United States Department of Agriculture

Agricultural Research Service

Technical Bulletin Number 1931

September 2013

Long-Term Trends in Ecological Systems:

A Basis for Understanding Responses to Global Change

Contents

Chapter 14

Long-Term Trends in Production, Abundance, and Richness of Plants and Animals

Trends in biotic structure have been of interest in the United States since the establishment of the Division of Biological Survey in the U.S. Department of Agriculture in the late 1890s. Changes in biotic structure can serve as a bellwether for quantifying the effects of climate change, land-use change, and the spread of exotic species, as well as the loss of rare and endangered species. Considerable evidence suggests that changes in biotic structure can have significant consequences for ecosystem functioning and the provisioning of ecosystems goods and services.

In this chapter, we first describe common methods for measuring responses of plants and animals and our rationale for the selection of variables included in this book. We then show graphs of biotic data through time for each site arrayed across the continent.

Methods of Measurements and Selection of Variables

Biotic structure can be characterized by a wide array of variables, but we limit our discussion to those variables that represent key components of ecological systems. One of the most important variables in all ecosystems is net primary production (NPP), the accumulation of biomass over a specified time period, usually seasonally or annually. NPP represents the amount of energy fixed by producers (for example, vascular plants or algae) that can be used for their growth and reproduction and that is available for consumption by herbivores. Life on Earth depends on this conversion of inorganic compounds to organic molecules and the release of oxygen; thus NPP is a critical variable for all ecosystems, even though the primary producers vary from vascular plants on land to algae and phytoplankton in the lakes and oceans. Terrestrial NPP consists of both aboveground (ANPP) and belowground (BNPP) components, although ANPP is the most commonly measured in long-term studies (chapter 5).

Other variables of particular importance are the biomass, cover, and density of key species and groups of similar species (that is, functional groups) that represent each ecosystem. Biomass is the mass per unit area of living material (plants, animals, microbes), typically measured as grams per square meter (g/m^2) or kilograms per hectare (kg/ha). Changes in biomass over time are often used to calculate NPP. Biomass is a measure of stored energy (in wood, sugar cane, corn, for example) and carbon that is sequestered from the atmosphere. Cover is the amount of surface area occupied by plants or animals and is often represented as a percentage of the total area (for instance, [m^2 leaf area ÷ m^2 ground area] × 100). Density is the number of individuals found in a unit of area, such as number per square meter or per hectare.

Biomass, cover, or density can be used as estimates of the abundance of organisms and species composition (the percentage that each species contributes to a measurement). Species richness, the number of species in an area (such as per m^2), is an important measure of biodiversity. Species richness is available for some sites, although differences in sampling area often result in difficulties in comparing across sites.

The long-term biotic structure data represent a somewhat eclectic set of species on which, for the most part, the same measurements are rarely collected at all sites—in contrast to climatic, biogeochemical, and human population data (chapters 11-13). This diversity of species is to be expected given the uniqueness of the biota across the broad range of sites represented in the EcoTrends database. Also, a research philosophy that originally helped structure the LTER Network was a focus on core research areas relevant to each site. One of these areas was the measurement of the spatial and temporal distribution of populations selected to represent trophic structure within a given ecosystem. As a consequence, most LTER sites have quantitative data on plant community composition and structure, but many different kinds of consumer species are represented in figures14-1 to 14-12. In many cases, the graphs present aggregate variables (species richness, total abundance); however, data on long-term species trends are available on the EcoTrends website (http://www.ecotrends.info).

At most sites, NPP is shown in comparable units, such as grams/m^2/year, despite a variety of measurement techniques. For terrestrial ecosystems, most sites only estimate long-term ANPP; difficulties in obtaining accurate and cost-effective estimates of BNPP result in very few, if any, long-term datasets of this variable. Repeated clipping of herbaceous biomass or estimations of changes in plant sizes are often used in grasslands and deserts to estimate ANPP. Diameter at breast height (DBH) or basal area increment (BAI) and annual litterfall are most often used in forests. Chlorophyll content or measurement of either O_2 or CO_2 consumption or production in light and dark bottles can be used as surrogates for NPP in aquatic systems. Although the methods in terrestrial and aquatic systems are highly disparate, all measurements can be converted to common units for cross-system comparisons. At very large spatial scales, satellite data and remotely sensed images can be used to estimate “greenness” which can be correlated with NPP in freshwater, marine, and terrestrial systems.

Similarly, the measurements of species composition and abundance also differ among terrestrial and aquatic systems, as well as in different types of ecosystem. These differences are reflected in the different units of measure on the graphs below.

Graphs Showing Long-Term Trends

The remainder of this chapter is devoted to showing trends in plant and animal variables by site across the continent. For plants, we focus on four variables that are often measured at many sites: species richness, ANPP, biomass, and DBH. For animals, we include species richness of birds, insects, and fish and abundance of birds, insects, and small mammals. Data are shown annually through time, and a regression line is shown if the relationship was significant ($p < 0.05$) and the trend appears linear. Long-term means and regression coefficients can be found in appendices 16 through 23.

Summary

At many sites, multiple locations are sampled for plant and animal dynamics. The large within-site variability in responses often overwhelms trends through time. Although plant response variables of ANPP, richness, and biomass are sampled for most LTER sites to allow cross-site comparisons, animal response variables are more variable among sites with fewer comparable groups. These results reflect the underlying organizational structure of the LTER to select representative trophic groups from a site rather than attempting to standardize across sites. The length of the time series also varies across sites, which further complicates cross-site comparisons.

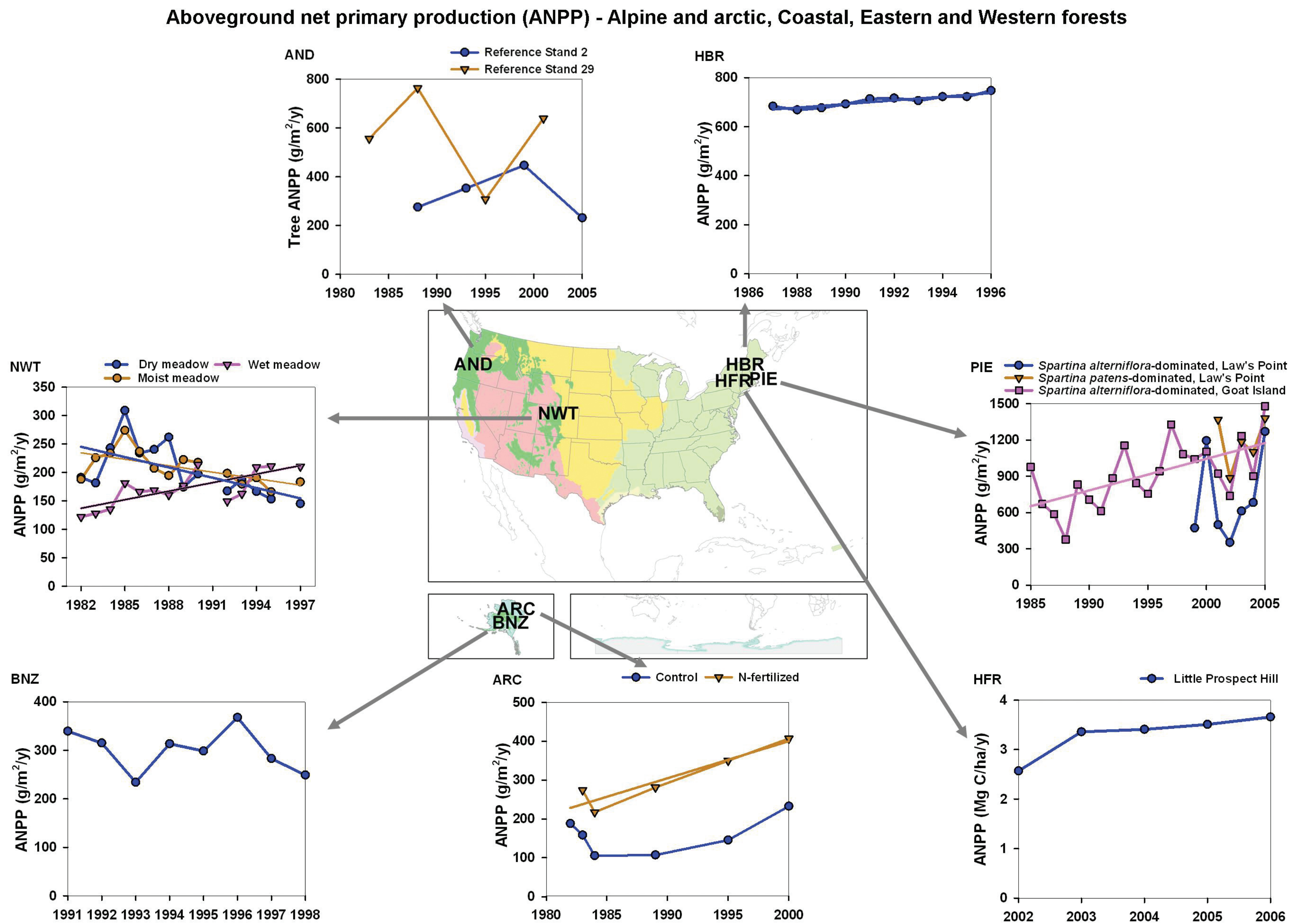

Figure 14-1. Aboveground net primary production (ANPP, g/m²/y or Mg C/ha/y) for arctic and alpine (ARC and NWT), coastal (PIE), and eastern and western forest (AND, BNZ, HBR, and HFR) sites. A simple linear regression line is displayed if the slope is statistically significant ($p < 0.05$) and the trend appears linear. The significant slopes are: ARC (10), HBR (7), NWT (-6, -4, 5), and PIE (26). Original data from Internet home pages (see table 1-1). Synthesized data from http://www.ecotrends.info.

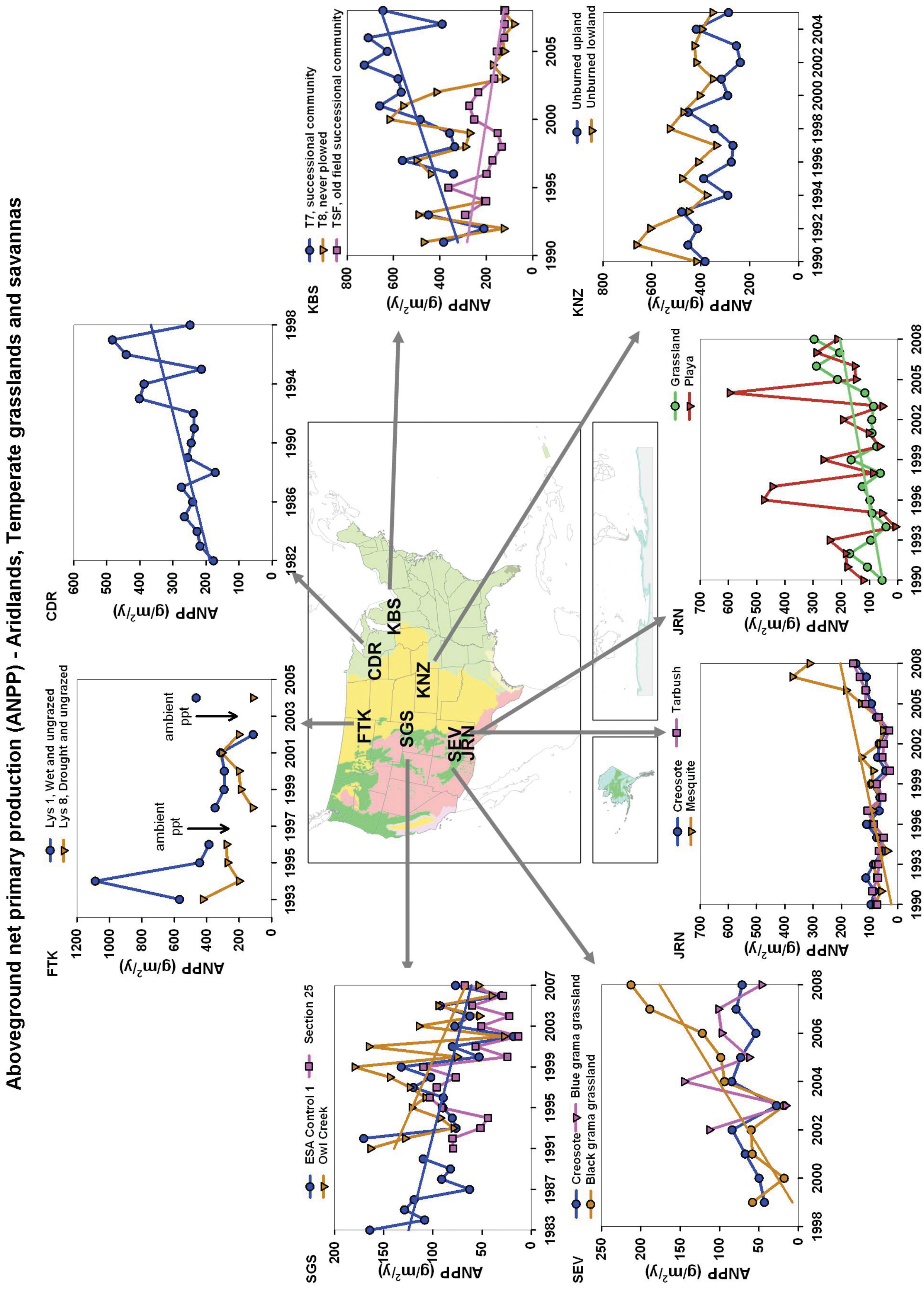

Figure 14-2. Aboveground net primary production (ANPP, g/m²/y) for aridland (FTK, JRN, SEV, and SGS) and temperate grassland/savanna (CDR, KBS, and KNZ) sites. A simple linear regression line is displayed if the slope is statistically significant ($p < 0.05$) and the trend appears linear. The significant slopes are CDR (11), JRN (8, 10), KBS (22, -10), SEV (19), and SGS (-3, -5). Original data from Internet home pages (see table 1-1). Synthesized data from http://www.ecotrends.info.

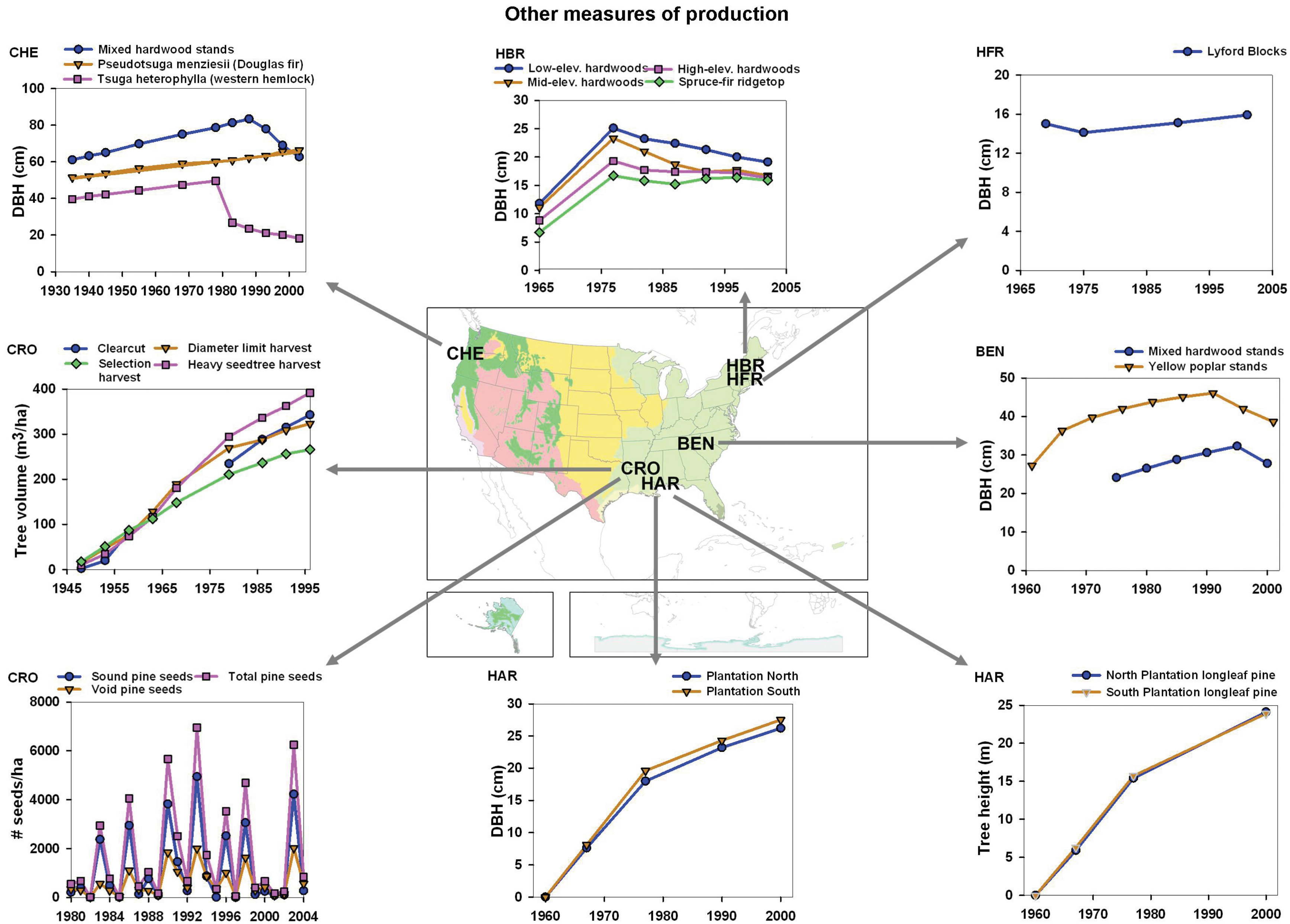

Figure 14-3. Other measures of terrestrial productivity for six forest sites (BEN, CHE, CRO, HAR, HBR, and HFR). A simple linear regression line is displayed if the slope is statistically significant ($p < 0.05$) and the trend appears linear. The significant slope is CHE (1). Original data from Internet home pages (see table 1-1). Synthesized data from http://www.ecotrends.info.

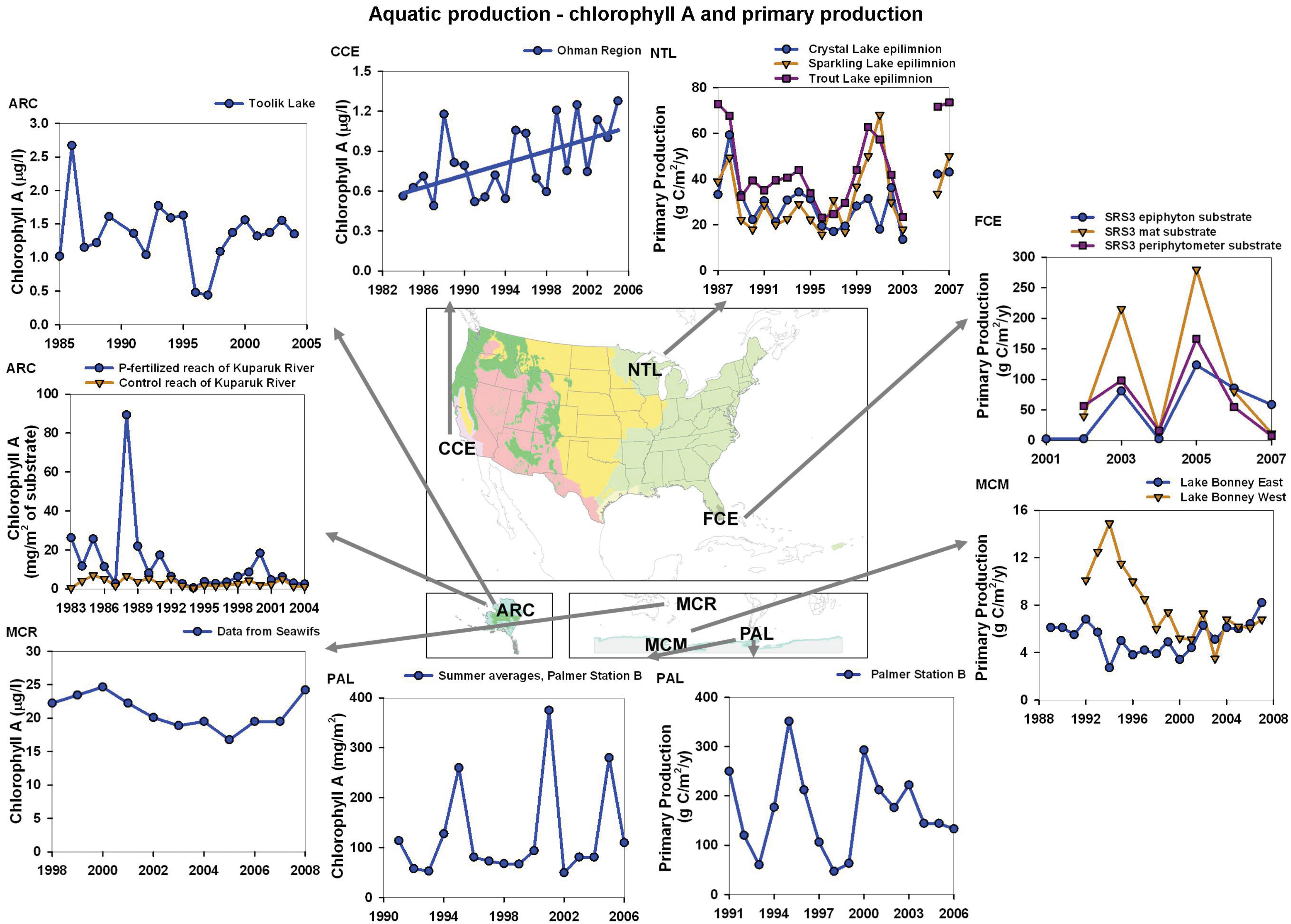

Figure 14-4. Aquatic productivity, either as chlorophyll A (µg/L or mg/m^2) or primary production (g C/m^2/y) for seven sites (ARC, CCE, FCE, MCM, MCR, NTL, and PAL). A simple linear regression line is displayed if the slope is statistically significant ($p < 0.05$) and the trend appears linear. The significant slope is CCE (0.02). Original data from Internet home pages (see table 1-1). Synthesized data from http://www.ecotrends.info.

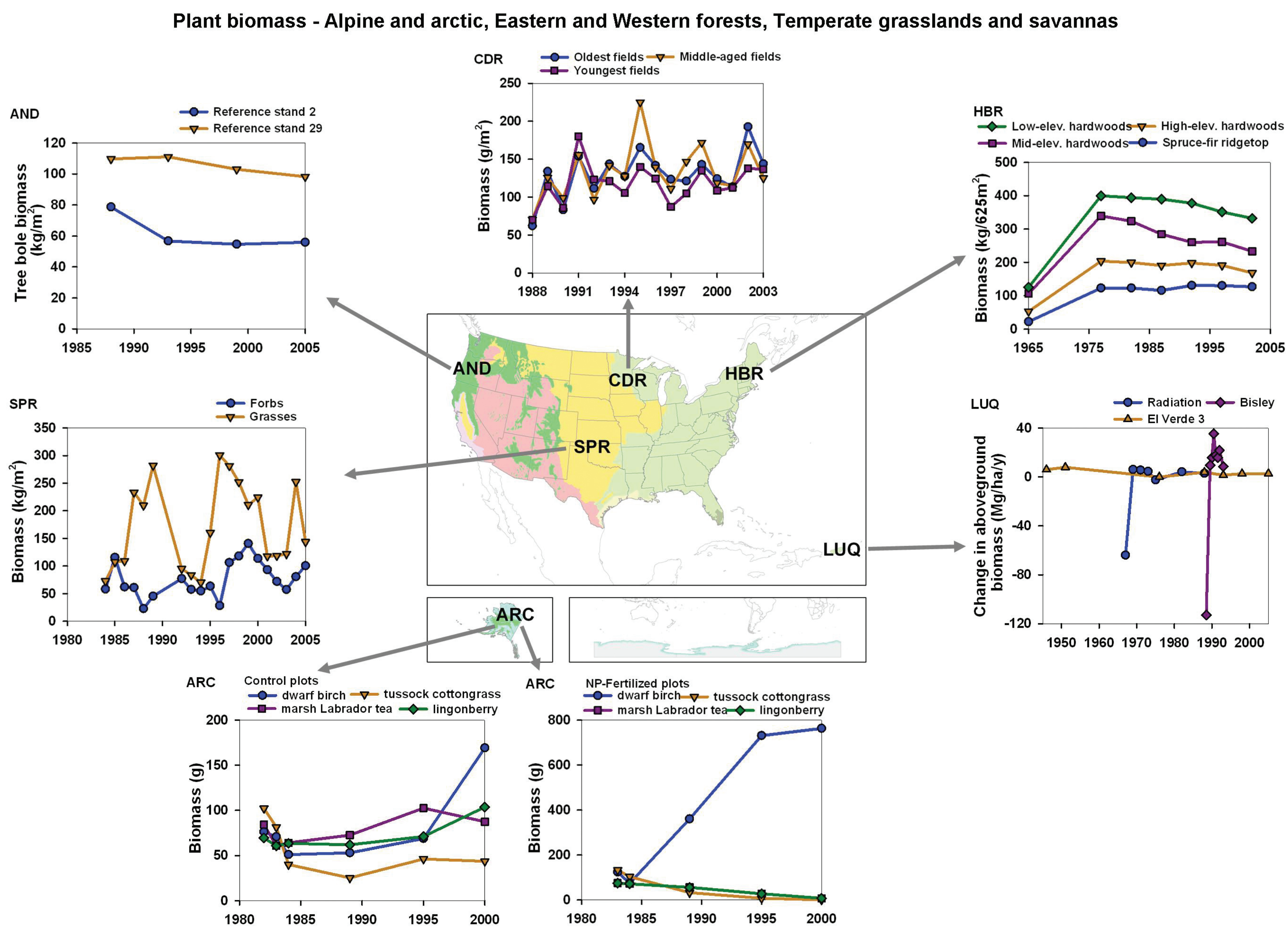

Figure 14-5. Plant biomass for alpine/arctic (ARC), forest (AND and HBR), and grassland (CDR and SPR) sites. See appendix 19 for the taxon/taxa specific to each site. A simple linear regression line is displayed if the slope is statistically significant ($p < 0.05$) and the trend appears linear. Original data from Internet home pages (see table 1-1). Synthesized data from http://www.ecotrends.info.

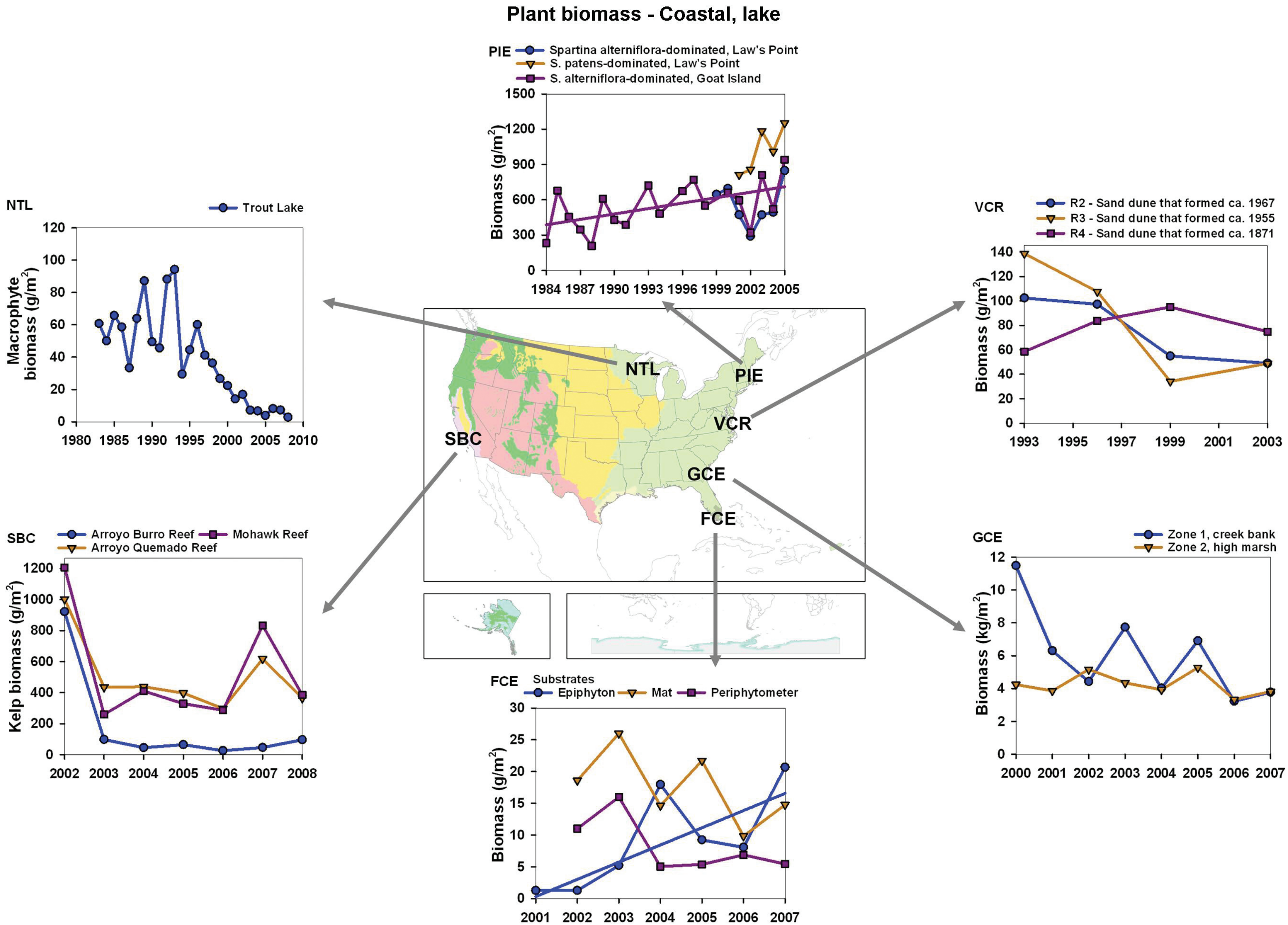

Figure 14-6. Plant biomass (and algae, if noted) for coastal and lake sites (FCE, GCE, NTL, PIE, SBC, and VCR). See appendix 19 for the taxon/taxa specific to each site. A simple linear regression line is displayed if the slope is statistically significant ($p < 0.05$) and the trend appears linear. The significant slopes are FCE (2.7) and PIE (15). Original data from Internet home pages (see table 1-1). Synthesized data from http://www.ecotrends.info.

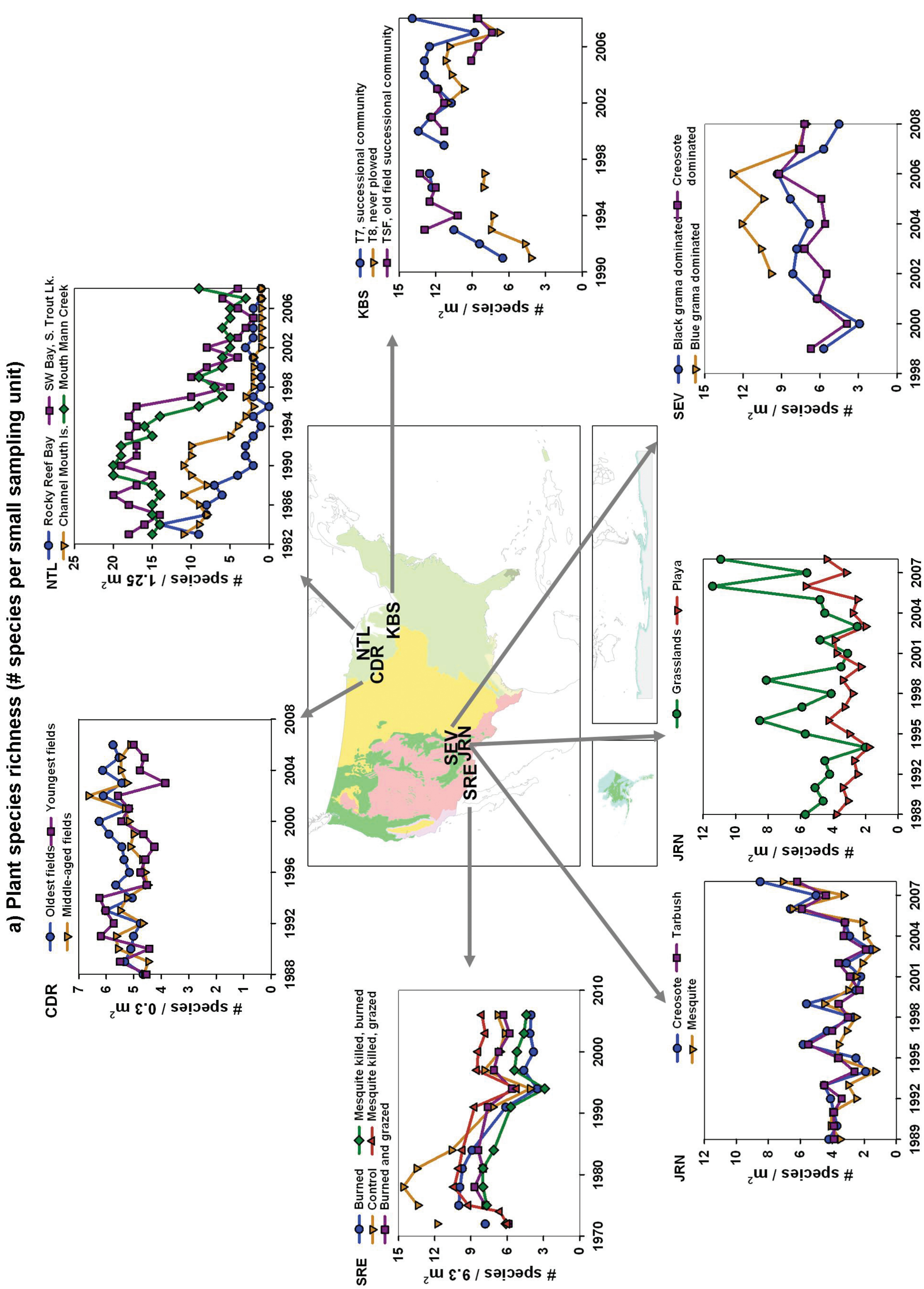

Figure 14-7 continued next page.

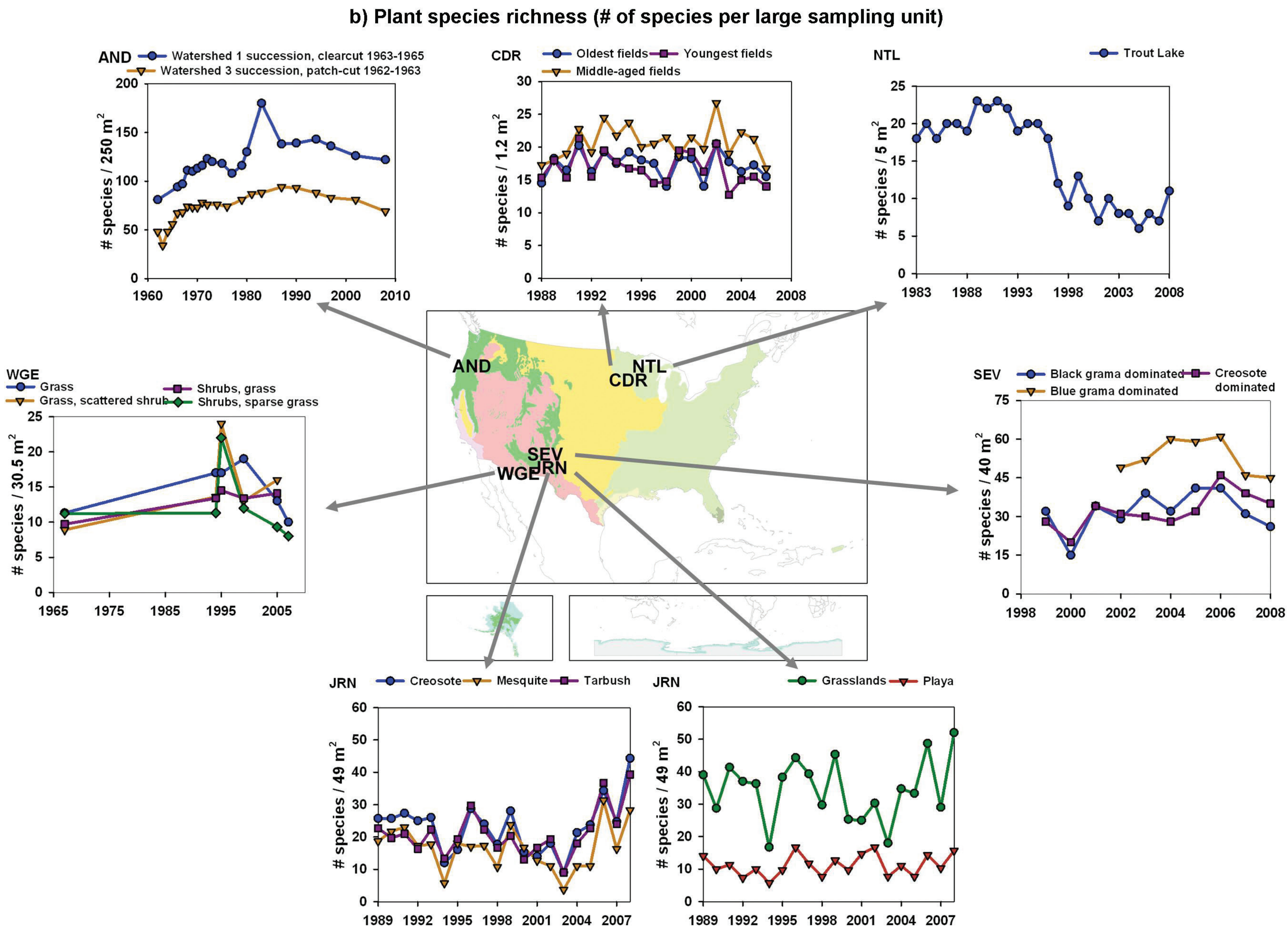

Figure 14-7. Plant species richness for eight sites (AND, CDR, JRN, KBS, NTL, SEV, SRE, and WGE): (a) at small sampling units (0.3-9.3 m^2) and (b) at large sampling units (1.2-250 m^2). A simple linear regression line is displayed if the slope is statistically significant ($p < 0.05$) and the trend appears linear. Original data from Internet home pages (see table 1-1). Synthesized data from http://www.ecotrends.info.

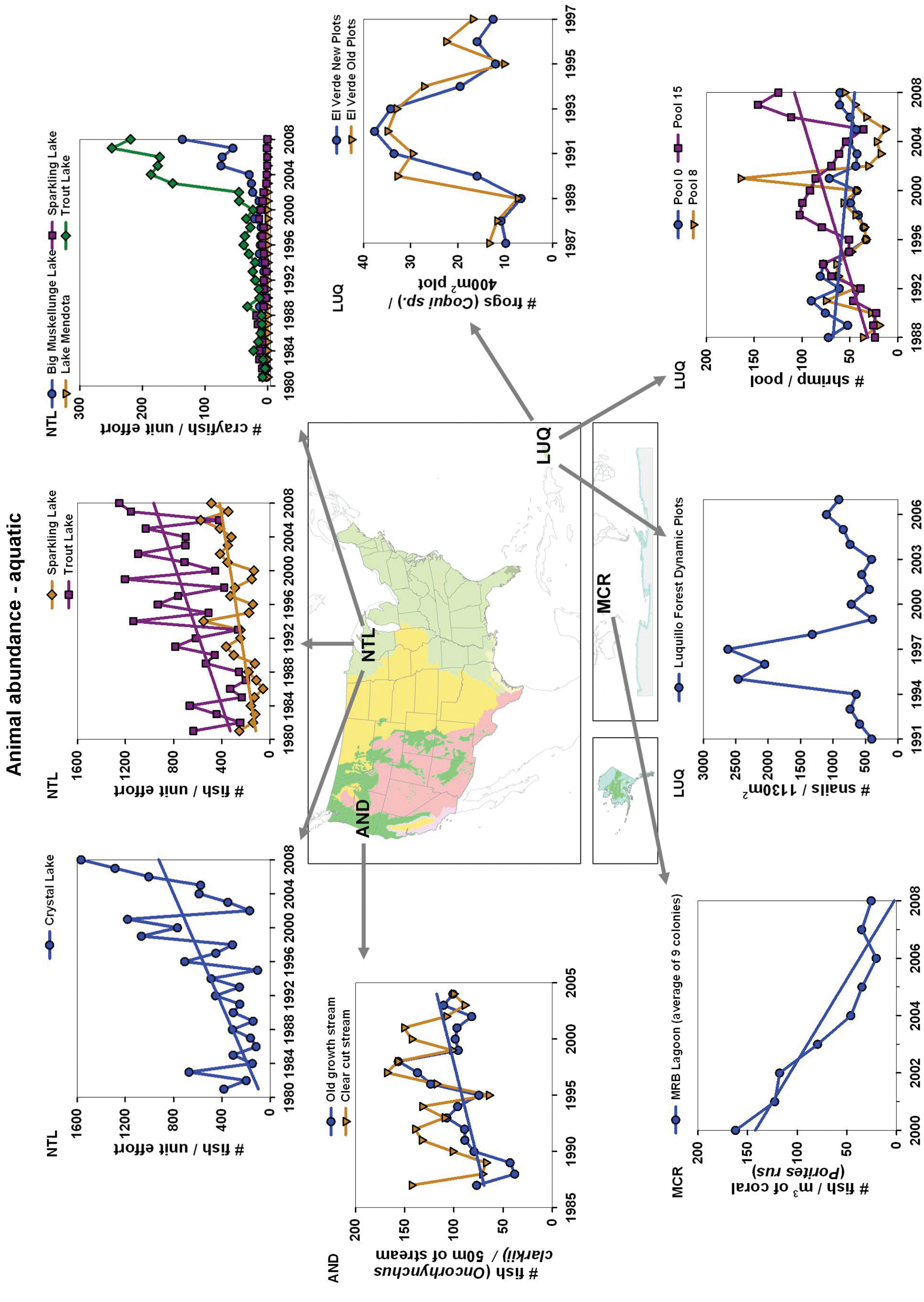

Figure 14-8. Abundance of aquatic animals at four sites (AND, LUQ, MCR, and NTL). A simple linear regression line is displayed if the slope is statistically significant ($p < 0.05$) and the trend appears linear. The significant slopes are AND (2), LUQ (-1, 4), MCR (-17), and NTL (11, 24, 31). Original data from Internet home pages (see table 1-1). Synthesized data from http://www.ecotrends.info.

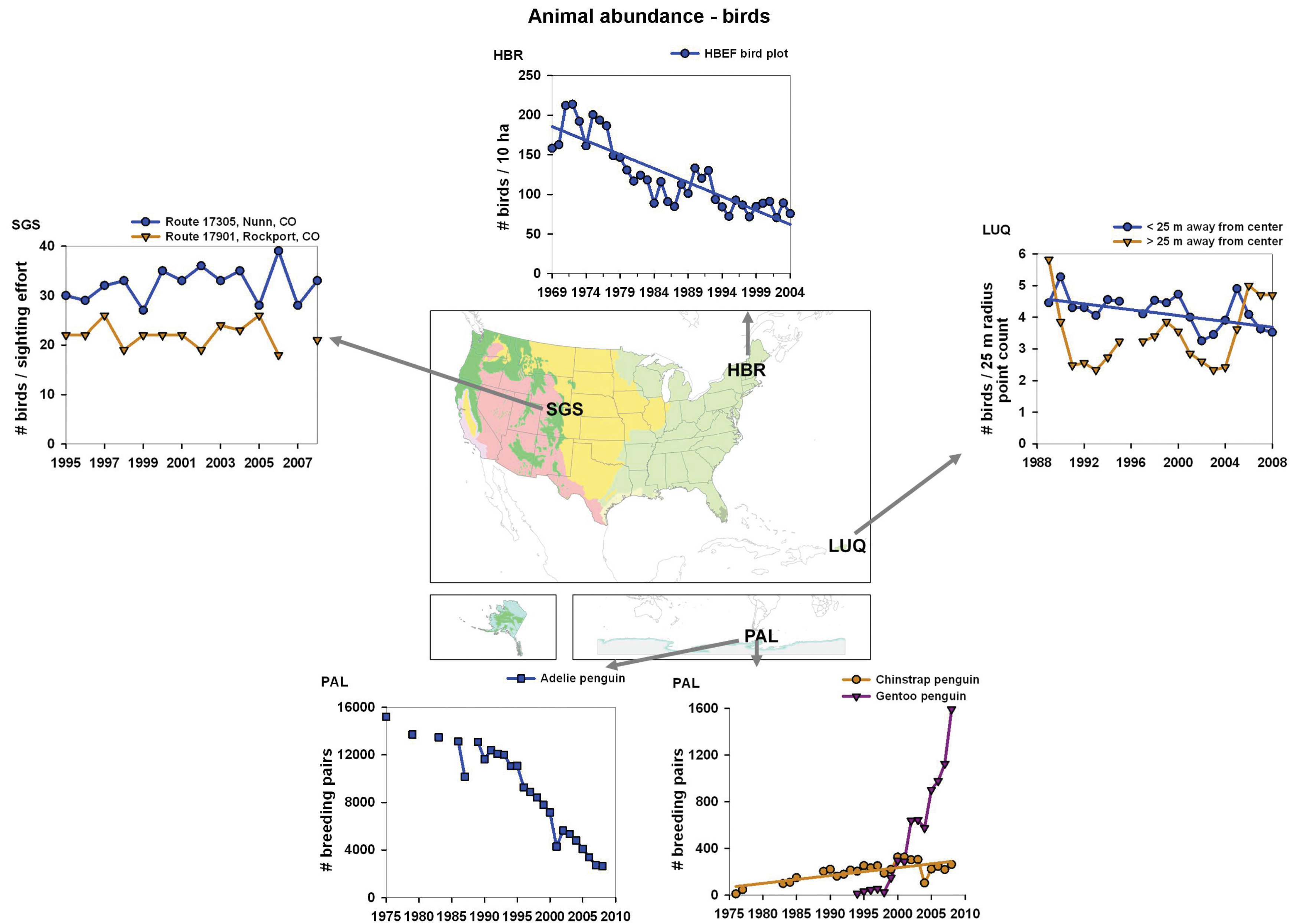

Figure 14-9. Abundance of birds at four sites (HBR, LUQ, PAL, and SGS,). A simple linear regression line is displayed if the slope is statistically significant ($p < 0.05$) and the trend appears linear. The significant slopes are HBR (-3.53), LUQ (-0.05), and PAL (6.70). Original data from Internet home pages (see table 1-1). Synthesized data from http://www.ecotrends.info.

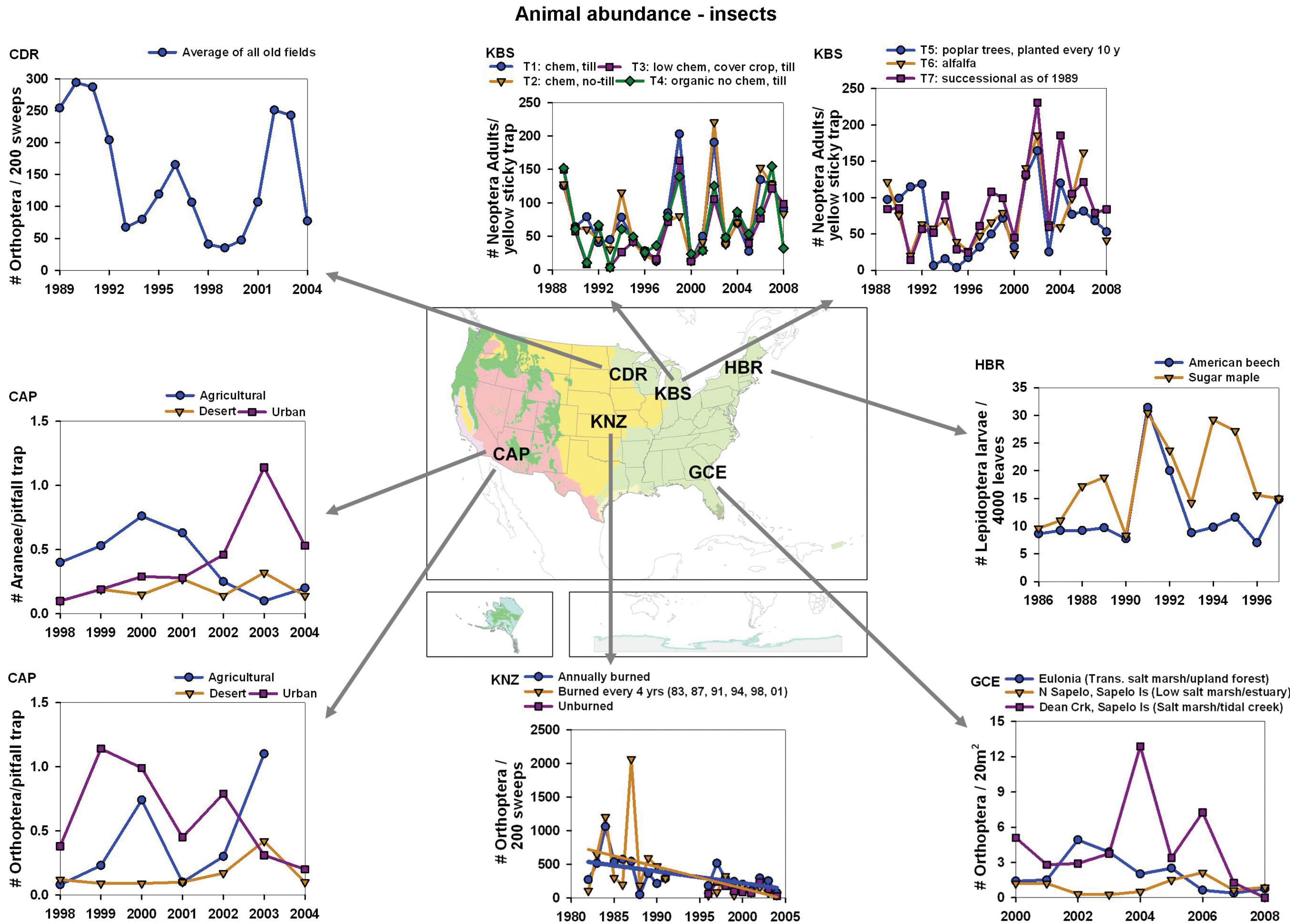

Figure 14-10. Abundance of insects at six sites (CAP, CDR, GCE, HBR, KBS, and KNZ). A simple linear regression line is displayed if the slope is statistically significant ($p < 0.05$) and the trend appears linear. The significant slopes are KNZ (-18, -32). Original data from Internet home pages (see table 1-1). Synthesized data from http://www.ecotrends.info.

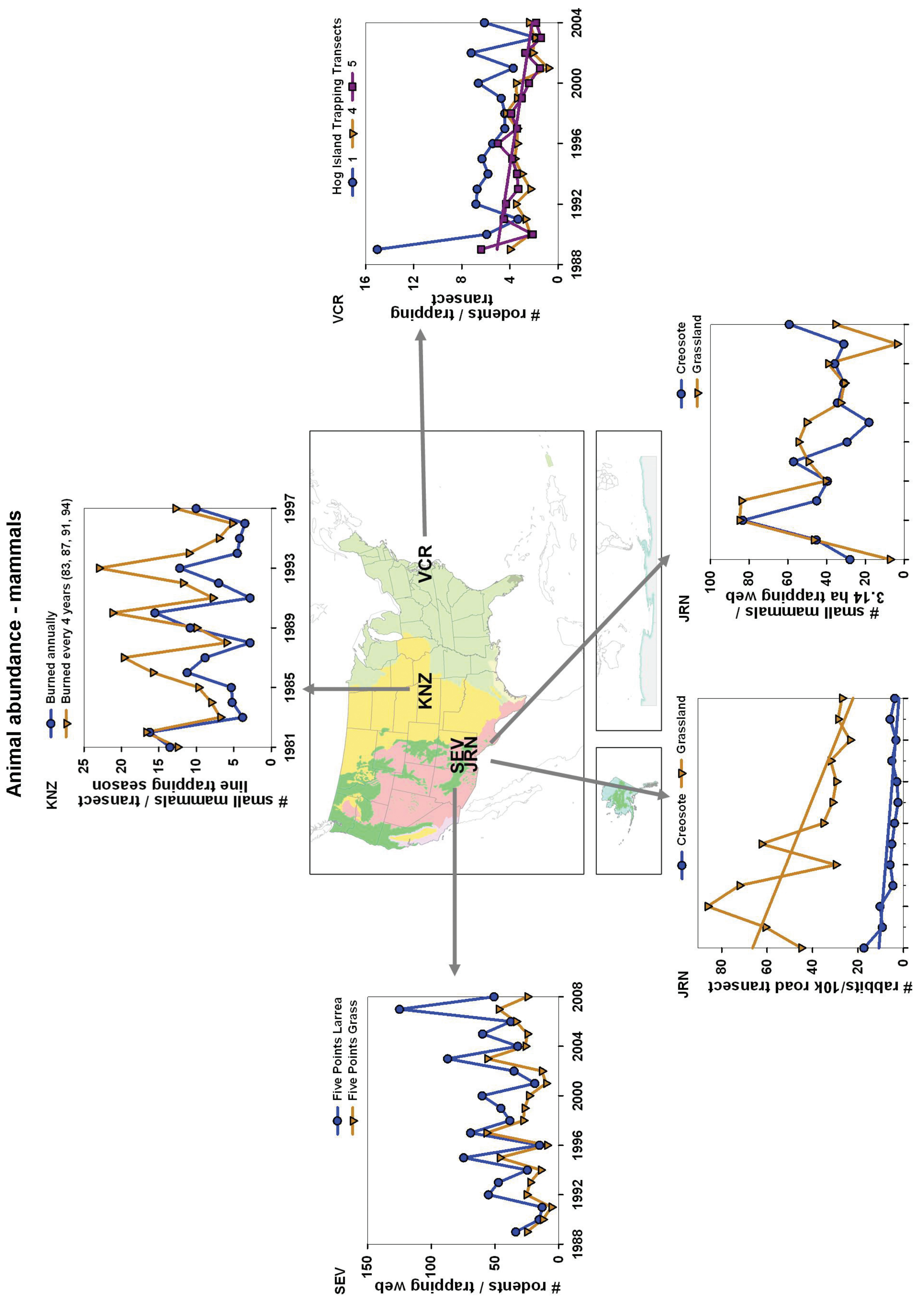

Figure 14-11. Abundance of mammals at four sites (JRN, KNZ, SEV, and VCR). A simple linear regression line is displayed if the slope is statistically significant ($p < 0.05$) and the trend appears linear. The significant slopes are JRN (-0.7, -3.7) and VCR (-0.2). Original data from Internet home pages (see table 1-1). Synthesized data from http://www.ecotrends.info.

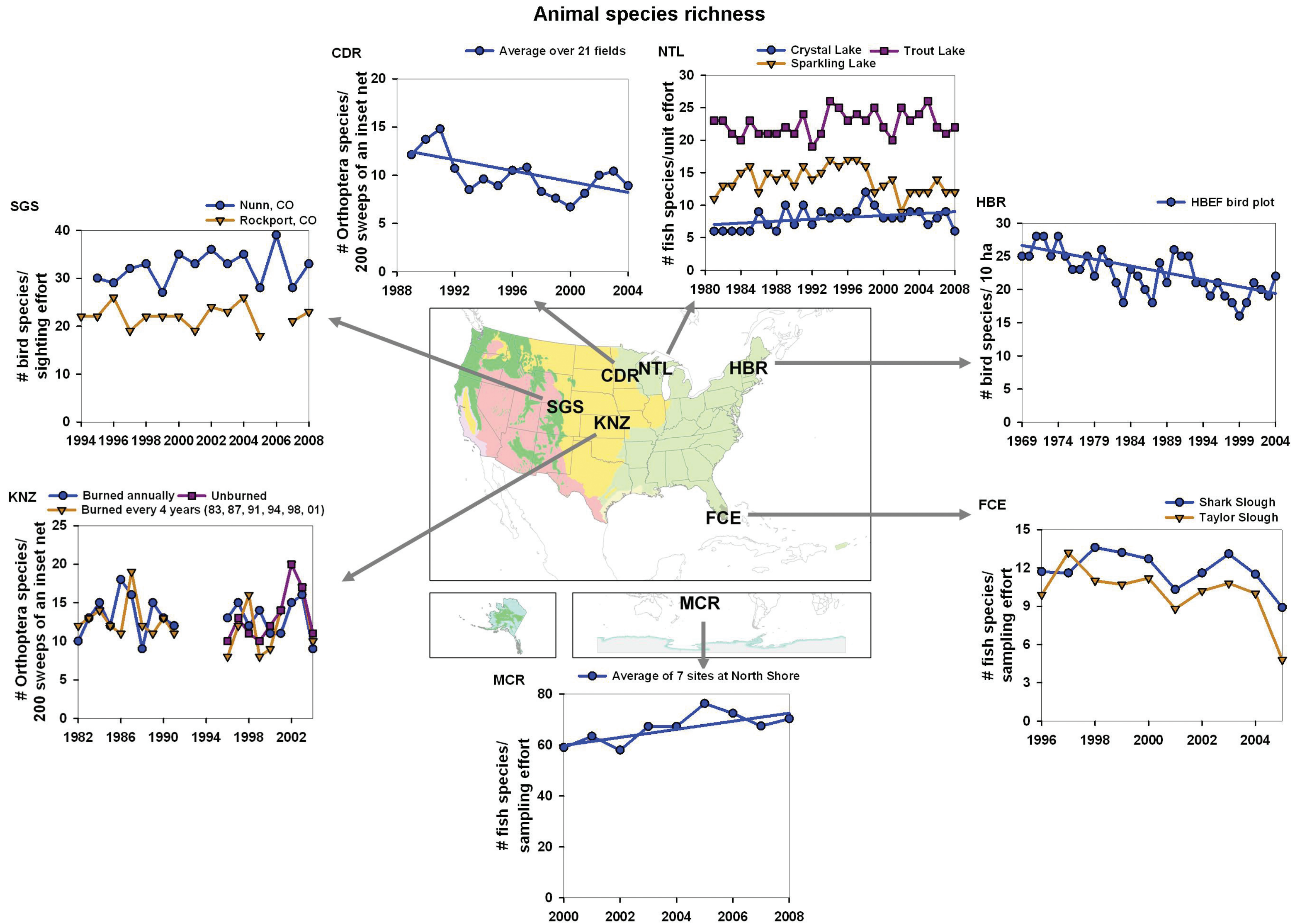

Figure 14-12. Animal species richness at seven sites (CDR, FCE, HBR, KNZ, MCR, NTL, and SGS). A simple linear regression line is displayed if the slope is statistically significant ($p < 0.05$) and the trend appears linear. The significant slopes are CDR (-0.28), HBR (-0.21), MCR (1.55), and NTL (0.07). Original data from Internet home pages (see table 1-1). Synthesized data from http://www.ecotrends.info.