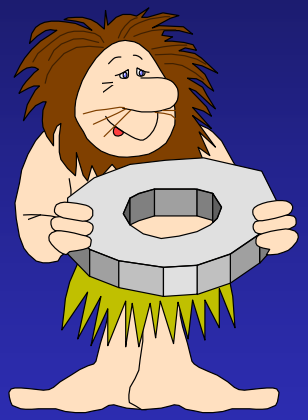
Prairie Cluster

Long-term
Ecological
Monitoring

Prototype Confessions . . . . .

We did not initiate the Prairie Cluster Prototype Program with formal planning process -- convening panels of experts. We recently reviewed monitoring components within context of ecosystem models rather late in the design phase.



Prairie Cluster Monitoring Components

Terrestrial and Aquatic Ecosystems

Landscape Monitoring

- Adjacent land use

Terrestrial Ecosystem

Community Monitoring

- Plant communities
- Grassland birds[1]
- Grassland butterflies[1] [4]

Population Monitoring

- State-listed T&E plants
- Missouri bladderpod (*Lesquerella filiformis*)[*]
- Western prairie fringed orchid (*Platanthera praeclara*)[*]
- Black-tailed prairie dog (*Cynomis ludovicianus*)

Environmental Monitoring

- Local weather (related to L. filiformis and P. praeclara dynamics)[2]

Aquatic Ecosystem

Community Monitoring

- Macroinvertebrates as indicators of stream health

Population Monitoring

- Topeka shiner (*Notropis topeka*)[3 *]

[*] Federally threatened or endangered species

[1] Phase II (moderate priority) in original proposal

[2] Not included in original proposal

[3] No park occurrence record at time of original proposal

[4] Not implemented

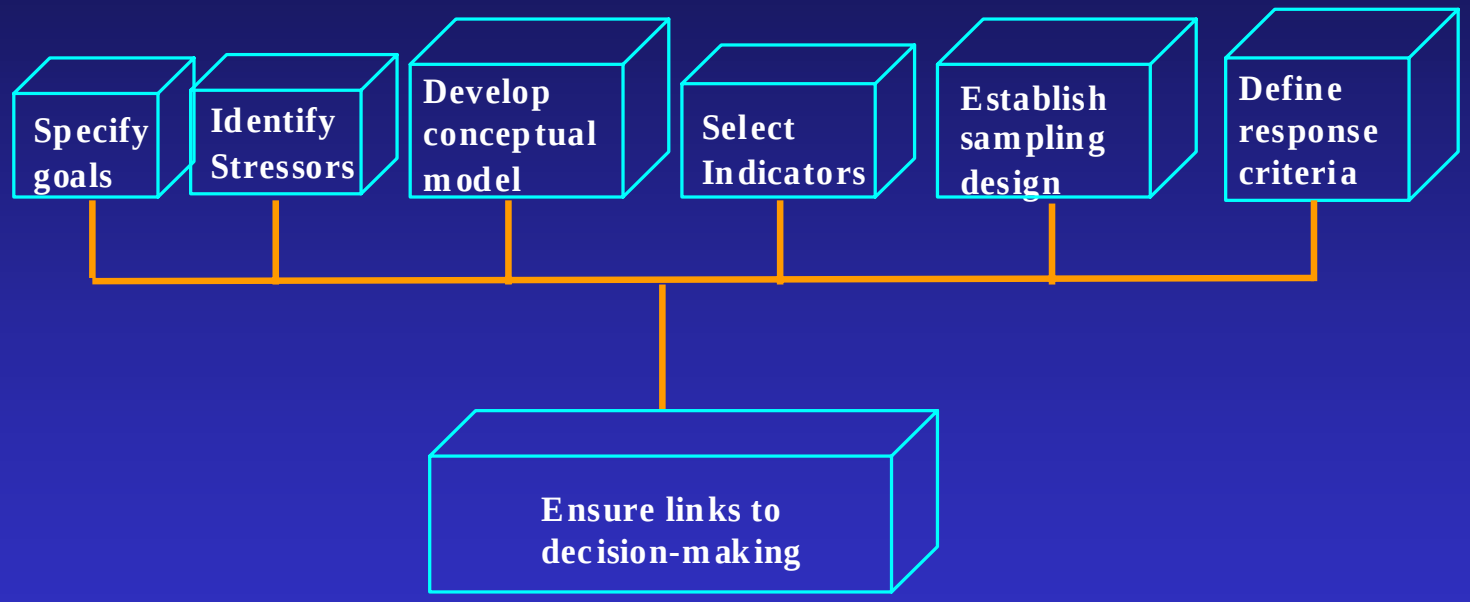
Heartland Inventory and Monitoring Network

Prairie Cluster LTEM

Goals of NPS Monitoring Program

- Determine status and trends of the health of park ecosystems
- Establish normal limits of variation in key park resources
- Provide early warning of resource decline
- Evaluate the effectiveness of resource management practices
- Develop a predictive understanding of environmental change

Steps in the Design of a Monitoring Program



From Noon et al. 1999

Stressor

disturbance events that result in significant ecological effects -- these effects can be either positive or negative; proximate causes of effects on an organism or system

Indicator

biotic or abiotic features of the environment that can be measured; referred to as "indicators" under the assumption that their values are somehow indicative of the quality, health or integrity of the larger system to which they belong.

Retrospective or Effects --Oriented Monitoring **seeks to find effects by detecting changes in status or condition of some organism, population, or community. It is retrospective in that it is based on detecting an effect after it has occurred. It does not assume any knowledge of cause-effect relationships. This includes most of the monitoring in national parks, such as measuring changes in foliage condition of trees, size or trends in animal populations, or diversity of aquatic macroinvertebrates in streams, and it takes advantage of the fact that biological indicators integrate conditions over time.**

Predictive or Stressor -- Oriented Monitoring **seeks to detect the known or suspected cause of an undesirable effect before the effect has had a chance to occur or become serious (e.g. stress levels along a geologic fault, presence of carcinogens in animal tissue, canary in a coal-mine). It is predictive in that the cause-effect relationship is known, so that if the cause can be detected early, the effect can be predicted before it occurs. Predictive monitoring is not commonly used in national parks because our knowledge of ecosystem processes is still poor and cause-effect relationships have often not been established.**

National Research Council. 1995. Review of EPA's Environmental Monitoring and Assessment Program.

The NRC concluded that in cases where the cost of failing to detect an effect early is high, use of predictive monitoring and modeling is preferred over retrospective monitoring. They concluded that traditional retrospective monitoring was inappropriate for environmental threats such as acid precipitation, exotic species effects, ozone depletion, and biological extinctions, because of the large time lag required for mitigation, and recommended that EPA investigate new indicators for monitoring these threats.

Effects-oriented monitoring does not require knowing a cause-effect relationship, but if stressors and effects are both included in the monitoring, then analyses may be directed at establishing cause-effect relationships.

Anticipatory Monitoring **does not require monitoring ecological condition or assessment of endpoints of interest. It attempts to detect effects as they are occurring by measuring anticipatory indicators, rather than describing effects after they have occurred. Its success depends on the validity of the assumed cause-effect relations among the stressor(s), their ecological effects, and the selected indicators of stress. This approach carries the risk of failing to detect the ecological effects of significant but unanticipated stressors.**

Noon et al. 1999

Monitoring objectives may be met through one or a combination of:

- **Effects-Oriented Monitoring**
  (detect change in resource status or condition)

- **Stressor- Oriented Monitoring**
  (cause-effect relationship known)

- **Anticipatory Monitoring**
  (hypothesized model of stressors, effects, and 'anticipatory indicators')

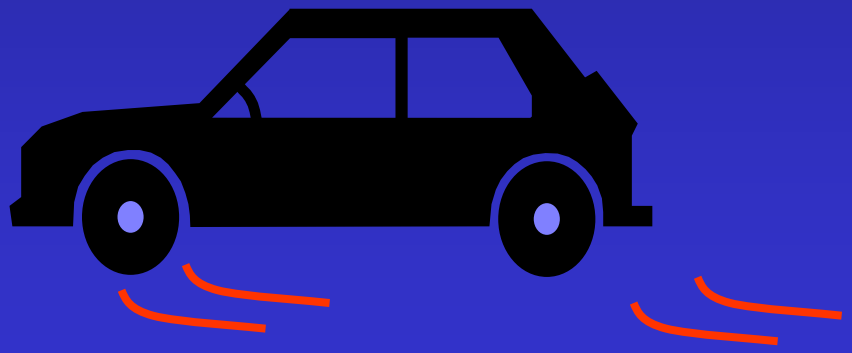
Example Monitoring Objective: **Are park populations of the federally endangered black-footed ferret stable?**

Is black-footed ferret population size stable?
Is the incident rate of canine distemper on the rise?
How is the abundance of black-tailed prairie dogs changing?

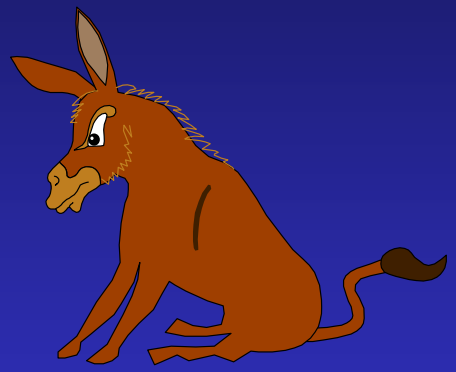
A conceptual model is a mental picture of how something works….

We have a conceptual model of a car that allows us to drive by relating certain actions (e.g. pressing the brake pedal) to certain results (e.g. the car stops).

We don’t have to understand automotive engineering for our driving model to work. But if we need to repair the engine, a different model would be required.



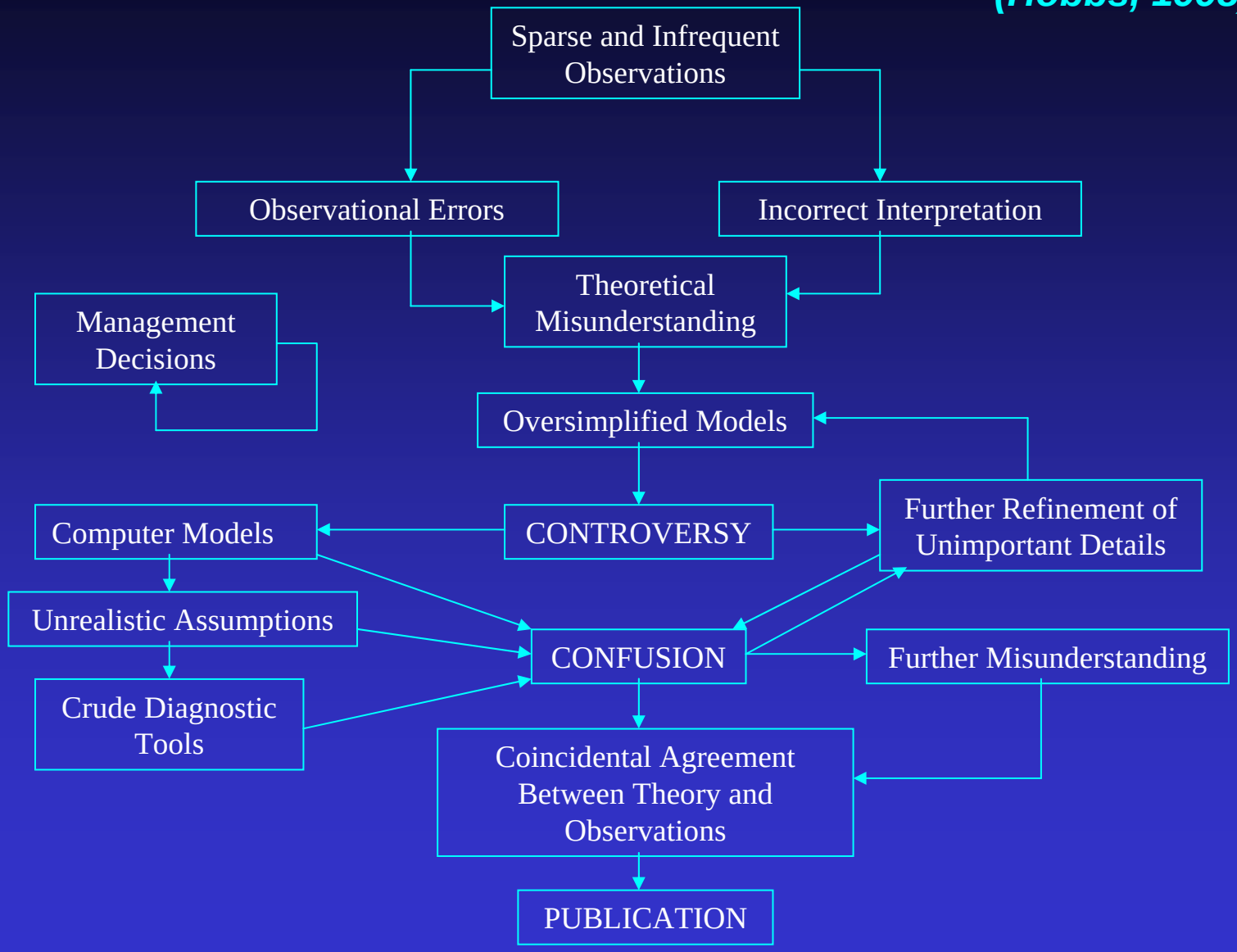
Why Aren't Conceptual Models Routinely Used to Develop Ecological Monitoring?



- Cynicism regarding utility of modeling
- Incomplete understanding of ecosystem function
- Confusion over modeling objectives

Cynic's View of Interface Between Ecological Research and Management

(Hobbs, 1998)



Tactical Models versus **Strategic Models**

(May 1973)

attempt to measure all relevant factors and determine how they interact

way of formalizing generalizations about the ecological system of interest

---

"a purposeful representation of reality" *(Starfield et al. 1994)*

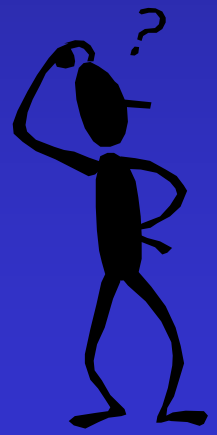
Common Misconceptions *(Starfield et al. 1997)*

A model cannot be built with incomplete understanding.
Managers make decisions with incomplete information all the time! This should be an added incentive for model-building as a statement of current best understanding.

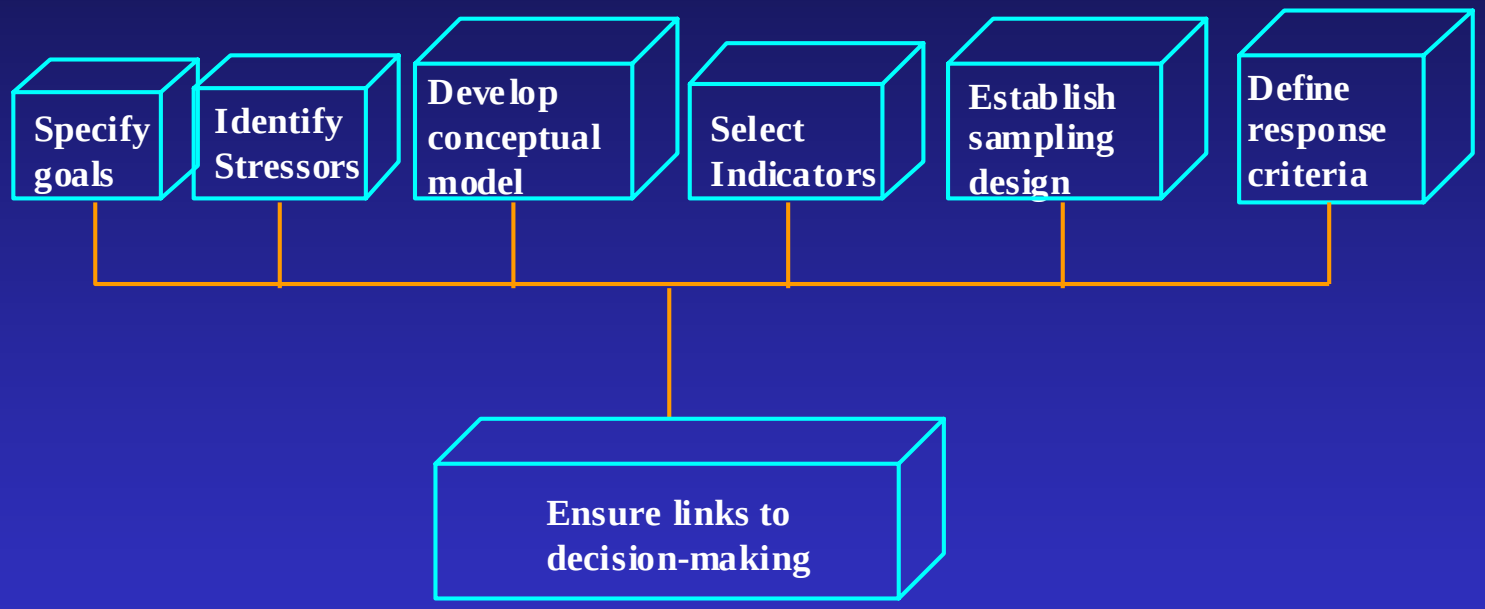
A model must be as detailed and realistic as possible.
If models are constructed as 'purposeful representations of reality', then design the leanest model possible. Identify the variables that make the system behave and join them in the most simple of formal structures.

Modeling Confusion?

- Conceptual Models of Indicator Selection Process
- Conceptual Ecosystem Models
- Small, Focused Models -- Conceptual or predictive models of populations or communities
- Holistic Program Models -- Conceptual models of how monitoring information will feed back into decision-making process

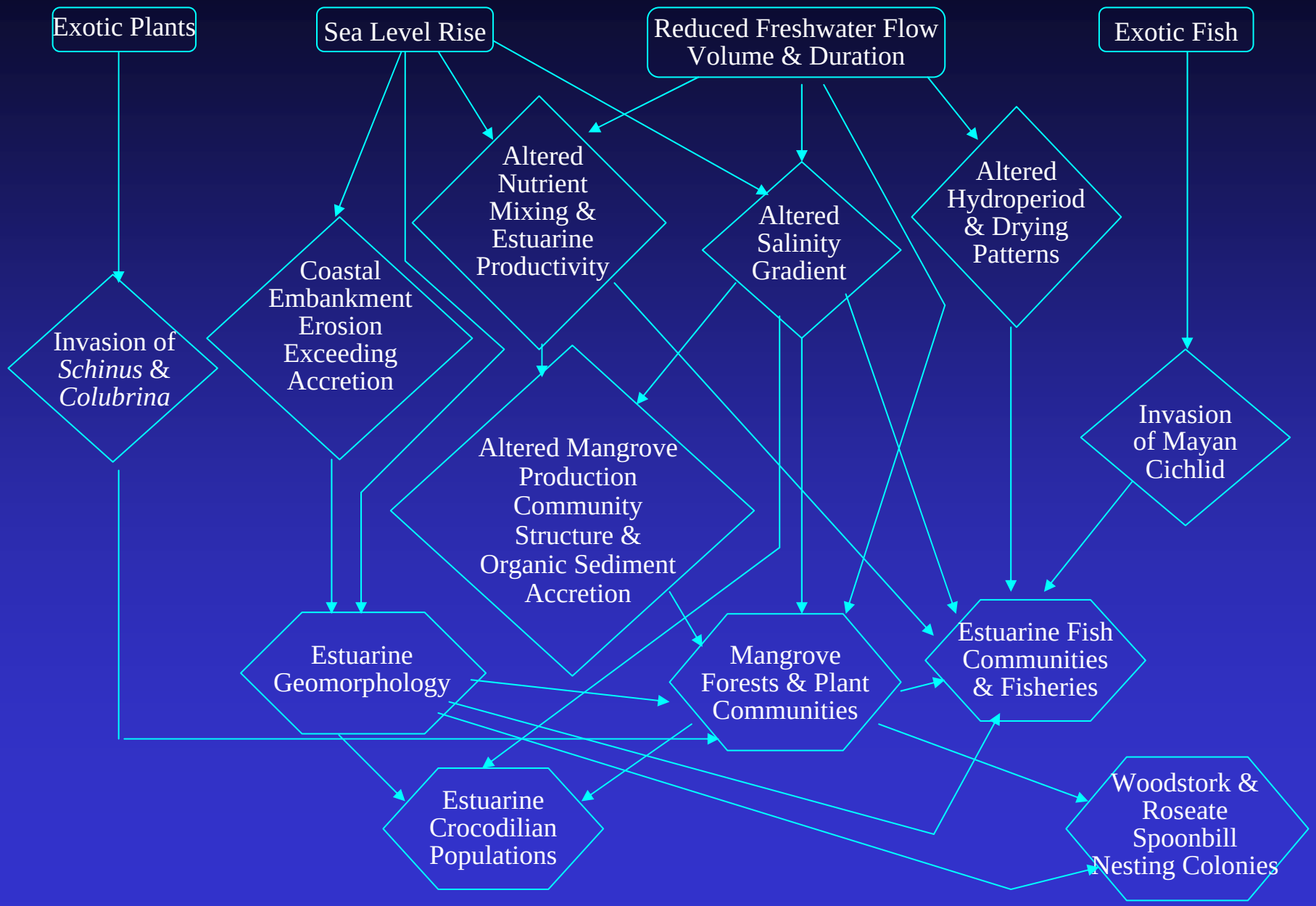


Conceptual Model of Indicator Selection Process



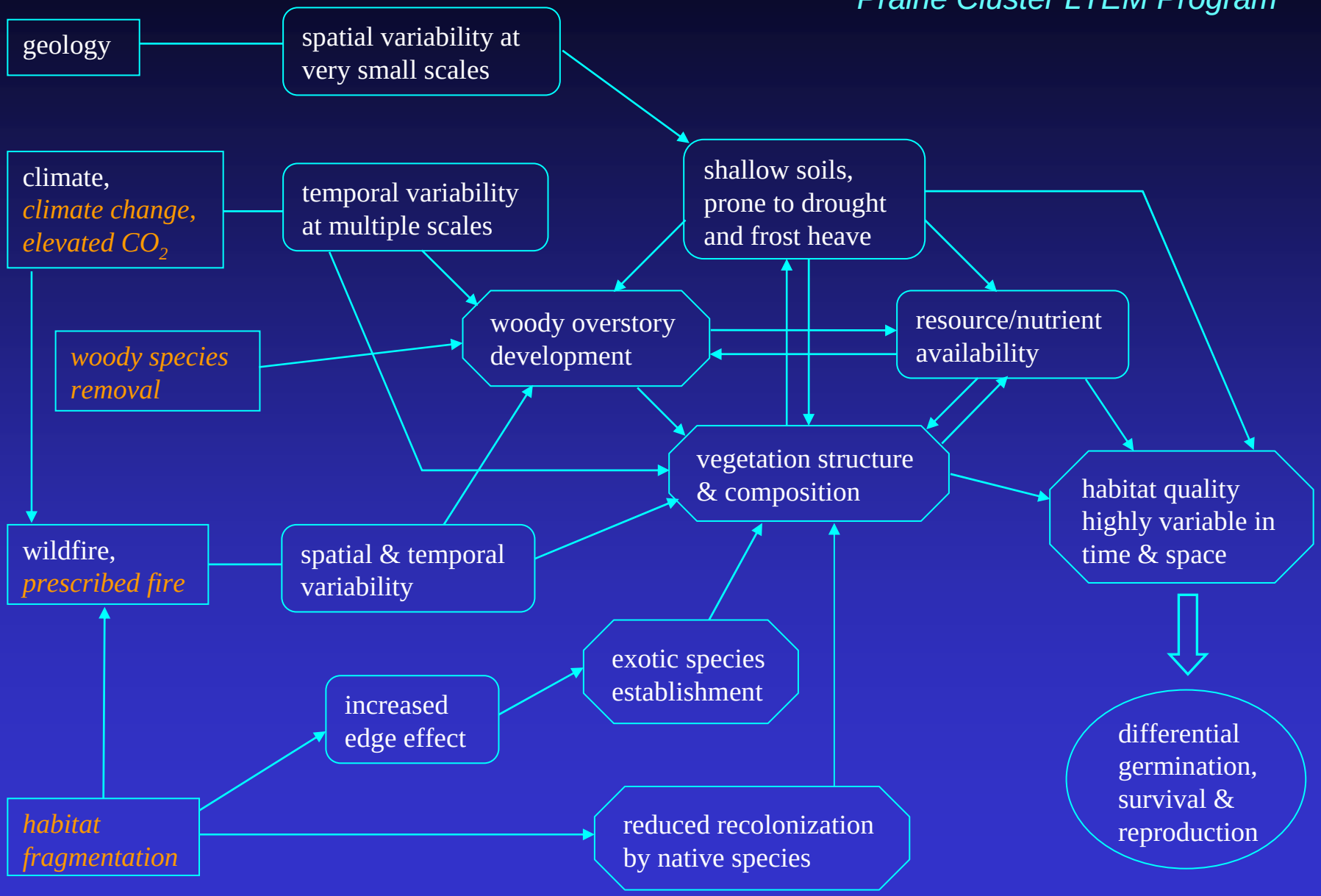
From Noon et al. 1999

Conceptual Ecosystem Model: South Florida Mangrove Estuary Transition



Small Focused Model: Influences on Missouri bladderpod Habitat Quality

Prairie Cluster LTEM Program



Holistic Program Model: Prairie Cluster Prototype Monitoring Program

Are prairie remnants sustainable within small parks?

	Threats	Indicators of Ecosystem Health	Resource Actions
Landscape	How is external land use changing? Are land-use changes affecting prairie remnants?	Is the proximity or size of nearby prairie remnants changing?	How is prescribed fire affecting prairie plant communities?
Community	Is the water quality of prairie streams declining? Where are are invasive exotics distributed within and adjacent to the park?	Do prairie streams support diverse macroinvertebrate communities? Do small prairie remnants support diverse native plant communities?	Are restoration methods working? Is rare species habitat protection & restoration working?
Population	Are rare species re-colonization sources disappearing?	Do small prairie remnants support diverse butterfly and bird communities? Are rare species populations stable?	Are exotic control efforts effective?

Why Do We Need Conceptual Ecosystem Models?

Short Answer:

“You got to be very careful if you don’t know where you’re going, because you might not get there.”

-- Yogi Berra

Why Do We Need Conceptual Ecosystem Models?

Long Answer #1:

Despite the complexity of ecosystems and the limited knowledge of their functions, to begin monitoring, we must first simplify our view of the system. The usual method has been to take a species-centric approach, focusing on a few high-profile species; that is those of economic, social, or legal interest. Because of the current wide (and justified) interest in all components of biological diversity, however, the species-centric approach is no longer sufficient. This wide interest creates a conundrum; we acknowledge the need to simplify our view of ecosystems to begin the process of monitoring, and at the same time we recognize that monitoring needs to be broadened beyond its usual focus to consider additional ecosystem components.

Noon et al. 1999

Why Do We Need Conceptual Models?

Long Answer #2:

Monitoring data are intended to detect long-term environmental change, provide insights into the ecological consequences of change and help decision-makers determine if observed change indicates a correction to management practices (Noon et al. 1999).

Detecting meaningful change is complex because natural systems are inherently dynamic and spatially heterogeneous. Changes in time may not be the result of human-induced effects, but rather the result of intrinsic variability of natural systems (e.g. stochastic or cyclic variation, succession). Generally, extrinsic drivers of change arising from human impacts are of greater interest to environmental monitoring programs than intrinsic factors.

One goal of a monitoring program is to filter out the effects of expected intrinsic variation from the additive, human-induced patterns of change (Noon et al. 1999).

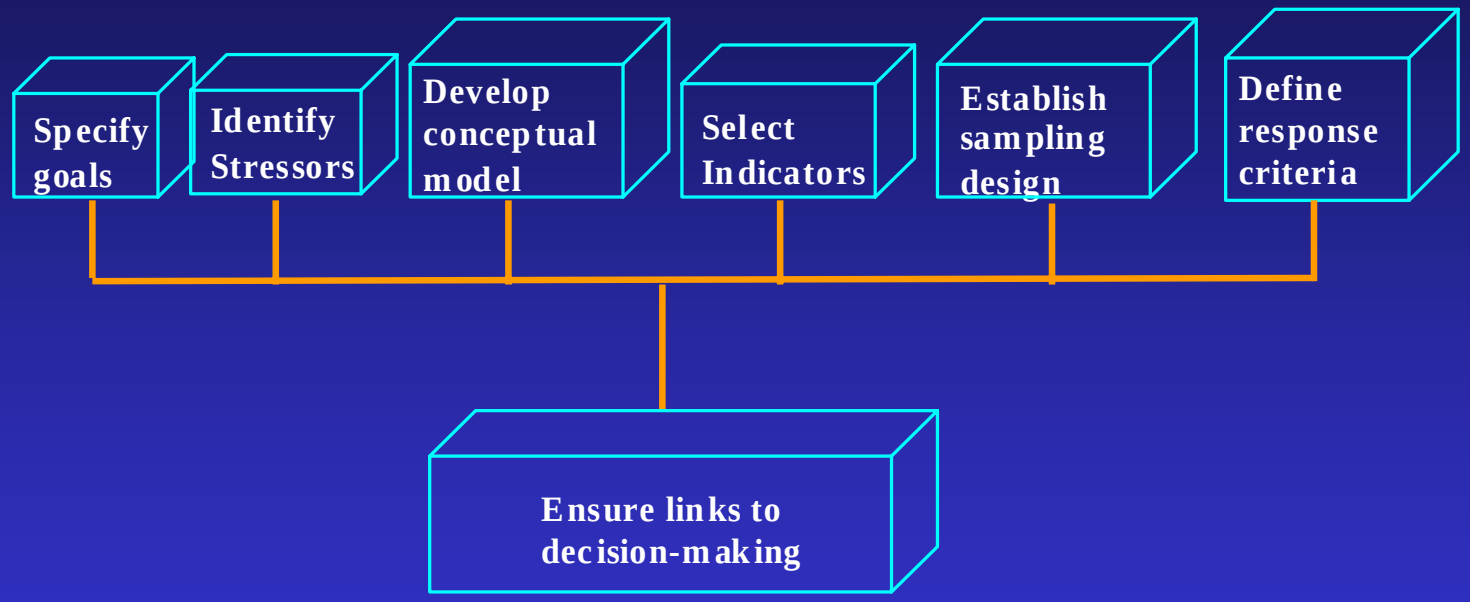
Conceptual models are useful throughout the monitoring process:

- formalize our current understanding of the context and scope of the natural processes and anthropogenic stressors affecting ecological integrity
- help expand our consideration across traditional discipline boundaries

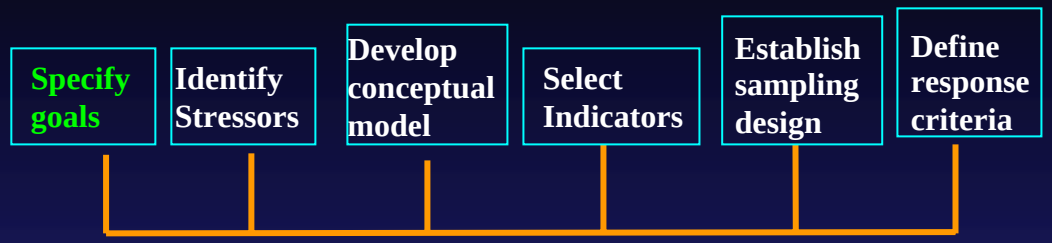
Most importantly, clear, simple models facilitate communication between:

- scientists from different disciplines
- researchers and managers
- managers and the public

Steps in the Design of a Monitoring Program



From Noon et al. 1999



Step 1: Develop Monitoring Objectives

By first considering the most significant park natural resources and resource issues, we are better able to define monitoring objectives.

Tallgrass Prairie Resources
prairie ecosystems
native tallgrass prairie
restored tallgrass prairie
oak savanna/woodland
prairie streams
riparian corridors, wetlands
springs, caves
unique habitats
grassland birds
grassland herpetofauna
T&E species
Missouri bladderpod
Western prairie fringed orchid
Tpoeka shiner
Gray bat
state-listed rare species

Heartland Network: Tallgrass Prairie Parks Most Significant Natural Resource Issues

- Managing remnant prairies and savannas with prescribed fire
- Restoring prairie/savanna vegetation to recreate historic landscapes
- Controlling invasive exotic species
- Managing T&E species habitats to maintain stable populations
- Maintaining integrity of unique habitats and their associated flora/fauna
- Providing adequate habitat for grassland bird and herpetofauna communities
- Preventing deer impacts associated with shrinking adjacent habitat
- Declining stream water quality associated with external development and landuse
- Controlling visitor use to minimize resource impacts

- **Natural resources that NPS is mandated to monitor and protect**

  federally listed T&E species

  other legislated mandates

  Examples:

  Are park populations of the federally endangered black-footed ferret stable?

  Is the park maintaining high-quality black-footed ferret habitat?

- **Monitoring questions relating to natural resource threats**

  Examples:

  Is the water quality of Cub Creek declining?

  Is pollution altering the biotic integrity of the creek?

  Are invasive exotic species displacing native plant species in prairies?

  Is an increase in deer abundance affecting woodland species diversity?

- **Monitoring questions relating to natural resource management practices**

  Examples:

  Is the prescribed fire regime maintaining healthy native prairie?

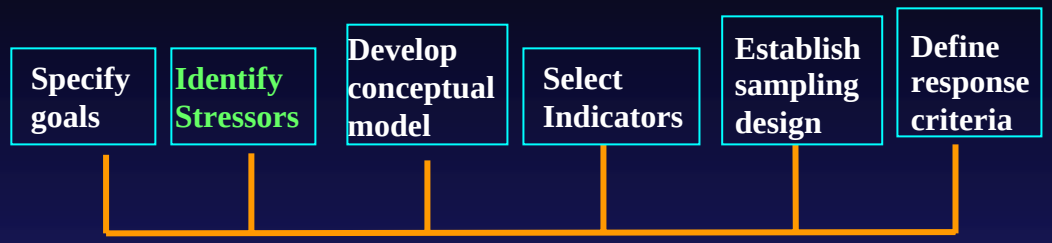
  Are restoration practices achieving model community structure & composition?

- **Monitoring directed toward assessing long-term ecosystem health**

  Identify the most significant natural resources of your park

  Example:

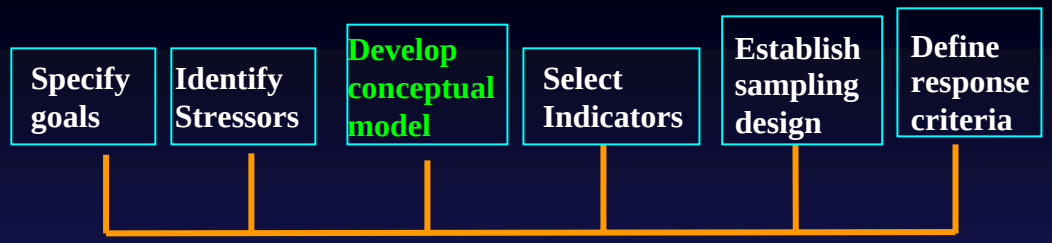
  Does the prairie support a diverse assemblage of flora and fauna?



Step 2: Identify Stressors

Stressor ***disturbance events that result in significant ecological effects -- these effects can be either positive or negative; proximate causes of effects on an organism or system***

Stressor	Resource at Risk	Effect	Monitoring Question
Grazing-related water pollution	Water quality	Increased nutrient enrichment, increased algal growth, decreased DO	Is grazing-related water pollution altering abiotic or biotic stream integrity?
Agri-chemical water pollution	Water quality	Increased contaminant levels	Are agri-chemical contaminant levels increasing? Are increased contaminant levels resulting in altered biotic integrity?
Water diversion, ground water pumping	Water quantity	Decreased or disrupted stream flow	Is water diversion decreasing or disrupting stream flow? Is water diversion disrupting biotic stream integrity?
Unrestricted cattle access to springs & streams	Water quality	Increased sedimentation, decreased water clarity	Are sedimentation rates and water clarity changing? Is sedimentation resulting in altered biotic stream integrity?
Stocking of exotic or predatory fish	Fish communities	Altered community composition, decline of rare species	Is the presence of exotic or predatory fish altering community composition? Are rare species populations stable in presence of exotic or predatory fish?



Step 3: Develop Conceptual Models

Aspects to Consider as Conceptual Models are Developed

from Barber (1994)

1. **Identify the structural components of the resource, interactions between components, inputs and outputs to surrounding resources, and important factors and stressors that determine the resource's ecological operation and sustainability.**

2. **Consider the temporal and spatial dynamics of the resource at multiple scales because information from different scales can result in different conclusions about resource condition.**

3. **Identify how major stressors of resource are expected to impact its structure and function**

Are we monitoring the right things?

Lengthy period to develop and test protocols, establish baseline conditions

- **Are we monitoring the right components to detect a decline in ecological integrity?**
- **Is the monitoring program relevant to park natural resource management?**

Thomas, L.P., M.D. DeBacker, J.R. Boetsch and D.G. Peitz. 2001. Conceptual framework, monitoring components and implementation of a NPS long-term ecological monitoring program: Prairie Cluster Prototype Program status report.

Summarizing Key Characteristics and Drivers of Prairie Ecosystems

Collins, S.L. and L.L. Wallace. 1990. *Fire in North American Tallgrass Prairies.* University of Oklahoma Press, Norman, Oklahoma.

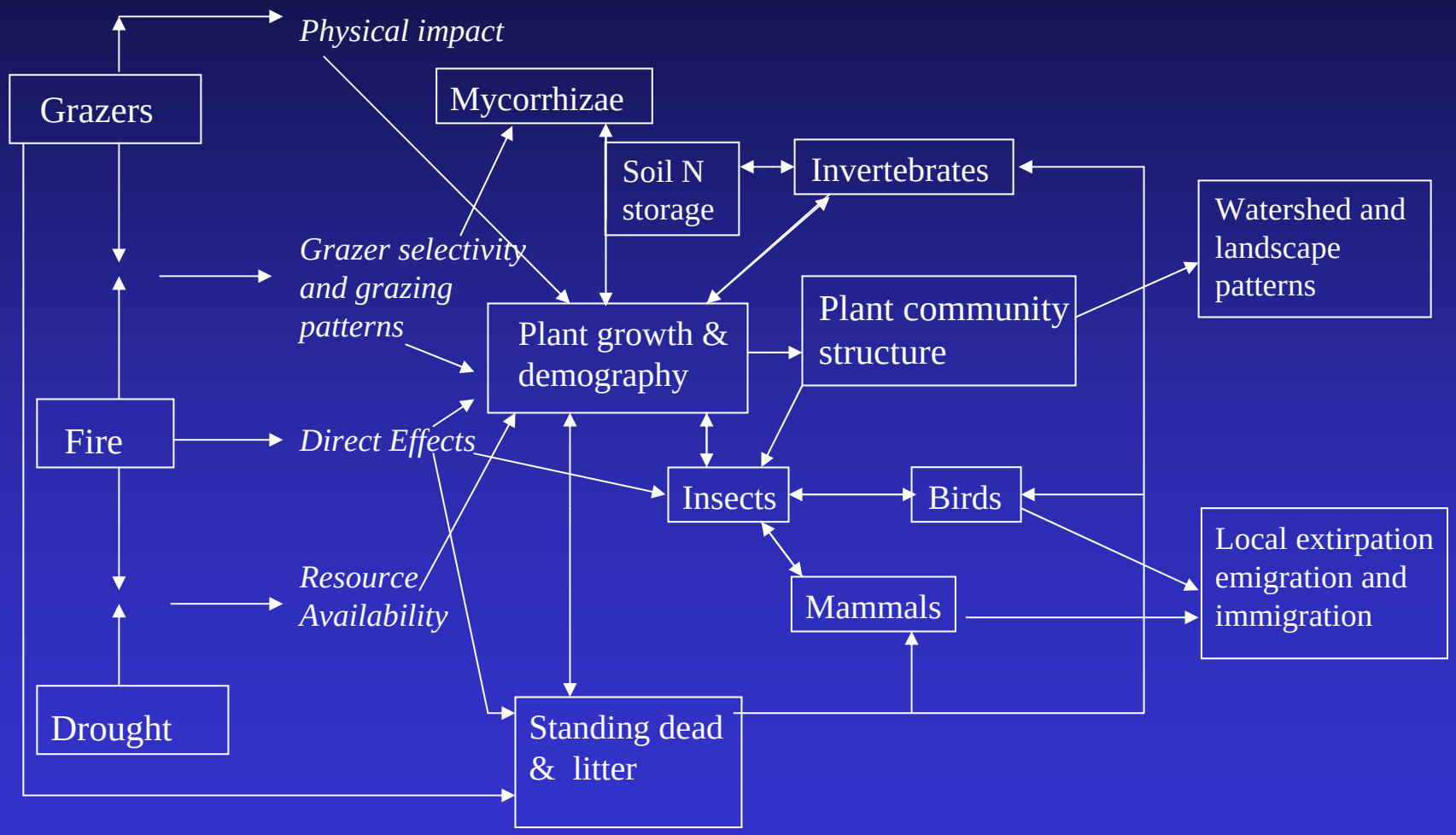
Joern, A and K.H. Keeler. 1995. *The Changing Prairie, North American Grasslands.* Oxford University Press, New York.

Knapp, A.K., J.M. Briggs, D.C. Hartnett and S.L. Collins. 1998. *Grassland Dynamics; Long-Term Ecological Research in Tallgrass Prairie.* Oxford University Press, New York.

Knopf, F.L. and F.B. Samson. 1996. *Ecology and Conservation of Great Plains Vertebrates.* Springer-Verlag, New York.

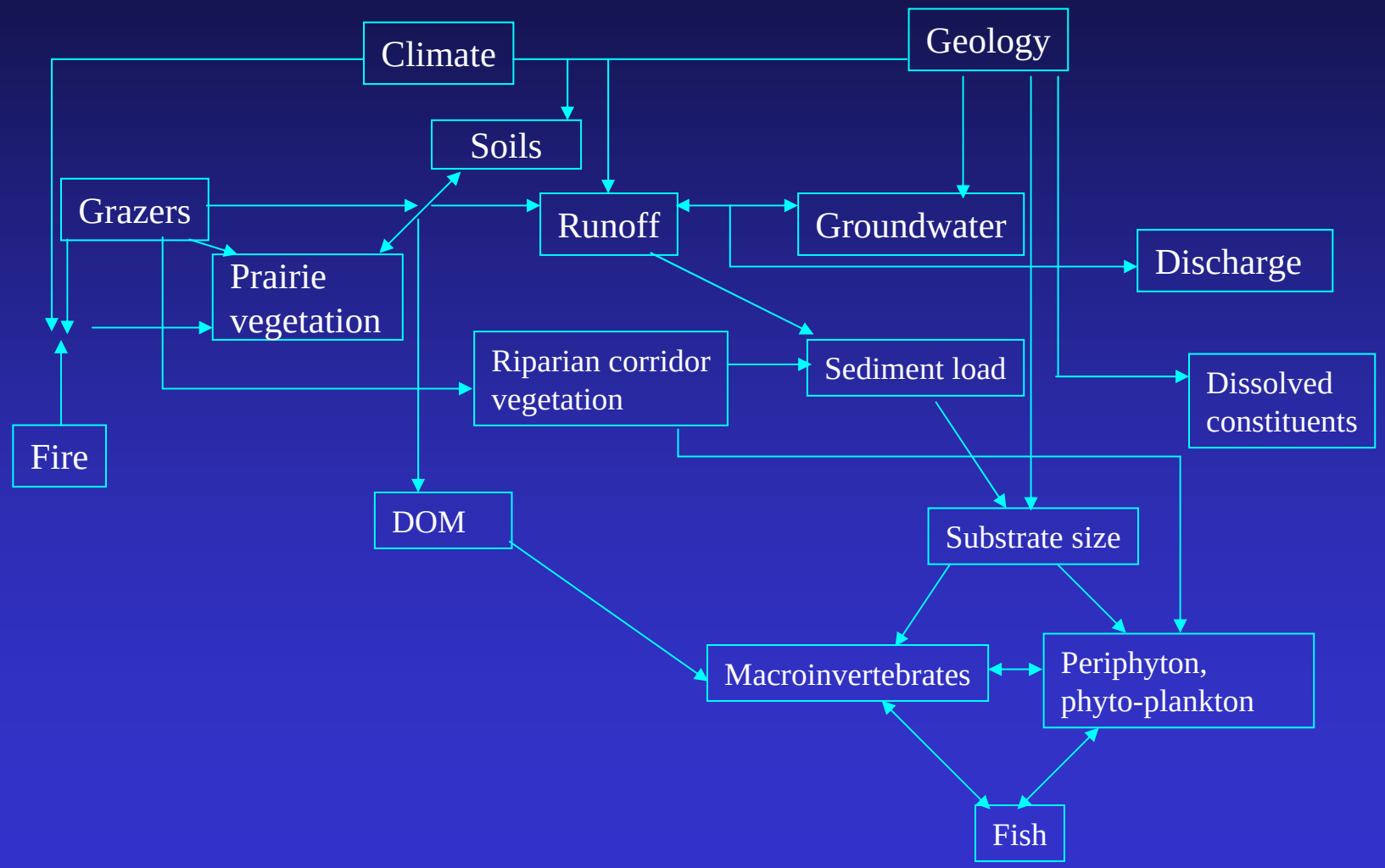
TERRESTRIAL PRAIRIE ECOSYSTEM -- NATURAL DRIVERS		
Driver	***Resource***	***Effect***
CLIMATE		
Periodic drought		
	Plant communities	Mortality of trees/shrubs; reduced, patchy vegetative cover; reduced seed production; shifts in species composition
FIRE		
	Plant communities	Prevention of woody species establishment; increased productivity and seed production (tallgrass prairie); dominance of C_4 grasses (spring fire). Varied seasonality and fire frequency resulted in increased landscape heterogeneity.
	Soils	Loss of nitrogen through volatilization; water loss through surface evaporation; increased root production
	Bison	Foraging patterns follow recently burned areas.
GRAZERS		
Bison	Plant communities	Reduced C_4 grass dominance due to selective grazing; increased heterogeneity & species diversity associated with grazing patches, wallows; moderates fire effects by decreasing C_4 grass dominance
	Soils	Consumption of ANPP and redistribution of N in urea and feces moderates fire-regulated N loss through volatilization.
PRAIRIE GRASSES & SOIL BIOTA		
	Soils	High organic matter & nutrient retention; high below-ground productivity, low nitrogen availability, high moisture holding capacity

Conceptual Model of Core Abiotic and Biotic Relationships Within Terrestrial Prairie Ecosystems *modified from Hartnett and Fay (1998)*



AQUATIC PRAIRIE ECOSYSTEM -- NATURAL DRIVERS		
Driver	***Resource***	***Effect***
CLIMATE (drought, floods)		
	Prairie streams	Highly variable streamflow with stable flows during spring/early summer, and intermittent to dry conditions during late summer & winter
	Macroinvertebrate communities	Communities dominated by small, rapidly growing species that can colonize quickly following disturbance
	Fish communities	Plains species relatively tolerant of hypoxia and high temperature variability/maxima.
	Fish communities	Headwater springs provide important refugia during intermittent or dry conditions
PRAIRIE SOILS		High infiltration and soil water storage capacity of prairie soils results in low surface runoff.
PRAIRIE VEGETATION	Prairie streams	High water demand in late summer, early fall contributes to low flow conditions; "tight" nutrient cycling by prairie vegetation results in low within-stream N concentrations
RIPARIAN CORRIDOR VEGETATION	Periphyton, phytoplankton, macrophytes	Organic matter inputs primarily from within-stream primary production due to high light availability

Relationships Between the Core Abiotic and Biotic Components Affecting Aquatic Prairie Ecosystems



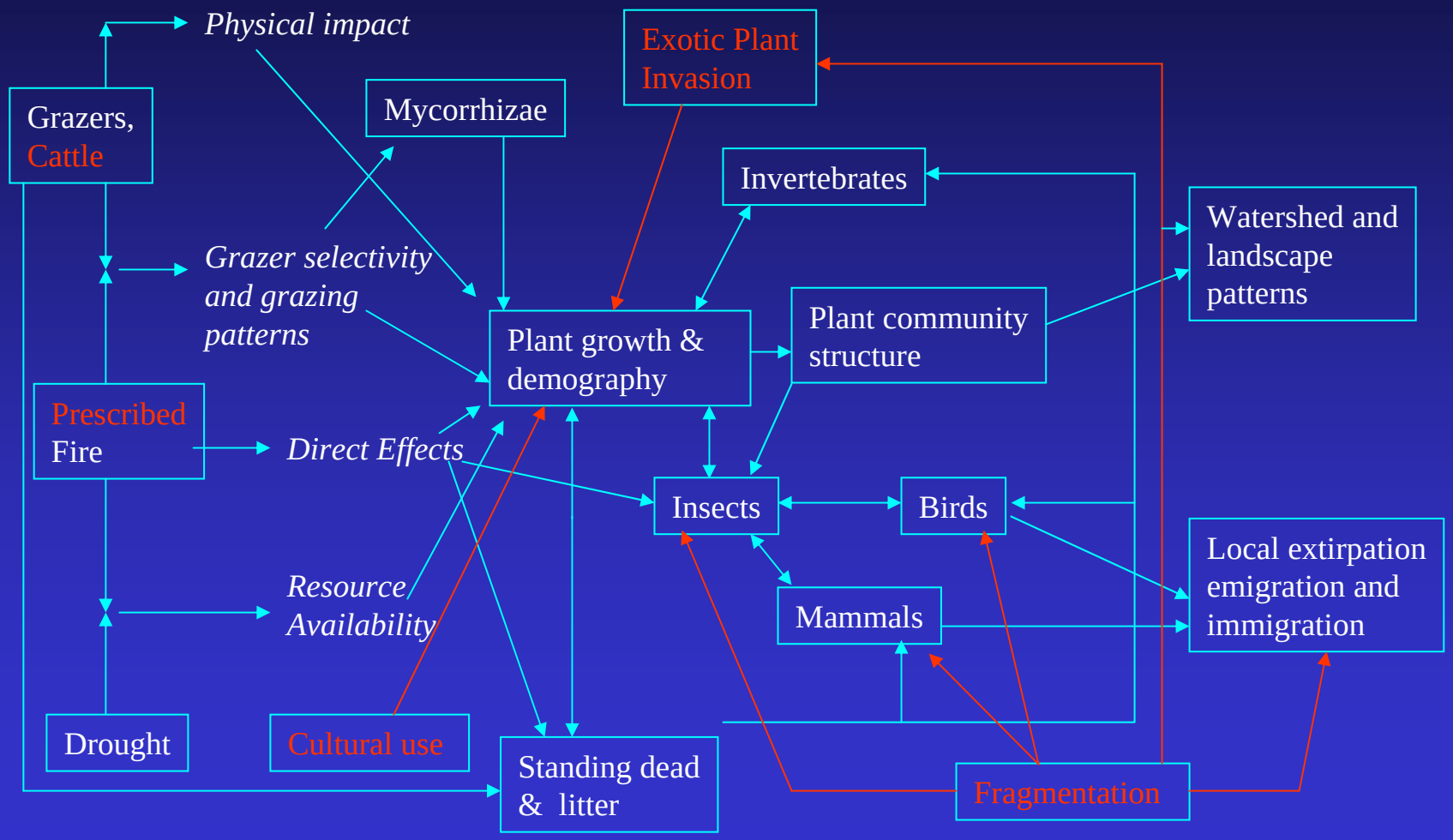
Terrestrial Prairie Ecosystem -- Current Anthropogenic Stressors -- Development & Use Effects

Stressor	*Resource*	*Effect*	*Indicator*
Adjacent Habitat Loss & Fragmentation			Land use change maps
Isolation of native plant populations	Grassland plant communities	Loss of colonization and pollination sources, resulting in reduced abundance or loss of native species	Plant community composition; pollinator abundance
Fire suppression	Grassland plant communities	Woody invasion of prairie; conversion of savanna to woodland	Woody seedling/sapling density
Reduced wildlife habitat	Woodland plant communities	Deer over-abundance resulting in selective browsing pressure, loss of forb species	Plant community composition using exclosures
Reduced wildlife habitat	Grassland birds communities	Increase in edge and ruderal species resulting in displacement of grassland species	Bird community composition, relative abundance
Isolation of rare populations	Rare species populations	Loss of re-colonization sources following local extinction; reduced gene flow between populations	Decreased population persistence; reduced genetic diversity
Exotic Species Invasion	Grassland plant communities	Displacement of native species, alteration in community composition, structure and diversity	Plant community composition; distribution, abundance of exotics
Elevated CO_2 levels	Grassland plant communities	Shifts in species' range	Changes in persistence/abundance of edge-of-range populations
Cultural Use			
Trail Development/Use	Grassland plant communities, unique habitats	Further fragmentation of remnant communities, corridors for exotic invasion, soil compaction	Plant community composition
Fencing for cattle, watering points,		Disrupt spatial distribution of grazing, reducing landscape heterogeneity; high-impact zones adjacent to water, shade	Reduced Beta diversity, compositional changes in high-impact zones
Over-grazing	Grassland plant communities	Increased allocation to foliar production, resulting in reduced root mass; more rapid N-cycling results in increased soil N availability -- reduces dominance of prairie grasses. Reduced root mass & soil compaction reduce soil moisture retention.	Plant community composition, dominance; increased abundance of exotic species; soil nitrogen availability, soil compaction
Over-grazing	Grassland bird communities	Changes in vegetation structure result in poorer habitat quality for grassland birds	Bird community composition, abundance, diversity;
Quarrying pipestone	Rare species habitat	Pumping water from quarries may result in altered ground-water hydrology, ultimately affecting mesic prairie and stream habitats of T&E species.	Rare species abundance, plant community composition, stream, groundwater hydrology

Terrestrial Prairie Ecosystem -- Current Anthropogenic Drivers -- Resource Management Actions			
Stressor	***Resource***	***Effect***	***Indicator***
Prescribed Fire		Increased habitat heterogeneity and structural diversity;	Distribution of community types; beta diversity; grassland bird diversity and abundance
	Grassland plant communities, unique habitats	Maintain prairie communities; potential for species losses related to fire seasonality and frequency	Community composition, abundance, diversity; guild abundance; butterfly diversity
	Oak savanna plant communities	Conversion of woodland to savanna	Overstory composition, basal area; understory composition
	Grassland bird communities	Changes in vegetation structure, habitat quality; potential for fire-related mortality during breeding season	Community composition, diversity, abundance; nesting success
	Ground-nesting vertebrates	Fire-related mortality	Community composition, abundance and diversity
	T&E plants	improve quality of T&E plant habitat; potential for fire-related mortality	T&E species persistence, abundance
Prairie / Savanna Restoration	Historic grassland landscapes	recreation of historic landscapes	Distribution of community types, Beta diversity
	Grassland plant communities	Increase extent of prairie/savanna areas, buffer remnants from exotic invasion	Communitiy composition, abundance & diversity approaching that of model plant community
	Grassland birds/vertebrates	Increase in habitat size	Community composition, abundance and diversity
Exotic Species Control			Distribution/size of exotic patches; frequency, abundance of invasive exotic species
	Grassland plant communities	improve native communities	Community composition, abundance & diversity
	T&E species habitat	improve quality of T&E plant habitat	T&E species persistence, abundance
	Woodland/savanna communities	reduce abundance of targeted species	Density of woody species
	T&E species	improve quality of T&E habitat	T&E plant population size

Conceptual model of core abiotic and biotic relationships within terrestrial prairie ecosystems, including anthropogenic stressors (*in red*) affecting Prairie Cluster parks.

Modified from Hartnett and Fay 1998



Monitoring Implications From Terrestrial Prairie Model

KEY CHARACTERISTICS OF PRAIRIE ECOSYSTEMS	IMPLICATIONS FOR MONITORING
Interannual variability in ANPP (aboveground net primary production) in tallgrass prairie ecosystems is extreme.	High natural variability in ANPP may make it difficult to detect stressor-driven trends in foliar cover. Plant community monitoring should be accompanied by local climate data.
Prairie vegetation evolved in a nitrogen-limited environment.	Overgrazing of prairie vegetation may result in increased nitrogen availability, thus altering composition and increasing susceptibility to exotic species invasion.
Light to moderate grazing pressure may promote spatial heterogeneity within prairie ecosytems.	Plant community monitoring in grazed prairies should include a measure of beta (among-site) diversity.
Fire regimes that mimic natural fire frequency and seasonality may promote spatial heterogeneity within prairie ecosystems.	Plant community monitoring in prairies undergoing prescribed fire should include a measure of beta (among-site) diversity.
Heavy grazing pressure may result in soil compaction, resulting in reduced soil moisture infiltration.	Plant community monitoring in heavily grazed prairie should include measures of soil compaction/soil porosity.

Monitoring Implications From Aquatic Prairie Model

KEY CHARACTERISTICS OF PRAIRIE ECOSYSTEMS	IMPLICATIONS FOR MONITORING
Prairie streams exhibit variable stream flow, periodic drought and unpredictable scouring floods.	Macroinvertebrate assemblages and Topeka shiner (*Notropis topeka*) populations should be monitored within the context of local precipitation and streamflow patterns.
Stream reaches flowing through treeless prairie are dominated by autochthonous production, while allochthonous inputs predominate in gallery forest reaches.	Macroinvertebrate monitoring within streams with prairie and gallery forest reaches should be stratified to track potentially different assemblages. Habitat data should be expanded to describe riparian corridor vegetation.
Prairie streams are nitrogen-limited.	Nutrient loading may shift resource limitation in prairie streams from nitrogen to other factors, such as oxygen.
High moisture infiltration rates of prairie soils and high surface roughness of prairie vegetation result in low surface erosion following heavy precipitation events.	Increasing sediment loads are indicative of changing land use within prairie watersheds.

- **Underscores need to integrate climate data with core datasets and stream flow data with water quality monitoring**
- **Emphasizes important role of prairie soils in maintaining both aquatic and terrestrial prairie ecosystems**
- **Stresses climate variability as a defining, characteristic of prairie ecosystems and the resulting importance of adaptive responses of prairie biota to drought**
- **Reminds us of the complex interaction of climate, fire and grazing that historically regulated prairie ecosystems**
- **Clarifies the difficulty of detecting human-induced patterns of change against a background of high intrinsic variability**

"The spatial and temporal variability (of prairies) is not simply a hindrance to sampling and estimation of plant population and community patterns but rather an important characteristic of these grasslands of direct ecological interest." Hartnett and Fay 1998

Why Do We Need Conceptual Models?

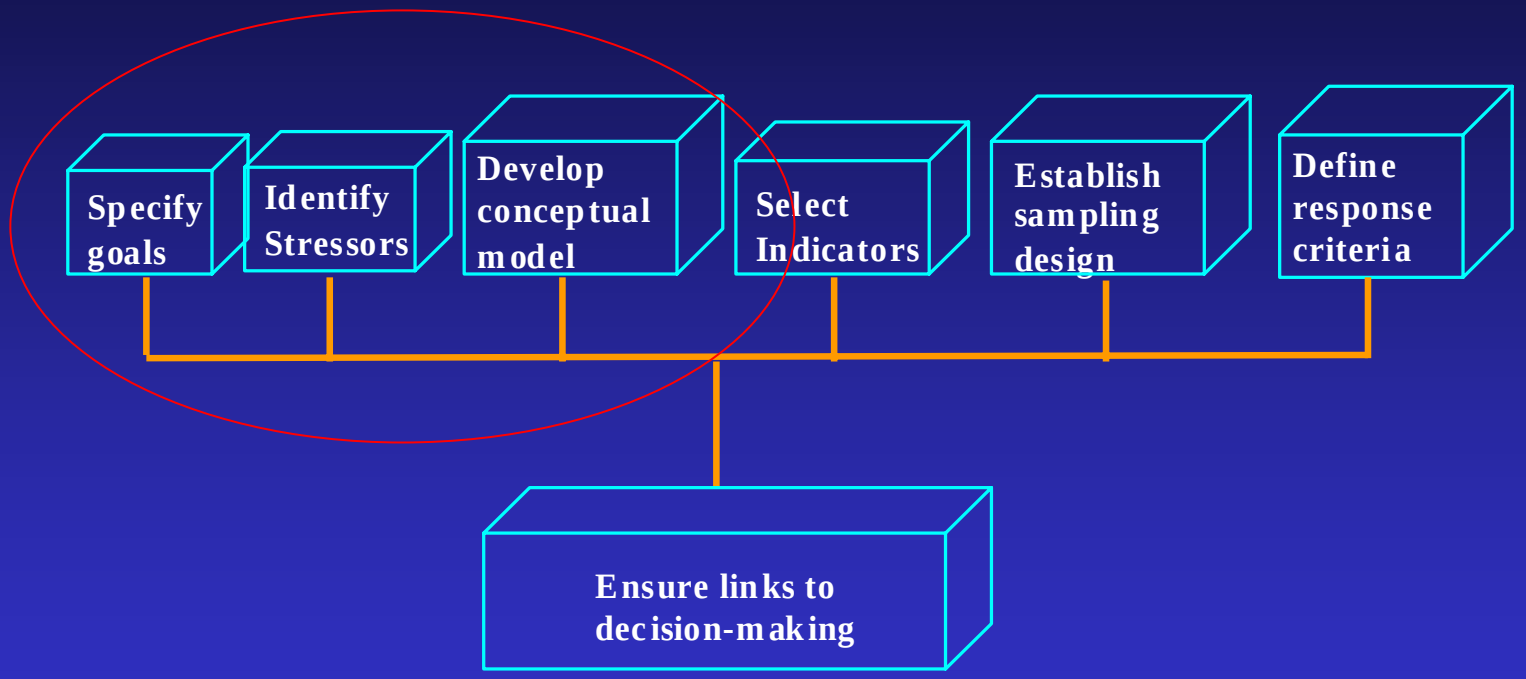
1) Ecosystems (communities, populations) are messy; our ability to provide early warning of resource decline is uncertain. We need a road map.

2) Long-term monitoring is an iterative process (i.e. we may not get it right the first time); modeling will help ensure that mistakes are instructive and not repeated.

3) A balanced monitoring program should consider multiple spatial/temporal scales and integrate monitoring across ecological disciplines. Models serve as heuristic devices to foster better communication and clarify scaling issues.

4) A balanced monitoring program should address short-term management issues and long-term ecological integrity. Clear models serve as heuristic devices to foster better communication between managers and scientists, and between managers and the general public.

Steps in the Design of a Monitoring Program



From Noon et al. 1999

One of the most difficult tasks …….

Building a program within current fiscal reality
……. but with vision to the future and room to grow

Can be accomplished through

1) Starting with a comprehensive plan and following a process of elimination

or

2) Beginning with core components and defining stages to add if fiscal resources or partners become available

Use an Iterative Process -- Bouncing Back and Forth Between

1) most important monitoring objectives
2) conceptual models of resources, stressors and their linkages

Trying to Build a Balanced Monitoring Program:

Management Issues vs. Ecosystem Integrity
Effects -Oriented, Stressor-Oriented, Anticipatory Monitoring
Multiple Ecological Scales

Characteristics of Balanced Monitoring Program

Early warning of resource change
Likely to detect change in resource status
Appealing to general public
Cost-effective
Indicative of cause
Logically linked to decision making
Keystone attributes