AN ABSTRACT OF THE THESIS OF

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Title: Modeling Riparian Zone Processes: Biomass Production and Grazing

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Seasonal trends in forage production and environmental parameters for five plant community types within a northeastern Oregon riparian zone were described and modeled using correlation and path analysis. Wet meadows produced the greatest amount of herbage biomass, followed by moist bluegrass meadows, gravel bars, forests and dry bluegrass meadows. Trends in soil moisture generally increased and then declined from spring to fall. Depth to the water table declined and then increased. Soil temperatures steadily increased. Variables driving seasonal forage production varied by community type. Soil moisture was most important in dry bluegrass meadows and least important in wet meadows. Depth to the water table was most important in wet meadows and least important in dry bluegrass meadows. The amount of herbage production which had already occurred was also an important variable in describing biomass production. Streamflow levels and the amount of production having occurred were driving variables in the gravel bar communities.

Preference for grazing different riparian vegetation community types and forage intake by cattle was monitored over a three-week grazing period occuring at the end of summer. Concurrent to preference and intake, vegetative and nutritional characteristics of the forage available for grazing were monitored and relationships between these variables and both community preference and intake described through correlation and path analyses. Grazing cattle initially favored communities with highly digestibile forage, hence communities dominated by Kentucky bluegrass were

most preferred. Late in the grazing period community preference was best associated with community abundance, indicating that cattle were grazing communities in proportion to their abundance in the pasture. Intake levels were greater during the first year of the study than the second (2.15 versus 1.81 percent of body weight). Daily grazing time declined as livestock neared the end of the grazing period. Intake was correlated with *in vitro* dry matter digestibility and the amount of time spent grazing, but poorly related to the amount of forage available. The indirect effect of the amount of forage available on intake was greater than the direct effect and functioned through increases in grazing time as a result of increased availability of highly digestible forage.

Modeling Riparian Zone Processes: Biomass Production and Grazing

by

Edwin J. Korpela

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This thesis is dedicated to my mother and my family and my canine companion Mocha who once again never complained about the long hot days in the field or getting stomped by a steer.

Patti take note - I won the bet - but it was so long ago I don't remember what it was.

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CHAPTER I

INTRODUCTION

Riparian zones are an integral part of both forest and range landscapes. They are typically highly productive, rich in diversity and frequently provide at least a portion, if not all, of the habitat requirement for inhabitants of the landscape. Riparian zones also constitute the buffer between the stream and associated uplands. As such they help mediate the timing and delivery of water, sediment and debris into the stream itself. During periods of high stream flows, riparian zones serve to reduce stream velocity thus aiding in the capture of instream sediments and contributing to bank stability and integrity. Consequently, the maintenance of the ecological integrity of riparian zones is a key part of maintaining the integrity of the landscape as well as the delivery of an adequate quantity and quality of water to both instream and downstream users.

Because of the importance of the health of riparian systems to society, it is important that both policy and management be based upon the best available scientific information about the ecological consequences of management practices. One of the main barriers to this end is the lack of basic information about both the structure and function of riparian systems as well as their relationship with associated uplands.

A large body of research has been dedicated to both the inventory of riparian attributes as well as the documentation of the effects of past management, or lack thereof, upon various characteristics of the riparian system. Relatively little research effort has however, been directed towards the quantitative description of mechanisms operating within the riparian ecosystem, especially those directly impacted by management.

Management practices which possess the potential to result in the degradation of the ecological integrity of a riparian zone must be based upon a sound understanding of the structure and function of the riparian ecosystem with due consideration given to the potential impacts of management upon riparian system processes.

The production of vegetative biomass is an ecological process common to all terrestrial ecosystems. The components essential to this process are carbon dioxide, water, sunlight and other chemical elements. Various terrestrial systems utilize these components in different ways depending upon the environment and the autecology of the species present. The riparian environment provides the opportunity to investigate the functioning of the biomass production process under circumstances often quite different from upland situations.

Conversion of vegetation into animal products through grazing is another process common to most terrestrial ecosystems. Although widely studied in upland situations, the selection of plant communities for grazing and consequent intake of forage has not been investigated in the riparian setting. The unique assemblage and diversity of vegetation typically available for grazing within riparian systems provides the opportunity to investigate the application of grazing theory developed in either irrigated pastures or uplands to the grazing process within a riparian system.

The application of current theory on biomass production, plant community preference, forage intake and consequent weight gain of cattle to quantitative models describing these processes within the riparian setting thus forms the focus for this research.

CHAPTER 2

PATH ANALYSIS OF ENVIRONMENTAL AND PRODUCTION PARAMETERS FOR FIVE NORTHEASTERN OREGON RIPARIAN ZONE PLANT COMMUNITY TYPES

PATH ANALYSIS OF ENVIRONMENTAL AND PRODUCTION PARAMETERS FOR FIVE NORTHEASTERN OREGON RIPARIAN ZONE PLANT COMMUNITY TYPES

Abstract

Seasonal trends in forage production and environmental parameters for five vegetation communities within a northeastern Oregon riparian zone were described and modeled using correlation and path analysis. Wet meadows dominated by sedges and bullrushes produced the greatest amount of herbage biomass, followed by moist bluegrass meadows, gravel bars, forests and dry bluegrass meadows. Soil moisture generally increased initially and then declined over the remainder of the growing season. Trends opposite to that for soil moisture were observed for depth to the water table which initially declined and then increased. Soil temperatures steadily increased over the growing season.

Correlation and path analysis indicated the variables driving seasonal forage production varied by community type. Soil moisture was most important in dry bluegrass meadows and least important in wet meadows. Depth to the water table was most important in wet meadows and least important in dry bluegrass meadows. Moist bluegrass meadows and forests were intermediate with regard to the importance of soil moisture and depth to the water table in forage production. The amount of forage production which had already occurred was also an important variable in describing growth at any time during the growing season. Streamflow levels and the amount of production having occurred were driving variables in the gravel bar communities.

Introduction

Riparian zones have become a focal point in the management of forests and rangelands due to their productivity, diversity, and importance to wildlife and livestock as well as to man. As a result, numerous studies have been conducted to document the effects of various management activities (e.g. timber harvesting, grazing, mining etc.) upon riparian vegetation (Gunderson 1968), wildlife populations (Kauffman 1982), streambank erosion (Buckhouse et al. 1981), stream channels (Lusby 1970), water quality (Skinner et al. 1974) and fisheries resources (Marcuson 1977). Comparatively few studies, however, have sought to investigate the functioning of ecological processes within the riparian zone.

Seasonal accumulation of biomass is an ecological process common to all terrestrial plant communities. However riparian zone communities generally possess environmental characteristics which make them uniquely productive. Several authors (Johnson and Bell 1976, Brinson et al. 1981, Carter 1986) have indicated that the primary characteristics of riparian zones which make them so productive are their relative lack of moisture stress combined with periodic flooding. Periodic flooding results in an influx of soils and nutrients in combination with a ventilating effect on soils and roots, so that gases are more easily exchanged. Periodic flooding also results in the removal of dissolved organic compounds, some of which are metabolic wastes which may have built up in the rooting zone. These authors have also indicated that differences in floodplain microrelief may not only determine the kind of community, but its productivity level as well, simply as a result of changes in depth to the water table.

Thus the purpose of this study was twofold: first, to monitor trends in biomass and environmental parameters for different plant communities in a northeastern Oregon riparian zone, and second, to describe the relationships between environmental parameters and forage production through the use of path models.

Study Area

The study area was located in the southwestern foothills of the Wallowa mountains on the Hall ranch portion of the Eastern Oregon Agricultural Research Center (EOARC), approximately 19.3 kilometers southeast of Union, Oregon (Figure 2.1). The study area consisted of a long narrow pasture, approximately 41 hectares in size, located in a valley bottom along Catherine Creek.

The majority of the precipitation on the study area occurs as snow between the months of November and May (Figure 2.2). EOARC records for two weather stations near the study area indicate that average annual precipitation in the area is about 610 millimeters. Temperatures in the area may range from below freezing to in excess of 38 degrees C. Figure 2.2 illustrates monthly trends in precipitation and temperature during the course of the study. Elevation of the study area averages about 1050 meters. Soils on the area have been mapped as belonging to the veasie-voats soil complex (USDA 1985). The veasie series is classified as a coarse-loamy over sandy or sandy-skeletal, mixed, mesic cumulic haploxeroll, while the voats series is classified as a sandy-skeletal, mixed, mesic pachic haploxeroll. However Kauffman (1982) indicates that due to the variable nature of soils within the riparian zone, many of the soils which occur on the study area do not fit these soil series descriptions.

Catherine Creek is a third order tributary of the Grande Ronde River which eventually drains into the Columbia river system. A gauging station (station number 13320000) located approximately 10 kilometers downstream from the study area was used to obtain streamflow data used in the study. Figure 2.3 illustrates monthly trends in stream discharge. The average annual discharge of Catherine Creek is 106 hm^3/yr or 3.37 m^3/s (USGS 1984, USGS 1985). Peak flows occur during the months of April, May and June depending upon upstream snowmelt conditions.

The vegetation in the study area consists of a complex array of plant types and communities. In mapping the vegetation within a 50 meter strip on each side of the stream, Kauffman (1982) identified 60 distinct

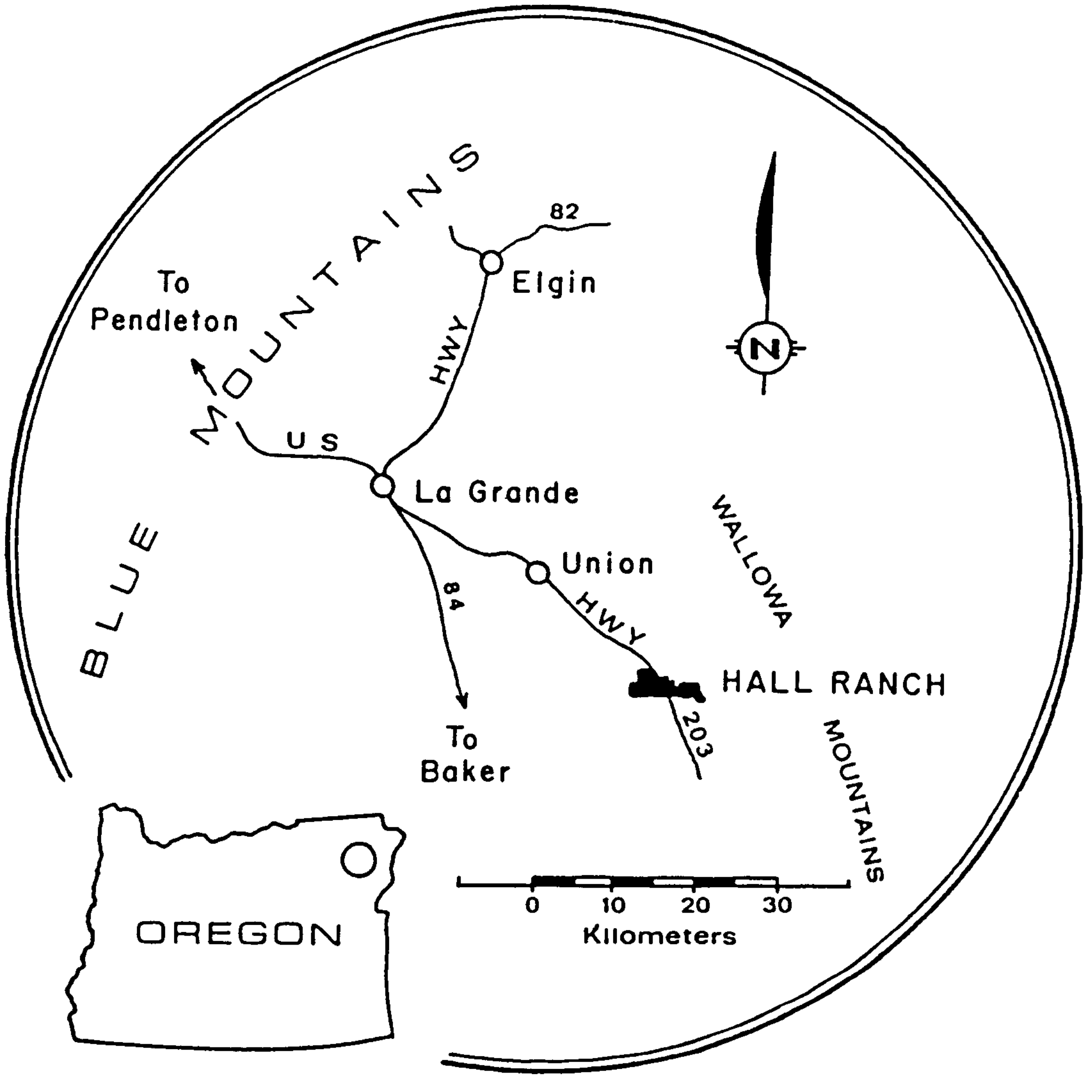

Figure 2.1. Location of the study area in northeastern Oregon.

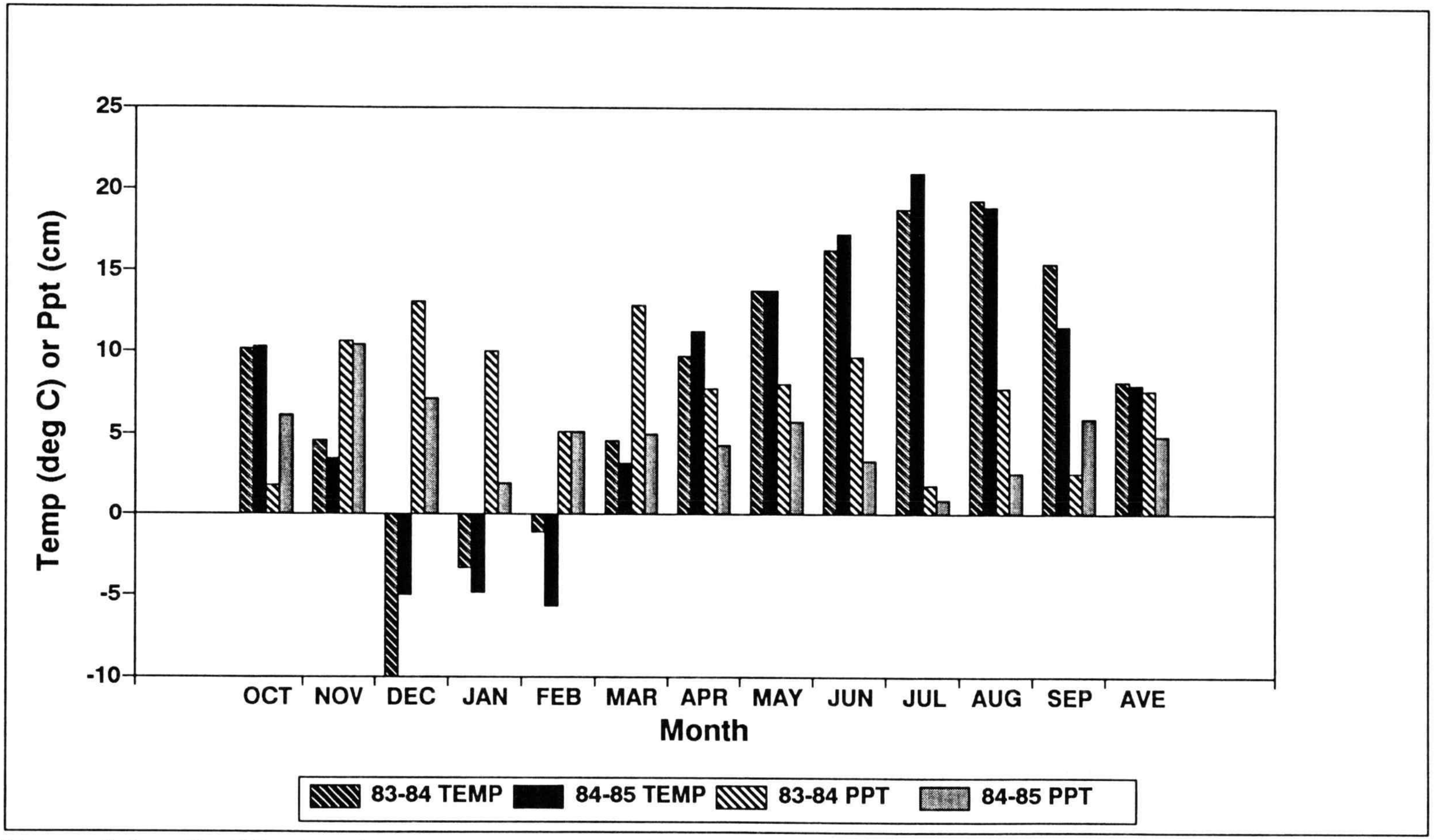

Figure 2.2. Monthly trends in temperature and precipitation from two Hall ranch weather stations over the duration of the study.

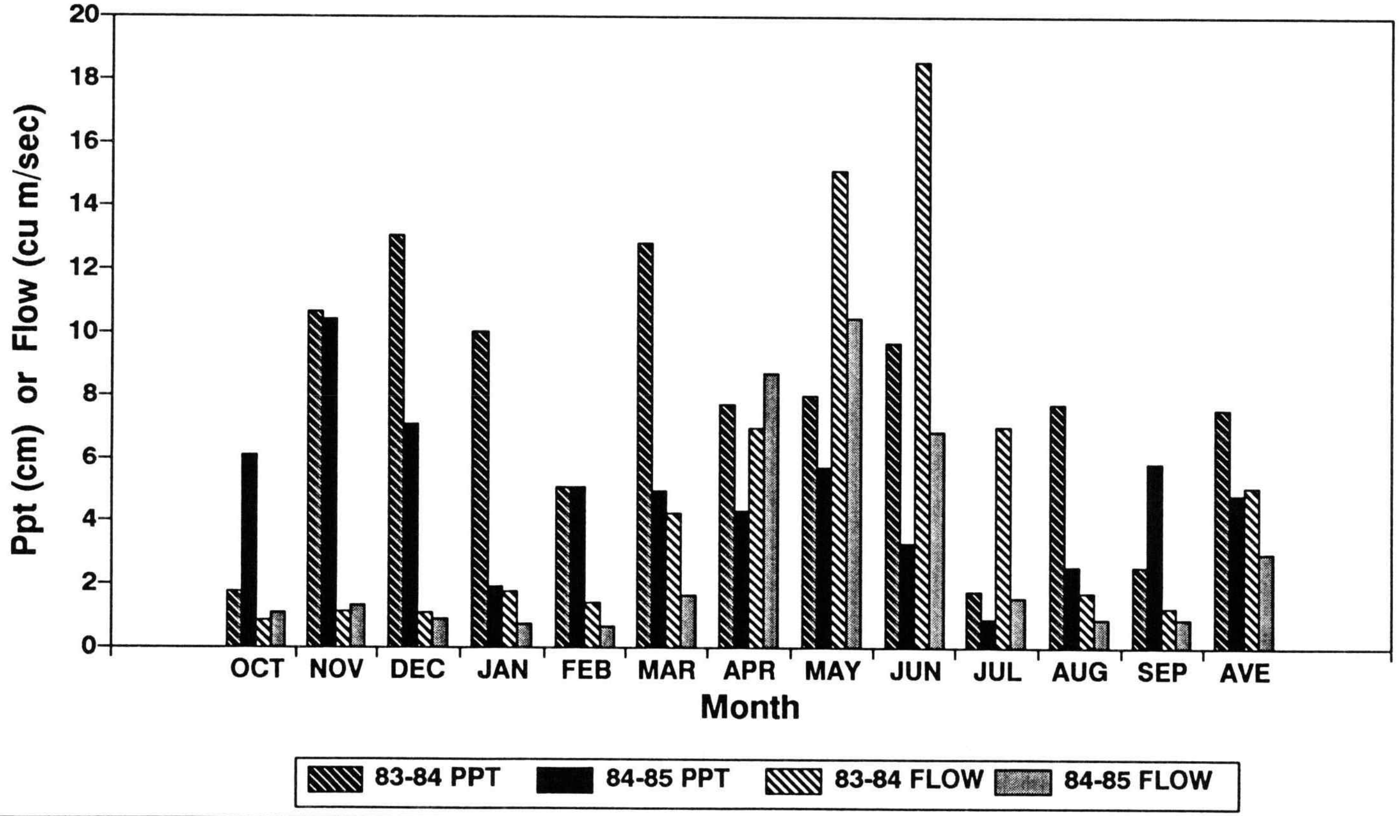

Figure 2.3. Monthly trends in precipitation and streamflow for Catherine Creek during the course of the study.

plant communities. The communities ranged from meadow communities dominated by Kentucky bluegrass (*Poa pratensis*), cheatgrass (*Bromus tectorum*) or sedges (*Carex* spp.) to tree-dominated communities containing ponderosa pine (*Pinus ponderosa*), grand fir (*Abies grandis*) or black cottonwood (*Populus trichocarpa*). Both low shrub communities dominated by snowberry (*Symphoricarpos albus*) or wood rose (*Rosa woodsii*) and tall shrub communities dominated by thin leaf alder (*Alnus incana*) or black hawthorne (*Crataegus douglasii*) occur within the study area.

Materials and Methods

This study was based upon the description of relationships among environmental and vegetative parameters during the growing seasons of 1984 and 1985. The following sections describe the methods used in gathering data, as well as the statistical analyses used for each objective.

Plant Community Designation

As this study was conducted on a plant community basis, the study area was mapped by community type. Vegetation communities were mapped in accordance with the procedures outlined by Kauffman (1982). Aerial photographs were used to delineate and determine the areal extent of the vegetation types. Initial reconnaissance of the study area indicated that seven plant community types could be identified and mapped. These seven plant communities, the first five of which were sampled intensively, consisted of the following:

1. Gravel bar communities dominated by willows (*Salix* spp.) and cottonwoods.
2. Wet meadows dominated by rushes (*Juncus* spp.) and sedges.
3. Moist bluegrass meadows dominated by Kentucky bluegrass and forbs with a sedge component.
4. Dry bluegrass meadows dominated by Kentucky bluegrass.
5. Mixed coniferous forests dominated by ponderosa pine and grand fir.
6. Tall shrub communities dominated by black hawthorne.
7. Miscellaneous disturbance communities dominated by cheatgrass including old gravel bars not within the banks of Catherine Creek.

Field Sampling

The development of a model of forage production for the five communities sampled entailed the monitoring of several potential predictor variables, any combination of which may be used in a model describing forage production. Five potential predictor variables were selected for monitoring during the course of this study. These included the following:

1. Soil moisture.
2. Depth to the water table.
3. Initial or residual vegetation.
4. Temperature.
5. Precipitation.

Soil moisture was measured at monthly intervals in each community type. Gravitational soil moisture content was determined using the method described by Gardiner (1976). Five samples from both the 10-15 cm and 35-40 cm ranges were collected from each community type except gravel bars. Soil moisture estimates for the two depths were then averaged for path analysis purposes. No soil moisture determinations were made on gravel bars due to the extremely coarse textured nature of the soils found on the gravel bars. Neither were soil moisture samples collected from flooded communities (e.g. wet meadows and gravel bars early in the spring). However, soil moisture content of flooded wet meadow communities was estimated as being the moisture content of the saturated soil.

Water table height was measured at monthly intervals at five locations within each community type except for gravel bars. Water table height was not determined for gravel bars, as the gravel bars are generally located within the banks of Catherine Creek. The method described by Padgett (1982) was used to monitor water table levels. Maximum likelihood estimation for right censored data was used to estimate depth to the water table when it was in excess of 120 centimeters (SAS 1987).

Initial or residual vegetation was monitored at monthly intervals as well. Then the amount of vegetation at each subsequent sampling period was defined as the residual amount of vegetation which provides photosynthetic surface area for the following growth period.

Temperature was monitored continously in the study area. The equipment and methodology used has been described by Unwin (1980) and the National Academy of Sciences (1971). Hygrothermographs were set up at six locations within the study pasture. Two stations were set up in wet meadows, two in mixed conifer forests and one each in a moist and a dry bluegrass meadow.

Soil temperature was monitored at monthly intervals in each community type following the methods of Taylor and Jackson (1976). Ten measurements, 25 centimeters (cm) below the surface of the soil were made in each of the five community types as well as on the gravel bars.

Precipitation was monitored at monthly intervals at two nearby weather stations maintained by the Eastern Oregon Agricultural Experiment Station.

Forage production was monitored at approximately monthly intervals. The method described by Kauffman (1982) in which 30, randomly located, 0.25 m^2 plots were clipped to ground level in each of the five community types was used. Production from each plot was separated into two categories (i.e. grass and grass-likes or forbs). Shrub production was determined by clipping a portion, approximately 12.5 percent, of the shrub biomass in 15 one m^2 plots in the forest and gravel bar communities. Since the intervals between monthly clippings varied, forage production was converted to daily biomass accumulation rates by dividing the amount of biomass produced between two clippings by the number of days between clippings.

Path Analysis

Data from both years were combined and analyzed using correlation and path analysis. This technique consists of developing an *a priori* structural model (path diagram) describing the relationships among a system of dependent and independent variables (Figure 2.4). The technique assumes that the causal structure among the variables is known and that the system is causally closed. The method also assumes that the data meet the following requirements usually associated with regression analysis:

1. That the relationships between dependent and independent variables are linear and additive thus excluding curvilinear and multiplicative models.
2. That dependent variables are continous and normally distributed.

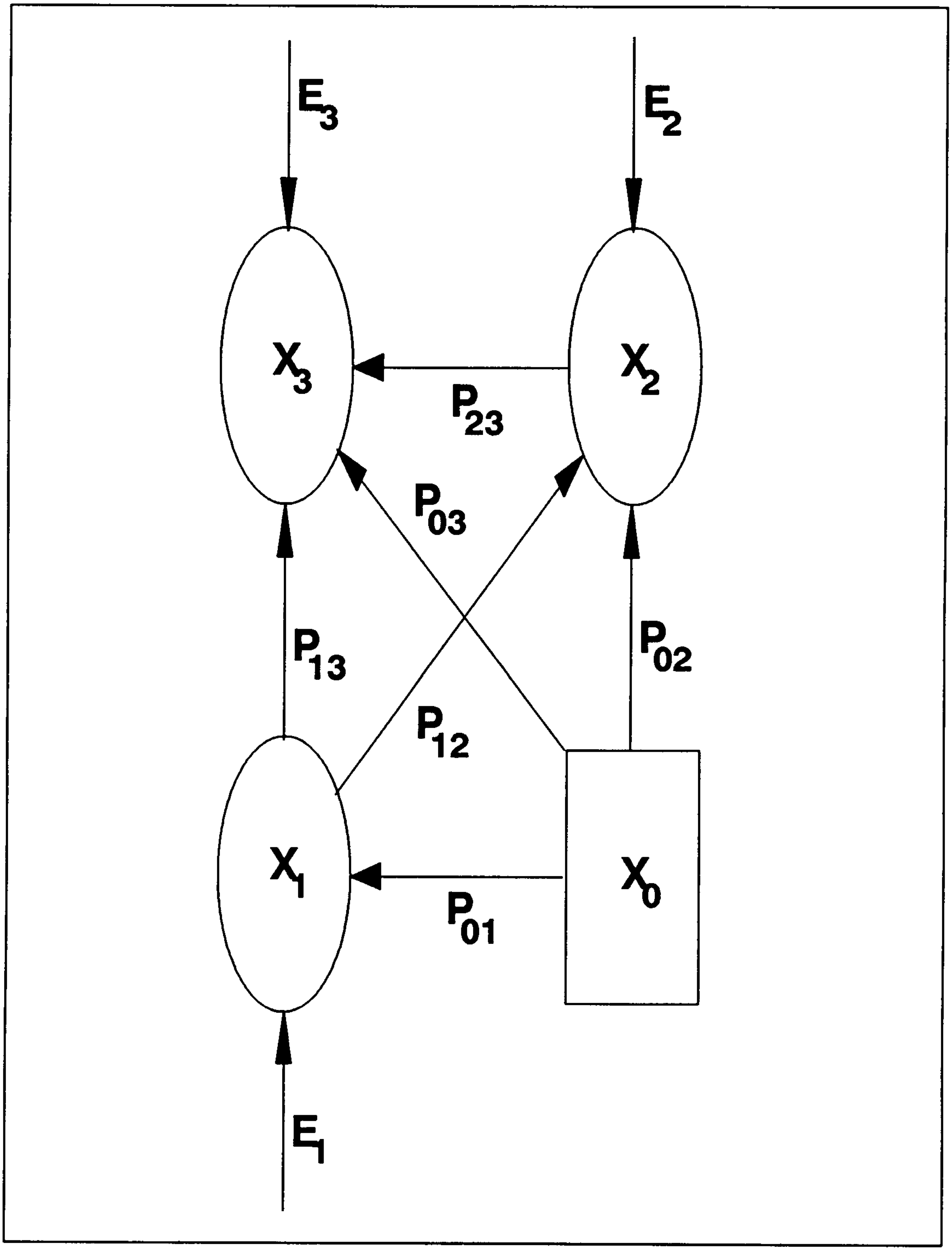

Figure 2.4. A theoretical four variable path model. The P's indicate pathways from independent to dependent variables while the E's indicate unknown latent factors. Note the existence of several indirect effects (e.g. the influence of X_0 on X_3 through X_1 or X_2).

3. That independent variables are measured without error.
4. That error terms are uncorrelated.

The technique then uses repeated (i.e. for each dependent variable) stepwise multiple regression to estimate path coefficients as the standardized regression coefficients associated with postulated directional paths.

The normal stepwise regression analysis was replaced with ridge regression to reduce the effects of multicollinearity among the independent variables on the sign, maginitude and stability of coefficients associated with the independent variables. However, as ridge regression is a biased regression technique, statistics (e.g. significance tests) normally associated with regression coefficients cannot be calculated, as their distributional properties are not known. Thus only approximate standard errors of the coefficients were calculated. Selection of a biasing constant (k) is an important feature of ridge regression. Several methods have been proposed and are reviewed by Vinod (1978). The biasing constant (k) was selected based upon inspection of the ridge trace (Figure 2.5). The following four criteria proposed by Hoerl and Kennard (1970) were used as criteria in selecting a value for k.

1. Stabilization of the ridge trace.
2. Coefficients will not have unreasonable absolute values in terms of a priori knowledge.
3. Coefficients with theoretically improper signs at k=0 will have proper signs.
4. The residual sum of squares will not be considerably inflated.

A value of k=0.5 was used for all path analyses. In addition to the path coefficients, it is customary to determine the residual effect due to unmeasured latent variables for each dependent variable. The residual effect is calculated as one minus r-square for each dependent variable.

The effect of each independent variable on a dependent variable can then be direct (i.e. a direct path exists between the two), indirect (i.e. the two are related through other variable(s)), spurious (i.e. the two are correlated but are not linked) or unanalyzed (i.e the independent variable

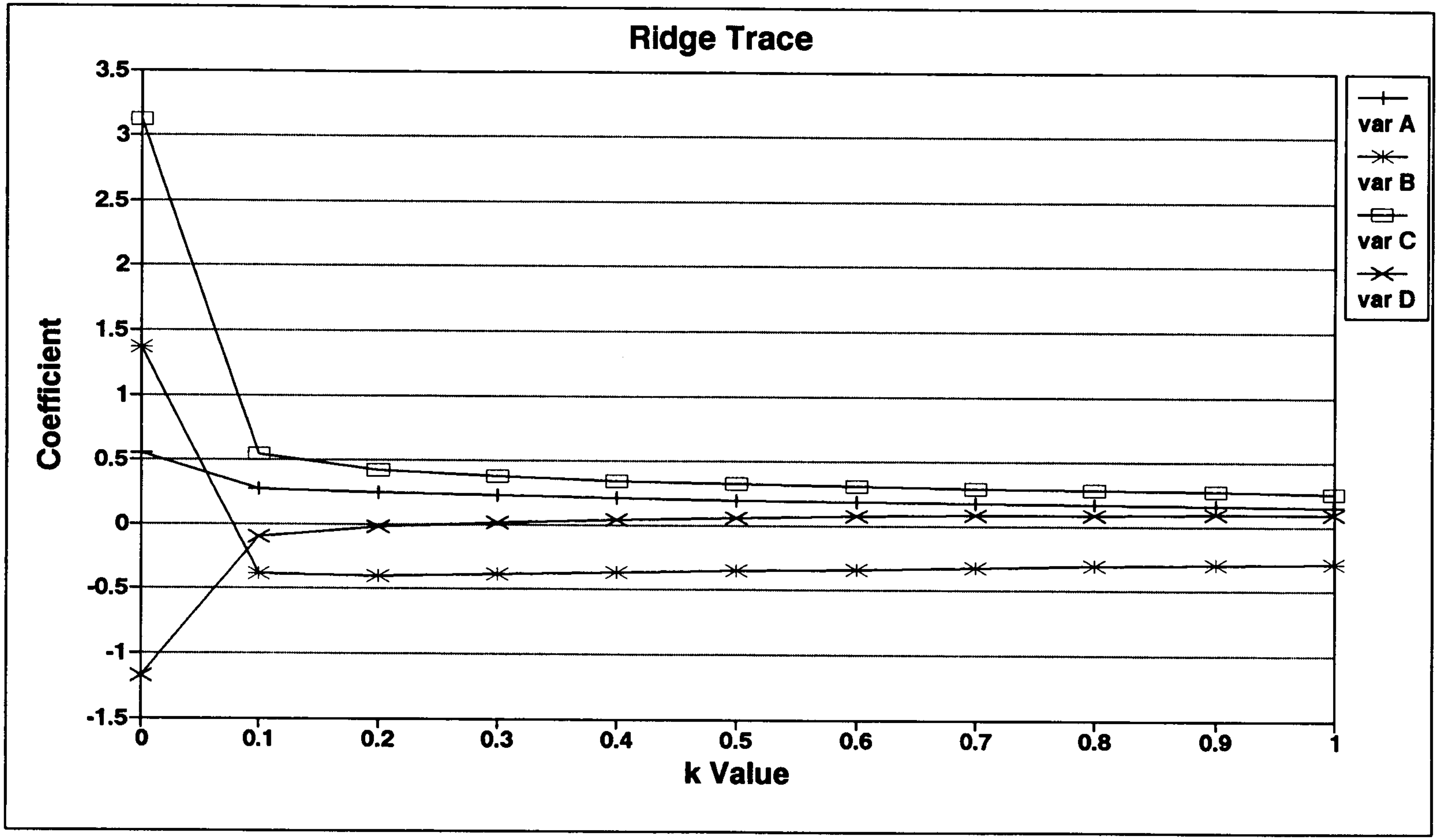

Figure 2.5. A ridge trace diagram produced as a result of ridge regression analysis. Note the high degree of collinearity exhibited by variables B, C and D as indicated by the rapid change in regression coefficient values as the biasing constant k increases.

was not included in pathways in the model). Indirect pathways are calculated as the product of path coefficients along the indirect pathway.

In ordinary path analysis the sum of direct and indirect effects for a dependent variable is equal to the simple correlation between the dependent and independent variables provided the model is fully recursive (i.e. that all possible connections between the two variables have been made). However, this is not the case when ridge regression coefficients are used. For detailed discussions of regression techniques and path analysis methodology see Wright (1934), Blalock (1964), Li (1975), Gunst and Mason (1980), Wonnacott and Wonnacott (1981) and Dillon and Goldstein (1984). For recent examples of path analysis used in analyzing vegetation data see Hermy (1987) or Kuusipalo (1987).

The Theoretical Model

The theoretical model developed is illustrated in Figure 2.6. The dependent variables forage growth (Gro), soil moisture (SoilM), depth to the water table (Depth), and streamflow (Flow) are represented within circles while the observed independent variables air temperature (AirT), precipitation (Ppt), and previous biomass production (PrevP) are represented within squares. As illustrated in Figure 2.6, biomass growth is a function of air temperature, soil moisture, depth to the water table, previous biomass accumulation and precipitation. Soil moisture is a function of air temperature, previous production, precipitation and depth to the water table. Depth to the water table is described as being a function of streamflow and soil moisture. Streamflow is described as being a function of depth to the water table and precipitation.

Temperature has long been recognized as having an influence on plant growth and development. Temperature plays a major role in controlling the process of photosynthesis through its influence upon enzymatic reactions and regulation of stomatal aperature (Berry and Bjorkman 1980). According to these authors, the rate of photosynthesis generally increases with increasing light intensity and/or intercellular carbon dioxide. In addition, plant species have varying optimums with regard to photosynthetic rates depending upon their photosynthetic pathway and/or

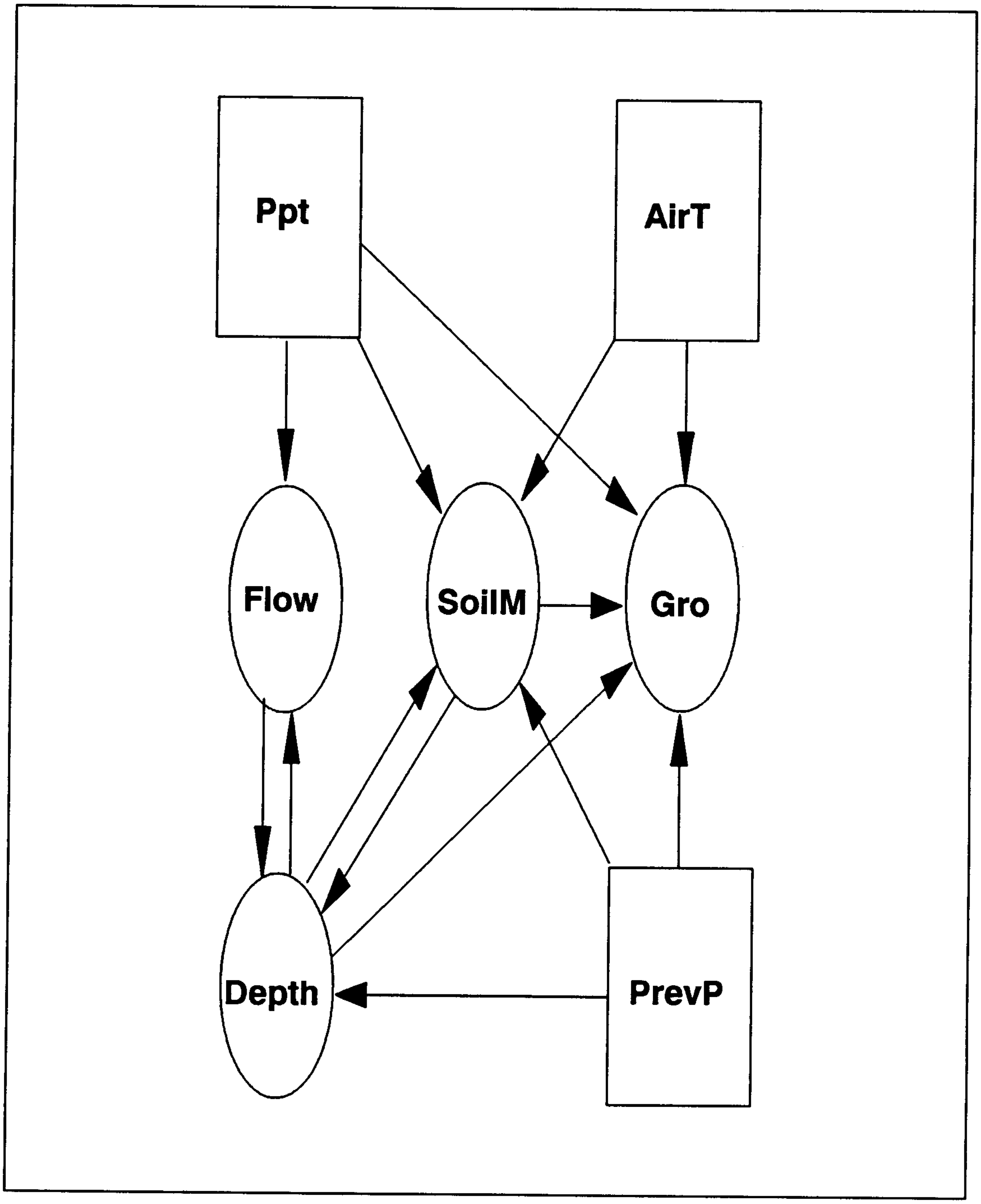

Figure 2.6. The proposed path model for the dry bluegrass meadow, moist bluegrass meadow, wet meadow and forest communities found within a northeastern Oregon riparian zone. Acronyms as follows; growth (Gro), previous production (PrevP), soil moisture (SoilM), depth to the water table (Depth), air temperature (AirT), monthly precipitation (Ppt) and monthly streamflow (Flow).

the environment in which they are growing. Plants possessing the C3 pathway typically begin photosynthesis at around 5 degrees C and reach maximum rates of photosynthesis at around 30 degrees C. In addition to direct effects upon photosynthesis, air temperature also plays a direct role in determining soil moisture status through its role in determining evaporative potential (Hillel 1971) and an indirect role through its influence upon plant transpiration (Kramer 1983).

Soil moisture also plays a significant role in the growth and development of vegetation. Deficiencies in soil moisture typically result in reduced quantities of above-ground biomass through any one or combination of the following mechanisms (Kramer 1983); reduced leaf growth due to reduced cell division and/or enlargement, reduced cell wall and cellular protein production, inhibition of photosynthesis through reduced xylem conductance of water and hence reduced enzymatic activity, stomatal closure, reduced respiration and a change in photosynthate aportioning from above-ground to below-ground biomass. In addition to the direct effects of soil moisture upon plant growth, soil moisture may also play a role in determining the depth to a water table via its intermediate role in transferring precipitation to the water table when moisture infiltrates the soil profile and percolates down to the water table (Hillel 1971).

Depth to the water table may play a role in determining soil moisture status through the movement of moisture upward through the soil profile (Hillel 1971), thus providing moisture for plant growth, or may influence growth directly, either positively or negatively, when plants are rooted within the water table (Teskey and Hinckley 1977). In addition to effects upon soil moisture and growth, the depth of the water table may influence stream flow either by contributing water to the stream or by removing water from the stream (Wisler and Brater 1959).

The amount of production which has already occurred has an impact upon subsequent biomass production. This biomass provides the leaf area for future production as well as providing a representation of all that has occurred before in terms of growth and the environment (e.g. temperature regimes, soil moisture regimes, etc.) to that point in time. In addition to an effect upon future growth, previous production also influences soil moisture through the amount it has extracted. Previous production may also have lowered the water table through transpiration.

Streamflow levels may influence depth to the water table by contributing water to the water table or by removing water from the water table (Wisler and Brater 1959) and may influence forage production if plants are rooted in the stream as in the case of gravel bars within the streambed.

Precipitation may influence growth by providing moisture which may increase soil moisture levels (Hillel 1971).

The theoretical model for gravel bar communities is essentially the same as for the other four communities except that measurements on soil moisture and depth to the water table were not made. Instead streamflow levels were used as an index to moisture relations for gravel bar communities located within the banks of Catherine Creek. The model for gravel bar communities is illustrated in Figure 2.7.

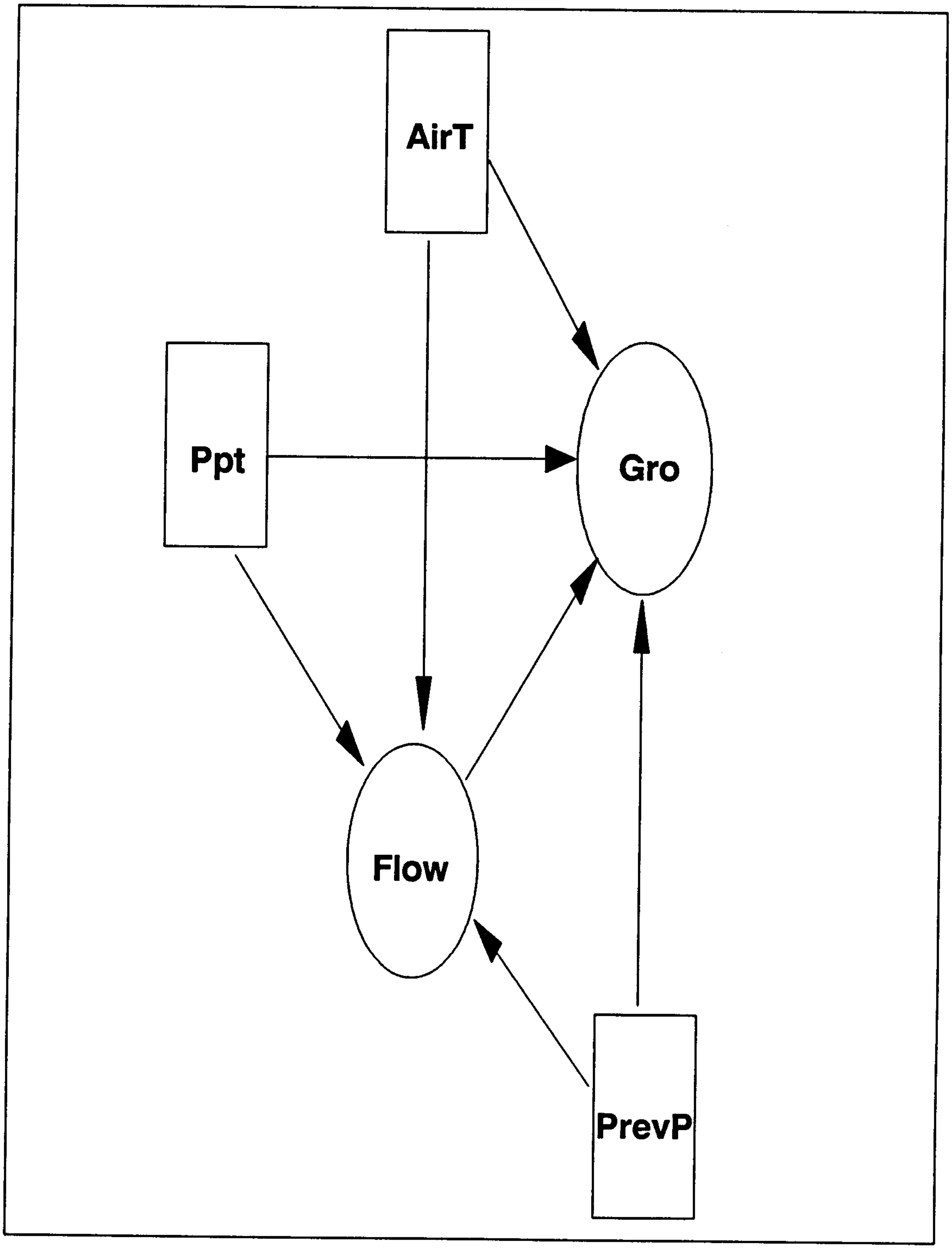

Figure 2.7. The proposed path model for the gravel bar communities found within a northeastern Oregon riparian zone. Acronyms as follows; growth (Gro), previous production (PrevP), air temperature (AirT), monthly precipitation (Ppt) and monthly streamflow (Flow).

Results and Discussion

Forage Production and Environmental Parameters

Trends in forage production for the five community types found within the study area are illustrated in Figures 2.8 and 2.9. As illustrated in both figures, forage production for all classes of forage (i.e. grasses, forbs, shrubs) across community types generally increased from May through mid-July and then declined. In 1984 precipitation in the fall brought about an increase in forage production from mid-August through early November. In 1985 little regrowth occurred in the fall as a result of low fall precipitation.

Production of dry and moist bluegrass meadows reported here were similar to results reported by Bernard (1974) who found dry bluegrass meadow production to be bimodal producing two peaks in production; the first in early June of 4000 kg/ha with a subsequent decline, and a later peak of 2500 kg/ha in late September to a low production level of 880 kg/ha in November. Peak production when considering green biomass only was 1140 kg/ha in June and 1490 kg/ha in late September for old fields in central Minnesota. Leege et al. (1981) in northern Idaho found that moist bluegrass meadows produced approximately 4140 kg/ha while dry bluegrass meadow production ranged from 2880 kg/ha to 1180 kg/ha. Kauffman et al. (1982) in an earlier study in the same area as this study found dry bluegrass meadows produced an average of about 3383 kg/ha over a three year period from 1978 to 1980. He found that moist bluegrass meadows produced an average of 7484 kg/ha while forests and gravel bars produced averages of 2033 kg/ha and 1839 kg/ha respectively. Other studies include Roath and Krueger (1982) who found that dry and moist bluegrass meadows produced an average of 2531 kg/ha in eastern Oregon and Gillen et al. (1985) who found dry bluegrass meadows produced an average of 2440 kg/ha in north central Oregon.

Similar trends in wet meadow forage production have been reported elsewhere. Gorham and Somers (1973) described seasonal changes in the standing crop both of green *Carex aquatilis* and *Carex rostrata* in the Canadian Rockies and found that *C. rostrata* production ranged from a low

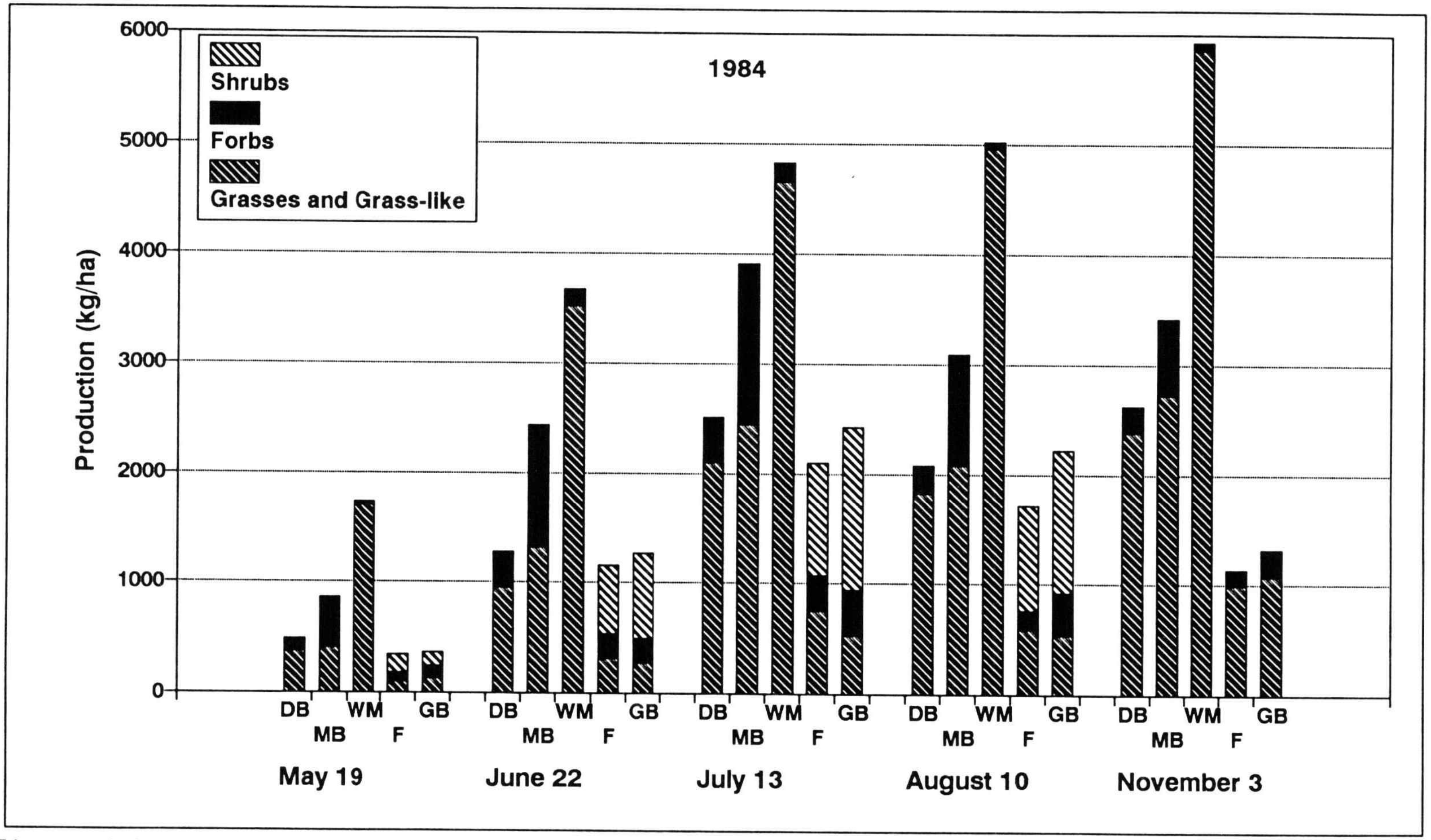

Figure 2.8. Seasonal trends in grass, forb and shrub production for 1984 from different plant communities in a northeastern Oregon riparian zone. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows. Shrub production was not measured in November due to leaf abcission.

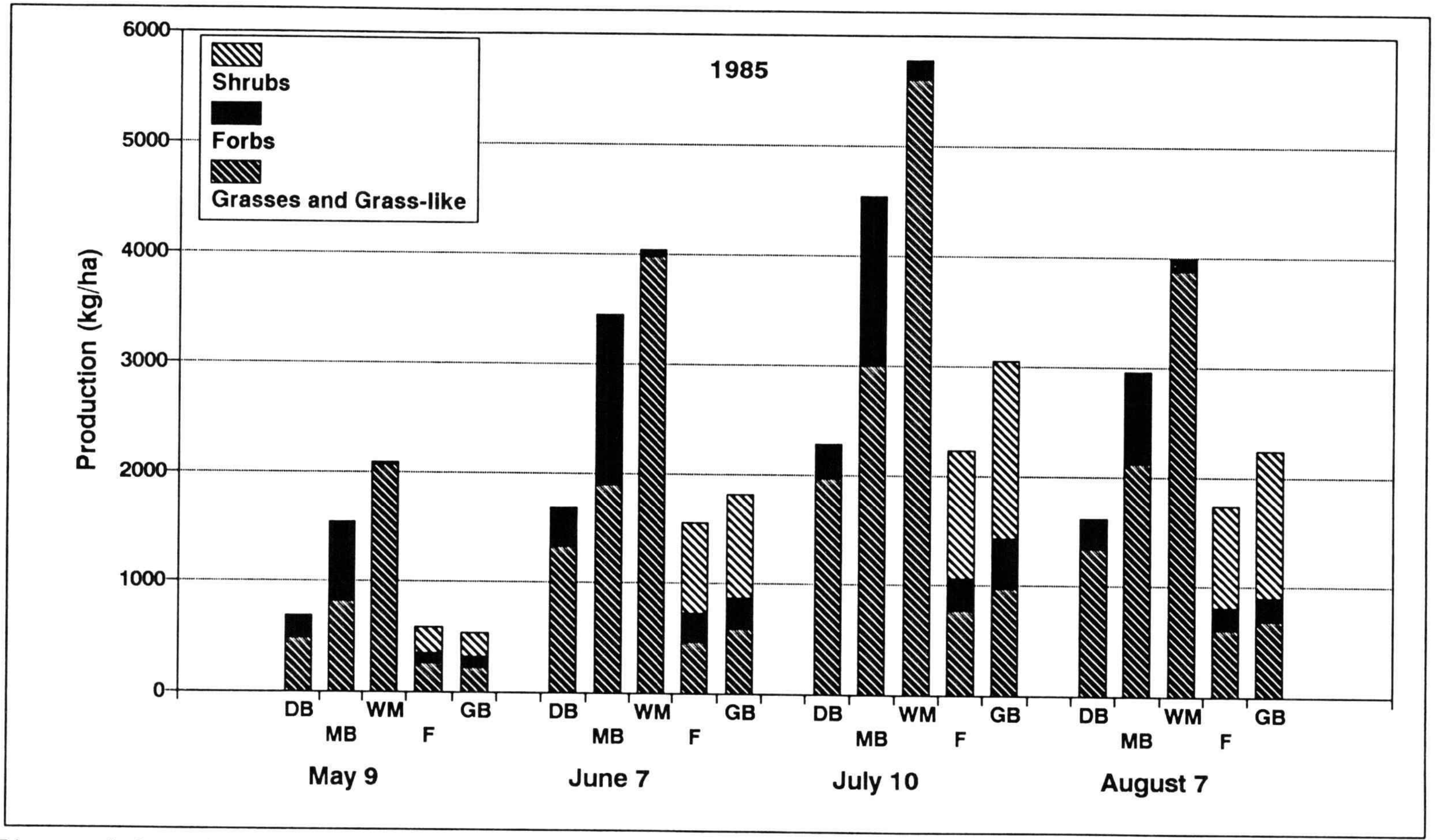

Figure 2.9. Seasonal trends in grass, forb and shrub production for 1985 from different plant communities in a northeastern Oregon riparian zone. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows.

of about 1250 kg/ha in late November to a high of about 6400 kg/ha while *C. aquatilis* produced from 400 to 500 kg/ha during the months of December through March to a peak of approximately 3800 kg/ha by mid-August. They also indicated that peak standing crop of green and brown (dead) *C. aquatilis* was about 5500 kg/ha also achieved in mid-August. Bernard (1974) reported a peak standing crop for *C. rostrata* of about 8520 kg/ha also in mid-August in central Minnesota. When attached dead material was included, total standing crop increased to about 10,320 kg/ha. Standing crop low was 1140 kg/ha of green material and 5640 kg/ha when both green and brown were included. Other reported peak standing crops include Pearsall and Gorham (1956) who reported that *C. rostrata* produced 4900 kg/ha in England and Leege et al. (1981) who reported that wet meadows in Northern Idaho produced 4430 kg/ha.

Trends in soil moisture for four of the five community types found within the study area are illustrated in Figures 2.10 through 2.13. In contrast to forage production, soil moisture declined as the growing season progressed at both depths sampled. No similar studies of trends in soil moisture in similar plant community types could be found.

Trends in depth to the water table for four of the five community types found within the study area are illustrated in Figures 2.14 and 2.15. As in the case of forage production, depth to the water table increased as the growing season progressed. Padgett (1982) monitored water table levels in several plant community types in central Oregon and found that the water table in Kentucky bluegrass communities was generally 50 cm or more below the surface of the soil similar to trends for dry bluegrass communities in this study. In wet meadows dominated by *C. rostrata* or *C. aquatilis*, he found that the water table was generally at or near the ground surface until at least mid-summer.

Trends in soil temperature for the five communities monitored as well as air temperature for the study area are illustrated in Figures 2.16 and 2.17. No similar studies of trends in temperature in similar plant community types could be found.

Daily biomass accumulation rates of grasses and grass-likes, forbs and shrubs are illustrated in Figures 2.18 through 2.20, respectively. Similar patterns of production were observed both years. Between the May

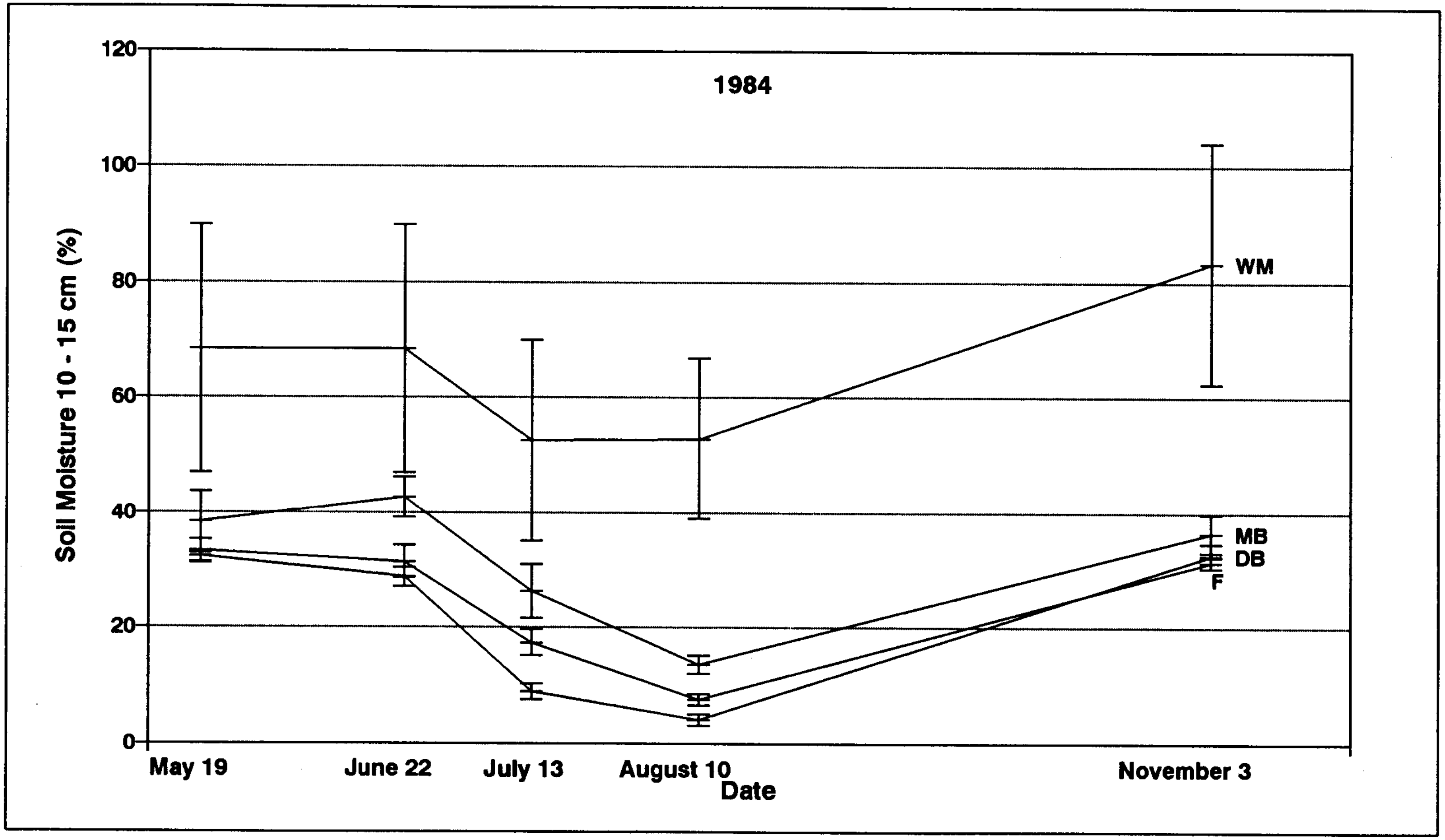

Figure 2.10. Seasonal trends in average soil moisture content at the shallow depth (10-15 cm) for 1984 within different plant communities in a northeastern Oregon riparian zone. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows. Vertical bars indicate standard error of the mean.

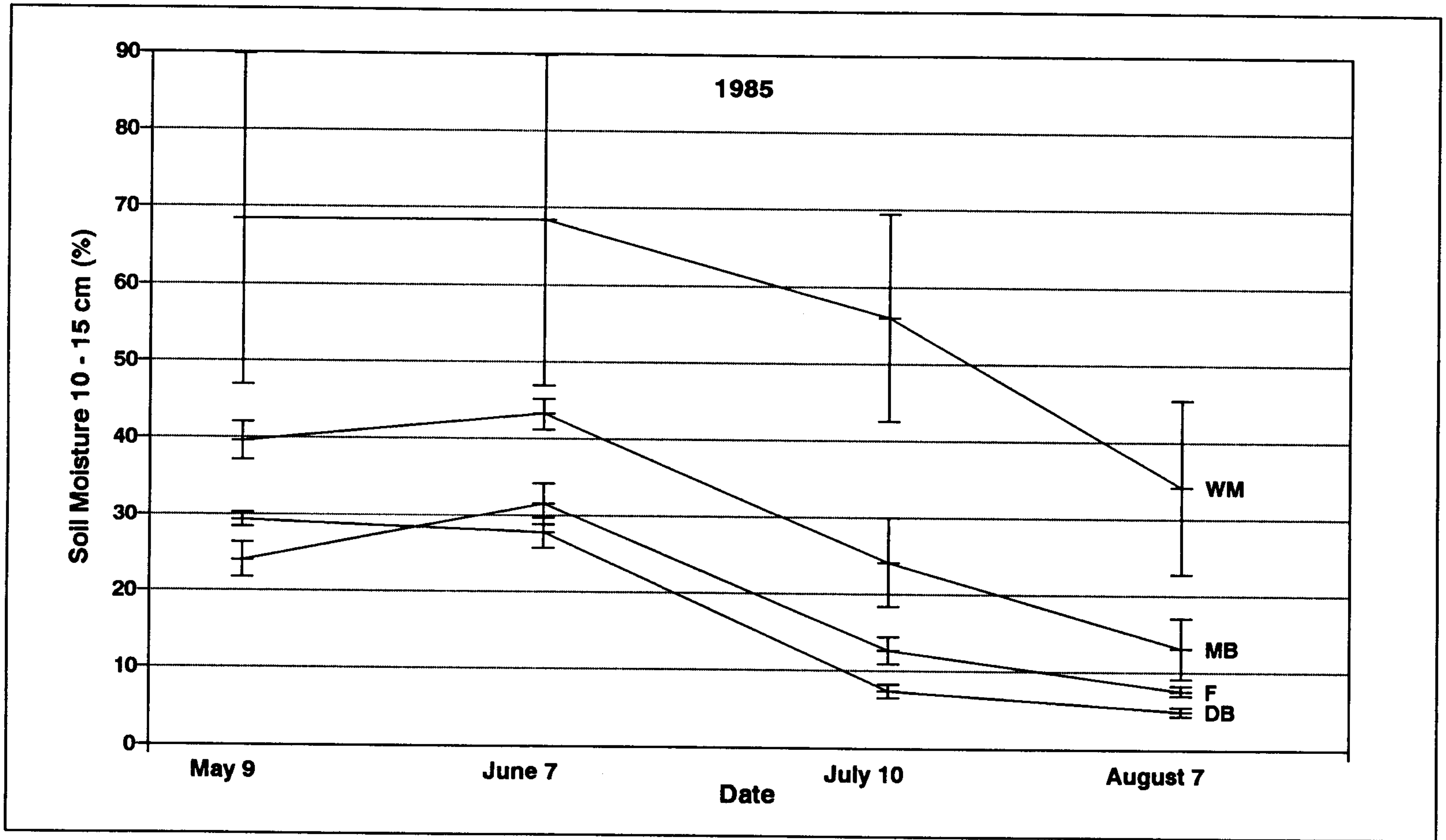

Figure 2.11. Seasonal trends in average soil moisture content at the shallow depth (10-15 cm) for 1985 within different plant communities in a northeastern Oregon riparian zone. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows. Vertical bars indicate standard error of the mean.

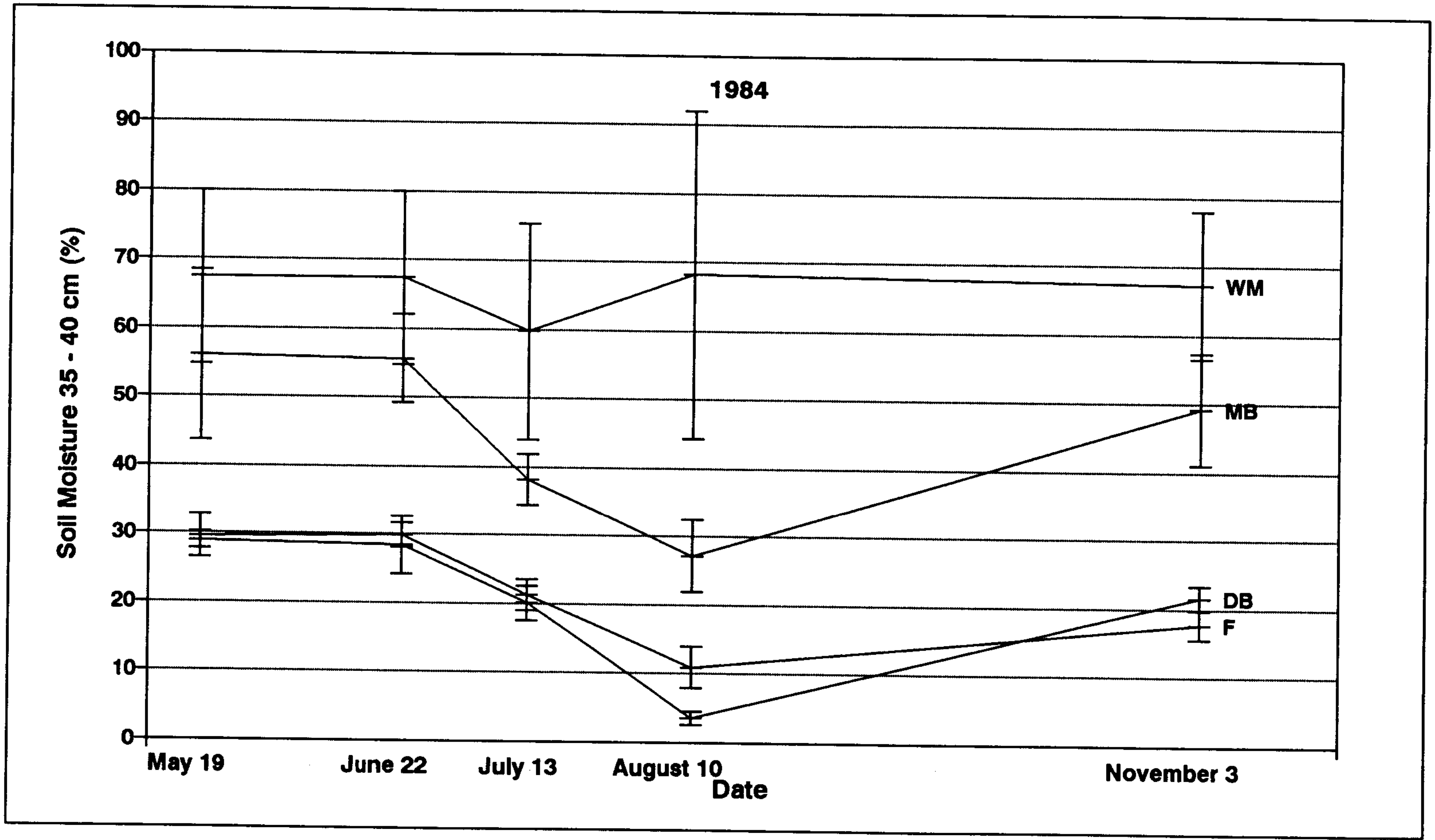

Figure 2.12. Seasonal trends in average soil moisture content at the deeper depth (35-40 cm) for 1984 within different plant communities in a northeastern Oregon riparian zone. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows. Vertical bars indicate standard error of the mean.

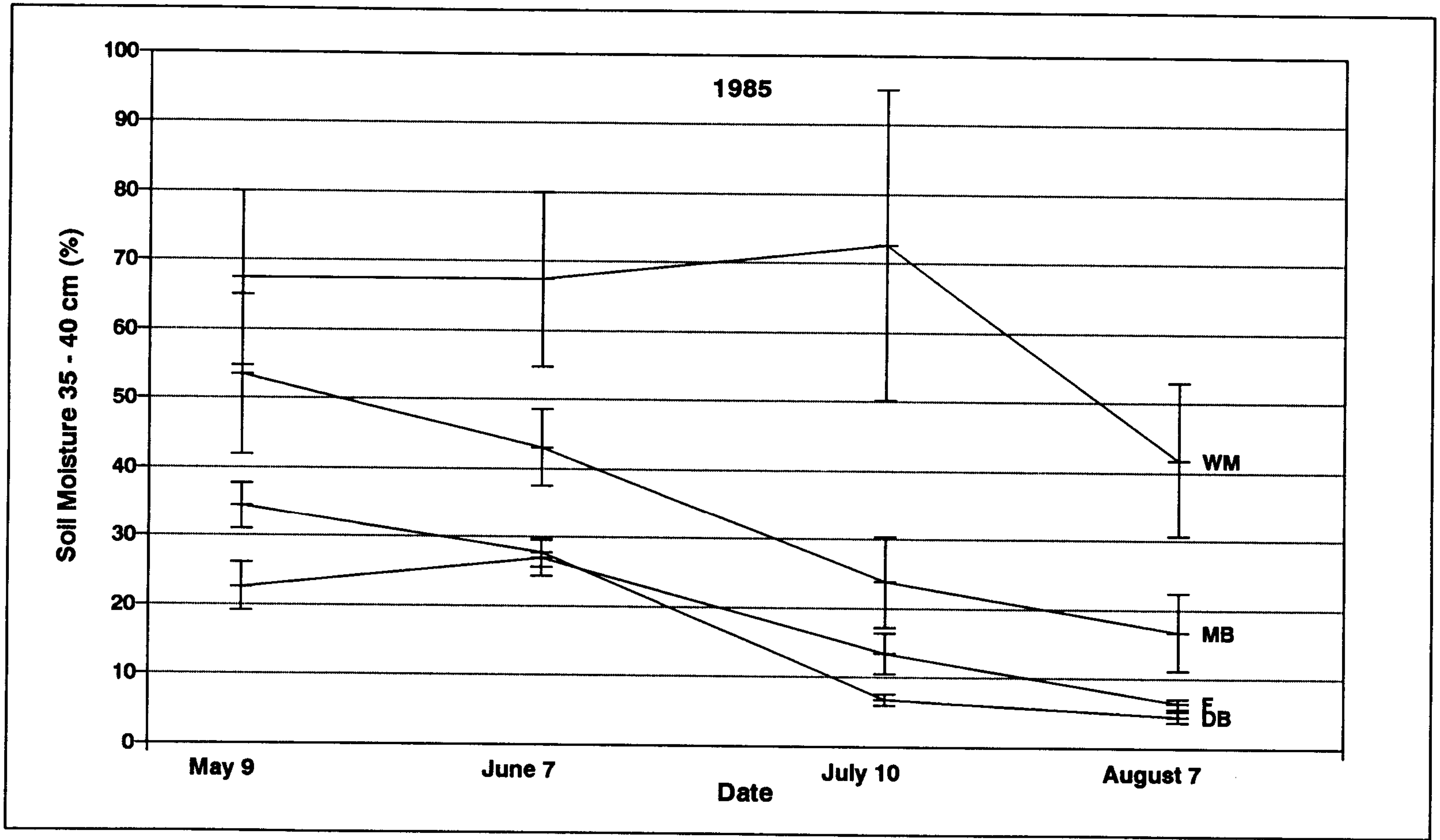

Figure 2.13. Seasonal trends in average soil moisture content at the deeper depth (35-40 cm) for 1985 within different plant communities in a northeastern Oregon riparian zone. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows. Vertical bars indicate standard error of the mean.

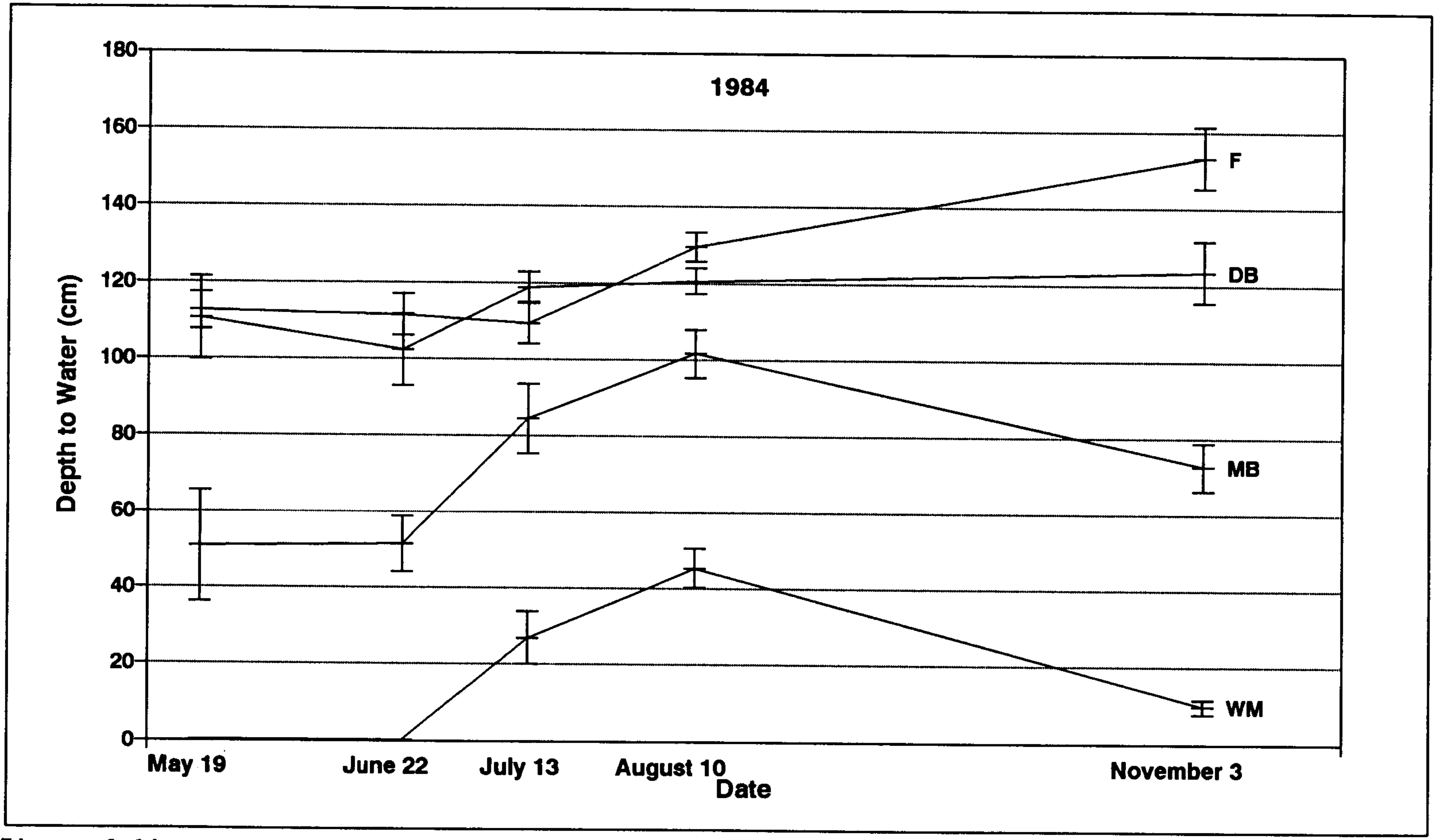

Figure 2.14. Seasonal trends in average depth to the water table for 1984 within different plant communities in a northeastern Oregon riparian zone. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows. Vertical bars indicate standard error of the mean.

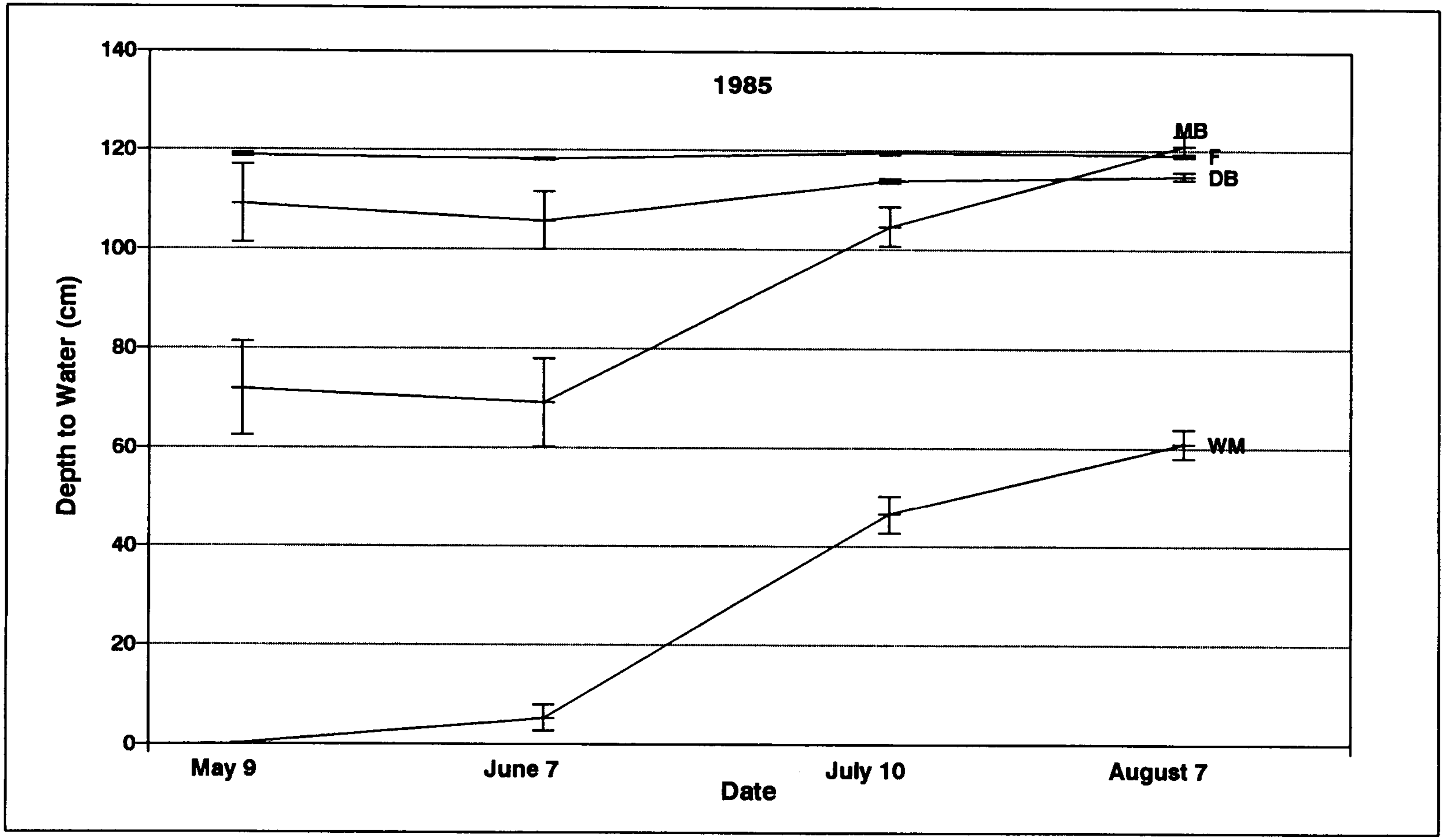

Figure 2.15. Seasonal trends in average depth to the water table for 1985 within different plant communities in a northeastern Oregon riparian zone. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows. Vertical bars indicate standard error of the mean.

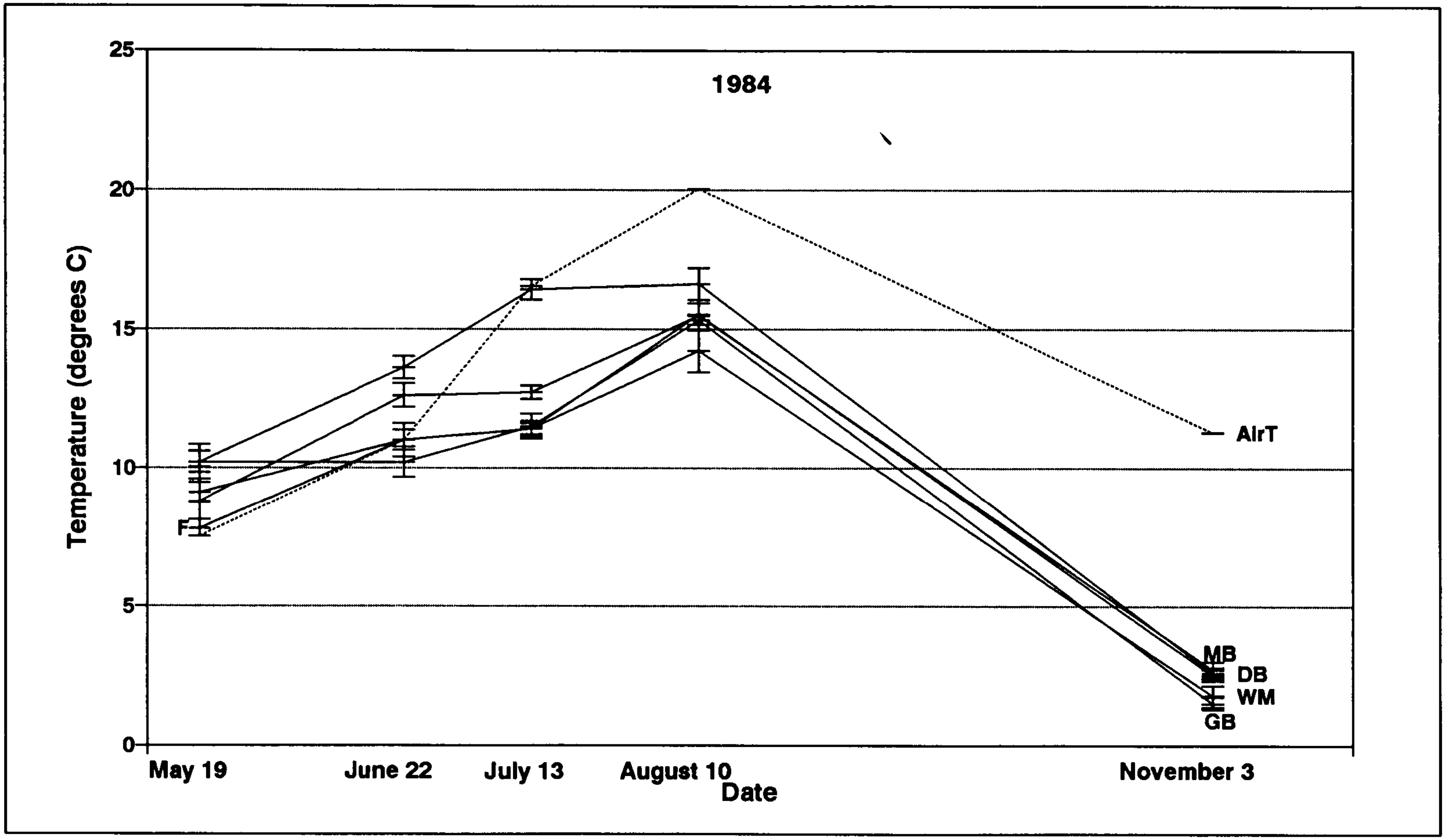

Figure 2.16. Seasonal trends in average air and soil temperature for 1984 within different plant communities in a northeastern Oregon riparian zone. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows. Vertical bars indicate standard error of the mean.

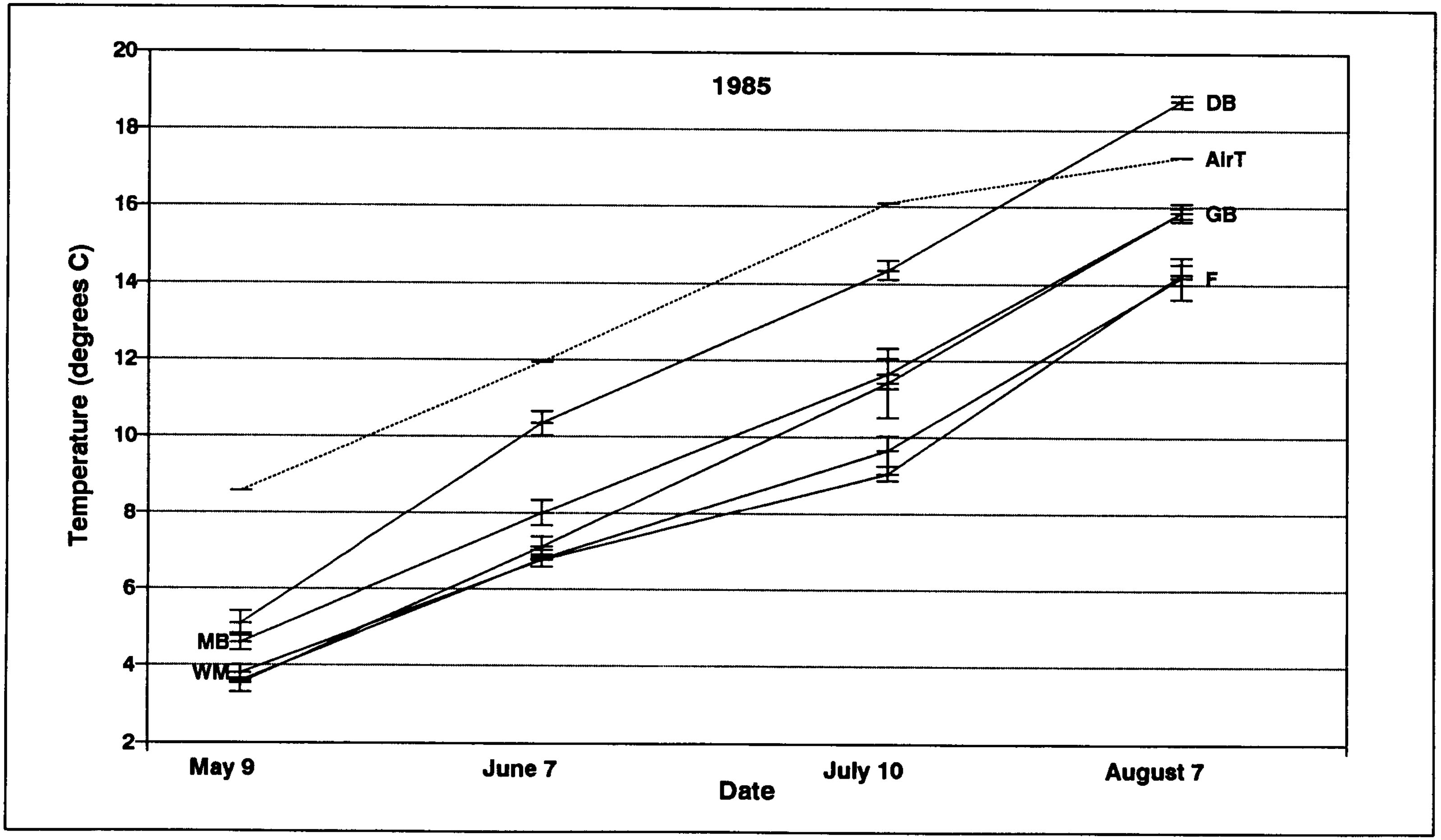

Figure 2.17. Seasonal trends in average air and soil temperature for 1985 within different plant communities in a northeastern Oregon riparian zone. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows. Vertical bars indicate standard error of the mean.

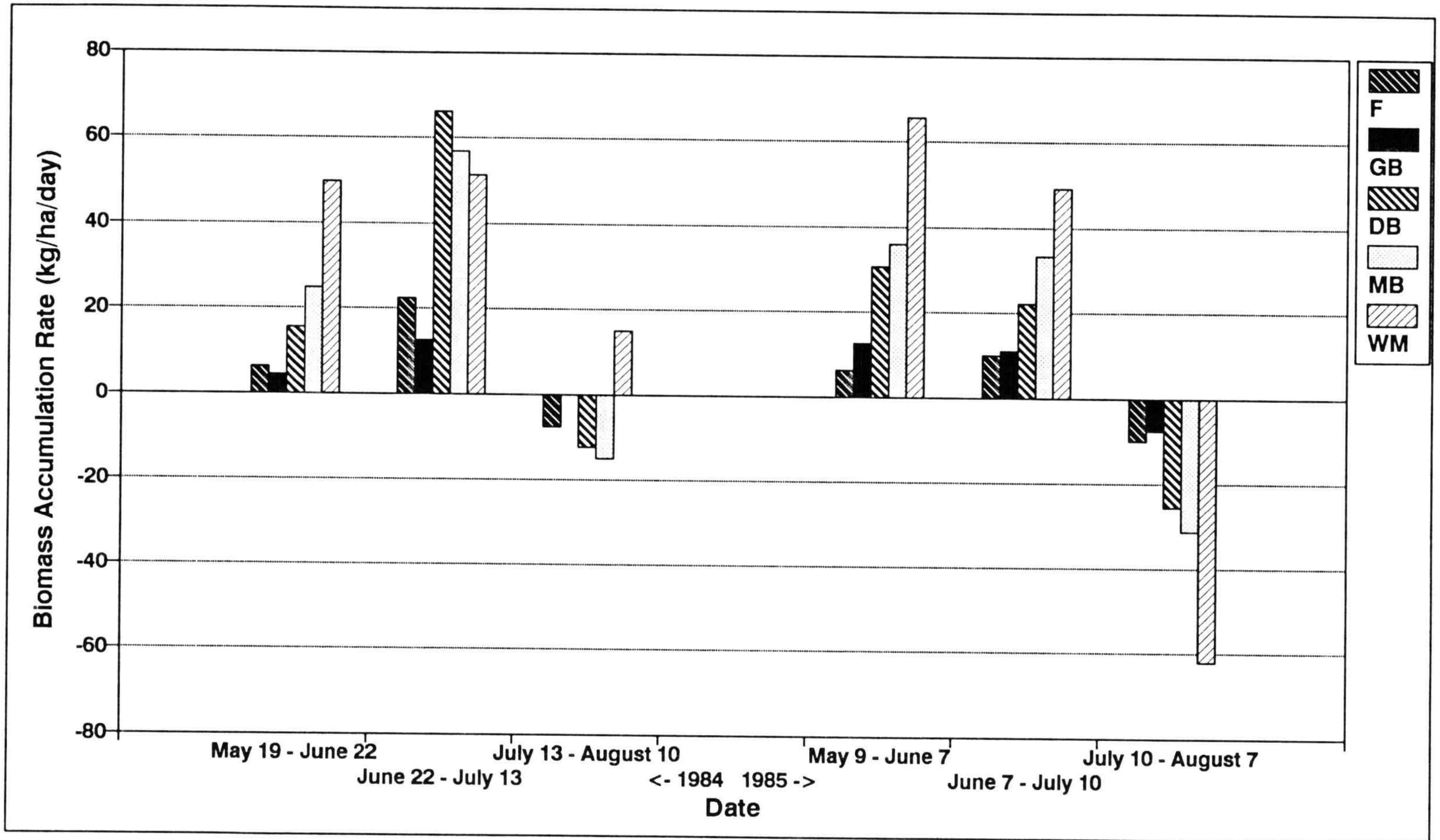

Figure 2.18. Seasonal trends in daily biomass accumulation rate of grasses in 1984 and 1985 within different plant communities in a northeastern Oregon riparian zone. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows.

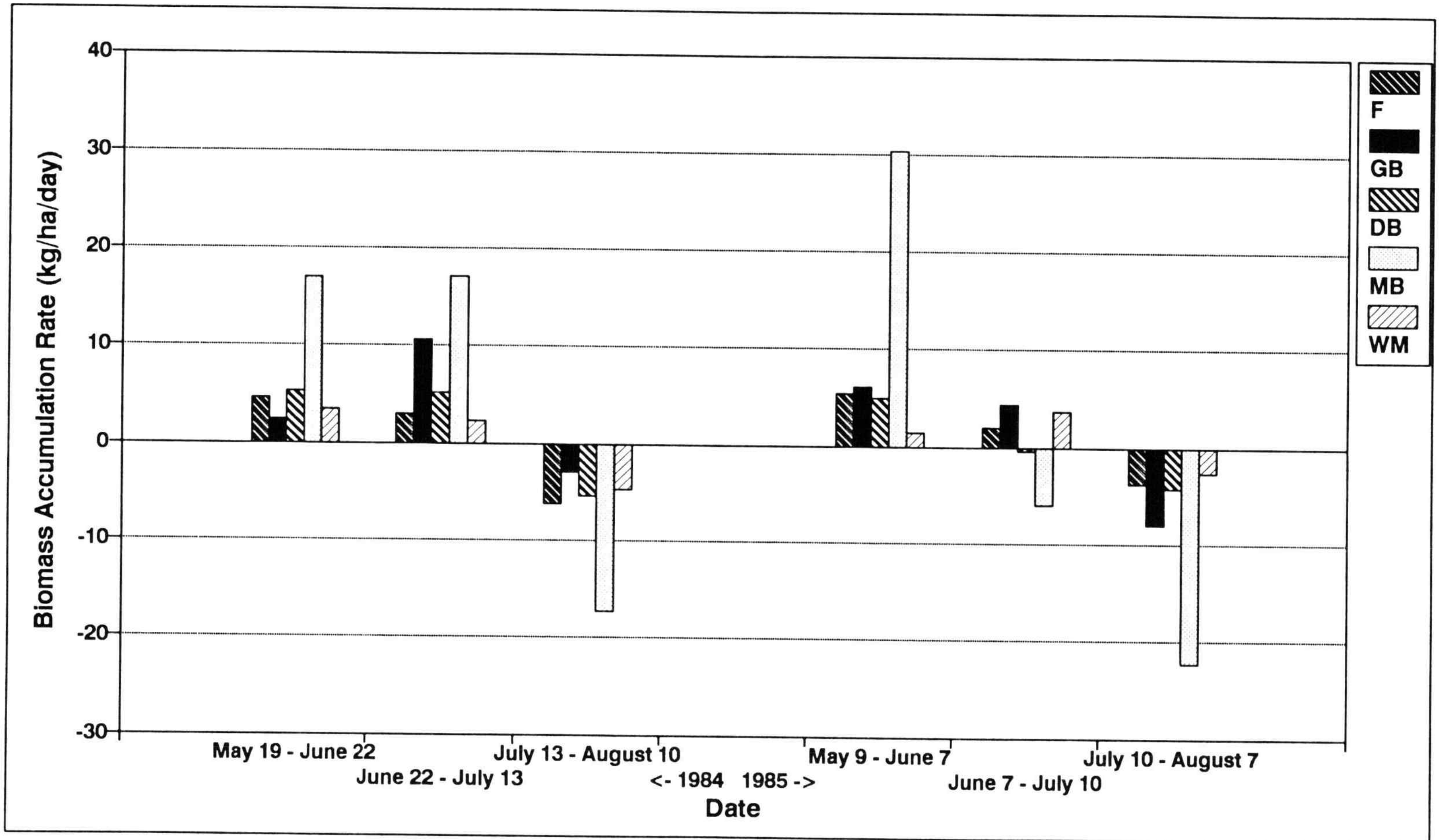

Figure 2.19. Seasonal trends in daily biomass accumulation rate of forbs in 1984 and 1985 within different plant communities in a northeastern Oregon riparian zone. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows.

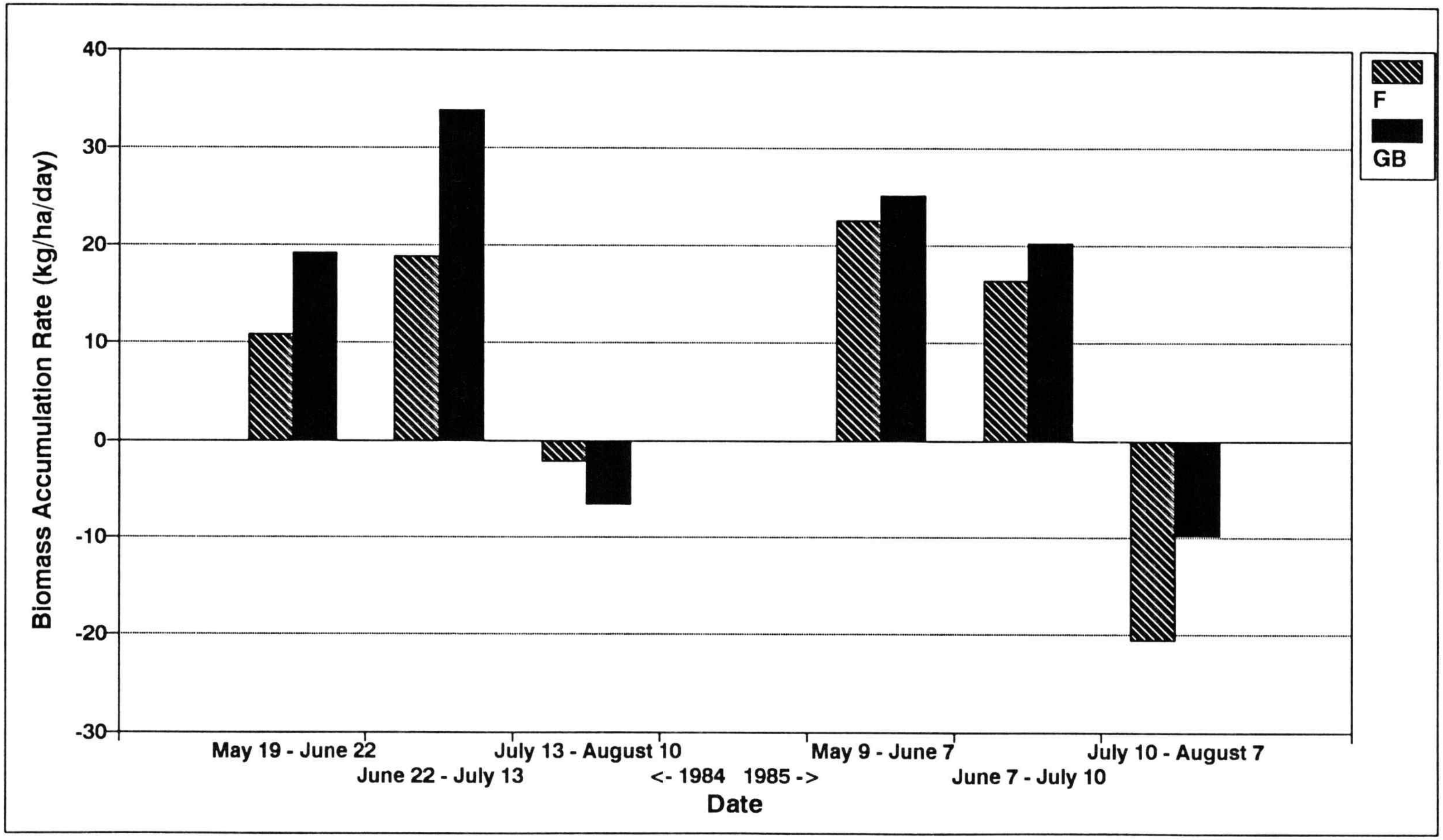

Figure 2.20. Seasonal trends in daily biomass accumulation rate of shrubs in 1984 and 1985 within different plant communities in a northeastern Oregon riparian zone. Communities designated as follows; F - forests and GB - gravel bars.

and June sampling dates, accumulation rates for all three classes of vegetation were positive with the greatest amount of grass, forb, and shrub growth occurring in the wet meadow, moist bluegrass meadow and gravel bar communities respectively. Trends for the June to July period demonstrated positive growth rates for grasses, forbs, and shrubs in 1984, while in 1985 forb production was negative in the dry and moist bluegrass meadow communities. This may well have been the result of 1985 having been a drier year than 1984, hence vegetation produced in the dry and moist bluegrass meadows grew more rapidly, matured and underwent earlier senescence than in 1984. The July to August period for both years resulted in negative growth, due to senescence, of all vegetation classes in all community types.

Path Analysis

Correlations between the environmental variables and forage production across and within communities located within the riparian zone are illustrated in Table 2.1. In general, biomass growth parameters were well correlated with each other (i.e. GroG was correlated with GroF) and with soil moisture parameters (e.g. SoilM, Depth and Flow) as well as temperature. The strength of correlations among variables were, however, dependent upon the community sampled. In dry bluegrass meadows, biomass accumulation was strongly correlated with soil moisture and poorly correlated with depth to the water table. However, as one progressed to moist bluegrass meadows and on to wet meadows, the strength of the correlation with depth to the water table increased while that with soil moisture decreased.

The results of the path analysis for various classes of forage production for the combined communities is illustrated in Figure 2.21 and Table 2.2. The analysis across community types indicated that all variables except Ppt were important in explaining grass and forb biomass accumulation. That precipitation is a relatively unimportant variable is not surprising, given that most of the precipitation the study area receives occurs in the winter as snow, which either runs off or percolates into the soil contributing to increased soil moisture levels. Pumphrey

Table 2.1. Simple correlations between the environmental and production variables used in the path analyses.

	GroGFS[a]	GroGF	GroG	GroF	GroS	PrevGFS	PrevGF	PrevG	PrevF	PrevS	AirT	SoilM	Depth	Flow
ALL[c]	[b]													
GroG		0.95												
GroF		0.62	0.36											
PrevGF		-0.28	-0.20	-0.37										
PrevG		-0.26	-0.19	-0.31			0.95							
PrevF		-0.15	-0.07	-0.30			0.43	0.14						
AirT		-0.42	-0.33	-0.46			0.45	0.40	0.31					
SoilM		0.34	0.31	0.24			0.33	0.39	-0.09		-0.26			
Depth		-0.41	-0.41	-0.20			-0.42	-0.48	0.08		0.20	-0.69		
Flow		0.54	0.46	0.48			-0.46	-0.41	-0.28		-0.73	0.28	-0.24	
Ppt		-0.13	-0.08	-0.21			0.10	0.08	0.09		0.47	-0.05	0.01	0.10
DB														
GroG		0.98												
GroF		0.44	0.26											
PrevGF		-0.63	-0.55	-0.57										
PrevG		-0.64	-0.58	-0.50			0.99							
PrevF		-0.22	-0.09	-0.68			0.56	0.44						
AirT		-0.39	-0.31	-0.49			0.83	0.79	0.66					
SoilM		0.64	0.57	0.55			-0.82	-0.80	-0.56		-0.86			
Depth		-0.25	-0.23	-0.14			0.27	0.25	0.26		0.35	-0.36		
Flow		0.62	0.55	0.54			-0.77	-0.74	-0.57		-0.74	0.83	-0.27	
Ppt		-0.15	-0.13	-0.18			0.32	0.31	0.21		0.46	-0.26	0.20	0.11
MB														
GroG		0.94												
GroF		0.79	0.53											
PrevGF		-0.73	-0.57	-0.76										
PrevG		-0.75	-0.64	-0.69			0.94							
PrevF		-0.36	-0.17	-0.58			0.69	0.39						
AirT		-0.56	-0.39	-0.68			0.76	0.66	0.61					
SoilM		0.65	0.51	0.70			-0.61	-0.69	-0.17		-0.60			
Depth		-0.64	-0.51	-0.66			0.67	0.75	0.23		0.56	-0.83		
Flow		0.67	0.53	0.69			-0.80	-0.72	-0.61		-0.71	0.67	-0.76	
Ppt		-0.23	-0.14	-0.31			0.16	0.12	0.16		0.52	-0.09	-0.05	0.07
WM														
GroG		0.99												
GroF		0.26	0.15											
PrevGF		-0.75	-0.74	-0.28										
PrevG		-0.75	-0.74	-0.23			1.00							
PrevF		-0.31	-0.24	-0.70			0.39	0.32						
AirT		-0.48	-0.44	-0.41			0.78	0.76	0.54					
SoilM		0.08	0.08	0.05			0.19	0.22	-0.34		-0.11			
Depth		-0.73	-0.71	-0.29			0.83	0.83	0.30		0.75	-0.13		
Flow		0.59	0.56	0.38			-0.78	-0.77	-0.35		-0.74	0.11	-0.84	
Ppt		-0.01	0.02	-0.18			0.12	0.10	0.26		0.46	-0.01	0.09	0.11

Table 2.1. (Continued)

	GroGFS[a]	GroGF	GroG	GroF	GroS	PrevGFS	PrevGF	PrevG	PrevF	PrevS	AirT	SoilM	Depth	Flow
									F					
GroGF	0.93													
GroG	0.91	0.96												
GroF	0.60	0.68	0.46											
GroS	0.80	0.69	0.68	0.41										
PrevGFS	-0.68	-0.65	-0.56	-0.63	-0.54									
PrevGF	-0.68	-0.64	-0.51	-0.72	-0.51	0.81								
PrevG	-0.71	-0.67	-0.57	-0.66	-0.55	0.77	0.98							
PrevF	-0.43	-0.38	-0.20	-0.73	-0.29	0.72	0.81	0.67						
PrevS	-0.63	-0.54	-0.49	-0.45	-0.70	0.79	0.68	0.65	0.58					
AirT	-0.49	-0.46	-0.28	-0.73	-0.38	0.82	0.74	0.66	0.78	0.59				
SoilM	0.65	0.60	0.46	0.75	0.58	-0.63	-0.70	-0.69	-0.57	-0.59	-0.72			
Depth	-0.26	-0.41	-0.37	-0.35	-0.07	0.26	0.19	0.23	0.02	0.22	0.21	-0.44		
Flow	0.61	0.61	0.50	0.64	0.44	-0.79	-0.74	-0.71	-0.62	-0.69	-0.74	0.81	-0.49	
Ppt	-0.19	-0.19	-0.08	-0.39	-0.12	0.20	0.18	0.13	0.29	0.01	0.46	-0.07	0.15	0.11
									GB					
GroGF	0.79													
GroG	0.77	0.94												
GroF	0.70	0.93	0.76											
GroS	0.81	0.32	0.37	0.23										
PrevGFS	-0.73	-0.62	-0.61	-0.55	-0.60									
PrevGF	-0.64	-0.69	-0.66	-0.64	-0.39	0.87								
PrevG	-0.61	-0.63	-0.63	-0.54	-0.39	0.86	0.96							
PrevF	-0.55	-0.65	-0.56	-0.67	-0.30	0.69	0.87	0.68						
PrevS	-0.62	-0.38	-0.40	-0.31	-0.66	0.90	0.59	0.63	0.39					
AirT	-0.38	-0.30	-0.30	-0.27	-0.42	0.82	0.64	0.58	0.61	0.83				
Flow	0.54	0.41	0.36	0.42	0.51	-0.83	-0.74	-0.74	-0.59	-0.78	-0.74			
Ppt	-0.11	-0.13	-0.16	-0.08	-0.19	0.17	0.06	-0.04	0.22	0.24	0.46			0.11

[a] - Gro or Prev followed by GFS indicates growth or previous production of grasses, forbs and shrubs combined. In a similar manner, GF indicates grasses and forbs combined, G indicates grasses, F indicates forbs and S indicates shrubs. SoilM represents average soil moisture content, Depth represents average depth to the water table and Flow represents average streamflow levels.
[b] - Blank cells within the table indicate communities in which no shrub production occurred.
[c] - Community designations as follows; ALL - across all communities, DB - dry bluegrass communities, MB - moist bluegrass communities, WM - wet meadows, F - forests and GB - gravel bar communities.

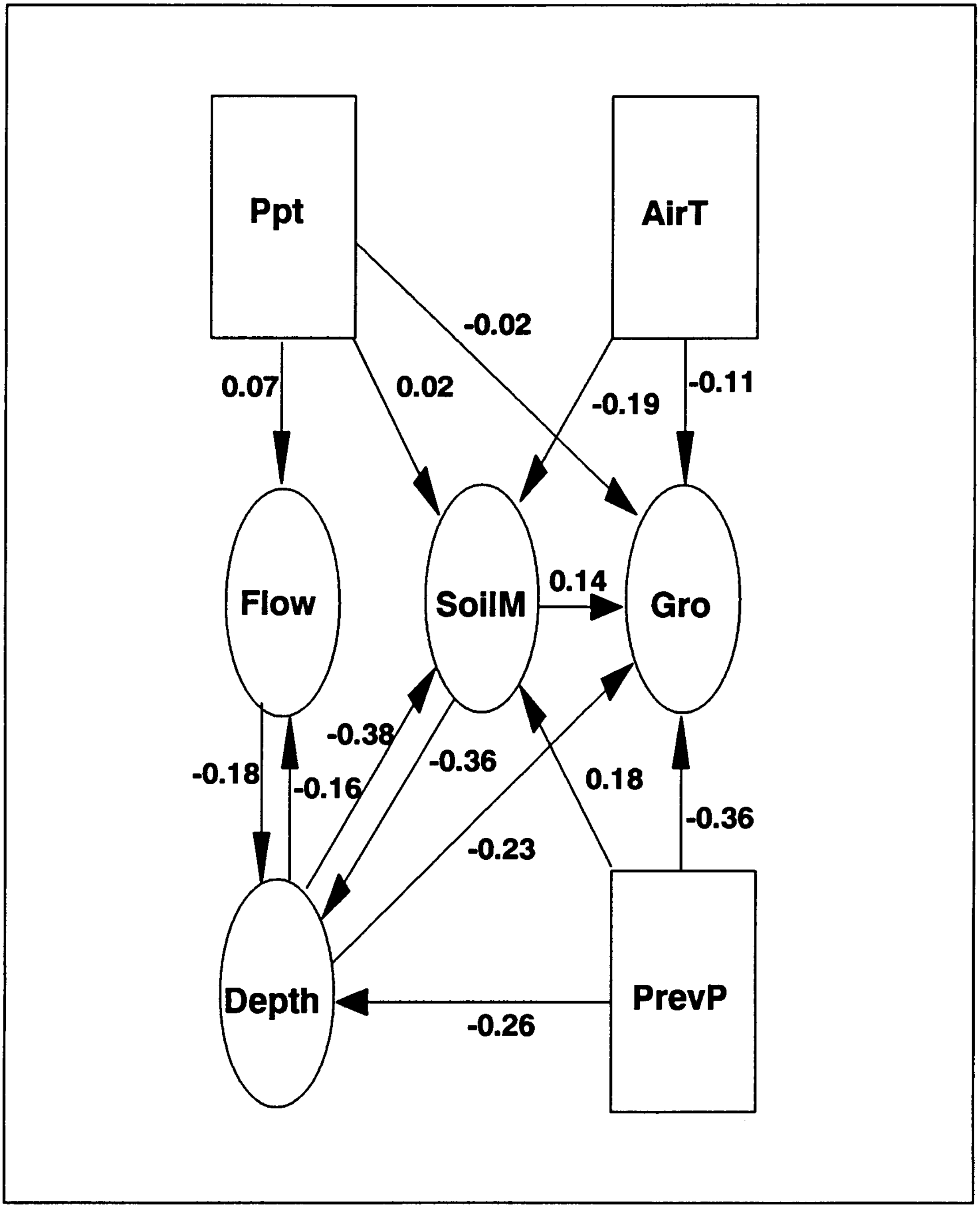

Figure 2.21. Path coefficients for the growth of grasses and forbs across the dry bluegrass meadow, moist bluegrass meadow, wet meadow and forest community types found within a northeastern Oregon riparian zone. Acronyms as follows; growth (Gro), previous production (PrevP), soil moisture (SoilM), depth to the water table (Depth), air temperature (AirT), monthly precipitation (Ppt) and monthly streamflow (Flow).

Table 2.2. Standardized regression coefficients for the regression of biomass accumulation rate upon average monthly precipitation (Ppt), depth to the water table (Depth), soil moisture (SoilM), mean daily air temperature (AirT) and previous grass and forb production (PrevP) of various vegetation classes for five different riparian zone community types.

Community	Class	Ppt	Depth	SoilM	AirT	PrevP	R^2
ALL[a]	GF[b]	-0.02 (0.05)[c]	-0.23 (0.05)	0.14 (0.05)	-0.11 (0.05)	-0.36 (0.05)	48
	G	0.01 (0.06)	-0.23 (0.06)	0.12 (0.06)	-0.07 (0.05)	-0.32 (0.05)	38
	F	-0.07 (0.06)	-0.10 (0.06)	0.12 (0.06)	-0.16 (0.05)	-0.27 (0.05)	34
DB	GF	-0.01 (0.10)	-0.06 (0.10)	0.30 (0.08)	0.09 (0.08)	-0.29 (0.09)	45
	G	-0.01 (0.10)	-0.07 (0.10)	0.28 (0.09)	0.12 (0.08)	-0.26 (0.09)	37
	F	-0.01 (0.11)	0.02 (0.11)	0.19 (0.09)	-0.09 (0.09)	-0.22 (0.09)	32
MB	GF	-0.10 (0.08)	-0.17 (0.08)	0.20 (0.08)	-0.05 (0.08)	-0.29 (0.08)	58
	G	-0.07 (0.10)	-0.15 (0.09)	0.16 (0.10)	0.01 (0.09)	-0.25 (0.10)	36
	F	-0.13 (0.07)	-0.16 (0.07)	0.21 (0.07)	-0.13 (0.07)	-0.28 (0.07)	67
WM	GF	0.05 (0.09)	-0.28 (0.08)	0.07 (0.09)	-0.04 (0.07)	-0.36 (0.07)	63
	G	0.06 (0.09)	-0.28 (0.08)	0.07 (0.09)	-0.02 (0.08)	-0.37 (0.08)	61
	F	-0.04 (0.13)	-0.07 (0.12)	0.02 (0.13)	-0.20 (0.11)	-0.06 (0.11)	16
F[d]	GFS	-0.08 (0.09)	-0.04 (0.09)	0.29 (0.09)	0.02 (0.07)	-0.32 (0.08)	52
	GF	-0.10 (0.09)	-0.16 (0.09)	0.23 (0.09)	0.03 (0.07)	-0.32 (0.08)	51
	G	-0.05 (0.10)	-0.16 (0.10)	0.17 (0.10)	0.11 (0.09)	-0.33 (0.09)	38
	F	-0.18 (0.07)	-0.11 (0.08)	0.30 (0.07)	-0.20 (0.06)	-0.14 (0.07)	66
	S	-0.04 (0.11)	0.05 (0.11)	0.30 (0.11)	0.03 (0.09)	-0.25 (0.10)	37

[a] - Community designations as follows; ALL - across all communities, DB - dry bluegrass communities, MB - moist bluegrass communities, WM - wet meadows and F - forests.
[b] - Vegetation classes as follows; GFS - grasses, forbs and shrubs combined, GF - grasses and forbs combined, G - grasses, F - forbs and S - shrubs.
[c] - Number in parentheses indicates the approximate standard error of the regression coefficient.
[d] - Where previous production represents grasses, forbs and shrubs combined.

(1980) found that neither monthly or monthly combinations of precipitation were well correlated with non-fertilized upland meadow forage production. Depth was of greater importance than SoilM in terms of describing grass and grass-like production, suggesting that grasses and grass-like species may maintain roots long enough to obtain moisture directly from the water table throughout the growing season while forbs may not. AirT was of greater importance in describing the biomass accumulation of forbs than grasses and grass-likes, perhaps due to the relatively rapid senescence of early growing forbs during the mid to latter part of the growing season. Previous production (PrevP) was of about equal importance in describing grass and grass-like production and forb production. The ability of the path model proposed to describe the production of various classes of forage depended upon the forage class under consideration (Table 2.2). R-squares varied from a low of 38 to a high of 48 percent.

Analyses within community types indicated significant differences among community types with regard to the importance of individual variables in describing forage production. With the exception of forb production in the wet meadows, depth became increasingly important in describing biomass accumulation across forage classes as one progressed from drier to more mesic community types (i.e dry bluegrass meadows to moist bluegrass meadows to wet meadows), while SoilM became less important. This indicates that some of the communities (e.g. DB, F and to a lesser extent MB) in a riparian zone may be dependent upon soil moisture levels rather than obtaining moisture directly from the water table throughout the growing season. As in the case of the combined community analysis, AirT was more important in describing forb production than grass and grass-like production with the exception of wet meadows. Also Ppt was a relatively unimportant variable in describing forage production in all community types. No clearly discernible trend in the importance of PrevP was observed within any of the community types. The ability of the path model to describe the production of various classes of forage generally increased in comparison to the across community analysis and was dependent upon the community and/or forage class under consideration (Table 2.2). Within communities R-squares varied from a low of 16 to a high of 67 percent.

The indirect effects of the explanatory variables upon the dependent variable were generally less than 10 percent of their direct effect however there were some notable exceptions. For grasses and forbs, the indirect effect of AirT upon Gro through SoilM was about 122 percent of the direct effect (-0.11 versus a coefficient of -0.09) in dry bluegrass meadows. In the forest community type this effect was approximately 267 percent of the direct effect (-0.08 versus a coefficient of -0.03) while in the moist bluegrass community type this effect was approximately equivalent to the direct effect (-0.03 versus a coefficient of -0.03). These findings suggest that communities with the least amount of biomass and/or overstory cover may be subject to the greatest relative evaporation losses of soil moisture. Also for the biomass accumulation of grasses and forbs, in dry bluegrass meadows, the indirect effect of PrevP through SoilM was approximately 38 percent of the size of its direct effect (-0.11 versus a coefficient of -0.29). In the forest community type this latter effect was 24 percent of the direct effect (-0.07 versus a coefficient of -0.29) while in the moist bluegrass meadows the indirect effect was about six percent of the direct effect (-0.02 versus a coefficient of -0.32). This suggests either a more rapid depletion of soil moisture in the forests and dry bluegrass meadows than in the other community types or reduced replenishment of soil moisture as a result of deeper water tables. In the wet meadows the indirect effect of PrevP upon grass and forb biomass accumulation through Depth was about 28 percent of the size of its direct effect (-0.10 versus a coefficient of -0.36). In the moist bluegrass meadow type this effect was 10 percent of the direct effect (-0.03 versus a coefficient of -0.29). This suggests that wet meadows may transpire large amounts of water, thus increasing the depth to the water table.

The results of the path analysis for soil moisture are contained in Table 2.3. The path model describing trends in soil moisture indicated that all variables except Ppt were important in describing trends in soil moisture across and within community types. Since little Ppt occurred during the growing seasons encompassed by the study, it is not surprising that Ppt had little effect upon soil moisture levels and hence little

Table 2.3. Standardized regression coefficients for the regression of soil moisture upon average monthly precipitation (Ppt), depth to the water table (Depth), mean daily air temperature (AirT) and previous grass and forb production (PrevP) for five different riparian zone community types.

Community	Ppt	Depth	AirT	PrevP	R^2
ALL[a]	0.02 (0.05)[b]	-0.38 (0.04)	-0.19 (0.04)	0.18 (0.04)	48
DB	0.03 (0.06)	-0.10 (0.06)	-0.38 (0.06)	-0.33 (0.06)	75
MB	-0.00 (0.07)	-0.43 (0.07)	-0.18 (0.07)	-0.12 (0.07)	66
WM	0.03 (0.13)	-0.17 (0.12)	-0.15 (0.11)	0.29 (0.12)	16
F	0.07 (0.08)	-0.20 (0.08)	-0.33 (0.07)	-0.29 (0.07)	64
Fgfs[c]	0.08 (0.08)	-0.20 (0.08)	-0.37 (0.07)	-0.19 (0.08)	57

[a] - Community designations as follows; ALL - across all communities, DB - dry bluegrass communities, MB - moist bluegrass communities, WM - wet meadows and F - forests.

[b] - Number in parentheses indicates the approximate standard error of the regression coefficient.

[c] - Where previous production represents grasses, forbs and shrubs.

effect upon biomass accumulation. AirT most influenced SoilM in the community with the least biomass or overstory (i.e. dry bluegrass meadows). Depth was most important in influencing SoilM in the moist bluegrass meadows, but was relatively unimportant in the dry bluegrass meadow or wet meadow types. This supports the above contention that relatively shallow water tables may replenish soil moisture levels in some community types, thus increasing their potential productivity. The wet meadow types may have had shallow enough water tables that vegetation production in these communities was not dependent upon soil moisture but upon obtaining moisture directly from the water table. Increases in PrevP were strongly associated with declines in soil moisture in all community types except wet meadows, again suggesting the direct role of water table depth upon biomass accumulation in wet meadows. Also, in the combined community analysis, the relationship between previous production and soil moisture was positive (Tables 2.1 and 2.3), thus suggesting that as the amount of biomass accumulates soil moisture levels increase. Looking within communities, this was obviously not the case except for wet meadows, which showed very little relationship between previous production and soil moisture (r=0.19). When the wet meadow data are combined with the other community data, the relationship between previous production and soil moisture increased (r=0.33) and resulted in a positive coefficient between the two variables (Table 2.3 and Figure 2.21) which is misleading in terms of understanding the functioning of the system. The explanatory ability of the path model for soil moisture varied depending upon community type from an R-square low of 16 to a high of 75 percent.

The results of the path analysis for depth to the water table are contained in Table 2.4. The model for describing trend in depth to the water table indicated that all variables were important components. Flow increased in importance as an explanatory variable as the community type became more mesic (i.e. as one progressed from dry bluegrass meadows to moist bluegrass meadows to wet meadow community types). The interpretation of this is unclear. One cannot tell whether the stream is contributing to the water table or whether the water table is contributing to streamflow levels. It is clear that they are co-varying, thus the bidirectional arrow between the two (Figures 2.6 and 2.21). Soil moisture

Table 2.4. Standardized regression coefficients for the regression of depth to the water table upon monthly streamflow (Flow), soil moisture (SoilM) and previous grass and forb production (PrevP) for five different riparian zone community types.

Community	Flow	SoilM	PrevP	R^2
ALL[a]	-0.18 (0.04)[b]	-0.36 (0.04)	-0.26 (0.04)	52
DB	-0.06 (0.11)	-0.18 (0.10)	0.05 (0.11)	11
MB	-0.25 (0.06)	-0.37 (0.07)	0.16 (0.06)	73
WM	-0.36 (0.07)	-0.11 (0.07)	0.35 (0.07)	73
F	-0.27 (0.10)	-0.19 (0.10)	-0.10 (0.10)	26
Fgfs[c]	-0.25 (0.09)	-0.17 (0.10)	-0.03 (0.10)	24

[a] - Community designations as follows; ALL - across all communities, DB - dry bluegrass communities, MB - moist bluegrass communities, WM - wet meadows and F - forests.
[b] - Number in parentheses indicates the approximate standard error of the regression coefficient.
[c] - Where previous production represents grasses, forbs and shrubs.

bidirectional arrow between the two (Figures 2.6 and 2.21). Soil moisture was an important variable in all community types except wet meadows. A discussion similar to that for the relationship between streamflow levels and water table depth may be proposed for the relationship between soil moisture levels and depth to the water table, since one does not know whether or not precipitation is contributing to reduced water table depths via rapid (i.e. thus not positively influencing biomass accumulation) percolation through the soil or whether capillary rise from the water table is increasing soil moisture levels. The results summarized in Table 2.4 suggest that the relationship is strongest in the across communities analysis and the moist bluegrass community type. PrevP was most important in influencing depth to the water table in wet meadows. This is not surprising since wet meadows have the shallowest water tables and the greatest biomass production. These meadows may have high transpiration rates, which may in turn increase depths to the water table. R-squares ranged from 11 to 73 percent and increased as the community type became more moist.

The results of the path analysis for streamflow are presented in Table 2.5. The path model relating streamflow to Ppt and Depth indicated that Depth was the most influential variable influencing streamflow levels. With the possible exception of high-intensity convectional storms, growing season precipitation apparently contributes little to flow levels as the moisture is either evaporated or tied up in the soil moisture - groundwater system and slowly delivered to the stream, if at all. As in the discussion above, depth and streamflow levels are tied together but which was influencing which was difficult to determine. R-squares ranged six to 64 percent and were the highest in community types with shallow water tables.

Figure 2.22 and Table 2.6 contain the results of the path analysis for gravel bar communities. Previous production and streamflow levels were the most important variables influencing biomass accumulation on the gravel bars. Increased streamflow levels corresponded to increased biomass accumulation rates. This may have resulted in increased moisture availability for rapid growing shallow rooted species on the gravel bars early in the growing season. Precipitation and air temperature were

Table 2.5. Standardized regression coefficients for the regression of streamflow upon monthly average precipitation (Ppt) and depth to the water table (Depth) for five different riparian zone community types.

Community	Ppt	Depth	R^2
ALL[a]	0.07 (0.06)[b]	-0.16 (0.06)	6
DB	0.09 (0.12)	-0.20 (0.12)	9
MB	0.03 (0.09)	-0.51 (0.09)	52
WM	0.11 (0.08)	-0.56 (0.08)	64
F	0.04 (0.11)	-0.32 (0.11)	21

[a] - Community designations as follows; ALL - across all communities, DB - dry bluegrass communities, MB - moist bluegrass communities, WM - wet meadows and F - forests.
[b] - Number in parentheses indicates the approximate standard error of the regression coefficient.

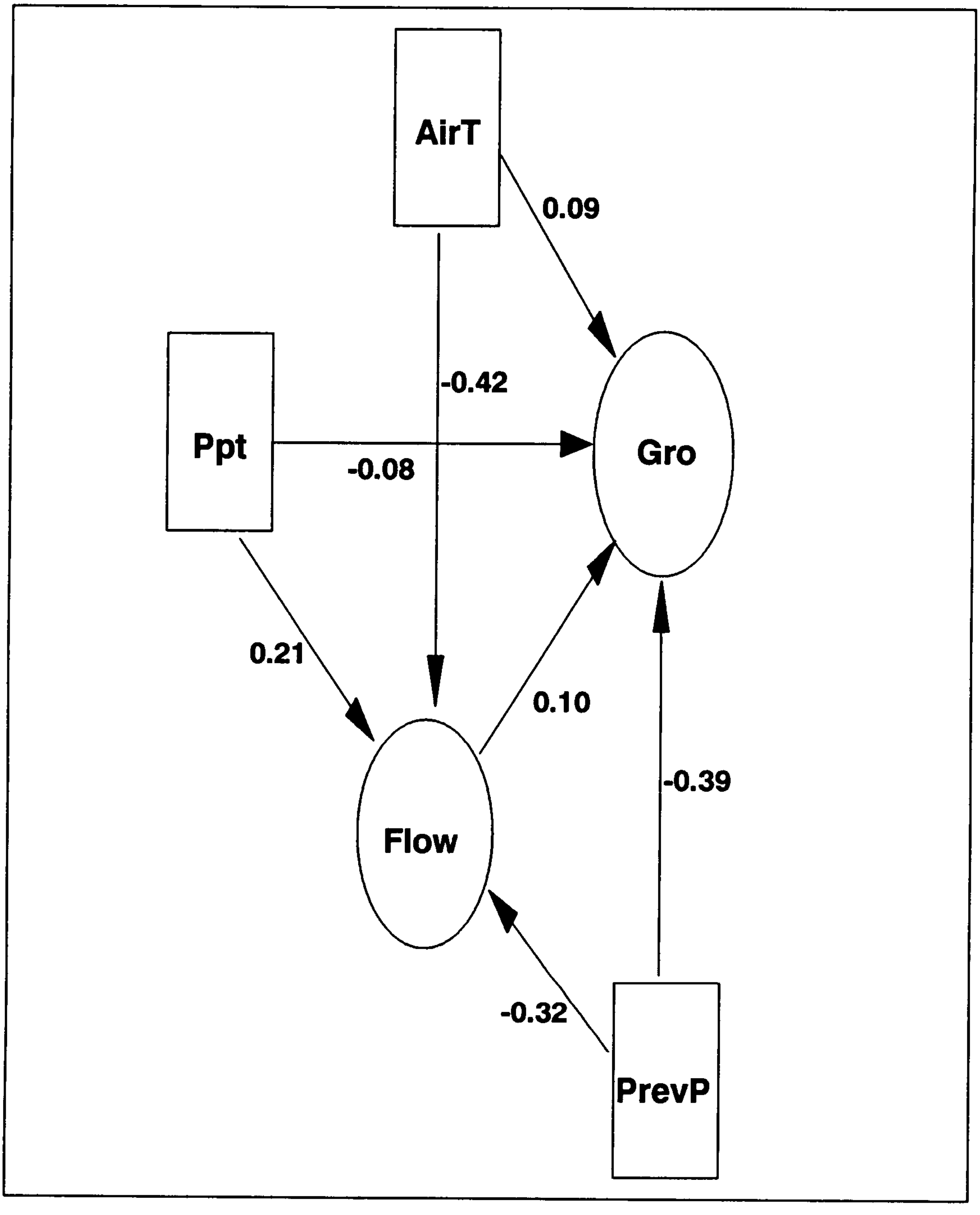

Figure 2.22. Path coefficients for the growth of grasses and forbs within the gravel bar community type found within a northeastern Oregon riparian zone. Acronyms as follows; growth (Gro), previous production (PrevP), air temperature (AirT), monthly precipitation (Ppt) and monthly streamflow (Flow).

Table 2.6. Standardized regression coefficients for the regression of biomass accumulation upon average monthly precipitation (Ppt), average monthly streamflow (Flow), mean daily air temperature (AirT) and previous grass, forb and shrub production (PrevP) for the gravel bar community type.

Community	Ppt	Flow	AirT	PrevP	R^2
GFS[a]	-0.05 (0.09)[b]	0.17 (0.07)	0.08 (0.07)	-0.43 (0.08)	49
GF	-0.08 (0.10)	0.10 (0.08)	0.09 (0.08)	-0.39 (0.09)	36
G	-0.09 (0.10)	0.06 (0.08)	0.08 (0.08)	-0.41 (0.09)	35
F	-0.06 (0.10)	0.14 (0.09)	0.09 (0.09)	-0.33 (0.09)	29
S	-0.11 (0.10)	0.19 (0.08)	0.01 (0.08)	-0.29 (0.09)	35

[a] - Forage classes as follows; GFS - grasses, forbs and shrubs combined, GF - grasses and forbs combined, G - grasses, F - forbs and S - shrubs.
[b] - Number in parentheses indicates the approximate standard error of the regression coefficient.

relatively unimportant again due to low precipitation quantities and, perhaps, the relative lack of limiting temperatures for species growing on the gravel bars. The explanatory ability of the model ranged from 33 to 62 percent.

The results of the path analysis for streamflow using gravel bar data are presented in Table 2.7. Precipitation was again a relatively unimportant variable in describing streamflow levels, while previous production and air temperature were relatively important. Previous production may reduce streamflow levels through transpiration while air temperature reduces streamflow levels through an evaporative mechanism. The explanatory ability of the model ranged from 74 to 78 percent.

Table 2.7. Standardized regression coefficients for the regression of average monthly streamflow upon average monthly precipitation (Ppt), mean daily air temperature (AirT) and previous production (PrevP) for the gravel bar community type.

Class	Ppt	AirT	PrevP	R^2
GFS[a]	0.22 (0.06)[b]	-0.35 (0.05)	-0.39 (0.05)	77
GF	0.21 (0.06)	-0.42 (0.06)	-0.32 (0.06)	74

[a] - Vegetation classes as follows; GFS - grasses, forbs and shrubs combined and GF - grasses and forbs combined.
[b] - Number in parentheses indicates the approximate standard error of the regression coefficient.

Conclusion

The predominant conclusions which can be drawn from the results of this study concern either the functioning of the riparian system or the data analysis technique. With regard to the functioning of the riparian system, the results of this study indicated that moisture, in one of its guises (i.e. soil moisture, depth to the water table or streamflow or even previous production) was the predominant variable controlling the seasonal biomass accumulation process, and that the greater the accessibility of moisture to growth processes, the greater the amount of biomass produced. The results also indicated that not all communities in the riparian zone obtain and utilize moisture in the same fashion (e.g. wet meadow vegetation may obtain moisture directly from the water table while other communities are dependent upon soil moisture levels). Both of these points have been posed by other authors and are supported by this study.

With regard to the path analysis technique, a number of important conclusions can be drawn. First, the results obtained are largely a function of the model assumed. That is to say that it is possible that other variables (e.g. soil nutrient status, duration of soil saturation, etc) played a greater role in the ecological process under investigation than those measured. Some indication of this may be observed by noting the high residual amounts of variation (i.e. $1-r^2$) yet to be described through either the addition of other variables or possibly through the rearrangement of the variables in the current model. Second, the interpretation of the results of path analysis must be analyzed with care, or one may be misled, as in the case of the positive correlation and path coefficient relating previous production to soil moisture. In any case, one of the values of the path analysis technique lies in the active involvement of the researcher in utilizing theory to describe the data during the analysis procedure. This provides a logical follow-up to the common practice of interpreting axes derived from the use of many ordination programs as principal components or discriminant analysis. A second value to the technique lies in its ability to provide the researcher with a means of quantifying the indirect effects of independent upon dependent variables, thus providing a fuller description of the ecological process under study. A final point to keep in mind concerning the use of path analysis was well put by Hermy (1987) when he indicated that path analysis is not intented to prove causation but rather to estimate the degree of assumed causation.

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CHAPTER 3

LINEAR MODELING OF PLANT COMMUNITY PREFERENCE BY CATTLE GRAZING

A

NORTHEASTERN OREGON RIPARIAN ZONE

LINEAR MODELING OF PLANT COMMUNITY PREFERENCE BY CATTLE GRAZING

A

NORTHEASTERN OREGON RIPARIAN ZONE

Abstract

Livestock preference for different riparian zone vegetation community types for grazing was monitored over a three-week grazing period occuring at the end of the summers of 1984 and 1985. Concurrent to preference, vegetative and nutritional characteristics of the forage available for grazing were also monitored and the relationships between these variables and community preference explored through correlation and path analyses. Results indicated that grazing cattle favored communities high in digestibility, hence communities dominated by Kentucky bluegrass were the most preferred. Toward the end of the grazing period community preference for grazing was best associated with community abundance, indicating that cattle were grazing communities in proportion to their abundance in the pasture.

Introduction

Riparian zones have become a focal point in the management of forests and rangelands due to their productivity, diversity, and importance to wildlife and livestock as well as man. As a result, numerous studies have been conducted to document the effects of livestock grazing upon riparian vegetation (Gunderson 1968), wildlife populations (Kauffman 1982), streambank erosion (Buckhouse et al. 1981), stream channels (Lusby 1970), water quality (Skinner et al. 1974) and fisheries resources (Marcuson 1977). Comparatively few studies, however, have sought to investigate the functioning of the grazing process within the riparian zone itself.

Studies of livestock grazing have generally been conducted in either improved pasture or upland situations and have resulted in a rudimentary understanding of the factors which influence the spatial distribution of livestock upon rangelands. Identified variables influencing the distribution of livestock on uplands include distance to water, distance to salt, slope, forage availability, forage quality, etc. (Arnold and Dudzinski 1978). The applicability of this body of knowledge to the riparian setting, is not well understood.

Thus the purpose of this study was twofold: first, to monitor trends in community preference by grazing cattle and environmental parameters for different plant communities in a northeastern Oregon riparian zone and, second, to describe the relationships between environmental parameters and cattle community preference through the use of path models.

Study Area

The study area was located in the southwestern foothills of the Wallowa mountains on the Hall ranch unit of the Eastern Oregon Agricultural Research Center (EOARC), approximately 19.3 kilometers southeast of Union, Oregon (Figure 3.1). The study area consisted of a long narrow pasture, approximately 41 hectares in size, located in a valley bottom along Catherine Creek.

The majority of the precipitation on the study area occurs as snow between the months of November and May. Figure 3.2 illustrates monthly trends in precipitation and temperature during the course of the study. EOARC records for two weather stations near the study area indicate that average annual precipitation in the area is about 610 millimeters. Temperatures in the area may range from below freezing to in excess of 38 degrees C. Elevation of the study area averages about 1050 meters. Soils on the area have been mapped as belonging to the veasie-voats soil complex (USDA 1985). The veasie series is classified as a coarse-loamy over sandy or sandy-skeletal, mixed, mesic cumulic haploxeroll, while the voats series is classified as a sandy-skeletal, mixed, mesic pachic haploxeroll. However Kauffman (1982) indicates that, due to the variable nature of soils within the riparian zone, many of the soils which occur on the study area do not fit these soil series descriptions.

Catherine Creek is a third order tributary of the Grande Ronde River which eventually drains into the Columbia river system. Figure 3.3 illustrates monthly trends in stream discharge. The average annual discharge of Catherine Creek is 106 hm^3/yr or 3.37 m^3/s (USGS 1984, USGS 1985). Peak flows occur during the months of April, May and June depending upon upstream snowmelt conditions.

The vegetation in the study area consists of a complex array of plant types and communities. In mapping the vegetation within a 50 meter strip on each side of the stream, Kauffman (1982) identified 60 distinct plant communities. The communities ranged from meadow communities dominated by Kentucky bluegrass (*Poa pratensis*), cheatgrass (*Bromus tectorum*) or sedges (*Carex* spp.) to tree dominated communities containing ponderosa pine

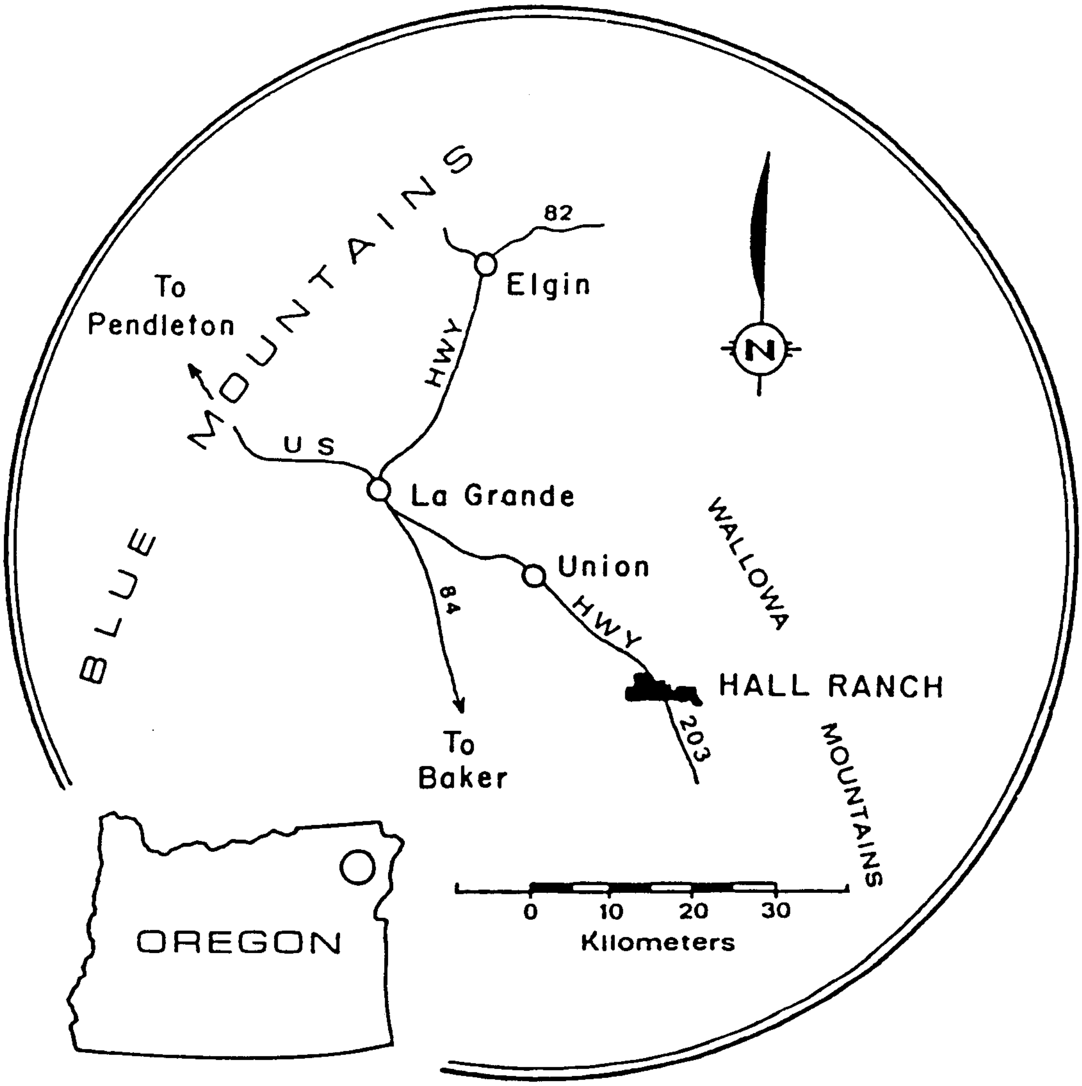


Figure 3.1. Location of the study area in northeastern Oregon.

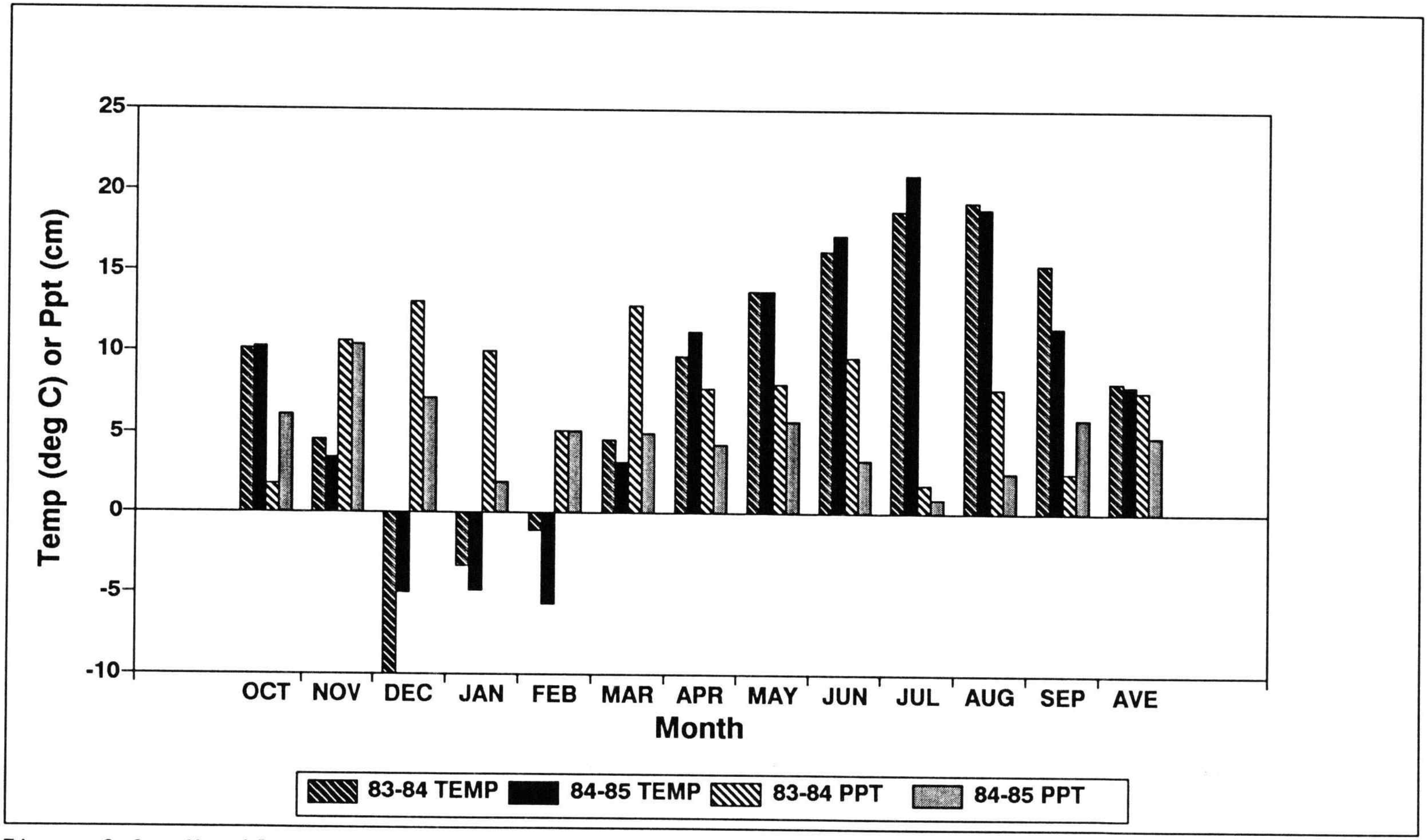


Figure 3.2. Monthly trends in temperature and precipitation from two Hall ranch weather stations over the duration of the study.

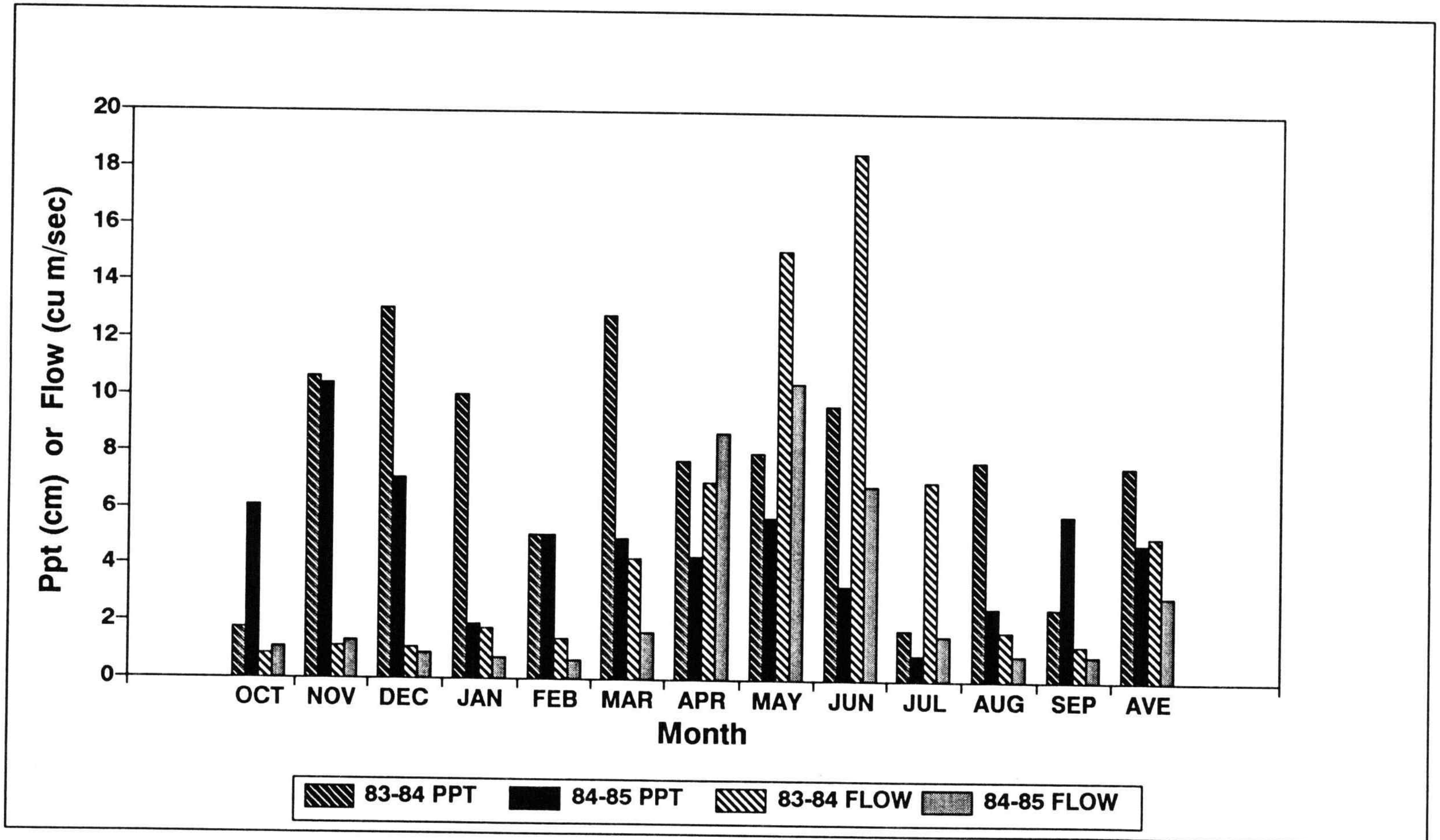


Figure 3.3. Monthly trends in precipitation and streamflow for Catherine Creek during the course of the study.

(*Pinus ponderosa*), grand fir (*Abies grandis*) or black cottonwood (*Populus trichocarpa*). Both low shrub communities dominated by snowberry (*Symphoricarpos albus*) or wood rose (*Rosa woodsii*) and tall shrub communities dominated by thin leaf alder (*Alnus incana*) or black hawthorne (*Crataegus douglasii*) occur within the study area.

Management of the riparian zone as a special use pasture has been described by Kauffman (1982). This management strategy essentially consists of grazing the riparian zone late in the season, thus minimizing livestock impacts upon riparian vegetation and wildlife. Grazing by livestock within the study area usually begins in late August, after the forage supply in the uplands has been utilized, and continues for about three weeks until mid-September. About 80 Hereford-Simmental cross cow/spring-calf pairs graze the study area at a stocking rate of about 1.7 animal unit months per hectare. Water for the livestock is provided by Catherine Creek and salt is supplied *ad libitum* at two points within the pasture. No efforts are made to influence the distribution and utilization patterns of the livestock within the study area. The livestock are moved to another pasture after the Kentucky bluegrass meadows within the study area have attained about 65 percent utilization.

Materials and Methods

This study was based upon the description of relationships among vegetative, environmental and grazing animal parameters during the grazing seasons of 1984 and 1985. The following sections describe the methods used in gathering data, as well as the statistical analyses used for each objective.

Plant Community Designation

Since this study was conducted on a plant community basis, the pasture was mapped by community type. Vegetation communities were mapped in accordance with the procedures outlined by Kauffman (1982). Aerial photographs were used to delineate and determine the areal extent of the vegetation types. Initial reconnaissance of the study area indicated that seven plant community types could be identified and mapped. These seven plant communities, the first five of which were sampled intensively, consisted of the following:

1. Gravel bar communities dominated by willows (*Salix* spp.) and cottonwoods (16 stands comprising 8% of the pasture).
2. Wet meadows dominated by rushes (*Juncus* spp.) and sedges (11 stands comprising 6% of the pasture).
3. Moist bluegrass meadows dominated by Kentucky bluegrass and forbs with a sedge component (50 stands comprising 31% of the pasture).
4. Dry bluegrass meadows dominated by Kentucky bluegrass (30 stands comprising 15% of the pasture).
5. Mixed coniferous forests dominated by ponderosa pine and grand fir (16 stands comprising 36% of the pasture).
6. Tall shrub communities dominated by black hawthorne.
7. Miscellaneous disturbance communities dominated by cheatgrass including old gravel bars not within the banks of Catherine Creek.

The latter two community types made up about 4% of the pasture.

Field Sampling

The development of a model describing plant community preference entailed the monitoring of several potential predictor variables. Six potential predictor variables were selected for monitoring during the course of this study. These included the following plant community characteristics:

1. Forage production.
2. Species composition.
3. Vegetation utilization (herbaceous and shrub).
4. Vegetation height (herbaceous and shrub).
5. Forage nutritional quality.
6. Community phenology.

Forage production by community type was measured using the method described by Kauffman (1982) in which 30, randomly located, 0.25 m^2 plots were clipped to ground level in each of the five communities. Production from each plot was separated into the following forage classes: Kentucky bluegrass, false-gold groundsel (*Senecio pseudareus*), grasses, forbs, rushes and sedges. Thus forage class composition, by weight, was determined from the production clipping which occured approximately one week before the cattle were allowed to graze the study area. Shrub production was determined by clipping a portion, about 12.5 percent, of the shrub biomass in 15 one meter square plots in the forest and gravel bar communities. Each shrub occurring within the meter square plot was mentally divided into eighths along a horizontal circle with the mainstem of the shrub at the center and one of these sections was randomly selected for clipping. Thus not all current annual growth was removed from each shrub.

Community forage utilization estimates were obtained by clipping 20 0.25 m^2 plots in each of the five community types midway through and at the end of each grazing period. Total biomass obtained from these plots was then expressed as a percentage of pregrazing biomass. Shrub utilization was estimated through occular estimates of shrub use before and after grazing in 15 one meter square plots and expressed as a percentage of pregrazing shrub biomass.

Vegetation height was measured in each of the 20 utilization plots immediately prior to clipping. Vegetation height was estimated by standing a ruler in the middle of each plot and mentally averaging height of the vegetation occurring within the plot. Shrub density and height in the forest and gravel bar communities was measured at the same time as shrub production estimates were made. Shrub density was determined by counting the number of stems occurring within the meter square plot and then converting to a stems-per-hectare basis. Shrub height was estimated by standing a meterstick in the middle of each plot and mentally averaging height of the shrubs occurring within the plot.

Nutritional quality of the vegetation available for grazing was also monitored during the grazing period. All the vegetation occurring within five randomly located 0.25 m^2 plots was clipped in each community type at the beginning, midway through, and at the end of the grazing period. In addition three shrub samples were obtained at the beginning and at the end of the grazing period from the gravel bar and forest communities. Snowberry samples from the forests and willow samples from the gravel bars were obtained by randomly selecting and clipping approximately 20 grams of current annual growth from the selected shrubs for nutritional analysis.

The forage and shrub samples were ground through a two millimeter mesh screen using a wiley mill and analyzed for nutritional quality. Samples were analyzed for several chemical components, including dry matter content, *in vitro* dry matter digestibility (IVDMD), neutral detergent fiber, acid detergent fiber, potassium permanganate lignin, silica, total ash and crude protein. Procedures used for dry matter content, total ash and Kjeldahl crude protein have been described by Harris (1970). Analysis techniques used for neutral detergent fiber, acid detergent fiber, cellulose, potassium permanganate lignin and silica have been described by Waldern (1971). *In vitro* dry matter digestibility was determined following a modification of the Tilley and Terry (1963) technique described by Holechek et al. (1982). Cell contents were determined as one hundred minus neutral detergent fiber content. Hemi-cellulose content was estimated by subtracting acid detergent fiber from neutral detergent fiber. Van Soest and Robertson (1980) have discussed the implications of determining hemi-cellulose in this fashion. They indicate that a sample's biogenic silica, pectin and tannin content reduces the estimate of hemi-cellulose while the cell wall protein content increases the hemi-cellulose estimate. Thus the errors are somewhat compensating and provide a reasonable index as to the hemi-cellulose content of a sample.

In order to characterize the phenology of the communities in which the cattle were grazing, the phenology scale used by Low et. al. (1981) was used. This system described the condition of the forage in each community type available for grazing in a qualitative manner using the following scale. Quality or growth state was described as: green (1), green tinge (2), or dry (3). In a similar fashion, forage quantity was assessed as: ungrazed (1 - less than 10% utilization), abundant (2 - 11% to 30% utilization), moderate (3 - 31% to 70% utilization) and sparse (4 - greater than 70% utilization). This system was used to assess community conditions at the time cattle locations were recorded.

The dependent variable, cattle locations, were observed approximately every three or four days during the period the cattle grazed the study area. The location of all mature cattle were noted on air photo overlays and a notation of their behavior (walking, grazing, resting or nursing) made. Preference indices for each community type and sampling date were calculated as the ratio of the number of cattle in a community type to the expected number of cattle in the community based on the proportion of the pasture the community occupies. A square root transformation was then conducted upon the community preference indices in order to linearize the relationship between the dependent and independent variables.

Index Construction

Construction of a theoretical path model describing community preference requires that singular variables be used to represent the variables in a path diagram (e.g. a path diagram variable representing forage quality may be represented by a singular measure of forage quality as energy content or crude protein or an index which includes elements of both). Indices representing forage quality, forage anti-quality, community utilization, community abundance, species composition and preferred and/or unpreferred species abundances were constructed for each community type.

The community utilization index (COMMUSE) reflects the amount of grazing which has occurred in a community and is expressed as the average percent utilization a community had received to that point in time.

The community abundance index (COMMNDX) reflects components of both the areal extent of a community type as well as the number of stands in which a particular community type occurs. This index was calculated as the product of the number of stands a community makes up and the percentage areal extent of the pasture the community occupies.

The index representing species composition (SPPCOMP) was represented as being composed of percent grass, forb, shrub and sedge compositions. This index weights shrubs and sedges greater than grasses and forbs. The index was constructed as follows:

SPPCOMP=(1*GRASS%)+(10*FORBS%)+(100*SHRUBS%)+(1000*SEDGES%)/1111

Thus communities composed primarily of grasses and/or forbs score lower than communities composed primarily of shrubs and/or sedges. In this way the communities are organized along a single axis representing a continum from grass to sedge dominated communities with forb and shrub dominated communities intermediate.

The preferred to unpreferred species index (SPPREF) is calculated as the ratio of the sum of sedge, rush and false-gold groundsel biomasses to the Kentucky bluegrass component in a community. As a result communities composed primarily of Kentucky bluegrass score lower on this scale than do communities high in sedges, rushes or false-gold groundsel. The intent of this index was to contrast communities containing a highly preferred species for grazing, Kentucky bluegrass, from communities containing high quantities of undesirable, sedges, rushes and false-gold groundsel, for grazing.

Path Analysis

Data from both years were combined and analyzed using correlation and path analysis. This technique consists of developing an *a priori* structural model (path diagram) describing the relationships among a system of dependent and independent variables (Figure 3.4). The technique assumes that the causal structure among the variables is known and that the system is causally closed. The method also assumes that the data meet the following requirements usually associated with regression analysis:

1. That the relationships between dependent and independent variables are linear and additive thus excluding curvilinear and multiplicative models.
2. That dependent variables are continous and normally distributed.
3. That independent variables are measured without error.
4. That error terms are uncorrelated.

The technique then uses repeated (i.e. for each dependent variable) stepwise multiple regression to estimate path coefficients as the standardized regression coefficients associated with postulated directional paths.

The normal stepwise regression analysis was replaced with ridge regression to reduce the effects of multicollinearity among the independent variables on the sign, magnitude and stability of coefficients associated with the independent variables. However as ridge regression is a biased regression technique, statistics (e.g. significance tests) normally associated with regression coefficients cannot be calculated as their distributional properties are not known. Thus only approximate standard errors of the coefficients were calculated. Selection of a biasing constant (k) is an important feature of ridge regression. Several methods have been proposed and are reviewed by Vinod (1978). The biasing constant (k) was selected based upon inspection of the ridge trace (Figure 3.5). The following four criteria proposed by Hoerl and Kennard (1970) were used as criteria in selecting a value for k:

1. Stabilization of the ridge trace.

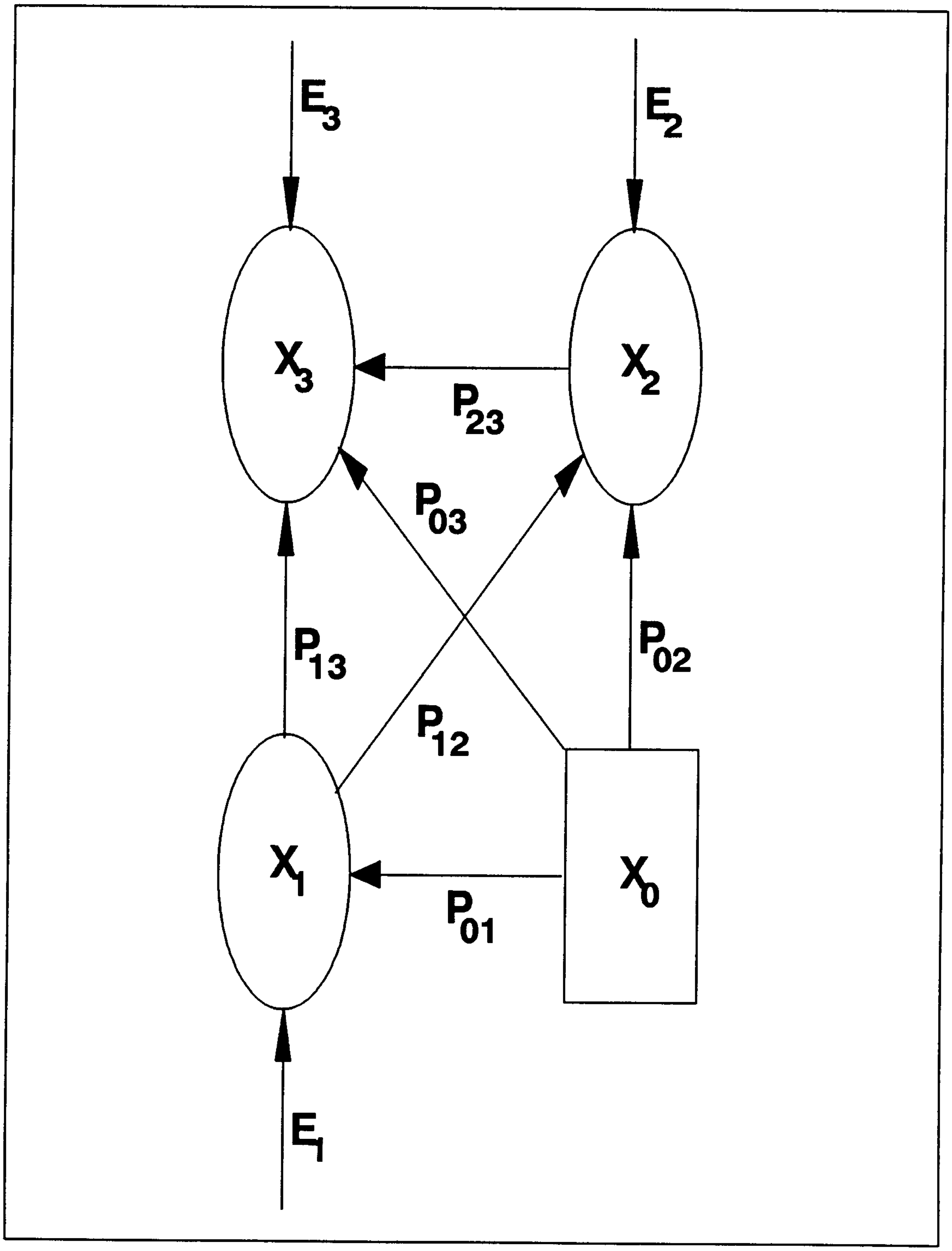


Figure 3.4. A theoretical four variable path model. The P's indicate pathways from independent to dependent variables while the E's indicate unknown latent factors. Note the existence of several indirect effects (e.g. the influence of X_0 on X_3 through X_1 or X_2).

2. Coefficients will not have unreasonable absolute values in terms of a priori knowledge.
3. Coefficients with theoretically improper signs at k=0 will have proper signs.
4. The residual sum of squares will not be considerably inflated.

A value of k=2.25 was used for all path analyses. In addition to the path coefficients, it is customary to determine the residual effect due to unmeasured latent variables for each dependent variable. The residual effect is calculated as one minus r-square for each dependent variable.

The effect of each independent variable on a dependent variable can then be direct (i.e. a direct path exists between the two), indirect (i.e. the two are related through other variable(s)), spurious (i.e. the two are correlated but are not linked) or unanalyzed (i.e the independent variable was not included in pathways in the model). Indirect pathways are calculated as the product of path coefficients along the indirect pathway.

In ordinary path analysis the sum of direct and indirect effects for a dependent variable is equal to the simple correlation between the dependent and independent variables, provided the model is fully recursive (i.e. that all possible connections between the two variables have been made). However this is not the case when ridge regression coefficients are used. For detailed discussions of regression techniques and path analysis methodology see Wright (1934), Blalock (1964), Li (1975), Gunst and Mason (1980), Wonnacott and Wonnacott (1981) and Dillon and Goldstein (1984). For recent examples of path analysis used in analyzing vegetation data see Hermy (1987) or Kuusipalo (1987).

The Theoretical Model

Distribution of grazing animals has long been of concern to range managers as well as livestock producers. Numerous efforts have been made to understand and influence the distribution patterns of grazing animals in order to efficiently utilize the forage resource from both range management and livestock production viewpoints. Spatial use of rangelands has been related to numerous factors including distance to water, distance to salt, topography, microclimate, plant community type,

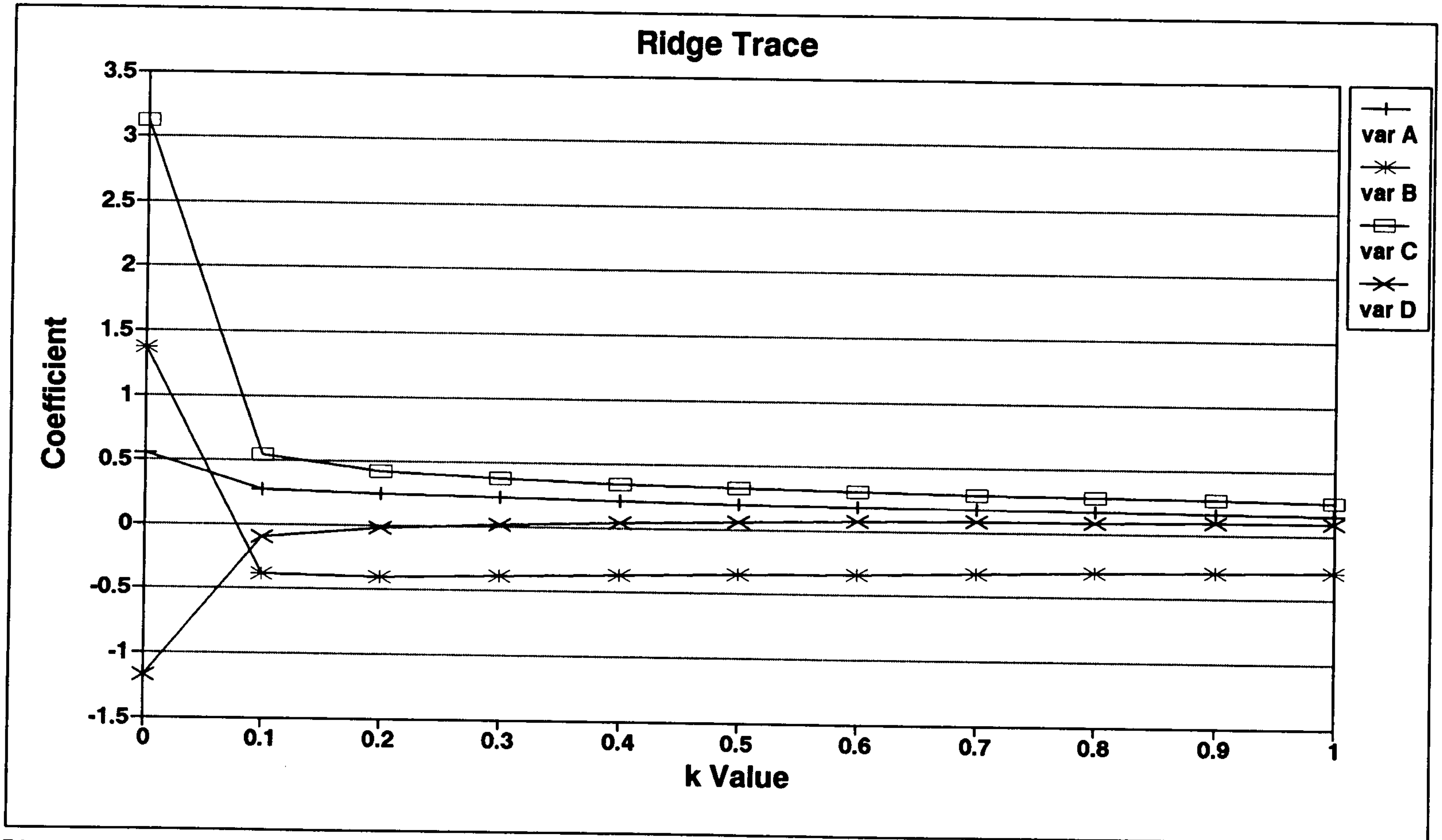


Figure 3.5. A ridge trace diagram produced as a result of ridge regression analysis. Note the high degree of collinearity exhibited by variables B, C and D as indicated by the rapid change in regression coefficient values as the biasing constant k increases.

forage quality, species composition, etc (Arnold and Dudzinski 1978). These factors as well as others influence the utilization of riparian zones as well as uplands.

A model describing community preference by livestock grazing a riparian zone may be a function of several variables. As illustrated in Figure 3.6, community preference is described as being a function of: community availability; *in vitro* dry matter digestibility; total forage biomass or species composition or relative biomass of preferred species for grazing; and, the level of utilization which has occurred to that point in time. Note that physical factors as distance to water and/or salt and topography have been excluded from the model due to the generally uniform physiogonomy of riparian pastures which often exclude uplands.

Community availability may influence preference for grazing in any of several ways. Community types which compose a significant portion of the pasture total and occur as numerous scattered stands will be more likely encountered by cattle grazing a pasture than are community types which occur infrequently in either larger or smaller stands depending upon their spatial distribution in relation to pasture attributes (e.g. water and/or salt locations, shelter, preferred community types for grazing, etc.) which grazing livestock find desirable. Frequent occurence of community types normally associated with low grazing preference may result in their being more preferred simply as a result of their increased availability. Conversely preferred community types of low relative availability may not be as preferred as normally would be expected. However it must be recognized that just the opposite may occur. A highly preferred community type may remain highly preferred just as an undesirable community type may retain a low preference rating depending upon the behavior (i.e. searching effort or knowledge of the pasture) of the livestock grazing the area.

The application of optimal foraging theory to community preference by grazing livestock has generally resulted in the conclusion that grazing animals tend to maximize nutrient, especially energy, intake over such other considerations as exposure to predation or minimizing energy expenditures relative to energy needs (Westoby 1974, Owen-Smith and Novellie 1982, Belovsky 1986). The forage quality measurement most

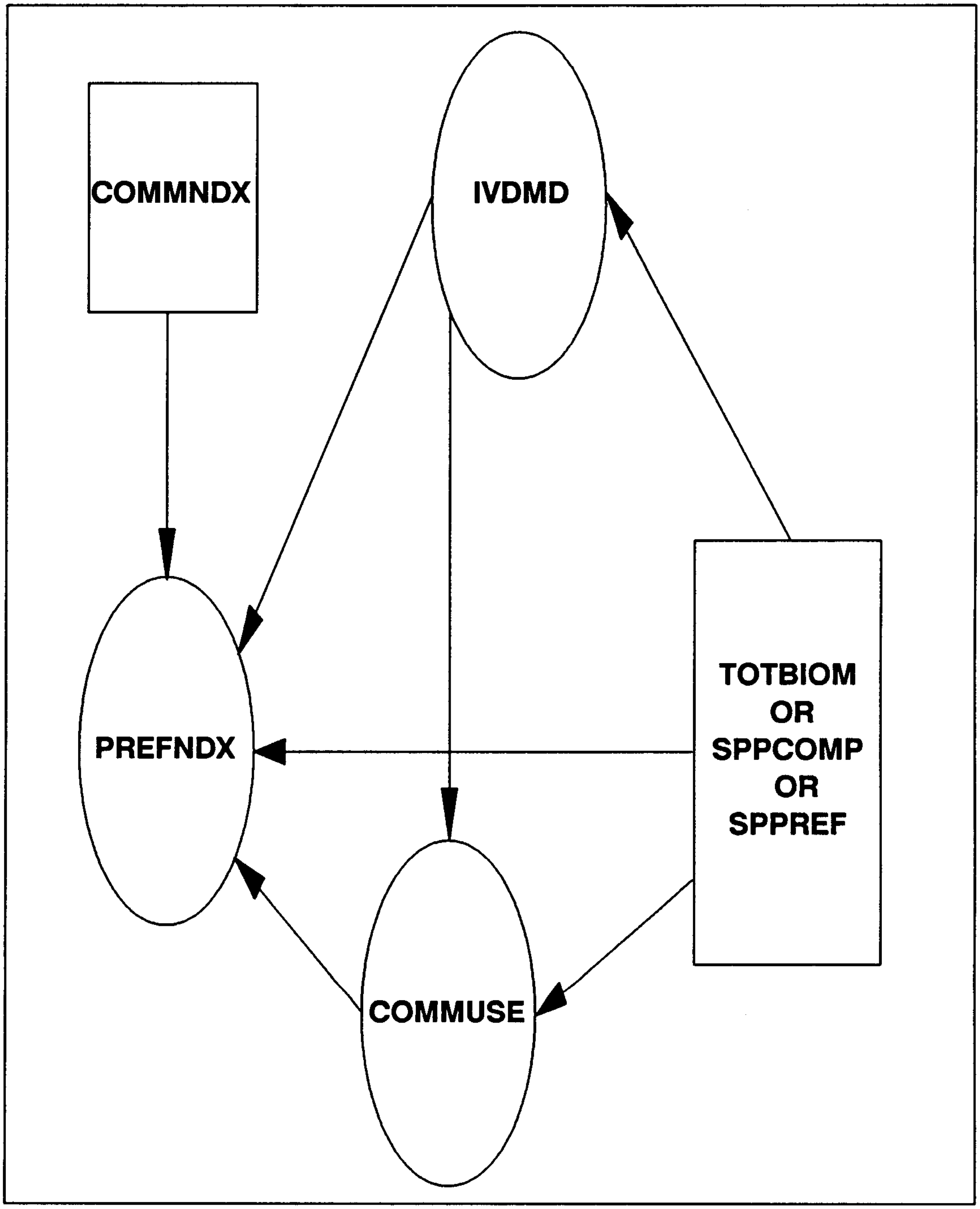


Figure 3.6. The proposed path model for describing livestock community preference. Community preference (PREFNDX) is described as being a function of: community availability (COMMNDX); *in vitro* (IVDMD) dry matter digestibility; total forage biomass (TOTBIOM) or species composition (SPPCOMP) or relative biomass of preferred species (SPPREF) for grazing; and, the level of utilization (COMMUSE) which has occurred to that point in time.

closely associated with energy content is *in vitro* dry matter digestibility (Van Soest 1982). Thus it is expected that livestock would first graze communities of the greatest digestibility followed by other community types.

The amount or composition of biomass available for grazing in a community type as modified by the amount of utilization which has occurred may influence grazing animal preference for that community type in any of several ways (Arnold and Dudzinski 1978). Livestock may graze the community type with the most forage available for consumption and switch to other communities as forage becomes limiting. As a refinement of this concept, species composition and/or the biomass of preferred species for grazing may influence community preference in that grazing livestock (cattle) have a demonstrated preference for grasses over sedges, forbs, or shrubs in their diets, although they will include sedges, forbs and shrubs in their diets when necessary (Arnold and Dudzinski 1978, VanDyne 1980, Senft et al. 1980, Van Soest 1982). Thus it is expected that cattle will most prefer communities dominated by grass species over community types composed primarily of sedge, forb or shrub species.

Results and Discussion

Environmental Parameters and Community Preference

Pre-grazing forage production estimates for both years for the five community types are illustrated in Figure 3.7. As shown by the figure, the most productive vegetation type were the wet meadow communities composed primarily of sedges with small grass and forb components. Moist bluegrass meadows were the next most productive type followed by gravel bar communities. Dry bluegrass meadows and forests were the least productive and produced about the same amount of biomass. The second year of the study (1985) was much drier than the first (1984) and as a result forage production levels were lower. In terms of composition the dry bluegrass meadows consisted primarily of grasses, the bulk of which was Kentucky bluegrass. Forests and gravel bars had very small sedge components and similar grass components, however forests had a higher proportion of Kentucky bluegrass. Gravel bars had larger proportions of both forbs and shrubs than did the forests. The moist bluegrass meadows had relatively large grass components, over half of which was Kentucky bluegrass. This community type also had a significant sedge component and a relatively large forb component.

Trends in utilization and height reduction of forage available for grazing for the other communities are illustrated in Tables 3.1 and 3.2 as well as in Figures 3.8 and 3.9. The tables and figures both indicate that dry bluegrass meadows received the fastest and heaviest utilization and the greatest reduction in height during both years. Trends for the other community types were somewhat similar however final utilization estimates for individual community types varied between years.

Community phenology for the five community types is illustrated in Table 3.3. In both years dry bluegrass meadows scored the highest thus indicating that they were the most mature in comparison to the other community types. This, in combination with the community utilization data, indicated that cattle grazing the study pasture preferred to graze mature brown Kentucky bluegrass over other green, less mature, community types. Scores were generally higher in 1985 than in 1984 indicating the

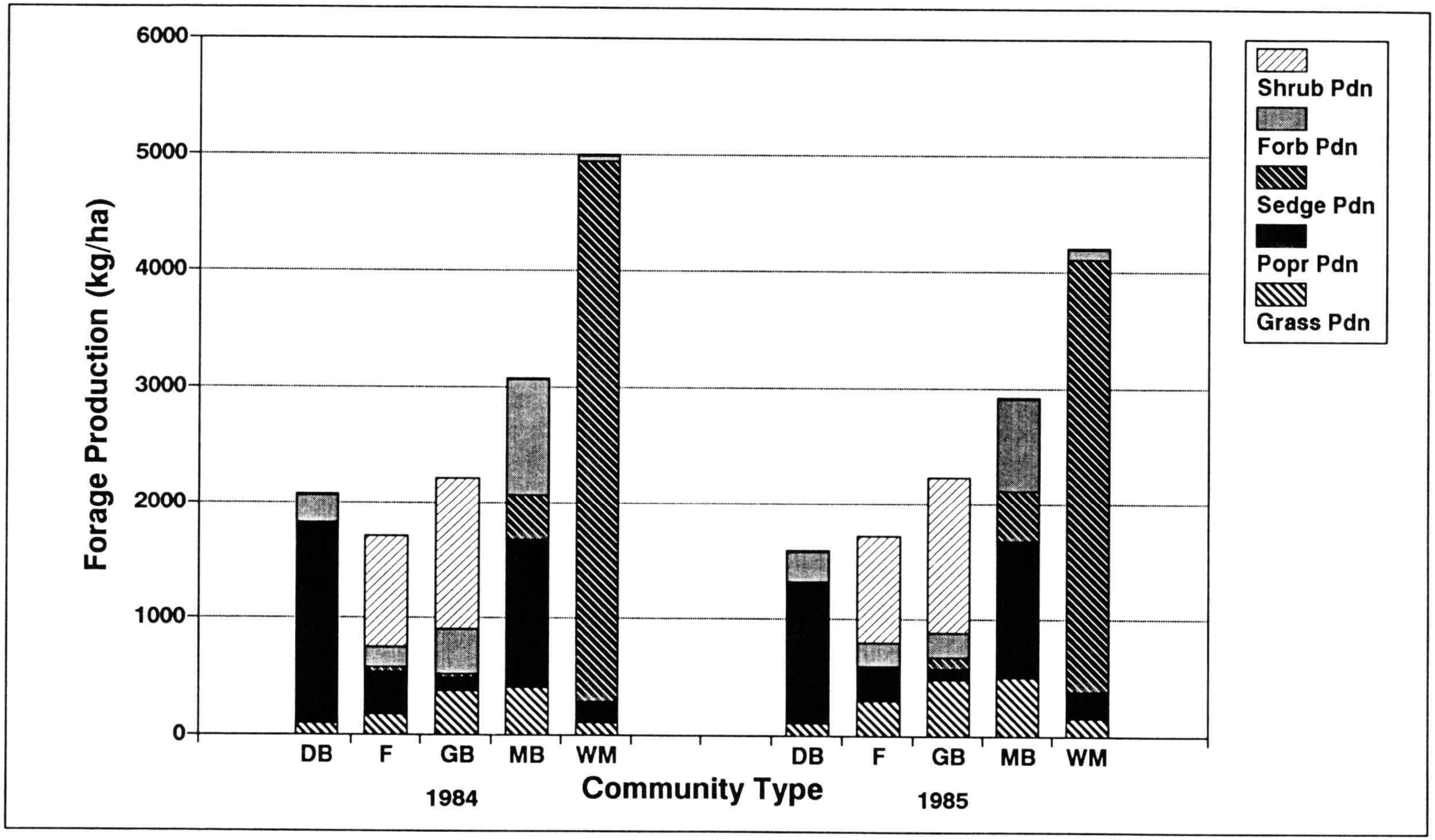


Figure 3.7. Forage production and composition of the different community types just prior to grazing in 1984 and 1985. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows.

Table 3.1. Trends in forage utilization (%) by weight for five plant community types found within an eastern Oregon riparian zone.

	Time					
	Before		Mid-way		End	
Community	1984	1985	1984	1985	1984	1985
DB[a]	0.0	0.0	71.6	69.5	88.7	78.7
F	0.0	0.0	26.7	28.9	57.5	48.1
GB	0.0	0.0	35.9	2.5	33.8	51.0
MB	0.0	0.0	9.2	25.5	48.5	53.5
WM	0.0	0.0	0.0	6.5	26.6	40.9

[a] - Community designations as follows: DB - dry bluegrass meadows; F - forests; GB - gravel bar communities; MB - moist bluegrass meadows, and; WM - wet meadows.

Table 3.2. Vegetation height (cm) in five riparian zone plant communities in eastern Oregon before, mid-way through and at the end of the grazing period.

	Time									
	Before		Mid-way				End			
Community	1984	1985	1984		1985		1984		1985	
DB[a]	27.7	21.3	8.9	(32)[b]	5.8	(27)	3.8	(14)	3.8	(18)
F	31.8	34.3	21.1	(66)	20.1	(59)	16.0	(50)	15.2	(44)
GB	36.6	26.7	19.3	(53)	13.5	(50)	11.4	(31)	15.0	(56)
MB	32.3	32.8	29.0	(90)	19.1	(58)	12.7	(39)	11.9	(36)
WM	67.6	47.8	50.0	(74)	34.3	(72)	26.7	(39)	21.1	(44)

[a] - Community designations as follows: DB - dry bluegrass meadows; F - forests; GB - gravel bar communities; MB - moist bluegrass meadows, and; WM - wet meadows.
[b] - Numbers in parentheses indicate height as a percentage of pregrazing height.

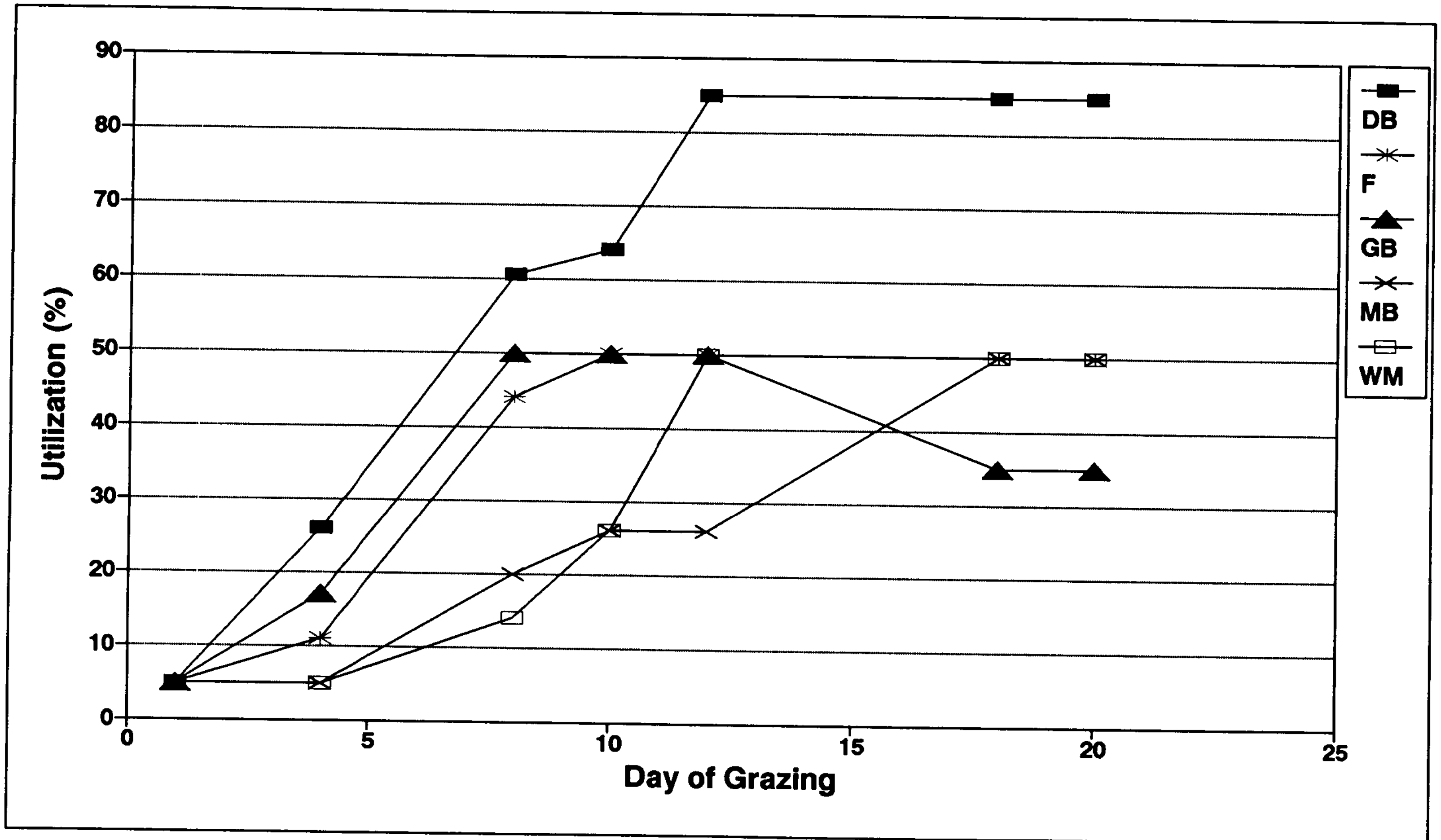


Figure 3.8. Trends in estimated utilization of the riparian zone community types in 1984. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows.

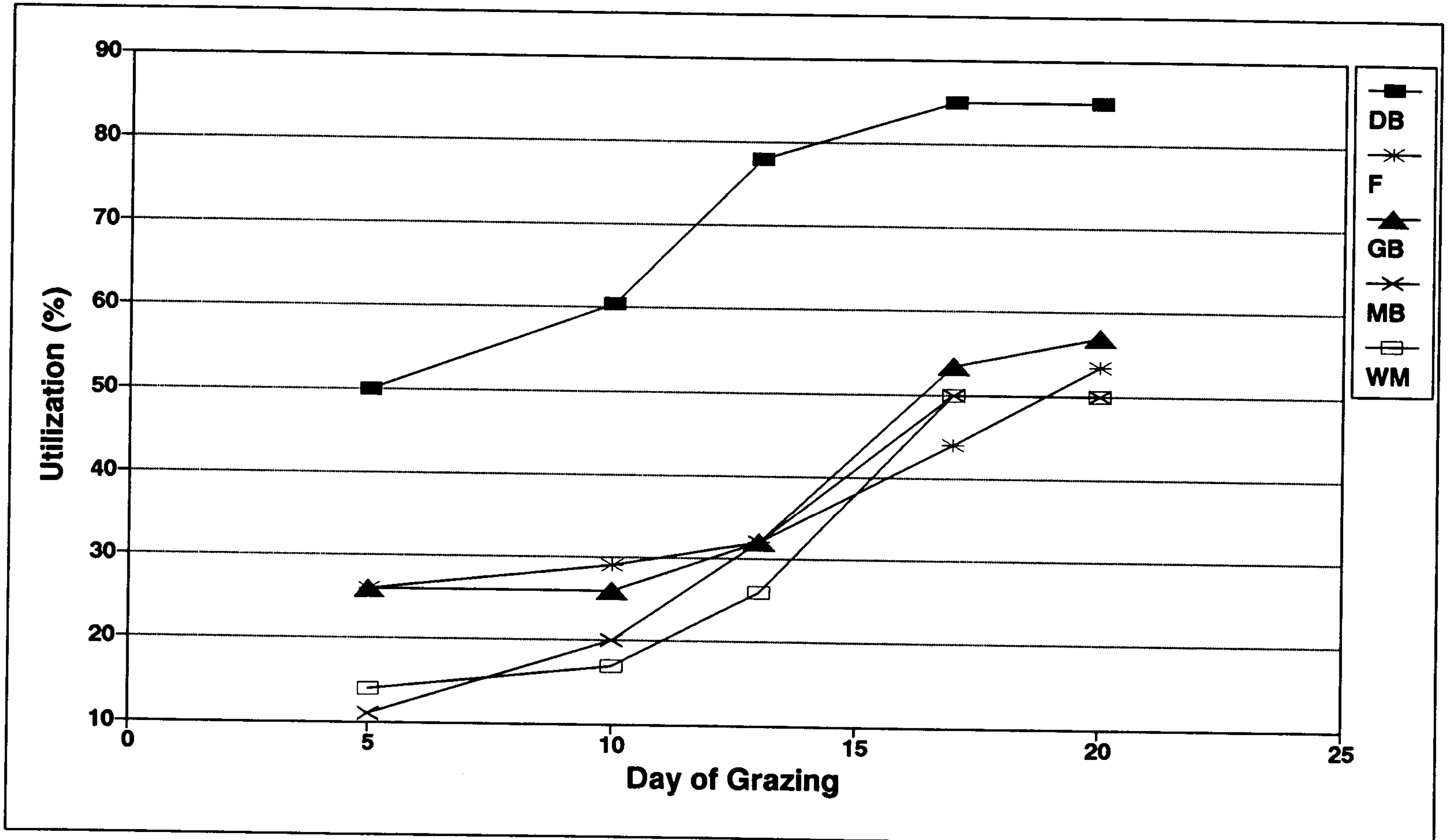


Figure 3.9. Trends in estimated utilization of the riparian zone community types in 1985. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows.

Table 3.3. Forage quality indices for five riparian zone community types located in northeastern Oregon.

COMMUNITY	YEAR 1984	YEAR 1985
DB[a]	2.29[b]	2.96
F	1.04	1.98
GB	1.29	1.98
MB	1.40	2.00
WM	1.00	2.00

[a] - Community designations as follows: DB - dry bluegrass meadows; F - forests; GB - gravel bars; MB - moist bluegrass meadows, and; WM - wet meadows.
[b] - Quality values are interpreted as follows: 1 - green vegetation; 2 - vegetation has a green tint, and; 3 - vegetation is dry and brown.

more rapid onset of forage maturity in 1985 than in 1984.

The nutritional content of forage samples and selected species from the different community types is shown in Tables 3.4 and 3.5. The tables indicate that for both years all community types were relatively high in fiber components as indicated by the relatively high neutral detergent fiber, acid detergent fiber and lignin levels along with the low cell content percentages. Digestibility and crude protein levels varied depending upon the species or forage class under consideration. As a consequence of 1985 being drier than 1984 the forage matured earlier and, as a result, the fiber contents of the vegetation sampled were generally higher in the second year of the study than in the first. In addition protein and digestibility levels were somewhat lower. With regard to specific community types, the dry bluegrass meadows generally had the highest digestibility and among the lowest crude protein levels for the forage available.

In both years the digestibility levels of the forage available as well as most species sampled were above recommended levels for grazing cattle. The NRC (1984) nutrient requirement guide indicated that mature cows in the second trimester of pregnancy require forage of approximately 52 percent digestibility (after converting metabolizable energy requirements to digestible energy requirements and thence to digestibility requirements using the equations developed by Rittenhouse et al. 1971) and seven percent crude protein content in order to meet their nutritional needs. The cattle grazing the study area were able to select diets containing adequate to marginal levels of both energy and crude protein (Korpela 1992). Digestibility levels were approximately 10 percent higher than forage available averages and crude protein levels were approximately 1.5 percent higher than generally available.

Trends in community preference for the six community types found within the study area are illustrated in Figures 3.10 and 3.11. In 1984 preference for dry bluegrass meadows and forests were highest early in the grazing period and declined thereafter. Preference for moist bluegrass meadows generally increased as the grazing period progressed. Preference for gravel bar and wet meadow community types generally started low, increased, and then declined.

Table 3.4. Nutritional content (%) of forage samples and selected species from within five plant community types found within a northeastern Oregon riparian zone for 1984.

Community	Class	Time	N	Crude Protein	Total Ash	ND Fiber	Cell Contents	AD Fiber	Lignin	Cellulose	HemiCellulose	Silica	IVDMD
DB [a]	FA [b]	E [c]	5	5.66 (0.20) [d]	10.24 (0.25)	69.39 (2.03)	30.61 (2.03)	43.98 (1.79)	7.11 (1.13)	29.80 (1.36)	25.41 (1.07)	7.07 (0.44)	55.70 (1.53)
DB	FA	L	5	7.80 (1.02)	10.50 (0.59)	74.69 (2.92)	25.31 (2.92)	44.37 (1.85)	6.40 (0.52)	30.87 (1.48)	30.32 (1.31)	7.09 (0.21)	56.50 (1.62)
DB	Popr	E	3	6.45 (0.38)	10.33 (0.18)	71.32 (2.62)	28.68 (2.62)	44.93 (2.06)	8.79 (0.55)	29.83 (2.06)	26.40 (0.57)	6.30 (0.50)	55.40 (2.03)
DB	Popr	L	3	7.33 (0.81)	10.54 (0.77)	69.35 (0.14)	30.65 (0.14)	44.30 (1.05)	8.00 (0.37)	28.48 (0.31)	25.05 (1.18)	7.83 (0.99)	55.27 (0.85)
F	FA	E	5	6.98 (0.16)	13.99 (2.70)	68.91 (1.13)	31.09 (1.13)	47.23 (0.29)	10.51 (0.65)	31.83 (0.80)	21.68 (1.13)	4.89 (0.49)	54.99 (0.83)
F	FA	L	5	8.15 (0.51)	10.61 (0.35)	69.87 (1.33)	30.13 (1.33)	44.05 (0.53)	8.53 (0.63)	30.56 (1.14)	25.83 (1.47)	4.95 (0.87)	54.40 (1.24)
F	Popr	E	3	6.51 (0.55)	10.59 (0.32)	73.12 (0.79)	26.88 (0.79)	46.19 (0.91)	8.83 (0.69)	31.11 (1.16)	26.93 (0.89)	6.26 (0.40)	55.16 (1.76)
F	Popr	L	3	6.70 (0.48)	11.08 (0.42)	71.71 (1.77)	28.29 (1.77)	47.05 (1.59)	8.71 (0.49)	31.30 (1.93)	24.65 (0.50)	7.04 (0.76)	51.77 (1.29)
F	Syal	E	3	7.75 (0.68)	8.67 (0.49)	43.80 (1.56)	56.20 (1.56)	31.38 (1.28)	12.10 (0.79)	18.81 (1.88)	12.42 (0.85)	0.47 (0.14)	56.64 (1.05)
F	Syal	L	3	7.73 (0.24)	7.20 (0.64)	44.08 (1.58)	55.92 (1.58)	33.94 (2.01)	14.70 (0.35)	18.55 (1.80)	10.14 (0.43)	0.69 (0.06)	57.53 (1.45)
GB	FA	E	5	7.88 (1.47)	12.31 (1.55)	62.12 (1.62)	37.88 (1.62)	42.12 (0.76)	7.97 (0.50)	28.70 (1.17)	20.00 (1.26)	5.45 (1.23)	47.68 (1.92)
GB	FA	L	5	7.84 (0.70)	14.13 (1.44)	68.17 (1.30)	31.83 (1.30)	45.65 (1.42)	10.84 (0.72)	26.91 (1.20)	22.52 (0.77)	7.90 (0.88)	52.34 (1.53)
GB	Forbs	E	3	10.54 (0.61)	12.80 (1.82)	50.13 (2.16)	49.87 (2.16)	38.12 (1.09)	10.03 (2.01)	24.96 (2.81)	12.02 (1.72)	3.12 (0.85)	56.84 (0.78)
GB	Forbs	L	3	8.76 (1.21)	10.88 (0.50)	48.87 (0.54)	51.13 (0.54)	38.13 (0.66)	15.01 (0.48)	20.22 (1.07)	10.73 (1.12)	2.91 (1.00)	56.38 (1.97)
GB	Grasses	E	3	8.46 (0.99)	13.60 (0.46)	68.28 (0.47)	31.72 (0.47)	43.92 (1.55)	6.73 (1.15)	29.60 (0.76)	24.36 (1.21)	7.60 (0.38)	53.04 (3.54)
GB	Grasses	L	3	4.09 (0.18)	10.61 (0.87)	73.16 (0.31)	26.84 (0.31)	48.73 (0.65)	9.25 (0.14)	32.80 (0.12)	24.43 (0.35)	6.69 (0.58)	53.30 (1.23)
GB	Salix sp.	E	3	10.05 (0.58)	5.50 (0.48)	46.76 (2.88)	53.24 (2.88)	39.47 (1.10)	12.85 (1.79)	26.52 (2.55)	7.29 (3.39)	0.10 (0.02)	41.99 (3.29)
GB	Salix sp.	L	3	9.12 (0.63)	6.15 (0.91)	43.03 (2.89)	56.97 (2.89)	35.54 (3.25)	12.77 (1.29)	22.60 (4.02)	7.49 (0.62)	0.18 (0.08)	43.90 (3.92)
MB	Carex sp.	E	3	6.85 (0.43)	8.92 (0.74)	70.66 (0.26)	29.34 (0.26)	39.90 (0.85)	6.52 (0.66)	29.77 (0.62)	30.77 (0.91)	3.60 (1.43)	52.11 (1.95)
MB	Carex sp.	L	3	5.68 (0.35)	8.86 (0.20)	72.94 (1.40)	27.06 (1.40)	43.34 (0.74)	8.03 (0.81)	29.93 (0.44)	29.60 (1.28)	5.38 (0.62)	55.11 (7.38)
MB	FA	E	5	6.62 (0.43)	9.72 (0.34)	69.42 (0.85)	30.58 (0.85)	46.47 (1.73)	9.81 (0.94)	31.99 (0.80)	22.95 (1.48)	4.67 (1.13)	48.93 (2.35)
MB	FA	L	5	6.11 (0.18)	10.36 (0.93)	70.79 (1.67)	29.21 (1.67)	45.94 (1.88)	10.30 (1.21)	30.56 (0.82)	24.85 (1.11)	5.08 (1.74)	50.39 (4.18)
MB	Pogr	E	3	7.12 (0.06)	7.56 (0.07)	41.13 (1.47)	58.87 (1.47)	32.67 (0.70)	9.87 (2.03)	22.40 (2.02)	8.46 (0.94)	0.40 (0.10)	38.15 (1.02)
MB	Pogr	L	3	5.81 (0.40)	7.29 (0.58)	47.73 (0.62)	52.27 (0.62)	38.09 (0.35)	11.76 (2.32)	25.59 (1.92)	9.65 (0.66)	0.74 (0.19)	42.57 (2.90)
MB	Popr	E	3	5.82 (0.39)	10.38 (0.73)	66.17 (2.21)	33.83 (2.21)	41.39 (0.46)	6.04 (0.69)	29.39 (0.99)	24.79 (1.96)	5.96 (0.04)	51.31 (0.70)
MB	Popr	L	3	5.48 (0.35)	11.03 (0.48)	71.01 (1.11)	28.99 (1.11)	45.11 (0.17)	7.41 (0.16)	29.14 (0.51)	25.90 (1.23)	8.57 (0.83)	57.13 (0.57)
WM	Carex sp.	E	3	6.19 (0.61)	10.95 (1.25)	72.87 (1.74)	27.13 (1.74)	43.11 (1.15)	6.78 (0.72)	30.30 (1.34)	29.76 (1.06)	6.03 (1.21)	47.64 (3.49)
WM	Carex sp.	L	3	5.47 (0.38)	9.42 (0.41)	72.02 (0.63)	27.98 (0.63)	43.11 (2.20)	9.42 (1.26)	27.81 (0.73)	28.92 (2.81)	5.88 (0.51)	39.43 (7.44)
WM	FA	E	5	6.48 (0.16)	9.37 (0.71)	75.38 (0.80)	24.62 (0.80)	44.33 (0.84)	7.59 (0.56)	32.98 (0.52)	31.05 (1.37)	3.76 (0.50)	38.60 (1.45)
WM	FA	L	5	6.19 (0.37)	10.92 (0.37)	76.02 (0.47)	23.98 (0.47)	47.04 (0.69)	7.66 (0.34)	32.63 (0.45)	28.99 (0.66)	6.75 (0.42)	41.76 (2.61)
WM	Scam	E	3	6.57 (0.47)	10.26 (0.50)	68.89 (0.96)	31.11 (0.96)	41.39 (1.60)	7.99 (2.64)	29.19 (0.24)	27.49 (0.91)	4.21 (0.84)	50.74 (4.36)
WM	Scam	L	3	7.56 (0.85)	12.16 (0.20)	69.98 (0.17)	30.02 (0.17)	42.43 (0.43)	7.58 (0.39)	28.61 (1.65)	27.55 (0.26)	6.23 (1.89)	58.53 (2.54)

[a] - Community designations as follows; DB - dry bluegrass meadows; F - forests; GB - gravel bars; MB - moist bluegrass meadows, and; WM - wet meadows.
[b] - Class represents species class while FA represents forage available. Species classes as follows; Popr - Kentucky bluegrass; Syal - common snowberry; Salix sp. - willow species; Carex sp. - sedge species; Pogr - northwest cinquefoil, and; Scam - panicled bulrush.
[c] - E and L indicate early and late in the grazing period respectively.
[d] - Number in parentheses represents the standard error of the mean.

Table 3.5. Nutritional content (%) of forage samples and selected species from within five plant community types found within a northeastern Oregon riparian zone for 1985.

Community	Class	Time	N	Crude Protein	Total Ash	ND Fiber	Cell Contents	AD Fiber	Lignin	Cellulose	HemiCellulose	Silica	IVDMD
DB [a]	FA [b]	E [c]	5	5.70 (0.31) [d]	8.72 (0.45)	73.61 (1.14)	26.39 (1.14)	46.42 (0.97)	5.77 (0.37)	35.14 (0.92)	27.19 (0.79)	5.50 (0.25)	49.21 (2.06)
DB	FA	M	5	5.71 (0.22)	9.86 (0.49)	70.28 (1.11)	29.72 (1.11)	46.82 (1.07)	8.20 (0.60)	32.41 (0.72)	23.46 (0.84)	6.21 (0.46)	43.09 (1.19)
DB	FA	L	5	6.86 (0.49)	9.89 (1.18)	75.28 (1.21)	24.72 (1.21)	49.29 (0.62)	9.49 (0.85)	33.41 (1.28)	25.99 (1.60)	6.39 (1.53)	36.73 (3.05)
DB	Popr	E	3	7.36 (0.50)	9.09 (0.44)	71.91 (0.54)	28.09 (0.54)	40.76 (0.67)	2.00 (1.43)	32.79 (1.27)	31.16 (1.21)	5.96 (0.50)	62.31 (6.04)
DB	Popr	L	3	5.62 (0.16)	9.62 (0.27)	76.59 (1.42)	23.41 (1.42)	46.74 (1.42)	5.55 (0.68)	35.89 (1.76)	29.85 (1.00)	5.29 (1.02)	46.21 (3.54)
F	FA	E	5	6.77 (0.11)	9.97 (0.35)	68.76 (2.78)	31.24 (2.78)	45.01 (0.82)	5.87 (1.16)	34.74 (1.61)	23.76 (2.02)	4.40 (0.27)	48.55 (1.54)
F	FA	M	5	7.31 (0.35)	10.60 (0.59)	67.63 (0.93)	32.37 (0.93)	41.84 (0.69)	6.22 (0.44)	30.99 (0.31)	25.80 (1.14)	4.63 (0.22)	39.81 (2.39)
F	FA	L	5	6.41 (0.54)	8.69 (0.78)	74.26 (2.14)	25.74 (2.14)	47.05 (1.58)	8.52 (0.97)	33.95 (0.56)	27.21 (2.40)	4.58 (0.47)	31.88 (1.18)
F	Popr	E	3	7.56 (0.57)	8.04 (0.13)	75.02 (2.07)	24.98 (2.07)	40.39 (1.85)	2.52 (0.79)	34.73 (0.96)	34.63 (0.24)	3.15 (0.76)	52.78 (3.89)
F	Popr	L	3	6.64 (0.18)	8.63 (0.22)	73.35 (0.68)	26.65 (0.68)	43.60 (0.20)	4.80 (0.66)	34.78 (1.46)	29.75 (0.82)	4.01 (0.87)	52.63 (1.09)
F	Syal	E	3	8.21 (0.46)	8.65 (0.74)	48.14 (0.79)	51.86 (0.79)	30.60 (1.24)	10.33 (0.32)	19.58 (1.33)	17.55 (0.52)	0.68 (0.14)	43.54 (1.02)
F	Syal	L	3	8.36 (0.27)	8.04 (0.17)	50.35 (0.73)	49.65 (0.73)	32.24 (0.76)	9.32 (0.79)	22.69 (1.03)	18.11 (0.61)	0.23 (0.11)	44.31 (0.11)
GB	FA	E	5	6.14 (0.52)	9.58 (0.51)	65.79 (0.92)	34.21 (0.92)	41.12 (0.64)	5.05 (0.70)	32.08 (0.97)	24.67 (0.38)	4.00 (0.61)	50.14 (0.74)
GB	FA	M	5	6.14 (0.84)	12.27 (1.72)	69.30 (1.41)	30.70 (1.41)	43.03 (1.08)	6.96 (0.51)	30.77 (0.93)	26.26 (0.82)	5.31 (0.56)	34.93 (3.36)
GB	FA	L	5	4.65 (0.43)	9.91 (0.42)	75.50 (1.63)	24.50 (1.63)	48.17 (1.46)	7.24 (0.62)	35.54 (1.52)	27.33 (1.86)	5.39 (1.22)	26.19 (1.61)
GB	Forbs	E	3	8.17 (0.09)	9.25 (0.56)	44.43 (0.50)	55.57 (0.50)	36.53 (0.58)	9.56 (0.69)	25.49 (0.97)	7.90 (0.46)	1.47 (0.25)	47.32 (3.03)
GB	Forbs	L	3	8.79 (0.62)	12.05 (0.32)	45.11 (2.50)	54.89 (2.50)	37.92 (2.72)	9.00 (0.86)	27.22 (2.89)	7.19 (0.38)	1.70 (0.72)	61.86 (1.35)
GB	Grasses	E	3	4.41 (0.36)	8.47 (0.46)	68.46 (0.77)	31.54 (0.77)	39.78 (1.90)	6.71 (0.79)	30.22 (1.38)	28.68 (1.16)	2.85 (0.94)	43.98 (1.06)
GB	Grasses	L	3	4.38 (0.50)	9.56 (1.22)	73.15 (1.82)	26.85 (1.82)	46.21 (1.32)	5.79 (0.54)	34.73 (2.31)	26.93 (0.72)	5.69 (0.60)	44.31 (4.38)
GB	Salix sp.	E	3	9.21 (0.80)	6.14 (0.06)	47.09 (0.46)	52.91 (0.46)	38.74 (0.52)	12.23 (0.37)	26.16 (0.27)	8.35 (0.14)	0.35 (0.11)	29.55 (1.26)
GB	Salix sp.	L	3	8.41 (0.18)	5.54 (0.55)	52.68 (2.48)	47.32 (2.48)	42.88 (2.78)	12.77 (0.83)	29.86 (2.32)	9.81 (0.73)	0.25 (0.02)	22.79 (1.16)
MB	Carex sp.	E	3	6.32 (0.31)	9.33 (0.41)	71.12 (0.78)	28.88 (0.78)	38.75 (1.32)	3.38 (1.09)	31.33 (1.05)	32.37 (0.99)	4.04 (0.39)	48.15 (2.40)
MB	Carex sp.	L	3	5.06 (0.23)	8.95 (0.52)	71.90 (0.50)	28.10 (0.50)	39.31 (0.48)	3.95 (0.67)	31.11 (1.03)	32.59 (0.09)	4.25 (0.63)	51.79 (5.63)
MB	FA	E	5	4.52 (0.25)	7.93 (0.30)	71.72 (1.55)	28.28 (1.55)	43.93 (0.73)	7.57 (0.38)	32.43 (0.74)	27.79 (1.00)	3.92 (0.42)	40.30 (1.18)
MB	FA	M	5	5.68 (0.16)	9.52 (0.38)	66.52 (0.60)	33.48 (0.60)	44.25 (1.61)	7.59 (0.63)	32.69 (0.83)	22.27 (1.30)	3.98 (0.68)	30.74 (1.61)
MB	FA	L	5	6.37 (0.30)	9.52 (0.36)	72.56 (1.05)	27.44 (1.05)	46.65 (1.15)	8.45 (0.98)	34.09 (0.57)	25.92 (1.97)	4.11 (0.75)	29.71 (2.32)
MB	Pogr	E	3	5.85 (0.08)	7.17 (0.22)	45.84 (0.99)	54.16 (0.99)	34.72 (0.75)	7.59 (0.47)	26.80 (0.55)	11.12 (0.25)	0.33 (0.06)	47.45 (0.84)
MB	Pogr	L	3	5.67 (0.24)	7.80 (0.07)	44.86 (2.04)	55.14 (2.04)	35.98 (1.11)	8.55 (0.42)	26.93 (1.50)	8.87 (1.18)	0.50 (0.11)	50.43 (0.70)
MB	Popr	E	3	5.59 (0.37)	8.82 (0.59)	66.71 (1.11)	33.29 (1.11)	37.58 (1.75)	4.00 (0.55)	29.65 (1.25)	29.14 (1.32)	3.92 (1.27)	57.93 (0.21)
MB	Popr	L	3	5.34 (0.71)	8.92 (0.14)	73.04 (0.50)	26.96 (0.50)	45.51 (0.28)	5.89 (0.05)	34.73 (0.60)	27.53 (0.37)	4.89 (0.35)	47.93 (1.53)
WM	Carex sp.	E	3	6.71 (0.46)	9.93 (0.65)	71.64 (2.14)	28.36 (2.14)	41.47 (1.63)	3.49 (0.89)	34.11 (1.56)	30.18 (0.53)	3.87 (0.21)	50.33 (2.15)
WM	Carex sp.	L	3	6.13 (0.20)	9.70 (0.17)	73.20 (1.01)	26.80 (1.01)	42.00 (1.14)	5.62 (0.59)	31.70 (1.05)	31.20 (1.47)	4.67 (1.07)	33.80 (4.70)
WM	FA	E	5	6.13 (0.27)	9.54 (0.53)	75.08 (1.06)	24.92 (1.06)	41.30 (1.01)	5.20 (0.12)	32.68 (0.51)	33.77 (1.87)	3.42 (1.10)	48.88 (2.75)
WM	FA	M	5	6.45 (0.29)	13.24 (2.31)	72.97 (1.19)	27.03 (1.19)	43.73 (0.97)	6.25 (0.37)	29.31 (1.44)	29.24 (1.78)	8.17 (2.03)	28.26 (1.66)
WM	FA	L	5	5.95 (0.71)	10.63 (0.93)	76.60 (0.70)	23.40 (0.70)	45.68 (0.66)	6.35 (0.54)	32.72 (0.73)	30.92 (0.65)	6.61 (0.70)	30.65 (3.98)
WM	Scam	E	3	6.76 (0.49)	9.56 (0.84)	68.62 (1.53)	31.38 (1.53)	37.33 (1.17)	4.20 (1.54)	28.60 (0.21)	31.29 (0.82)	4.53 (0.80)	45.21 (0.46)
WM	Scam	L	3	5.03 (0.14)	11.20 (0.44)	70.08 (1.62)	29.92 (1.62)	40.90 (0.44)	6.78 (0.85)	29.06 (0.65)	29.18 (1.29)	5.07 (0.98)	34.33 (2.48)

[a] - Community designations as follows: DB - dry bluegrass meadows; F - forests; GB - gravel bars; MB - moist bluegrass meadows, and; WM - wet meadows.
[b] - Class represents species class while FA represents forage available. Species classes as follows; Popr - Kentucky bluegrass; Syal - common snowberry; Salix sp. - willow species; Carex sp. - sedge species; Pogr - northwest cinquefoil, and; Scam - panicled bulrush.
[c] - E, M and L indicate early, midway through and late in the grazing period respectively.
[d] - Number in parentheses represents the standard error of the mean.

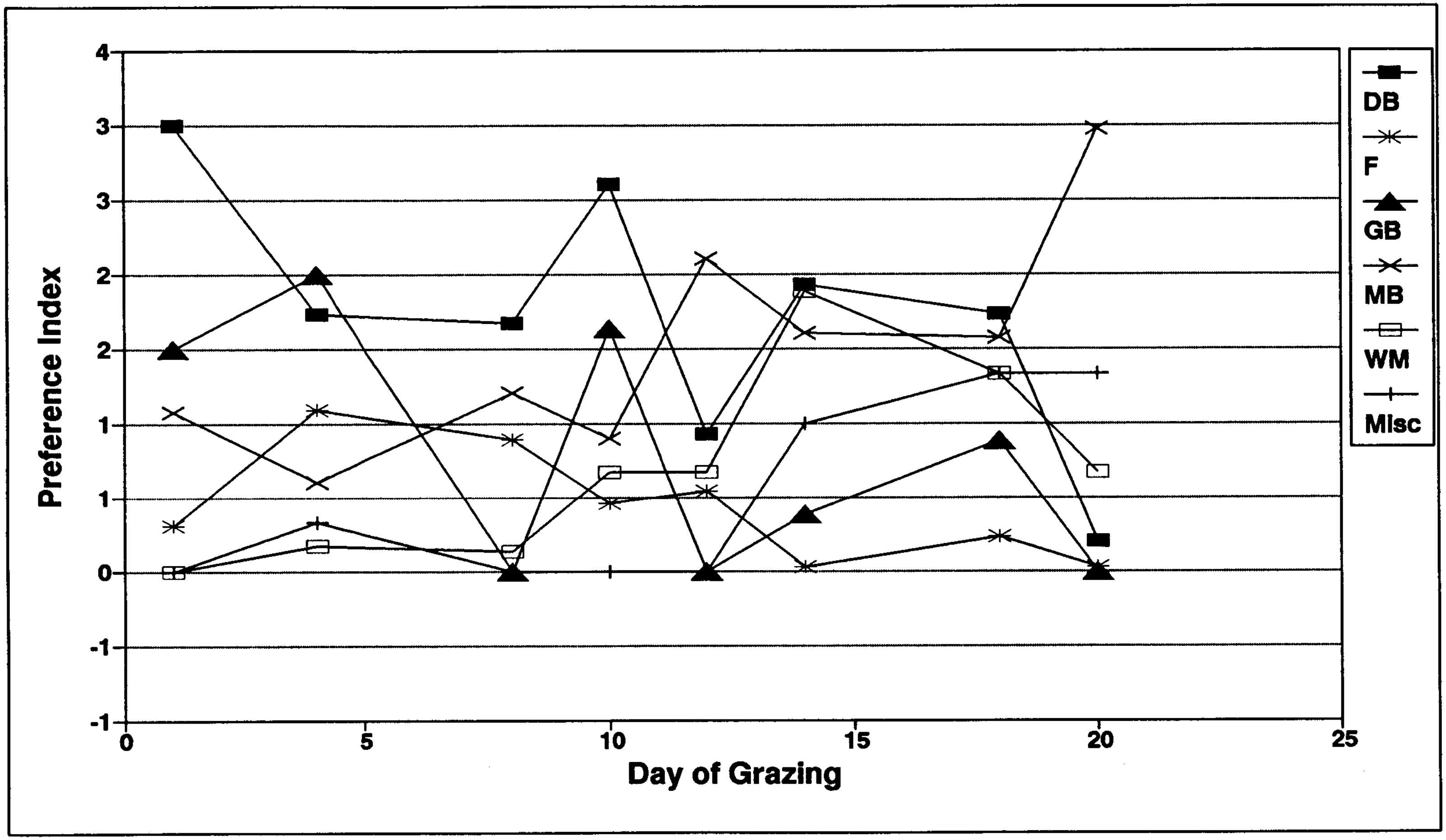


Figure 3.10. Trends in preference for the different riparian zone community types in 1984. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows.

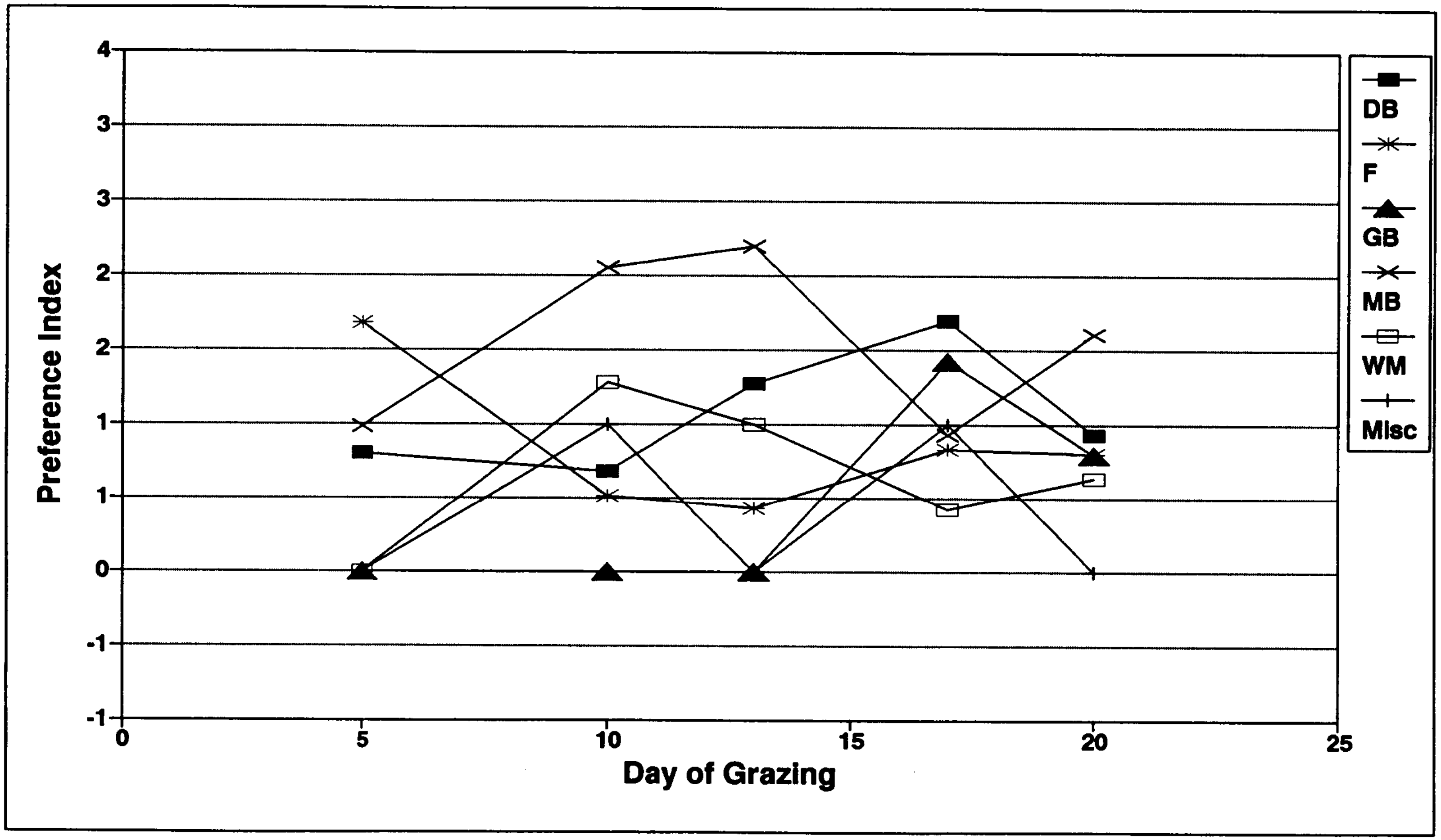


Figure 3.11. Trends in preference for the different riparian zone community types in 1985. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows.

The pattern in community preference for 1985 was similar to that for 1984 but more variable. Preference for dry bluegrass meadows and gravel bars increased from day five to about day 17, then declined. Trends for wet meadows and moist bluegrass meadows were similar, increasing until about day 13 and then declining. Preference for the forests generally declined from day five on. Clear trends may have been obscured, since sampling for community preference could not begin until day five, too late for observation of initial community preferences. However the data illustrated in Figure 3.9 as well as that in Table 3.1 indicated that utilization of the dry bluegrass meadows was very rapid since, by day five they had already received 50 percent use (Figure 3.9) and midway through the grazing period had received 70 percent use (Table 3.1). In addition, vegetation height in the dry bluegrass meadows was reduced to one-fourth its original height by the middle of the grazing period (Table 3.2). The other community types had received less than 30 percent utilization by day five. Thus it appeared that preference for the dry bluegrass meadows was probably very high initially and fell to a low by day five.

Path Analysis

Results of the correlation analysis for the environmental variables and the response variable community preference are shown in Table 3.6. When the early and late grazing periods were combined, the preference index was best correlated with TOTBIOM, SPPCOMP and SPPREF, the three variables which describe the amount and composition of the forage available for grazing. In addition, the preference index was well correlated with the index expressing community availability. The index was, however, poorly correlated with the nutritional parameters lignin and/or digestibility. The correlation analysis for the early data indicated that the preference index was not only well correlated with the parameters describing forage available, but was also positively correlated with digestibility. The late data correlations indicated that preference was correlated best with the community availability index only, suggesting that cattle graze communities in proportion to their abundance in the pasture.

Table 3.6. Simple correlations among the environmental variables and the response variable community preference early, mid-way through and late in the grazing period.

	COMMNDX[a]	TOTBIOM	LIGNIN	IVDMD	SPPCOMP	COMMUSE	SPPREF
Combined data							
TOTBIOM	-0.16						
LIGNIN	0.67	-0.45					
IVDMD	0.06	-0.2	-0.14				
SPPCOMP	-0.37	0.76	-0.46	-0.6			
COMMUSE	0.05	-0.7	0.37	-0.47	-0.14		
SPPREF	-0.44	0.65	-0.51	-0.59	0.96	-0.05	
PREFNDX	0.49	-0.53	0.24	0.36	-0.59	0.22	-0.45
Early							
TOTBIOM	-0.14						
LIGNIN	0.77	-0.25					
IVDMD	0.03	-0.94	0.12				
SPPCOMP	-0.38	0.94	-0.34	-0.82			
COMMUSE	0.07	-0.63	0.23	0.83	-0.47		
SPPREF	-0.46	0.92	-0.42	-0.78	0.99	-0.42	
PREFNDX	0.36	-0.9	0.2	0.88	-0.95	0.6	-0.93
Late							
TOTBIOM	-0.25						
LIGNIN	0.64	-0.47					
IVDMD	0.17	-0.93	0.16				
SPPCOMP	-0.35	0.94	-0.73	-0.75			
COMMUSE	0.21	-0.82	0.17	0.89	-0.67		
SPPREF	-0.46	0.9	-0.81	-0.7	0.99	-0.63	
PREFNDX	0.74	0.0	0.28	0.03	-0.04	0.36	-0.13

[a] - Acronyms as follows: COMMNDX - community availability index; TOTBIOM - total forage biomass; LIGNIN - lignin content; IVDMD - *in vitro* dry matter digestibility; SPPCOMP - species composition; COMMUSE - the level of utilization which has occurred to that point in time, and; SPPREF - relative biomass of preferred species for grazing.

The results of the path analysis for the combined data are illustrated in Figure 3.12. Cattle selected communities for grazing which were negatively related to total biomass and positively related to digestibility. The negative relationship between total biomass and community preference may have been the result of the least productive community type being composed primarily of the relatively nutritious Kentucky bluegrass (Tables 3.4 and 3.5) which the cattle preferred to graze. The level of utilization had very little effect, as the path coefficient for it was very close to zero while the community availability index had the greatest positive effect since this pathway had the largest path coefficient (Figure 3.12). The indirect pathways for the utilization index did, however, indicate that utilization had an indirect effect more than twice the size of its direct effect. The pathway from utilization through total biomass to the preference index (Figure 3.12) was positive, indicating that utilization reduced total biomass which was attractive to grazing cattle as they preferred communities which were low or had been reduced in biomass. However, their preference for those communities could only last as long as there was a grazeable quantity of desirable forge still remaining in the community. The pathway from utilization through digestibility (Figure 3.12) was negative, indicating that utilization had a negative impact upon community preference, as utilization resulted in less digestible forage remaining after grazing and hence had a negative influence upon preference. Another important point suggested by the diagrams was that livestock do not see nutrient content while grazing but perhaps do see forage and the relative availability of different community types. This was indicated by the fact that the magnitude of the coefficients from total biomass and community index were greater than that from digestibility to preference. The explanatory ability of the model was only 50 percent, indicating that livestock preferences either are influenced by a host of other factors or that combined data represent two different scenarios, the combination of which results in a low value for r-square.

Figures 3.13 through 3.15 represent path diagrams describing the relationships between community preference and the environmental variables during the early portion of the grazing period. A consistent trend was

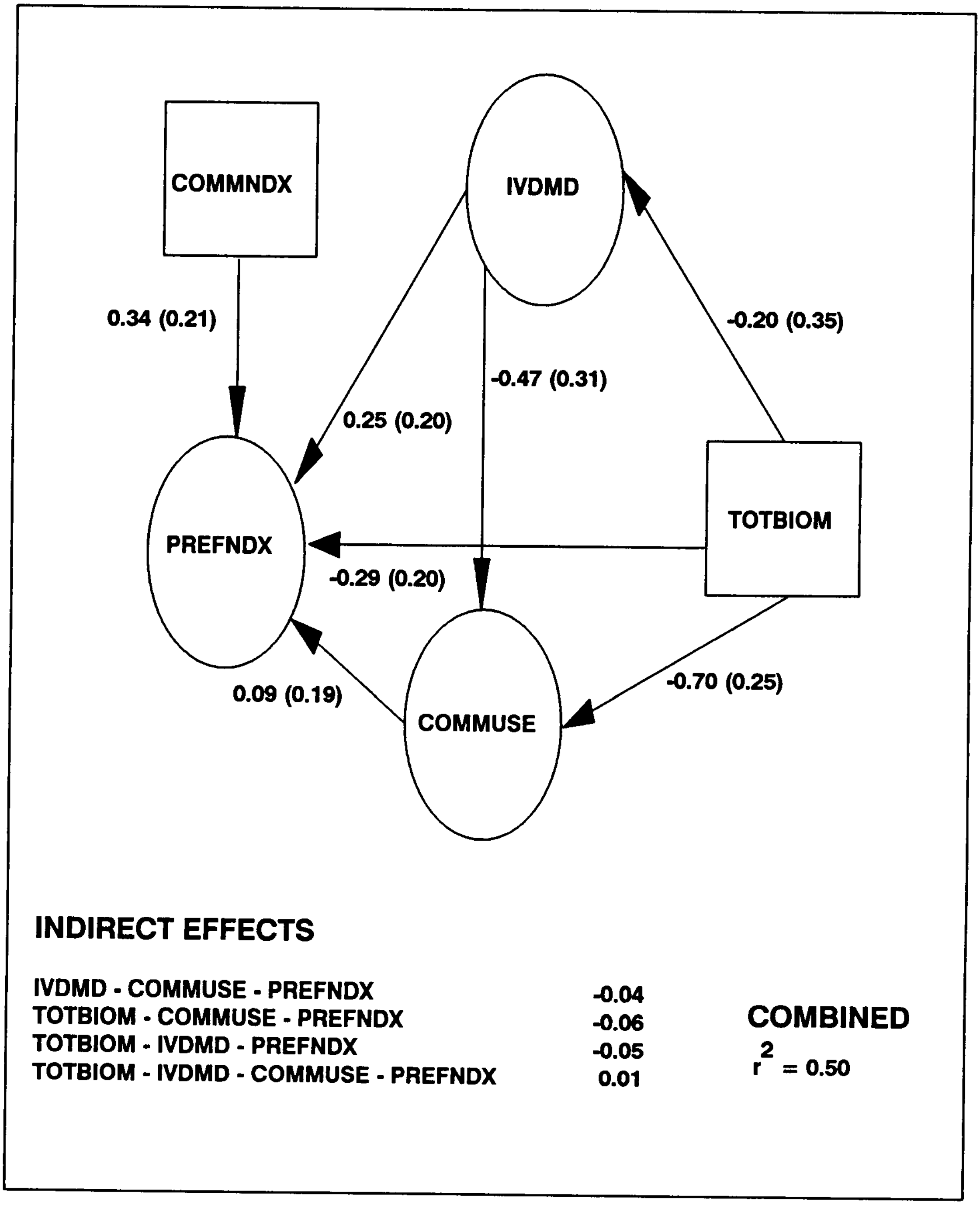
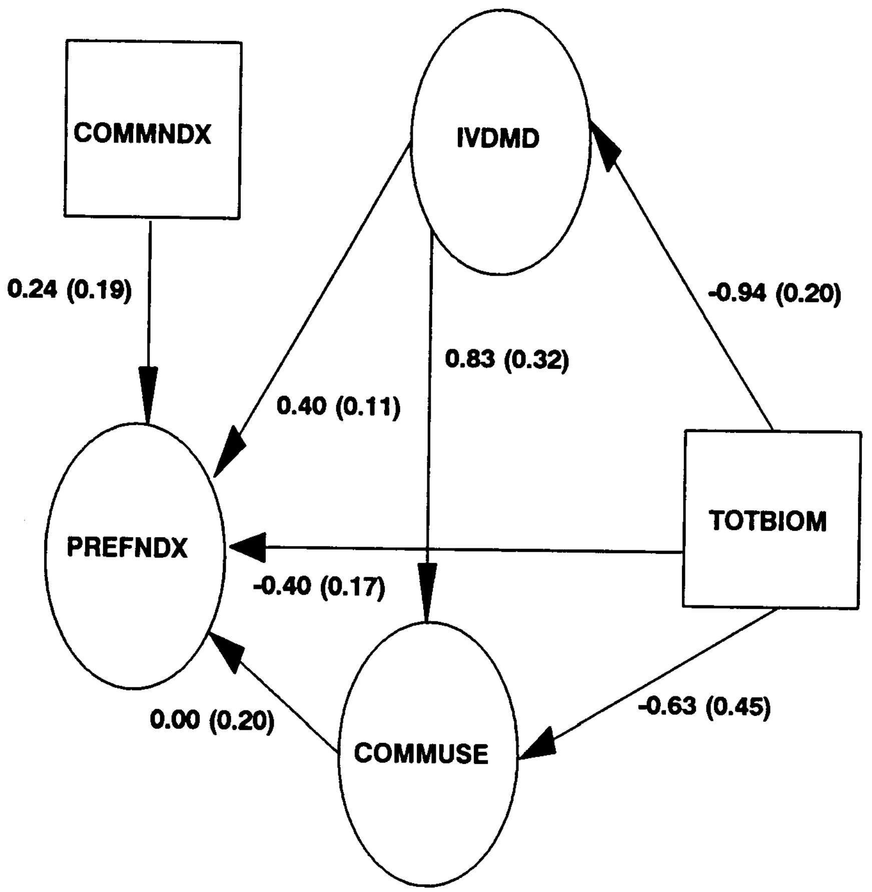


Figure 3.12. Path diagram for the combined data describing community preference (PREFNDX) as a function of a community index (COMMNDX), community utilization (COMMUSE), digestibility (IVDMD), and total biomass (TOTBIOM). Numbers in parentheses indicate the approximate standard errors of the coefficients.



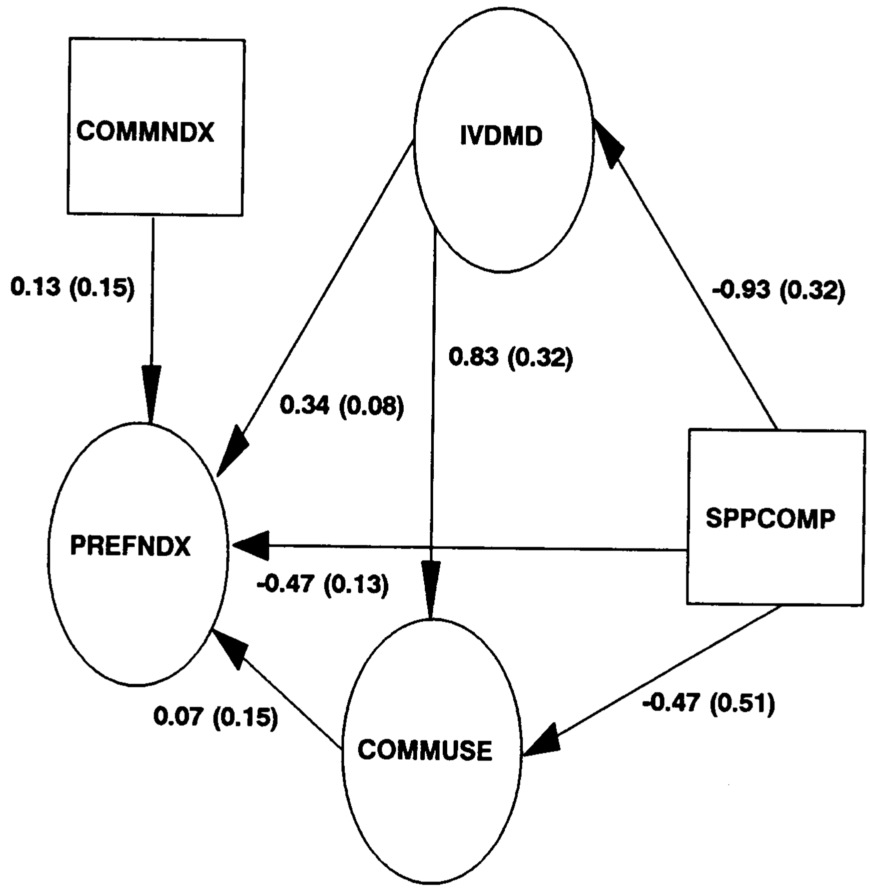
INDIRECT EFFECTS

IVDMD - COMMUSE - PREFNDX	0.00
TOTBIOM - COMMUSE - PREFNDX	0.00
TOTBIOM - IVDMD - PREFNDX	-0.38
TOTBIOM - IVDMD - COMMUSE - PREFNDX	0.00

EARLY

$r^2 = 0.88$

Figure 3.13. Path diagram for the early data describing community preference (PREFNDX) as a function of a community index (COMMNDX), community utilization (COMMUSE), digestibility (IVDMD), and total biomass (TOTBIOM). Numbers in parentheses indicate the approximate standard errors of the coefficients.



INDIRECT EFFECTS

IVDMD - COMMUSE - PREFNDX	0.06
SPPCOMP - COMMUSE - PREFNDX	0.03
SPPCOMP - IVDMD - PREFNDX	-0.28
SPPCOMP - IVDMD - COMMUSE - PREFNDX	-0.05

EARLY

$r^2 = 0.93$

Figure 3.14. Path diagram for the early data describing community preference (PREFNDX) as a function of a community index (COMMNDX), community utilization (COMMUSE), digestibility (IVDMD), and species composition (SPPCOMP). Numbers in parentheses indicate the approximate standard errors of the coefficients.

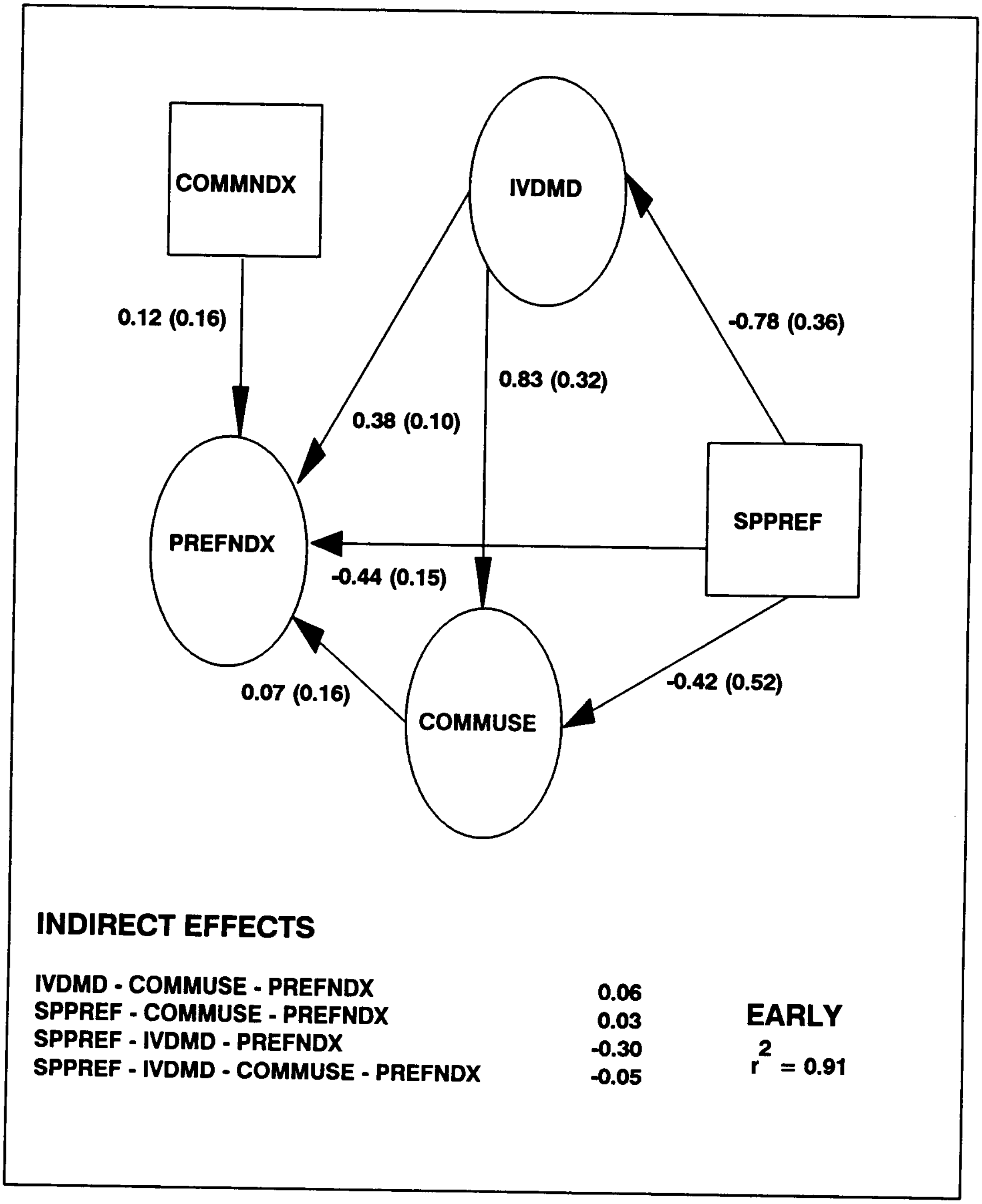


Figure 3.15. Path diagram for the early data describing community preference (PREFNDX) as a function of a community index (COMMNDX), community utilization (COMMUSE), digestibility (IVDMD), and the ratio of undesirable to desirable species (SPPREF). Numbers in parentheses indicate the approximate standard errors of the coefficients.

illustrated in all the diagrams. Grazing cattle selected communities which were high in digestibility. Cattle also selected communities which were low in biomass or had low values for the species composition or preferred species indices for the same reasons as indicated above. Thus cattle were selecting communities either low in sedges and/or shrubs or communities high in Kentucky bluegrass. In terms of a direct path, the level of utilization which occurred was unimportant; however, the indirect effects through digestibility and the variable representing forage available for grazing (i.e. TOTBIOM, SPPCOMP or SPPREF) were significant. The importance of the community availability index was less than it was in the case of the combined data. The explanatory ability of the model was generally very high with r-squares ranging from 88 to 96 percent.

The results of the path analysis for the latter part of the grazing period are illustrated in Figure 3.16. In comparison to the analyses representing the combined and early data, the analysis of the late data illustrated some marked differences from the other data sets. The magnitude of the path coefficient representing community availability was greatly increased, indicating that cattle were grazing the more commonly available community types. The coefficient from total biomass to preference index was large and positive indicating that cattle were grazing communities with more available forage. The amount of utilization a community had received became a significant variable explaining community preference. Since the magnitude and sign of this coefficient was large and positive, it indicated that cattle still preferred communities which had been grazed. Thus the cattle preferred to graze relatively abundant community types with adequate quantities of forage which had been grazed before. The importance of digestibility in the path model was greatly reduced over the early or combined data. Given the concept that grazing animals, including cattle, select forage based upon maximizing energy content, it was puzzling as to why the cattle appeared to deviate from this to selecting forage lower in digestibility. Possible reasons for this may include: inadequate sampling; behavioral characteristics of the cattle; the use of high quality forages, by this time fairly scarce in the pasture, as a supplement; or the cattle may have changed scales in terms of their foraging. In other words, the cattle may

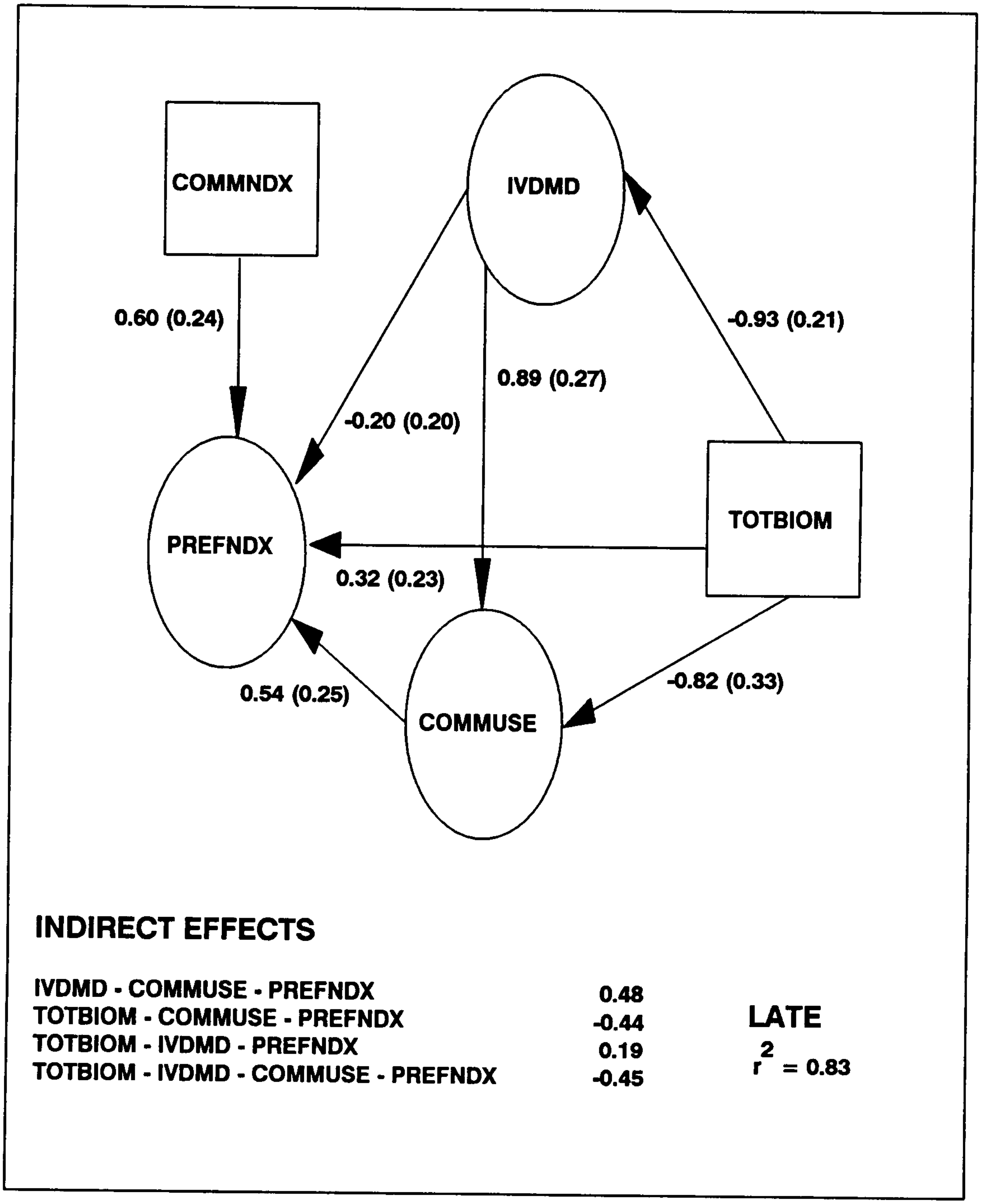


Figure 3.16. Path diagram for the late data describing community preference (PREFNDX) as a function of a community index (COMMNDX), community utilization (COMMUSE), digestibility (IVDMD), and total biomass (TOTBIOM). Numbers in parentheses indicate the approximate standard errors of the coefficients.

not have been selecting grazing areas on the basis of community type but rather on the basis of smaller patch types as described by Senft et al. (1987). The explanatory ability of the model was still fairly high as r-square was 83 percent.

Conclusion

The primary conclusions which can be drawn from the results of this study concern both the functioning of the grazing process and the data analysis technique. With regard to the grazing process it appeared that livestock initially selected communities for grazing based upon maximizing the energy content of their diet. Later in the grazing period, after the more nutritious forage had been grazed, it appeared that cattle were less selective about the forage they grazed or that they were operating upon a different scale than researchers usually perceive (i.e. patch versus community scales).

With regard to the path analysis technique a number of important conclusions can be drawn. First, the results obtained are largely a function of the model assumed. That is to say that it is possible that other variables (e.g. behavior, social parameters, etc.) played a greater role in the ecological process under investigation than those measured. Second, the interpretation of the results of path analysis on combined data must be analyzed with care, or one may be misled, as in the case of the early versus late data sets, which suggested that different mechanisms may be at work during the latter part of the grazing period. In any case, one of the values of the path analysis technique lies in the active involvement of the researcher in utilizing theory to describe the data during the analysis procedure. This provides a logical follow-up to the common practice of interpreting axes derived from the use of many ordination programs as principal components or discriminant analysis. A second value to the technique lies in its ability to provide the researcher with a means of quantifying the indirect effects of independent upon dependent variables thus providing a fuller description of the ecological process under study. A final point to keep in mind concerning the use of path analysis was well put by Hermy (1987) when he indicated that path analysis is not intented to prove causation but rather to estimate the degree of assumed causation.

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CHAPTER 4

LINEAR MODELING OF INTAKE BY CATTLE GRAZING

A

NORTHEASTERN OREGON RIPARIAN ZONE

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Abstract

Intake of livestock grazing a northeastern Oregon riparian zone was monitored in terms of both quantity and quality and related to vegetation community characteristics of the riparian zone immediately prior to and during the grazing period. Average intake levels were greater during the first year of the study than the second (2.15 versus 1.81 percent of body weight). In both years daily grazing time declined as livestock neared the end of the grazing period.

Correlation and path analysis relating intake to livestock and vegetation community characteristics indicated that intake was well correlated with *in vitro* dry matter digestibility and the amount of time spent grazing, but poorly related to the amount of forage available. The indirect effect of the amount of forage available on intake was greater than the direct effect and functioned through increases in grazing time as a result of increased availability of highly digestible forage.

Introduction

Grazing herbivores are continually faced with food resources which are changing in terms of both quality and quantity. In order to meet their nutritional requirements for maintenance and growth these animals must consume adequate quantities of forage of sufficient quality.

Riparian zones provide an important forage source for livestock grazing rangelands in the western United States (Roath and Krueger 1982). In addition to livestock, riparian zones are important to the maintenance of wildlife populations (Kauffman 1982), fisheries resources (Marcuson 1977), water quality (Skinner et al. 1974) and recreation. In order to alleviate potential conflicts between livestock grazing and these other riparian values, grazing systems have been proposed which attempt to minimize livestock impacts upon the riparian zone while including the riparian zone as part of the livestock forage base. One of the systems proposed involves managing the riparian zone as a special use pasture grazed during the latter part of the grazing season (Kauffman 1982).

Studies of livestock response to grazing systems have generally been conducted in either improved pasture or upland situations and have resulted in a basic understanding of the factors which influence intake by livestock grazing rangelands. Variables identified as influencing intake by grazing livestock include such animal parameters as breed, stage of production and energy status plus environmental factors including climate, forage availability and forage quality (Arnold and Dudzinski 1978).

However, the applicability and implications of this body of knowledge to animals grazing the riparian setting is not well understood. Thus the purpose of this study was twofold: 1) To monitor trends in intake by grazing livestock and environmental parameters influencing intake for different plant communities in a northeastern Oregon riparian zone, and 2) to describe the relationships between environmental parameters and intake through the use of a path model.

Study Area

The study area was located in the southwestern foothills of the Wallowa mountains on the Hall ranch unit of the Eastern Oregon Agricultural Research Center (EOARC), approximately 19.3 kilometers southeast of Union, Oregon (Figure 4.1). The study area consisted of a long narrow pasture, approximately 41 hectares in size, located in a valley bottom along Catherine Creek.

The majority of the precipitation on the study area occurs as snow between the months of November and May. Figure 4.2 illustrates monthly trends in precipitation and temperature during the course of the study. EOARC records for two weather stations near the study area indicate that average annual precipitation in the area is about 610 millimeters. Temperatures in the area may range from below freezing to in excess of 38 degrees C. Elevation of the study area averages about 1050 meters. Soils on the area have been mapped as belonging to the veasie-voats soil complex (USDA 1985). The veasie series is classified as a coarse-loamy over sandy or sandy-skeletal, mixed, mesic cumulic haploxeroll, while the voats series is classified as a sandy-skeletal, mixed, mesic pachic haploxeroll. However Kauffman (1982) indicates that, due to the variable nature of soils within the riparian zone, many of the soils which occur on the study area do not fit either of these soil series descriptions.

Catherine Creek is a third order tributary of the Grande Ronde River, which eventually drains into the Columbia river system. Figure 4.3 illustrates monthly trends in stream discharge. The average annual discharge of Catherine Creek is 106 hm^3/yr or 3.37 m^3/s (USGS 1984, USGS 1985). Peak flows occur during the months of April, May and June depending upon upstream snowmelt conditions.

The vegetation in the study area consists of a complex array of plant types and communities. In mapping the vegetation within a 50 meter strip on each side of the stream, Kauffman (1982) identified 60 distinct plant communities. The communities ranged from meadow communities dominated by Kentucky bluegrass (*Poa pratensis*), cheatgrass (*Bromus*

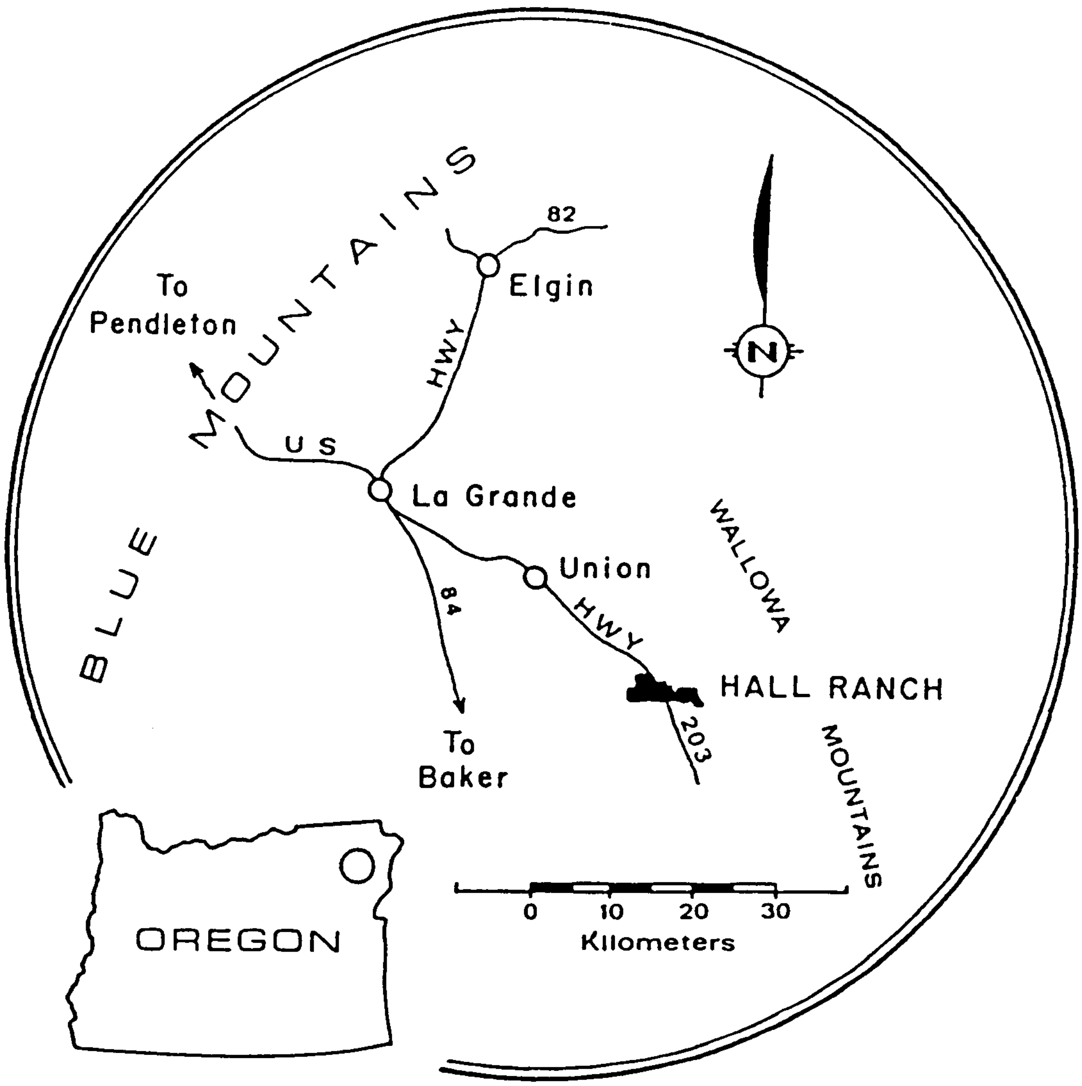

Figure 4.1. Location of the study area in northeastern Oregon.

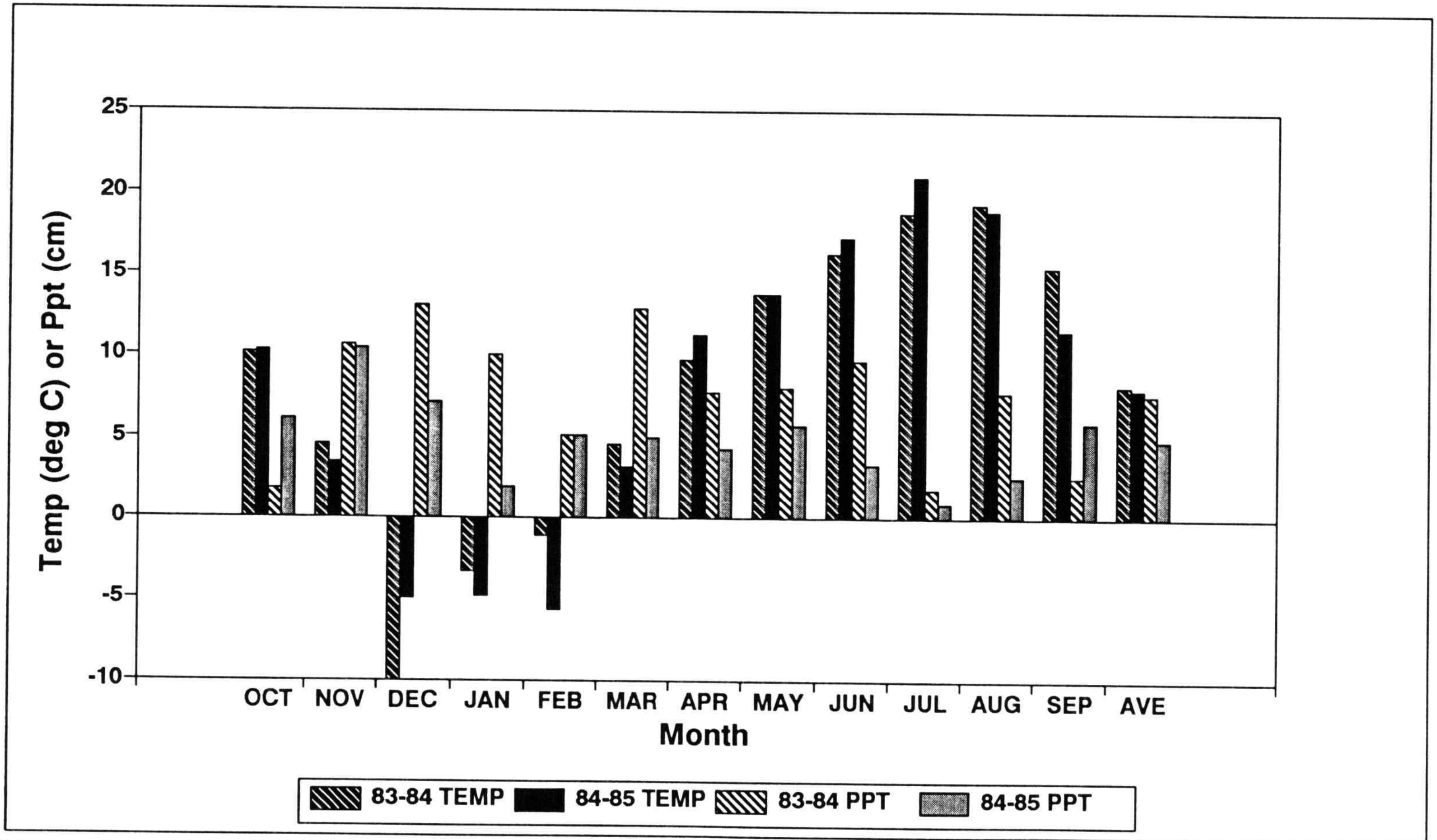

Figure 4.2. Monthly trends in temperature and precipitation from two Hall ranch weather stations over the duration of the study.

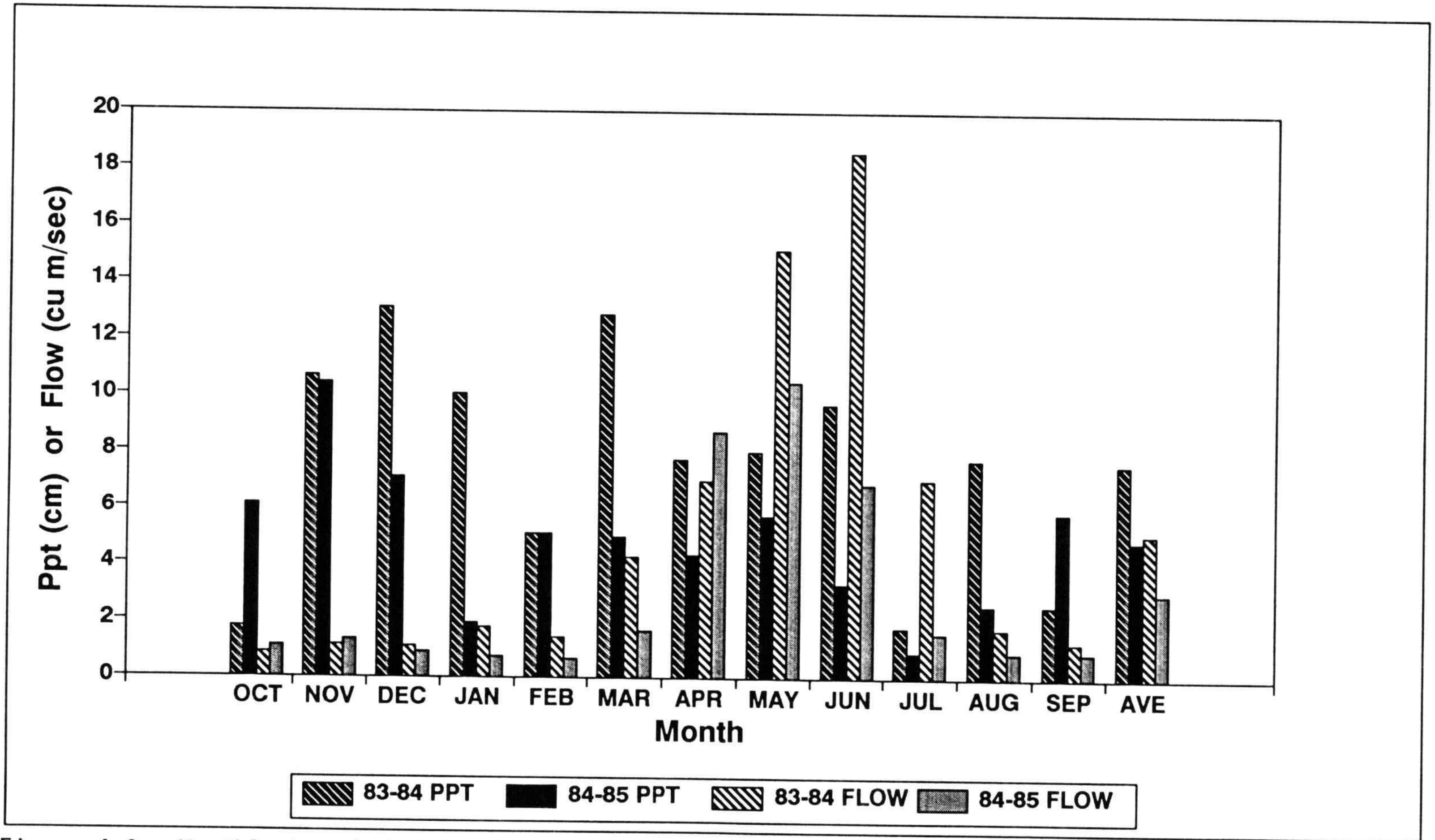

Figure 4.3. Monthly trends in precipitation and streamflow for Catherine Creek during the course of the study.

tectorum) or sedges (*Carex* spp.) to tree-dominated communities containing ponderosa pine (*Pinus ponderosa*), grand fir (*Abies grandis*) or black cottonwood (*Populus trichocarpa*). Both low shrub communities dominated by snowberry (*Symphoricarpos albus*) or wood rose (*Rosa woodsii*) and tall shrub communities dominated by thin leaf alder (*Alnus incana*) or black hawthorne (*Crataegus douglasii*) occur within the study area.

Management of the riparian zone as a special use pasture has been described by Kauffman (1982). This management strategy essentially consists of grazing the riparian zone late in the season, thus minimizing livestock impacts upon riparian vegetation and wildlife. Grazing by livestock within the study area usually begins in late August, after the forage supply in the uplands has been utilized, and continues for about three weeks until mid-September. About 80 Hereford-Simmental cross cow/spring- calf pairs graze the study area at a stocking rate of about 1.7 animal unit months per hectare. Water for the livestock is provided by Catherine Creek and salt is supplied *ad libitum* at two points within the pasture. No efforts are made to influence the distribution and utilization patterns of the livestock within the study area. The livestock are moved to another pasture after the Kentucky bluegrass meadows within the study area have attained about 65 percent utilization.

Materials and Methods

This study was based upon the description of relationships among vegetative, environmental and grazing animal parameters during the grazing seasons of 1984 and 1985. The following sections describe the methods used in gathering data, as well as the statistical analyses used for each objective.

Plant Community Designation

Since this study was conducted on a plant community basis, the pasture was mapped by community type. Vegetation communities were mapped in accordance with the procedures outlined by Kauffman (1982). Aerial photographs were used to delineate and determine the areal extent of the vegetation types. Initial reconnaissance of the study area indicated that seven plant community types could be identified and mapped. These seven plant communities, the first five of which were sampled intensively, consisted of the following:

1. Gravel bar communities dominated by willows (*Salix* spp.) and cottonwoods.
2. Wet meadows dominated by rushes (*Juncus* spp.) and sedges.
3. Moist bluegrass meadows dominated by Kentucky bluegrass and forbs with a sedge component.
4. Dry bluegrass meadows dominated by Kentucky bluegrass.
5. Mixed coniferous forests dominated by ponderosa pine and grand fir.
6. Tall shrub communities dominated by black hawthorne.
7. Miscellaneous disturbance communities dominated by cheatgrass including old gravel bars not within the banks of Catherine Creek.

Field Sampling

The development of a model describing intake by grazing livestock entailed the monitoring of several potential predictor variables. Four potential predictor variables were selected for monitoring during the course of this study. These included the following plant community characteristics:

1. Forage production.
2. Vegetation utilization (herbaceous and shrub).
3. Forage and diet nutritional quality.
4. Grazing time.

Forage production by community type was measured using the method described by Kauffman (1982) in which 30, randomly located, 0.25 m^2 plots were clipped to ground level in each of the five communities. Production from each plot was separated into the following forage classes; Kentucky bluegrass, false-gold groundsel (*Senecio pseudareus*), grasses, forbs, rushes and sedges. Thus forage class composition, by weight, was determined from the production clipping which occured approximately one week before the cattle were allowed to graze the study area. Shrub production was determined by clipping a portion, about 12.5 percent of the shrub biomass, in 15 one meter square plots in the forest and gravel bar communities. Each shrub occurring within the meter square plot was mentally divided into eighths along a horizontal circle with the mainstem of the shrub at the center, and one of these sections was randomly selected for clipping. Thus not all current annual growth was removed from each shrub.

Community forage utilization was estimated in two ways. First, utilization estimates were obtained by clipping 20 0.25 m^2 plots in each of the five community types midway through and at the end of each grazing period. Total biomass obtained from these plots was then expressed as a percentage of pregrazing biomass. Second, in order to assess community conditions every three to five days during the grazing period, the utilization scale described by Low et. al. (1981) was used. This scale describes forage quantity in four categories as follows: ungrazed (1 - less than 10% utilization), abundant (2 - 11% to 30% utilization), moderate (3 - 31% to 70% utilization) and sparse (4 - greater than 70% utilization). Shrub utilization was estimated through occular estimates of shrub use before and after grazing in 15 one meter square plots and expressed as a percentage of pregrazing shrub biomass.

Nutritional quality of the vegetation available for grazing was also monitored during the grazing period. All the vegetation occurring within five randomly located 0.25 m^2 plots was clipped in each community type at the beginning, midway through, and at the end of the grazing period. In addition, three shrub samples were obtained at the beginning and at the end of the grazing period from the gravel bar and forest communities. Snowberry samples from the forests and willow samples from the gravel bars were obtained by randomly selecting and clipping approximately 20 grams of current annual growth from the selected shrubs for nutritional analysis.

Nutritional quality of the diets of livestock grazing the study area were determined using four esophageally fistulated cows (Holechek 1980). Animals were penned the night prior to esophageal collection, and the following morning led to a community to be sampled and allowed to graze until sufficient sample for nutritional analysis was obtained. The animals were kept within the appropriate community type through the use of lead ropes approximately 12 meters long. Each cow sampled two communities per day for one week prior to and during the first week of the grazing period as well as doing the same during the last week of the grazing period and the week after the cattle had left the pasture. In this way, approximately sixteen diet samples from each of the five community types were obtained at the beginning and at the end of the of the grazing period.

The diet, forage and shrub samples were dried at 40 degrees C, then ground through a two millimeter mesh screen using a wiley mill, and analyzed for nutritional quality. Samples were analyzed for several chemical components, including dry matter content, *in vitro* dry matter digestibility (IVDMD), neutral detergent fiber, acid detergent fiber, potassium permanganate lignin, silica, total ash and crude protein. Procedures used for dry matter content, total ash and Kjeldahl crude protein have been described by Harris (1970). Analysis techniques used for neutral detergent fiber, acid detergent fiber, cellulose, potassium permanganate lignin and silica have been described by Waldern (1971). *In vitro* dry matter digestibility was determined following a modification of the Tilley and Terry (1963) technique described by Holechek et al. (1982). Cell contents were determined as one hundred minus neutral detergent fiber content. Hemi-cellulose content was estimated by subtracting acid detergent fiber from neutral detergent fiber. Van Soest and Robertson (1980) have discussed the implications of determining hemi-cellulose in this fashion. They indicate that a sample's biogenic silica, pectin and tannin content reduces the estimate of hemi-cellulose while the cell wall protein content increases the hemi-cellulose estimate. Thus the errors are somewhat compensating and provide a reasonable index as to the hemi-cellulose content of a sample.

Grazing time was determined through the use of vibracorders in a manner similar to that described by Stobbs (1970). Four mature cows were fitted with vibracorders which they wore during the entire grazing period. In order to contrast daily grazing time early and late during the grazing period, daily grazing times were averaged over the first and last weeks of the grazing period.

The dependent variable, cattle intake, was determined in the manner described by Holechek (1980). Four steers were outfitted for complete fecal collections over a period of four days at the beginning and at the end of the grazing period, thus resulting in approximately 16 estimates of intake at the beginning and at the end of the grazing period.

Liveweight gain of the cattle grazing the study area as well as those grazing nearby associated uplands was determined through the use of shrunk (24 hour) weights at the beginning and at the end of the grazing period.

Path Analysis

Data from both periods, early and late, for both years were combined and analyzed using correlation and path analysis. This technique consists of developing an *a priori* structural model (path diagram) describing the relationships among a system of dependent and independent variables (Figure 4.4). The technique assumes that the causal structure among the variables is known and that the system is causally closed. The method also assumes that the data meet the following requirements usually associated with regression analysis:

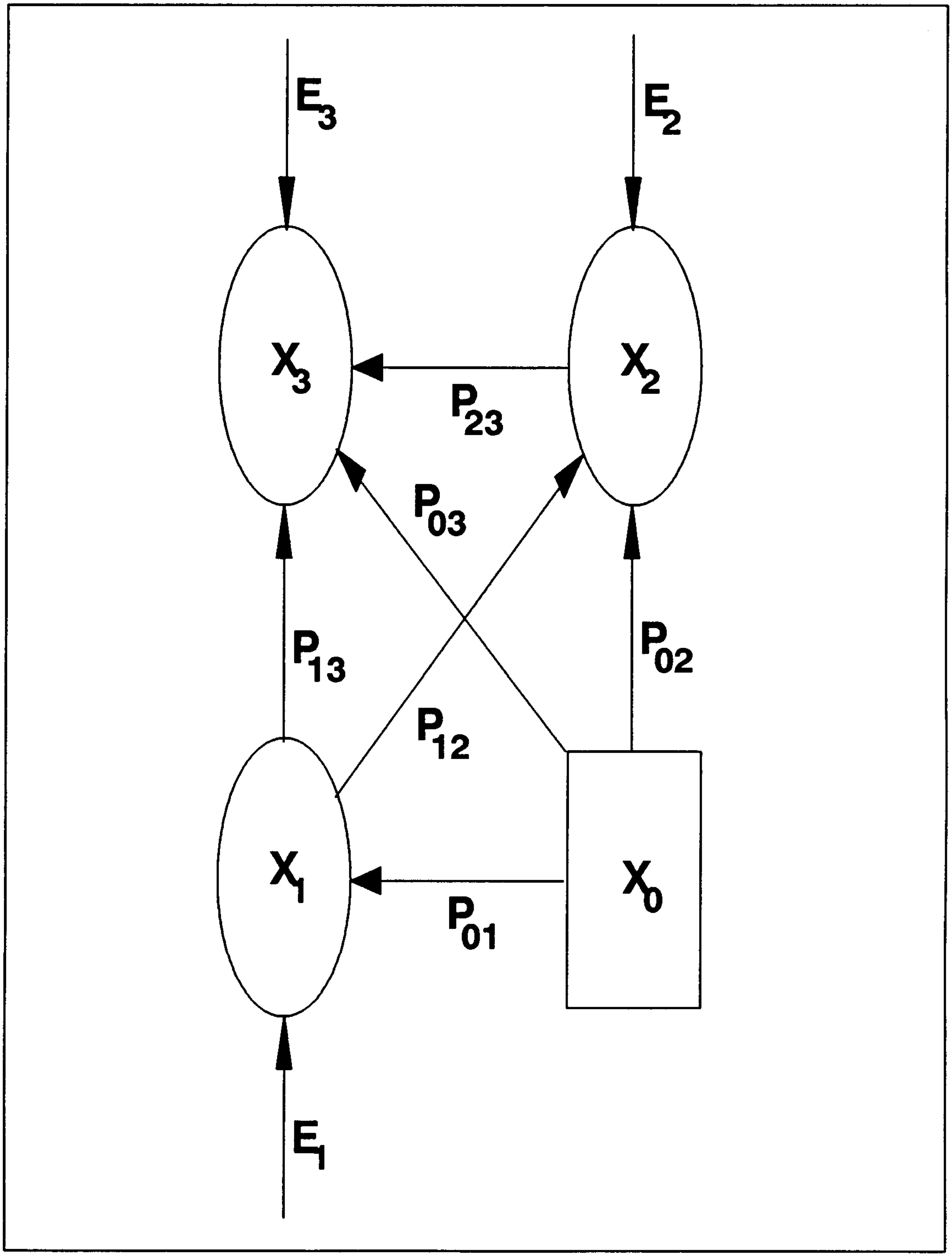

Figure 4.4. A theoretical four variable path model. The P's indicate pathways from independent to dependent variables while the E's indicate unknown latent factors. Note the existence of several indirect effects (e.g. the influence of X_0 on X_3 through X_1 or X_2).

1. That the relationships between dependent and independent variables are linear and additive thus excluding curvilinear and multiplicative models.
2. That dependent variables are continous and normally distributed.
3. That independent variables are measured without error.
4. That error terms are uncorrelated.

The technique then uses repeated (i.e. for each dependent variable) stepwise multiple regression to estimate path coefficients as the standardized regression coefficients associated with postulated directional paths. The normal stepwise regression analysis was replaced with ridge regression to reduce the effects of multicollinearity among the independent variables on the sign and magnitude of coefficients associated with the independent variables. Selection of a biasing constant (k) is an important feature of ridge regression. Several methods have been proposed and are reviewed by Vinod (1978). The biasing constant (k) was selected based upon inspection of the ridge trace (Figure 4.5). The following four criteria proposed by Hoerl and Kennard (1970) were used as criteria in selecting a value for k:

1. Stabilization of the ridge trace.
2. Coefficients will not have unreasonable absolute values in terms of a priori knowledge.
3. Coefficients with theoretically improper signs at k=0 will have proper signs.
4. The residual sum of squares will not be considerably inflated.

A value of k=2.10 was used for the path analysis. However, as ridge regression is a biased regression technique, statistics (e.g. significance tests) normally associated with regression coefficients cannot be calculated, as their distributional properties are not known. Thus only approximate standard errors of the coefficients were calculated. In addition to the path coefficients, it is customary to determine the residual effect due to unmeasured latent variables for each dependent variable. The effect of each independent variable on a dependent variable can then be direct (i.e. a direct path exists between the two), indirect (i.e. the two are related through other variable(s)), spurious (i.e. the two are correlated but are not linked) or unanalyzed (i.e the independent

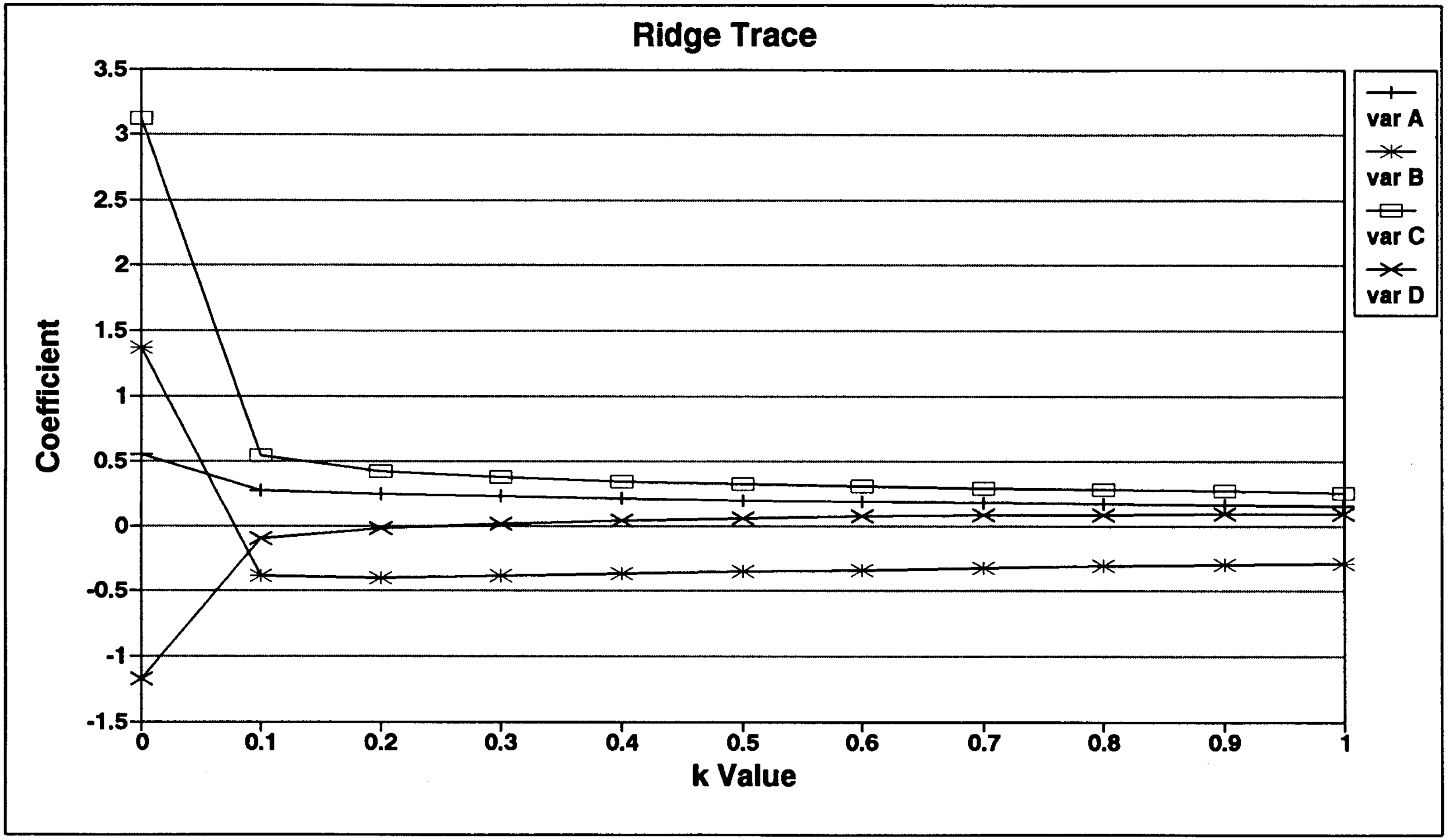

Figure 4.5. A ridge trace diagram produced as a result of ridge regression analysis. Note the high degree of collinearity exhibited by variables B, C and D as indicated by the rapid change in regression coefficient values as the biasing constant k increases.

variable was not included in pathways in the model). Indirect pathways are calculated as the product of path coefficients along the indirect pathway.

In ordinary path analysis, the sum of direct and indirect effects for a dependent variable is equal to the simple correlation between the dependent and independent variables provided the model is fully recursive (i.e. that all possible connections between the two variables have been made). For detailed discussions of regression techniques and path analysis methodology see Wright (1934), Blalock (1964), Li (1975), Gunst and Mason (1980), Wonnacott and Wonnacott (1981) and Dillon and Goldstein (1984). For recent examples of path analysis used in analyzing vegetation, data see Hermy (1987) or Kuusipalo (1987).

The Theoretical Model

Forage intake by grazing animals has long been of concern to range managers as well as livestock producers. Numerous efforts have been made to understand and optimize intake of grazing animals in order to efficiently utilize the forage resource from both range management and livestock production viewpoints. Intake of livestock grazing rangelands has been related to numerous factors including animal parameters (e.g. energy status, nutrient satiation, physical fill, etc), microclimate, plant community type, forage quality, forage quantity, species composition, etc. (Freer 1981, Forbes 1986). These factors, as well as others, influence intake by livestock grazing riparian zones as well as those grazing uplands.

A model describing intake by livestock grazing a riparian zone may be a function of several variables. As illustrated in Figure 4.6, intake is described as being a function of: *in vitro* dry matter digestibility; total forage biomass; and, the level of utilization which has occurred to that point in time.

Intake has generally been shown to be linearly related to digestibility suggesting that the dietary fiber characteristics which determine the rate of passage of forage from the alimentary tract are quantified in the digestibility coefficient (Freer 1981). Thus the forage quality measurement most closely associated with rate of passage is *in*

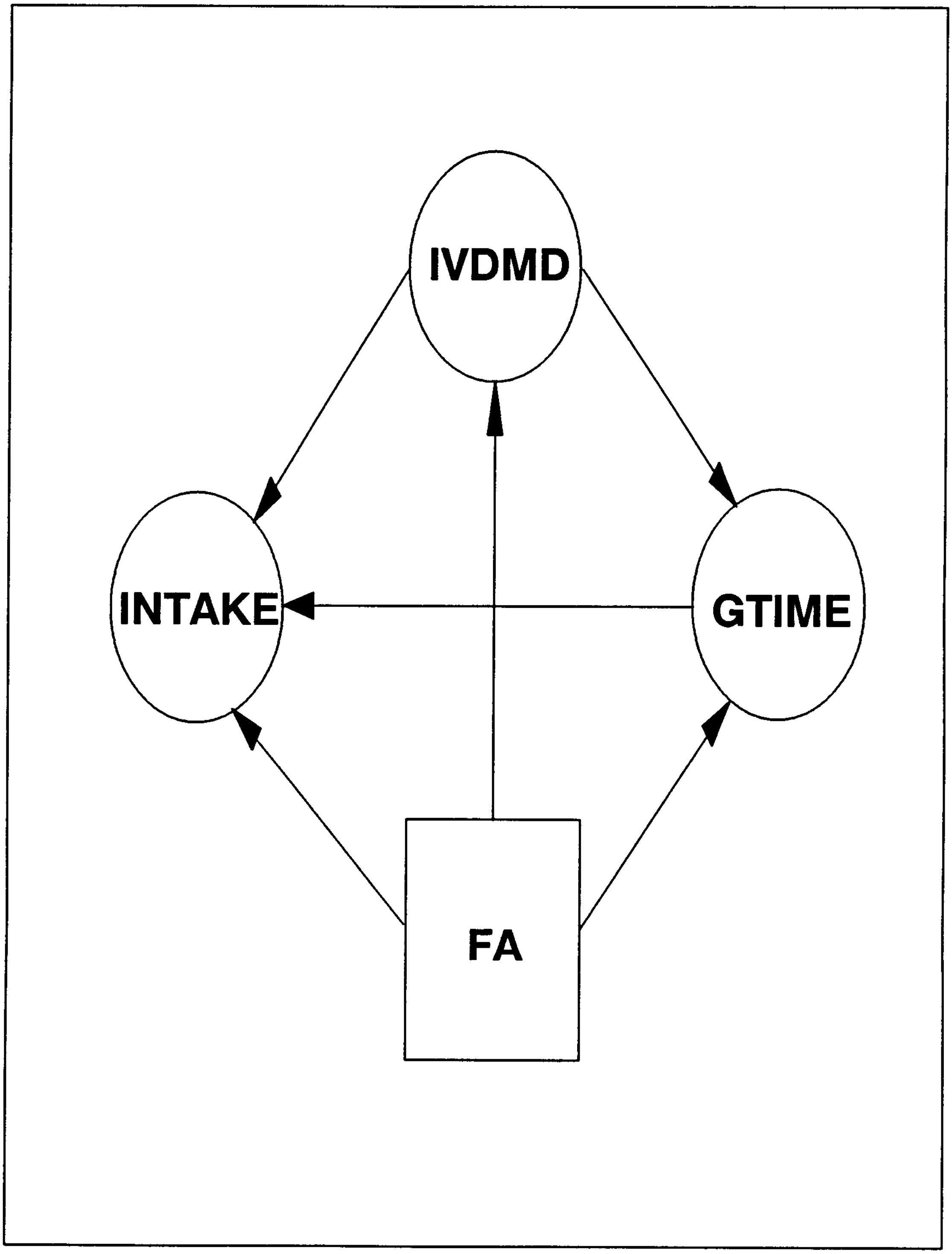

Figure 4.6. The proposed path model for describing intake of grazing livestock. Intake is described as being a function of *in vitro* dry matter digestibility (IVDMD), grazing time (GTIME) and the amount of forage available (FA).

vitro dry matter digestibility. Hence it is expected that livestock intake would be highest early in the grazing period when the most digestible forage is available and decline as the animals are forced to consume forage lower in digestibility.

Grazing time may limit intake in grazing animals in that less time spent grazing may reflect reduced intake levels (Arnold and Dudzinski 1978).

The amount of biomass available for grazing in a community type, as modified by the amount of utilization which has occurred, may influence grazing animal intake in any of several ways (Forbes 1986). Livestock may graze the community type with the most forage available for consumption, and switch to other communities as forage becomes limiting, in order to maintain intake levels. As an alternative, livestock may reduce intake by continuing to graze communities which have already been closely grazed, depending upon the quality of forage available relative to nutritional needs.

Results and Discussion

Intake and Environmental Parameters

Pregrazing forage production estimates for both years for the five community types are illustrated in Figure 4.7. As shown by the figure, the most productive vegetation type were the wet meadow communities, composed primarily of sedges with small grass and forb components. Moist bluegrass meadows were the next most productive type, followed by gravel bar communities, dry bluegrass meadows and forests were the least productive and produced about the same amount of biomass. The second year of the study (1985) was much drier than the first (1984) and, as a result, forage production levels were lower. In terms of composition, the dry bluegrass meadows consisted primarily of grasses, the bulk of which was Kentucky bluegrass. Forests and gravel bars had very small sedge components and similar grass components; forests, however, had a higher proportion of Kentucky bluegrass. Gravel bars had larger proportions of both forbs and shrubs than did the forests. The moist bluegrass meadows had relatively large grass components, over half of which was Kentucky bluegrass. This community type also had a significant sedge component and a relatively large forb component.

Community types varied with regard to forage utilization and height reduction patterns (Table 4.1). The data indicates that utilization of the dry bluegrass meadows was very rapid, since by the middle of the grazing period they had already received 70 percent use. In addition, vegetation height in the dry bluegrass meadows was reduced to one-third or one-fourth its original height by the middle of the grazing period. The other community types had received 35 percent utilization or less by the middle of the grazing period.

The nutritional content of forage samples, selected species and diets from the different community types, is illustrated in Tables 4.2 and 4.3. For both years all community types were relatively high in fiber components as indicated by the relatively high neutral detergent fiber, acid detergent fiber and lignin levels in combination with the low cell content percentages. Diet *in vitro* dry matter digestibility levels were

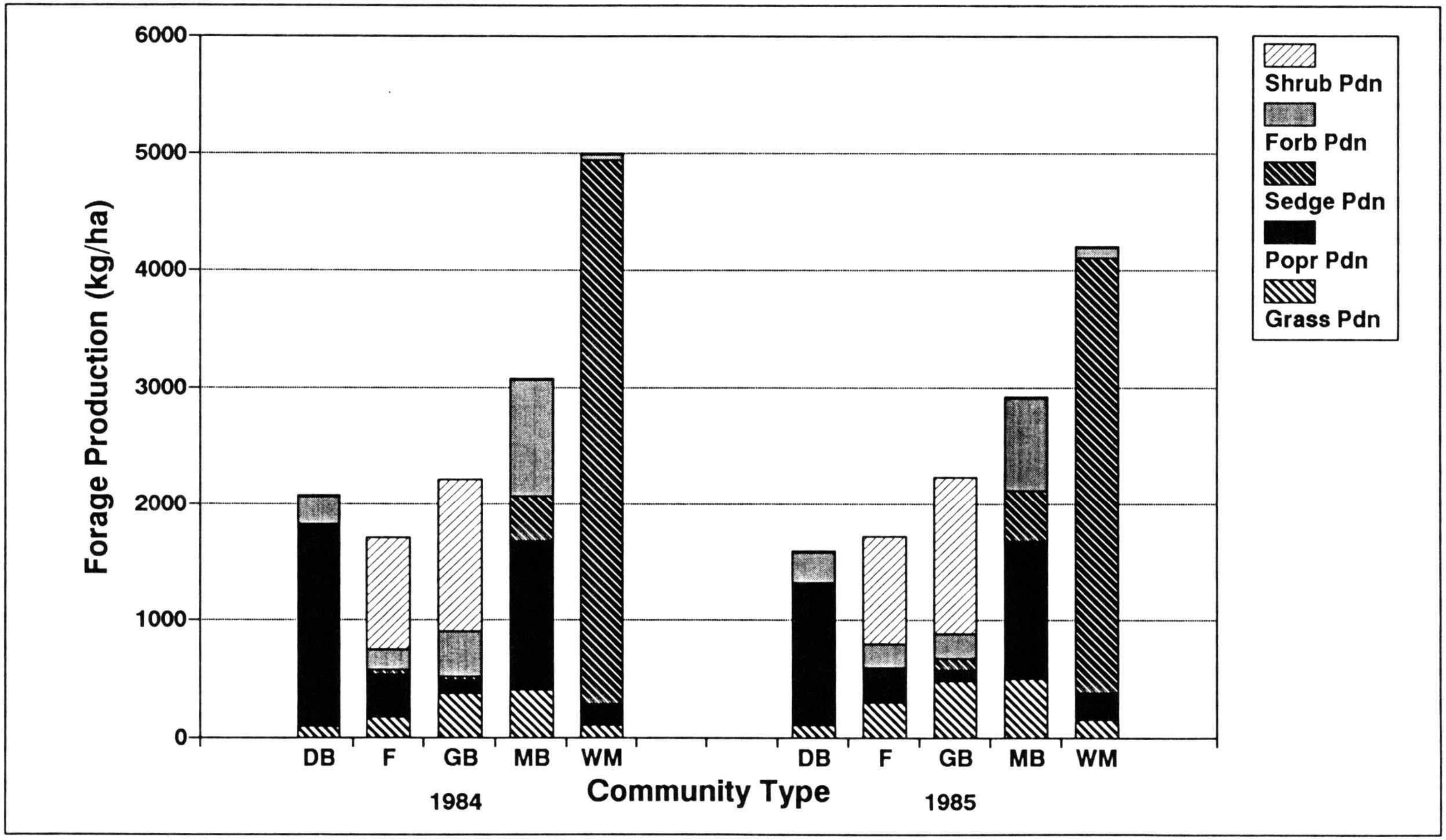

Figure 4.7. Forage production and composition of the different community types just prior to grazing in 1984 and 1985. Communities designated as follows; F - forests, GB - gravel bars, DB - dry bluegrass communities, MB - moist bluegrass communities and WM - wet meadows. Popr Pdn represents Kentucky bluegrass production.

Table 4.1. Trends in clipped forage utilization (%) and vegetation height (cm) in five riparian zone plant communities in northeastern Oregon before, mid-way through and at the end of the grazing period.

	Before		Mid-way		End	
	1984	1985	1984	1985	1984	1985
Community			Utilization			
DB [a]	0.0	0.0	71.6	69.5	88.7	78.7
F	0.0	0.0	26.7	28.9	57.5	48.1
GB	0.0	0.0	35.9	2.5	33.8	51.0
MB	0.0	0.0	9.2	25.5	48.5	53.5
WM	0.0	0.0	0.0	6.5	26.6	40.9
			Height			
DB	27.7	21.3	8.9	5.8	3.8	3.8
F	31.8	34.3	21.1	20.1	16.0	15.2
GB	36.6	26.7	19.3	13.5	11.4	15.0
MB	32.3	32.8	29.0	19.1	12.7	11.9
WM	67.6	47.8	50.0	34.3	26.7	21.1

[a] - Community designations as follows: DB - dry bluegrass meadows; f - Forests; GB - gravel bars; MB - moist bluegrass meadows, and; WM - wet meadows.

Table 4.2. Nutritional quality of livestock diets, forage available (FA) for grazing, selected species and forage classes at the beginning (E) and end (L) of a 21 day grazing period for a northeastern Oregon riparian zone in 1984.

Community	Class	Time	N	Crude Protein	Total Ash	ND Fiber	Cell Contents	AD Fiber	Lignin	Cellulose	HemiCellulose	Silica	IVDMD	ME
DB [a]	Diet [b]	E [c]	16	7.91 (0.19) [d]	14.45 (1.17)	68.56 (0.59)	31.44 (0.59)	43.28 (0.56)	6.35 (0.23)	31.02 (0.45)	25.28 (0.77)	5.91 (0.56)	61.53 (1.24)	2.06 [e]
DB	Diet	L	19	9.38 (0.86)	19.94 (0.29)	71.72 (0.79)	28.28 (0.79)	47.67 (0.72)	7.70 (0.27)	31.25 (0.56)	24.05 (0.53)	8.73 (0.41)	59.62 (0.75)	2.01
DB	FA	E	5	5.66 (0.20)	10.24 (0.25)	69.39 (2.03)	30.61 (2.03)	43.98 (1.79)	7.11 (1.13)	29.80 (1.36)	25.41 (1.07)	7.07 (0.44)	55.70 (1.53)	1.88
DB	FA	L	5	7.80 (1.02)	10.50 (0.59)	74.69 (2.92)	25.31 (2.92)	44.37 (1.85)	6.40 (0.52)	30.87 (1.48)	30.32 (1.31)	7.09 (0.21)	56.50 (1.62)	1.91
DB	Popr	E	3	6.45 (0.38)	10.33 (0.18)	71.32 (2.62)	28.68 (2.62)	44.93 (2.06)	8.79 (0.55)	29.83 (2.06)	26.40 (0.57)	6.30 (0.50)	55.40 (2.03)	1.87
DB	Popr	L	3	7.33 (0.81)	10.54 (0.77)	69.35 (0.14)	30.65 (0.14)	44.30 (1.05)	8.00 (0.37)	28.48 (0.31)	25.05 (1.18)	7.83 (0.99)	55.27 (0.85)	1.87
F	Diet	E	14	10.19 (0.53)	13.46 (0.44)	59.52 (2.06)	40.48 (2.06)	46.09 (1.32)	14.66 (1.00)	28.49 (1.13)	13.42 (1.28)	2.94 (0.55)	54.75 (1.77)	1.85
F	Diet	L	18	7.94 (0.25)	12.00 (0.25)	68.94 (1.22)	31.06 (1.22)	51.04 (0.58)	13.84 (0.61)	33.18 (0.56)	17.90 (1.16)	4.03 (0.45)	47.84 (1.69)	1.64
F	FA	E	5	6.98 (0.16)	13.99 (2.70)	68.91 (1.13)	31.09 (1.13)	47.23 (0.29)	10.51 (0.65)	31.83 (0.80)	21.68 (1.13)	4.89 (0.49)	54.99 (0.83)	1.86
F	FA	L	5	8.15 (0.51)	10.61 (0.35)	69.87 (1.33)	30.13 (1.33)	44.05 (0.53)	8.53 (0.63)	30.56 (1.14)	25.83 (1.47)	4.95 (0.87)	54.40 (1.24)	1.84
F	Popr	E	3	6.51 (0.55)	10.59 (0.32)	73.12 (0.79)	26.88 (0.79)	46.19 (0.91)	8.83 (0.69)	31.11 (1.16)	26.93 (0.89)	6.26 (0.40)	55.16 (1.76)	1.87
F	Popr	L	3	6.70 (0.48)	11.08 (0.42)	71.71 (1.77)	28.29 (1.77)	47.05 (1.59)	8.71 (0.49)	31.30 (1.93)	24.65 (0.50)	7.04 (0.76)	51.77 (1.29)	1.76
F	Syal	E	3	7.75 (0.68)	8.67 (0.49)	43.80 (1.56)	56.20 (1.56)	31.38 (1.28)	12.10 (0.79)	18.81 (1.88)	12.42 (0.85)	0.47 (0.14)	56.64 (1.05)	1.91
F	Syal	L	3	7.73 (0.24)	7.20 (0.64)	44.08 (1.58)	55.92 (1.58)	33.94 (2.01)	14.70 (0.35)	18.55 (1.80)	10.14 (0.43)	0.69 (0.06)	57.53 (1.45)	1.94
GB	Diet	E	15	10.86 (0.49)	17.25 (1.03)	63.31 (1.40)	36.69 (1.40)	46.17 (0.98)	12.73 (0.84)	27.78 (0.94)	17.14 (1.11)	5.65 (0.86)	58.27 (1.29)	1.96
GB	Diet	L	16	10.96 (0.49)	15.02 (0.93)	67.18 (1.19)	32.82 (1.19)	50.79 (1.03)	15.99 (0.83)	28.83 (1.11)	16.39 (0.91)	5.96 (0.71)	50.02 (1.26)	1.71
GB	FA	E	5	7.88 (1.47)	12.31 (1.55)	62.12 (1.62)	37.88 (1.62)	42.12 (0.76)	7.97 (0.50)	28.70 (1.17)	20.00 (1.26)	5.45 (1.23)	47.68 (1.92)	1.63
GB	FA	L	5	7.84 (0.70)	14.13 (1.44)	68.17 (1.30)	31.83 (1.30)	45.65 (1.42)	10.84 (0.72)	26.91 (1.20)	22.52 (0.77)	7.90 (0.88)	52.34 (1.53)	1.78
GB	Forbs	E	3	10.54 (0.61)	12.80 (1.82)	50.13 (2.16)	49.87 (2.16)	38.12 (1.09)	10.03 (2.01)	24.96 (2.81)	12.02 (1.72)	3.12 (0.85)	56.84 (0.78)	1.92
GB	Forbs	L	3	8.76 (1.21)	10.88 (0.50)	48.87 (0.54)	51.13 (0.54)	38.13 (0.66)	15.01 (0.48)	20.22 (1.07)	10.73 (1.12)	2.91 (1.00)	56.38 (1.97)	1.90
GB	Grasses	E	3	8.46 (0.99)	13.60 (0.46)	68.28 (0.47)	31.72 (0.47)	43.92 (1.55)	6.73 (1.15)	29.60 (0.76)	24.36 (1.21)	7.60 (0.38)	53.04 (3.54)	1.80
GB	Grasses	L	3	4.09 (0.18)	10.61 (0.87)	73.16 (0.31)	26.84 (0.31)	48.73 (0.65)	9.25 (0.14)	32.80 (0.12)	24.43 (0.35)	6.69 (0.58)	53.30 (1.23)	1.81
GB	Salix sp.	E	3	10.05 (0.58)	5.50 (0.48)	46.76 (2.88)	53.24 (2.88)	39.47 (1.10)	12.85 (1.79)	26.52 (2.55)	7.29 (3.39)	0.10 (0.02)	41.99 (3.29)	1.46
GB	Salix sp.	L	3	9.12 (0.63)	6.15 (0.91)	43.03 (2.89)	56.97 (2.89)	35.54 (3.25)	12.77 (1.29)	22.60 (4.02)	7.49 (0.62)	0.18 (0.08)	43.90 (3.92)	1.52
MB	Carex sp.	E	3	6.85 (0.43)	8.92 (0.74)	70.66 (0.26)	29.34 (0.26)	39.90 (0.85)	6.52 (0.66)	29.77 (0.62)	30.77 (0.91)	3.60 (1.43)	52.11 (1.95)	1.77
MB	Carex sp.	L	3	5.68 (0.35)	8.86 (0.20)	72.94 (1.40)	27.06 (1.40)	43.34 (0.74)	8.03 (0.81)	29.93 (0.44)	29.60 (1.28)	5.38 (0.62)	55.11 (7.38)	1.86
MB	Diet	E	15	7.69 (0.41)	12.39 (0.30)	63.78 (2.19)	36.22 (2.19)	43.08 (0.80)	9.31 (0.64)	30.02 (1.03)	20.70 (1.71)	3.75 (0.51)	61.90 (1.19)	2.08
MB	Diet	L	16	7.72 (0.52)	12.97 (0.56)	70.48 (0.48)	29.52 (0.48)	47.75 (0.59)	9.66 (0.37)	31.98 (0.47)	22.73 (0.51)	6.11 (0.28)	57.95 (1.16)	1.95
MB	FA	E	5	6.62 (0.43)	9.72 (0.34)	69.42 (0.85)	30.58 (0.85)	46.47 (1.73)	9.81 (0.94)	31.99 (0.80)	22.95 (1.48)	4.67 (1.13)	48.93 (2.35)	1.67
MB	FA	L	5	6.11 (0.18)	10.36 (0.93)	70.79 (1.67)	29.21 (1.67)	45.94 (1.88)	10.30 (1.21)	30.56 (0.82)	24.85 (1.11)	5.08 (1.74)	50.39 (4.18)	1.72
MB	Pogr	E	3	7.12 (0.06)	7.56 (0.07)	41.13 (1.47)	58.87 (1.47)	32.67 (0.70)	9.87 (2.03)	22.40 (2.02)	8.46 (0.94)	0.40 (0.10)	38.15 (1.02)	1.34
MB	Pogr	L	3	5.81 (0.40)	7.29 (0.58)	47.73 (0.62)	52.27 (0.62)	38.09 (0.35)	11.76 (2.32)	25.59 (1.92)	9.65 (0.66)	0.74 (0.19)	42.57 (2.90)	1.47
MB	Popr	E	3	5.82 (0.39)	10.38 (0.73)	66.17 (2.21)	33.83 (2.21)	41.39 (0.46)	6.04 (0.69)	29.39 (0.99)	24.79 (1.96)	5.96 (0.04)	51.31 (0.70)	1.75
MB	Popr	L	3	5.48 (0.35)	11.03 (0.48)	71.01 (1.11)	28.99 (1.11)	45.11 (0.17)	7.41 (0.16)	29.14 (0.51)	25.90 (1.23)	8.57 (0.83)	57.13 (0.57)	1.93
WM	Carex sp.	E	3	6.19 (0.61)	10.95 (1.25)	72.87 (1.74)	27.13 (1.74)	43.11 (1.15)	6.78 (0.72)	30.30 (1.34)	29.76 (1.06)	6.03 (1.21)	47.64 (3.49)	1.63
WM	Carex sp.	L	3	5.47 (0.38)	9.42 (0.41)	72.02 (0.63)	27.98 (0.63)	43.11 (2.20)	9.42 (1.26)	27.81 (0.73)	28.92 (2.81)	5.88 (0.51)	39.43 (7.44)	1.38
WM	Diet	E	14	9.52 (0.40)	13.21 (0.30)	68.12 (2.25)	31.88 (2.25)	41.98 (0.78)	7.89 (0.50)	29.11 (0.73)	26.15 (1.81)	4.97 (0.55)	60.27 (1.31)	2.03
WM	Diet	L	17	7.19 (0.22)	11.83 (0.41)	75.35 (0.42)	24.65 (0.42)	46.31 (0.51)	8.06 (0.35)	32.93 (0.29)	29.04 (0.64)	5.32 (0.30)	60.40 (0.73)	2.03
WM	FA	E	5	6.48 (0.16)	9.37 (0.71)	75.38 (0.80)	24.62 (0.80)	44.33 (0.84)	7.59 (0.56)	32.98 (0.52)	31.05 (1.37)	3.76 (0.50)	38.60 (1.45)	1.35
WM	FA	L	5	6.19 (0.37)	10.92 (0.37)	76.02 (0.47)	23.98 (0.47)	47.04 (0.69)	7.66 (0.34)	32.63 (0.45)	28.99 (0.66)	6.75 (0.42)	41.76 (2.61)	1.45
WM	Scam	E	3	6.57 (0.47)	10.26 (0.50)	68.89 (0.96)	31.11 (0.96)	41.39 (1.60)	7.99 (2.64)	29.19 (0.24)	27.49 (0.91)	4.21 (0.84)	50.74 (4.36)	1.73
WM	Scam	L	3	7.56 (0.85)	12.16 (0.20)	69.98 (0.17)	30.02 (0.17)	42.43 (0.43)	7.58 (0.39)	28.61 (1.65)	27.55 (0.26)	6.23 (1.89)	58.53 (2.54)	1.97

[a] - Community designations as follows: DB - dry bluegrass meadows; F - forests; GB - gravel bars; MB - moist bluegrass meadows, and; WM - wet meadows.

[b] - Class represents species class (e.g. Popr), cattle diets (Diet) or forage available (FA). Species classes as follows; Popr - Kentucky bluegrass; Syal - common snowberry; Salix sp. - willow species; Carex sp. - sedge species; Pogr - northwest cinquefoil, and; Scam - panicled bulrush.

[c] - E and L represent early and late in the grazing period respectively.

[d] - Number in parentheses represents the standard error of the mean.

[e] - ME represents metabolizable energy (Mcal/Kg) determined from IVDMD via the equations by Rittenhouse et al. (1971) and the NRC (1984).

Table 4.3. Nutritional quality of livestock diets, forage available (FA) for grazing, selected species and forage classes at the beginning (E) and end (L) of a 21 day grazing period for a northeastern Oregon riparian zone in 1985.

Community	Class	Time	N	Crude Protein	Total Ash	ND Fiber	Cell Contents	AD Fiber	Lignin	Cellulose	HemiCellulose	Silica	IVDMD	ME
DB [a]	Diet [b]	E [c]	11	8.24 (0.24) [d]	12.51 (0.32)	70.60 (0.70)	29.40 (0.70)	42.63 (0.67)	5.12 (0.40)	32.29 (0.75)	27.97 (0.62)	5.21 (0.72)	57.67 (1.04)	1.94 [e]
DB	Diet	L	16	8.39 (0.41)	15.54 (0.34)	71.24 (0.83)	28.76 (0.83)	45.74 (0.58)	8.06 (0.49)	30.67 (0.58)	25.51 (0.76)	7.01 (0.54)	50.79 (1.17)	1.73
DB	FA	E	5	5.70 (0.31)	8.72 (0.45)	73.61 (1.14)	26.39 (1.14)	46.42 (0.97)	5.77 (0.37)	35.14 (0.92)	27.19 (0.79)	5.50 (0.25)	49.21 (2.06)	1.68
DB	FA	M	5	5.71 (0.22)	9.86 (0.49)	70.28 (1.11)	29.72 (1.11)	46.82 (1.07)	8.20 (0.60)	32.41 (0.72)	23.46 (0.84)	6.21 (0.46)	43.09 (1.19)	1.49
DB	FA	L	5	6.86 (0.49)	9.89 (1.18)	75.28 (1.21)	24.72 (1.21)	49.29 (0.62)	9.49 (0.85)	33.41 (1.28)	25.99 (1.60)	6.39 (1.53)	36.73 (3.05)	1.29
DB	Popr	E	3	7.36 (0.50)	9.09 (0.44)	71.91 (0.54)	28.09 (0.54)	40.76 (0.67)	2.00 (1.43)	32.79 (1.27)	31.16 (1.21)	5.96 (0.50)	62.31 (6.04)	2.09
DB	Popr	L	3	5.62 (0.16)	9.62 (0.27)	76.59 (1.42)	23.41 (1.42)	46.74 (1.42)	5.55 (0.68)	35.89 (1.76)	29.85 (1.00)	5.29 (1.02)	46.21 (3.54)	1.59
F	Diet	E	13	9.27 (0.32)	12.80 (0.54)	60.67 (1.33)	39.33 (1.33)	44.39 (0.81)	13.78 (0.83)	27.66 (0.67)	16.28 (1.23)	2.95 (0.53)	55.87 (1.33)	1.89
F	Diet	L	13	7.66 (0.19)	11.81 (0.36)	65.51 (1.74)	34.49 (1.74)	48.83 (0.93)	14.90 (0.65)	31.14 (0.79)	16.68 (1.25)	2.79 (0.47)	49.29 (1.33)	1.68
F	FA	E	5	6.77 (0.11)	9.97 (0.35)	68.76 (2.78)	31.24 (2.78)	45.01 (0.82)	5.87 (1.16)	34.74 (1.61)	23.76 (2.02)	4.40 (0.27)	48.55 (1.54)	1.66
F	FA	M	5	7.31 (0.35)	10.60 (0.59)	67.63 (0.93)	32.37 (0.93)	41.84 (0.69)	6.22 (0.44)	30.99 (0.31)	25.80 (1.14)	4.63 (0.22)	39.81 (2.39)	1.39
F	FA	L	5	6.41 (0.54)	8.69 (0.78)	74.26 (2.14)	25.74 (2.14)	47.05 (1.58)	8.52 (0.97)	33.95 (0.56)	27.21 (2.40)	4.58 (0.47)	31.88 (1.18)	1.14
F	Popr	E	3	7.56 (0.57)	8.04 (0.13)	75.02 (2.07)	24.98 (2.07)	40.39 (1.85)	2.52 (0.79)	34.73 (0.96)	34.63 (0.24)	3.15 (0.76)	52.78 (3.89)	1.79
F	Popr	L	3	6.64 (0.18)	8.63 (0.22)	73.35 (0.68)	26.65 (0.68)	43.60 (0.20)	4.80 (0.66)	34.78 (1.46)	29.75 (0.82)	4.01 (0.87)	52.63 (1.09)	1.79
F	Syal	E	3	8.21 (0.46)	8.65 (0.74)	48.14 (0.79)	51.86 (0.79)	30.60 (1.24)	10.33 (0.32)	19.58 (1.33)	17.55 (0.52)	0.68 (0.14)	43.54 (1.02)	1.50
F	Syal	L	3	8.36 (0.27)	8.04 (0.17)	50.35 (0.73)	49.65 (0.73)	32.24 (0.76)	9.32 (0.79)	22.69 (1.03)	18.11 (0.61)	0.23 (0.11)	44.31 (0.11)	1.53
GB	Diet	E	14	9.48 (0.55)	13.63 (0.61)	62.31 (1.70)	37.69 (1.70)	45.95 (0.78)	10.82 (0.99)	29.61 (0.79)	16.36 (1.26)	5.53 (0.57)	54.45 (0.70)	1.84
GB	Diet	L	16	8.38 (0.46)	12.59 (0.71)	67.54 (1.27)	32.46 (1.27)	50.26 (0.62)	14.15 (1.29)	31.52 (0.68)	17.28 (1.69)	4.59 (0.79)	49.82 (1.37)	1.70
GB	FA	E	5	6.14 (0.52)	9.58 (0.51)	65.79 (0.92)	34.21 (0.92)	41.12 (0.64)	5.05 (0.70)	32.08 (0.97)	24.67 (0.38)	4.00 (0.61)	50.14 (0.74)	1.71
GB	FA	M	5	6.14 (0.84)	12.27 (1.72)	69.30 (1.41)	30.70 (1.41)	43.03 (1.08)	6.96 (0.51)	30.77 (0.93)	26.26 (0.82)	5.31 (0.56)	34.93 (3.36)	1.24
GB	FA	L	5	4.65 (0.43)	9.91 (0.42)	75.50 (1.63)	24.50 (1.63)	48.17 (1.46)	7.24 (0.62)	35.54 (1.52)	27.33 (1.86)	5.39 (1.22)	26.19 (1.61)	0.96
GB	Forbs	E	3	8.17 (0.09)	9.25 (0.56)	44.43 (0.50)	55.57 (0.50)	36.53 (0.58)	9.56 (0.69)	25.49 (0.97)	7.90 (0.46)	1.47 (0.25)	47.32 (3.03)	1.62
GB	Forbs	L	3	8.79 (0.62)	12.05 (0.32)	45.11 (2.50)	54.89 (2.50)	37.92 (2.72)	9.00 (0.86)	27.22 (2.89)	7.19 (0.38)	1.70 (0.72)	61.86 (1.35)	2.08
GB	Grasses	E	3	4.41 (0.36)	8.47 (0.46)	68.46 (0.77)	31.54 (0.77)	39.78 (1.90)	6.71 (0.79)	30.22 (1.38)	28.68 (1.16)	2.85 (0.94)	43.98 (1.06)	1.52
GB	Grasses	L	3	4.38 (0.50)	9.56 (1.22)	73.15 (1.82)	26.85 (1.82)	46.21 (1.32)	5.79 (0.54)	34.73 (2.31)	26.93 (0.72)	5.69 (0.60)	44.31 (4.38)	1.53
GB	Salix sp.	E	3	9.21 (0.80)	6.14 (0.06)	47.09 (0.46)	52.91 (0.46)	38.74 (0.52)	12.23 (0.37)	26.16 (0.27)	8.35 (0.14)	0.35 (0.11)	29.55 (1.26)	1.07
GB	Salix sp.	L	3	8.41 (0.18)	5.54 (0.55)	52.68 (2.48)	47.32 (2.48)	42.88 (2.78)	12.77 (0.83)	29.86 (2.32)	9.81 (0.73)	0.25 (0.02)	22.79 (1.16)	0.86
MB	Carex sp.	E	3	6.32 (0.31)	9.33 (0.41)	71.12 (0.78)	28.88 (0.78)	38.75 (1.32)	3.38 (1.09)	31.33 (1.05)	32.37 (0.99)	4.04 (0.39)	48.15 (2.40)	1.65
MB	Carex sp.	L	3	5.06 (0.23)	8.95 (0.52)	71.90 (0.50)	28.10 (0.50)	39.31 (0.48)	3.95 (0.67)	31.11 (1.03)	32.59 (0.09)	4.25 (0.63)	51.79 (5.63)	1.76
MB	Diet	E	13	7.78 (0.39)	12.39 (0.57)	63.27 (2.11)	36.73 (2.11)	41.81 (0.62)	8.95 (0.80)	27.68 (1.06)	21.46 (1.77)	5.17 (0.51)	57.58 (0.90)	1.94
MB	Diet	L	16	6.92 (0.36)	14.41 (1.13)	70.54 (0.64)	29.46 (0.64)	46.52 (0.85)	9.48 (0.43)	29.11 (0.58)	24.03 (0.95)	7.93 (1.04)	53.33 (1.21)	1.81
MB	FA	E	5	4.52 (0.25)	7.93 (0.30)	71.72 (1.55)	28.28 (1.55)	43.93 (0.73)	7.57 (0.38)	32.43 (0.74)	27.79 (1.00)	3.92 (0.42)	40.30 (1.18)	1.40
MB	FA	M	5	5.68 (0.16)	9.52 (0.38)	66.52 (0.60)	33.48 (0.60)	44.25 (1.61)	7.59 (0.63)	32.69 (0.83)	22.27 (1.30)	3.98 (0.68)	30.74 (1.61)	1.11
MB	FA	L	5	6.37 (0.30)	9.52 (0.36)	72.56 (1.05)	27.44 (1.05)	46.65 (1.15)	8.45 (0.98)	34.09 (0.57)	25.92 (1.97)	4.11 (0.75)	29.71 (2.32)	1.07
MB	Pogr	E	3	5.85 (0.08)	7.17 (0.22)	45.84 (0.99)	54.16 (0.99)	34.72 (0.75)	7.59 (0.47)	26.80 (0.55)	11.12 (0.25)	0.33 (0.06)	47.45 (0.84)	1.63
MB	Pogr	L	3	5.67 (0.24)	7.80 (0.07)	44.86 (2.04)	55.14 (2.04)	35.98 (1.11)	8.55 (0.42)	26.93 (1.50)	8.87 (1.18)	0.50 (0.11)	50.43 (0.70)	1.72
MB	Popr	E	3	5.59 (0.37)	8.82 (0.59)	66.71 (1.11)	33.29 (1.11)	37.58 (1.75)	4.00 (0.55)	29.65 (1.25)	29.14 (1.32)	3.92 (1.27)	57.93 (0.21)	1.95
MB	Popr	L	3	5.34 (0.71)	8.92 (0.14)	73.04 (0.50)	26.96 (0.50)	45.51 (0.28)	5.89 (0.05)	34.73 (0.60)	27.53 (0.37)	4.89 (0.35)	47.93 (1.53)	1.64
WM	Carex sp.	E	3	6.71 (0.46)	9.93 (0.65)	71.64 (2.14)	28.36 (2.14)	41.47 (1.63)	3.49 (0.89)	34.11 (1.56)	30.18 (0.53)	3.87 (0.21)	50.33 (2.15)	1.72
WM	Carex sp.	L	3	6.13 (0.20)	9.70 (0.17)	73.20 (1.01)	26.80 (1.01)	42.00 (1.14)	5.62 (0.59)	31.70 (1.05)	31.20 (1.47)	4.67 (1.07)	33.80 (4.70)	1.20
WM	Diet	E	14	8.63 (0.33)	14.90 (2.27)	68.28 (1.03)	31.72 (1.03)	42.49 (1.04)	6.22 (0.38)	29.10 (0.84)	25.79 (1.00)	7.17 (1.83)	55.67 (1.75)	1.88
WM	Diet	L	16	7.49 (0.42)	11.88 (0.40)	73.56 (0.34)	26.44 (0.34)	44.83 (0.69)	7.10 (0.42)	32.75 (0.38)	28.73 (0.79)	4.98 (0.45)	60.74 (0.98)	2.04
WM	FA	E	5	6.13 (0.27)	9.54 (0.53)	75.08 (1.06)	24.92 (1.06)	41.30 (1.01)	5.20 (0.12)	32.68 (0.51)	33.77 (1.87)	3.42 (1.10)	48.88 (2.75)	1.67
WM	FA	M	5	6.45 (0.29)	13.24 (2.31)	72.97 (1.19)	27.03 (1.19)	43.73 (0.97)	6.25 (0.37)	29.31 (1.44)	29.24 (1.78)	8.17 (2.03)	28.26 (1.66)	1.03
WM	FA	L	5	5.95 (0.71)	10.63 (0.93)	76.60 (0.70)	23.40 (0.70)	45.68 (0.66)	6.35 (0.54)	32.72 (0.73)	30.92 (0.65)	6.61 (0.70)	30.65 (3.98)	1.10
WM	Scam	E	3	6.76 (0.49)	9.56 (0.84)	68.62 (1.53)	31.38 (1.53)	37.33 (1.17)	4.20 (1.54)	28.60 (0.21)	31.29 (0.82)	4.53 (0.80)	45.21 (0.46)	1.56
WM	Scam	L	3	5.03 (0.14)	11.20 (0.44)	70.08 (1.62)	29.92 (1.62)	40.90 (0.44)	6.78 (0.85)	29.06 (0.65)	29.18 (1.29)	5.07 (0.98)	34.33 (2.48)	1.22

[a] - Community designations as follows: DB - dry bluegrass meadows; F - forests; GB - gravel bars; MB - moist bluegrass meadows, and; WM - wet meadows.
[b] - Class represents species class (e.g. Popr), cattle diets (Diet) or forage available (FA). Species classes as follows; Popr - Kentucky bluegrass; Syal - common snowberry; Salix sp. - willow species; Carex sp. - sedge species; Pogr - northwest cinquefoil, and; Scam - panicled bulrush.
[c] - E, M and L represent early, midway through and late in the grazing period respectively.
[d] - Number in parentheses represents the standard error of the mean.
[e] - ME represents metabolizable energy (Mcal/Kg) determined from IVDMD via the equations by Rittenhouse et al. (1971) and the NRC (1984).

quite high, while crude protein levels ranged from about 6% to over 10% depending upon community type. As a consequence of 1985 being drier than 1984, the forage matured earlier, and, as a result, the fiber contents of the vegetation sampled were generally higher in the second year of the study than in the first. In addition, protein and digestibility levels were somewhat lower. With regard to specific community types, the dry bluegrass meadows generally had the highest digestibility and among the lowest crude protein levels for the forage available.

In both years the digestibility levels of diets selected by the animals, as well as the forage available in most communities and most of the species sampled, were above recommended levels for grazing cattle. The NRC (1984) nutrient requirement guide for 550 kg cows in the second trimester of pregnancy indicates that cattle require forage containing approximately 1.76 Mcal/Kg dry matter and seven percent crude protein content in order to meet their nutritional needs. Using the equation for converting metabolizable energy to digestible energy described in NRC (1984) and the equations developed by Rittenhouse et al. (1971) for converting digestible energy levels to *in vitro* dry matter digestibility levels, the above energy requirement is equivalent to a diet digestibility of about 52 percent. Diet digestibilities were generally greater than animal needs early in the grazing period and marginally adequate or inadequate late in the grazing period during both years of the study. Diet digestibility levels ranged from approximately 5 to 10 percent higher than forage available averages and diet crude protein levels were approximately 1.5 percent higher than generally available.

The pattern in grazing time for the two years of the study are illustrated in Figure 4.8. During both years of the study, grazing time generally declined as the grazing period progressed. In 1984 grazing time declined from 587 minutes per day to 521 minutes per day, while in 1985 the decline was from 541 minutes per day to 506 minutes per day. Vibracorder data indicated that cattle did occasionally graze for short periods at night. Similar grazing patterns and durations of about seven to eight hours have been reported by Johnstone-Wallace and Kennedy (1944), and Arnold and Dudzinski (1978).

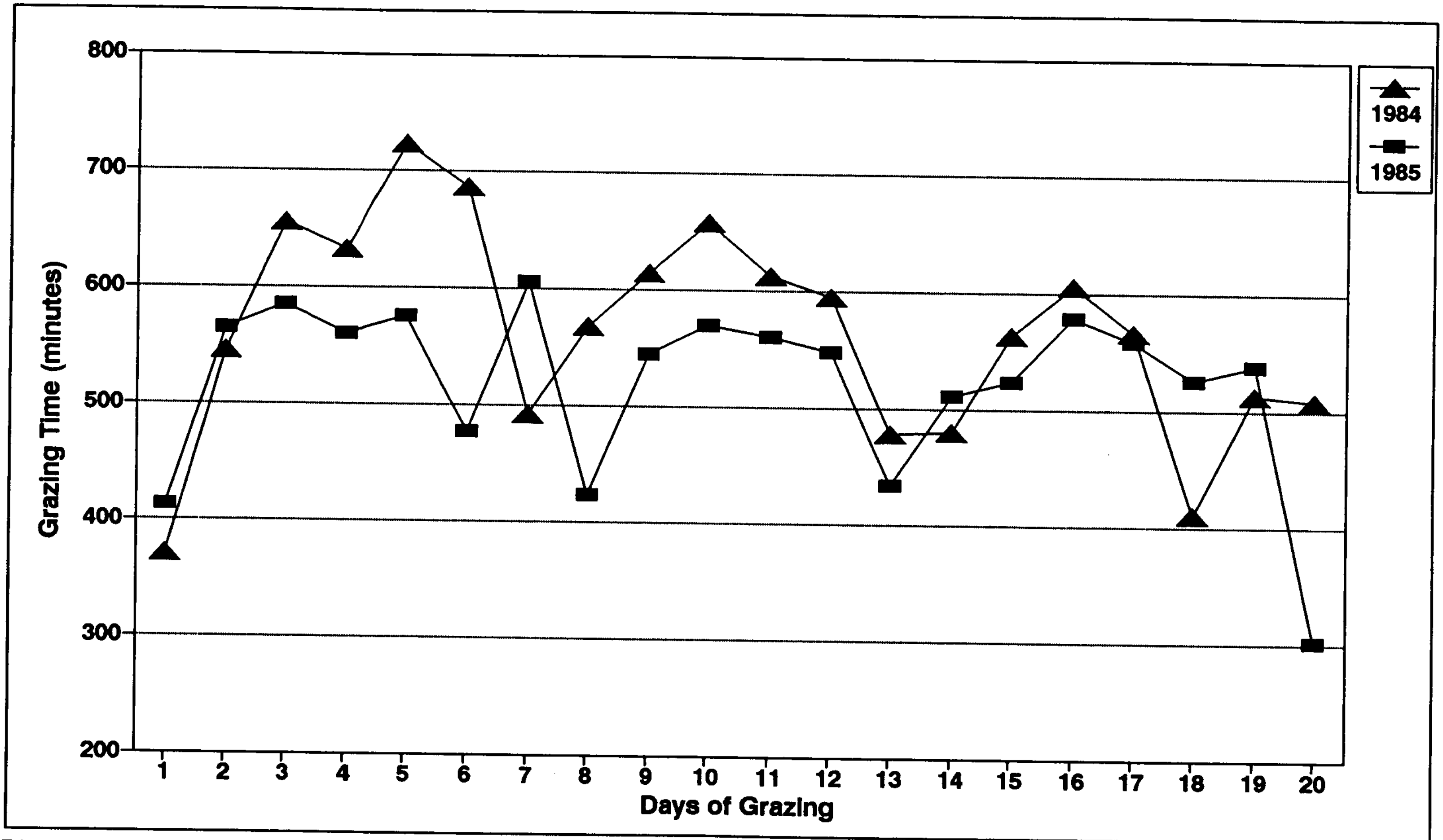

Figure 4.8. Daily grazing times for cattle grazing a northeastern Oregon riparian zone.

Trends in dry matter intake and weight gain are illustrated in Figure 4.9. As illustrated in the figure, intake was 2.25% of body weight early in the grazing period in 1984 and fell to 2.04% of body weight by the end. The opposite trend occurred in 1985 where intake was 1.78% of body weight early and increased to 1.89% of body weight by the end of the grazing period. These intake levels are well within the one to three percent levels reported by other studies (Holechek and Vavra 1982, Van Dyne et al. 1980). The intake level during the early part of the grazing period in 1985 was lower than expected, and may have been the result of new steers being used for fecal collections which were not familiar with either the cattle grazing the pasture or the pasture itself. Thus, intake levels may have been reduced as a result of behavioral changes. Intake levels for both years of the study, however, were more than adequate for pregnant cows in the middle one-third of pregnancy (NRC 1984 requirement for 550 kg cows is about 1.72% of body weight). Given the above levels of energy, protein and intake, the cattle grazing the study area gained 1.6 kg per day in 1984 and 1.3 kg per day in 1985 while cattle grazing adjacent associated uplands only gained 0.5 and 0.05 kg per day during the two years respectively. Calves grazing the riparian zone gained 0.1 kg per day more in 1984 and 0.5 kg per day more in 1985 than their upland counterparts.

The Role of Kentucky Bluegrass

The importance of riparian zones as forage resources for grazing livestock has been suggested by several authors (Reid and Pickford 1946, Phillips 1965, Cook 1966). Specific mechanisms for this importance from a livestock production perspective have, however, not been documented other than in a general fashion (e.g. riparian zones are attractive to livestock due to the presence of more palatable and nutritious forage than is available in adjacent uplands). The results of this study in combination with other work suggested that Kentucky bluegrass may play a significant role in the livestock production potential of some riparian systems. This study as well as those by Kauffman (1982) and Roath and Krueger (1982) document the rapid and heavy utilization of Kentucky bluegrass dominated meadows often found within riparian zones. Wallace-

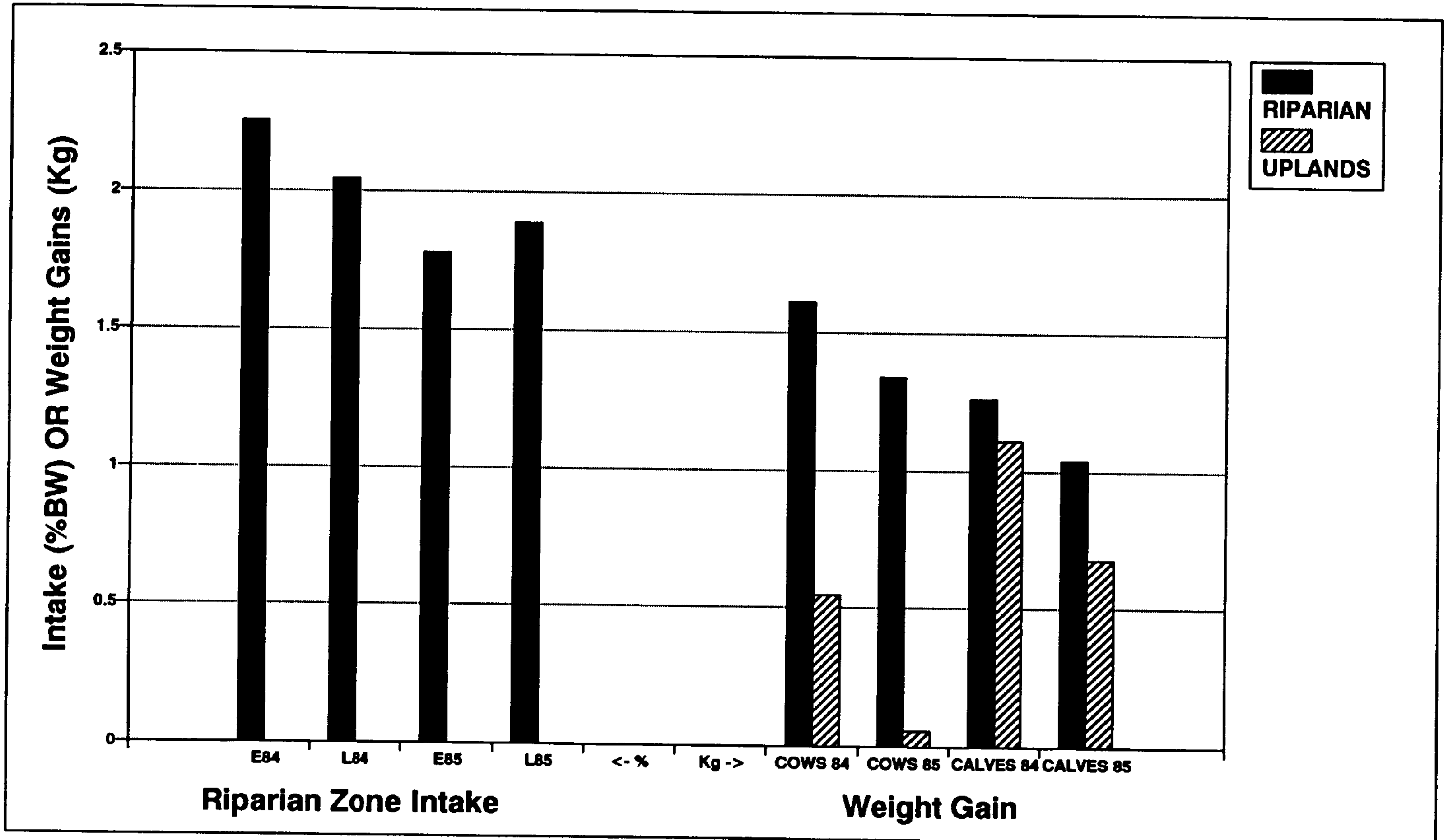

Figure 4.9. Intake and weight gains of cattle grazing the riparian zone in comparison to weight gains of cattle grazing associated uplands.

Johnstone and Kennedy (1944) indicated that Hereford and Aberdeen Angus cattle averaging 550 kg in weight grazing white clover Kentucky bluegrass mix pastures consumed from 9.1 kg to 14.5 kg of herbage per day depending upon the amount of vegetation available for grazing. These consumption rates more than adequately met intake requirements suggested by the NRC (1984) of about 9 to 12 kg per day. The combination of relative palatability of Kentucky bluegrass with adequate intake levels on the part of grazing livestock and high digestibility even when mature (Tables 4.2 and 4.3) clearly indicated the importance of this species to increased weight gains of livestock grazing Kentucky bluegrass dominated riparian systems. Even though the crude protein levels of mature Kentucky bluegrass are marginal for the requirements of grazing livestock, other species within the riparian zone possess higher levels of crude protein (Tables 4.2 and 4.3), which may compliment the energy content of Kentucky bluegrass quite well.

Given that Kentucky bluegrass is important to grazing livestock from a production perspective, due consideration must be given to the ability of Kentucky bluegrass to persist within riparian plant communities. The sod-forming rhyzomatous growth form of Kentucky bluegrass allows the species to withstand close grazing. Johnstone-Wallace and Kennedy (1944) suggested that Kentucky bluegrass white clover pastures be grazed when Kentucky bluegrass was 10 to 15 cm in height down to a stubble height of about 2.5 cm. Volland (1978) indicated that Kentucky bluegrass required grazing in order to avoid reductions in yield associated with no grazing. On the other hand, Etter (1951) documented reduced yields of Kentucky bluegrass after four years of clipping to a height of about 2.5 cm, however rhyzome and tiller production was not affected. Alghren (1938) recommended grazing Kentucky bluegrass when it was 10 to 13 cm in height in order to stimulate tiller production. The results of this study as well as those of Kauffman (1982) and Roath and Krueger (1982) clearly suggest that Kentucky bluegrass can withstand the close grazing which frequently occurs within riparian zones. Further research into the exact competitive capability of Kentucky bluegrass with other riparian flora as well as its adaptability to the range in environments found in riparian zones is clearly warranted whether considered to be a desirable species or not.

Path Analysis

Results of the correlation analysis for the environmental variables and the response variable animal intake are shown in Table 4.4. Intake was well correlated with crude protein content of the diet, *in vitro* dry matter content of the diet, and grazing time. Acid detergent fiber was also well correlated with intake, while neutral detergent fiber and lignin content were not. However acid detergent fiber was positively rather than negatively correlated with intake. This may have been due to the small sample size or a relatively large amount of variability in neutral detergent fiber over a small range in data (i.e. the change in acid detergent fiber over the grazing period was only about 2-3 percent).

The results of the path analysis for the combined data are illustrated in Figure 4.10. The figure indicates that intake of grazing cattle is positively related to grazing time and digestibility, and not significantly related to forage available (standard error substantially greater than the coefficient). Thus, as either grazing time and/or digestibility increases, intake increases. The indirect pathways for digestibility through grazing time indicate that the effect of *in vitro* dry matter digestibility on intake operates primarily through increases in grazing time allowed by increased digestibility as well as being a direct effect. The indirect pathways for forage available suggest that increases in forage available for grazing result in increased grazing times with concomitant increases in intake. In addition, increases in forage available results in increased amounts of highly digestible forage, hence increasing intake through increases in grazing time, as before.

Table 4.4. Simple correlations between environmental and dietary parameters for cattle grazing a northeastern Oregon riparian zone.

n=4

	INTAKE	CP[a]	IVDMD	NDF	ADF	LIGNIN	GTIME	FA
INTAKE	1.00							
CP	0.62	1.00						
IVDMD	0.67	0.99	1.00					
NDF	-0.21	-0.69	-0.70	1.00				
ADF	0.67	-0.05	-0.01	0.59	1.00			
LIGNIN	0.49	-0.37	-0.31	0.65	0.92	1.00		
GTIME	0.67	0.91	0.94	-0.85	-0.09	-0.29	1.00	
FA	0.29	0.84	0.90	-0.97	-0.50	-0.67	0.90	1.00
PREFFA	0.83	0.89	0.92	-0.70	0.14	-0.06	0.97	0.78

[a] - Acronyms as follows; CP - crude protein, IVDMD - in vitro dry matter digestibility, NDF - neutral detergent fiber, ADF - acid detergent fiber, Gtime - grazing time, and FA - the amount of forage available.

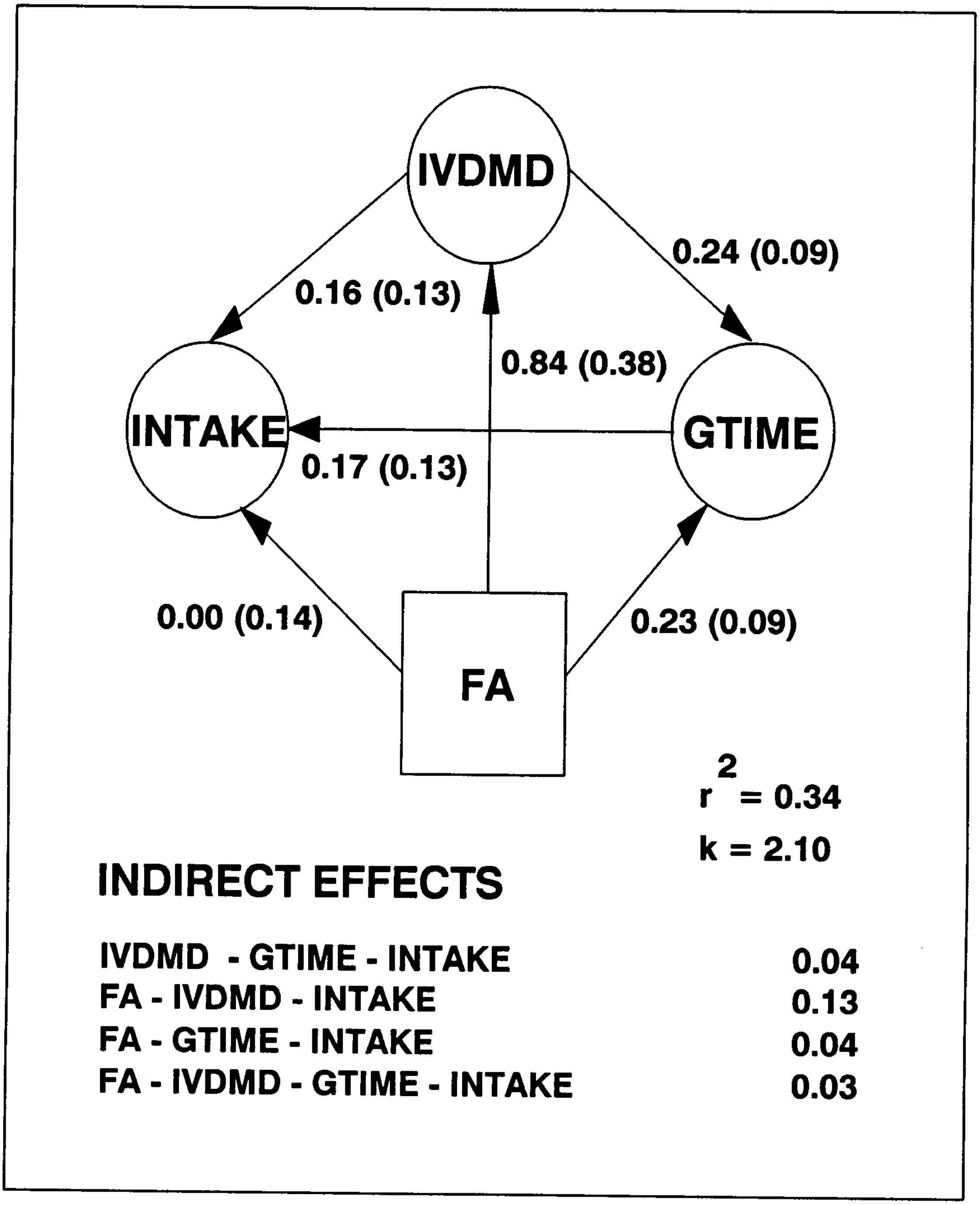

Figure 4.10. Path diagram for the combined (i.e. early and late in the grazing period) data describing intake of grazing livestock. Intake is described as being a function of *in vitro* dry matter digestibility (IVDMD), grazing time (GTIME) and the amount of forage available (FA). Numbers in parentheses indicate the approximate standard errors of the coefficients.

Conclusion

Conclusions which can be drawn from the results of this study concern the functioning of the grazing process, implications for management, and the data analysis technique. With regard to the grazing process, it appeared that livestock intake levels were related to both *in vitro* dry matter digestibility and grazing time and poorly related to the amount of forage available. The indirect effects of forage available were more important than the direct effect. Management schemes which capitalize upon the quality of forage available within riparian zones as a result of deferral from grazing until late in the year may realize increased weight gains and hence increased revenues, especially in dry years.

With regard to the path analysis technique a number of important conclusions can be drawn. First, the results obtained are largely a function of the model assumed. That is to say it is possible that other variables (e.g. behavior, social parameters, etc.) played a greater role in the ecological process under investigation than those measured. Second, the results of path analysis must be analyzed with care in order to understand the mechanisms at work. In this case quality rather than quantity of forage available in the pasture was the limiting factor throughout the grazing period. Thus the pathway from forage available to intake was not significant even though its sign was negative. The relative importance of this variable may increase under different grazing circumstances. In any case, one of the values of the path analysis technique lies in the active involvement of the researcher in utilizing theory to describe the data during the analysis procedure. This provides a logical follow-up to the common practice of interpreting axes derived from the use of many ordination programs as principal components or discriminant analysis. A second value to the technique lies in its ability to provide the researcher with a means of quantifying the indirect effects of independent upon dependent variables thus providing a fuller description of the ecological process under study. A final point to keep in mind concerning the use of path analysis was well put by Hermy (1987) when he indicated that path analysis is not intended to prove causation but rather to estimate the degree of assumed causation.

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CHAPTER 5

SUMMARY

SUMMARY

Investigation into the functioning of processes within the riparian system has resulted in the extension of our understanding of these systems. Biomass accumulation within different plant community types appears to be regulated in large measure by the ability of species within the community types to obtain moisture. Plant community preference and forage intake processes of cattle grazing the riparian zone appear reasonably well to follow theory developed in upland situations. Not generally included within theory about the grazing process, however, are the temporal changes in relative importance of the different elements composing grazing process theory. More research directed at the effects of temporal changes upon the relative magnitude of factors affecting the grazing process is warranted in both upland and riparian systems.

Management of the riparian zone as a late season special use pasture which attempts to take advantage of the quantity and quality of forage produced within the riparian zone provides a basis for increased livestock production. The quality of the forage resource supplied by the riparian zone provides for increased livestock weight gains over grazing management strategies which use upland pastures late in the grazing season.

The importance of preserving the integrity of riparian systems has focused a great deal of research upon attributes associated with riparian systems and their management. All of this research has been conducted with the intent of providing the scientific basis for the management of riparian systems in ways which preserve the integrity of both riparian and upland systems and provide for needs of society. Hopefully this research has contributed towards that end.

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APPENDIX

APPENDIX A

Development of the ridge regression template used for data analysis.

Biased estimation procedures for regression analysis have been developed for the purpose of avoiding some of the pitfalls associated with ordinary least squares analysis. These procedures are commonly used when the purpose of the analysis is to construct either descriptive or predictive models based upon sound theoretical grounds when partial correlations exist between potential independent variables within the data under examination. This partial correlation (multicollinearity) among independent variables frequently results in regression coefficients which are either highly unstable (i.e. they change drastically when new variables are added to the model) or of the wrong sign. Commonly used biased procedures include ridge regression, James-Stein estimation, fractional rank, generalized ridge regression and principal components regression.

Few commercial ridge regression packages include as a part of their output estimates of coefficient standard errors, estimates of r^2 or the error sum of squares. The reason for this is that the calculation of these estimates involves an assumption of normality about the coefficients. Because ridge regression coefficients are biased their distributional properties are unknown. This invalidates traditional significance tests involving the ridge regression coefficients. In addition, the value of k selected as a biasing constant influences both the value for r^2 and the resulting values for the standard errors of the regression coefficients. Nevertheless these statistics can be calculated and used in the interpretation of the models derived although valid tests for significance cannot be made.

The following template is designed to perform ridge regression analysis using the Lotus 123 menu structure included in Version 2 of Borland Corporation's Quattro Pro spreadsheet Program. The template is capable of analyzing a 256 column by 256 row data matrix given that the computer possesses adequate random access memory (RAM) to perform the necessary calculations. Output includes a table of ridge regression coeffecients for the range in k selected, a correlation matrix for the independent variables used, the regression coeffecients and approximate standard errors of the coeffecients for a specific value of k, an approximate value for r^2, an estimate of the total, regression and error sum of squares and a graph of the ridge trace. Output begins where the cursor is positioned at the conclusion of the analysis and expands to the right and downward depending upon the number of independent variables in the model. The author assumes a working familiarity with the operation of spreadsheet programs on the part of the reader, hence specific directions on how to import or enter data, begin macros, print graphs and other output and, most importantly, how not to destroy the functioning of the macro commands are not included as a part of this appendix. All that is required is that the reader enter the following text and macro commands in the appropriate cells, name the macros, enter data as required and be familiar with the general operation of the spreadsheet program.

The convention used for naming macros in this spreadsheet template is as follows:

	A	B
1	\a	macro commands
2		more macro commands
3		even more macro commands
4		
5	\b	macro commands
6		more macro commands
7		

The appropriate names for the above macros are \a and \b contained within the ranges addressed as B1..B3 and B5..B6.

Ridge Regression Template

```
A1: 'Ridge Regression Template
A2: 'Created by Ed Korpela
D2: 'Date 09-14-88
A4: 'Enter or import your data beginning in column I and row 1 to the
A5: 'appropriate ending row.
A7: '* Note that variable names should be in row 1 and that the dependent
A8: '  variable should be the last column on the right side of your data.
A10: 'Enter the beginning value for k here ------->
F10: 0
A11: 'Enter the ending value for k here ---------->
F11: 1
A12: 'Enter the number of iterations here ------->
F12: 10
A14: 'Press alt-s to standardize the dependent variables.
A15: 'Press alt-r to perform ridge regression without an intercept term.
A17: '* Note that standardization creates a correlation matrix as X'X.
```

```
A18: '* Note that template macro commands begin one screen below.
A21: 'enddn
B21: '{end}{down}
D21: 'endrt
E21: '{end}{right}
G21: 'endlt
H21: '{end}{left}
A23: '\s
B23: '{indicate BUSY!}{goto}il~/rnccount~.
B24: '{endrt}~/~ic~@count(count)-1~/rv~~{right}{down}/rncxes~.{endrt}
B25: '{enddn}~{left}0~{down}0~{down}1~{down}0~{end}{up}{branch \a}
A27: '\a
B27: '{for i2,i3,il,i4,b47}
B28: '{endlt}{right}{enddn}{enddn}/rv.{endrt}{enddn}~~/rncmeans~
B29: '.{endrt}~{down}/rncstds~.{endrt}~{endrt}{right}0~{endlt}
B30: '{down}/c.{endrt}~{down 2}~{down 2}{right}{branch \b}
A32: '\b
B32: '{for i5,i3,il,i4,b52}
B33: '{goto}count~{down}{left}/re.{enddn}~1~/c~.{right}{enddn}{left}~
B34: '/rncones~.{enddn}~{enddn}{right}{enddn}{down}{endrt}/re.{endrt}
B35: '{enddn}~{left}{endlt}{enddn}{down 2}{enddn}/c~{up}~/c~.
B36: '{down il}~{end}{up}{down il}{down}/re.{endrt}{enddn}~{up}{end}
B37: '{up}/rncxd~.{endrt}{enddn}~/mxd~{up}~{up 2}/re.{endrt}~{up}
B38: '{end}{up}{end}{up}{end}{up}{down}{endrt}{right 2}/dmmones~
B39: 'means~~/rnccell~~/rnctemp~.{endrt}{enddn}~{enddn}{down 2}
B40: '/ctemp~~+j2-cell~/c~.{endrt}{enddn}~/rv.{endrt}{enddn}~~
B41: '/rndtemp~~/rnctemp~.{endrt}{enddn}~{enddn}{down 2}/dmmtemp~xd~~
B42: '/retemp~{end}{up}{end}{up}/rndtemp~/rnctemp~.{endrt}{enddn}~
B43: '{endlt}{down}/ctemp~xes~/retemp~/rndtemp~/rndones~/rexd~/rndxd~
B44: '/rndxes~/rndcount~/rndcell~{goto}il~/~dc~
B45: '{home}{down 11}{right 5}{quit}
A47: '\c
B47: '{right}{down}/rncvar~.{enddn}~{enddn}{down 2}@avg(var)~{down}
B48: '@sqrt((@count(var)/(@count(var)-1))*@var(var))~{down}
B49: '+1/((@sqrt((@count(var)/(@count(var)-1))*@var(var)))
B50: '*(@sqrt((@count(var))-1)))~{end}{up}{end}{up}{end}{up}/rndvar~
A52: '\d
B52: '/c.{endrt}~{down}~0~/c~.{right il}~{down 2}0~/c~.{down il}~
B53: '/c~{left}~{up}{right}
A55: '\r
B55: '{goto}il~/wic~^INT~/rncnms~{esc}{right}.{endrt}{left}~{down}1~
B56: '/c~.{right}{enddn}{left}~{right}/rncx~.{endrt}{left}{enddn}~
B57: '/rncy~{esc}{endrt}.{enddn}~{left}/rtx~{home}{pgdn 15}~{home}
B58: '{pgdn 15}/rnctx~.{endrt}{enddn}~{goto}il~{endrt}{right 2}{down}
B59: '/dmmtx~x~~/rncxtx~.{endrt}{enddn}~/rncinitial~~/c.{endrt}
B60: '{enddn}~{enddn}{down 2}~/rnccorr~.{endrt}{enddn}~{enddn}
B61: '{down 2}/rnckstart~~0~/c~.{endrt}{enddn}~/rnckm~.{endrt}
B62: '{enddn}~{endrt}{enddn}{right}{down}+$f$94+$f$92~{goto}
B63: 'kstart~/c.{endrt}{enddn}~{enddn}{down 2}~{branch \e}
A65: '\e
B65: '{down}{right}/rncdup~~{branch \f}
A67: '\f
```

```
B67: '{if dup=$f$94+$f$92}{branch \h}
B68: '{branch \g}
A70: '\g
B70: '+kstart~/rnddup~{branch \e}
A72: '\h
B72: '{goto}kstart~/rnddup~{enddn}{down 2}+initial+kstart~
B73: '/c~.{endrt}{enddn}~/rnctoinvert~.{endrt}{enddn}~{enddn}{down 2}
B74: '/dmitoinvert~~/rncinvtd~.{endrt}{enddn}~/dmm~y~{enddn}
B75: '{enddn}{enddn}{enddn}{enddn}{enddn}{enddn}{down 2}~{enddn}
B76: '{down 2}/rnctxy~.{enddn}~{enddn}{down 2}/dmminvtd~txy
B77: '~{enddn}{down 2}{right}~/rnctmp~~/rtnms~tmp~/rnctmpn~.{enddn}~
B78: '{right}/rncbrs~.{enddn}~{goto}tx~{enddn}{down 2}/rty~~/rncty~
B79: '.{endrt}~{down 3}{right}/ctmpn~~{left}**~/c~.{right}{enddn}
B80: '{left}~/rndtmp~/rndtmpn~{goto}kstart~{branch \i}
A82: '\i
B82: '{for f95,f93,f94,f92,b89}
B83: '{goto}tx~{enddn}{down 4}**~{right}^K~{right}0~/rncno~~{right}
B84: '+no+$f$92~/c~.{down}{endrt}{up}~/rv.{endrt}~~{endlt}/re.{enddn}
B85: '~{right}/m.{endrt}{enddn}~{left}~{left}/rnccoeffs~.{endrt}
B86: '{enddn}~/rtcoeffs~{enddn}{down 2}~{enddn}{down 2}/rndcoeffs~
B87: '/rnccoeffs~.{endrt}{enddn}~{down}/rndno~{branch \k}
A89: '\j
B89: '{goto}kstart~+f95~{calc}/dmi~~/dmmtx~y~txy~/dmminvtd~
B90: 'txy~brs~{goto}tx~{enddn}{down 5}{endrt}{right}/cbrs~~
A92: 'The appropriate criterion interval is ------>
F92: (F11-F10)/F12
A93: 'The beginning value for the counter is ----->
F93: +F10
A94: 'The ending value for the counter is -------->
F94: +F11
A95: 'The counter cell is f95.
F95: 0.5
A97: '\k
B97: '{endrt}{right}0~{endlt}{right 2}/rnctestb~~{right}/rnctestc~~
B98: '{right}/rnctestd~~{right}/rncteste~~{right}/rnctestf~~{left 5}
B99: '{up}/rncaa~~{right}/rncbb~~{right}/rnccc~~{right}/rncdd~~
B100: '{right}/rncee~~{right}/rncff~~{left 6}{down}/gtxx.{enddn}~q
B101: '{right}/ga.{enddn}~ola{aa}~fabqqq{right}{branch \l}
A103: '\l
B103: '{if testb=0}{branch \m}
B104: '{if testc=0}{branch \n}
B105: '{if testd=0}{branch \o}
B106: '{if teste=0}{branch \p}
B107: '{if testf=0}{branch \q}
B108: '{branch \t}
A110: '\m
B110: '{left}{branch \u}
A112: '\n
B112: '/gb.{enddn}~olb{bb}~fbbqqq{left 2}{branch \u}
A114: '\o
B114: '/gb.{enddn}~olb{bb}~fbbqqq{right}/gc.{enddn}~olc{cc}~fcbq
B115: 'qq{left 3}{branch \u}
```

```
A117: '\p
B117: '/gb.{enddn}~olb{bb}~fbbqqq{right}/gc.{enddn}~olc{cc}~fcbqqq
B118: '{right}/gd.{enddn}~old{dd}~fdbqqq{left 4}{branch \u}
A120: '\q
B120: '/gb.{enddn}~olb{bb}~fbbqqq{right}/gc.{enddn}~olc{cc}~fcbqqq
B121: '{right}/gd.{enddn}~old{dd}~fdbqqq{right}/ge.{enddn}~ole{ee}~
B122: 'febqqq{left 5}{branch \u}
A124: '\t
B124: '/gb.{enddn}~olb{bb}~fbbqqq{right}/gc.{enddn}~olc{cc}~fcbqqq
B125: '{right}/gd.{enddn}~old{dd}~fdbqqq{right}/ge.{enddn}~ole{ee}~
B126: 'febqqq{right}/gf.{enddn}~olf{ff}~ffbqqq{left 6}{branch \u}
A128: '\u
B128: '/gotfRIDGE TRACE~txK VALUE~tyCOEFFECIENT~gbqofmbiqqqq/gooogbq
B129: '/gncRidge~rgq/rndtestb~/rndtestc~/rndtestd~/rndteste~/rndtestf~
B130: '/rndaa~/rndbb~/rndcc~/rnddd~/rndee~/rndff~{endrt}/re~/gnu~q
B131: '{branch \v}
A133: '\v
B133: '{goto}brs~{enddn}{down 2}{left}
B134: 'Enter an appropriate value for k here ------>~{right 5}{?}~
B135: '/rnckk~~/c~kstart~/c~f95~{goto}kstart~{\j}{goto}brs~{right 2}
B136: '/rtbrs~~/rnctbrs~.{endrt}~{left 2}{enddn}{down 2}{left}{down 2}
B137: '/dmmty~y~{esc}{enddn}{down 4}{left}~/rncytot~~{down}+ytot-
B138: '((@count(y))*((@avg(y))^2))~/rv~~/rnctssadj~~{up}/dmmty~x~~
B139: '/c.{endrt}~{down 3}~/re.{endrt}~{down 3}/rnctemp1~.{endrt}~
B140: '/dmmtemp1~brs~ytot~/retemp1~{goto}tbrs~/rnctemp2~~{down}
B141: '+temp2*$kk~/c~.{up}{endrt}{down}~/rv.{endrt}~~/rndtemp2~
B142: '/c.{endrt}~{up}~/re.{endrt}~{goto}ytot~/c~{right}~{right}
B143: '/rndtemp1~/rnctemp1~~/dmmtbrs~brs~~{down 2}{left}+ytot+temp1~
B144: '/rv~~/rndtemp1~/rndytot~/rncssrbr~~{down}+tssadj-ssrbr~/rv~~
B145: '/rncssebr~~{down}+ssebr/(@count(y)-(@count(nms)+1))~/rv~~
B146: '/rncsigma~~{down}+ssrbr/tssadj~/rv~~/rncr^2~~{end}{up}
B147: '/re.{right}~{down}/m.{enddn}~{up}~/dmminvtd~tx~{enddn}
B148: '{down 4}~{enddn}{down 4}/rnctemp1~.{endrt}{enddn}~/dmmtemp1~x~
B149: '{enddn}{down 2}~{enddn}{down 2}/rnctemp2~.{endrt}{enddn}~/dmm
B150: 'temp2~invtd~{enddn}{down 2}~{enddn}{down 2}/rnctemp3~.{endrt}
B151: '{enddn}~/retemp1~/retemp2~/ctemp3~temp1~/retemp3~/rndtemp1~/rnd
B152: 'temp2~/rndtemp3~{end}{up}{end}{up}{up}/rnccomp~~@count(nms)-2~
B153: '/rv~~{right}/rncstart~~0~{right}/rncend~~+comp~/rv~~{right}1~
B154: '/rncinc~~/retbrs~/rndtbrs~{endlt}/rnccount~~0~{down}{branch \w}
A156: '\w
B156: '{for count,start,end,inc,b171}
B157: '/rndcount~/rndstart~/rndend~/rndinc~{endlt}{end}{up}
B158: '/re.{endrt}~{down}/rncsquare~~{right}@sqrt((square*$sigma))~
B159: '/c~.{left}{enddn}{right}~/rv.{enddn}~~/rndsquare~/rndcomp~
B160: '/rncses~.{enddn}~{left}/re.{enddn}~{goto}brs~{right}/mses~~
B161: '{endlt}{enddn}{enddn}{enddn}/m.{enddn}~{right}~SSTOT~{down}
B162: 'SSRbr~{down}SSEbr~{down}sigma^2~{down}Rsquare~{goto}nms~
B163: '/rncnms~{right}~{goto}brs~{left}/rtnms~~{endrt}{right 2}
B164: '/rtmeans~~{right}/rtstds~~{endlt}{endlt}{left}{up}Kbetas~
B165: '{right}SEkbetas~{right 2}Mean~{right}Std~{endlt}{endlt}{endlt}
B166: '{left}{down}{enddn}/re~{down}Kvalue~{right}+kk~/rv~~{left}
B167: '/rekk~/rndkk~{enddn}{down 2}/ccoeffs~~{enddn}{down 3}{right}
```

```
B168: '/ccorr~~{left}/rtnms~~{up}{right}/cnms~~{goto}brs~{left}{up}
B169: '{indicate}{quit}
A171: '\x
B171: '{right}/re.{endrt}~{down}/c~{endlt}~/re.{enddn}~
```