Ecosystem Conceptual Models for Bighorn Canyon National Recreation Area, Grand Teton National Park, and Yellowstone National Park

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Adaptive management within the national parks requires an understanding of the complexity of the natural and human systems that interact in these areas. Adaptive management includes several important processes that produce information and understanding of the system enabling decision makers to proceed in an informed fashion. Although adaptive management is basically a way of "learning while doing", it is necessary to describe the interactive nature of the system being managed and monitored which leads to further management steps.

Important procedures needed within an adaptive management framework include (a) development of conceptual models of the system as well as issues and processes within the system, (b) identification of important issues and uncertainties, (c) development of research and programs to understand the uncertainties and to address issues, and (d) development of long-term monitoring programs that will assist assessment of management decisions and understanding of research outcomes.

The National Park Service has undertaken a program to identify "vital signs" or indicators of important changing conditions within the parks. Information from monitoring these indicators will be used to develop management decisions within an adaptive management framework. In a sense, vital signs or indicators are selected to be "the canary in the mine", forewarning managers of changes in important ecosystem parameters prior to these parameters, or related processes, reaching some critical threshold stage.

The conceptual models developed in this part of the vital signs program will be used to better understand the ecosystems of concern and to help guide those who will be selecting appropriate vital signs. These models have been developed based on the authors' understanding of the literature and the systems, and in consultation with scientists at the different parks. Consequently, this report does not include a literature review on which the models are based.

Rather than develop a single conceptual model to represent all of the important processes within the parks, we have chosen to develop a nest of models including (a) a general and simple overview model of the whole system, (b) a complex interactive system model for the whole system, (c) a set of sub-models relating to particular components or issues within each park, many potentially overlapping in stressors and/or indicators, and (d) temporal/spatial models of stressors, processes and outcomes to be used to help identify the importance of time and space in selection of vital signs or indicators for monitoring the system.

The temporal/spatial (time/space) models have been developed for only a few ecosystem sub-models. Three time/space models are presented in this report representing different aspects of the ecosystems. One is associated with the Bighorn Canyon uplands, one with the Grand Teton National Park water-related system, and one with the Yellowstone National Park aspen communities. The shaded area within the time/space models (100 years and 100-500 km^2) represents a temporal and spatial monitoring scope to be used to identify parameters that may likely be useful for monitoring. The line for each parameter is at the greatest time period in which that parameter functions; however, this means that the parameter may also be functioning in time frames much shorter than where the line falls and possibly as short as a year or less. The discussion about the time/space models is limited to a few comments on how the models might be used to select indicators.

In the ecosystem sub-models, drivers are represented in rectangles, stressors in ovals, processes in diamonds, outcomes in hexagons and indicators (possible vital signs) in parallelograms. The process polygon (diamond) may represent a set of interactions or a small internal sub-models. These internal process sub-models are not presented in this report, but rather, the statement “dynamics” within many diamond polygons often implies more than a simple process.

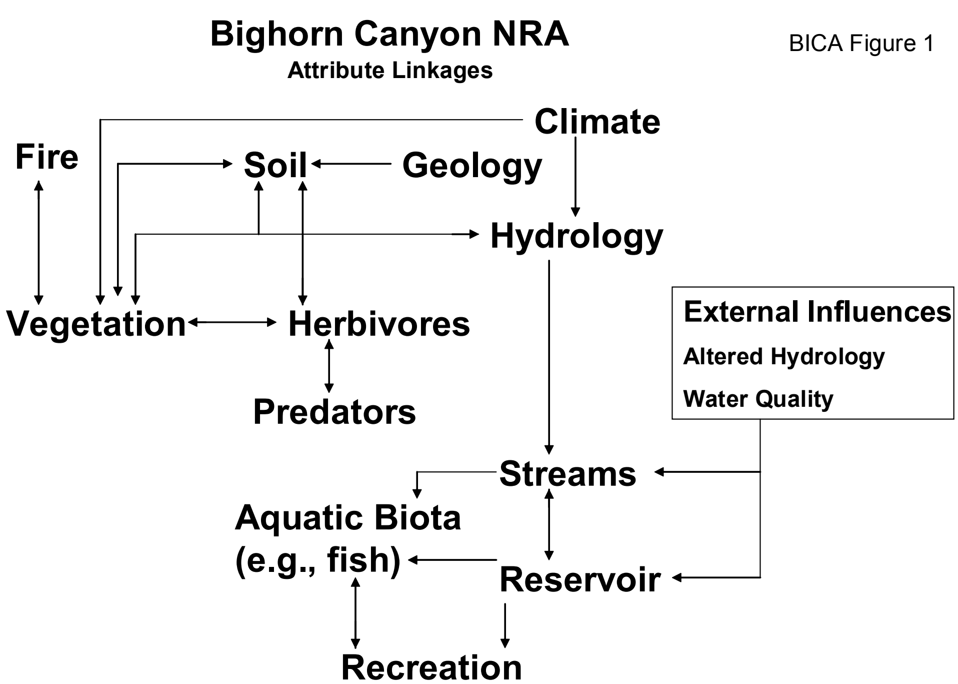
This project has developed conceptual models for Bighorn Canyon National Recreation Area, Grand Teton National Park, and Yellowstone National Park. The latter two parks are adjacent and thus share many similar attributes and issues, while Bighorn Canyon is in an arid region and quite separate from the other parks. Although the conceptual model development process was similar, the models are quite different with the exception of the general systems model for Yellowstone and Grand Teton. In some cases, models addressing similar issues between parks are quite different because the importance of drivers or stressors of the ecosystem or attribute of concern are different.

Bighorn Canyon National Recreation Area

Bighorn Canyon National Recreation Area (BICA) was established in response to recreational potentials related to Bighorn Canyon reservoir. Uplands associated with the reservoir were also included. These arid uplands encompassed part of a wild horse range, and supported a population of bighorn sheep. Conceptual model development for BICA had to consider both the water related components of the system as well as the uplands.

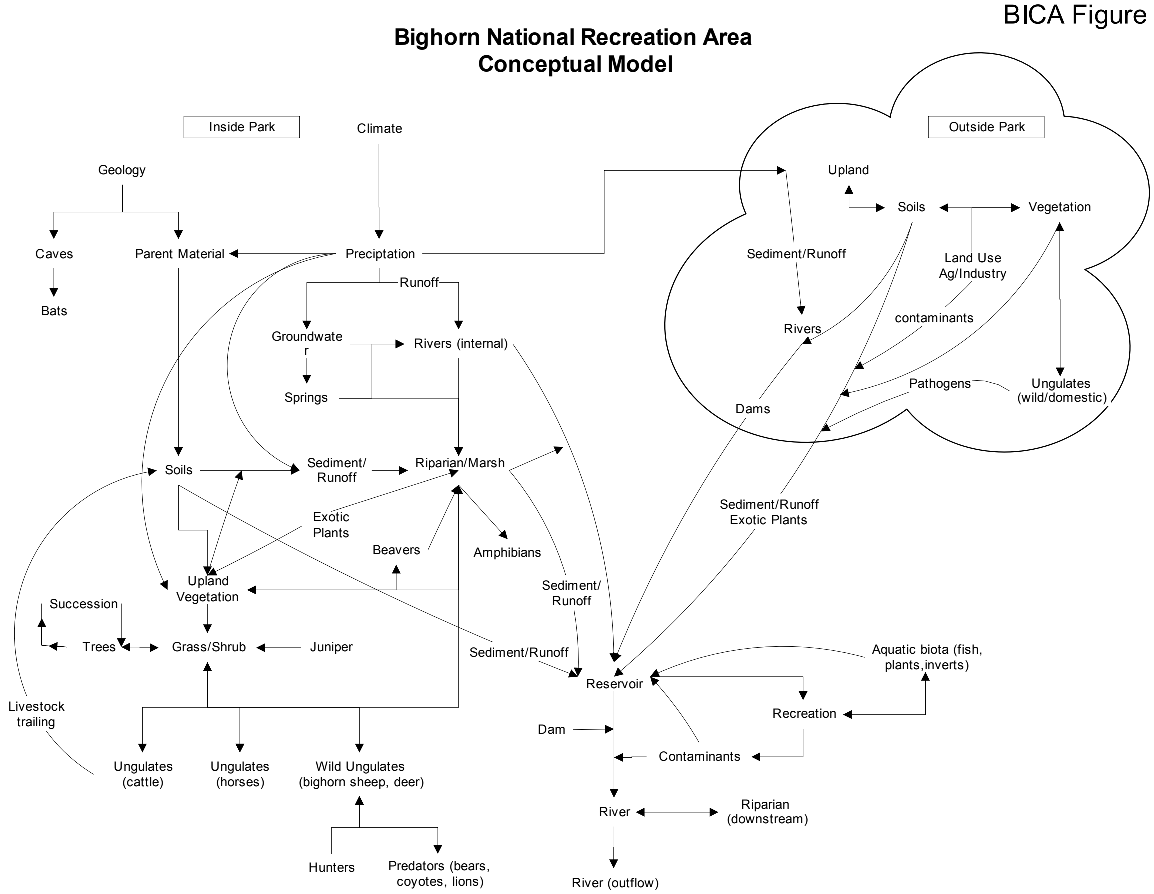
An important aspect of understanding the BICA systems is an understanding of the external influences on the park. Unlike Yellowstone National Park and Grand Teton National Park, BICA is greatly influenced by activities in the surrounding and upstream watersheds, especially those factors that influence quality and quantity of inputs to the reservoir.

The simple overview model of BICA (BICA Figure 1) shows the linkages among the major attributes of the system. Internally within BICA geology and climate drive biological and hydrological aspects. Various biotic components respond to these attributes, for example, herbivore response to vegetation and aquatic biota response to streams and reservoirs. Of significance, as pointed out above, are the external influences on streams and the reservoir.



Bighorn Canyon NRA General Conceptual Model. The general conceptual model of the whole BICA system (BICA Figure 2) expands on the simple model showing details of the factors that control the system and the interactions among the internal and external attributes. External inputs relate directly to hydrological controls upstream of BICA and use of the external watersheds, for example, grazing and agriculture. The internal interactions show upland processes tied to vegetation and influencing factors, and reservoir processes and inputs. Although this model shows a complexity of interactions, the sub-models that follow show greater detail.

BICA Figure 2



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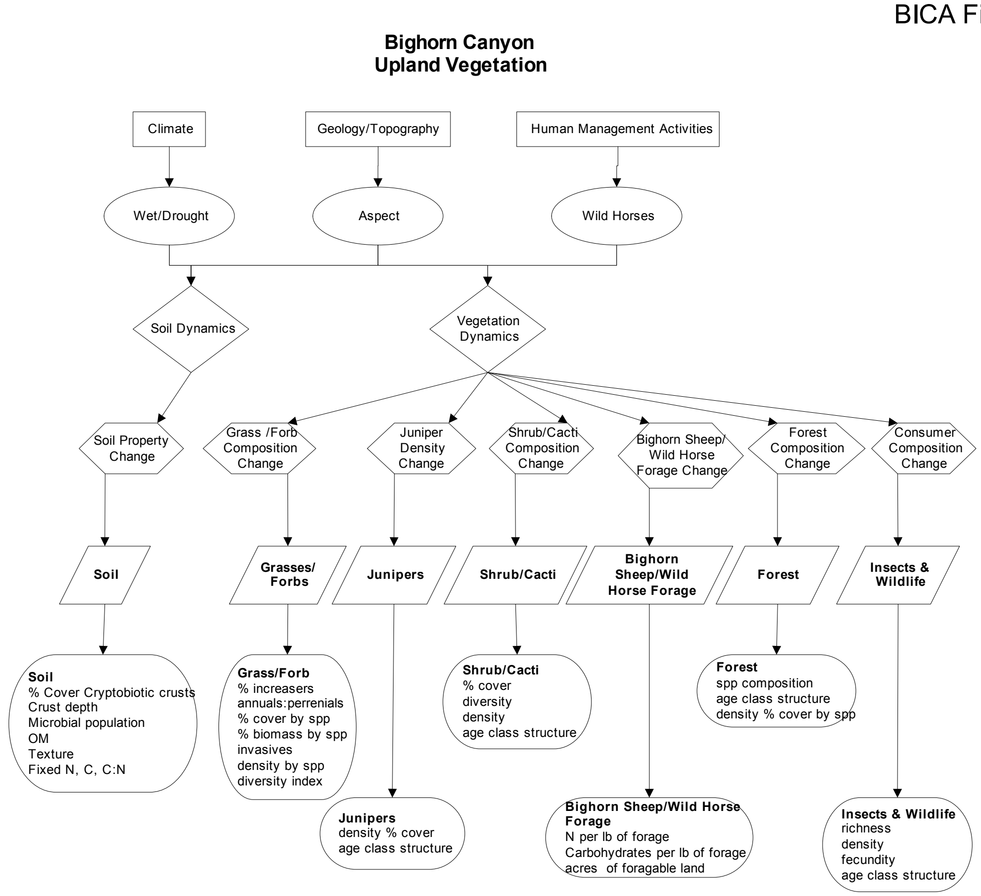
Bighorn Canyon NRA Sub-Models

Two sub-models were developed for BICA. One presents the upland system, and the other the water-related system.

Upland Vegetation Sub-Model. The upland system model (BICA Figure 3) shows the factors that drive vegetation and how the vegetation change. The indicators or potential vital signs of vegetation change include parameters of the different vegetation community types (e.g., grasses/forbs, shrubs/cacti, forest). Invasion of exotic plants and the increase of juniper stands in the upland may be of concern. Also, animals associated with the vegetation types may also be possible indicators of unacceptable change in the upland of BICA. This sub-model presents possible metrics that might be measure for each indicator.

BICA Figure 3



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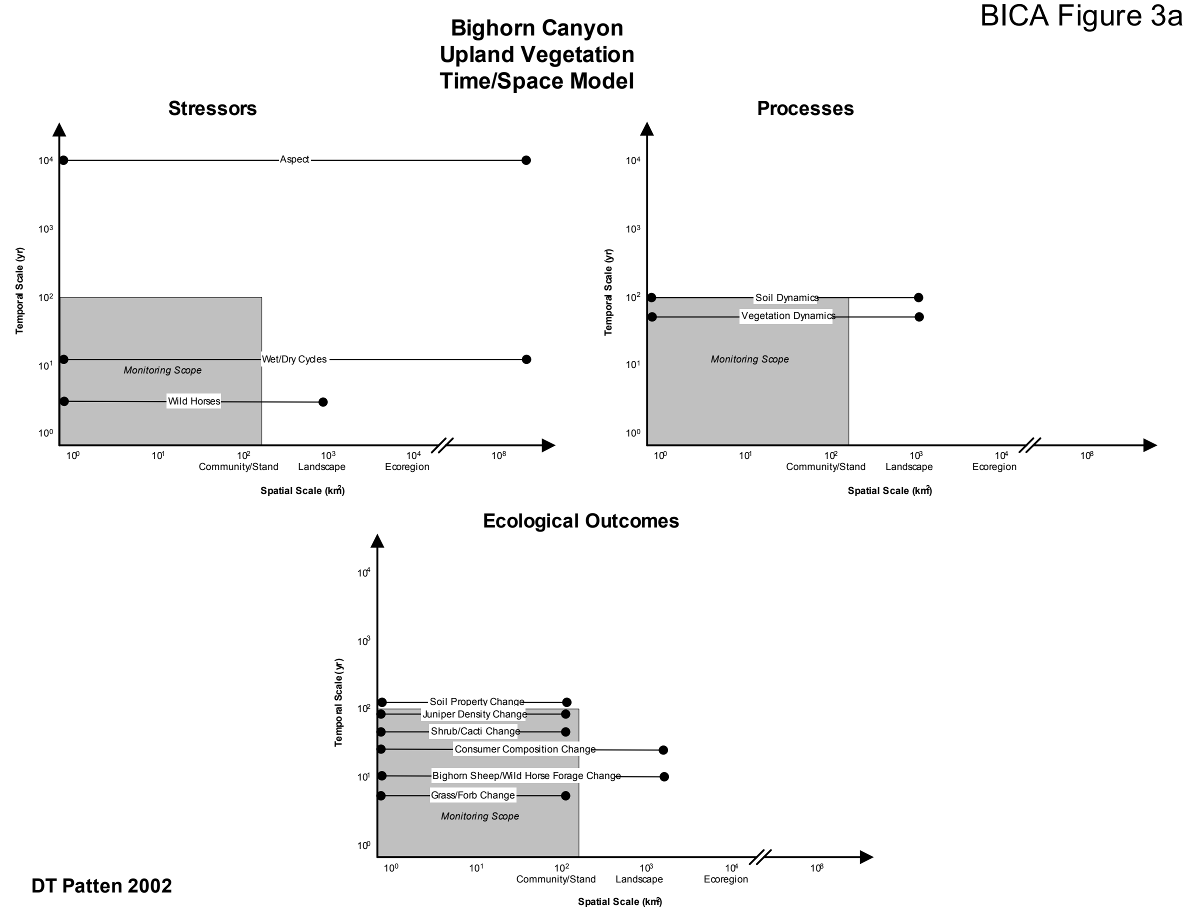
Upland Vegetation Time/Space Model. The time/space model for upland vegetation in Bighorn Canyon NRA (BICA Figure 3a) has three stressors, two within the monitoring scope time limits but extending beyond the spatial limits while the third (topographic aspect) relates to geological time and space. Except for climatic changes, the stressors relate directly to the presence of wild horses, a stressor that should probably continue to be monitored. Most of the outcomes also are with a monitoring time frame that would make indicators associated with these outcomes logical ones to consider. Change in herbaceous vegetation is short-term and may lead to a logical single indicator.

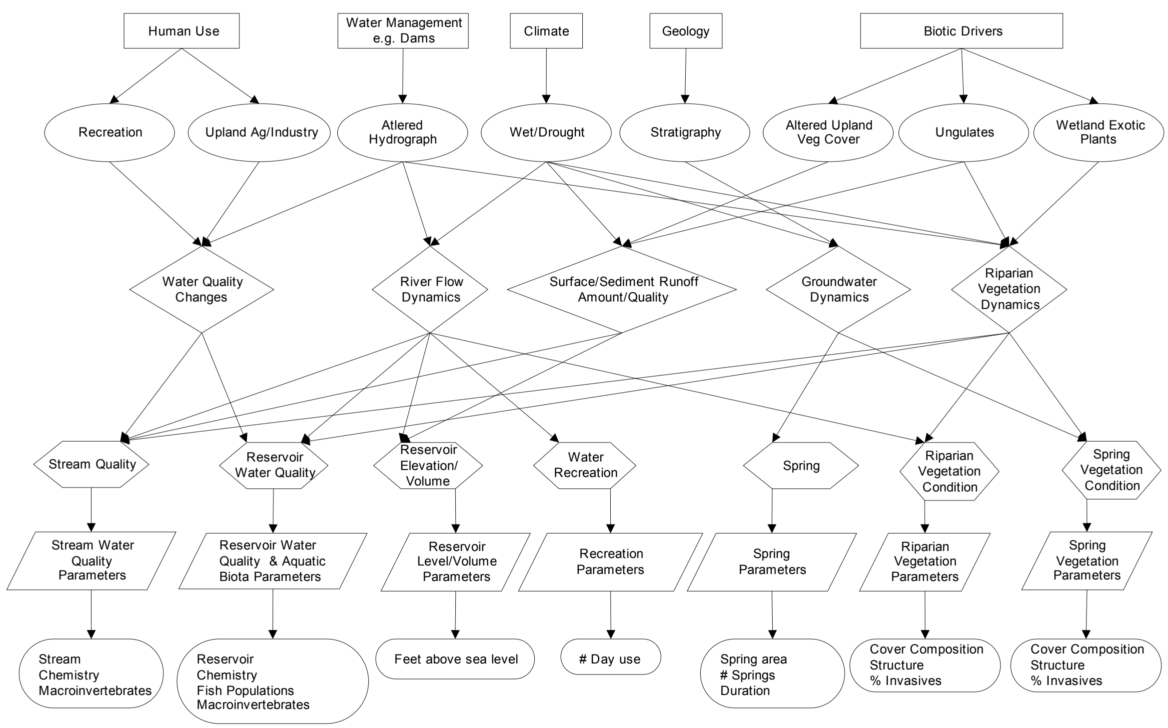
BICA Figure 3a



Water-Related Sub-Model. The water-related sub-model for BICA (BICA Figure 4) shows both water-related issues relative to streams and the reservoir, and riparian and spring related parameters. Similar stressors influence these different groups which include human activities in the upland and on the reservoir as well as upland land uses and changes. Changing climate and altered hydrology from within and outside the park also play a role in influencing the water-related attributes of BICA. Consequently, the model shows that possible indicators of water-related issues include parameters tied to streams, reservoir, springs, riparian areas and recreation. Selecting among these many potential water-related parameters will require a close evaluation of their interactions.

BICA Figure 4

Bighorn Canyon
Water Related Resources



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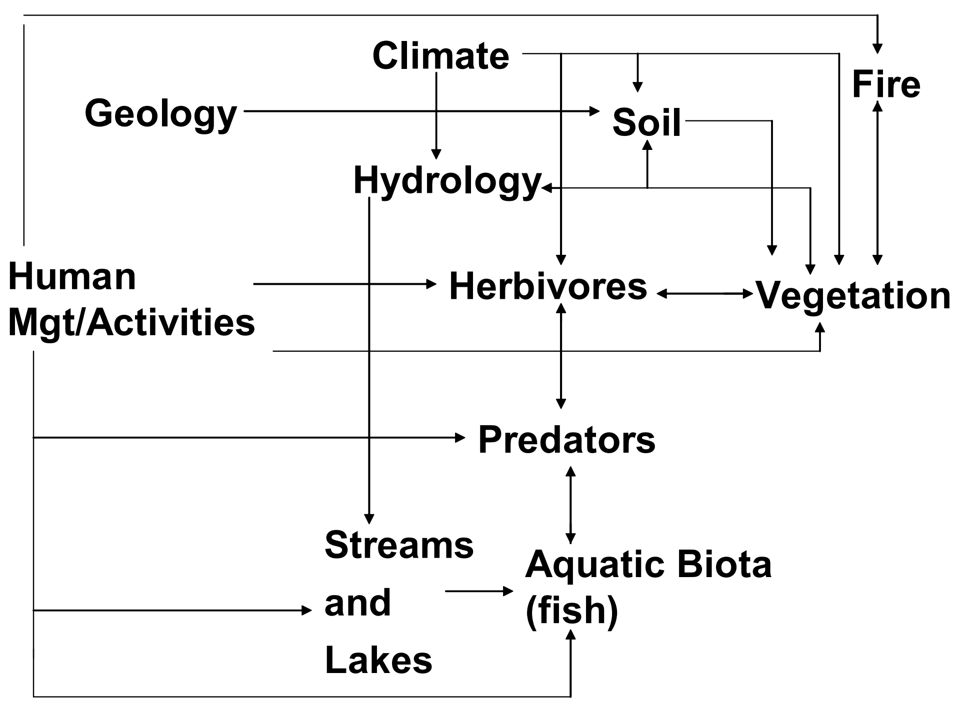
Grand Teton National Park

Conceptual models for Grand Teton National Park (GTNP) include a simple and complex system model and sub-models related to uplands and components of uplands, and water related attributes and components of these. The simple system model (GTNP Figure 1) shows the relationships and linkages among the many primary components of the park. Climate, geology and human activities are the primary drivers. Human activities are used in this simple model but not in the one for Yellowstone National Park, not because humans don't influence many aspects of Yellowstone, but because when GTNP was enlarged in the 1950s many human activities were "grandfathered" into activities and management of the park, for example, a dam and reservoir, domestic grazing, and hunting. These activities have not existed or no longer occur in Yellowstone. GTNP Figure 1 also shows the interactions between many factors demonstrating that ecosystem processes are not unidirectional.

Teton National Park

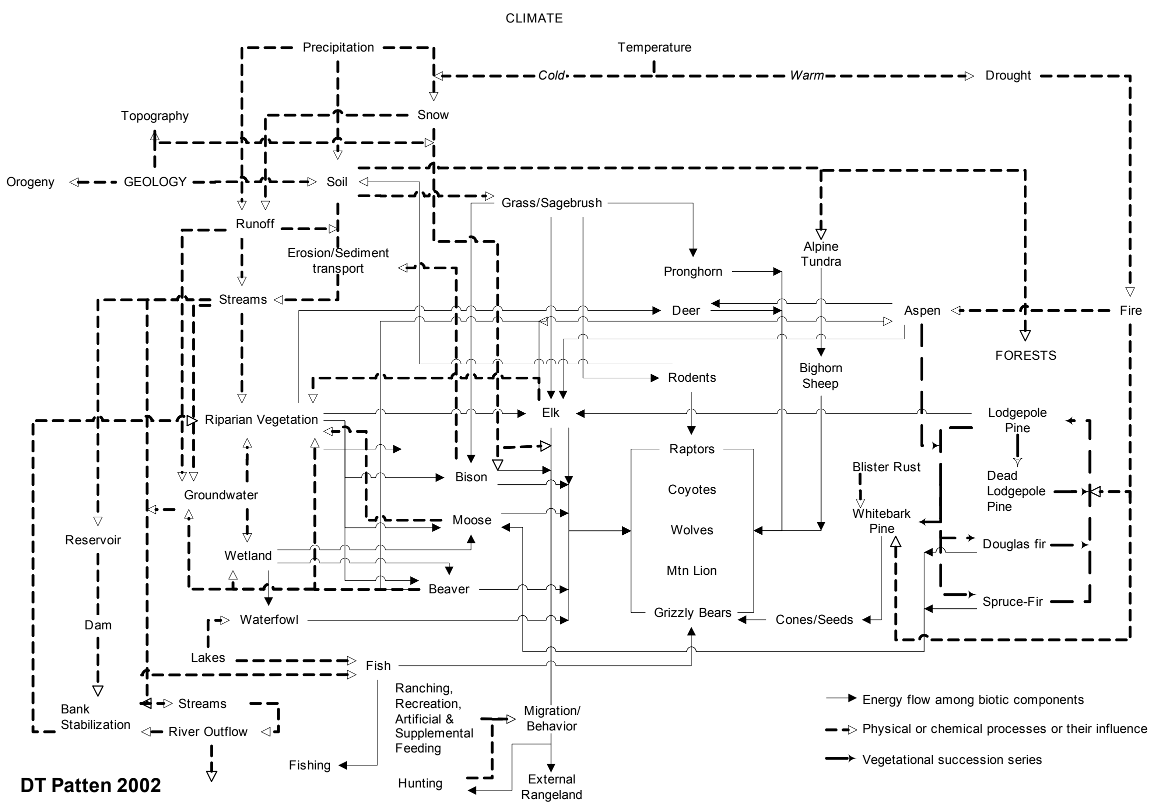
GTNP Figure 1



Grand Teton National Park Complex System Model. The complex systems model for GTNP (GTNP Figure 2) attempts to show all of the major attributes of the park and relationships among them. There are many attributes not included in this model, such as insects and small birds, but some of these attributes are covered in sub-models of the system. Of importance in this systems model are primary drivers of climate and geology and the interactions among vegetation, herbivores and predators. Also, the model shows how the controlled hydrology of the Jackson Lake reservoir relates to the whole system, as well as the role of fire and forest succession. This model, like a similar one for Yellowstone, uses different arrow types to show whether a process is an energy flow, physical or chemical, or successional process. The role of humans in recreation and influence on animal behavior and migration also are shown. Details of various interactive processes within the GTNP system are shown in sub-models and associated time/space models.

GTNP Figure 2

GRAND TETON NATIONAL PARK

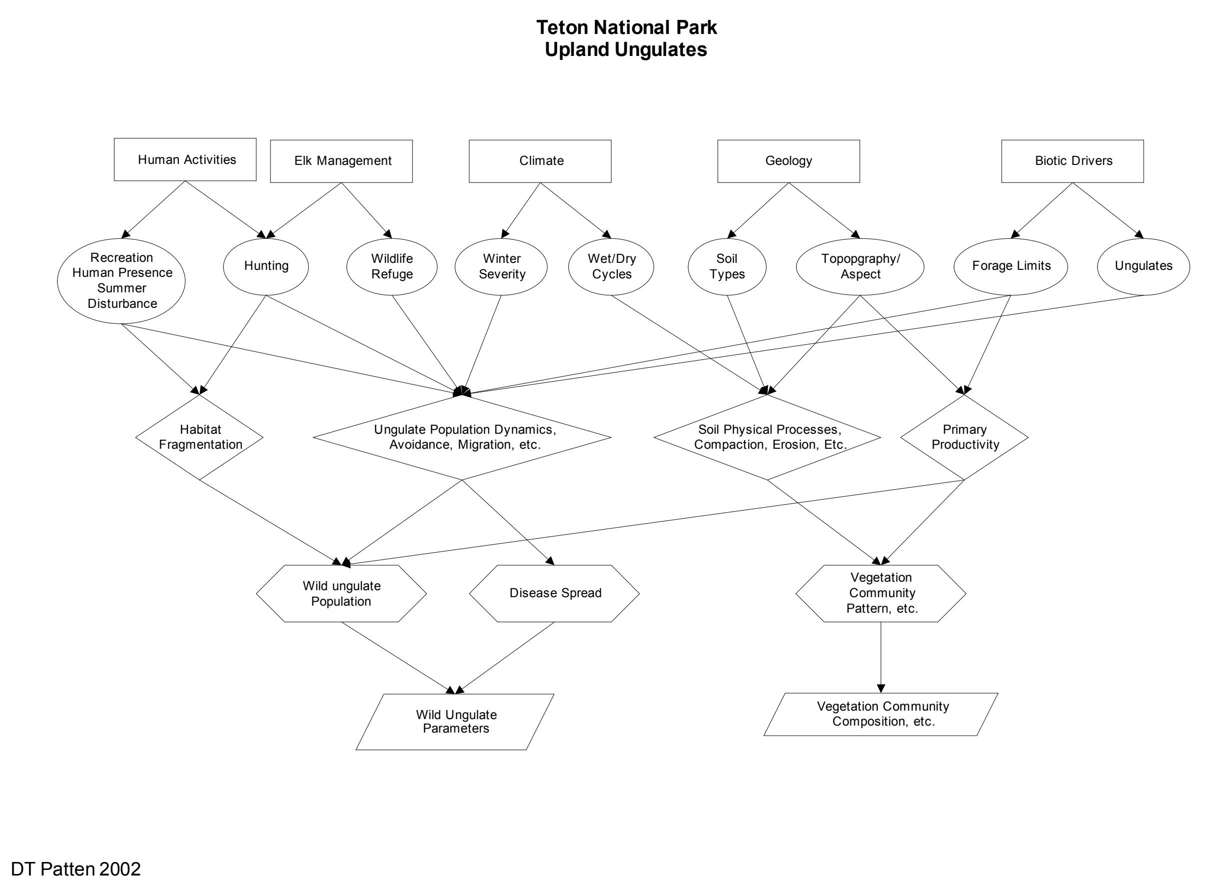


Grand Teton National Park Sub-Models

Sub-models for GTNP relate to both uplands and water-related issues. In addition to the Upland Ungulates Sub-model (GTNP Figure 3), two additional sub-models were developed that relate to upland ecosystems. One is a sub-model showing ecosystem processes that influence medium sized predators and herbivores (GTNP Figure 4) and the other relates to birds (GTNP Figure 5). This was done because the model on upland ungulates covered large herbivores and predators and ignored smaller species.

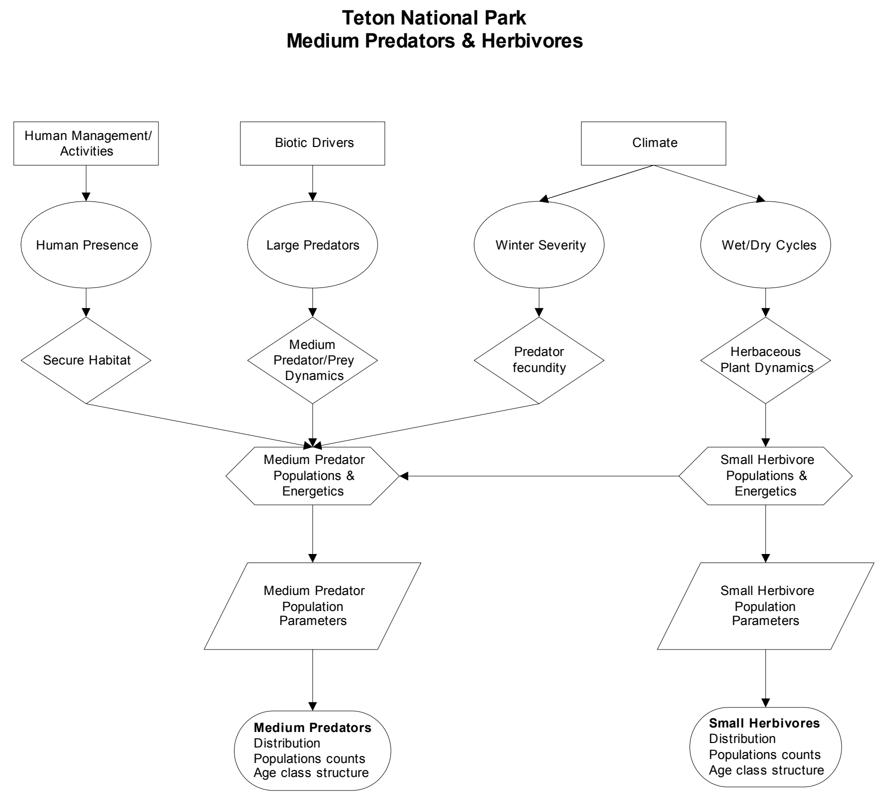
Upland Ungulates Sub-Model. The primary upland model (GTNP Figure 3) deals with upland ungulates (e.g., elk and deer). This model shows an array of stressors that influence the ungulate population and the vegetation on which ungulates depend. Humans play an important role in ungulate behavior just by their presence as well as through hunting, an activity that is relatively unique to GTNP. Unlike the Bighorn models, this upland ungulate sub-model only presents indicators and does not suggest possible metrics for these indicators. Other GTNP sub-models may suggest metrics. In this upland ungulate model, although the stressors are many, the indicators are few, that is, ungulate parameters and vegetation parameters.

GTNP Figure 3



Medium Sized Ungulates and Predators Sub-Model. Medium sized ungulates and predators (GTNP Figure 4) are greatly influenced by humans, large predators and climatic variables. The latter, in turn, influences productivity of the herbivore food source. Possible indicators and metrics for this model primarily include demographic parameters of each group of species.

GTNP Figure 4



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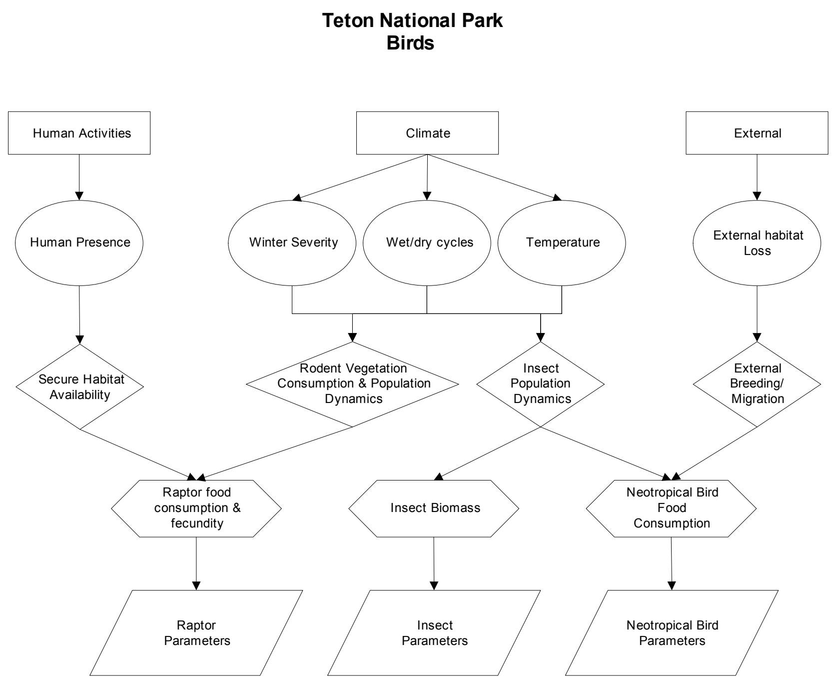
Bird Sub-Model. The second upland related sub-model (GTNP Figure 5) covers birds, a group of species that were not fully covered in the complex systems model. In this model, humans, climate and factors that influence avian habitat, and food sources (e.g., plants, seeds and insects) are the primary drivers and stressors. The indicators cover most functional groups of bird species as well as associated insects.

GTNP Figure 5



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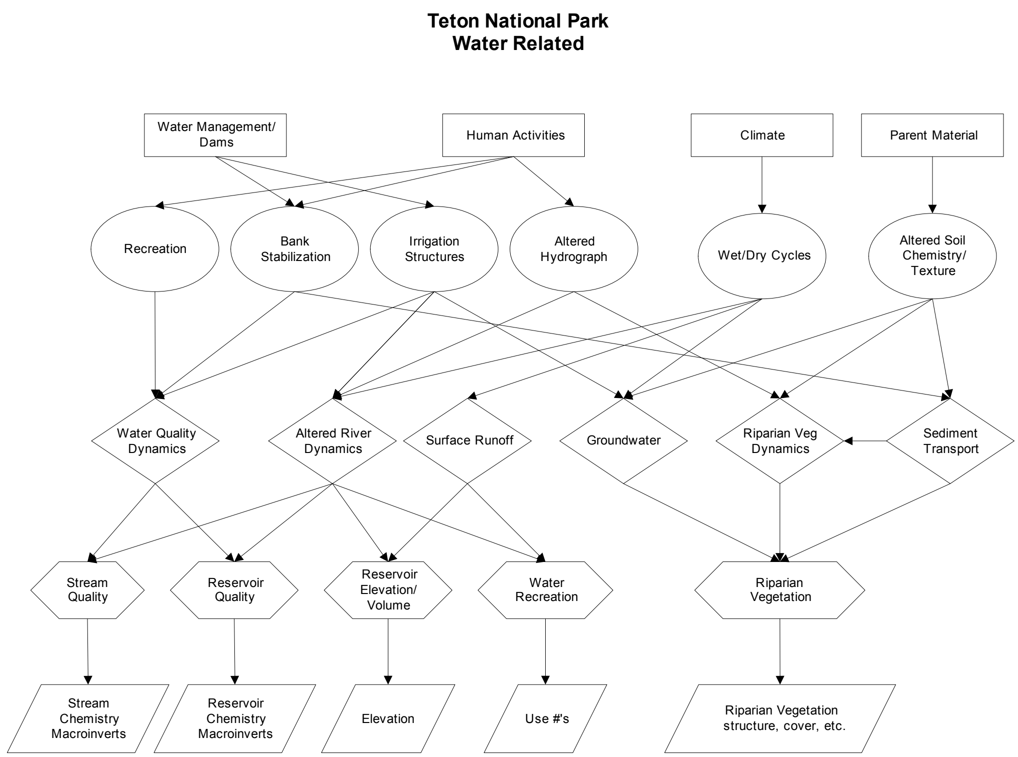
Water Related Sub-Models. The next three conceptual model sets relate to water or water-oriented attributes of GTNP. The first (GTNP Figure 6) is a relatively general model that covers water-oriented recreation, water quality, altered hydrology and factors influencing riparian vegetation. The emphasis of this model is the role of modification of the river through establishment of a dam and reservoir along with limited bank stabilization as well as other hydrological modifications such as irrigation take-outs and return flows. Consequently, the set of indicators are quite broad and cover an array of factors including water quality, recreation use and riparian condition.

GTNP Figure 6



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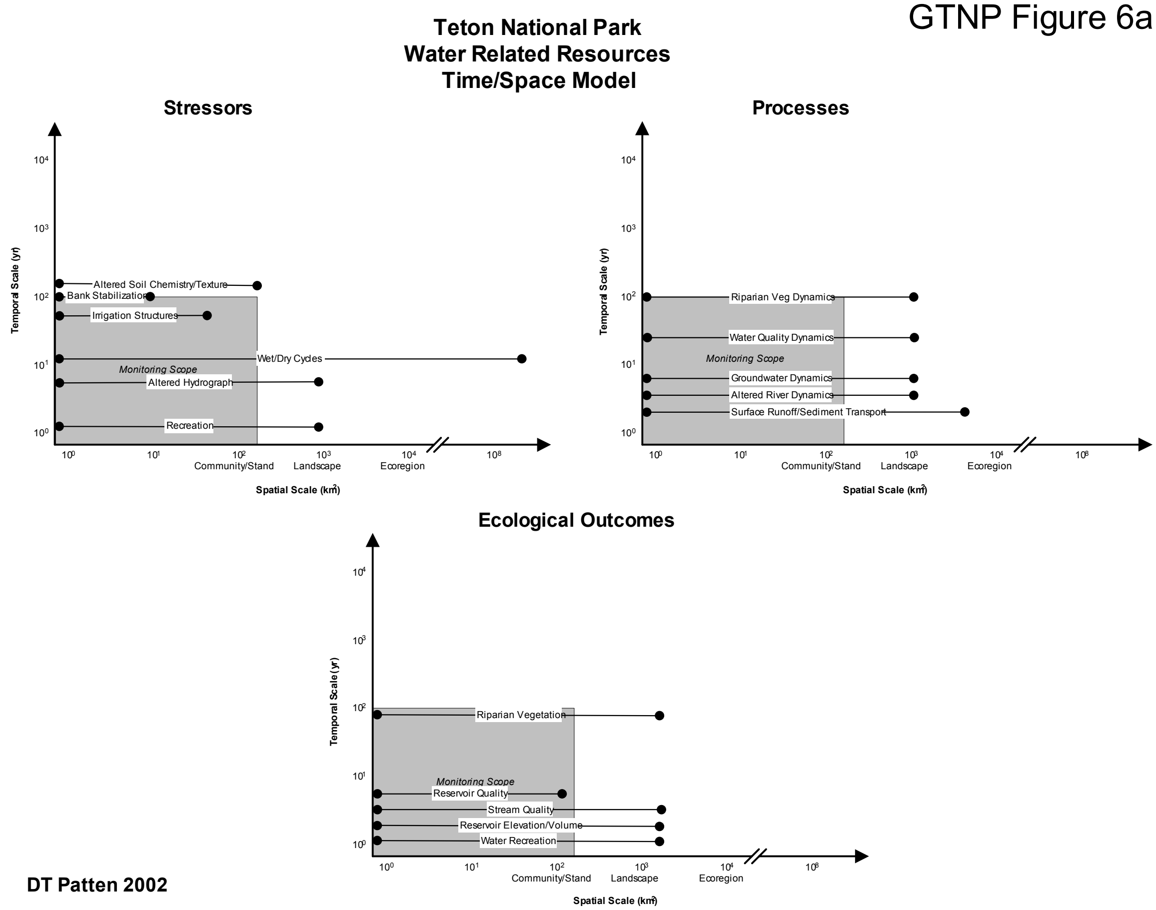
Water-Related Time/Space Model. The time/space model for water related processes within Grand Teton National Park shows most stressor, process and outcome parameters falling within the monitoring scope area with some, such as climatic factors, falling outside the area spatially. This does not mean these should not be considered for measurement, but rather their importance relates to the whole park but still may be important parameters to consider for measuring or monitoring. Several outcome parameters are short-term and relate to hydrological conditions, conditions that may have logical indicators for long-term monitoring, but that which require regular short-term measurements.

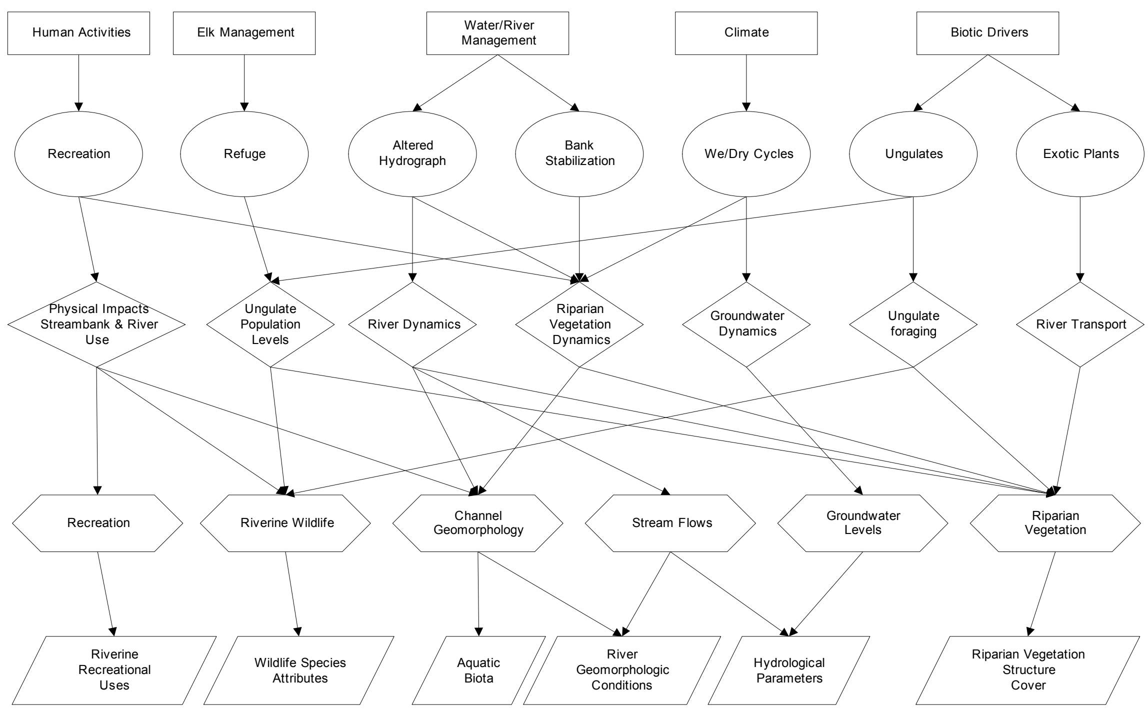
GTNP Figure 6a



Riverine Sub-Model. The second water-related model (GTNP Figure 7) relates to the riverine system of GTNP and emphasizes hydrological, fluvial and riparian processes. There are some similar drivers, stressors and indicators as the prior model (GTNP Figure 6), but the indicators of this model relate to the river and not the reservoir. Many of the processes lead to riparian vegetation and thus one might assume that riparian vegetation in these water-related models may be an important indicator. Other indicators such as exotic plants and river geomorphology may also rise to the surface as important, across-the-board indicators.

GTNP Figure 7

Teton National Park
Riverine



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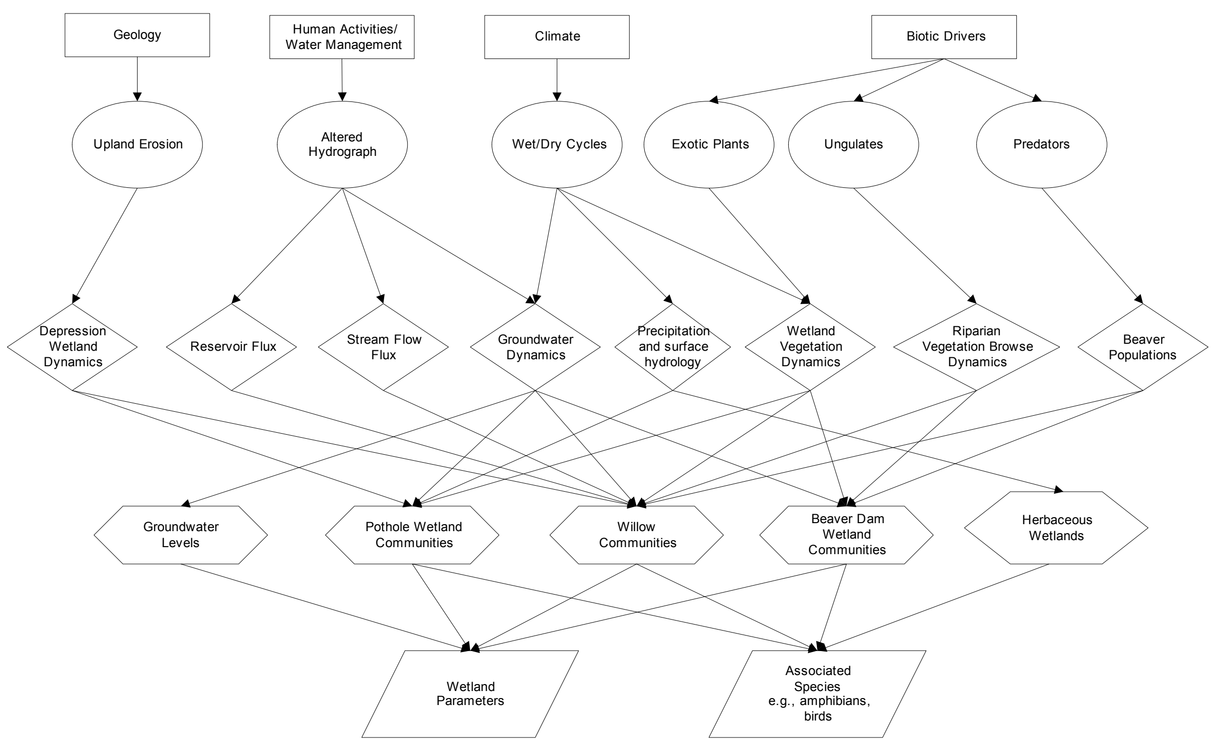
Wetlands Sub-Model. Wetlands are often considered sites of high biodiversity. Consequently, the third of the water-related conceptual models deals with wetlands within GTNP (GTNP Figure 8). Many factors influence processes that create or maintain wetlands such as climate, humans, predators on beavers, and wetland plant herbivores. These all, in some way, eventually influence the condition of the several different wetland types in GTNP (i.e., potholes, willow communities, beaver dam wetlands, and herbaceous wetlands). Indicators of wetlands are not exclusively habitat oriented, such as vegetation parameters, but also include important species that use the habitat. For this reason, important indicators of wetlands may include amphibians and birds that may exclusively depend on these habitats.

GTNP Figure 8

Teton National Park
Wetlands



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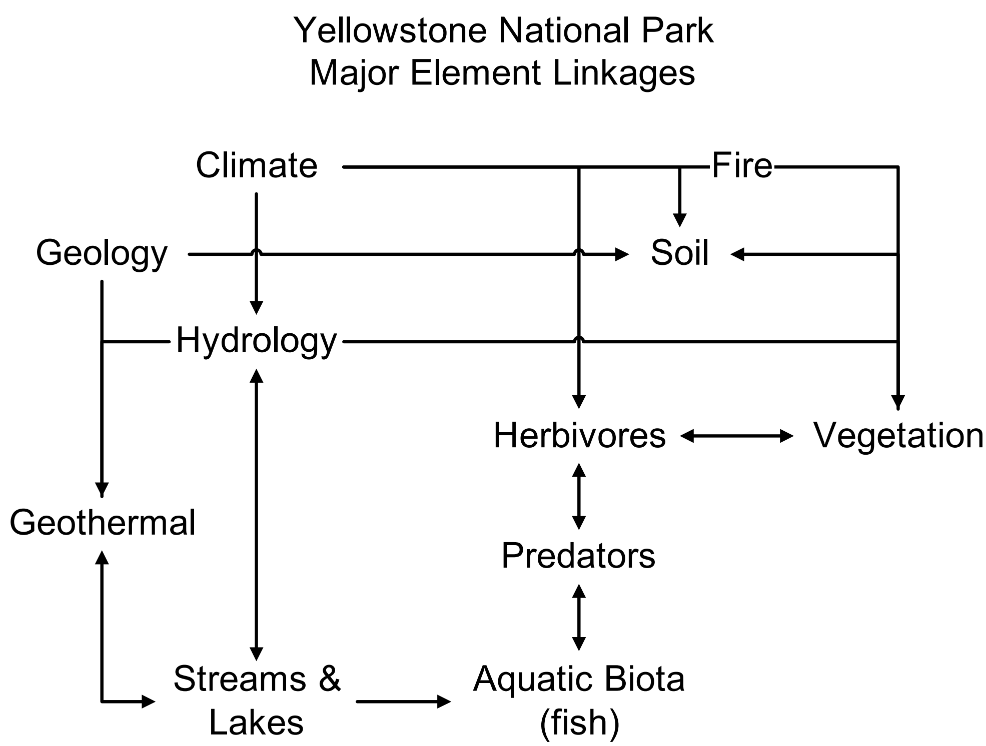
Yellowstone National Park

Conceptual models developed for Yellowstone National Park (YNP) are similar to those developed for GTNP in that they include a simple overview model, a complex system model and a set of sub-models that represent various ecosystems or components of the overall YNP system. The simple model of the YNP system (YNP Figure 1) illustrates the primary linkages among the general components of YNP. Unlike the GTNP simple model, this one does not include the role of humans, because YNP internally is not open to significant human actions that may modify components of the system as hunting and dam operations do within GTNP. However, human presence and management decisions do play an important role in the condition of ecosystems, communities and species populations within YNP.

YNP Figure 1



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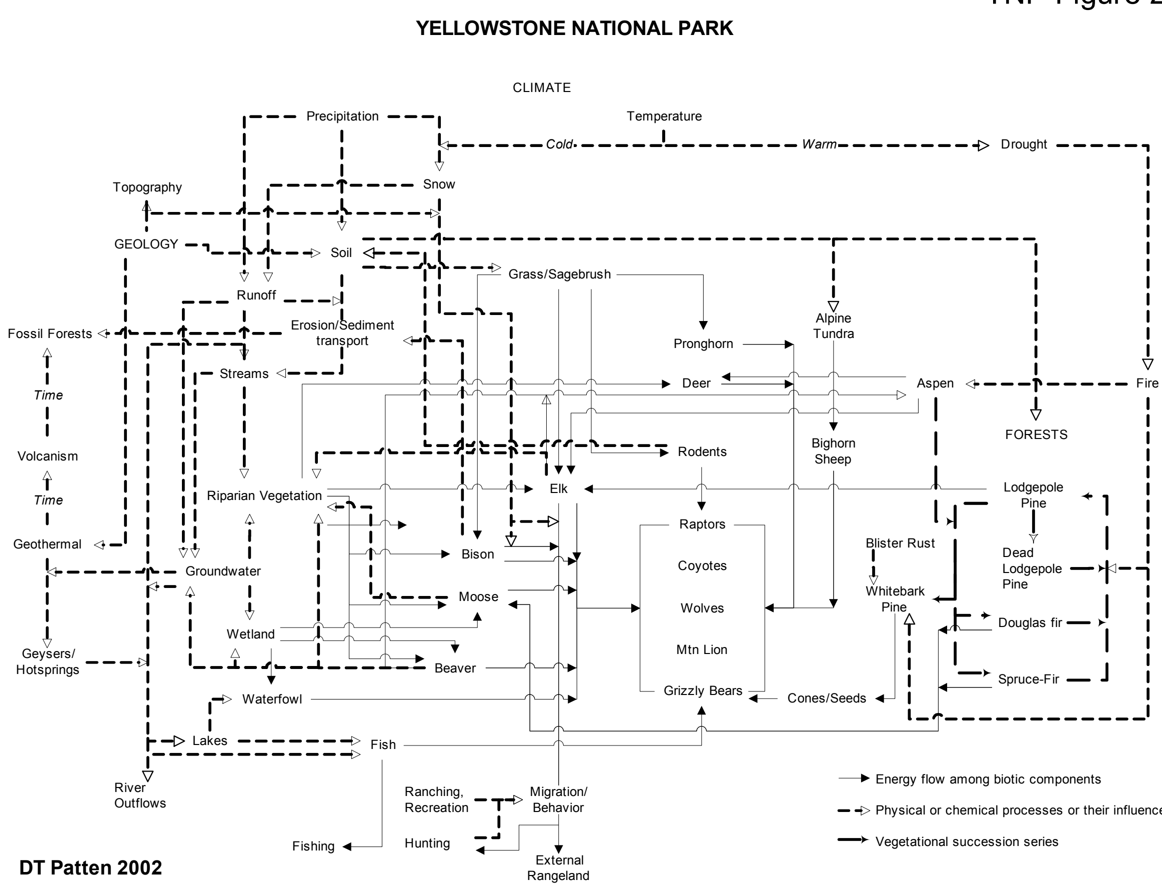
Complex System Model. The complex system model for YNP (YNP Figure 2) includes most of the primary ecosystem components, and like the Teton model shows whether the interactions between components are energy flow, physical or chemical, or successional processes. The primary drivers of the model are climate and geology with the former (climate) producing conditions that influence major ecosystem altering conditions, such as fire, and conditions that influence wildlife such as snow, while the latter (geology) drives important attributes such as topography and soils, but may be more obvious as a driver of the geothermal features of YNP. The role of humans is documented in the model as influencing ungulate migration and behavior, some of this being done from outside the park as hunting and development pressures. The model attempts to show linkages among hydrology, vegetation and wildlife, interactions and processes that have become important management issues.

YNP Figure 2



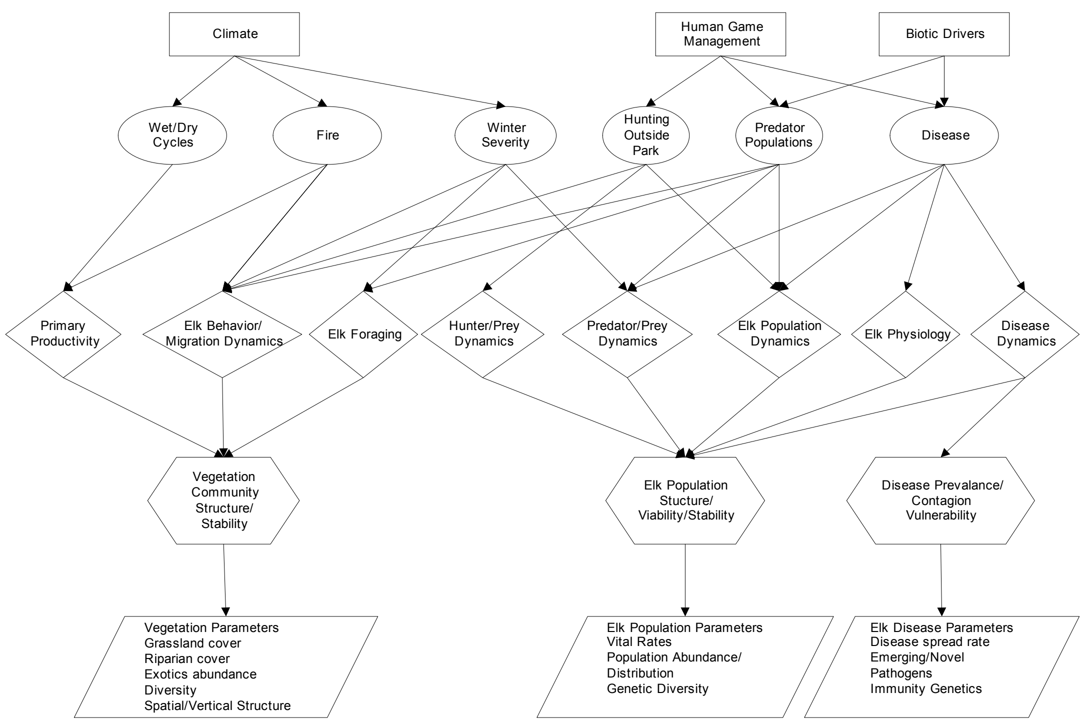
Yellowstone National Park Sub-Models

Several sub-models of important processes or attributes within the YNP system have been developed to allow a better understanding of the interrelationships among stressors, processes, outcomes and indicators than can be discerned from the whole system conceptual model. The sub-models presented here include ones dealing with elk, aspen, riparian/wetlands, and sediment/erosion processes. There are many other potential models such as those dealing with other ungulates and predators, or fires, but the ones included here have many of the drivers, stressors and processes that would be in those models as well.

Elk Sub-Model. The elk sub-model (YNP Figure 3) emphasizes both the climatic and predatory (hunting and predators) nature of the stressors on elk populations. Disease also plays a role as do those factors influencing food sources for elk. The indicators for this sub-model list some potential metrics for monitoring.

YNP Figure 3

Yellowstone National Park
Elk



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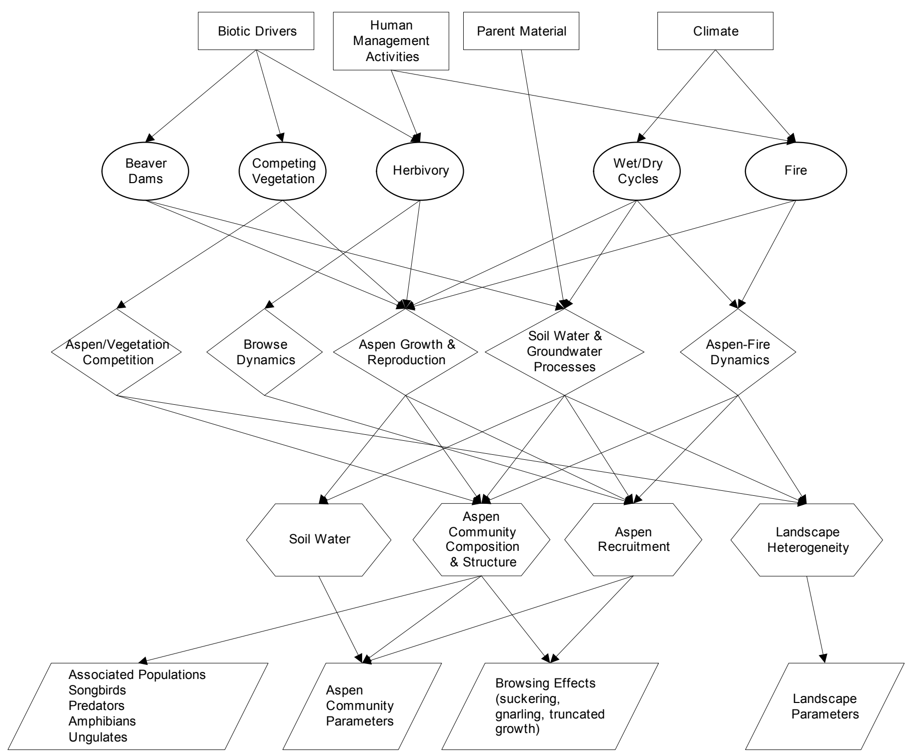
Aspen Sub-Model. The condition of aspen in YNP has become a management issue as well as an ecological problem. Aspen stands appear to be declining and no new mature aspen have established since the 1920s. The aspen sub-model shows the role of several animals as stressors. These include herbivory and girdling by ungulates, and the effects of beavers altering soil and ground water, and directly affecting aspen stands through cutting and girdling. Aspen sometimes functions as a riparian species when elevated groundwater levels create moist soil conditions. Fire is also considered a major stressor influencing destruction and recovery of aspen stands. Indicators for aspen communities include attributes other than just plant features. Most important non-vegetation parameters are the associated species that use aspen stands, such as songbirds.

YNP Figure 4

Yellowstone National Park
Aspen Communities



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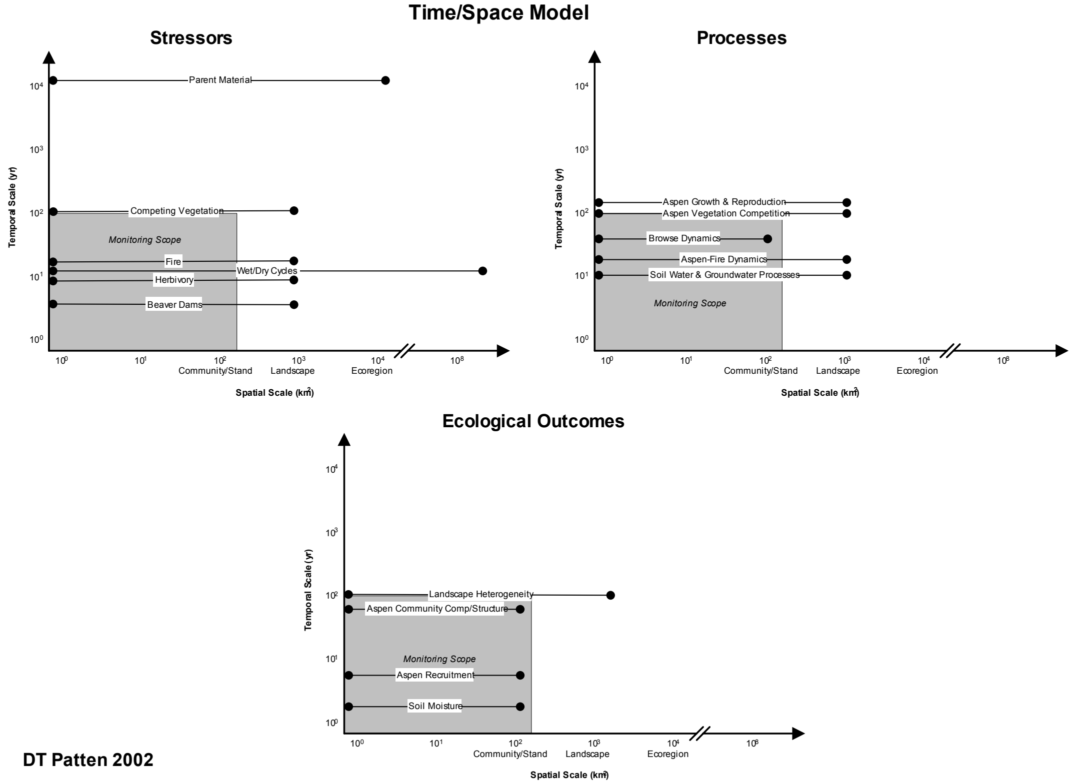
Aspen Time/Space Model. The time/space model for aspen in Yellowstone National Park (YNP Figure 4a) shows that most of the stressors, processes and outcomes fall within the monitoring scope although some may extend across the landscape or region. When considering parameters to monitor relative to aspen communities, using outcomes that fall not only in the monitoring scope area but are short-term such as soil moisture and aspen recruitment as guidance may lead to potentially viable indicators more so than using outcomes that are long-term. Monitoring tied to community structure may also be possible if long-term results are needed. To understand the aspen system there is also a need to measure stressors. Those that are very long-term such as parent material need only be measured once or every decade or so, while short-term stressors that could change every year, such as herbivory or beaver dams and activity may need to be measured regularly (e.g., every year or two).

YNP Figure 4a

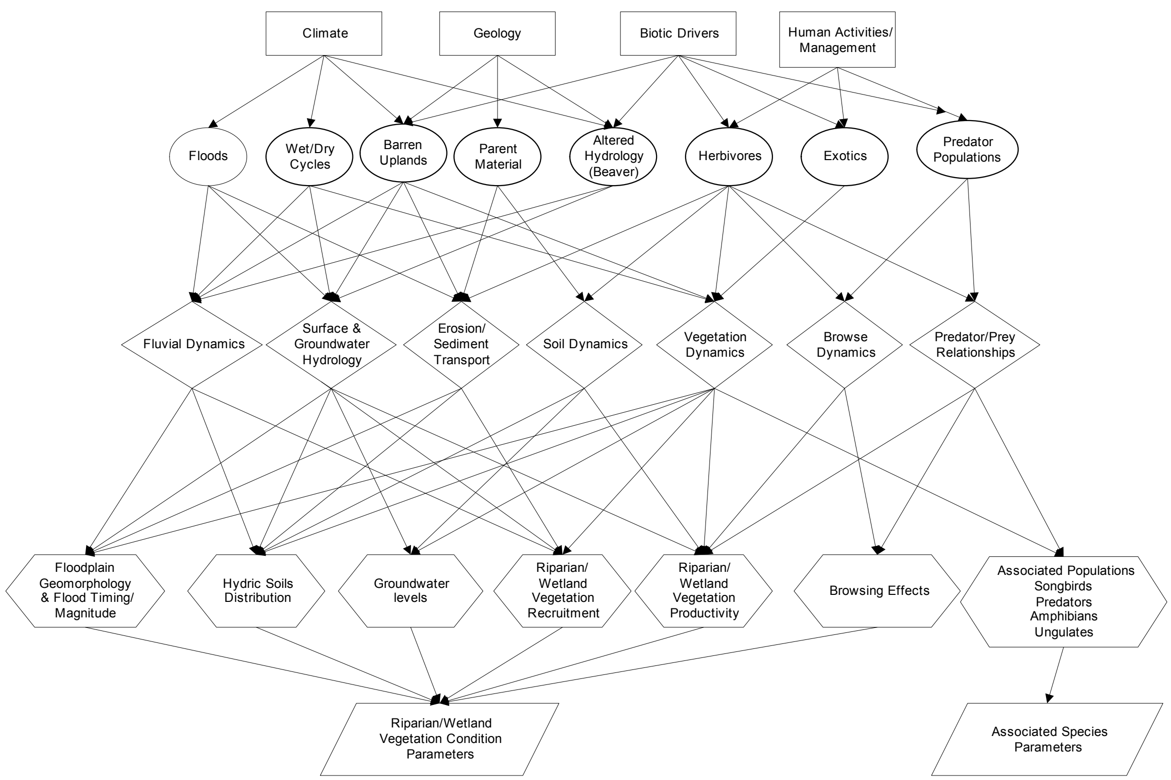
Yellowstone National Park
Aspen Communities
Time/Space Model



Riparian and Wetland Sub-Model. Riparian and wetland ecosystems within YNP are known to maintain high levels of biodiversity. They also are systems that may be threatened by ungulate populations and potential climate change. The riparian/wetland conceptual model (YNP Figure 5) shows the multitude of drivers and stressors that influence these systems. The many processes that result from these stressors demonstrate the complex interactive nature of systems that interface between aquatic and terrestrial environments. Indicators of the condition of riparian/wetland ecosystems should include, not only vegetation conditions, but those species that use these ecosystems as habitat. In several cases, these associated species, for example amphibians, have been found to be very sensitive to environmental change.

YNP Figure 5

Yellowstone National Park
Riparian/Wetland Areas



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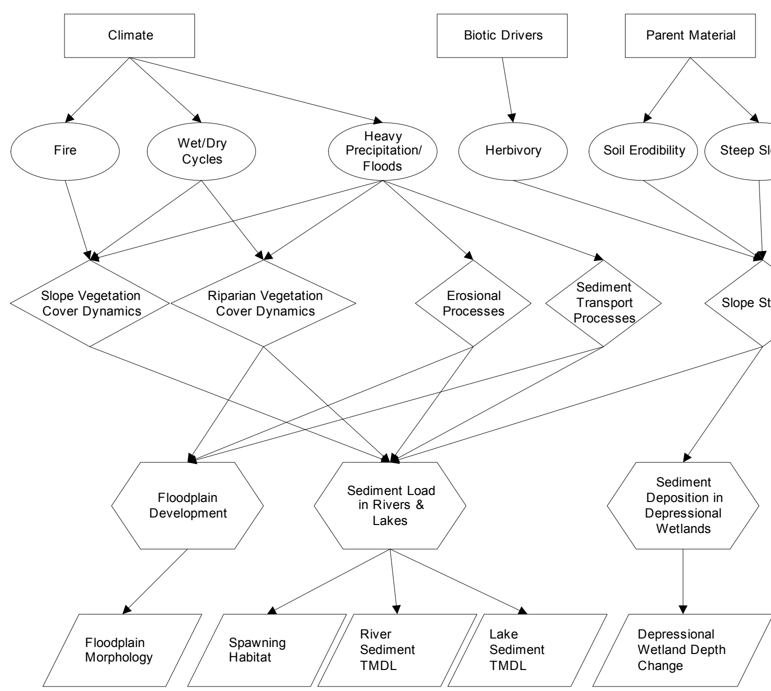
Erosion and Sediment Transport Sub-Model. The final sub-model for the YNP ecosystem illustrates the complex processes of erosion and sediment transport (YNP Figure 6). The important drivers and stressors in this model include more physical processes than biological processes. The role of some biological components of the ecosystem, such as physical alteration of soil surfaces and vegetation structure by large herbivores, also may greatly influence the physical processes. Sediment loss from the land is a natural process but can be accelerated by many ecosystem components that are acting outside their historic range of variability. Consequently, the influence of sediment transport and deposition not only affects streams and depression areas but species that may depend on these systems. For this reason, the model includes spawning habitat in rivers. It doesn't include other animals that may be associated with wetland depressions because these are included in the riparian/wetland model. This is just one example of the overlap among the sub-models.

YNP Figure 6

Yellowstone National Park
Erosion/Sediment Transport



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