appendix 10. Regression coefficients and R^2 values for sulfur (sulfate) from various sources for which linear regression against time is significant ($p < 0.05$)—*Continued*

Site code	Source	Slope	Y-intercept[1]	R^2
Temperate grasslands and savannas				
GRL	Wet deposition	-0.051	4.1	0.3
KBS	Precipitation (concentration)	-0.023	1.1	0.9
	Wet deposition	-0.231	10.8	0.8
KNZ	Precipitation (concentration)	-0.006	0.5	0.6
	Wet deposition	-0.039	4.0	0.2
SGS	Precipitation (concentration)	-0.007	0.4	0.3
	Wet deposition	-0.031	1.6	0.4
Urban				
BES	Precipitation (concentration)	-0.017	0.9	0.7
	Wet deposition	-0.170	8.9	0.4
CAP	Stream	-1.215	29.9	0.4
Western forests				
AND	Precipitation (concentration)	-0.001	0.1	0.3
CSP	Precipitation (concentration)	-0.002	0.1	0.5
	Wet deposition	-0.022	1.1	0.2
FRA	Precipitation (concentration)	-0.004	0.2	0.6

[1] Y-intercept was calculated for the first year of a dataset, which contains records of one variable over time for one site.

Appendix 11. Annual average (standard error) chloride from various sources at sites with data

(Sites are grouped by ecosystem type. See Appendix 27 for length of record for each station at a site.)

Site code	Precipitation (concentration) *mg/L*	Wet deposition *kg/ha*	Lake *mg/L*	Stream *mg/L*
Alpine and arctic				
ARC	0.34 (0.17)			
GLA	0.08 (0.01)*	0.98 (0.09)*		
LVW	0.07 (0.01)*	0.72 (0.08)*		0.2 (0.01)*
MCM			707.6 (61.04)*	
NWT	0.08 (0.01)*	1.38 (0.12)	0.1 (0.01)	
Aridlands				
JRN	0.56 (0.07)	0.02 (0.002)		
RCE	0.10 (0.01)*	0.26 (0.03)*		
WGE	0.12 (0.01)*	0.45 (0.07)		
Coastal				
FCE	0.93 (0.04)	13.62 (0.72)		
PIE	0.61 (0.03)*	6.75 (0.38)		
VCR	3.51 (0.54)	42.19 (6.26)		
Eastern forests				
BEN	0.09 (0.01)	1.52 (0.12)		
CRO	0.25 (0.01)	3.40 (0.19)		
CWT	0.17 (0.01)	2.97 (0.17)*		
FER	0.11 (0.01)*	1.46 (0.08)*		0.5 (0.01)*
HBR	0.16 (0.01)*	1.97 (0.15)		0.5 (0.01)*
HFR	0.23 (0.01)	2.90 (0.19)		
LUQ	2.71 (0.10)	85.16 (4.92)		8.5 (0.11)
MAR	0.07 (0.01)*	0.51 (0.04)*		
NTL	0.07 (0.01)*	0.54 (0.05)*	4.7 (0.29)*	
SAN	0.40 (0.02)	4.56 (0.32)		
TAL	0.24 (0.01)	3.41 (0.17)		
WBW	0.19 (0.01)*	2.54 (0.12)		0.9 (0.03)
Temperate grasslands and savannas				
CDR	0.07 (0.003)	0.50 (0.04)		
GRL	0.18 (0.01)	1.66 (0.13)*		
KBS	0.14 (0.02)	1.29 (0.22)		11.2 (0.13)
KNZ	0.11 (0.004)*	0.92 (0.05)		
SGS	0.09 (0.01)*	0.30 (0.02)*		
Urban				
BES	0.40 (0.03)*	4.16 (0.23)		119.3 (12.20)
CAP	0.89 (0.14)	1.24 (0.20)		386.6 (29.70)

Appendix 11. Annual average (standard error) chloride from various sources at sites with data—*Continued*

Site code	Precipitation (concentration) *mg/L*	Wet deposition *kg/ha*	Lake *mg/L*	Stream *mg/L*
Western forests				
AND	0.31 (0.01)	6.88 (0.43)		1.0 (0.04)
BLA	0.05 (0.003)	0.42 (0.04)*		
BNZ	0.04 (0.003)*	0.16 (0.03)*		
CSP	0.58 (0.04)	5.54 (0.60)		
FRA	0.08 (0.01)*	1.38 (0.12)		
PRI	0.05 (0.003)	0.38 (0.03)		

* indicates significant slopes ($p < 0.05$) for regression of each variable against time.

Appendix 12. Regression coefficients and R^2 values for chloride from various sources for which linear regression against time is significant ($p < 0.05$)

(Sites are grouped by ecosystem type. See Appendix 27 for length of record for each station.)

Site code	Source	Slope	Y-intercept[1]	R^2
Alpine and arctic				
GLA	Precipitation (concentration)	-0.004	0.1	0.7
	Wet deposition	-0.038	1.4	0.4
LVW	Precipitation (concentration)	-0.002	0.1	0.3
	Stream	0.003	0.2	0.4
	Wet deposition	-0.026	1.1	0.3
MCM	Lake	30.382	479.8	0.3
NWT	Precipitation (concentration)	-0.003	0.1	0.5
Aridlands				
RCE	Precipitation (concentration)	-0.004	0.1	0.4
	Wet deposition	-0.010	0.4	0.4
WGE	Precipitation (concentration)	-0.006	0.2	0.5
Coastal				
PIE	Precipitation (concentration)	-0.008	0.7	0.2
Eastern forests				
CWT	Wet deposition	-0.046	3.8	0.2
FER	Precipitation (concentration)	-0.002	0.2	0.6
	Stream	-0.005	0.6	0.4
	Wet deposition	-0.032	2.0	0.5
HBR	Precipitation (concentration)	-0.003	0.2	0.2
	Stream	-0.003	0.5	0.3
MAR	Precipitation (concentration)	-0.003	0.1	0.6
	Wet deposition	-0.022	0.9	0.7
NTL	Lake	0.188	2.2	0.96
	Precipitation (concentration)	-0.002	0.1	0.5
	Wet deposition	-0.022	0.9	0.6
WBW	Precipitation (concentration)	-0.002	0.2	0.2
Temperate grasslands and savannas				
GRL	Wet deposition	-0.043	2.2	0.2
KNZ	Precipitation (concentration)	-0.002	0.1	0.3
SGS	Precipitation (concentration)	-0.003	0.1	0.6
	Wet deposition	-0.011	0.5	0.6
Urban				
BES	Precipitation (concentration)	-0.008	0.5	0.2

Appendix 12. Regression coefficients and R^2 values for chloride from various sources for which linear regression against time is significant ($p < 0.05$)—*Continued*

Site code	Source	Slope	Y-intercept[1]	R^2
Western forests				
BLA	Wet deposition	0.031	0.3	0.5
BNZ	Precipitation (concentration)	-0.002	0.1	0.4
	Wet deposition	-0.013	0.3	0.6
FRA	Precipitation (concentration)	-0.003	0.1	0.5

[1] Y-intercept was calculated for the first year of a dataset, which contains records of one variable over time for one site.

Appendix 13. Annual average (standard error) calcium from various sources at sites with data

(Sites are grouped by ecosystem type. See Appendix 27 for length of record for each station at a site.)

Site code	Precipitation (concentration)	Wet deposition	Lake	Stream
	mg/L	*kg/ha*	*mg/L*	*mg/L*
Alpine and arctic				
ARC	0.19 (0.07)			
GLA	0.20 (0.02)	2.4 (0.21)*		
LVW	0.19 (0.02)	1.8 (0.17)		2 (0.04)*
MCM			79 (3.8)	
NWT	0.20 (0.01)	3.6 (0.37)*	4 (0.2)*	
Aridlands				
JRN	1.36 (0.18)*	0.1 (0.01)		
RCE	0.14 (0.01)*	0.3 (0.03)*		
WGE	0.24 (0.02)	0.8 (0.10)		
Coastal				
FCE	0.13 (0.01)*	1.9 (0.10)		
PIE	0.08 (0.01)	0.8 (0.06)		
VCR	0.16 (0.02)	1.9 (0.22)		
Eastern forests				
BEN	0.04 (0.002)*	0.7 (0.05)*		
CRO	0.11 (0.01)	1.5 (0.08)		
CWT	0.06 (0.004)	1.0 (0.06)*		
FER	0.15 (0.01)*	1.9 (0.13)*		2 (0.03)
HBR	0.06 (0.004)*	0.7 (0.05)*		1 (0.04)*
HFR	0.06 (0.003)	0.7 (0.04)		
LUQ	0.14 (0.005)	4.4 (0.23)		4 (0.13)*
MAR	0.20 (0.01)	1.5 (0.06)*		
NTL	0.19 (0.01)	1.5 (0.08)*	10 (0.2)*	
SAN	0.09 (0.004)	1.0 (0.05)		
TAL	0.09 (0.01)*	1.3 (0.08)*		
WBW	0.11 (0.01)	1.5 (0.06)		24 (0.57)
Temperate grasslands and savannas				
CDR	0.31 (0.02)	2.3 (0.23)		
GRL	0.31 (0.02)	2.7 (0.15)		
KBS	0.22 (0.01)*	2.0 (0.09)*		70 (0.21)
KNZ	0.36 (0.01)	3.0 (0.14)*		
SGS	0.28 (0.02)	0.9 (0.06)		

Appendix 13. Annual average (standard error) calcium from various sources at sites with data—*Continued*

Site code	Precipitation (concentration)	Wet deposition	Lake	Stream
	mg/L	*kg/ha*	*mg/L*	*mg/L*
Urban				
BES	0.08 (0.004)*	0.8 (0.03)	--	--
CAP	1.04 (0.13)	--	--	58 (3.42)
Western forests				
AND	0.03 (0.001)*	0.6 (0.04)	--	3 (0.04)
BLA	0.03 (0.002)	0.2 (0.03)	--	--
BNZ	0.03 (0.002)*	0.1 (0.01)	--	--
CSP	0.03 (0.002)*	0.3 (0.03)	--	--
FRA	0.20 (0.01)	3.6 (0.37)*	--	--
PRI	0.06 (0.004)	0.4 (0.02)	--	--

* Slope is significant ($p < 0.05$) for regression of each variable against time.

Appendix 14. Regression coefficients and R^2 values for calcium from various sources for which linear regression against time is significant ($p < 0.05$)

(Sites are grouped by ecosystem type. See Appendix 27 for length of record for each station at a site.)

Site code	Source	Slope	Y-intercept[1]	R^2
Alpine and arctic				
GLA	Wet deposition	0.064	1.6	0.2
LVW	Stream	0.021	1.7	0.4
NWT	Lake	0.117	2.2	0.5
	Wet deposition	0.110	2.1	0.2
Aridlands				
JRN	Precipitation (concentration)	0.069	0.6	0.3
RCE	Precipitation (concentration)	-0.004	0.2	0.3
	Wet deposition	-0.012	0.5	0.4
Coastal				
FCE	Precipitation (concentration)	-0.002	0.2	0.3
Eastern forests				
BEN	Precipitation (concentration)	0.001	0.03	0.2
	Wet deposition	0.020	0.4	0.3
CWT	Wet deposition	-0.014	1.3	0.2
FER	Precipitation (concentration)	-0.005	0.2	0.6
	Wet deposition	-0.060	2.9	0.6
HBR	Precipitation (concentration)	-0.002	0.1	0.4
	Stream	-0.019	1.4	0.9
	Wet deposition	-0.017	1.0	0.3
LUQ	Stream	0.051	3.8	0.3
MAR	Wet deposition	-0.015	1.7	0.2
NTL	Lake	0.098	8.8	0.8
	Wet deposition	-0.021	1.8	0.2
TAL	Precipitation (concentration)	0.002	0.1	0.3
	Wet deposition	0.030	0.9	0.4
Temperate grasslands and savannas				
KBS	Precipitation (concentration)	-0.003	0.3	0.3
	Wet deposition	-0.031	2.5	0.3
KNZ	Wet deposition	0.044	2.4	0.2
Urban				
BES	Precipitation (concentration)	-0.001	0.1	0.3

Appendix 14. Regression coefficients and R^2 values for calcium from various sources for which linear regression against time is significant ($p < 0.05$)—*Continued*

Site code	Source	Slope	Y-intercept[1]	R^2
Western forests				
AND	Precipitation (concentration)	-0.0004	0.03	0.2
BNZ	Precipitation (concentration)	0.001	0.02	0.5
CSP	Precipitation (concentration)	-0.001	0.04	0.2
FRA	Wet deposition	0.110	2.1	0.2

[1] Y-intercept was calculated for the first year of a dataset, which contains records of one variable over time for one site.

Appendix 15. Human population and economy variables in 2000 for the focal county of each site, as grouped by ecosystem type

Site code	Focal county	Total population	Population density	Urban population	Employment by sector			
					Commercial[1]	Farming[2]	Manufacturing[3]	Service[4]
			#/km²	% total population				
Alpine and arctic								
ARC	North Slope, AK	7,385	0	59	4.6	0.0	-	7.3
GLA	Albany, WY	32,014	3	88	5.7	0.5[2]	1.3	6.1[4]
LVW	Larimer, CO	251,494	37	86	7.1	0.3[2]	3.6	4.7[4]
MCM	-	-	-	-	-	-	-	-
NWT	Boulder, CO	291,288	152	91	8.4	0.1	5.6	6.7
Aridlands								
EOA	Harney, OR	7,609	0	57	4.4	3.8[2]	4.2[3]	2.3[4]
JRN	Dona Ana, NM	174,682	18	80	4.4	0.4	1.1	7.1
RCE	Owyhee, ID	10,644	1	26	3.6	4.6[2]	5.6	1.1[4]
SEV	Socorro, NM	18,078	1	47	2.9	0.8	0.6[3]	7.0
SRE	Pima, AZ	843,746	36	92	6.1	0.1	1.9	4.1[4]
WGE	Santa Cruz, AZ	38,381	12	68	11.3	0.3[2]	1.9[3]	3.8[4]
Coastal								
CCE	San Diego, CA	2,813,833	259	96	6.3	0.1	2.7	7.1
FCE	Miami-Dade, FL	2,253,362	447	99	8.4	0.1	2.3	6.9
GCE	McIntosh, GA	10,847	10	26	7.2	0.1	3.3[3]	7.2
MCR	-	-	-	-	-	-	-	-
PAL	-	-	-	-	-	-	-	-
PIE	Essex, MA	723,419	558	95	7.0	0.0	5.1	6.6
SBC	Santa Barbara, CA	399,347	56	95	6.0	0.3	2.1	7.7
VCR	Northampton, VA	13,093	24	-	4.5	0.7	10.7[3]	7.9

Appendix 15. Human population and economy variables in 2000 for the focal county of each site, as grouped by ecosystem type—*Continued*

Site code	Focal county	Total population	Population density	Urban population	Employment by sector			
					Commercial[1]	Farming[2]	Manufacturing[3]	Service[4]
			#/km²	*% total population*				
Eastern forests								
BEN	Buncombe, NC	206,330	122	71	6.7	0.1	7.8[3]	7.6
CRO	Ashley, AR	24,209	10	49	4.0	0.7[2]	13.4	1.2[4]
CWT	Macon, NC	29,811	22	19	6.6	0.2	4.1	6.7
FER	Tucker, WV	7,321	7	-	3.6	0.4	5.2[3]	9.1
HAR	Harrison, MS	189,601	126	79	6.9	0.1[2]	1.9	5.3[4]
HBR	Grafton, NH	81,743	18	35	8.9	0.2	6.4	8.3
HFR	Worcester, MA	750,963	192	81	6.5	0.1	5.3	6.8
LUQ	Rio Grande, PR	52,362	333	96	1.7	-	2.8	4.6
MAR	Itasca, MN	43,992	6	19	6.4	0.4[2]	4.5	3.2[4]
NTL	Dane, WI	426,526	137	85	9.8	0.4	4.6	7.4
SAN	Berkeley, SC	142,651	50	66	3.1	0.1[2]	3.3	1.7[4]
TAL	Lafayette, MS	38,744	24	50	6.0	0.4[2]	4.5	4.5[4]
WBW	Roane, TN	51,910	56	51	4.3	0.4[2]	3.2	2.1[4]
Temperate grasslands and savannas								
CDR	Anoka, MN	298,084	271	86	6.4	0.1	6.0	6.6
FTK	Custer, MT	11,696	1	83	7.8	2.2[2]	0.9[3]	5.4[4]
GRL	Grady, OK	45,516	16	34	4.7	1.8[2]	5.4	2.2[4]
GSW	Bell, TX	237,974	87	82	4.6	0.3[2]	2.6	3.0[4]
KBS	Kalamazoo, MI	238,603	164	80	9.3	0.1	6.7	7.9
KNZ	Riley, KS	62,843	40	85	6.0	0.6	0.7	8.8
SGS	Weld, CO	180,936	18	72	5.4	0.9	4.7	7.1
SPR	Woodward, OK	18,486	6	60	7.6	2.1[2]	2.1	3.3[4]
Urban								
BES	Baltimore City, MD[5]	651,154	3,104	100	5.5	0.0	3.2	7.9
CAP	Maricopa, AZ	3,072,149	129	97	7.4	0.1	3.2	6.8

Appendix 15. Human population and economy variables in 2000 for the focal county of each site, as grouped by ecosystem type—*Continued*

Site code	Focal county	Total population	Population density	Urban population	Employment by sector			
					Commercial[1]	Farming[2]	Manufacturing[3]	Service[4]
			#/km²	*% total population*				
Western forests								
AND	Lane, OR	322,959	27	81	7.8	0.2	4.6	7.6
BLA	Lassen, CA	33,828	3	41	3.2	0.6[2]	2.1[3]	2.3[4]
BNZ	Fairbanks North Star, AK	82,840	4	70	6.4	0.1	0.4[3]	6.5
CHE	Tillamook, OR	24,262	9	24	4.9	1.2[2]	4.5	4.6[4]
CSP	Mendocino, CA	86,265	10	54	6.7	0.7[2]	3.8	4.3[4]
FRA	Grand, CO	12,442	3	0	6.8	1.1[2]	1.1[3]	12.3
PRI	Bonner, ID	36,835	8	23	7.6	0.8[2]	4.6	4.1[4]
WIN	Skamania, WA	9,872	2	0[6]	1.5	0.3[2]	4.6[3]	2.4[4]

[1] Data from 1997. The 1997 total population size is interpolated from long-term data for the county.

[2] With footnote, data are from 1992; without footnote, data are from 2000. The 1992 total population size is interpolated from long-term data for the county.

[3] With footnote, data are from 1992; without footnote, data are from 1997. The 1992 and 1997 total population sizes are interpolated from long-term data for the county.

[4] With footnote, data are from 1997; without footnote, data are from 2000. The 1997 total population size is interpolated from long-term data for the county.

[5] The focal county is Baltimore City, not Baltimore County.

[6] Percentage of urban population in 1990, not 2000.

- No available data.

Appendix 16. Annual average (standard error) aboveground net primary production (ANPP) at sites with data

(Multiple stations are given if possible. Sites are grouped by ecosystem type. See appendix 28 for length of record for each station.)

Site code	Station	ANPP[1]
Alpine and arctic		
ARC	Control ANPP plots	156 (20)
	Nitrogen-fertilized ANPP plots	306 (33)*
NWT	Dry meadow plots at Saddle Location	204 (13)*
	Moist meadow plots at Saddle Location	208 (8)*
	Wet meadow plots at Saddle Location	171 (8)*
Aridlands		
JRN	Creosote Study Sites	84 (6)
	Grassland Study Sites	130 (17)*
	Mesquite Study Sites	113 (20)*
	Playa Study Sites	204 (36)
	Tarbush Study Sites	79 (8)
SEV	Blue Grama Study Site	83 (17)
	Five-Points Grass Study Site	93 (21)*
	Five-Points *Larrea* Study Site	63 (6)
Coastal		
PIE	*Spartina alterniflora*-dominated salt marsh at Law's Point, Rowley River, Plum Island Environment, MA	725 (137)
	Spartina patens-dominated salt marsh at Law's Point, Rowley River, Plum Island Environment, MA	1183 (92)
	Spartina alterniflora-dominated salt marsh at Goat Island, North Inlet, Georgetown, SC	913 (58)*
Eastern forests		
HBR	Unknown	705 (8)*
HFR	Little Prospect Hill at Harvard Forest, trees only; unit: Mg carbon/ha	3 (0.2)
Temperate grasslands and savannas		
CDR	Unknown	277 (22)*
FTK	Lysimeter 1	430 (83)
	Lysimeter 8	231 (29)
	Treatment 8, never plowed, 200 m south of the others, serves as a historical control for soil organic matter studies	302 (44)
	Treatment SF, old field successional community, never tilled	197 (19)*
KBS	Treatment 7, native successional treatment, abandoned after spring plowing in 1989	501 (39)*

Appendix 16. Annual average (standard error) aboveground net primary production (ANPP) at sites with data—*Continued*

Site code	Station	ANPP[1]
KNZ	Watershed 020b, burned every 20 years, on shallow Florence soils	338 (15)
	Watershed 020b, burned every 20 years, on deep Tully soils	424 (19)
SGS	ESA Control 1	92 (7)*
	Owl Creek, coarse texture soil	104 (11)*
	Sec 25, fine texture soil	62 (7)
Western forests		
AND	Reference Stand 2, tree boles only	326 (47)
	Reference Stand 29. tree boles only	566 (96)
BNZ	Unknown	300 (16)

[1] Unit is g/m^2 unless otherwise specified.

* Linear regression of the variable against time is significant ($p < 0.05$) and the trend appears linear.

Appendix 17. Other measures of average (standard error) terrestrial production at sites with data
(Multiple stations are given if possible. Sites are grouped by ecosystem type. See Appendix 28 for length of record for each station.)

Site code	Variable	Station	Terrestrial production
Eastern forests			
BEN	DBH[1] (cm)	Mixed hardwood plots	28 (1)
		Yellow Poplar plots	40 (2)
CRO	Production volume (m^3/ha), pine	Clearcut logging stands	184 (55)
		Diameter limit logging stands	183 (40)
		Heavy seedtree logging stands	200 (50)
		Selection logging stands	154 (31)
	Seed production (#/ha), pine	Unknown	
	Viable seed		1175 (307)
	Void		641 (127)
	Total		1816 (429)
HAR	DBH (cm), *Pinus palustris*	North plantation	15 (5)
		South plantation	16 (5)
	Height (m), *P. palustris*	North plantation	11 (5)
		South plantation	11 (5)
HBR	DBH (cm)	Vegetation zones 2 and 3 at watershed 6	16 (1)
		Vegetation zone 5 at watershed 6	20 (2)
		Vegetation zone 4 at watershed 6	18 (1)
		Vegetation zone 1 at watershed 6	15 (1)
HFR		Lyford Blocks within the Prospect Hill Tract	15 (0.4)
Western forests			
CHE	DBH (cm)	HSGY Study Plots	
	Picea sitchensis		71 (2)
	Pseudotsuga menziesii		59 (2)*
	Tsuga heterophylla		34 (4)

[1] DBH: diameter at breast height of trees.
* indicates that the linear regression of the variable against time is significant ($p < 0.05$) and the trend appears linear.

Appendix 18. Average (standard error) aquatic production at sites with data

(Multiple stations are given if possible. Sites are grouped by ecosystem type. See Appendix 28 for length of record for each station.)

Site code	Variable	Station	Aquatic production
Alpine and arctic			
ARC	Chlorophyll a (mg/m^2)	Fertilized reach of Kuparuk River	13 (4)
		Reference reach of Kuparuk River	3 (0.4)
	Chlorophyll a (µg/L)	Toolik Lake	1 (0.1)
MCM	Primary production (g carbon/m^2/yr)	East Lake Bonney	5 (0.3)
		West Lake Bonney	8 (1)
Coastal			
CCE	Chlorophyll a (µg/L)	Ohman Region: subset of CalCOFI stations inshore and nearshore in the Southern California Bight region; CalCOFI lines 80-93, stations from shore offshore to station 70	1 (0.1)*
	Primary production (g carbon/m^2/yr)	Ohman Region: subset of CalCOFI stations inshore and nearshore in the Southern California Bight region; CalCOFI lines 80-93, stations from shore offshore to station 70	363 (4)
FCE	Net primary production (g carbon/m^2/yr)	Shark River Slough sites 1, 2, and 3, Epiphyton substrate	40 (11)
		Shark River Slough sites 1, 2, and 3, Mat substrate	72 (25)
		Shark River Slough sites 1, 2, and 3, Periphyton substrate	49 (15)
MCR	Chlorophyll a (µg/L)	SeaWiFS data for Moorea Coral Reef Vicinity, area for chlorophyll and SST data	21 (1)
PAL	Chlorophyll a (mg/m^2)	Palmer Station B	123 (24)
	Primary production (g carbon/m^2/yr)	Palmer Station	169 (21)
Eastern forests			
NTL	Primary production, hypsometrically weighted (g carbon/m^2/yr)	Crystal Lake, epilimnion	30 (3)
		Sparkling Lake, epilimnion	32 (3)
		Trout Lake, epilimnion	45 (4)

* Linear regression of the variable against time is significant ($p < 0.05$) and the trend appears linear.

Appendix 19. Average (standard error) biomass of primary producers (plants, algae) for sites with data

(Multiple stations are given if possible. Sites are grouped by ecosystem type. See Appendix 28 for length of record for each station.)

Site code	Taxon	Station	Biomass[1]
Alpine and arctic			
ARC		Tussock Tundra 1981 Plots,	
	Betula nana (Dwarf birch)	control	81 (18)
		fertilized	410 (146)
	Eriophorum vaginatum	control	56 (12)
	(Tussock cottongrass)	fertilized	55 (27)
	Ledum palustre	control	79 (6)
	(Marsh labrador tea)	fertilized	48 (13)
	Vaccinium vitis-idaea	control	72 (7)
	(Lingonberry)	fertilized	23 (12)
Coastal			
FCE	Periphyton (algae)	Shark River Slough sites 1, 2, and 3,	
		Epiphyton substrate	9 (3)*
		Mat substrate	18 (2)
		Periphyton substrate	8 (2)
GCE	Plants	High Marsh site	4245 (238)
		Zone 1, Creek Bank	5984 (972)
PIE	*Spartina* spp. (Cordgrass)	*Spartina alterniflora*-dominated salt marsh at Goat Island, North Inlet, Georgetown, SC	547 (46)*
		Spartina alterniflora-dominated salt marsh at Law's Point, Rowley River, PIE, MA	560 (69)
		Spartina patens-dominated salt marsh at Law's Point, Rowley River, PIE, MA	1023 (87)
SBC	*Macrocystis pyrifera* (Kelp)	Arroyo Burro Reef, Santa Barbara Channel	185 (123)
		Arroyo Quemado Reef, Santa Barbara Channel	508 (90)
		Mohawk Reef, Santa Barbara Channel	530 (134)
VCR	Plants	Randomly selected, destructively sampled, non-treated plots at	
		Frank Day Well Location R2, Hog Island	112 (15)
		Frank Day Well Location R3, Hog Island	141 (27)
		Frank Day Well Location R4, Hog Island	139 (16)
Eastern forests			
HBR	Plants (kg/625 m^2)	Vegetation zone 1 at watershed 6	110 (15)
		Vegetation zone 4 at watershed 6	258 (29)
		Vegetation zone 5 at watershed 6	338 (37)
		Vegetation zones 2 and 3 at watershed 6	172 (20)
NTL	Aquatic plants	Trout Lake	39 (5)

Appendix 19. Average (standard error) biomass of primary producers (plants, algae) for sites with data—*Continued*

Site code	Taxon	Station	Biomass[1]	
Temperate grasslands and savannas				
CDR	Plants	Old Fields 24, 4, 41, 28	118	(7)
		Old Fields 72, 35, 45, 5	130	(8)
		Old Fields 77, 70, 26, 53	134	(9)
SPR	Forbs	Watershed 1	76	(7)
	Grass	Watershed 1	172	(17)
Western forests				
AND	Tree boles (kg/m^2)	Reference Stand 2	62	(6)
		Reference Stand 29	106	(3)

[1] The unit is g/m^2 if not specified.

* Linear regression of the variable against time is significant ($p < 0.05$) and the trend appears linear.

Appendix 20. Average (standard error) plant species richness for sites with data

(Multiple stations are given if possible. Sites are grouped by ecosystem type. See Appendix 28 for length of record for each station.)

Site code	Station	Richness[1]	Sampling area
Aridlands			
JRN	Creosote Study Sites	4(0.4)	1 m^2
		23(1.8)	49 m^2
	Grassland Study Sites	5(0.6)	1 m^2
		35(2.1)	49 m^2
	Mesquite Study Sites	3(0.3)	1 m^2
		17(1.5)	49 m^2
	Playa Study Sites	3(0.2)	1 m^2
		11(0.7)	49 m^2
	Tarbush Study Sites	4(0.2)	1 m^2
		21(1.6)	49 m^2
SEV	Blue Grama Study Site	10(0.8)	1 m^2
		53(2.6)	40 m^2
	Five-Points Grass Study Site	7(0.6)	1 m^2
		32(2.5)	40 m^2
	Five-Points *Larrea* Study Site	6(0.5)	1 m^2
		32(2.2)	40 m^2
SRE	Burned treatment: pasture 21	7(0.8)	9.3 m^2
	Control treatment: pastures 8 and 22	9(1.1)	9.3 m^2
	Pastures that were grazed and burned: pastures 2N and 6A	7(0.3)	9.3 m^2
	Pastures where the existing mesquite were killed and the pastures were grazed:pastures 3, 5N, 5S, 6B and 12B	8(0.5)	9.3 m^2
	Pastures where the mesquite were killed and the pastures were burned: pasture 2S	6(0.5)	9.3 m^2
WGE	Grass and scattered shrub vegetation zone	10(1.6)	30.5 m^2
	Grass vegetation zone	9(0.9)	30.5 m^2
	Shrubs and sparse grass vegetation zone	9(0.9)	30.5 m^2
	Shrubs with grass vegetation zone	9(0.6)	30.5 m^2
Eastern forests			
NTL	Site 31, Channel Mouth Island	5(0.8)	1.25 m^2
	Site 50, Southwest Bay of South Trout Lake	12(1.2)	1.25 m^2
	Site 56, Mouth of Mann Creek	11(1.1)	1.25 m^2
	Site 7, Rocky Reef Bay	3(0.6)	1.25 m^2
	Trout Lake	15(1.2)	5 m^2

Appendix 20. Average (standard error) plant species richness for sites with data—*Continued*

Site code	Station	Richness[1]	Sampling area
Temperate grasslands and savannas			
CDR	Old Fields 24, 4, 41, 28	5(0.2)	0.3 m^2
		17(0.5)	1.2 m^2
	Old Fields 72, 35, 45, 5	5(0.1)	0.3 m^2
		17(0.4)	1.2 m^2
	Old Fields 77, 70, 26, 53	5(0.1)	0.3 m^2
		21(0.6)	1.2 m^2
KBS	Treatment 7, native successional treatment, abandoned after spring plowing in 1989	11(0.5)	1 m^2
	Treatment 8, never plowed, 200 meters (m) south of the others, that serves as an historical control for soil organic matter studies	8(0.6)	1 m^2
	Treatment SF, old field successional community, never tilled	11(0.5)	1 m^2
Western forests			
AND	Watershed 1	119(3.6)	250 m^2
	Watershed 3	73(3.3)	250 m^2

[1] Unit is number of species per sampling area.

Appendix 21. Average (standard error) animal abundance for sites with data

(Multiple stations are given if possible. Sites are grouped by ecosystem type. See Appendix 28 for length of record for each station.)

Site code	Taxon	Station	Abundance		Unit
Aridlands					
JRN	Leporidae	Rabbit survey route in creosote vegetation zone	6	(1.1)*	#/10 km road
		Rabbit survey route in grassland vegetation zone	43	(5.6)*	#/10 km road
	Rodentia	Rodent trapping web in creosote vegetation zone	41	(4.7)	#/3.14 ha trapping web
		Rodent trapping web in grassland vegetation zone	43	(6.6)	#/3.14 ha trapping web
SEV	Rodentia	Five-Points Grass Study Site	26	(3.3)	#/trapping web
		Five-Points *Larrea* Study Site	47	(6.2)	#/trapping web
Coastal					
GCE	Orthoptera	Study Site 1, Eulonia, GA	2	(0.5)	#/20 m^2
		Study Site 3, North Sapelo, Sapelo Island, GA	1	(0.2)	#/20 m^2
		Study Site 6, Dean Creek, Sapelo Island, GA	4	(1.3)	#/20 m^2
MCR	Fish	MRB Lagoon research site	71	(17.1)*	#/m^3 coral
PAL	*Pygoscelis adeliae*	Palmer Station	8936	(780.4)	# breeding pairs
	P. antarcticus	Palmer Station	202	(16.3)*	# breeding pairs
PAL	*P. papua*	Palmer Station	491	(125.5)	# breeding pairs
VCR	Muridae	Hog Island Rodent Trapping Transect 1	6	(0.7)	#/trapping transect
		Hog Island Rodent Trapping Transect 4	3	(0.2)	#/trapping transect
		Hog Island Rodent Trapping Transect 5	3	(0.3)*	#/trapping transect
Eastern forests					
HBR	Aves	10-hectare bird count plot	123	(7.2)*	#/10 ha
	Lepidoptera	on *Acer saccharum*	18	(2.2)	#/4000 leaves
		on *Fagus grandifolia*	12	(2.0)	#/4000 leaves
LUQ	Aves	El Verde	3	(0.2)	# counted outside a 25 m -radius circle
			4	(0.1)*	# counted inside a 25 m -radius circle
	Caridea	El Verde Study Area, Pool 0, Quebrada Prieta	56	(3.5)*	#/pool
		Pool 15 in Quebrada Prieta (upstream pool)	70	(7.5)*	#/pool
		Pool 8 in Quebrada Prieta	46	(6.9)	#/pool

Appendix 21. Average (standard error) animal abundance for sites with data—*Continued*

Site code	Taxon	Station	Abundance		Unit
	Eleutherodactylus coqui	El Verde New Plot	19	(3.3)	#/400 m^2
		El Verde Old Plot	22	(3.1)	#/400 m^2
	Gastropoda	Luquillo Forest Dynamics Plot at El Verde	993	(173.0)	#/1130 m^2
NTL	Orconectes	Big Muskellunge Lake	21	(5.6)	# caught/unit effort
		Lake Mendota	0.003	(0.002)	# caught/unit effort
		Sparkling Lake	7	(0.9)	# caught/unit effort
		Trout Lake	59	(13.9)	# caught/unit effort
	Fish	Crystal Lake	510	(73.9)*	# caught/unit effort
		Sparkling Lake	265	(26.4)*	# caught/unit effort
		Trout Lake	646	(61.4)*	# caught/unit effort
Temperate grasslands and savannas					
CDR	Orthoptera	Cedar Creek	149	(23.3)	#/200 sweeps of an insect net
KBS	Neoptera	Treatment 1, standard levels of chemical inputs, conventional chisel plowed tillage	77	(12.2)	# adults/yellow sticky trap
		Treatment 2, standard levels of chemical inputs, no tillage	73	(11.8)	# adults/yellow sticky trap
		Treatment 3, organic-based low chemical input (banded herbicide, starter N), winter leguminous crop, annual tillage and post-planting cultivation	62	(10.4)	# adults/yellow sticky trap
		Treatment 4, certified organic, no chemical inputs, annual tillage, rotary-hoed to control weeds	66	(10.2)	# adults/yellow sticky trap
		Treatment 5, poplar trees (fallow 2008), planted on a 10-year rotation cycle	69	(10.4)	# adults/yellow sticky trap
		Treatment 6, continuous alfalfa (wheat 2008)	76	(10.7)	# adults/yellow sticky trap
		Treatment 7, native successional treatment, abandoned after spring plowing in 1989	88	(11.8)	# adults/yellow sticky trap
		Treatment 7, native successional treatment, abandoned after spring plowing in 1989	88	(11.8)	# adults/yellow sticky trap

Appendix 21. Average (standard error) animal abundance for sites with data—*Continued*

Site code	Taxon	Station	Abundance		Unit
KNZ	Mammalia	Watershed 001d	8	(1.1)	#/transect line/4-day trapping season
		Watershed 004b	12	(1.3)	#/transect line/4-day trapping season
	Orthoptera	Watershed 001d	346	(54.3)*	#/200 sweeps of an insect net
		Watershed 004b	374	(114.8)*	#/200 sweeps of an insect net
		Watershed 020b	126	(25.2)	#/200 sweeps of an insect net
SGS	Aves	USGS Bird Breeding Survey area 17901, Rockport, CO	20	(1.7)	#/sighting effort
		USGS Breeding Bird Survey Route 17305, Nunn, CO	32	(0.9)	#/sighting effort
Urban					
CAP	Araneae (spiders)	Agricultural study sites	0.4	(0.1)	#/pitfall trap
		Desert study sites	0.2	(0.03)	#/pitfall trap
		Urban study sites	0.4	(0.1)	#/pitfall trap
	Orthoptera	Agricultural study sites	0.4	(0.2)	#/pitfall trap
		Desert study sites	0.2	(0.05)	#/pitfall trap
		Urban study sites	1	(0.1)	#/pitfall trap
Western forests					
AND	*Oncorhynchus clarkii*	Clearcut section of Mack Creek	108	(6.1)	#/50 m reach of stream
		Old growth section of Mack Creek	91	(5.7)	#/50 m reach of stream

* indicates that the linear regression of the variable against time is significant ($p < 0.05$) and the trend appears linear.

Appendix 22. Average (standard error) animal species richness for sites with data

(Multiple stations are given if possible. Sites are grouped by ecosystem type. See Appendix 28 for length of record for each station.)

Site code	Taxon	Station	Richness[1]	Sampling area/effort
Coastal				
FCE	Osteichthyes	Shark Slough	12 (0.5)	Unknown
		Taylor Slough	10 (0.7)	Unknown
MCR	Fish	North Shore region (7 research sites)	67 (2.0)*	Unknown
Eastern forests				
HBR	Aves	10-ha bird count plot	22 (0.5)*	10 ha
NTL	Fish	Crystal Lake	8 (0.3)*	Unit effort
		Sparkling Lake	14 (0.4)	Unit effort
		Trout Lake	23 (0.4)	Unit effort
Temperate grasslands and savannas				
CDR	Orthoptera	Cedar Creek	10 (0.5)*	200 sweeps of an insect net
KNZ	Orthoptera	Watershed 001d	11 (1.2)	200 sweeps of an insect net
		Watershed 004b	11 (1.2)	200 sweeps of an insect net
		Watershed 020b	13 (1.1)	200 sweeps of an insect net
SGS	Aves	USGS Bird Breeding Survey area 17901, Rockport, CO	22 (0.6)	Sighting effort
		USGS Breeding Bird Survey Route 17305, Nunn, CO	32 (0.9)	Sighting effort

[1] Unit is number of species per sampling area or effort.
* Linear regression of the variable against time is significant ($p < 0.05$) and the trend appears linear.

Appendix 23. Regression coefficients and R^2 values for plant and animal variables for which linear regression of each variable against time is significant ($p < 0.05$) and the trend appears linear

(Sites are grouped by ecosystem type. See Appendix 28 for length of record for each station.)

Site code	Variable	Station	Slope	Y-intercept[1]	R^2
Alpine and arctic					
ARC	Aboveground net primary production	Nitrogen-fertilized ANPP plots	9.5	218.1	0.9
NWT	Aboveground net primary production	Dry meadow plots at Saddle site	-6.0	251.6	0.4
		Moist meadow plots at Saddle site	-3.8	238.4	0.4
		Wet meadow plots at Saddle site	5.0	131.4	0.6
Aridlands					
JRN	Aboveground net primary production	Grassland Plots	8.3	46.6	0.4
		Mesquite Plots	10.1	12.0	0.4
	Animal abundance, Leporidae	Rabbit survey route in creosote vegetation zone	-0.7	11.2	0.5
		Rabbit survey route in grassland vegetation zone	-3.7	69.2	0.5
SEV	Aboveground net primary production	Five-Points Grass Study Site	18.7	-10.5	0.7
Coastal					
CCE	Chlorophyll a	Ohman Region: subset of CalCOFI stations inshore and nearshore in the Southern California Bight region; CalCOFI lines 80-93, stations from shore offshore to station 70	0.02	0.6	0.3
FCE	Biomass, periphyton	Shark River Slough sites 1, 2, and 3, Epiphyton substrate	2.7	-1.7	0.6
MCR	Animal abundance, fish	MRB Lagoon research site	-17.5	158.9	0.9
	Animal species richness, fish	North Shore region (7 research sites)	1.6	58.8	0.5
PAL	Animal abundance, *Pygoscelis antarcticus*	Palmer Station	6.7	61.2	0.6
PIE	Aboveground net primary production	Spartina alterniflora-dominated salt marsh at Goat Island, North Inlet, Georgetown, SC	26.1	625.5	0.4
	Plant biomass	Spartina alterniflora-dominated salt marsh at Goat Island, North Inlet, Georgetown, SC	15.4	371.9	0.3
VCR	Animal abundance, Muridae	Hog Island Rodent Trapping Transect 5	-0.2	5.0	0.5

Appendix 23. Regression coefficients and R^2 values for plant and animal variables for which linear regression of each variable against time is significant ($p < 0.05$) and the trend appears linear—*Continued*

Site code	Variable	Station	Slope	Y-intercept[1]	R^2
Eastern forests					
HBR	Aboveground net primary production	Unknown	7.4	663.5	0.8
	Animal abundance, Aves	10-hectare bird count plot	-3.5	188.6	0.7
	Animal species richness, Aves	10-hectare bird count plot	-0.2	26.2	0.5
LUQ	Animal abundance, Aves	El Verde	-0.05	4.7	0.3
	Animal abundance, Caridea	El Verde Study Area, Pool 0, Quebrada Prieta	-1.1	68.9	0.2
		Pool 15 in Quebrada Prieta (upstream pool)	3.8	27.8	0.5
NTL	Animal abundance, fish	Crystal Lake	30.6	67.0	0.4
		Sparkling Lake	11.1	103.9	0.4
		Trout Lake	23.6	303.6	0.4
	Animal species richness, fish	Crystal Lake	0.1	6.9	0.1
Temperate grasslands and savannas					
CDR	Aboveground net primary production	Unknown	11.1	177.4	0.4
	Animal species richness, Orthoptera	Cedar Creek	-0.3	12.4	0.4
KBS	Aboveground net primary production	Treatment 7, native successional treatment, abandoned after spring plowing in 1989	21.9	314.8	0.5
		Treatment SF, old field successional community, never tilled	-9.9	275.4	0.4
KNZ	Animal abundance, Orthoptera	Watershed 001d	-17.5	554.5	0.3
		Watershed 004b	-32.1	756.0	0.2
SGS	Aboveground net primary production	ESA Control 1	-2.9	128.1	0.3
		Owl Creek, coarse texture soil	-4.6	144.8	0.3
Western forests					
AND	Animal abundance, fish	Old growth section of Mack Creek	2.4	67.1	0.3
CHE	Diameter at breast height, *Pseudotsuga menziesii* (Douglas fir)	HSGY Study Plots	1.0	50.7	1.0

[1] Y-intercept was calculated for the first year of a dataset, which contains records of one variable over time for one site.

Appendix 24. Lead principal investigators (PI) with information managers (IM) and administrative program of the LTER programs

Site code	Title	Name[1]	Affiliation[2]	Administrative program
AND	PI	Barbara Bond	Oregon State University	Oregon State University
	IM	Donald Henshaw	USFS Pacific Northwest Research Station	
ARC	PI	John E. Hobbie	Ecosystems Center,	Marine Biological Laboratory
	IM	James Laundre	Marine Biological Laboratory	
BES	PI	Steward T. A. Pickett	Cary Institute of Ecosystem Studies	Cary Institute of Ecosystem Studies
	IM	Jonathan Walsh		
BNZ	PI	F. Stuart Chapin	University of Alaska, Fairbanks	University of Alaska, Fairbanks
	IM	Jason Downing (C)		
	IM	Brian Riordan (P)		
CAP	PI	Nancy B. Grimm	Arizona State University	Arizona State University
	IM	Philip Tarrant		
		Corinna Gries		
CCE	PI	Mark D. Ohman	Scripps Institution of Oceanography	University of California at San Diego
	IM	Karen Baker	University of California at San Diego	
CDR	PI	G. David Tilman	University of Minnesota	University of Minnesota
	IM	Dan Bahauddin (C)		
		Stephanie Lyon (P)		
CWT	PI	Ted L. Gragson	University of Georgia	University of Georgia
	IM	John Chamblee (C)		
		Barrie Collins (P)		
FCE	PI	Evelyn E. Gaiser (C)	Florida International University	Florida International University
		Dan Childers (P)		
	IM	Linda Powell		

Appendix 24. Lead principal investigators (PI) with information managers (IM) and administrative program of the LTER programs—*Continued*

Site code	Title	Name[1]	Affiliation[2]	Administrative program
GCE	PI	Merryl Alber (C)	University of Georgia	University of Georgia
		Steve Pennings (P)	University of Houston	
	IM	Wade Sheldon	University of Georgia	
HBR	PI	Charles T. Driscoll	Syracuse University	Cornell University
	IM	John Campbell	USFS Northern Research Station	
HFR	PI	David R. Foster	Harvard University	Harvard University
	IM	Emery Boose		
JRN	PI	Debra P. C. Peters	USDA ARS Jornada Experimental Range	New Mexico State University
	IM	Ken Ramsey	New Mexico State University	
KBS	PI	G. Philip Robertson	Michigan State University	Michigan State University
	IM	Sven Bohm		
KNZ	PI	John M. Blair	Kansas State University	Kansas State University
	IM	Adam Skibbe (C)		
		Jincheng Gao (P)		
LUQ	PI	Nicholas V. L. Brokaw	University of Puerto Rico, Rio Piedras	University of Puerto Rico, Rio Piedras
	IM	Eda Melendez-Colom		
MCM	PI	Diane McKnight (C)	University of Colorado	Ohio State University
		William B. Lyons (P)	Ohio State University	
		Andrew Fountain (P)	Portland State University	
	IM	Susan A. Welch (C)	Ohio State University	
	IM	Chris Gardner (P)	Ohio State University	

Appendix 24. Lead principal investigators (PI) with information managers (IM) and administrative program of the LTER programs—*Continued*

Site code	Title	Name[1]	Affiliation[2]	Administrative program
MCR	PI	Russell J. Schmitt	University of California at Santa Barbara	University of California at Santa Barbara
	IM	Mary Gastil-Buhl (C)		
		Sabine Grabner (P)		
NTL	PI	Emily Stanley (C)	University of Wisconsin, Madison	University of Wisconsin, Madison
		Stephen R. Carpenter (P)		
	IM	Corinna Gries (C)		
		David Balsiger (P)		
		Barbara Benson (P)		
NWT	PI	Mark W. Williams	University of Colorado	University of Colorado
	IM	Hope Humphries (C)		
		Todd Ackerman (P)		
PAL	PI	Hugh W. Ducklow	Ecosystems Center, Marine Biological Laboratory	Marine Biological Laboratory
	IM	Karen Baker	University of California at San Diego	
PIE	PI	Anne Giblin (C)	Ecosystems Center, Marine Biological Laboratory	Marine Biological Laboratory
		Charles S. Hopkinson (P)		
	IM	Hap Garritt		
SBC	PI	Daniel C. Reed	University of California at Santa Barbara	University of California at Santa Barbara
	IM	Margaret O'Brien		
SEV	PI	Scott L. Collins (C)	University of New Mexico	University of New Mexico
		Jim Gosz (P)		
	IM	Kristin Vanderbilt		

Appendix 24. Lead principal investigators (PI) with information managers (IM) and administrative program of the LTER programs—*Continued*

Site code	Title	Name[1]	Affiliation[2]	Administrative program
SGS	PI	John Moore (C)	Colorado State University	Colorado State University
		Michael Antolin (P)		
		Eugene F. Kelly (P)		
	IM	Nicole Kaplan		
VCR	PI	Karen J. McGlathery	University of Virginia	University of Virginia
	IM	John Porter		

[1] C = Current PI or IM; P = Previous PI or IM.

[2] Affiliation when active in EcoTrends; may not represent current affiliation.

Appendix 25. Researchers involved in the EcoTrends project at non-LTER sites.

Site code	Title	Name	Affiliation[1, 2]
BEN	Project Leader	David Loftis	USFS Southern Research Station
	Lead Forestry Technician	Tracy Roof	
BLA	Vegetation Dynamics Team Leader	Martin Ritchie	USFS Pacific Southwest Research Station
	Forestry Technician	Brian Wing	
CHE	Wildlife Biologist/Research Natural Areas Coordinator	Todd Wilson	USFS Pacific Northwest Research Station
	Forester (retired)	Sarah Greene	
	Senior Faculty Research Assistant (former)	Howard Bruner	
CRO	Supervisory Ecologist and Project Leader	Jim Guldin	USFS Southern Research Station
CSP	Project Leader	Thomas Lisle	USFS Pacific Southwest Research Station Redwood Sciences Laboratory
	Mathematical Statistician (retired)	Jack Lewis	
EOA	Research Leader	Tony Svejcar	USDA ARS Eastern Oregon Agricultural Research Center
	Range Technician	Clare Pouslon	
FER	Supervisory Soil Scientist	Mary Beth Adams	USFS Northern Research Station
	Information Technology Specialist	Frederica Wood	
FRA	Research Hydrologist	Kelly Elder	USFS Rocky Mountain Research Station
FTK	Research Leader	Mark Petersen	USDA ARS Fort Keogh Livestock and Range Research Laboratory
	Research Leader (retired)	Rod Heitschmidt	
	Rangeland Scientist	Jennifer Muscha	
GLA	Plant physiologist	Bob Musselman	USFS Rocky Mountain Research Station
	Air and Water Quality Specialist	John Korfmacher	

Appendix 25. Researchers involved in the EcoTrends project at non-LTER sites—*Continued*

Site code	Title	Name	Affiliation[1, 2]
GRL	Research Leader Laboratory Director (retired)	Jean Steiner Herman Mayeux	USDA ARS Grazinglands Research Laboratory
GSW	Supervisory Ecologist Agricultural Engineer	Wayne Polley Daren Harmel	USDA ARS Grassland, Soil and Water Research Laboratory
HAR	Research Geneticist	James Roberds	USFS Southern Research Station
LVW	Senior Research Scientist	Jill Baron	USGS Fort Collins Science Center
MAR	Hydrologic Technician	Carrie Dorrance	USFS Northern Research Station
PRI	Forester Research Silviculturalist	Robert Denner Russell T. Graham	USFS Rocky Mountain Research Station
RCE	Research Plant Physiologist Research Hydraulic Engineer	Stuart Hardegree Gerald Flerchinger	USDA ARS Northwest Watershed Research Center
SAN	Project Leader Research Hydrologist	Carl Trettin Devendra M. Amatya	USFS Center for Forested Wetlands Research
SPR	Animal Scientist, Research Leader Research Leader (retired) Range Scientist (retired)	Stacey Gunter Phil Sims Robert Gillen	USDA ARS Southern Plains Range Research Station
TAL	Research Hydrologist	Dan Marion	USFS Center for Bottomland Hardwoods Research
WBW	Aquatic Ecologist	Patrick Mulholland	USDOE Oak Ridge National Laboratory
WGE	Research Leader Hydrologist	Susan Moran Timothy Keefer	USDA ARS Southwest Watershed Research

Appendix 25. Researchers involved in the EcoTrends project at non-LTER sites—*Continued*

Site code	Title	Name	Affiliation[1, 2]
SRE	Professor of Range Management	Mitch McClaren	University of Arizona
WIN	Wildlife Biologist/Research Natural Areas Coordinator	Todd Wilson	USFS Pacific Northwest Research Station
	Forester (retired)	Sarah Greene	
	Senior Faculty Research Assistant (former)	Howard Bruner	

[1] Agency abbreviations:
USDA ARS: U.S. Department of Agriculture, Agricultural Research Service
USFS: U.S. Department of Agriculture, Forest Service
USGS: U.S. Geological Survey
USDOE: U.S. Department of Energy

[2] Affiliation when active in EcoTrends; may not represent current affiliation.

Appendix 26. Stations and length of record for each climate variable by site

(Sites are grouped by ecosystem type.)

Site code	Variable	Station	Start	End
Alpine and arctic				
ARC	Air temperature	Toolik Lake Field Station	1989	2005
	Precipitation		1989	2005
	Ice duration	Toolik Lake	1988	2005
	Water clarity		1989	2004
	Water temperature		1975	2004
	Streamflow	Kuparuk River	1983	2004
GLA	Air temperature	Glacier Lakes Ecosystem Experiments Site	1989	2005
	Precipitation		1995	2005
LVW	Air temperature	USGS Biological Resources Division and Water Resources Division meteorological stations	1984	2006
	Precipitation	NADP Station CO98, Rocky Mountain National Park, Loch Vale, CO	1984	2006
	Streamflow	Loch Outlet	1984	2004
	Water temperature		1992	2006
MCM	Air temperature	Lake Hoare	1988	2007
	Precipitation	Lake Bonney	1995	2006
	Streamflow	Onyx River at Vanda	1969	2004
	Water temperature	Von Guerard Stream at F6	1990	2005
NWT	Air temperature	C-1 Meteorological Station	1953	2006
	Precipitation		1965	2006
	Ice duration	Green Lake 4	1982	2006
	Streamflow		1982	2001
Aridlands				
EOA	Air temperature	NWS COOP #358029, Squaw Butte Experimental Station, OR	1937	2008
	Precipitation		1937	2008
JRN	Air temperature	NWS COOP #294426, Jornada Experimental Range, NM	1916	2008
	Precipitation		1919	2008
RCE	Air temperature	NWS COOP #107648, Reynolds, ID	1962	2007
	Precipitation		1962	2007
	Streamflow	036x68 streamflow station	1963	1995
SEV	Air temperature	NWS COOP #298387, Socorro, NM	1893	2008
	Precipitation		1899	2008
SRE	Air temperature	NWS COOP #027593, Santa Rita Experimental Range, AZ	1951	2004
	Precipitation		1951	2004
WGE	Air temperature	NWS COOP #028619 Tombstone, AZ	1898	2007
	Precipitation		1898	2007
	Streamflow	Flume 1	1958	2008

Appendix 26. Stations and length of record for each climate variable by site—*Continued*

Site code	Variable	Station	Start	End
Coastal				
CCE	Air temperature	Lindbergh Field Airport, San Diego, CA	1927	2008
	Precipitation		1927	2008
	Sea level	NOAA Station 9410170, San Diego, CA	1906	2008
	Water clarity	Inshore Area at CCE	1969	2007
	Water temperature	Scripps Institution of Oceanography Pier	1917	2006
FCE	Air temperature	Royal Palm Ranger Station	1950	2008
	Precipitation		1950	2008
	Sea level	NOAA Station 8724580, Key West, FL	1913	2008
	Streamflow	Tamiami Canal at S-12-A (USGS 254543080491101)	1964	2008
	Water clarity	Duck Key, Taylor Slough/Panhandle Site 9	2000	2004
	Water temperature	National Data Buoy Center Station LONF1, Long Key, FL	1993	2008
GCE	Air temperature	NWS COOP #091340, Brunswick, GA	1915	2008
	Precipitation		1918	2008
	Sea level	NOAA Station 8670870, Ft. Pulaski, GA	1936	2008
	Streamflow	Altamaha River at Doctor Town (USGS)	1932	2008
	Water temperature	Hudson Creek	2002	2008
MCR	Air temperature	MeteoFrance Afareaitu #2	1977	2007
	Precipitation		1977	2007
	Sea level	Papeete station, Moorea	1976	2008
PAL	Air temperature	Palmer Station	1975	2008
	Precipitation		1990	2008
	Ice duration	Palmer Basin	1979	2006
PIE	Air temperature	NWS COOP #193505, Haverhill, MA	1901	2008
	Precipitation		1901	2008
	Sea level	NOAA Station 8443970, Boston, MA	1921	2008
	Streamflow	Parker River at Byefield MA (USGS)	1945	2009
SBC	Air temperature	NWS COOP #047902, Mission Creek, Santa Barbara, CA	1895	2006
	Precipitation	Santa Barbara County Public Works Department Flood Control District Site at Ellison Hall Roof, UC Santa Barbara	1952	2007
	Sea level	NOAA Station 9410660, Los Angeles, CA	1924	2008
	Streamflow	USGS Station 11119500, Carpinteria Creek near Carpinteria CA	1941	2007
	Water temperature	Santa Barbara Manual Shore Station, Santa Barbara Harbor	1955	2004
VCR	Air temperature	NWS COOP #446475, Painter 2W, VA	1956	2007
	Precipitation		1956	2007
	Sea level	NOAA Station 8534720, Atlantic City, NJ	1912	2008
	Water clarity	Phillips Creek Mouth	1992	2008

Appendix 26. Stations and length of record for each climate variable by site—*Continued*

Site code	Variable	Station	Start	End
Eastern forests				
BEN	Air temperature	NWS COOP #310724, Bent Creek, NC	1949	2008
	Precipitation		1949	2004
	Streamflow	USGS Station 03448000, French Broad River at Bent Creek, NC	1935	1986
CRO	Air temperature	NWS COOP #031730, Crossett 7 S, Crossett, AR	1916	2008
	Precipitation		1916	2008
CWT	Air temperature	NWS COOP #312102, Coweeta Experimental Station, NC	1943	2008
	Precipitation		1944	2008
	Streamflow	Watershed 18 flume	1937	2007
FER	Air temperature	NWS COOP #466867, Parsons 1 NE, WV	1899	2006
	Precipitation		1905	2006
	Streamflow	Watershed 1 at Fernow	1952	2007
HAR	Air temperature	NWS COOP #227840, Saucier Experimental Forest, MS	1955	2004
	Precipitation		1955	2006
HBR	Air temperature	Weather Station Headquarters	1957	2007
	Ice duration	Mirror Lake	1968	2005
	Precipitation	Hubbard Brook Ecosystem Study Headquarters	1978	2008
	Streamflow	GS Watershed 6	1963	2007
HFR	Air temperature	Harvard Forest Meteorological Stations Shaler and Fisher (sequential at same site)	1964	2008
	Precipitation		1964	2008
LUQ	Air temperature	Bisley Tower	1996	2004
	Precipitation		1988	2004
	Sea level	NOAA Station 9755371, San Juan, PR	1963	2008
	Streamflow	Puente Roto gage	1987	2006
MAR	Air temperature	NWS COOP #213303, Grand Rapids Forest Lab, MN	1916	2007
	Precipitation		1916	2007
	Streamflow	Total runoff of South Unit Watershed S2 weir	1962	2006
NTL	Air temperature	NWS COOP #475516, Minocqua Dam, WI	1904	2008
	Precipitation		1904	2008
	Ice duration	Lake Mendota	1856	2008
	Streamflow	USGS Station 05427948, Pheasant Branch at Middleton, WI	1975	2007
	Water clarity	Sparkling Lake	1981	2007
	Water temperature		1982	2008
SAN	Air temperature (max and min)	NWS COOP #388922, Walterboro 1 SW, Walterboro, SC	1904	2008
	Air temperature (mean)	Conglomerate of data from Santee, ChARP, Lotti, Met5, Met25, and Witherbee weather stations	1946	2005
	Precipitation		1946	2007
	Streamflow	Control Watershed 80 flume	1990	1999

Appendix 26. Stations and length of record for each climate variable by site—*Continued*

Site code	Variable	Station	Start	End
TAL	Air temperature	NWS COOP #229079, University, MS	1902	2008
	Precipitation		1905	2008
WBW	Air temperature	NWS COOP #406750, Oak Ridge, TN	1949	2008
	Precipitation		1949	2008
	Streamflow	West Fork of Walker Branch Watershed	1982	2005
Temperate grasslands and savannas				
CDR	Air temperature	NWS COOP #211227, Cambridge 5ESE, MN	1893	2007
	Precipitation	Conglomerate of Ft. Snelling and Composite datasets	1837	2008
FTK	Air temperature	NWS COOP #245690, Miles City-Frank Wiley Field, MT	1938	2008
	Precipitation		1938	2008
GRL	Air temperature	NWS COOP #342818, El Reno 1 N, NV	1893	2006
	Precipitation		1893	2006
GSW	Air temperature	Riesel, TX	1940	2008
	Precipitation	Rain Gauge 75A	1938	2008
	Streamflow	Stream gage Y2	1940	2008
KBS	Air temperature	NWS COOP #203504, Gull Lake Biological Station, MI	1934	2008
	Precipitation		1931	2008
	Ice duration	Gull Lake, MI	1924	2006
	Streamflow	Kalamazoo River at Comstock, MI (USGS)	1931	2009
KNZ	Air temperature	NWS COOP #144972, Manhattan, KS	1899	2008
	Precipitation		1898	2008
	Streamflow	USGS Station 06879650, Kings Creek near Manhattan, KS	1980	2008
SGS	Air temperature	Central Plains Experimental Range (1944-1968) and Shortgrass Steppe 11 (1969-present) weather stations	1944	2008
	Precipitation		1944	2009
SPR	Air temperature	NWS COOP #349760, Woodward, OK	1909	1976
	Precipitation		1909	2007
Urban				
BES	Air temperature	NWS COOP #180465, Baltimore Washington International Airport, MD	1940	2008
	Precipitation		1940	2008
	Sea level	NOAA Station 8574680, Baltimore, MD	1903	2008
	Streamflow	Villanova	1957	2009
CAP	Air temperature	NWS COOP #021026, Buckeye AZ	1894	2002
	Precipitation		1894	2002
	Streamflow	USGS Station 09502000, Salt River below Stewart Mountain Dam, AZ	1941	2007

Appendix 26. Stations and length of record for each climate variable by site—*Continued*

Site code	Variable	Station	Start	End
Western forests				
AND	Air temperature	Climatic Station at Watershed 2	1958	2006
	Precipitation		1958	2006
	Streamflow	Watershed 2	1953	2008
	Water temperature	Lookout Creek upper thermograph site	1977	2006
BNZ	Air temperature	LTER1	1989	2009
	Streamflow	C3 Flume in the Caribou-Poker Creeks Research Watershed	1969	2007
CHE	Air temperature	NWS COOP #356366, Otis, OR	1950	2008
	Precipitation		1949	2008
CSP	Air temperature	NWS COOP #043161, Fort Bragg 5N, CA	1935	2008
	Precipitation		1913	2008
	Streamflow	South Fork Caspar Creek	1986	2004
	Water temperature	ARF Station	1989	2004
FRA	Air temperature	NWS COOP #053261, Georgetown, CO	1898	2006
	Precipitation		1909	2006
	Streamflow	Lower Fool Creek	1941	1984
PRI	Air temperature	NWS COOP #107386, Priest River Experimental Station, ID	1901	2008
	Precipitation		1901	2008
	Streamflow	USGS Station 12395000, Priest River near Priest River, ID	1950	2008
WIN	Air temperature	NWS COOP #459342, Wind River, WA and NWS COOP #451160, Carson Fish Hatchery, WA	1931	2009
	Precipitation		1931	2008

Appendix 27. Stations and length of record for each precipitation or surface water chemistry variable by site

(Sites grouped by ecosystem type.)

Site code	Variable[1]	Station	Start	End
Alpine and arctic				
ARC	PPT: concentration	Toolik Lake Field Station	1989	2003
	PPT: deposition: ammonium, nitrate		1988	2003
	Stream: ammonium	Kuparuk River	1990	2006
	Stream: nitrate		1990	2005
GLA	PPT: concentration, deposition	NADP Station WY00, Snowy Range, WY	1986	2008
LVW	PPT: concentration, deposition	NADP Station CO98, Rocky Mountain National Park, Loch Vale, CO	1984	2008
	Stream	Loch Outlet	1992	2006
MCM	Lake: ammonium, nitrate	East Lake Bonney	1993	2007
	Lake: calcium, chloride, sulfate		1993	2006
NWT	Lake: ammonium	Green Lake 4	1993	2006
	Lake: calcium, sulfate		1982	2006
	Lake: chloride, nitrate		1985	2006
	PPT: concentration, deposition	NADP Station CO02, Niwot Saddle	1984	2008
Aridlands				
JRN	PPT: concentration, deposition	LTER Weather Station	1984	2008
RCE	PPT: concentration, deposition	NADP Station ID11, Reynolds Creek, ID	1984	2008
WGE	PPT: concentration, deposition	NADP Station AZ98, Chiricahua, AZ	2000	2008
Coastal				
CCE	Coastal water: nitrate	Ohman Region: subset of CalCOFI stations inshore and nearshore in the Southern California Bight region; CalCOFI lines 80-93, stations from shore offshore to station 70	1984	2005
FCE	Coastal water: ammonium, nitrate	Taylor Slough/Panhandle Site 6a	2002	2007
	PPT: concentration, deposition	NADP Station FL11, Everglades National Park Research Center, FL	1982	2008
GCE	PPT: concentration, deposition	NADP Station GA33, Sapelo Island, GA	2004	2008

Appendix 27. Stations and length of record for each precipitation or surface water chemistry variable by site—*Continued*

Site code	Variable[1]	Station	Start	End
PAL	Coastal water: ammonium	Palmer Station B	1995	2006
	Coastal water: nitrate		1994	2007
PIE	PPT: concentration, deposition	NADP Station MA13, East, MA	1982	2008
	Stream: ammonium, nitrate	Ipswich Dam	1994	2003
SBC	Coastal water: ammonium	Arroyo Quemado Reef, Santa Barbara Channel	2002	2007
	Coastal water: nitrate		2001	2007
VCR	Coastal water: ammonium, nitrate	Phillips Creek Mouth	1992	2007
	PPT: concentration, deposition	Oyster, VA at LTER Lab in Shirley House, Rt 600 and GATR Tract	1990	2007
Eastern forests				
BEN	PPT: concentration, deposition	NADP Station NC45, Mt. Mitchell, NC	1985	2008
CRO	PPT: concentration, deposition	NADP Station AR02, Warren 2WSW	1983	2008
CWT	PPT: concentration, deposition	NADP Station NC25, Coweeta, NC	1979	2008
FER	PPT: concentration, deposition	NADP Station WV18, Parsons, WV	1979	2008
	Stream: calcium, nitrate, sulfate	Watershed 4	1980	2006
	Stream: chloride		1988	2006
HBR	PPT: concentration, deposition	NADP Station NH02, Hubbard Brook, NH	1979	2008
	Stream: ammonium	Watershed 6	1967	2005
	Stream: calcium		1964	2005
	Stream: chloride, nitrate, sulfate		1965	2005
HFR	PPT: concentration, deposition	NADP Station MA08, Quabbin Reservoir, MA	1985	2008
LUQ	PPT: concentration, deposition	NADP Station PR20, El Verde, PR	1986	2008
	Stream: except sulfate	Quebrada Bisley 3 Cuenca	1986	2007
	Stream: sulfate		1986	2002
MAR	PPT: concentration, deposition	NADP Station MN16, Marcell Experimental Forest, MN	1979	2008
NTL	Lake: ammonium, nitrate	Sparkling Lake	1984	2007
	Lake: calcium, chloride, sulfate		1982	2007
	PPT: concentration, deposition	NADP Station WI36, Trout Lake, WI	1980	2008
SAN	PPT: concentration, deposition	NADP Station SC06, Santee National Wildlife Refuge, SC	1985	2008
TAL	PPT: concentration, deposition	NADP Station MS30, Coffeeville, MS	1985	2008

Appendix 27. Stations and length of record for each precipitation or surface water chemistry variable by site—*Continued*

Site code	Variable[1]	Station	Start	End
WBW	PPT: concentration, deposition	NADP Station TN00, Walker Branch Watershed, TN	1981	2008
	Stream	West Fork of Walker Branch Watershed	1989	2005
Temperate grasslands and savannas				
CDR	PPT: concentration, deposition	NADP Station MN01, Cedar Creek, MN	1997	2008
GRL	PPT: concentration, deposition	NADP Station OK17, Kessler Farm Field Laboratory, OK	1984	2006
KBS	PPT: concentration, deposition	NADP Station MI26, Kellogg Biological Station, MI	1980	2008
	Stream	Augusta Creek	1998	2008
KNZ	PPT: concentration, deposition	NADP Station KS31, Konza Prairie, KS	1983	2008
	Stream: ammonium	N04D	1989	2004
	Stream: nitrate		1985	2004
SGS	PPT: concentration, deposition	NADP Station CO22, Pawnee, CO	1980	2008
Urban				
BES	PPT: Concentration	NADP Station MD13, Wye, MD	1984	2008
	PPT: deposition: calcium, chloride		1984	2008
	PPT: deposition: ammonium, nitrate, sulfate	CASTNET Station BEL116, Beltsville, MD	1989	2006
	Stream: chloride, nitrate, sulfate	USGS Station #01589180, Gwynns Falls at Glyndon, MD	1999	2008
CAP	PPT: concentration	Lost Dutchman State Park Deposition Site	1999	2007
	PPT: deposition: ammonium, chloride, nitrate		2000	2005
	PPT: deposition: sulfate		2000	2003
	Stream	Lower Salt River	1998	2008
Western forests				
AND	PPT: concentration except sulfate	NADP Station OR10, H. J. Andrews Experimental Forest, OR	1981	2008
	PPT: deposition except sulfate		1981	2008
	PPT: concentration, deposition: sulfate		1985	2008
	Stream: ammonium, calcium, nitrate	Watershed 2	1982	2006

Appendix 27. Stations and length of record for each precipitation or surface water chemistry variable by site—*Continued*

Site code	Variable[1]	Station	Start	End
AND	Stream: chloride		1990	2006
	Stream: sulfate		1991	2006
BLA	PPT: concentration, deposition	NADP Station CA96, Lassen Volcanic National Park Manzanita Lake	2000	2008
BNZ	PPT: concentration	NADP Station AK01, Poker Creek	1994	2008
	PPT: deposition except ammonium		1993	2008
CSP	PPT: concentration, deposition	NADP Station CA45, Hopland, CA	1980	2007
FRA	PPT: concentration, deposition	NADP Station CO02, Niwot Saddle	1984	2008
PRI	PPT: concentration, deposition	NADP Station ID02, Priest River Experimental Forest, ID	2003	2007

[1] Up to five variables were measured at each station: calcium, chloride, nitrogen (ammonium and nitrate), and sulfur (sulfate). When the elements are not specified, concentration or deposition of all five elements is given. When the elements are specified, concentration or deposition is given for the elements specified.

Appendix 28. Stations and length of record for each plant and animal variable by site, as grouped by ecosystem type

Site code	Variable	Station	Start	End
Alpine and arctic				
ARC	Aboveground net primary production	Control ANPP plots	1982	2000
		Nitrogen-fertilized ANPP plots	1983	2000
	Chlorophyll a	Fertilized reach of Kuparuk River	1983	2004
		Reference reach of Kuparuk River	1983	2004
		Toolik Lake	1985	2004
	Plant biomass			
	Betula nana (dwarf birch)	Tussock Tundra 1981 Plots, control	1982	2000
	Eriophorum vaginatum (tussock cottongrass)		1982	2000
	Ledum palustre (marsh Labrador tea)		1982	2000
	Vaccinium vitis-idaea (lingonberry)		1982	2000
	B. nana	Tussock Tundra 1981 Plots, fertilized	1983	2000
	E. vaginatum		1983	2000
	L. palustre		1983	2000
	V. vitis-idaea		1983	2000
MCM	Primary production, measured as carbon	East Lake Bonney	1989	2007
		West Lake Bonney	1992	2007
NWT	Aboveground net primary production	Dry meadow plots at Saddle Location	1982	1997
		Moist meadow plots at Saddle Location	1982	1997
		Wet meadow plots at Saddle Location	1982	1997
Aridlands				
JRN	Aboveground net primary production	Creosote Study Sites	1990	2008
	Plant species richness		1989	2008
	Aboveground net primary production	Grassland Study Sites	1990	2008
	Plant species richness		1989	2008
	Aboveground net primary production	Mesquite Study Sites	1990	2008
	Plant species richness		1989	2008
	Aboveground net primary production	Playa Study Sites	1990	2008
	Plant species richness		1989	2008
	Aboveground net primary production	Tarbush Study Sites	1990	2008
	Plant species richness		1989	2008

Appendix 28. Stations and length of record for each plant and animal variable by site, as grouped by ecosystem type—*Continued*

Site code	Variable	Station	Start	End
	Animal abundance, Leporidae	Rabbit survey route in creosote vegetation zone	1996	2008
		Rabbit survey route in grassland vegetation zone	1996	2008
	Animal abundance, Rodentia	Rodent trapping web in creosote vegetation zone	1995	2007
		Rodent trapping web in grassland vegetation zone	1995	2007
SEV	Aboveground net primary production	Blue Grama Study Site	2002	2008
	Plant species richness		2002	2008
	Aboveground net primary production	Five-Points Grass Study Site	1999	2008
	Animal abundance, Rodentia		1989	2008
	Plant species richness		1999	2008
	Aboveground net primary production	Five-Points Larrea Study Site	1999	2008
	Animal abundance, Rodentia		1989	2008
	Plant species richness		1999	2008
SRE	Plant species richness	Burned treatment: pasture 21	1972	2006
		Control treatment: pastures 8 and 22	1972	2006
		Pastures that were grazed and burned: pastures 2N and 6A	1972	2006
		Pastures where the existing mesquite were killed and were grazed: pastures 3, 5N, 5S, 6B and 12B	1972	2006
		Pastures where the mesquite were killed and were burned: pasture 2S	1972	2006
WGE	Plant species richness	Grass and scattered shrub vegetation zone	1967	2005
		Grass vegetation zone	1967	2007
		Shrubs and sparse grass vegetation zone	1967	2007
		Shrubs with grass vegetation zone	1967	2005
Coastal				
CCE	Chlorophyll a	Ohman Region: subset of CalCOFI stations inshore and nearshore in the Southern California Bight region; CalCOFI lines 80-93, stations from shore offshore to station 70	1984	2005
	Primary production (carbon)		1984	2005
FCE	Animal species richness, Osteichthyes	Shark Slough	1996	2005
		Taylor Slough	1996	2005
	Biomass, periphyton	Shark River Slough sites 1, 2, and 3, Epiphyton substrate	2001	2007

Appendix 28. Stations and length of record for each plant and animal variable by site, as grouped by ecosystem type—*Continued*

Site code	Variable	Station	Start	End
	Net primary production (carbon)		2001	2007
	Biomass, periphyton	Shark River Slough sites 1, 2, and 3, Mat substrate	2002	2007
	Net primary production (carbon)		2002	2007
	Biomass, periphyton	Shark River Slough sites 1, 2, and 3, Periphyton substrate	2002	2007
	Net primary production (carbon)		2002	2007
GCE	Animal abundance, Orthoptera	Study Site 1, Eulonia, GA	2000	2008
		Study Site 3, North Sapelo, Sapelo Island, GA	2000	2008
		Study Site 6, Dean Creek, Sapelo Island, GA	2000	2008
	Plant biomass	High Marsh site	2000	2007
		Zone 1, Creek Bank	2000	2007
MCR	Animal abundance, fish	MRB Lagoon research site	2000	2008
	Animal species richness, fish	North Shore region (7 research sites)	2000	2008
	Chlorophyll a	SeaWiFS data for Moorea Coral Reef Vicinity, area for chlorophyll and SST data	1998	2008
PAL	Animal abundance, *Pygoscelis adeliae*	Palmer Station	1975	2008
	Animal abundance, *P. antarcticus*		1976	2008
	Animal abundance, *P. papua*		1994	2008
	Primary production (carbon)		1991	2006
	Chlorophyll a	Palmer Station B	1991	2006
PIE	Aboveground net primary production	*Spartina alterniflora*-dominated salt marsh at Goat Island, North Inlet, Georgetown, SC	1985	2005
	Plant biomass		1984	2005
	Aboveground net primary production	*S. alterniflora*-dominated salt marsh at Law's Point, Rowley River, Plum Island Ecosystem, MA	1999	2005
	Plant biomass		1999	2005
	Aboveground net primary production	*S. patens*-dominated salt marsh at Law's Point, Rowley River, Plum Island Ecosystem, MA	2001	2005
	Plant biomass		2001	2005
SBC	Biomass, *Macrocystis pyrifera* (Kelp)	Arroyo Burro Reef, Santa Barbara Channel	2002	2008
		Arroyo Quemado Reef, Santa Barbara Channel	2002	2008
		Mohawk Reef, Santa Barbara Channel	2002	2008

Appendix 28. Stations and length of record for each plant and animal variable by site, as grouped by ecosystem type—*Continued*

Site code	Variable	Station	Start	End
VCR	Animal abundance, Muridae	Hog Island Rodent Trapping Transect 1	1989	2004
		Hog Island Rodent Trapping Transect 4	1989	2004
		Hog Island Rodent Trapping Transect 5	1989	2004
	Plant biomass	Randomly selected, destructively sampled, non-treated plots		
		at Frank Day Well Location R2, Hog Island	1993	2006
		at Frank Day Well Location R3, Hog Island	1993	2006
		at Frank Day Well Location R4, Hog Island	1993	2006
Eastern forests				
BEN	Diameter at breast height of trees	Mixed hardwood plots	1975	2000
		Yellow Poplar plots	1961	2001
CRO	Production of seeds, pine	Unknown	1980	2004
	Production volume, pine	Clearcut logging stands	1948	1996
		Diameter limit logging stands	1948	1996
		Heavy seedtree logging stands	1948	1996
		Selection logging stands	1948	1996
HAR	Diameter at breast height, *Pinus palustris* (longleaf pine)	North plantation	1960	2000
	Height, *P. palustris*		1960	2000
	Diameter at breast height, *P. palustris*	South plantation	1960	2000
	Height, *P. palustris*		1960	2000
HBR	Aboveground net primary production	Unknown	1987	1996
	Animal abundance, Aves	10-hectare bird count plot	1969	2004
	Animal species richness, Aves		1969	2004
	Animal abundance, Lepidoptera	on *Acer saccharum*	1986	1997
		on *Fagus grandifolia*	1986	1997
	Diameter at breast height of trees	Vegetation zone 1 at watershed 6	1965	2002
	Plant biomass		1965	2002
	Diameter at breast height of trees	Vegetation zones 2 and 3 at watershed 6	1965	2002
	Plant biomass		1965	2002
	Diameter at breast height of trees	Vegetation zone 4 at watershed 6	1965	2002
	Plant biomass		1965	2002

Appendix 28. Stations and length of record for each plant and animal variable by site, as grouped by ecosystem type—*Continued*

Site code	Variable	Station	Start	End
	Diameter at breast height of trees	Vegetation zone 5 at watershed 6	1965	2002
	Plant biomass		1965	2002
HFR	Aboveground net primary production of trees	Little Prospect Hill	2002	2006
	Diameter at breast height of trees	Lyford Blocks within the Prospect Hill Tract	1969	2001
LUQ	Animal abundance, Aves	El Verde	1989	2008
	Animal abundance, Caridea	El Verde Study Area, Pool 0, Quebrada Prieta	1988	2008
		Pool 15 in Quebrada Prieta (upstream pool)	1988	2008
		Pool 8 in Quebrada Prieta	1988	2008
	Animal abundance, *Eleutherodactylus coqui*	El Verde New Plot	1987	1997
		El Verde Old Plot	1987	1997
	Animal abundance, Gastropoda	Luquillo Forest Dynamics Plot at El Verde	1991	2007
NTL	Animal abundance, Orconectes	Big Muskellunge Lake	1981	2008
		Lake Mendota	1981	2008
		Sparkling Lake	1981	2008
	Animal abundance, fish		1981	2008
	Animal species richness, fish		1981	2008
	Animal abundance, Orconectes	Trout Lake	1981	2008
	Animal abundance, fish		1981	2008
	Animal species richness, fish		1981	2008
	Plant biomass	Trout Lake	1983	2008
	Plant species richness		1983	2008
	Animal abundance, fish	Crystal Lake	1981	2008
	Animal species richness, fish		1981	2008
	Plant species richness	Site 31, Channel Mouth Island	1983	2008
		Site 50, Southwest Bay of South Trout Lake	1983	2008
		Site 56, Mouth of Mann Creek	1983	2008
		Site 7, Rocky Reef Bay	1983	2008
	Primary production, hypsometrically weighted	Crystal Lake, epilimnion	1987	2007
		Sparkling Lake, epilimnion	1987	2007
		Trout Lake, epilimnion	1987	2007

Appendix 28. Stations and length of record for each plant and animal variable by site, as grouped by ecosystem type—*Continued*

Site code	Variable	Station	Start	End
Temperate grasslands and savannas				
CDR	Aboveground net primary production	Unknown	1982	1998
	Animal abundance, Orthoptera	Cedar Creek	1989	2004
	Animal species richness, Orthoptera		1989	2004
	Plant biomass	Old Fields 4, 24, 28, 41	1988	2003
	Plant species richness		1988	2006
	Plant biomass	Old Fields 5, 35, 45, 72	1988	2003
	Plant species richness		1988	2006
	Plant biomass	Old Fields 26, 53, 70, 77	1988	2003
	Plant species richness		1988	2006
FTK	Aboveground net primary production	Lysimeter 1	1993	2004
		Lysimeter 8	1993	2004
KBS	Aboveground net primary production	Treatment 7, native successional treatment, abandoned after spring plowing in 1989	1991	2008
	Plant species richness		1991	2008
	Animal abundance, Neoptera		1989	2008
	Aboveground net primary production	Treatment 8, never plowed, 200 meters (m) south of the others, that serves as an historical control for soil organic matter studies	1991	2008
	Plant species richness		1991	2008
	Aboveground net primary production	Treatment SF, old field successional community, never tilled	1993	2008
	Plant species richness		1993	2008
	Animal abundance, Neoptera	Treatment 1, standard levels of chemical inputs, conventional chisel plowed tillage	1989	2008
		Treatment 2, standard levels of chemical inputs, no tillage	1989	2008
		Treatment 3, organic-based low chemical input (banded herbicide,starter N), winter leguminous crop, annual tillage and post-planting cultivation	1989	2008
		Treatment 4, certified organic, no chemical inputs, annual tillage, rotary-hoed to control weeds	1989	2008
		Treatment 5, Poplar trees (fallow 2008), planted on a 10-year rotation cycle	1989	2008

Appendix 28. Stations and length of record for each plant and animal variable by site, as grouped by ecosystem type—*Continued*

Site code	Variable	Station	Start	End
KBS	Animal abundance, Neoptera	Treatment 6, Continuous alfalfa (wheat 2008)	1989	2008
KNZ	Aboveground net primary production	Watershed 020b, burned every 20 years, on deep Tully soils	1984	2005
		Watershed 020b, burned every 20 years, on shallow Florence soils	1984	2005
	Animal abundance, Mammalia	Watershed 001d	1981	1997
	Animal abundance, Orthoptera		1982	2004
	Animal species richness, Orthoptera		1982	2004
	Animal abundance, Mammalia	Watershed 004b	1981	1997
	Animal abundance, Orthoptera		1982	2004
	Animal species richness, Orthoptera		1982	2004
	Animal abundance, Orthoptera	Watershed 020b	1996	2004
	Animal species richness, Orthoptera		1996	2004
SGS	Aboveground net primary production	ESA Control 1	1983	2007
		Owl Creek, coarse texture soil	1991	2007
		Sec 25, fine texture soil	1991	2007
	Animal abundance, Aves	USGS Bird Breeding Survey area 17901, Rockport, CO	1995	2008
	Animal species richness, Aves		1994	2008
	Animal abundance, Aves	USGS Breeding Bird Survey Route 17305, Nunn, CO	1995	2008
	Animal species richness, Aves		1995	2008
SPR	Plant biomass, forbs	Watershed 1	1984	2005
	Plant biomass, grass		1984	2005
Urban				
CAP	Animal abundance, Araneae (spiders)	Agricultural study sites	1998	2004
	Animal abundance, Orthoptera		1998	2003
	Animal abundance, Araneae (spiders)	Desert study sites	1998	2004
	Animal abundance, Orthoptera		1998	2004
	Animal abundance, Araneae (spiders)	Urban study sites	1998	2004
	Animal abundance, Orthoptera		1998	2004

Appendix 28. Stations and length of record for each plant and animal variable by site, as grouped by ecosystem type—*Continued*

Site code	Variable	Station	Start	End
Western forests				
AND	Aboveground net primary production, tree boles	Reference Stand 2	1988	2005
	Plant biomass, tree boles		1988	2005
	Aboveground net primary production, tree boles	Reference Stand 29	1983	2001
	Plant biomass, tree boles		1988	2005
	Animal abundance, *Oncorhynchus clarkii*	Clearcut section of Mack Creek	1987	2007
		Old growth section of Mack Creek	1987	2007
	Plant species richness	Watershed 1	1962	2008
		Watershed 3	1962	2008
BNZ	Aboveground net primary production	Unknown	1991	1998
CHE	Diameter at breast height	HSGY Study Plots		
	Picea sitchensis (Sitka spruce)		1935	2003
	Pseudotsuga menziesii (Douglas fir)		1935	2003
	Tsuga heterophylla (Western hemlock)		1935	2003

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