REVEGETATION: A COMPARISON OF TREATED CONTAMINATED SOIL AND DISPLACED SOIL FOLLOWING BIOREMEDIATION OF A CRUDE OIL SPILL IN THE TALLGRASS PRAIRIE PRESERVE

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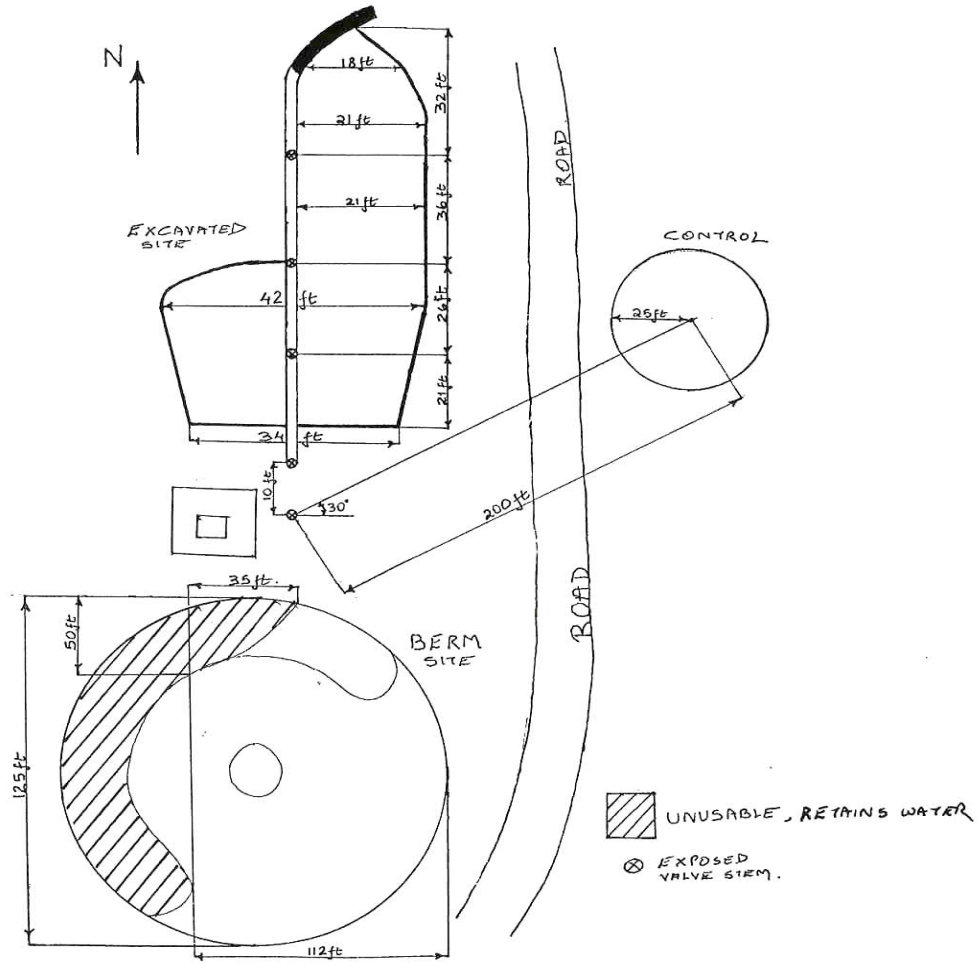
ABSTRACT

The rupture of a crude oil pipeline in 1992 in the Tallgrass Prairie Preserve resulted in the release of crude oil over an area of about 12 m by 40 m. At the time of the spill a vacuum truck was used to recover pooled oil but contamination remained that could not be recovered. The site was covered with hay and left alone. A site assessment in early 1996 showed that the crude oil had migrated downward to a depth of one meter with TPH (IR) concentrations in the 0 -1m interval ranging from 6,000 to 33,000 mg/kg. The downward migration of the oil was stopped by a clay layer at about one meter.

Nearby the spill was an old tank battery. All of the tanks had long since been removed but the original containment berm was still in place. The soil in the berm was free of hydrocarbon or salt contamination. In May, 1996 the contaminated soil was excavated and replaced with soil form the berm. The excavated soil was land treated within the confines of the old tank battery using standard methods with the addition of hay and N-P-K fertilizers. After 46 days of treatment average TPH levels were reduced to about 7,000 mg/kg on an average. The most recent TPH measurements (June, 2001) showed residual concentrations ranging from 2000 to 9800 mg/kg.

Both the site of the old land treatment cell and the excavation site have partially revegetated since active intervention ceased. This poster compares the current status of the two disturbed sites relative to unimpacted prairie in terms of aboveground biomass of grasses and forbs and species diversity.

Tallgrass Prairie Region
Revegetated Site



SITE HISTORY

- Situated in The Nature Conservancy's Tallgrass Prairie Preserve, Osage County, Oklahoma
- Crude oil contamination from a pipeline break in 1992
- Contamination area: 480 m^2
- TPH levels (EPA 418.1) measured in 1995 ranged from 6,000 mg/kg to 33,000 mg/kg

THE REMEDIATION PROCESS

- Remediation initiated in May, 1996
- Contaminated soil was excavated and moved mechanically to an adjacent treatment site (landfarm) and mixed with uncontaminated soil at a 5:1 ratio
- Fertilizer addition with tilling on the landfarm site to give an overall C:N:P:K of 100:3.33:1:1
- 75 bales of prairie hay addition with tilling applied evenly across the treatment
- Natural rainfall for moisture
- Project completed December, 1996
- June 2001 TPH levels (EPA 418.1): 2000 mg/kg to 9800 mg/kg

COMPARISON OF VEGETATION OF DISTURBED SITES WITH CONTROL

- Since June,2001 both the excavated and the landfarm (treated) site have been studied in terms of revegetation and compared with a control (native prairie)
- Sites have been sampled during spring and fall for
  - Identification (cumulative) of new plant species
  - Aboveground biomass
  - Species diversity
  - Species richness

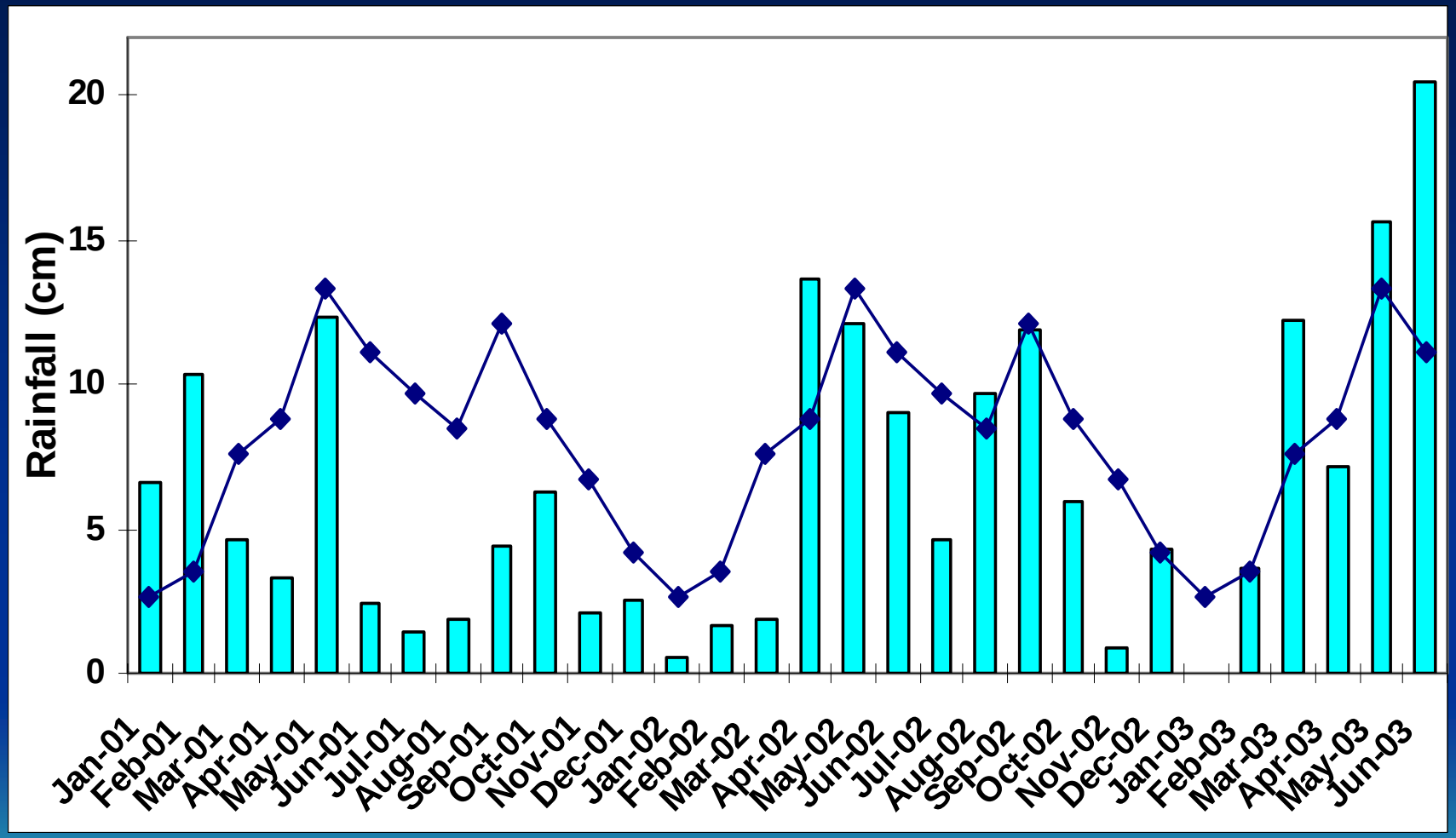
Excavated Site April '03

Landfarm Site April 2003

CONTROL SITE

- A native prairie site which is undisturbed and free of any contamination was chosen as a control
- About 25 ft in diameter, it is just east of the excavated and landfarm sites across a dirt small road
- Vegetation data from the two disturbed sites are compared with this control site

PRECIPITATION



IDENTIFICATION OF PLANT SPECIES (Cumulative plant species)

- Different plants collected from all three sites, pressed, and identified by family, genus, and species
  - 44 species identified on landfarm site
  - 56 species identified on excavated site
  - 60 species identified on control site
- 22 species overlap between all three sites
- 39 species common to excavated and control
- 26 species common to landfarm and control
- 28 species common to excavated and landfarm

PLANT SPECIES - EXCAVATED SITE

Species	Family	Species	Family
Achillea millefolium	Asteraceae	*Hordeum pusillum*	Poaceae
Ambrosia artmisiifolia	Asteraceae	*Iva annua*	Asteraceae
Ambrosia bidentata	Asteraceae	*Juncus interior*	Juncaceae
Ambrosia psilostachya	Asteraceae	*Kummerowia stipulaceae*	Fabaceae
Asclepias virdis	Asclepiadaceae	*Lepidum virginica*	Brassicaceae
Aster Oblongifolius	Asteraceae	*Leptoloma cognatum*	Poaceae
Bromus japonicus	Poaceae	*Lespedeza cuneata*	Fabaceae
Bromus tectorum	Poaceae	*Medicago lupulina*	Fabaceae
Carex sp	Cyperaceae	*Melilotus officinalis*	Fabaceae
Chamaecrista fasciculata	Fabaceae	*Oxalis dillenii*	Oxalidaceae
Cirsium altissimum	Asteraceae	*Panicum virgatum*	Poaceae
Cirsium undulatum	Asteraceae	*Panicum oligosanthes*	Poaceae
Coreopsis tinctoria	Asteraceae	*Plantago aristata*	Plantaginaceae
Croton capitatus	Euphorbiaceae	*Plantago patagonica*	Plantaginaceae
Cuscuta pentagona	Cuscutaceae	*Psoralidium tenuiflorum*	Fabaceae
Cynodon dactylon	Poaceae	*Rudbekia hirta*	Asteraceae
Cyperus croceus	Cyperaceae	*Ruellia humilis*	Acanthaceae
Cyperus echinatus	Cyperaceae	*Rumex crispus*	Polygonaceae
Cyperus lupulinus	Cyperaceae	*Salvia Azurea*	Lamiaceae
Dracopis amplexicaulis	Asteraceae	*Setaria parviflora*	Poaceae
Eleocharis sp	Cyperaceae	*Sporobulus Asper*	Poaceae
Elymus virginicus	Poaceae	*Solanum rostratum*	Solanaceae
Euphorbia prostrata	Euphorbiaceae	*Sorghum halepense*	Poaceae
Euthamia gymnospermoides	Asteraceae	*Strophostyles leiosperma*	Fabaceae
Festuca pratensis	Poaceae	*Torilis arvensis*	Apiaceae
Geranium carolinianum	Geraniaceae	*Triodanis perfoliata*	Campanulaceae
Gutierrezia dracunculoides	Asteraceae	*Vernonia baldwinii*	Asteraceae
Hedeoma hispida	Lamiaceae	*Xanthium strumarium*	Asteraceae

PLANT SPECIES - LANDFARM SITE

Species	Family	Species	Family
Ambrosia artimisiifolia	Asteraceae	*Iva angustifolia*	Asteraceae
Ambrosia bidentata	asteraceae	*Juncus interior*	Juncaceae
Ambrosia psilostachya	Poaceae	*Lepidum virginica*	Brassicaceae
Bothriochloa saccharoides	Poaceae	*Medicago Lupulina*	Fabaceae
Bromus japonicus	Poaceae	*Melilotus officinalis*	Fabaceae
Carex sp	Cyperaceae	*Panicum oligosanthes*	Poaceae
Conyza canadensis	Asteraceae	*Phalaris caroliniana*	Poaceae
Croton capitatus	Euphorbiaceae	*Physalis virginiana*	Solanaceae
Cynodon dactylon	Poaceae	*Polygonum aviculare*	Polygonaceae
Cyperus echinatus	Cyperaceae	*Polygonum lapathifolium*	Polygonacea
Desmodium ciliare	Asteraceae	*Pyrrhopappus carolinianus*	Asteraceae
Eleocharis sp	Cyperaceae	*Rudbekia hirta*	Asteraceae
Elymus canadensis	Poaceae	*Rumex crispus*	Polygonaceae
Erigeron strigosus	Asteraceae	Salvia Azurea	Lamiaceae
Euthamia gymnospermoides	Asteraceae	*Solanum carolinense*	Solanaceae
Festuca arundinacea	Poaceae	*Solanum rostratum*	Solanaceae
Festuca pratensis	Poaceae	*Sporobulus sp*	Poaceae
Geranium carolinianum	Geraniaceae	*Sporobulus asper*	Poaceae
Geranium pusillum	Geraniaceae	*Strophpstyles leiosperma*	Fabaceae
Gutierrezia dracunculoides	Asteraceae	*Torilis arvensis*	Apiaceae
Hordeum pusillum	Poaceae	*Typha domingensis*	Typhaceae
Iva annua	Asteraceae	*Xanthium strumarium*	Asteraceae

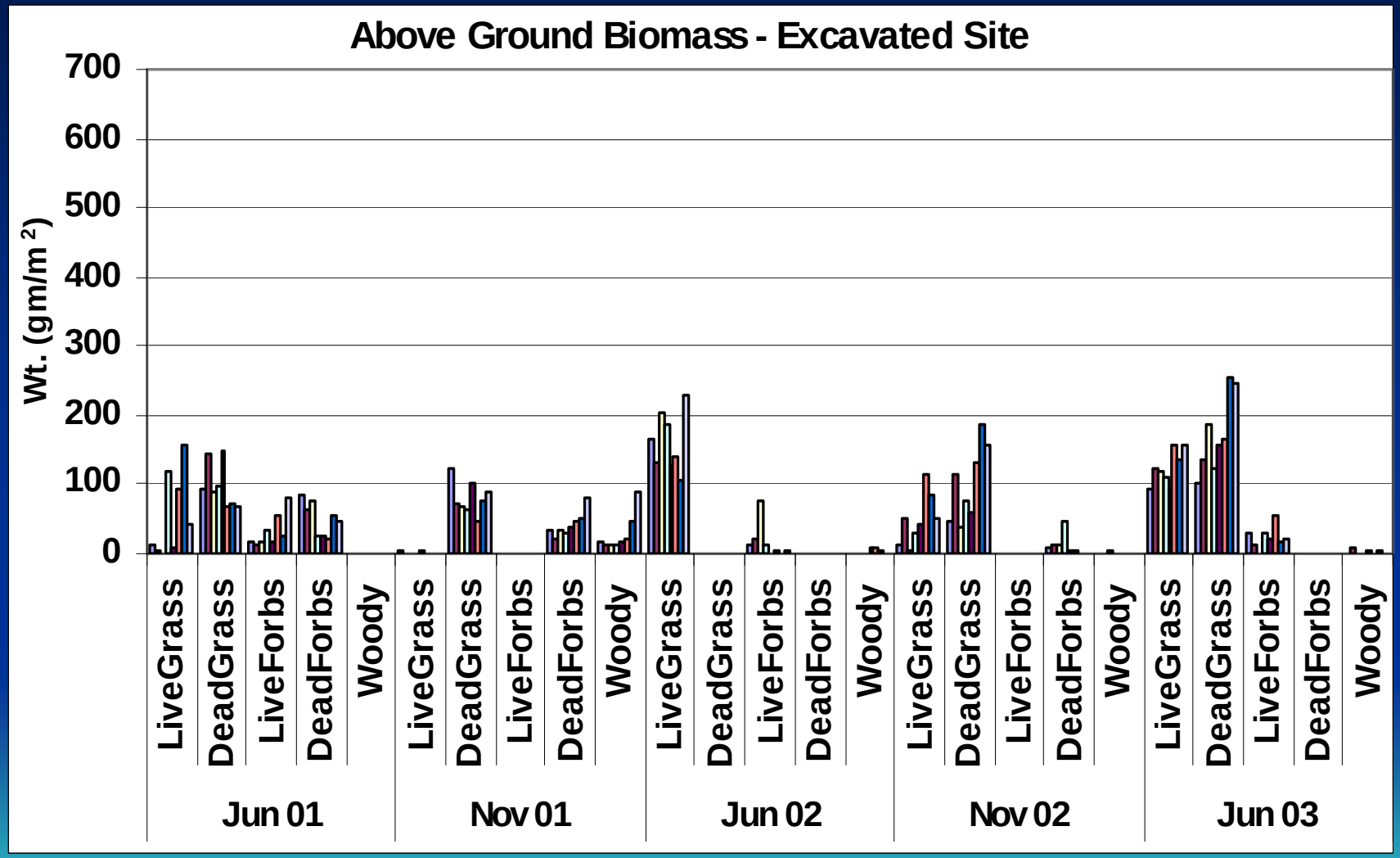
PLANT SPECIES - CONTROL SITE

Species	Family	Species	Family
Achillea millefolium	Asteraceae	*Helianthus mollis*	Asteraceae
Ambrosia artimisiifolia	Asteraceae	*Hordeum pusillum*	Poaceae
Ambrosia bidentata	Asteraceae	*Iva annua*	Asteraceae
Ambrosia psilostachya	Asteraceae	*Juncus interior*	Juncaceae
Amorpha canescens	Fabaceae	*Kummerowia Stipulaceae*	Fabaceae
Andropogon gerardii	Poaceae	*Lepidum virginica*	Brassicaceae
Arnoglossum plantagineum	Asteraceae	*Lespedeza cuneata*	Fabaceae
Artemesia ludoviciana	Asteraceae	*Medicago lupulina*	Fabaceae
Asclepias virdis	Asclepiadaceae	*Melilotus officinalis*	Fabaceae
Aster ericoides	Asteraceae	*Oxalis dillenii*	Oxalidaceae
Baptisia australis	Fabaceae	*Panicum oligosanthes*	Poaceae
Baptisia bracteata	Fabaceae	*Panicum virgatum*	Poaceae
Bromus japonicus	Poaceae	*Poa pratensis*	Poaceae
Bromus tectorum	Poaceae	*Plantago patagonica*	Plantaginaceae
Callirhoe alcaeoides	Malvaceae	*Plantago virginiana*	Plantaginaceae
Carex sp	Cyperaceae	*Psoralidium tenuilorum*	Fabaceae
Chamaecrista fasciculata	Fabaceae	*Ratibida columnifera*	Asteraceae
Cirsium Altissimum	Asteraceae	*Ruellia humilis*	Acanthaceae
Coreopsis tinctoria	Asteraceae	*S. canadensis*	Asteraceae
Cynodon dactylon	Poaceae	*Salvia azurea*	Lamiaceae
Cyperus echinatus	Cyperaceae	*Setaria parviflora*	Poaceae
Cyperus Lupulinus	Cyperaceae	*Silene antirrhina*	Caryophyllaceae
Elymus canadensis	Poaceae	*Solanum carolinense*	Solanaceae
Elymus virginicus	Poaceae	*Sorghastrum nutans*	Poaceae
Erigeron strigosus	Asteraceae	*Sporobulus asper*	Poaceae
Euthamia gymnospermoides	Asteraceae	*Schizachyrium scoparium*	Poaceae
Festuca arundinacea	Poaceae	*Torilis arvensis*	Apiaceae
Festuca pratensis	Poaceae	*Vernonia baldwinii*	Asteraceae
Geranium carolinianum	Geraniaceae	*Xanthium strumarium*	Asteraceae
Gutierrezia dracunculoides	Fabaceae	*Eragrostis spectabilis*	Poaceae

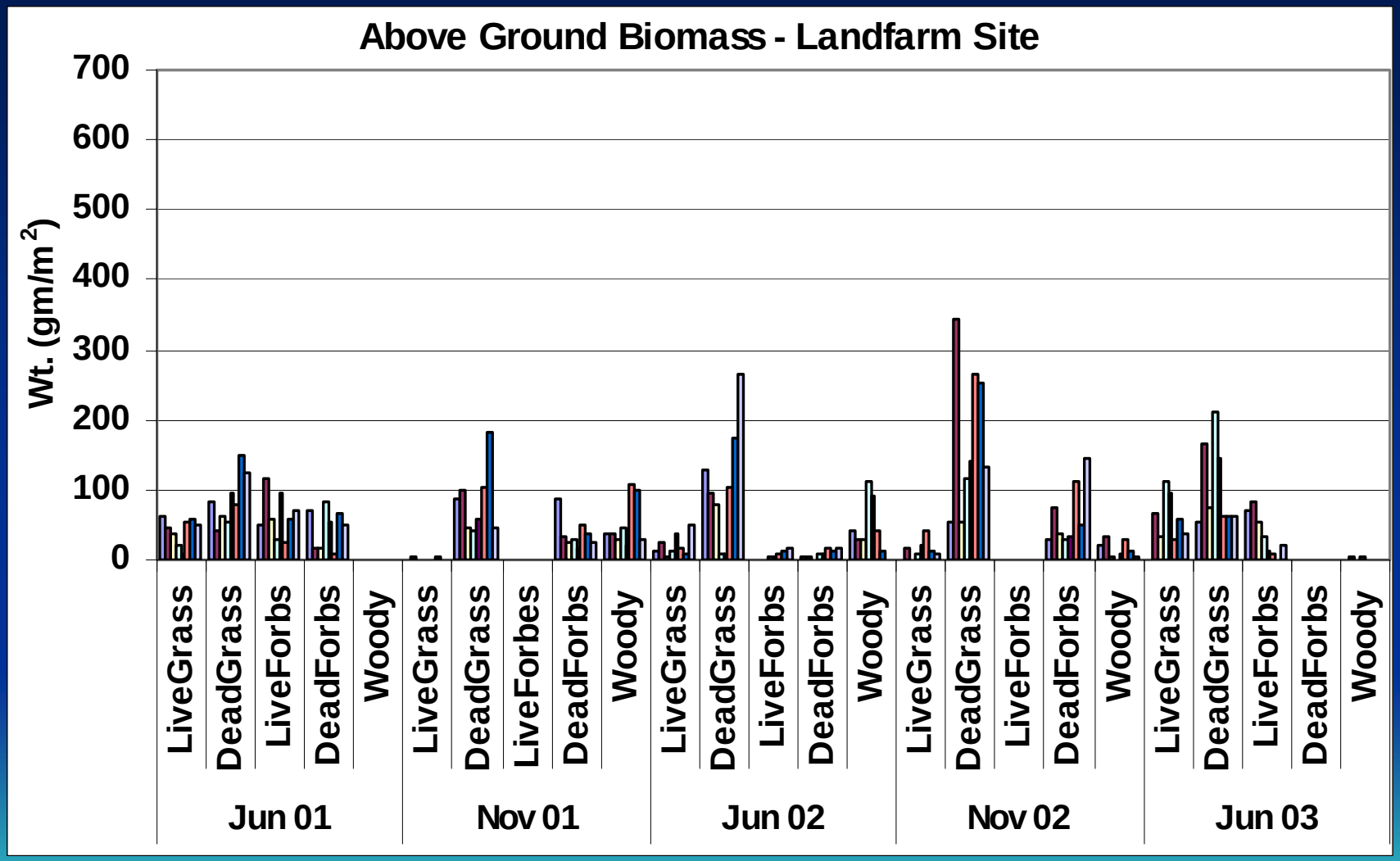
ABOVEGROUND BIOMASS

- Collected plant aboveground biomass for 8 1-m^2 equivalent strips for each site
- Sorted into live and dead grasses and forbs and woody
- Dried sorted samples for 12 hours in an oven at 60°C and then weighed

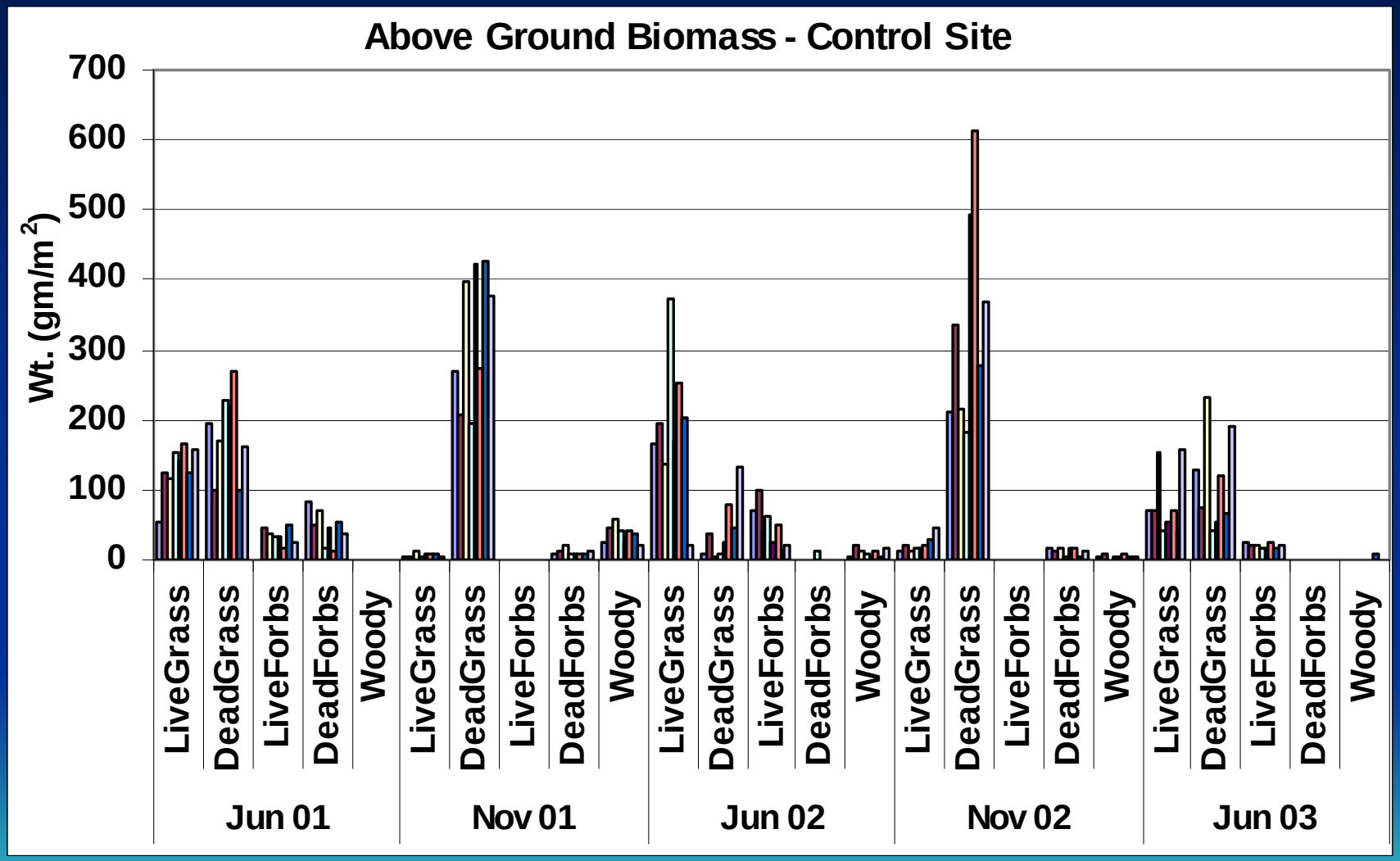
ABOVEGROUND BIOMASS EXCAVATED SITE



ABOVEGROUND BIOMASS LANDFARM SITE



ABOVEGROUND BIOMASS CONTROL SITE



COMPARISON OF ABOVEGROUND BIOMASS

Sample Date	% of Control	
	Excavated	Landfarm
Jun 01	60.7	61.4
Nov 01	42.7	46.0
Jun 02	61.7	64.7
Nov 02	43.1	69.7
Jun 03	147.4	89.5

GRASS/FORBS RATIO

	Excavated	Landfarm	Control
Jun 01	1.84	1.18	4.1
Nov 01	1.93	2.23	29.02
Jun 02	9.81	8.94	4.75
Nov 02	12.26	2.86	28.2
Jun 03	12.95	4.52	9.34

SPECIES DIVERSITY

OBJECTIVE

To estimate species diversity in the 3 sites

METHOD

- Collected plant species for 5 1-m^2 quadrat frames for all 3 sites
- Determined number and type of species present per quadrat frame per site
- Calculated Shannon's diversity index (H) and Shannon's equitability (E_H)

SHANNON'S INDICES

- Shannon's Diversity Index (H)
  - Characterizes species diversity in a community
  - The formula for calculating Shannon diversity index is

$$H = -\sum p_i \ln p_i$$

where p_i , the proportional abundance of the ith species = (n_i/N) and N = total number of species

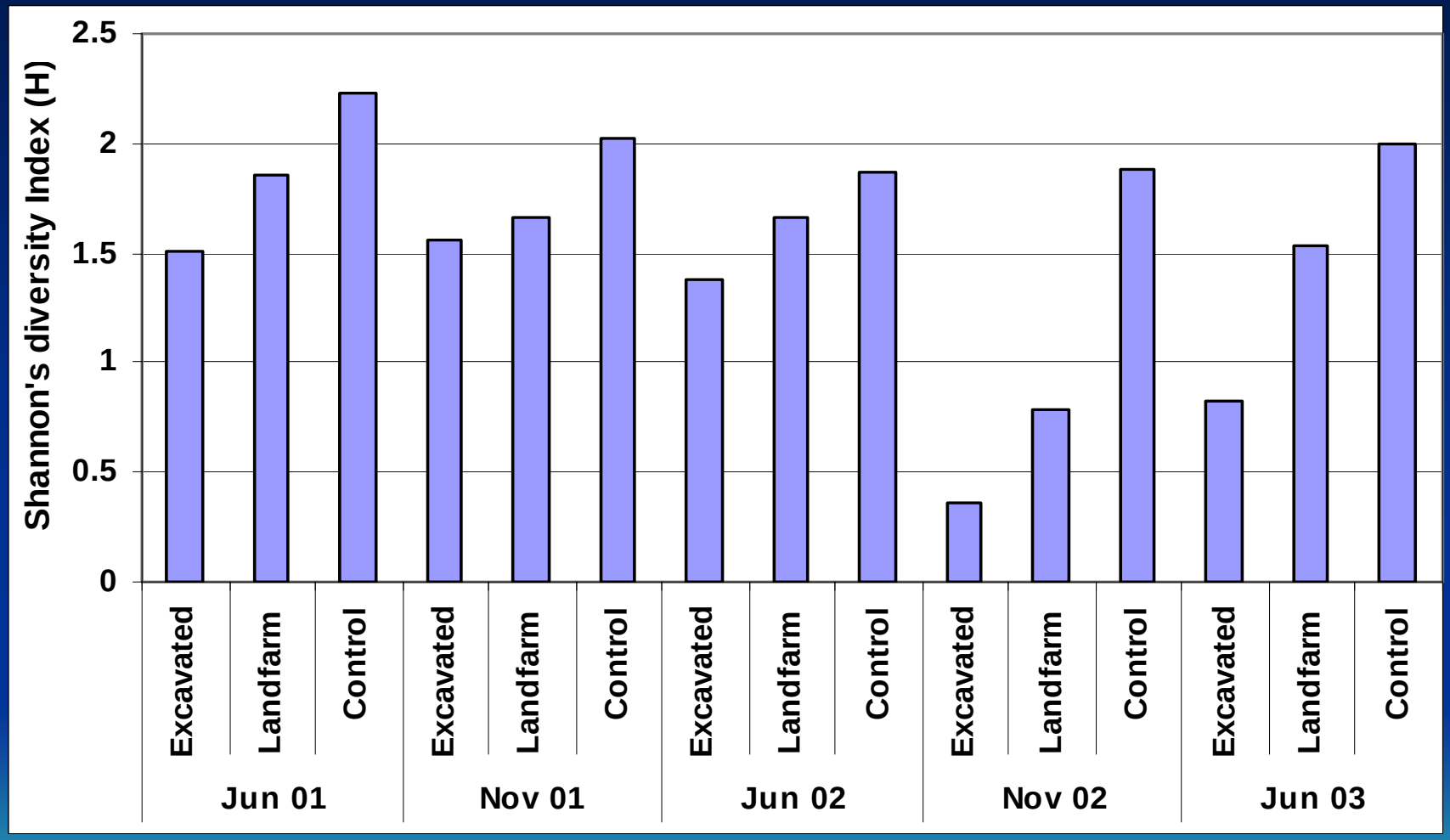
- Shannon's Equitability (E_H)
  - Given a distribution of types of individuals in a collection, the equitability index is considered to measure the degree to which these types are equally represented or even
  - E_H assumes a value between 0 and 1 with 1 being complete evenness
  - Shannon's equitability is calculated using the formula

$$E_H = H / \ln S$$

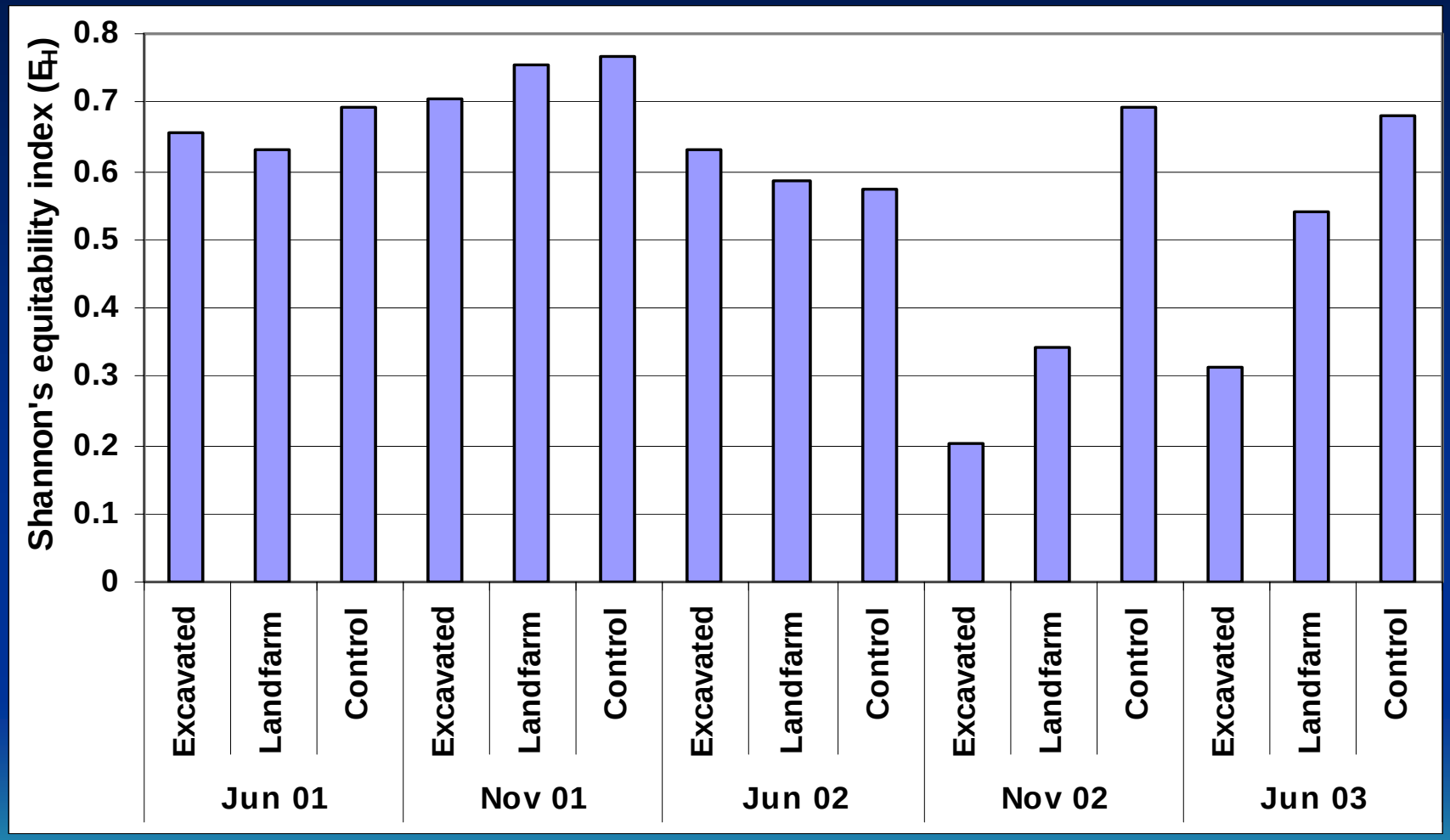
where S = total number of species in the community

- Species Richness
  - Total number of species occurring on the site

SHANNON'S DIVERSITY INDEX (H)



SHANNON'S EQUITABILITY (E_H)



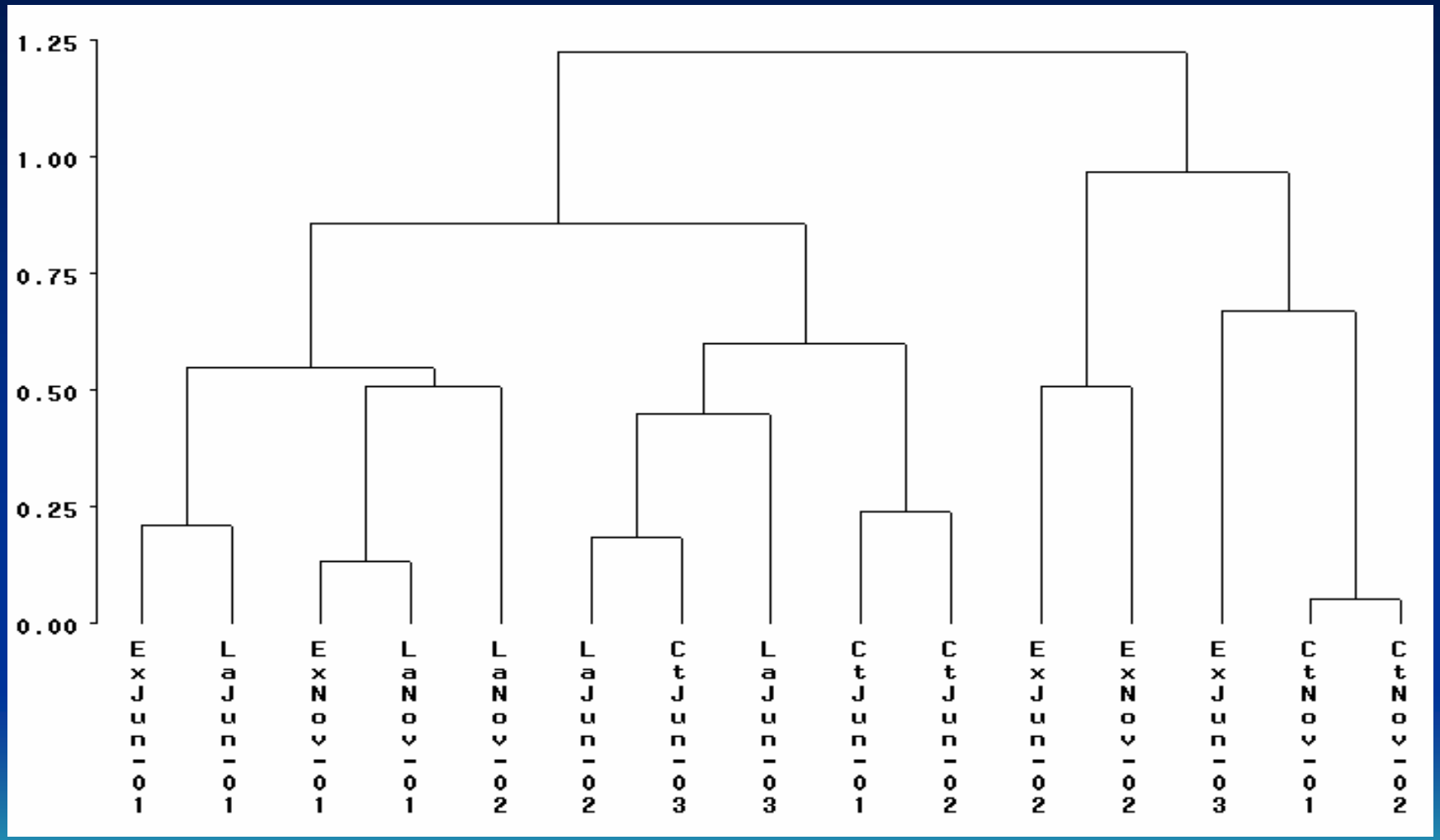
SPECIES RICHNESS

	Excavated	Landfarm	Control
Jun 01	16	17	25
Nov 01	9	8	15
Jun 02	8	16	26
Nov 02	6	10	15
Jun 03	14	17	19

CLUSTER ANALYSIS

- Based on
  - Total Biomass
  - Species Richness
  - Shannon's Diversity (H)
  - Shannon's Evenness (E)
  - Grass/Forbs Ratio
- Recent landfarm site data clusters with control
- Recent excavated site data clusters with previous data from control

CLUSTER ANALYSIS

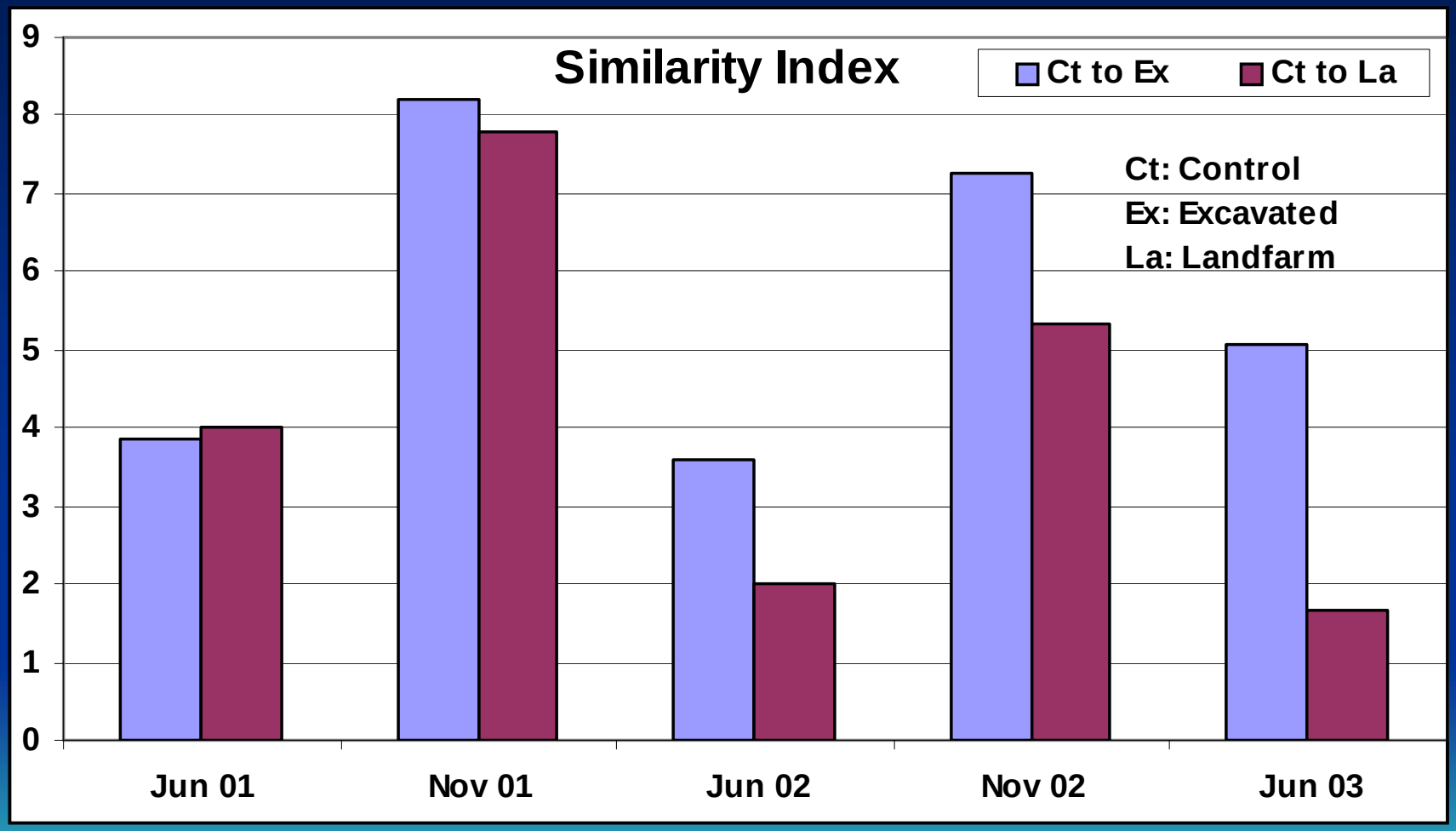


PRINCIPAL COMPONENT ANALYSIS

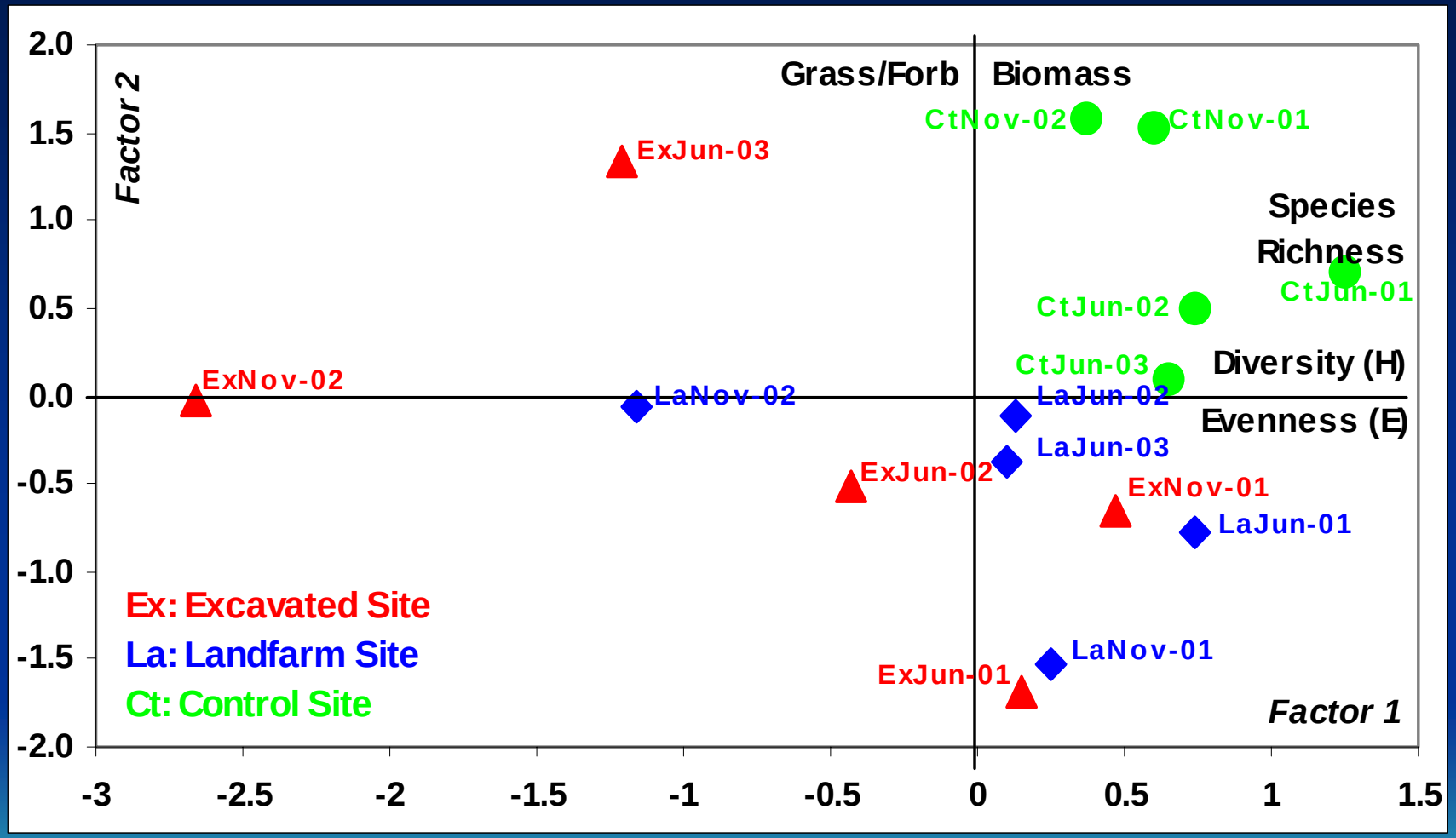
- Different parameters used in revegetation analysis may be treated as multivariant data
- Analyzed by principal component analysis (PCA) to provide information regarding differences or shifts in the three different sites viz., excavated, landfarm and control
- PCA reduces a number of correlated variables into only a few mutually independent variables (the principal components)
- Results are plotted in two-dimensional space and indicate how samples vary in PLFA composition and to what extent each structural group accounts for this variance
- Based on
  - Total Biomass
  - Species Richness
  - Shannon's Diversity (H)
  - Shannon's Evenness (E)
  - Grass/Forbs Ratio

SIMILARITY INDEX BASED ON PCA

(Smaller the value more similar to the control)



PRINCIPAL COMPONENT ANALYSIS



SUMMARY OF OBSERVATIONS

- Over a two-year period there have been more plant species in common between the excavated site and the control than between the landfarm site and control.
- Both disturbed sites were comparable in aboveground biomass and lower in biomass than the control from spring '01 through fall of '02. A particularly wet spring has resulted in significant improvement in biomass levels in both disturbed plots relative to the control.
- Both disturbed sites have improved over time in terms of the grass/forbs ratio but only the excavated site exceeded the control in June '03.
- Both disturbed sites have exhibited reduced plant species diversity relative to the control over the entire period of observation. However, the excavated site has consistently had a lower plant diversity than the landfarm site.
- Plant species richness has been consistently higher in the landfarm site than the excavated site over time.
- When all factors are considered together using principal component analysis (PCA), there has been more similarity between the landfarm site and the control than between the excavated site and the control since June '02.

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