



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

Contributors .....	VIII
Technical Consultants .....	X

## ***Introduction to Cross-Site Comparisons and History and Organization of the EcoTrends Project***

Chapter 1: Long-Term Trends in Ecological Systems: An Introduction to Cross-Site Comparisons and Relevance to Global Change Studies .....	1
Chapter 2: History and Organization of the EcoTrends Project .....	21

## ***Cross-Site Comparisons of Ecological Responses to Global Change Drivers***

Chapter 3: Cross-Site Comparisons of Ecological Responses to Climate and Climate-Related Drivers .....	28
Chapter 4: Cross-Site Comparisons of State-Change Dynamics .....	36
Chapter 5: Patterns of Net Primary Production Across Sites .....	42
Chapter 6: Cross-Site Comparisons of Precipitation and Surface Water Chemistry .....	46
Chapter 7: Cross-Site Comparisons of Ecological Responses to Long-Term Nitrogen Fertilization .....	51
Chapter 8: Long-Term Trends in Human Population Growth and Economy Across Sites .....	54
Chapter 9: Disturbance Regimes and Ecological Responses Across Sites .....	58
Chapter 10: Cross-Site Studies “By Design”: Experiments and Observations That Provide New Insights .....	72

## ***Long-Term Trends in Global Change Drivers and Responses at Site and Continental Scales***

Chapter 11: Long-Term Trends in Climate and Climate-Related Drivers .....	81
Chapter 12: Long-Term Trends in Precipitation and Surface Water Chemistry .....	115
Chapter 13: Long-Term Trends in Human Demography and Economy Across Sites .....	162
Chapter 14: Long-Term Trends in Production, Abundance, and Richness of Plants and Animals .....	191
Chapter 15: Management and Policy Implications of Cross- and Within-Site Long-Term Studies .....	206
Chapter 16: Recommendations for Data Accessibility .....	216
Chapter 17: Long-Term Research Across Sites, Ecosystems, and Disciplines: Synthesis and Research Needs .....	226

## ***Appendices***

Appendix 1: Site Descriptions .....	234
Appendix 2: Average (Standard Error) Maximum, Mean, and Minimum Air Temperature and Annual Precipitation at Each Site .....	312

Appendix 3: Average (Standard Error) Ice Duration, Sea Level, Streamflow, Water Clarity, and Water Temperature for Sites With Data .....	314
Appendix 4: Regression Coefficients and R <sup>2</sup> Values for Nine Climatic Variables for Which Linear Regression Against Time Is Significant (p < 0.05) .....	316
Appendix 5: Annual Average (Standard Error) Nitrogen (as Nitrate) From Various Sources at Sites With Data .....	319
Appendix 6: Regression Coefficients and R <sup>2</sup> Values for Nitrogen (as Nitrate) From Various Sources for Which Linear Regression Against Time Is Significant (p < 0.05) .....	321
Appendix 7: Annual Average (Standard Error) Nitrogen (as Ammonium) From Various Sources at Sites With Data .....	323
Appendix 8: Regression Coefficients and R <sup>2</sup> Values for Nitrogen (as Ammonium) From Various Sources for Which Linear Regression Against Time Is Significant (p < 0.05) .....	325
Appendix 9: Annual Average (Standard Error) Sulfur (as Sulfate) From Various Sources at Sites With Data .....	326
Appendix 10: Regression Coefficients and R <sup>2</sup> Values for Sulfur (Sulfate) From Various Sources for Which Linear Regression Against Time Is Significant (p < 0.05) .....	328
Appendix 11: Annual Average (Standard Error) Chloride From Various Sources at Sites With Data ..	330
Appendix 12: Regression Coefficients and R <sup>2</sup> Values for Chloride From Various Sources for Which Linear Regression Against Time Is Significant (p < 0.05) .....	332
Appendix 13: Annual Average (Standard Error) Calcium From Various Sources at Sites With Data ...	334
Appendix 14: Regression Coefficients and R <sup>2</sup> Values for Calcium From Various Sources for Which Linear Regression Against Time Is Significant (p < 0.05) .....	336
Appendix 15: Human Population and Economy Variables in 2000 for the Focal County of Each Site, as Grouped by Ecosystem Type .....	338
Appendix 16: Annual Average (Standard Error) Aboveground Net Primary Production (ANPP) at Sites With Data .....	341
Appendix 17: Other Measures of Average (Standard Error) Terrestrial Production at Sites With Data..	343
Appendix 18: Average (Standard Error) Aquatic Production at Sites With Data .....	344
Appendix 19: Average (Standard Error) Biomass of Primary Producers (Plants, Algae) for Sites With Data .....	345
Appendix 20: Average (Standard Error) Plant Species Richness for Sites With Data .....	347
Appendix 21: Average (Standard Error) Animal Abundance for Sites With Data .....	349
Appendix 22: Average (Standard Error) Animal Species Richness for Sites With Data .....	352
Appendix 23: Regression Coefficients and R <sup>2</sup> 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 .....	353
Appendix 24: Lead Principal Investigator(s) (PI), Information Managers (IM), and Administrative Program of the LTER Programs .....	355
Appendix 25: Researchers Involved in the EcoTrends Project at Non-LTER Sites .....	359

Appendix 26: List of Stations and Length of Record for Each Climate Variable by Site ..... 362

Appendix 27: List of Stations and Length of Record for Each Precipitation or Surface Water  
Chemistry Variable by Site ..... 367

Appendix 28: List of Stations and Length of Record for Each Plant and Animal Variable by Site, as  
Grouped by Ecosystem Type ..... 371

Index ..... i

**Appendix 23. Regression coefficients and R<sup>2</sup> 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 <sup>1</sup>	R <sup>2</sup>
<b>Alpine and arctic</b>					
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
<b>Aridlands</b>					
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
<b>Coastal</b>					
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, <i>Pygoscelis antarcticus</i>	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<sup>2</sup> 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 <sup>1</sup>	R <sup>2</sup>
<b>Eastern forests</b>					
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
<b>Temperate grasslands and savannas</b>					
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
<b>Western forests</b>					
AND	Animal abundance, fish	Old growth section of Mack Creek	2.4	67.1	0.3
CHE	Diameter at breast height, <i>Pseudotsuga menziesii</i> (Douglas fir)	HSGY Study Plots	1.0	50.7	1.0

<sup>1</sup> Y-intercept was calculated for the first year of a dataset, which contains records of one variable over time for one site.