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Developing Terrestrial Trophic Models for Petroleum and Natural Gas Exploration and Production Sites: The Oklahoma Tallgrass Prairie Preserve Example

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Executive Summary

This document details procedures to be used when constructing a conceptual terrestrial trophic model for natural gas and oil exploration and production sites. A site conceptual trophic model is intended for use in evaluating ecological impacts of oil and brine releases at E&P sites from a landscape or ecosystem perspective. The terrestrial trophic model protocol was developed using an example site, the Tallgrass Prairie Preserve (TPP) in Oklahoma. The procedure focuses on developing a terrestrial trophic model using information found in the primary literature, and augmented using site-specific research where available. Although the TPP has been the subject of considerable research and public interest since the high-profile reintroduction of bison (*Bison bison*) in 1993, little formal work has been done to develop a food web for the plant and animal communities found at the preserve. We describe how to divide species into guilds using explicit criteria on the basis of resource use and spatial distribution. For the TPP, sixteen guilds were developed for use in the trophic model, and the relationships among these guilds were analyzed. A brief discussion of the results of this model is provided, along with considerations for its use and areas for further study.

1. Introduction

The United States petroleum and natural gas industry owns and operates large numbers of exploration and production (E&P) sites. These are large sites (upwards of tens of thousands of acres) that are used for the exploration and production of natural gas and petroleum products. These sites typically contain intact expanses of natural habitat (such as grassland, forest or desert), in which exploration and production wells, distribution piping and tank batteries are installed and operated. Through the operation of such sites, releases of petroleum products and substances related to petroleum production (such as brine) periodically occur. Often, these releases only impact terrestrial resources, particularly in areas with limited numbers of wetlands or streams. The petroleum and natural gas industry is increasingly required to assess the ecological impacts of these releases. However, conducting an ecological risk assessment (ERA) focused only on the localized spill may provide a misleading and erroneous estimate of risk with respect to the entire E&P site. Experience in conducting ERAs in other industries (such as hazardous waste sites) have shown these ERAs often consider areas that are too small to be ecologically relevant.

Therefore, Lawrence Livermore National Laboratory (LLNL), collaborating with Oak Ridge National Laboratory (ORNL), is engaged in a project to create tools and techniques for evaluating ecological impacts at E&P sites from a larger landscape or ecosystem perspective. We have identified the creation of a site conceptual terrestrial trophic model as one of the first steps in evaluating a site from a landscape perspective. In this document, we outline the steps necessary to create such a trophic model. This is done through evaluating an example site, the Tallgrass Prairie Preserve (TPP) in northeastern Oklahoma. We have focused on creating a terrestrial trophic model using information from the primary literature and relevant research being currently conducted at the TPP. While other E&P sites may not have such extensive research activity, creation of a trophic model should still be possible using information found in the open literature on the types of habitats found at the site, regardless of whether the specific site has been studied. By following the steps outlined here, a conceptual terrestrial trophic model suitable for use in estimating the impacts from the operation of E&P sites should be possible.

The Tallgrass Prairie Preserve (TPP) consists of 15,200 hectares (ha) of rolling prairie in northeastern Oklahoma owned by the Nature Conservancy (ONHI, 1993; Hamilton, 1996). It plays host to a wide variety of plant and animal species (many of which are prairie-dependent), and represents one of the last substantial remnants of the tallgrass prairie ecosystem, which historically covered 5.7 million ha of the United States and Canada (Madson, 1990). The TPP became home again to bison when they were reintroduced in 1993. Since that time, the Nature Conservancy has used fire and bison grazing as primary management practices to achieve prairie restoration, reenacting the natural disturbances that historically functioned to maintain the ecosystem (Hamilton, 1996).

The TPP is also an E&P site, with over 600 historic wells, and 120 active wells in the preserve. Oil and brine spills have recently occurred in the preserve. The site contains five historic brine scars, several recent spills of brine, oil, or oil and brine (within the past 2 years), along with older spill sites (8 to 15 years). Thus, the TPP is ideally suited for use as an example site in creating tools and techniques to evaluate E&P sites from a landscape or ecosystem

perspective. In particular, the TPP will be useful in evaluating the effect of size and spatial distribution of terrestrial releases on community and ecosystem structure or function as a result of habitat destruction or degradation.

In this paper we evaluate the trophic system at the TPP, and develop a conceptual terrestrial trophic model for the preserve. In doing so, we develop a methodology for analyzing terrestrial trophic systems that may be used at other E&P sites. Here we describe the process of dividing species into guilds using several methods. These guilds are then used as building blocks to construct a model that represents the relationships among the terrestrial biota at a site. Such a trophic model can then be used to select representative species from each guild ("endpoint species") as indicators for the integrity of community structure and function of a site. The endpoint species are usually selected using four criteria (adapted from Suter, 1993): (1) social relevance, (2) biological relevance, (3) predictability and measurability, and (4) sensitivity to disturbance. The terrestrial trophic model was therefore developed with these four criteria in mind.

2. Material and Methods

There are three basic steps in the construction of a conceptual terrestrial trophic model. These are (1) creating a list of species expected to occur at the site, (2) assigning the species to guilds, and (3) constructing the trophic model through an analysis of the relationships between guilds. A conceptual terrestrial trophic model constructed for use in evaluating E&P sites is not intended to be an exhaustive model of all types of species found at the site. Rather, it focuses on the creation of guilds and foodwebs of those groups most likely to used in additional evaluations.

2.1. Species Lists

Prior to the construction of a species list, it is necessary to know the types of habitats found at the site. If site-specific data is not available, general habitat descriptions for most areas of the United States can be found in the open literature. A site visit by a knowledgeable biologist or ecologist may also be required. State natural heritage and fish and wildlife agencies may also have useful data. Once the habitats are defined, species data can be gathered from a variety of sources. For the TPP, these included a 1993 report published by the Oklahoma Biological Survey (ONHI, 1993), species lists obtained from the Nature Conservancy (Nature Conservancy, 1996) and Oklahoma State University (Palmer, unpublished data), as well as a survey of the open literature. Species found in similar ecosystems, such as the Konza Prairie Long-Term Environmental Research Site (LTER), were not included, although data regarding diet and habitat preferences in some cases were used. Although it was not necessary for us to use species data from similar ecosystems for the TPP, these types of data should be used at E&P sites that have not been as well studied as the TPP.

A master list of animal species found at the TPP is included in Appendix A. Time constraints and the focus of the study precluded a comprehensive analysis of plants and fungi, and invertebrates also received a limited treatment; these compartments may be expanded in the future if the need arises. As this study focuses on the terrestrial ecosystem, species strictly related to the aquatic systems at the TPP are also omitted, although a partial list of these species is

provided for reference (Appendix B). The sources for all information regarding each species is noted, except in the case of very general information or "common knowledge" (e.g., the designation of hawks as raptors).

2.2. Guild Criteria

Many different methods exist to define guilds. Wilson (1999) made a basic distinction between two types of guilds: alpha and beta. An alpha guild is based on resource use: guild members use the same class of resources in a similar way. This is what Root (1967) originally envisioned when he first introduced the concept of the guild, and these guilds are therefore commonly referred to as "Rootian" guilds. A beta guild, in contrast, bases classifications on environmental conditions: guild members share similar space along multiple environmental gradients (i.e., occupy the same or a similar niche). The two types of guilds therefore fundamentally diverge in character, as alpha guild members tend to be competitors, and hence are not expected to coexist, whereas beta guild members are found together occupying similar habitats. The distinction between the two types of guilds is useful; however, it remains theoretical. In practice, some crossover exists between these two concepts. For instance, environmental conditions, depending upon the context, can be construed as resources (e.g., habitat).

The literature review performed for this research indicated two key problems commonly associated with efforts to delineate guilds. First, we found that the criteria used to assign species to guilds are either poorly defined, arbitrary, or not provided at all. "Lack of stated, unambiguous criteria for these (guild) assignments can potentially lead to ambiguous results and controversial interpretations" (Simberloff and Dayan, 1991). Second, guild definitions, as theoretical constructs, often are not developed such that they are useful for further analysis.

To avoid these problems, the criteria used for guild assignment in the present analysis have been clearly and explicitly defined, with consideration given to their eventual use in both generating the conceptual trophic model and determining the results of disturbances throughout the TPP system. Guild definition descriptions follow Wilson (1999), as his is the most comprehensive review to date. Both alpha and beta guilds were constructed to increase the depth of analysis.

2.2.1. Alpha Guilds

In delineating the alpha guilds, we refer back to the classic definition of a guild: "…a group of species that exploit the same class of environmental resources in a similar way" (Root, 1967). Because we intend to develop a food web using these guilds, we considered food as the primary environmental resource. To partition this resource into classes, and to ensure that each guild is internally consistent in terms of method of exploitation, we used two criteria to delineate the alpha animal guilds:

- *Type of Food Consumed*. We divided species into three general categories: carnivore, herbivore, and omnivore. In some cases, subdivisions were made among these categories to allow higher resolution (e.g., dividing carnivores by the type of prey), although the guild categories as constructed do not define the life-stage or physical part of the food resource used (e.g., birds vs. eggs; folivores vs. granivores). Guild designations are based

on primary food consumption; incidental ingestion, unless it constitutes a significant portion of the diet, was not considered as relevant. Omnivory is used to describe species that feed upon both primary and secondary producers.

- *Taxonomy.* The categories obtained from (1) are then further divided either by taxonomy, as mammals (*Mammalia*), herptiles (*Amphibia* and *Reptilia*), birds (*Aves*), or invertebrates (all non-chordates). In some cases, further subdivisions are made on the basis of body size or method of food consumption, given its effect on either specific consumption patterns or use by predators.

Following Wilson (1999), these criteria form an "objective character Rootian guild," based on measurable attributes of the species. Criterion (1) is commonly found in many studies which assign species to guilds; however, criterion (2) is more unusual, as the classic "guild" ignores taxonomic boundaries, and guild members in many studies typically span a variety of taxa. We selected this second criterion for several reasons. First, animals with similar taxonomy tend to use resources in similar ways (MacNally and Doolan, 1986); therefore, the criterion could be potentially used as a proxy for specific foraging habit. For instance, by hunting from the air, raptors capture prey in quite a different way than do carnivorous mammals. Similarly, bison (*Bison bison*) and cattle (*Bos* spp.) share similar taxonomy and similar foraging habits. In contrast, the quantity of herbage consumed by an individual bison is orders of magnitude larger than that consumed by an individual deer mouse (*Peromyscus maniculatus*) (although deer mice may collectively consume more than bison). Second, closely related species often overlap in other ways besides foraging habit (Simberloff and Dayan, 1991); these overlaps can include habitat preference, home range size, role in ecosystem function, and more important, response to disturbance. In theory, events that affect the chosen class of environmental resource (food) will similarly affect all the members of the guild using that resource, although this may not be the case, when there is considerable diversity within a guild (see Section 3.4.3, Considerations, below). Third, as a convention, food webs are typically divided along taxonomic boundaries (DeAngelis, 1992). Whether this is an appropriate method for developing food webs, or simply an artifact stemming from habit or researchers' biases, is subject to debate. It should be noted that, as part of the analysis of the trophic structure at the preserve, several of the guild categories developed in this report are also aggregated into "metaguilds," which more closely follow the classic Rootian guilds that ignore taxonomic boundaries. Taxonomy remains only an approximate tool for delineating similarities between species.

The resulting guilds take the form of Schoener's (1986) "taxon-guilds," which he defines as groups of closely related species using the same resource.

2.2.2. Beta Guilds

For this study, habitat type is considered the primary criterion for dividing species into beta guilds. As defined by Oklahoma Natural Heritage Inventory (1993) and Payne and Caire (1999), six distinct terrestrial habitats are found at the TPP: prairie, upland deciduous forest, deciduous riparian forest, grassy riparian, disturbed areas, and rocky outcrops. Percentage areas for upland deciduous forest, deciduous riparian forest, deciduous riparian forest, grassy riparian, and disturbed areas were estimated using an area-line meter (Planix 5000) on topographic maps (Payne and Caire, 1999). As rock outcrop areas are not demarcated on these maps, they were estimated conservatively to be one-half of the amount of disturbed area. Percentage area of

prairie habitat was then obtained by subtracting these areas from the total area of the Preserve. Typical plant species for each habitat are given in Table 1.

- Prairie. These are classic open, rolling fields, covering 92.3% of the area of the preserve.
- Upland deciduous forest. This occurs at the top of many of the larger hills, and covers 4% of the preserve.
- Deciduous Riparian Forest. This habitat occurs adjacent to lowland creeks (e.g., Sand Creek, Wild Hog Creek, and Bird Creek), and constitutes approximately 2.5% of the area of the preserve.
- Grassy Riparian. This habitat borders spring-fed streams that meander through the prairie en route to the major creeks mentioned above, and constitutes 0.6% of the area of the preserve.
- Disturbed areas. These are habitats currently experiencing anthropogenic disturbance, consisting mainly of human-built structures, such as buildings, oil-production sites, corrals, or roads, and cover 0.4% of the preserve.
- Rocky outcrops. These are found on the edges of hills and in areas of extensive erosion, and cover 0.2% of the preserve area.

With these categories, we divided species into guilds utilizing observed data (in the case of most species of mammals) as well as deductions using general habitat preference (herptiles, invertebrates, birds, and some mammals). Therefore, these definitions are a mixture of the fundamental niches and realized niches for these species. As a result, they should be used as general guidelines for species occurrence rather than true indicators of actual location. In particular, the temporal (e.g., seasonal) variations in the location of species have not been examined, in part due to a lack of data (see discussion in Appendix C). The beta guilds correspond with Wilson's (1999) "spatial distribution (beta) guilds." See Appendix D for a list of sources of habitat data.

2.3. Trophic Model

Typically, trophic species are used as basic units for development of a trophic model. A trophic species is a set of organisms with identical predator and prey species (Schoener, 1989; Pimm et al., 1991). However, because the intent of this study relates to impact assessment, trophic species were abandoned in favor of alpha guilds. While the alpha guilds approximate trophic species, the level of species aggregation is higher in most of the alpha guilds in this study. As mentioned earlier, aggregation based on taxonomy, body size, etc., may assist with understanding other common aspects of guild members besides foraging, potentially including response to disturbance.

Relationships between the guilds were determined based on dietary information collected in the creation of the alpha guilds. Each guild was given the binary designation of prey/not prey relative to each of the other guilds in the study. The resulting connections form a "cumulative" web (with observations aggregated over time, in contrast with a time-specific web; Pimm et al., 1991). Statistical analyses were then performed on the web to increase understanding and compare it against other published food webs. These were completed in the following manner

(definitions mostly follow Pimm et al., 1991): (1) for the purposes of our analysis, guilds were treated as trophic species (S); (2) a "link" (L) is a predator/prey interaction; (3) the number of possible links was S^2 (i.e., the maximum number of possible predator/prey interactions; "looping," or feeding on members of one's own guild, was allowed); (4) connectance (C) was determined by dividing the number of realized links by the number of possible links (L/ S^2); and (5) the linkage density was defined as the average number of links per guild (L/S).

3. Results and Discussion

3.1. Alpha Guilds

Sixteen distinct alpha animal guilds are found at the TPP (Table 2). Because many of the species sharing guilds coexist, competitive exclusion does not seem to be present among the alpha guilds, at least at the large spatial scale of the preserve. This is not surprising, because guild members are expected to coexist when the type, size, or location of prey is different, or when the method of capturing prey varies within a guild (Risser et al., 1981). However, some evidence indicates that competitive exclusion may occur between several of the species with similar food habits. For instance, in the Konza Prairie LTER, Kaufman et al. (1998) found an inverse relationship between bison grazing on the one hand, and prairie vole and harvest mouse populations on the other hand. These three species are all part of the herbivorous mammal guilds (see below). This evidence may support the alpha guild structure, because it can be posited that such a relationship arises from competition; however, more study would be necessary to assert competitive exclusion within the guilds. Given the limited spatial distribution data and the short time period from which species information was drawn, other occurrences of competitive exclusion may not be evident.

The following is a brief description of the species found in each guild, their dietary habits, and common predators. These guilds should be taken as general guidelines for feeding habits, as feeding may occur outside these categories, particularly at times of stress or food scarcity.

3.1.1. Herbivorous Mammal Guilds

The herbivorous mammals are divided into three separate guilds because of clear differences in body size and feeding habits, which in turn affect quantity of vegetation consumed per animal, and the set of predators who prey upon these herbivores.

3.1.1.1. Herbivorous Mammal Guild 1a—Large Grazers

Two species make up this guild, the bison (*Bison bison)* and the cow (*Bos* spp.). The Nature Conservancy, as part of the management of the preserve, regulates the populations of both species (Hamilton, 1996). Bison eat primarily grasses and sedges, consisting of up to 99 percent of their diet by weight (Van Vuren, 1984; Coppedge and Shaw, 1998), and show a preference for vegetation in areas that have been burned in the last year (Knapp et al., 1999). Species consumed are primarily grasses in the bluestem complex (*Andropogen* spp., *Paspalum* spp., *Sorghastrum* spp., and *Sorghum* spp.), *Sporobolus* spp., and *Carex* spp. (Coppedge and Shaw, 1998). Comparative fecal analysis of cattle and bison show high dietary overlap, although cattle exhibit

wider dietary niche breadth, consuming a more variable set of species that generally includes a larger proportion of forbs and shrubs (Van Vuren and Bray, 1983; Van Vuren, 1984; Damhoureyeh and Hartnett, 1997). One study (Damhoureyeh and Hartnett, 1997) found differing impacts between bison and cattle in the composition of tallgrass plant communities; in particular, forb response was complex and varied significantly between plant species, fire regimes, and plant life history stage. Bison and cattle may also influence plant communities through other disturbances associated with non-grazing activities (e.g., trampling and excretion) (Damhoureyeh and Hartnett, 1997).

Predators of this guild include the coyote (*Canis latrans*) and mountain lion (*Felis concolor*), although predation may be limited to juveniles and carrion (Chapman and Feldhamer, 1982; Lindzey, 1987).

3.1.1.2. Herbivorous Mammal Guild 1b—Browsers

This guild consists of one species, the white-tailed deer (*Odocoileus virginianus*). The deer differs significantly from the previous set of herbivores in several ways. First, humans do not directly regulate its population in the TPP. Second, it is a browser rather than a grazer, and selects distinctly different plant species as food. Vegetation consumed varies with season and availability, but generally consists of forbs, browse, and smaller amounts of grasses and trees/shrubs (Bryant et al., 1996; Myers et al., 2000). In the cross-timbers region in Oklahoma (possessing similar vegetation to the TPP), Bryant et al. (1996) found a subset of seven species preferred by white-tailed deer: acorns (*Quercus* spp.), Osage orange (*Maclura pomifera*), Carolina snailseed (*Cocculus carolinus*), three-seeded mercury (*Acalypha* spp.), ticklover (*Desmodium* spp.), and brome (*Bromus* spp.).

The deer is preyed upon by large omnivorous and carnivorous mammals such as bobcat (*Felis rufus),* coyote (*Canis latrans*) and mountain lion (*Felis concolor*), and to a lesser extent, the gray fox (*Urocyon cinereoargenteus*) (Mech, 1984; Greenberg and Pelton, 1991; Brillhart and Kaufman, 1994; Myers et al., 2000).

3.1.1.3. Herbivorous Mammal Guild 2—Smaller Herbivores

Species in this guild include the beaver (*Castor canadensis*) and various species of lagomorph, rodent, and vole. Most species are generalist herbivores, feeding on a diversity of plant material. For instance, the eastern cottontail (*Sylvilagus floridanus*) feeds on herbaceous material, such as grasses and forbs, during the summer, and shifts to woody plant parts during the winter (Chapman et al., 1980; Myers, 2000). The eastern woodrat's (*Neotoma floridana*) diet consists of leaves, bark, fruits and seeds; the woodland vole (*Microtus pinetorum*) eats tubers, roots, seeds, leaves, and nuts. The beaver feeds on tree bark, leaves and aquatic vegetation (Allen, 1983; Myers et al., 2000). Species in this guild may consume large amounts of vegetation relative to their body size, because of either high metabolism or population density, and so should be considered to have impacts on the plant community that are potentially as significant as those of the larger herbivores.

Predators upon this guild include a variety of carnivorous and omnivorous mammals and herptiles, as well as raptors (Brillhart and Kaufman, 1994; INHS, 1998; Myers et al., 2000). For instance, mammalian predators upon the eastern cottontail and black-tailed jackrabbit include the

gray fox (*Urocyon cinereoargenteus*), coyote (*Canis latrans*), bobcat (*Felis rufus*), mink (*Mustela vison*), and mountain lion (*Felis concolor*). Other lagomorph predators include the great horned owl (*Bubo virginianus*), the barred owl (*Strix varia*), and a variety of hawks (Godin, 1977; Dunn et al., 1982; Janes, 1985; Giusti et al., 1992). Timber rattlesnake (*Crotalus horridus*), garter snake (*Thamnophis sirtalis*), raccoon (*Procyon lotor*), badger (*Taxidea taxis*), the striped skunk (*Mephitis mephitis*), and the Virginia opossum (*Didelphis virginiana*) will also preferentially take nestlings as well as adults (Vorhies and Taylor, 1933; Lechleitner, 1959; Rue, 1965).

3.1.2. Omnivorous Mammal Guilds

Omnivorous mammals were also divided into two separate categories based on differences in body size, to aid in the distinctions between both predators and feeding habits.

3.1.2.1. Omnivorous Mammal Guild 1—Larger Omnivores

The larger omnivores at the TPP are the coyote (*Canis latrans*), the Virginia opossum (*Didelphis virginiana*), the striped skunk (*Mephitis mephitis*), the raccoon (*Procyon lotor*), the nine-banded armadillo (*Dasypus novemcinctus*) and the gray fox (*Urocyon cinereoargenteus*). These species all feed on invertebrates, small mammals, fish, birds, carrion, and various parts of plants (Myers et al., 2000). The opossum and raccoon are particularly opportunistic species, and are selective feeders when food is abundant, and more generalist when food is scarce (Lotze and Anderson, 1970; Chapman and Feldhamer, 1982). The most important prey species by weight for the gray fox is eastern cottontail (*Sylivilagus floridanus*), followed by white-tailed deer (*Odocoileus virginianus*) and rodents, although terrestrial invertebrates and a variety of plant material are also taken (Trapp and Hallberg, 1975; Greenberg and Pelton, 1991). Mammals, particularly lagomorphs and rodents, are the most significant portion of coyote diets, but insects and vegetation (berries and grasses) are also taken in significant amounts (Bekoff, 1977; Brillhart and Kaufman, 1994).

The members of this guild are infrequently preyed upon (Davis and Schmidly, 1994). The raccoon is prey to mountain lion (*Felis concolor*), bobcat (*Felis rufus*), coyote (*Canis latrans*), and owls (Lotze and Anderson, 1970). The Virginia opossum is prey to owls and the gray fox (Davis and Schmidly, 1994). The gray fox is occasionally taken by coyote and bobcat, and pups are taken by bobcat and great horned owl (*Bubo virginianus*), and possibly large hawks (Trapp and Hallberg, 1975). Coyotes are occasionally preyed upon by mountain lions (Banfield, 1974).

3.1.2.2. Omnivorous Mammal Guild 2—Smaller Omnivores

All of the mammals in this guild are rodents, including the fox squirrel (*Sciurus niger*), the 13-lined ground squirrel (*Spermophilus tridecimlineatus*), and various species of rats and mice. Over the entire guild, diet includes insects and other invertebrates, small vertebrates, carrion (in the case of the 13-lined ground squirrel), seeds, fruit, flowers, nuts, and other plant products (Myers et al., 2000). The hispid cotton rat (*Sigmodon hispidus*) feeds on stems, foliage, and seeds, as well as occasional insects and small vertebrates (Martin et al., 1951; Whitaker, 1980). The deer mouse (*Peromyscus maniculatus*) mainly prefers arthropods and seeds, although it will also consume nuts, berries, other small fruits, and fungi (Whitaker, 1980). Fox squirrels feed on a variety of plant material, insects, bird eggs, and fungi (Chapman and Feldhamer, 1982; Myers et

al., 2000). The 13-lined ground squirrel consumes grasses (especially in early spring), seeds, and many insects (especially grasshoppers) and other animal matter (Timm and Pisani, 2000).

These species are prey to larger omnivorous and carnivorous mammals, snakes, and raptors (Myers et al., 2000). For instance, significant predators of the hispid cotton rat include Swainson's hawks (*Buteo swainsonii*), red-tailed hawk (*B. Jamaicensis*), and the short-eared owl (*Asio flammeus*) (Smith and Hanebrink, 1982; Bednarz, 1988; Toland, 1990). Relatively few predators can regularly capture adult fox squirrels; species include bobcat (*Felis rufus*), gray fox (*Urocyon cineoargenteus*), hawks, and owls. Juvenile fox squirrels are taken by raccoons, opossums, rat snakes (*Elaphe obseleta*), and bullsnakes (*Pituophis melanoleucus*) (Chapman and Feldhamer, 1982; Weigl et al., 1989).

3.1.3. Carnivorous Mammal Guilds

Species in these guilds exhibit clear differences in diet and body size, and have been divided accordingly.

3.1.3.1. Carnivorous Mammal Guild 1a—Fossorial Invertivores

This guild consists of two burrowing species, the eastern mole (*Scalopus aquaticus*) and the least shrew (*Cryptotis parva*). The least shrew feed principally upon insects, earthworms, snails, and carrion. Similar to the shrew, the eastern mole eats snails, earthworms, adult insects and other invertebrates, as well as larval insects and earthworms (Davis and Schmidly, 1994; Timm and Pisani, 2000). These species are subject to predation by larger herptiles, carnivorous and larger omnivorous mammals, and raptors (Timm and Pisani, 2000).

3.1.3.2. Carnivorous Mammal Guild 1b—Flying Invertivores

Two species of bat, the evening bat (*Nycticeius humeralis*) and the red bat (*Lasiurus borealis*), make up this guild. Their diets are restricted to flying insects (Davis and Schmidly, 1994; Myers et al., 2000). Hawks, owls, opossums, raccoons, and snakes are all predators of both species (Myers et al., 2000; Timm and Pisani, 2000).

3.1.3.3. Carnivorous Mammal Guild 2—Large Predators

Species in this guild are the badger (*Taxidea taxus*), bobcat (*Felis rufus*), mink (*Mustela vison*), and mountain lion (*Felis concolor*). They feed on a variety of species at lower trophic levels. Important food items for the mink include muskrats (*Ondantra zibethicus*), voles (*Microtus* spp.), eastern cottontail (*Sylvilagus floridanus*), fish, birds, frogs, and insects (Chapman and Feldhamer, 1982). Bobcats will take almost any available prey, including insects, fish, herptiles, birds, and mammals, although a wide variety of mammalian prey is most common, in particular the eastern cottontail (Chapman and Feldhamer, 1982; Myers et al., 2000). Mountain lions feed primarily on large ungulate species, especially deer; however, a variety of other mammals and birds will also be taken, including other carnivores (Lindzey, 1987). Badgers commonly prey on small vertebrates, especially fossorial rodents, as well as fish, snakes, lizards, carrion, insects, and eggs and nestlings of ground-nesting birds (Long, 1973; Long and Killingley, 1983).

Predation upon the large carnivorous mammals at the TPP, other than that of humans, is probably extremely rare. Raptors and other large carnivorous and omnivorous mammals may take juveniles (Myers et al., 2000).

3.1.4. Omnivorous Herptile Guild

This guild is made up of two species of turtle, the ornate box turtle (*Terrapene ornata*), and the three-toed box turtle (*Terrapene carolina*). The three-toed box turtle eats berries and fungi, as well as earthworms, snails, slugs, and insects. The ornate box turtle tends to be more carnivorous, eating insects, snails, earthworms, bird eggs and hatchlings, and carrion, as well as vegetation (INHS, 1998). This guild has few predators, although coyotes and badgers will take the limbs of these turtles (Dawson, 2000).

3.1.5. Carnivorous Herptile Guilds

3.1.5.1. Carnivorous Herptile Guild 1—Invertivores

A variety of lizards, frogs, toads, and snakes are found in this guild, and the array of invertebrate prey is similarly diverse. For instance, the brown snake (*Storeria dekayi*) feeds on earthworms and slugs, while the flathead snake (*Tantilla gracilis*) eats scorpions, spiders, centipedes and other small arthropods. The skinks (*Eumeces* spp., *Scintella lateralis*) feed on arthropods and spiders, while the Texas horned lizard (*Phrynosoma cornutus*) preys exclusively on ants (INHS, 1998).

Several species in this guild bear special mention for their exclusive focus on belowground invertebrates. The following species are known to be fossorial: the great plains narrowmouth toad (*Gastrophryne olivacea*), the lined snake (*Tropidoclonium lineatum*), the rough earth snake (*Birginia striatula*), and Strecker's chorus frog (*Pseudacris streckeri*) (INHS, 1998).

Predators on this guild include snakes and lizards from the carnivorous herptile guild 2 (below), raptors, and omnivorous and carnivorous mammals (INHS, 1998).

3.1.5.2. Carnivorous Herptile Guild 2—Other Carnivores

This guild also contains lizards and frogs, although the major constituents are the fifteen species of snake that may be found in this guild. Common vertebrate prey includes rodents and other small mammals, smaller herptiles and herptile eggs, fish, and birds and bird eggs (INHS, 1998; Cavitt, 2000). Several species are also distinguished by additionally taking invertebrates as prey: the bullfrog (*Rana catesbeiana*), the coachwhip (*Masticophis flagellum*), the garter snake (*Thamnophis sirtalis*), the eastern collared lizard (*Crotaphytus collaris*), the ringneck snake (*Diadophis punctatus*), the western glass lizard (*Ophisaurus attenuatus*), and the yellowbelly racer (*Coluber constrictor*). The only fossorial species is the crayfish frog (*Rana areolata*), which feeds on crayfish and small amphibians and reptiles (INHS, 1998).

Raptors, snakes, and omnivorous and carnivorous mammals feed upon this guild (INHS, 1998).

3.1.6. Bird Guilds

Birds (Aves) are the most diverse taxonomic group of vertebrates at the TPP, with well over 100 species found at the Preserve. Despite this diversity, only a small number of species maintain breeding populations. Four species comprise the majority of all individuals found in tallgrass prairie: the dickcissel (*Spiza americana*), the brown-headed cowbird (*Molothrus ater*), the grasshopper sparrow (*Ammodramus savannarum*), and the eastern meadowlark (*Sturnella magna*) (Zimmerman, 1993); these species are all omnivores. Rotenberry and Weins (1980) demonstrated that these particular four species show little niche overlap or resource partitioning.

Three bird guilds have been designated: the omnivorous bird guild, the carnivorous bird guild 1 (invertivores), and the carnivorous bird guild 2 (raptors). Data regarding dietary preferences of these species were taken from Peterson (1980), Risser et al. (1981), Myers et al. (2000), and Robinson (2000). Members of the first two guilds share similar predators - a combination of mammals, herptiles, and raptors, although some of these predator groups feed selectively on eggs or chicks rather than mature individuals.

3.1.6.1. Omnivorous Bird Guild

Species in this guild span a variety of feeding habits and morphologies, from waterfowl to tree-dwellers. Most species feed in the ground and shrub stratum, although several (e.g., woodpeckers) feed in the canopy or subcanopy (Zimmerman, 1993). Diets include plant parts, invertebrates, as well as many vertebrate species. For instance, the gadwall (*Anas strepera*) feeds on plants, insects, and amphibians; the king rail feeds primarily on insects such as beetles, grasshoppers, and dragonfly nymphs, although vegetation and frogs are also eaten (Robinson, 2000). House sparrows (*Passer domesticus*) eat various kinds of seeds supplemented by some insects. Wood thrushes (*Hylocichla mustelina*) feed preferentially on soil invertebrates and larvae, but will eat fruits in late summer, fall, and late winter, and will occasionally feed on arboreal insects, snails, and small salamanders. Blue jays (*Cyanocitta cristata*) are a generalist species that eat fruits, nuts, seeds, insects, mice, frogs, and other small birds and bird eggs. The American crow (*Corvus brachyrhynchos*) is also a generalist species; its diet includes fruit, grain, snails, salamanders, small birds, eggs, mice, toads, and large quantities of insects and carrion (Myers et al., 2000).

Predators on this guild include other carnivorous and omnivorous birds and mammals, as well as snakes. Predators of particular importance include striped skunk, coyote, fox, badger, raccoon, snakes, hawks, owls, gulls and crows (Robinson, 2000).

3.1.6.2. Carnivorous Bird Guild 1—Invertivores

These are mainly smaller birds such as flycatchers, swallows, and warblers, although larger birds such as sandpipers are also found. These species exhibit a variety of feeding and nesting heights; however, many are aerial feeders or reside in the canopy (Zimmerman, 1993). Diets span the range of invertebrate species. For instance, the blue-gray gnatcatcher (*Polioptila caerula*) eats mostly small insects (mainly cicadas, aphids, and beetles) and spiders. Barn swallows (*Hirundo rustica*) feed largely on Diptera (flies) and other flying insects (Myers et al., 2000). The eastern bluebird (*Sialia sialis*) mainly preys upon arthropods, most frequently grasshoppers and crickets, but also butterflies, moths, spiders, and beetles (Pinowski, 1979).

Predators, as already mentioned, are similar to the omnivorous birds. For example, the upland sandpiper (*Bartramia longicauda*) suffers predation upon eggs and chicks by coyotes, badgers, raccoons, mink, and skunks. Crows, sharp-shinned hawks, Cooper's hawks, northern harriers, and kestrels are known to be threats to both adults and young (Carter et al., 1992). The loggerhead shrike (*Lanius ludovicianus*) suffers predation of young and eggs by other birds such as crows (Porter et al., 1975), and the eastern bluebird suffers nest failure due to raccoon and house sparrow predation (Pinowski, 1974).

3.1.6.3. Carnivorous Bird Guild 2—Raptors

This guild includes the bald eagle (*Haliaeetus leucocephalus*), the peregrine falcon (*Falco peregrinus*), numerous species of hawks and owls, and several other birds of prey. While prey varies between species, these birds feed mainly on small mammals, herptiles, fish, and some smaller birds, although invertebrates and carrion are also eaten (especially in the case of the turkey vulture, *Cathartes aura*) (Myers et al., 2000). The bald eagle (*Haliaeetus leucocephalus*) prefers fish, and also preys on small mammals, waterfowl, small birds, and carrion (especially deer). The burrowing owl (*Athene cunicularia*) preys on small mammals such as lagomorphs and rodents, birds, reptiles, and a variety of insects and arachnids. The Mississippi kite (*Ictinia mississippiensis*) primarily preys on insects such as grasshoppers, cicadas, and beetles; however, frogs, toads, lizards, snakes, other birds and carrion are also eaten (Robinson, 2000).

Adult individuals in this guild have no natural predators at the TPP. Juveniles and eggs are sometimes preyed upon, particularly in ground-nesting species such as the northern harrier (*Circus cyaneus*) and the short-eared owl (*Asio flammeus*). Such predators include other raptors, crows and jays, snakes, and omnivorous mammals (Robinson, 2000).

3.1.7. Invertebrate Guilds

Invertebrates likely serve an extremely important role in the community at the TPP. At the Konza Prairie LTER, 62 families and more than 300 species of insects have been classified, and it is estimated that more than 3000 species exist at the site (Kaufman et al., 1998); the TPP is likely to be very similar. Indeed, Arenz (1995) asserts that 75% of all species at the TPP are animals, and of these, 95% are insects. Findings already indicate that insects, as a whole, have a large influence on tallgrass prairie plants (Hartnett and Fay, 1998); it is also possible that particular species of insect serve keystone functions in the community.

Despite the astonishingly diverse array of taxa and feeding mechanisms, only two guilds have been developed for invertebrates: the aboveground invertebrate guild and the soil invertebrate guild. The primary criterion for partitioning species into guilds, trophic level, was abandoned in favor of a criterion based on vertical spatial distribution, in an effort to simplify the connections between the invertebrate guilds and higher trophic levels.

Instead of delineating invertebrate guilds based on feeding habit, the additional complexities found within each of these two guilds are discussed by dividing each guild into several feeding categories. An exhaustive species list was not available for invertebrates at the TPP; guilds, categories, and descriptions are based on species found at the analogous Konza LTER (http://climate.konza.ksu.edu) and several other resources (Pearse et al., 1987; Preston-Mafham,

1993; Daly et al., 1998). For this reason, species lists for the invertebrates have not been included in Table 2.

3.1.7.1. Terrestrial Invertebrate Guild

At the TPP, the main categories of aboveground invertebrates are the herbivores, detritivores/omnivores, carrion feeders, nectar/pollen feeders, and predators. Descriptions of each follow.

3.1.7.1.1. Herbivores. Many different types of phytophagous invertebrates are found in the aboveground compartment of the TPP ecosystem. These include grass feeding, forb feeding, and tree feeding species, and within these divisions, foliage, seed, flower, stem, and fruit feeders, as well as gall forming insects. Major orders represented include Orthoptera (crickets and grasshoppers), Hemiptera (true bugs), Homoptera (aphids), and Coleoptera (beetles). Also included in this category are pulmonates from the order Stylommatophora (slugs and snails).

3.1.7.1.2. Detritivores and Omnivores. This category includes species which are xylophagous (feeding on dead woody plant material), phytosaprophagous (feeding on decaying vegetable matter), and catophagous (feeding on feces or dung), as well as the classic omnivores and detritivores (who may also feed on associated microbiota found in decaying matter). Main orders include Hymenoptera (ants), Isoptera (termites), Orthoptera (crickets), and Blattodea (roaches), as well as some species of slug and snail (Stylommatophora). Also of interest are the dung beetles (order Coleoptera, family Scarabaeidae), who take dung from the surface and move it belowground, hence falling into both the aboveground and belowground guilds.

3.1.7.1.3. Carrion Feeders. Carrion feeders are mainly composed of flies (Diptera) and beetles. The carrion feeding beetles are primarily from the family Silphidae. Carrion feeders may be distinguished from the detritivorous category above in that they are zoosaprophagous, i.e. they feed strictly on dead animal matter. Some overlap may exist between this category and the detritivorous category.

3.1.7.1.4. Nectar and Pollen Feeders. Bees and some wasps (order Hymenoptera), butterflies and moths (order Lepidoptera), and many beetle groups (order Coleoptera) are known to feed on nectar and pollen. In particular, the butterflies have been well studied at the TPP; Arenz (1995) suggests that they may serve as an excellent indicator group, given their high degree of measurability and social relevance. A butterfly monitoring program has already been initiated at the preserve.

3.1.7.1.5. Predators. Predatory invertebrates at the TPP include spiders (Arachnida), carabid beetles (Carabididae), some species of wasp (Hymenoptera), flies (Diptera), and grasshoppers (Orthoptera). These feed mainly on other invertebrates, although some taxa may be flesh eating.

3.1.7.2. Soil Invertebrate Guild

Several main categories of soil invertebrates may be found at the TPP: herbivores, xylem suckers, detritivores, and predators. Microscopic organisms, such as the microarthropods and nematodes, have been specifically excluded, as trophic linkages are negligible between these mesofauna and the macroinvertebrates. However, it should be noted that both microarthropods and nematodes possess their own trophic structure including herbivores, fungivores, and

predators. Nematoda, in particular, is recognized as the second largest of the animal phyla (Pearse et al., 1987), and may play a significant role in terms of energy flow in the TPP system.

3.1.7.2.1. Herbivores. This category comprises the largest fraction of soil invertebrates in terms of biomass. These phytophagous invertebrates are composed mainly of beetles in the families Scarabaeidae (white grubs), Elateridae (wireworms), Chrysomelidae (root worms) and Curculionidae (weevils) (Seastedt, 1984). These species feed on the roots and underground stems of vegetation. All of these species spend the adult portion of their life cycles above ground (Daly et al., 1998).

3.1.7.2.2. Xylem Suckers. This second phytophagous category consists of the cicadas, in the family Cicadidae. These insects are the second most abundant in terms of biomass. Cicadas feed by sucking the xylem from the roots of plants, causing them to filter massive quantities of water to extract nutrient content. Cicadas offer a high potential for use as bioindicators in contaminated soils because of their relatively long life cycle (4-6 yr) and the fact that their tissues should substantially represent the content of soil water. Cicadas also emerge to live their adult lives above ground (Callaham et al., 2000).

3.1.7.2.3. Detritivores. This category is primarily composed of earthworms. Taxa found in tallgrass prairie that are native to North America include *Diplocardia* spp. and *Bimastos* spp., while introduced European taxa include *Aporrectodea* spp. and *Octolasion* spp. (James and Cunningham, 1989; Callaham and Blair, 1999). All of these taxa feed on plant material in various states of decay, much of it as advanced as soil organic matter. Another group of detritivores includes the dung beetles, also part of the family Scarabaeidae. These species take detritus from aboveground and move it belowground, and so fall into the category of both terrestrial and soil invertebrates. Finally, one may find members of the class Diplopoda, or millipedes (Seastedt, 1984).

3.1.7.2.4. Predators. The soil entomophages are nearly all arthropods. Beetle predators include members of the *Carabidae*, *Cicindellidae*, and *Staphylinidae* families. Several varieties of centipede (class *Chilopoda*) are also common belowground predators (Seastedt, 1984).

3.2. Beta Guilds

The beta guilds (Table 3) were delineated by using observed distribution data taken from ONHI (1993), as well as using information from other sources regarding general habitat preference (see Appendix C for a list of sources). Beta guilds begin to offer an expansion upon the one-dimensional analysis of food relationships found in the alpha guilds, by providing insight into another key requirement of species: habitat. Loss of habitat, rather than loss of prey species, may be a more critical impact of oil and brine spills on the TPP, particularly the spills that directly affect the sensitive and small habitats. The rather small habitats represented by the five non-prairie guilds may be of either extreme ecological significance, as reservoirs of high species diversity (e.g., riparian zones) or as fundamental units supporting overall community and ecosystem structure and function. They could also enjoy social importance, as areas harboring public interest or value. The location of oil and brine spills relative to these habitats is uncertain at this time.

As mentioned earlier, the use of observed and induced data for species distribution creates a combination of realized and fundamental niches for these species, and should therefore be used only as a general guideline. Many species, particularly those with larger home range sizes, are likely to be found outside their preferred habitat, particularly during dispersal, times of food shortage, or other disturbance. Seasonal usage of various habitats by birds was available for the Konza Prairie; this data has been included in Appendix A.

3.3. Plants

Table 4 shows the relative frequency and cover of the 126 most frequent plant species at the preserve (Palmer, unpublished data). The most common species, occurring in more than 90 percent of the plots, are big bluestem (*Andropogon gerardii*, 97.4% of plots), tall dropseed (*Sporobolus compositus*, 97.4%), yellow wood sorrel (*Oxalis dillenii*, 96%), western ragweed (*Ambrosia psilostachya*, 95.4%), green milkweed (*Asclepias viridis*, 92.1%), and panic grass (*Dichanthelium oligosanthes*, 91.4%). The species with the largest percentage cover are big bluestem (4%), tall dropseed (2.8%), little bluestem (*Schizachyrium scoparium*, 2.3%), western ragweed (1.5%), and indian grass (*Sorghastrum nutans*, 1.3%).

Plants were not divided into guilds for several reasons. To begin with, because the area of the preserve directly impacted by oil or brine spills is relatively small, it was anticipated that the indirect (community-level) impacts on plants would be negligible (except perhaps in the case of locally rare species). Second, grassland plant communities are not easily divisible into well-defined guilds (Simberloff and Dayan, 1991). One could divide species using classic approaches such as carbon pathway (i.e., C3 vs. C4), life history (i.e., perennials vs. annuals), or life form (i.e., grass, forb, shrub, tree) (Wilson, 1999); however, these divisions would lend little insight into the impact of spills on animal communities. Finally, designation of guilds based on animal consumption (e.g., palatability) was limited by data gaps, local (as well as seasonal) variability in diet, and high degrees of dietary overlap.

It is recommended that the plant community be analyzed in more detail in the context of the selected endpoint species and the location of the oil and brine spills.

3.4. Trophic Model

Table 5 shows the community food web at the TPP, describing the binary feeding relationships (prey/not prey) between the guilds in the community (Solow and Beet, 1998). In addition to the animal guilds, two additional compartments were added to the trophic model to complete the analysis: (1) plants and fungi, and (2) detritus and carrion. Figure 1 shows source webs based on four guilds: aboveground invertebrates, belowground invertebrates, large herbivorous mammals, and small herbivorous mammals. A source web "…includes one or more kinds of organisms, the organisms that eat them, their predators and so on" (Pimm et al., 1991). These four webs effectively trace nearly all of the possible trophic pathways from basal species to top predators; for convenience, all of the trophic pathways have been depicted in Appendix E. As can be seen, the inclusion of invertebrates generates much greater web complexity.

The overall number of links in the TPP system is 63, resulting in a connectance of 0.246, which is well within the typical range (0.06–0.32) of empirical observations (Williams and

Martinez, 2000). The minimum chain length is 2 (D:CB2), while the maximum chain length is 8 (several different pathways); typical chain length at the TPP ranges from 3 to 5 (see Figure 1 and Appendix E). The linkage density, or average number of links per guild, is 3.94, nearly double the typical observed density (Schoener, 1989; Pimm et al., 1991). This higher density is likely attributable to the greater degree of aggregation of species in guilds relative to "trophic species." Indeed, Pimm et al. (1991) note that aggregation along taxonomic affinities (as was done in the guilds) can alter web properties, and further, that temporally cumulative webs usually overestimate linkage density relative to time-specific snapshots. Not surprisingly, cycling (e.g., *a* eats *b*, *b* eats *c*, *c* eats *a*) and compartmentalization (i.e., independence of food chains) were not found in the TPP system (see Pimm, 1982 or Schoener, 1989 for a discussion of these phenomena and their rarity). Looping (the empirically rare phenomenon of feeding on members of one's own guild), on the other hand, was common, being found in five guilds: the aboveground invertebrates, the belowground invertebrates, the large omnivorous mammals, the omnivorous birds, and guild 2 of the carnivorous herptiles. Again, this pattern may be attributable to the fact that the guilds are composed of multiple trophic species (Schoener, 1989).

We considered any guilds preying upon three or fewer guilds to be a feeding specialist. On this basis, the division between specialist and generalist feeders is nearly an even split: nine of the guilds feed on three or fewer guilds/compartments, while the remaining seven guilds feed on four or more, averaging 6.7. All of the specialist guilds restrict their diets to either invertebrates, plants or detritus, or some combination; the generalist guilds include omnivores (preying upon a variety of plants, carrion, animals) and carnivores (feeding on a combination of vertebrates and invertebrates). Specialist guilds may be more sensitive to the loss of an individual prey species (or an entire guild) than generalist guilds, particularly to the extent that the various species in each guild feed on identical prey species. Different definitions for a "specialist" guild may also yield varying results.

3.4.1. Aggregation of Guilds

Based on this trophic model, guilds may be aggregated using various criteria to offer additional insights into community structure in the TPP. As an example, certain guilds were aggregated into "metaguilds," using two methods: (1) based on shared prey species, and (2) based on shared predator species.

3.4.1.1. Similar Prey Species

By grouping together guilds based on shared prey species, two metaguilds can be defined: the herbivorous mammals, and the invertivores (Table 6). The first metaguild, as the name suggests, is composed of the three plant-eating mammalian guilds. The second metaguild is made up of the invertivorous herptiles and the invertivorous birds. This metaguild feeds on both aboveground invertebrates and soil invertebrates.

Taxonomic affinity has been ignored by the metaguild groupings. As discussed earlier, taxonomy has been criticized as an arbitrary convention for grouping species (Wilson, 1999). However, these metaguilds closely follow the first criterion in the classic definition of an alpha guild i.e., all members of a metaguild use the same class of resources. The metaguilds therefore show all species sharing similar food requirements. Both metaguilds consist of species that are relative specialists compared against many of the other guilds found at the TPP; as mentioned

above, such species may be more sensitive to the loss of an individual prey species, especially those metaguild members that feed on identical prey. This is limited by the fact that these metaguild classifications do not elucidate the specific species that are preyed upon; nor do they address the method or quantity of food taken or other issues such as resistance to disturbance, mobility, and other forms of adaptability of certain predators. They do, however, offer the researcher a procedure for quickly identifying several functional groups in the TPP ecosystem based on general diet.

3.4.1.2. Similar Predator Species

Each metaguild in this category shares identical predators. This approach turns the classic guild concept on its head; it categorizes species based on how they are used as a resource, as opposed to how they use resources, creating a sort of "inverse guild." Four different metaguilds were found (Table 6):

- *Metaguild A.* This metaguild consists of the large herbivorous mammals and the omnivorous herptiles (turtles), and serves as prey to the large omnivorous and carnivorous mammals.
- *Metaguild B*. This metaguild is made up of the small herbivorous and omnivorous mammals, the fossorial invertivorous mammals, and the large carnivorous herptiles. Large omnivorous and carnivorous mammals, flesh-eating herptiles, omnivorous birds, and raptors prey upon this metaguild.
- *Metaguild C (Non-raptorial birds).* These are the omnivorous and invertivorous birds. They are preyed on by various omnivorous and carnivorous mammals, birds, and herptiles.
- *Metaguild D (Top predators).* This metaguild consists of the raptors and large carnivorous mammals, and has no natural predators.

These metaguilds again offer the researcher a rapid method for identifying functional groups of species. They also offer insight into which guilds are potentially impacted by the loss of a particular species from one of these metaguilds. The impact will vary based on interaction strength between the two species (i.e., the loss of a particular species will have less impact on a generalist than a specialist). Also, while members of these metaguilds share identical guilds of predators, specific predator species may vary. It should be noted that Metaguilds B and C share extremely similar predator guilds.

3.4.2. Considerations for the Selection of Endpoint Species

In considering the selection of endpoint species based on the food web at the TPP, we refer back to the four criteria for endpoint selection: (1) social relevance, (2) biological relevance, (3) predictability and measurability, and (4) sensitivity to disturbance. The following discussion will address implications of the trophic model relative to these criteria, although it does not intend to be comprehensive.

This trophic model does not explicitly examine social relevance and predictability/measurability. However, it is clear that bison enjoy high social relevance; they are also easily measured and biologically important to the TPP community. Butterflies are another

socially relevant and measurable species; indeed, the TPP supports a pre-existing volunteer monitoring program (Arenz, 1995). Finally, the four most common species of prairie bird (the dickissel, the brown-headed cowbird, the grasshopper sparrow, and the eastern meadowlark) may provide good indicators as they are likely to be highly measurable.

The trophic model more directly addresses biological relevance, and to a limited extent, sensitivity to disturbance. As mentioned above, it is clear from the literature that bison play a large role in maintaining community structure and function. Bison are considered "keystone engineers," both impacting the integrity of the TPP ecosystem to an extent far greater than their size or number in the system, as well as modulating available resources by causing physical state changes in biotic and abiotic systems (Collins and Benning, 1996; Collins and Steinauer, 1998; Knapp et al., 1999). Bison are part of a relatively simple trophic relationship: they feed on the lowest trophic level, the plants, and have few predators (see Figure 1c and Section 3.1.1.1). However, bison populations are regulated by humans at the preserve, and so are unlikely to be as sensitive to disturbance as other species.

Other herbivorous and omnivorous species may not have a large direct effect on plant species diversity (Gibson et al., 1990). However, small-scale disturbances such as small mammal burrows are important to enhancing species diversity and heterogeneity in the tallgrass prairie (Hamilton, 1996). In complex food webs such as that found at the TPP, many feedback mechanisms are likely to exist, and disturbances such as oil or brine spills may not have easily predictable effects on the community structure (Pimm et al., 1991). In some cases, the species whose removal may have the largest impact on the community may be those with weak interaction strength (Berlow, 1999). Interaction strength is the relative feeding frequency of a given species upon other species. Berlow shows, through analysis of published data, the greatest variation in species effect occurs for species that are considered to be weak interactors. This may be because these species magnify spatiotemporal variation or that they play dampening or stabilizing roles in the overall community structure.

Determining which species are weak interactors is confounded by the fact that food web models regard feeding as one-dimensional; that is, a species is subject to a binary designation of prey/not prey. Interaction strength has not been considered in these designations. The population density of predator species is not considered; nor is the quantity of different prey consumed by each individual. As a result, various guild members may not have analogous impacts on specific prey species. In addition, as mentioned earlier, certain species within a guild may be more adaptable to changes in food resources, or have a greater ability to survive in the absence of suitable prey. Statistical approaches could be used to determine interaction strength; however, data are scarce for many species. For a further discussion, see Appendix C.

Despite this shortcoming, the distinction between feeding specialists and generalists may be important, since specialist species presumably have stronger interaction strengths with their associated prey species than do generalists. In addition, specialist species may be particularly sensitive if their prey is severely impacted by the spills (e.g., specialist herbivores whose feeding area contains a brine spill). Specialist guilds may be determined by examining Table 5.

Pimm et al. (1991) assert that complex webs (those with high linkage density, or many generalist species) will experience more secondary extinction as a result of loss of species at the top of the food web, rather than the bottom. Simple food webs, alternately, are more sensitive to

the loss of primary producers. At limited spatial scales (such as individual habitat areas within the TPP), food web structures tend to be more simple, causing plants to grow in importance; however, at the larger spatial scale of the entire preserve, the loss of top predators may be more important. It is unlikely that the limited spatial extent of the oil and brine spills will have a dramatic impact on top predators due to their large home ranges. Further, determining the top-down influence that these species may exert using a cascade model is complicated by the variety of food-chain lengths of which they are a part.

Several specific species may serve as excellent indicators based on sensitivity to disturbance. Cicadas are good indicators of soil contamination, for reasons discussed in Section 3.1.7.2.2. Animals that potentially feed or burrow in contaminated soil may also be good indicators for impacts from oil and brine spills. Such fossorial species are identified in the descriptions of the alpha guilds (Section 3.1).

Finally, two methods of selecting endpoint species bear discussion: selecting representative species from each functional group ("guild indicators"), and selecting representative species from important trophic pathways (see Figure 1 and Appendix E). Simberloff and Dayan (1991) warn that diversity within a guild may preclude selection of a guild indicator. For example, the omnivorous bird guild contains enough diversity that species probably differ sufficiently in ways other than resource use to cause different responses to habitat change or other stressors. On the other hand, certain guilds, such as the Herbivorous Mammal Guild 1a (large grazers), may be homogenous enough to transcend this limitation. However, even in cases where the species are sufficiently similar that a representative species may be selected, the loss of that alpha guild member could potentially result in a decrease in interspecific competition experienced by other members, causing reactions in other species which are opposite, not analogous, in sign.

Selection of species which are representatives from each of all (or several of the important) trophic pathways, on the other hand, potentially offers a satisfyingly comprehensive approach toward analyzing the impacts of spills at the TPP. Care should be taken to ensure that each representative species is highly relevant based on the four endpoint criteria.

3.4.3. Other Considerations

Several additional points help inform the analysis derived from the use of this trophic model. First, the species found at the preserve, and the relationships between and among them, vary over time. At the Konza Prairie LTER, Knapp et al. (1998) found that bird, small mammal, and grasshopper populations are highly spatially and temporally variable. Risser et al. (1981) found similar results with rodents at the TPP. As mentioned before, the trophic model as it has been constructed is a "cumulative web" (Pimm et al., 1991). Species lists were collected from two time periods, one immediately before bison reintroduction (ONHI, 1993), and the other three years after reintroduction (Nature Conservancy, 1996). Bison therefore may have caused, or may cause in the future, a shift in community structure that is not represented by this model. Further, other temporal variations and disturbance cycles are likely to influence community structure and function. In particular, fire is an important influence that alters the structure of plant, insect, and small mammal communities (Evans, 1988; Kaufman et al., 1988; Gibson et al., 1993).

Consideration of continuing changes in the communities at the TPP will assist in resolving these issues. Auxiliary information regarding particular species (e.g., species information in

Section 3.1, and seasonal bird distribution data in Appendix A), temporal cycles, etc., should be considered when undertaking analysis using the trophic model. Further research into particular species (especially endpoint species) and temporal dynamics may also be desirable, as discussed in Appendix C.

3.4.4. Expanding the Model: Combining Alpha and Beta Guilds

This model may also become more useful by considering the beta guilds in addition to the alpha guilds. Toward this purpose, species listings in the beta guilds (Table 3) provide alpha guild information, with members of each alpha guild grouped together within the beta guild categories. Developing trophic models specific to each beta guild, and examining the relationships between them, could offer a substantially increased understanding of community relationships and the effects of oil and brine spills, as predator/prey interactions may be significantly different at limited spatial scales. Constructing trophic models for the beta guilds in which contaminant spills are located may be particularly useful. Unfortunately, the specific locations of these spills relative to the six beta guilds are unknown at this time.

4. Acknowledgements

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Figures

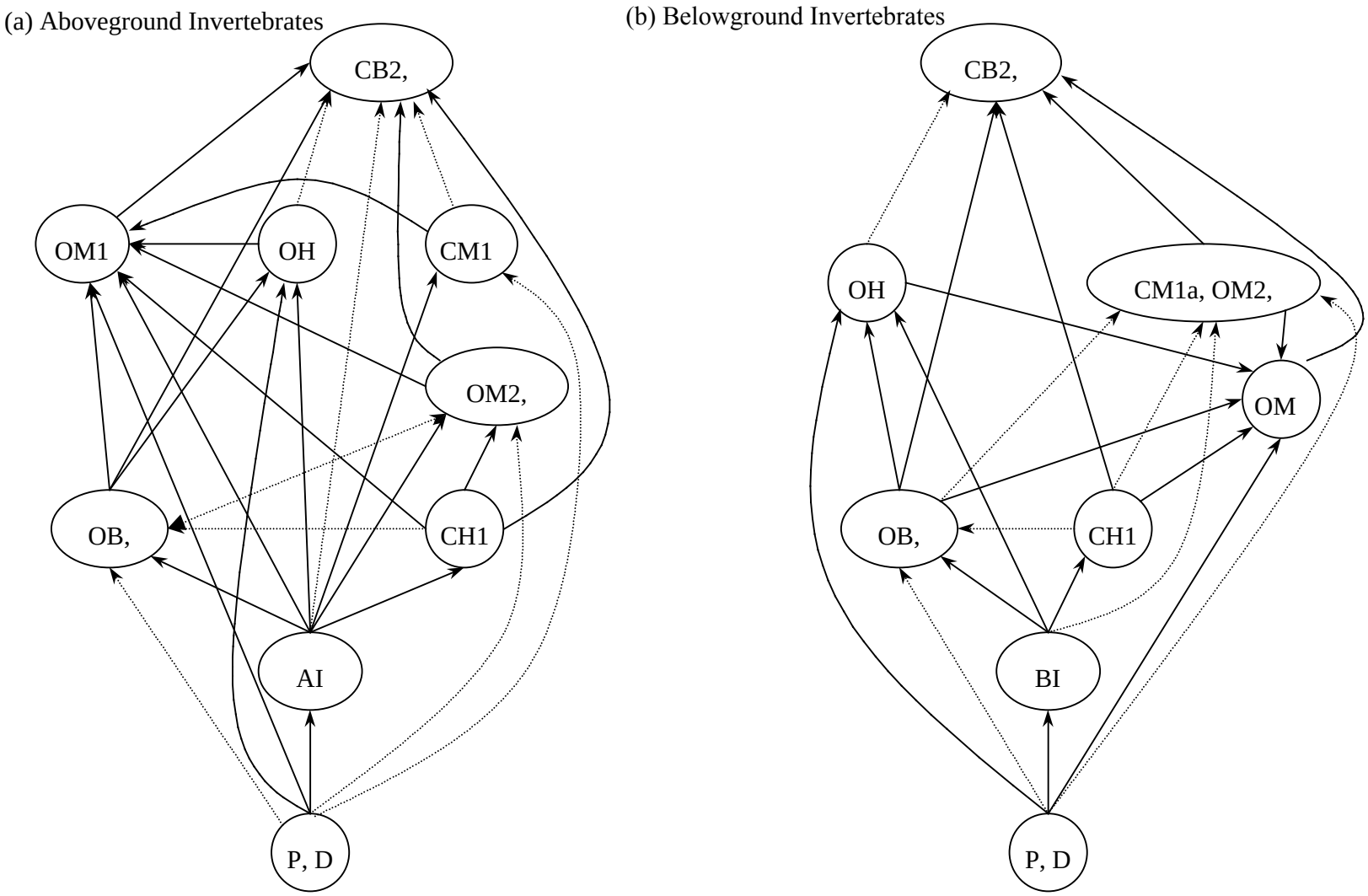

Figure 1. Source food webs at the Tallgrass Prairie Preserve, OK. Each figure begins with a guild that feeds on plants, and indicates the guilds which feed on it, their predators, and so on up the trophic system. Arrows move in the direction of energy flow (i.e., from prey to predator). For simplicity, certain guilds have been grouped together. A dashed line indicates that only one of the predator guilds applies. Looping (i.e., predation upon members of the same guild) has been omitted. It should be noted that, with the exception of the base plant eating guild in each figure, the depictions of prey for each guild may not be exhaustive (e.g., Figure 1a does not show all of the prey species that OM1 feeds upon). See page 2 of this figure for explanations of guild abbreviations.

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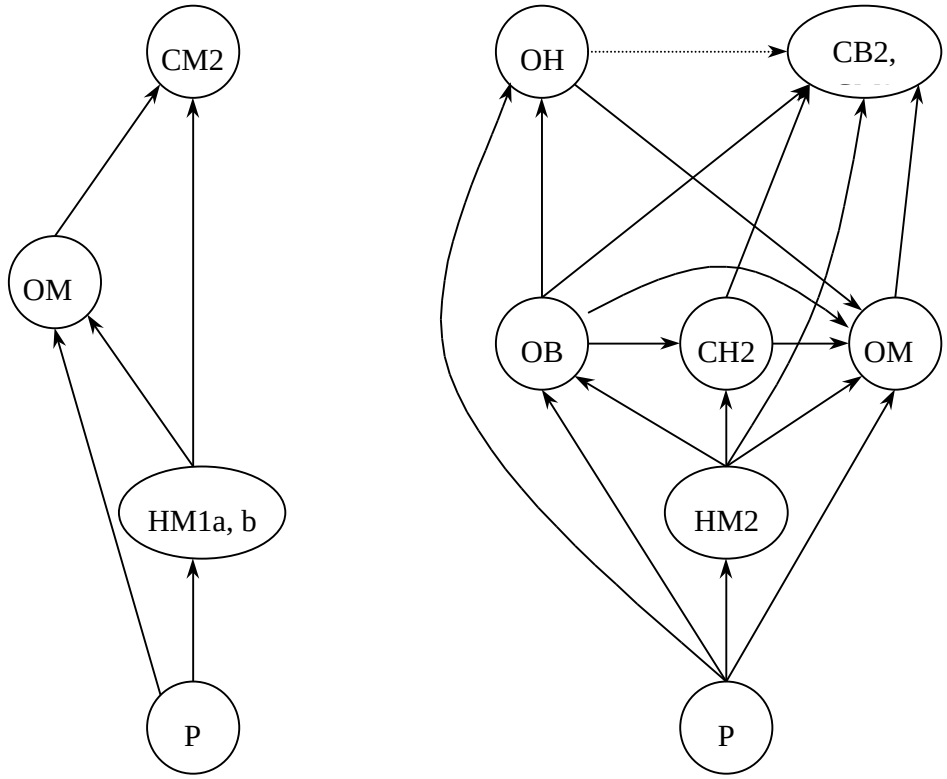
(c) Large Herbivorous Mammals (d) Small Herbivorous Mammals



Key to Alpha Guilds:

P	Plants and Fungi
D	Detritus and Carrion
AI	Aboveground Invertebrates
BI	Belowground Invertebrates
HM1a	Herbivorous Mammals - grazers
HM1b	Herbivorous Mammals - browsers
HM2	Small Herbivorous Mammals
HB	Herbivorous Birds
OM1	Large Omnivorous Mammals
OM2	Small Omnivorous Mammals
OB	Omnivorous Birds
OH	Omnivorous Herptiles
CH1	Invertivorous Herptiles
CH2	Other Carnivorous Herptiles
CB1	Invertivorous Birds
CB2	Raptors
CM1a	Fossorial Invertivorous Mammals
CM1b	Other Invertivorous Mammals
CM2	Large Carnivorous Mammals

Figure 1. Source food webs at the Tallgrass Prairie Preserve, OK (Cont.).

Tables

Table 1. Typical plant species of the Tallgrass Prairie Preserve, OK. Species are divided on the basis of habitat.

Common name	Scientific name	Source[a]
Deciduous Riparian Guild		
American bladdernut	*Staphylea trifolia*	1, 3
ash	*Fraxinus pennsylvanica*	1, 3
blackhaw	*Viburnum rufidulum*	1, 3
bur oak	*Quercus macrocarpa*	1, 3
buttonbush	*Cephalanthus occidentalis*	1, 3
cittamwood	*Bumelia lanuginosa*	1, 3
coral berry	*Symphoricarpos orbiculatus*	1, 3
dwarf chinquapin oak	*Quercus prinoides*	1, 3
eastern redbud	*Cercis canadensis*	1, 3
hickory	*Carya cordiformis*	1, 3
osage orange	*Maclura pomifera*	1, 3
roughleaf dogwood	*Cornus drummondii*	1, 3
shumard oak	*Quercus shumardii*	1, 3
slippery elm	*Ulmus rubra*	1, 3
sugarberry	*Celic occidentalis*	1, 3
sycamore	*Platanus occidentalis*	1, 3
willow	*Salix nigra*	1, 3
poison ivy	*Toxicodendron radicans*	1, 3
Virginia creeper	*Parthenocissus quinquefolia*	1, 3
Grassy Riparian Guild		
goldenrod	*Solidago* spp.	1, 3
white sweet clover	*Melilotus alba*	1, 3
yellow sweet clover	*Melilotus officinalis*	1, 3
big bluestem	*Andropogon gerardii*	1, 2, 3
Canada wild rye	*Elymus canadensis*	1, 3
eastern gama grass	*Tripsacum dactyloides*	1, 3
Indian grass	*Sorghastrum nutans*	1, 2, 3
little bluestem	*Schizachyrium scoparium*	1, 2, 3
rush	*Juncus* spp.	1, 3

Table 1. Typical plant species of the Tallgrass Prairie Preserve, OK (Cont.).

Common name	Scientific name	Source[a]
Grassy Riparian Guild (cont.)		
switchgrass	*Panicum virgatum*	1, 2, 3
tar dropseed	*Sporobolus asper*	1, 2, 3
Virginia wild rye	*Elymus virginicus*	1, 3
Prairie Guild		
gaura	*Gaura lindheimeri*	1, 3
yarrow	*Achillea millefolium*	1, 3
big bluestem	*Andropogon gerardii*	1, 2, 3
Canada wild rye	*Elymus canadensis*	1, 3
eastern gama grass	*Tripsacum dactyloides*	1, 3
Indian grass	*Sorghastrum nutans*	1, 2, 3
little bluestem	*Schizachyrium scoparium*	1, 2, 3
switchgrass	*Panicum virgatum*	1, 2, 3
tar dropseed	*Sporobolus asper*	1, 2, 3
Virginia wild rye	*Elymus virginicus*	1, 3
green briar	*Smilax* spp.	1, 3
Upland Deciduous Forest Guild		
blackjack oak	*Quercus marilandica*	1, 3
coral berry	*Symphoricarpos orbiculatus*	1, 3
dwarf chinquapin oak	*Quercus prinoides*	1, 3
eastern redbud	*Cercis canadensis*	1, 3
post oak	*Quercus stellata*	1, 3
poison ivy	*Toxicodendron radicans*	1, 3
Virginia creeper	*Parthenocissus quinquefolia*	1, 3
Rocky Outcrop Guild		
western ragweed	*Ambrosia psilostachya*	1, 2, 3
yarrow	*Achillea millefolium*	1, 3
Canada wild rye	*Elymus canadensis*	1, 3
little bluestem	*Schizachyrium scoparium*	1, 2, 3
peppergrass	*Lepidium virginicum*	1, 3
three-awn	*Aristida* spp.	1, 3
Virginia wild rye	*Elymus virginicus*	1, 3

Table 1. Typical plant species of the Tallgrass Prairie Preserve, OK (Cont.).

Common name	Scientific name	Source[a]
Rocky Outcrop Guild (cont.)		
blackjack oak	*Quercus marilandica*	1, 3
hackberry	*Celtis reticulata*	1, 3
post oak	*Quercus stellata*	1, 3
blackberry	*Rubus* spp.	1, 3
Disturbed Area Guild		
broomweed	*Gutierrezia dracunculoides*	1, 2, 3
gaura	*Gaura lindheimeri*	1, 3
goldenrod	*Solidago* spp.	1, 3
lamb's quarter	*Chenopodium album*	1, 3
nightshade	*Solanum* spp.	1, 3
western ragweed	*Ambrosia psilostachya*	1, 2, 3
white sweet clover	*Melilotus alba*	1, 3
yellow sweet clover	*Melilotus officinalis*	1, 3
little bluestem	*Schizachyrium scoparium*	1, 2, 3

[a] Sources: 1. Oklahoma Natural Heritage Inventory, 1993; 2. Coppedge and Shaw, 1998; Payne and Caire, 1999.

Table 2. Alpha animal guilds of the Tallgrass Prairie Preserve, OK. Species are divided into guilds on the basis of trophic level (i.e., herbivore, omnivore, carnivore) and taxonomy (i.e., mammal, herptile, bird).

Common name	Scientific name	Source[a]
Herbivorous Mammal Guild 1a, large grazers		
Bison	***Bison bison***	**2, 3, 5**
Cow	***Bos* spp.**	**18**
Herbivorous Mammal Guild 1b,browsers		
White tailed Deer	***Odocoileus virginianus***	**1, 2, 4, 5**
Herbivorous Mammal Guild 2, smaller herbivores		
Beaver	***Castor canadensis***	**1, 2, 4**
Black-tailed Jack Rabbit	***Lepus californicus***	**1, 2, 4**
Eastern Cottontail	***Sylvilagus floridanus***	**1, 4, 5**
Eastern Woodrat	***Neotoma floridana***	**1, 2, 4, 5**
Hispid Pocket Mouse	***Chaetodipus hispidus***	**1, 2, 5**
House Mouse	***Mus musculus***	**1, 2, 4**
Prairie Vole	***Microtus ochrogaster***	**1, 2, 5**
Woodchuck	***Marmota monax***	**2, 4, 5**
Woodland Vole	***Microtus pinetorum***	**1, 2, 4, 5**
Omnivorous Mammal Guild 1, larger omnivores		
Coyote	***Canis latrans***	**1, 2, 5, 7**
Gray Fox	***Urocyon cinereoargenteus***	**2, 4, 5, 6**
Virginia opossum	***Didelphis virginiana***	**1, 2, 5**
Nine-banded Armadillo	***Dasypus novemcinctus***	**1, 4, 5**
Raccoon	***Procyon lotor***	**1, 2, 5**
Striped Skunk	***Mephitis mephitis***	**1, 2, 5**
Omnivorous Mammal Guild 2, smaller omnivores		
13-lined Ground Squirrel	***Spermophilus tridecimlineatus***	**2, 5**
Cotton Mouse	***Peromyscus gossypinus***	**1, 2, 6**
Deer Mouse	***Peromyscus maniculatus***	**1, 2, 4, 5**
Eastern Harvest Mouse	***Reithrodontomys humulis***	**1, 2, 6**
Fox Squirrel	***Sciurus niger***	**1, 4, 5**
Fulvous Harvest Mouse	***Reithrodontomys fulvescens***	**1, 2, 5, 6**
Muskrat	***Ondatra zibethicus***	**2, 5**
Plains Harvest Mouse	***Reithrodontomys montanus***	**1, 2, 5**

Table 2. Alpha animal guilds of the Tallgrass Prairie Preserve, OK. (Cont.).

Common name	Scientific name	Source[a]
Omnivorous Mammal Guild 2, smaller omnivores (cont.)		
White-footed Mouse	*Peromyscus leucopus*	1, 2, 4, 5, 6
Western Harvest Mouse	*Reithrodontomys megalotis*	1, 2, 5
Hispid Cotton Rat	*Sigmodon hispidus*	1, 2, 5, 13
Carnivorous Mammal Guild 1a, fossorial invertivores		
Eastern Mole	*Scalopus aquaticus*	1, 2, 4, 5
Least Shrew	*Cryptotis parva*	1, 2, 4, 5
Carnivorous Mammal Guild 1b, flying invertivores		
Evening Bat	*Nycticeius humeralis*	1, 6
Red Bat	*Lasiurus borealis*	1, 2, 5, 6
Carnivorous Mammal Guild 2, large predators		
Badger	*Taxidea taxus*	1, 2, 4, 5
Bobcat	*Felis rufus*	1, 2, 5
Mink	*Mustela vison*	2, 4, 5
Mountain Lion	*Felis concolor*	1, 2, 4, 5
Omnivorous Herptile Guild		
Ornate Box Turtle	*Terrapene ornata*	2, 8
Three-toed Box Turtle	*Terrapene carolina*	2, 8
Carnivorous Herptile Guild 1, invertivores		
Broadhead Skink	*Eumeces laticeps*	2, 8, 15
Brown Snake	*Storeria dekayi*	2, 8
Cope's Tree Frog	*Hyla chrysoscelis*	2, 8
Dwarf American Toad	*Bufo americanus*	2, 8
Five-lined Skink	*Eumeces fasciatus*	2, 8
Flathead Snake	*Tantilla gracilis*	2, 8
Gray Tree Frog	*Hyla versicolor*	2, 8
Great Plains Narrowmouth Toad	*Gastrophryne olivacea*	2, 11
Great Plains Skink	*Eumeces obsoletus*	2, 11
Ground Skink	*Scincella lateralis*	2, 11
Ground Snake	*Sonora semiannulata*	2, 14
Lined Snake	*Tropidoclonium lineatum*	2, 8, 13
Plains Leopard Frog	*Rana blairi*	2, 8

Table 2. Alpha animal guilds of the Tallgrass Prairie Preserve, OK. (Cont.).

Common name	Scientific name	Source[a]
Carnivorous Herptile Guild 1, invertivores (cont.)		
Rough Earth Snake	***Virginia striatula***	**2, 16**
Rough Green Snake	***Opheodrys aestivus***	**2, 8**
Southern Leopard Frog	***Rana utricularia***	**2, 8**
Southern Prairie Skink	***Eumeces septentrionalis***	**2, 11**
Strecker's Chorus Frog	***Pseudacris streckeri***	**2, 8**
Texas Horned Lizard	***Phrynosoma cornutum***	**2, 11**
Western Chorus Frog	***Pseudacris triseriata***	**2, 8**
Woodhouse's Toad	***Bufo woodhousei***	**2, 11**
Carnivorous Herptile Guild 2, other carnivores		
Black Ratsnake	***Elaphe obseleta***	**2, 9**
Broad-banded Copperhead	***Agkistrodon contortrix***	**2, 8**
Bull Frog	***Rana catesbeiana***	**2, 8**
Bullsnake	***Pituophis melanoleucus***	**2, 8, 9**
Central Plains Milk Snake	***Lampropeltis triangulum***	**2, 8, 9**
Coachwhip	***Masticophis flagellum***	**2, 8**
Common Garter Snake	***Thamnophis sirtalis***	**2, 8**
Crawfish Frog	***Rana areolata***	**2, 8**
Eastern Collared Lizard	***Crotaphytus collaris***	**2, 4, 8**
Eastern Hognose Snake	***Heterodon platyrhinos***	**2, 8**
Great Plains Ratsnake	***Elaphe guttata***	**2, 8, 9**
Massasauga	***Sistrurus catenatus***	**2, 8**
Prairie Kingsnake	***Lampropeltis calligaster***	**2, 8, 9**
Ringneck Snake	***Diadophis punctatus***	**2, 8, 10**
Speckled Kingsnake	***Lampropeltis getulus***	**2, 8, 9**
Timber Rattlesnake	***Crotalus horridus***	**2, 8**
Western Glass Lizard	***Ophisaurus attenuatus***	**2, 8**
Western Ribbon Snake	***Thamnophis proximus***	**2, 8**
Yellowbelly Racer	***Coluber constrictor***	**2, 8, 9**

Table 2. Alpha animal guilds of the Tallgrass Prairie Preserve, OK. (Cont.).

Common name	Scientific name	Source[a]
Omnivorous Bird Guild		
Blue jay	*Cyanocitta cristata*	1, 2, 12
Bluebird, mountain	*Sialia currucoides*	1, 12
Bobwhite	*Colinus virginianus*	1, 2, 12
Brown thrasher	*Toxostoma rufum*	1, 2, 12
Bunting, indigo	*Passerina cyanea*	1, 2, 12
Bunting, painted	*Passerina ciris*	2, 12
Canada goose	*Branta canadensis*	1, 2, 4
Cardinal	*Cardinalis cardinalis*	1, 2, 12
Catbird	*Dumetella carolinensis*	2, 12
Chickadee, Carolina	*Parus carolinensis*	1, 2, 12
Coot, American	*Fulica americana*	2, 12
Cowbird, brown-headed	*Molothrus ater*	1, 2, 12
Crow, American	*Corvus brachyrhynchos*	1, 2, 12
Crow, fish	*Corvus ossifragus*	2, 12
Dickcissel	*Spiza americana*	1, 2, 12
Dove, mourning	*Zenaida macroura*	1, 2, 4
Dove, rock	*Columba livia*	2, 12
Duck, ring-necked	*Aythya collaris*	1, 2, 12
Gadwall	*Anas strepera*	2, 12
Goldfinch, American	*Carduelis tristis*	2, 12
Grackle, common	*Quiscalus quiscula*	1, 2, 17
Grackle, great-tailed	*Quiscalus mexicanus*	2, 12
Great prairie chicken	*Tympanuchus cupido*	1, 2, 17
Grosbeak, blue	*Guiraca caerulea*	1, 2, 12
Gull, Franklin's	*Larus pipixcan*	2, 12
Gull, ring-billed	*Larus delawarensis*	2, 12
Horned lark	*Eremophila alpestris*	1, 2, 12
Hummingbird, ruby-throated	*Arcjilochus colubris*	2, 12
Junco, dark-eyed	*Junco hyemalis*	2, 12
Mallard	*Anas platyrhynchos*	2, 12
Meadowlark, eastern	*Sturnella magna*	1, 2, 12
Mockingbird	*Mimus polyglottos*	1, 2, 12

Table 2. Alpha animal guilds of the Tallgrass Prairie Preserve, OK. (Cont.).

Common name	Scientific name	Source[a]
Omnivorous Bird Guild (cont.)		
Nuthatch, whitebreasted	*Sitta carolenensis*	1, 2, 12
Oriole, Northern	*Icterus galbula*	2, 12
Oriole, orchard	*Icterus spurius*	1, 2, 12
Pheasant, ring-necked	*Phasianus colchicus*	2, 12
Pintail, northern	*Anas acuta*	2, 12
Plover, lesser golden	*Pluvialis squatarola*	2, 12
Rail, king	*Rallus elegans*	2, 12
Redhead	*Aythya americana*	1, 2, 12
Robin	*Turdus migratorius*	1, 2, 12
Scaup, lesser	*Aythya affinis*	2, 12
Shoveler, Northern	*Anas clypeata*	2, 12
Sora	*Porzana carolina*	2, 12
Sparrow, American tree	*Spizella arborea*	2, 12
Sparrow, chipping	*Spizella passerina*	1, 2, 12
Sparrow, field	*Spizella pusilla*	1, 2, 12
Sparrow, grasshopper	*Ammodramus savannarum*	1, 2, 12
Sparrow, Harris'	*Zonotrichia querula*	2, 12
Sparrow, house	*Passer domesticus*	1, 2, 12
Sparrow, lark	*Chondestes grammacus*	1, 2, 12
Sparrow, Lincoln's	*Melospiza lincolnii*	2, 12
Sparrow, savannah	*Passerculus sandwichensis*	1, 2, 12
Sparrow, song	*Melospiza melodia*	2, 12
Sparrow, vesper	*Pooecetes gramineus*	1, 2, 12
Sparrow, white-crowned	*Zonotrichia leucophrys*	2, 12
Sparrow, white-throated	*Zonotrichia albicollis*	2, 12
Starling	*Sturnus vulgaris*	1, 2, 12
Summer tanager	*Piranga rubra*	1, 2, 12
Thrush, wood	*Hylocichla mustelina*	2, 12
Towhee, rufous-sided	*Pipilo erythrophthalmus*	2, 12
Tufted titmouse	*Parus inornatus*	1, 2, 12
Turkey	*Meleagris gallopavo*	1, 2, 12
Warbler, yellow-rumped	*Dendroica coronata*	2, 4

Table 2. Alpha animal guilds of the Tallgrass Prairie Preserve, OK. (Cont.).

Common name	Scientific name	Source[a]
Omnivorous Bird Guild (cont.)		
Waterthrush, Louisiana	*Seiurus motacilla*	1, 2, 12
Waxwing, cedar	*Bombycilla garrulus*	2, 12
Widgeon, American	*Anas americana*	2, 12
Woodpecker, pileated	*Dryocopus pileatus*	1, 2, 4
Woodpecker, red-headed	*Melanerpes erythrocephalus*	1, 2, 4
Carnivorous Bird Guild 1, invertivores		
Bluebird, eastern	*Sialia sialis*	1, 2, 12
Chimney swift	*Chaetura pelagica*	1, 2, 12
Chuck-will's-widow	*Caprimulgus carolinensis*	1, 2, 12
Creeper, brown	*Certhia familiaris*	2, 12
Dowitcher, long-billed	*Limnodromus griseus*	2, 12
Egret, cattle	*Bubulcus ibis*	1, 2, 12
Flycatcher, Acadian	*Empidomax virescens*	2, 12
Flycatcher, alder	*Empidomax alnorum*	2, 12
Flycatcher, great crested	*Myiarchus crinitus*	1, 2, 12
Flycatcher, least	*Empidomax minimus*	2, 12
Flycatcher, scissor-tailed	*Tyrannus forficatus*	1, 2, 12
Flycatcher, willow	*Empidomax traillii*	2, 12
Gnatcatcher, blue-gray	*Polioptila caerulea*	1, 2, 12
Godwit, Hudsonian	*Limosa haemastica*	2, 12
Killdeer	*Charadrius vociferous*	1, 2, 12
Kingbird, eastern	*Tyrannus tyrannus*	1, 2, 12
Kingbird, western	*Tyrannus verticalis*	1, 2, 12
Kinglet, golden-crowned	*Regulus satrapa*	2, 12
Loggerhead shrike	*Lanius ludovicianus*	1, 2, 12
Nighthawk	*Chordeiles minor*	1, 2, 12
Northern flicker	*Colaptes auratus*	1, 2, 12
Phoebe, eastern	*Savornis phoebe*	1, 12
Poorwill	*Phalaenoptilus nuttallii*	2, 12
Purple martin	*Progne subis*	1, 2, 12
Sandpiper, semipalmated	*Calidris pusilla*	1, 12
Sandpiper, solitary	*Tringa solitaria*	1, 2, 12

Table 2. Alpha animal guilds of the Tallgrass Prairie Preserve, OK. (Cont.).

Common name	Scientific name	Source[a]
Carnivorous Bird Guild 1, invertivores (cont.)		
Sandpiper, upland	*Bartramia longicauda*	1, 2, 12
Snipe	*Gallinago gallinago*	1, 2, 12
Swallow, bank	*Riparia riparia*	1, 12
Swallow, barn	*Hirundo rustica*	1, 2, 12
Swallow, cliff	*Hirundo pyrrhonata*	1, 2, 12
Swallow, rough-winged	*Stelgidopteryx serripennis*	1, 2, 12
Vireo, Bell's	*Vireo bellii*	2, 12
Vireo, red-eyed	*Vireo olivaceous*	2, 12
Vireo, yellow-throated	*Vireo flavifrons*	1, 12
Warbler, black and white	*Mniotilta varia*	1, 2, 12
Warbler, Cape May	*Dendroica tigrina*	2, 12
Warbler, Kentucky	*Oporornis formosus*	2, 12
Warbler, Northern parula	*Parula americana*	2, 12
Warbler, yellow	*Dendroica petechia*	2, 12
Whip-poor-will	*Caprimulgus vociferus*	2, 12
Woodpecker, downy	*Picoides pubescens*	1, 2, 12
Woodpecker, hairy	*Picoides villosus*	2, 12
Woodpecker, red-bellied	*Melanerpes carolinus*	1, 2, 12
Wood-pewee, eastern	*Contopus virens*	1, 2, 12
Wren, Bewick's	*Thryomanes bewickii*	1, 2, 17
Wren, Carolina	*Thryothorus ludovicianus*	1, 2, 12
Yellow-billed cuckoo	*Coccyzus americanus*	1, 2, 12
Yellowlegs, greater	*Tringa melanoleuca*	2, 12
Yellowlegs, lesser	*Tringa flavipes*	2, 12
Yellowthroat, common	*Geothlypis trichas*	1, 2, 12
Carnivorous Bird Guild 2, raptors		
Eagle, bald	*Haliaeetus leucocephalus*	2, 12
Falcon, peregrine	*Falco peregrinus*	2, 12
Harrier, northern	*Circus cyaneus*	1, 2, 12
Hawk, broad-winged	*Buteo platypterus*	2, 12
Hawk, Cooper's	*Accipiter cooperii*	1, 2, 12
Hawk, red-tailed	*Buteo jamaicensus*	1, 2, 12

Table 2. Alpha animal guilds of the Tallgrass Prairie Preserve, OK. (Cont.).

Common name	Scientific name	Source[a]
Carnivorous Bird Guild 2, raptors (cont.)		
Hawk, rough-legged	*Buteo lagopus*	2, 12
Hawk, sharp-shinned	*Accipiter striatus*	2, 12
Hawk, Swainson's	*Buteo swainsoni*	2, 12
Kestrel	*Falco sparverius*	1, 2, 12
Kite, Mississippi	*Ictinia mississippiensis*	2, 12
Merlin	*Falco columbarius*	2, 12
Owl, barn	*Tyto alba*	2, 12
Owl, barred	*Strix varia*	2, 12
Owl, burrowing	*Athene cunicularia*	2, 12
Owl, great horned	*Bubo virginianus*	1, 2, 12
Owl, screech	*Otus asio*	2, 12
Owl, short-eared	*Asio flammeus*	2, 12
Vulture, turkey	*Cathartes aura*	1, 2, 12

[a] Indicates source for both presence/absence and diet. Sources: 1. Oklahoma Natural Heritage Inventory, 1993; 2. Nature Conservancy, 1996; 3. Coppedge and Shaw, 1998; 4. Myers et al., 2000; 5. Risser et al., 1981; 6. Davis and Schmidly, 1994; 7. Brillhart and Kaufman, 1994; 8. INHS, 1998; 9. Cavitt, 2000; 10. Conant and Collins, 1998; 11. Bockstanz and Cannatella, 2000; 12. Peterson, 1980; 13. Whitaker, 1980; 14. Cossel, 1998; 15. Vitt and Cooper, 1986; 16. Rossi, 1990; 17. Robinson, 2000; 18. Hamilton, 1996.

Table 3. Beta animal guilds of the Tallgrass Prairie Preserve, OK. Six guilds are delineated on the basis of habitat. Alpha Guild members within each beta guild are grouped for easy reference.

Common name	Scientific name	Source[a]	Alpha guild[b]
Deciduous Riparian Guild			
Flycatcher, great crested	*Myiarchus crinitus*	12	CB1
Flycatcher, least	*Empidomax minimus*	12	CB1
Gnatcatcher, blue-gray	*Polioptila caerulea*	12	CB1
Kinglet, golden-crowned	*Regulus satrapa*	12	CB1
Northern flicker	*Colaptes auratus*	12	CB1
Phoebe, eastern	*Savornis phoebe*	12	CB1
Swallow, rough-winged	*Stelgidopteryx serripennis*	12	CB1
Vireo, red-eyed	*Vireo olivaceous*	12	CB1
Warbler, black and white	*Mniotilta varia*	12	CB1
Warbler, Kentucky	*Oporornis formosus*	12	CB1
Warbler, yellow	*Dendroica petechia*	12	CB1
Whip-poor-will	*Caprimulgus vociferus*	12	CB1
Woodpecker, downy	Picoides pubescens	12	CB1
Woodpecker, hairy	*Picoides villosus*	12	CB1
Wood-pewee, eastern	*Contopus virens*	12	CB1
Wren, Carolina	*Thryothorus ludovicianus*	12	CB1
Yellow-billed cuckoo	*Coccyzus americanus*	12	CB1
Hawk, Cooper's	*Accipiter cooperii*	12	CB2
Hawk, red-tailed	*Buteo jamaicensus*	12	CB2
Hawk, sharp-shinned	*Accipiter striatus*	12	CB2
Owl, barred	*Strix varia*	12	CB2
Owl, great horned	*Bubo virginianus*	12	CB2
Owl, screech	*Otus asio*	12	CB2
Broadhead Skink	*Eumeces laticeps*	2, 7	CH1
Brown Snake	*Storeria dekayi*	2, 7	CH1
Cope's Tree Frog	*Hyla chrysoscelis*	2, 7	CH1
Dwarf American Toad	*Bufo americanus*	2, 7	CH1
Five-lined Skink	*Eumeces fasciatus*	2, 7	CH1
Gray Tree Frog	*Hyla versicolor*	2, 7	CH1

Table 3. Beta animal guilds of the Tallgrass Prairie Preserve, OK (Cont.)

Common name	Scientific name	Source[a]	Alpha guild[b]
Deciduous Riparian Guild (cont.)			
Great Plains Narrowmouth Toad	*Gastrophryne olivacea*	2, 8	CH1
Ground Skink	*Scincella lateralis*	2, 7	CH1
Plains Leopard Frog	*Rana blairi*	2, 7	CH1
Rough Green Snake	*Opheodrys aestivus*	2, 7	CH1
Southern Leopard Frog	*Rana utricularia*	2, 7	CH1
Western Chorus Frog	*Pseudacris triseriata*	2, 7	CH1
Bull Frog	*Rana catesbeiana*	2, 7	CH2
Common Garter Snake	*Thamnophis sirtalis*	2, 7	CH2
Crawfish Frog	*Rana areolata*	2, 7	CH2
Eastern Hognose Snake	*Heterodon platyrhinos*	2, 7	CH2
Massasauga	*Sistrurus catenatus*	2, 7	CH2
Western Ribbon Snake	*Thamnophis proximus*	2, 7	CH2
Eastern Mole	*Scalopus aquaticus*	1, 2	CM1A
Evening Bat	*Nycticeius humeralis*	1	CM1B
Red Bat	*Lasiurus borealis*	1, 2	CM1B
Bobcat	*Felis rufus*	1, 2	CM2
Mink	*Mustela vison*	2, 4	CM2
Mountain Lion	*Felis concolor*	1, 2	CM2
Bison	*Bison bison*	1, 2	HM1A
Cow	*Bos* spp.	13	HM1A
White tailed Deer	*Odocoileus virginianus*	1, 2	HM1B
Beaver	*Castor canadensis*	1, 2	HM2
Eastern Cottontail	*Sylvilagus floridanus*	1	HM2
Eastern Woodrat	*Neotoma floridana*	1, 2, 11	HM2
Hispid Cotton Rat	*Sigmodon hispidus*	1, 2, 11	HM2
Muskrat	*Ondatra zibethicus*	2, 3	HM2
Prairie Vole	*Microtus ochrogaster*	1, 2, 11	HM2
Woodchuck	*Marmota monax*	2, 4	HM2
Blue jay	*Cyanocitta cristata*	12	OB
Bluebird, eastern	*Sialia sialis*	12	OB
Bobwhite	*Colinus virginianus*	12	OB

Table 3. Beta animal guilds of the Tallgrass Prairie Preserve, OK (Cont.)

Common name	Scientific name	Source[a]	Alpha guild[b]
Deciduous Riparian Guild (cont.)			
Bunting, indigo	*Passerina cyanea*	12	OB
Cardinal	*Cardinalis cardinalis*	12	OB
Cowbird, brown-headed	*Molothrus ater*	12	OB
Crow, american	*Corvus brachyrhynchos*	12	OB
Duck, wood	*Aix sponsa*	12	OB
Grackle, common	*Quiscalus quiscula*	12	OB
Hummingbird, ruby-throated	*Arcjilochus colubris*	12	OB
Junco, dark-eyed	*Junco hyemalis*	12	OB
Nuthatch, whitebreasted	*Sitta carolenensis*	12	OB
Oriole, Northern	*Icterus galbula*	12	OB
Robin	*Turdus migratorius*	12	OB
Sparrow, American tree	*Spizella arborea*	12	OB
Sparrow, chipping	*Spizella passerina*	12	OB
Sparrow, Harris'	*Zonotrichia querula*	12	OB
Sparrow, Lincoln's	*Melospiza lincolnii*	12	OB
Sparrow, song	*Melospiza melodia*	12	OB
Sparrow, white-crowned	*Zonotrichia leucophrys*	12	OB
Sparrow, white-throated	*Zonotrichia albicollis*	12	OB
Starling	*Sturnus vulgaris*	12	OB
Summer tanager	*Piranga rubra*	12	OB
Thrush, wood	*Hylocichla mustelina*	12	OB
Towhee, rufous-sided	*Pipilo erythrophthalmus*	12	OB
Tufted titmouse	*Parus inornatus*	12	OB
Turkey	*Meleagris gallopavo*	12	OB
Warbler, yellow-rumped	*Dendroica coronata*	12	OB
Waterthrush, Louisiana	*Seiurus motacilla*	12	OB
Waxwing, cedar	*Bombycilla garrulus*	12	OB
Woodpecker, red-bellied	*Melanerpes carolinus*	12	OB
Woodpecker, red-headed	*Melanerpes erythrocephalus*	12	OB
Three-toed Box Turtle	*Terrapene carolina*	2, 7	OH
Coyote	*Canis latrans*	1, 2	OM1

Table 3. Beta animal guilds of the Tallgrass Prairie Preserve, OK (Cont.)

Common name	Scientific name	Source[a]	Alpha guild[b]
Deciduous Riparian Guild (cont.)			
Gray Fox	*Urocyon cinereoargenteus*	2, 3	OM1
Nine-banded Armadillo	*Dasypus novemcinctus*	1	OM1
Raccoon	*Procyon lotor*	1, 2	OM1
Striped Skunk	*Mephitis mephitis*	1, 2	OM1
Cotton Mouse	*Peromyscus gossypinus*	1, 2, 11	OM2
Fox Squirrel	*Sciurus niger*	1	OM2
Fulvous Harvest Mouse	*Reithrodontomys fulvescens*	1, 2, 11	OM2
White-footed Mouse	*Peromyscus leucopus*	1, 2, 11	OM2
Grassy Riparian Guild			
Brown Snake	*Storeria dekayi*	2, 7	CH1
Dwarf American Toad	*Bufo americanus*	2, 7	CH1
Great Plains Narrowmouth Toad	*Gastrophryne olivacea*	2, 8	CH1
Plains Leopard Frog	*Rana blairi*	2, 7	CH1
Southern Leopard Frog	*Rana utricularia*	2, 7	CH1
Western Chorus Frog	*Pseudacris triseriata*	2, 7	CH1
Bull Frog	*Rana catesbeiana*	2, 7	CH2
Central Plains Milk Snake	*Lampropeltis triangulum*	2, 7	CH2
Crawfish Frog	*Rana areolata*	2, 7	CH2
Western Ribbon Snake	*Thamnophis proximus*	2, 7	CH2
Bobcat	*Felis rufus*	1, 2	CM2
Mink	*Mustela vison*	2, 4	CM2
Mountain Lion	*Felis concolor*	1, 2	CM2
Bison	*Bison bison*	1, 2	HM1A
Cow	*Bos* spp.	13	HM1A
White tailed Deer	*Odocoileus virginianus*	1, 2	HM1B
Beaver	*Castor canadensis*	1, 2	HM2
Elliot's Short-tailed shrew	*Blarina hylophaga*	1, 2, 11	HM2
Hispid Cotton Rat	*Sigmodon hispidus*	1, 2, 11	HM2
Muskrat	*Ondatra zibethicus*	2, 3	HM2
Prairie Vole	*Microtus ochrogaster*	1, 2, 11	HM2
Robin	*Turdus migratorius*	12	OB

Table 3. Beta animal guilds of the Tallgrass Prairie Preserve, OK (Cont.)

Common name	Scientific name	Source[a]	Alpha guild[b]
Grassy Riparian Guild (cont.)			
Starling	*Sturnus vulgaris*	12	OB
Coyote	*Canis latrans*	1, 2	OM1
Nine-banded Armadillo	*Dasypus novemcinctus*	1	OM1
Raccoon	*Procyon lotor*	1, 2	OM1
Deer Mouse	*Peromyscus maniculatus*	1, 2, 11	OM2
Fulvous Harvest Mouse	*Reithrodontomys fulvescens*	1, 2, 11	OM2
Plains Harvest Mouse	*Reithrodontomys montanus*	1, 2, 11	OM2
White-footed Mouse	*Peromyscus leucopus*	11	OM2
Prairie Guild			
Flycatcher, scissor-tailed	*Tyrannus forficatus*	12	CB1
Kingbird, eastern	*Tyrannus tyrannus*	12	CB1
Kingbird, western	*Tyrannus verticalis*	12	CB1
Loggerhead shrike	*Lanius ludovicianus*	12	CB1
Nighthawk	*Chordeiles minor*	12	CB1
Poorwill	*Phalaenoptilus nuttallii*	12	CB1
Purple martin	*Progne subis*	12	CB1
Sandpiper, upland	*Bartramia longicauda*	12	CB1
Swallow, barn	*Hirundo rustica*	12	CB1
Swallow, cliff	*Hirundo pyrrhonata*	12	CB1
Swallow, rough-winged	*Stelgidopteryx serripennis*	12	CB1
Yellowthroat, common	*Geothlypis trichas*	12	CB1
Falcon, peregrine	*Falco peregrinus*	12	CB2
Harrier, northern	*Circus cyaneus*	12	CB2
Hawk, rough-legged	*Buteo lagopus*	12	CB2
Hawk, Swainson's	*Buteo swainsoni*	12	CB2
Merlin	*Falco columbarius*	12	CB2
Owl, burrowing	*Athene cunicularia*	12	CB2
Owl, short-eared	*Asio flammeus*	12	CB2
Vulture, turkey	*Cathartes aura*	12	CB2
Brown Snake	*Storeria dekayi*	2, 7	CH1
Dwarf American Toad	*Bufo americanus*	2, 7	CH1

Table 3. Beta animal guilds of the Tallgrass Prairie Preserve, OK (Cont.)

Common name	Scientific name	Source[a]	Alpha guild[b]
Prairie Guild (cont.)			
Great Plains Narrowmouth Toad	*Gastrophryne olivacea*	2, 8	CH1
Great Plains Skink	*Eumeces obsoletus*	2, 8	CH1
Lined Snake	*Tropidoclonium lineatum*	2, 7	CH1
Plains Leopard Frog	*Rana blairi*	2, 7	CH1
Six-lined Racerunner	*Cnemidophorus sexlineatus*	2, 7	CH1
Southern Leopard Frog	*Rana utricularia*	2, 7	CH1
Southern Prairie Skink	*Eumeces septentrionalis*	2, 9	CH1
Strecker's Chorus Frog	*Pseudacris streckeri*	2, 7	CH1
Western Chorus Frog	*Pseudacris triseriata*	2, 7	CH1
Black Ratsnake	*Elaphe obseleta*	2, 7	CH2
Broad-banded Copperhead	*Agkistrodon contortrix*	2, 7	CH2
Bullsnake	*Pituophis melanoleucus*	2, 7	CH2
Central Plains Milk Snake	*Lampropeltis triangulum*	2, 7	CH2
Coachwhip	*Masticophis flagellum*	2, 7	CH2
Crawfish Frog	*Rana areolata*	2, 7	CH2
Great Plains Ratsnake	*Elaphe guttata*	2, 7	CH2
Massasauga	*Sistrurus catenatus*	2, 7	CH2
Prairie Kingsnake	*Lampropeltis calligaster*	2, 7	CH2
Western Glass Lizard	*Ophisaurus attenuatus*	2, 7	CH2
Least Shrew	*Cryptotis parva*	1, 2, 11	CM1A
Badger	*Taxidea taxus*	1, 2	CM2
Bobcat	*Felis rufus*	1, 2	CM2
Mountain Lion	*Felis concolor*	1, 2	CM2
Bison	*Bison bison*	1, 2	HM1A
Cow	*Bos* spp.	13	HM1A
Prairie Vole	*Microtus ochrogaster*	1, 2, 11	HM1B
White tailed Deer	*Odocoileus virginianus*	1, 2	HM1B
Black-tailed Jack Rabbit	*Lepus californicus*	1, 2, 3	HM2
Eastern Woodrat	*Neotoma floridana*	1, 2, 11	HM2
Elliot's Short-tailed shrew	*Blarina hylophaga*	1, 2, 11	HM2
Hispid Cotton Rat	*Sigmodon hispidus*	1, 2, 11	HM2

Table 3. Beta animal guilds of the Tallgrass Prairie Preserve, OK (Cont.)

Common name	Scientific name	Source[a]	Alpha guild[b]
Prairie Guild (cont.)			
House Mouse	*Mus musculus*	1, 2, 11	HM2
Woodland Vole	*Microtus pinetorum*	1, 2, 11	HM2
Bobwhite	*Colinus virginianus*	12	OB
Cowbird, brown-headed	*Molothrus ater*	12	OB
Dickcissel	*Spiza americana*	12	OB
Dove, mourning	*Zenaida macroura*	12	OB
Great prairie chicken	*Tympanuchus cupido*	12	OB
Gull, Franklin's	*Larus pipixcan*	12	OB
Gull, ring-billed	*Larus delawarensis*	12	OB
Horned lark	*Eremophila alpestris*	12	OB
Junco, dark-eyed	*Junco hyemalis*	12	OB
Meadowlark, eastern	*Sturnella magna*	12	OB
Pheasant, ring-necked	*Phasianus colchicus*	12	OB
Plover, lesser golden	*Pluvialis squatarola*	12	OB
Sparrow, American tree	*Spizella arborea*	12	OB
Sparrow, Harris'	*Zonotrichia querula*	12	OB
Sparrow, Henslow's	*Ammodramus henslowii*	12	OB
Sparrow, lark	*Chondestes grammacus*	12	OB
Sparrow, savannah	*Passerculus sandwichensis*	12	OB
Sparrow, vesper	*Pooecetes gramineus*	12	OB
Ornate Box Turtle	*Terrapene ornata*	2, 7	OH
Coyote	*Canis latrans*	1, 2	OM1
Gray Fox	*Urocyon cinereoargenteus*	2, 3	OM1
Kerr, Virginia opossum	*Didelphis virginiana*	1, 2	OM1
Nine-banded Armadillo	*Dasypus novemcinctus*	1	OM1
13-lined Ground Squirrel	*Spermophilus tridecimlineatus*	2, 3	OM2
Deer Mouse	*Peromyscus maniculatus*	1, 2, 11	OM2
Eastern Harvest Mouse	*Reithrodontomys humulis*	1, 2, 11	OM2
Fulvous Harvest Mouse	*Reithrodontomys fulvescens*	1, 2, 11	OM2

Table 3. Beta animal guilds of the Tallgrass Prairie Preserve, OK (Cont.)

Common name	Scientific name	Source[a]	Alpha guild[b]
Prairie Guild (cont.)			
Plains Harvest Mouse	*Reithrodontomys montanus*	1, 2, 11	OM2
Western Harvest Mouse	*Reithrodontomys megalotis*	1, 2, 5, 11	OM2
White-footed Mouse	*Peromyscus leucopus*	1, 2, 11	OM2
Upland Deciduous Forest Guild			
Flycatcher, great crested	*Myiarchus crinitus*	12	CB1
Flycatcher, least	*Empidomax minimus*	12	CB1
Flycatcher, willow	*Empidomax traillii*	12	CB1
Gnatcatcher, blue-gray	*Polioptila caerulea*	12	CB1
Kingbird, eastern	*Tyrannus tyrannus*	12	CB1
Kinglet, golden-crowned	*Regulus satrapa*	12	CB1
Loggerhead shrike	*Lanius ludovicianus*	12	CB1
Northern flicker	*Colaptes auratus*	12	CB1
Phoebe, eastern	*Savornis phoebe*	12	CB1
Warbler, black and white	*Mniotilta varia*	12	CB1
Warbler, yellow	*Dendroica petechia*	12	CB1
Woodpecker, downy	*Picoides pubescens*	12	CB1
Woodpecker, hairy	*Picoides villosus*	12	CB1
Woodpecker, red-bellied	*Melanerpes carolinus*	12	CB1
Wood-pewee, eastern	*Contopus virens*	12	CB1
Wren, Bewick's	*Thryomanes bewickii*	12	CB1
Yellow-billed cuckoo	*Coccyzus americanus*	12	CB1
Harrier, northern	*Circus cyaneus*	12	CB2
Hawk, Cooper's	*Accipiter cooperii*	12	CB2
Hawk, red-tailed	*Buteo jamaicensus*	12	CB2
Kestrel	*Falco sparverius*	12	CB2
Kite, Mississippi	*Ictinia mississippiensis*	12	CB2
Owl, great horned	*Bubo virginianus*	12	CB2
Owl, screech	*Otus asio*	12	CB2
Broadhead Skink	*Eumeces laticeps*	2, 7	CH1
Brown Snake	*Storeria dekayi*	2, 7	CH1
Fence Lizard	*Sceloporus undulatus*	2, 7	CH1

Table 3. Beta animal guilds of the Tallgrass Prairie Preserve, OK (Cont.)

Common name	Scientific name	Source[a]	Alpha guild[b]
Upland Deciduous Forest Guild (cont.)			
Five-lined Skink	*Eumeces fasciatus*	2, 7	CH1
Gray Tree Frog	*Hyla versicolor*	2, 7	CH1
Ground Skink	*Scincella lateralis*	2, 7	CH1
Black Ratsnake	*Elaphe obseleta*	2, 7	CH2
Broad-banded Copperhead	*Agkistrodon contortrix*	2, 7	CH2
Central Plains Milk Snake	*Lampropeltis triangulum*	2, 7	CH2
Common Garter Snake	*Thamnophis sirtalis*	2, 7	CH2
Eastern Hognose Snake	*Heterodon platyrhinos*	2, 7	CH2
Great Plains Ratsnake	*Elaphe guttata*	2, 7	CH2
Speckled Kingsnake	*Lampropeltis getulus*	2, 7	CH2
Timber Rattlesnake	*Crotalus horridus*	2, 7	CH2
Western Glass Lizard	*Ophisaurus attenuatus*	2, 7	CH2
Yellowbelly Racer	*Coluber constrictor*	2, 7	CH2
Mountain Lion	*Felis concolor*	1, 2	CM2
Bison	*Bison bison*	1, 2	HM1A
Cow	*Bos* spp.	13	HM1A
White tailed Deer	*Odocoileus virginianus*	1, 2	HM1B
Eastern Cottontail	*Sylvilagus floridanus*	1	HM2
Eastern Woodrat	*Neotoma floridana*	1, 2, 11	HM2
Elliot's Short-tailed shrew	*Blarina hylophaga*	1, 2, 11	HM2
Hispid Cotton Rat	*Sigmodon hispidus*	1, 2, 11	HM2
Woodchuck	*Marmota monax*	2, 4	HM2
Blackbird, red-winged	*Agelaius phoeniceus*	12	OB
Blue jay	*Cyanocitta cristata*	12	OB
Bluebird, eastern	*Sialia sialis*	12	OB
Bobwhite	*Colinus virginianus*	12	OB
Brown thrasher	*Toxostoma rufum*	12	OB
Bunting, indigo	*Passerina cyanea*	12	OB
Cardinal	*Cardinalis cardinalis*	12	OB
Catbird	*Dumetella carolinensis*	12	OB
Cowbird, brown-headed	*Molothrus ater*	12	OB

Table 3. Beta animal guilds of the Tallgrass Prairie Preserve, OK (Cont.)

Common name	Scientific name	Source[a]	Alpha guild[b]
Upland Deciduous Forest Guild (cont.)			
Crow, american	*Corvus brachyrhynchos*	12	OB
Dove, mourning	*Zenaida macroura*	12	OB
Goldfinch, American	*Carduelis tristis*	12	OB
Grackle, common	*Quiscalus quiscula*	12	OB
Grosbeak, blue	*Guiraca caerulea*	12	OB
Junco, dark-eyed	*Junco hyemalis*	12	OB
Nuthatch, whitebreasted	*Sitta carolenensis*	12	OB
Oriole, Northern	*Icterus galbula*	12	OB
Oriole, orchard	*Icterus spurius*	12	OB
Robin	*Turdus migratorius*	12	OB
Sparrow, American tree	*Spizella arborea*	12	OB
Sparrow, chipping	*Spizella passerina*	12	OB
Sparrow, field	*Spizella pusilla*	12	OB
Sparrow, Harris'	*Zonotrichia querula*	12	OB
Sparrow, lark	*Chondestes grammacus*	12	OB
Sparrow, Lincoln's	*Melospiza lincolnii*	12	OB
Sparrow, song	*Melospiza melodia*	12	OB
Sparrow, white-crowned	*Zonotrichia leucophrys*	12	OB
Sparrow, white-throated	*Zonotrichia albicollis*	12	OB
Starling	*Sturnus vulgaris*	12	OB
Towhee, rufous-sided	*Pipilo erythrophthalmus*	12	OB
Tufted titmouse	*Parus inornatus*	12	OB
Warbler, yellow-rumped	*Dendroica coronata*	12	OB
Waxwing, cedar	*Bombycilla garrulus*	12	OB
Woodpecker, red-headed	*Melanerpes erythrocephalus*	12	OB
Three-toed Box Turtle	*Terrapene carolina*	2, 7	OH
Coyote	*Canis latrans*	1, 2	OM1
Gray Fox	*Urocyon cinereoargenteus*	2, 3	OM1
Nine-banded Armadillo	*Dasypus novemcinctus*	1	OM1
Raccoon	*Procyon lotor*	1, 2	OM1
Cotton Mouse	*Peromyscus gossypinus*	1, 2, 11	OM2

Table 3. Beta animal guilds of the Tallgrass Prairie Preserve, OK (Cont.)

Common name	Scientific name	Source[a]	Alpha guild[b]
Upland Deciduous Forest Guild (cont.)			
Deer Mouse	*Peromyscus maniculatus*	1, 2, 11	OM2
White-footed Mouse	*Peromyscus leucopus*	1, 2, 11	OM2
Rocky Outcrops			
Vireo, Bell's	*Vireo bellii*	12	CB1
Warbler, yellow	*Dendroica petechia*	12	CB1
Wren, Bewick's	*Thryomanes bewickii*	12	CB1
Brown Snake	*Storeria dekayi*	2, 7	CH1
Black Ratsnake	*Elaphe obseleta*	2, 7	CH2
Central Plains Milk Snake	*Lampropeltis triangulum*	2, 7	CH2
Coachwhip	*Masticophis flagellum*	2, 7	CH2
Eastern Collared Lizard	*Crotaphytus collaris*	2, 7	CH2
Great Plains Ratsnake	*Elaphe guttata*	2, 7	CH2
Timber Rattlesnake	*Crotalus horridus*	2, 7	CH2
Mountain Lion	*Felis concolor*	1, 2	CM2
Bison	*Bison bison*	1, 2	HM1A
Cow	*Bos* spp.	13	HM1A
Fence Lizard	*Sceloporus undulatus*	2, 7	HM1B
Flathead Snake	*Tantilla gracilis*	2, 7	HM1B
Great Plains Narrowmouth Toad	*Gastrophryne olivacea*	2, 8	HM1B
Ground Snake	*Sonora semiannulata*	2, 10	HM1B
Six-lined Racerunner	*Cnemidophorus sexlineatus*	1, 2, 11	HM1B
Southern Prairie Skink	*Eumeces septentrionalis*	2, 7	HM1B
White tailed Deer	*Odocoileus virginianus*	1, 2	HM1B
Eastern Cottontail	*Sylvilagus floridanus*	1	HM2
Eastern Woodrat	*Neotoma floridana*	1, 2, 11	HM2
Hispid Cotton Rat	*Sigmodon hispidus*	1, 2, 11	HM2
Hispid Pocket Mouse	*Chaetodipus hispidus*	1, 2, 11	HM2
Bluebird, mountain	*Sialia currucoides*	12	OB
Brown thrasher	*Toxostoma rufum*	12	OB
Cardinal	*Cardinalis cardinalis*	12	OB
Catbird	*Dumetella carolinensis*	12	OB

Table 3. Beta animal guilds of the Tallgrass Prairie Preserve, OK (Cont.)

Common name	Scientific name	Source[a]	Alpha guild[b]
Rocky Outcrops (cont.)			
Cowbird, brown-headed	*Molothrus ater*	12	OB
Mockingbird	*Mimus polyglottos*	12	OB
Pheasant, ring-necked	*Phasianus colchicus*	12	OB
Sparrow, American tree	*Spizella arborea*	12	OB
Sparrow, song	*Melospiza melodia*	12	OB
Coyote	*Canis latrans*	1, 2	OM1
Nine-banded Armadillo	*Dasypus novemcinctus*	1	OM1
13-lined Ground Squirrel	*Spermophilus tridecimlineatus*	2, 6	OM2
Deer Mouse	*Peromyscus maniculatus*	1, 2, 11	OM2
Fulvous Harvest Mouse	*Reithrodontomys fulvescens*	1, 2, 11	OM2
White-footed Mouse	*Peromyscus leucopus*	1, 2, 11	OM2
Disturbed Areas			
Killdeer	*Charadrius vociferous*	12	CB1
Brown Snake	*Storeria dekayi*	2, 7	CH1
Dwarf American Toad	*Bufo americanus*	2, 7	CH1
Lined Snake	*Tropidoclonium lineatum*	2, 7	CH1
Black Ratsnake	*Elaphe obseleta*	2, 7	CH2
Least Shrew	*Cryptotis parva*	1, 2, 11	CM1A
Badger	*Taxidea taxus*	1, 2	CM2
Bobcat	*Felis rufus*	1, 2	CM2
Bison	*Bison bison*	1, 2	HM1A
White tailed Deer	*Odocoileus virginianus*	1, 2	HM1B
Black-tailed Jack Rabbit	*Lepus californicus*	1, 2, 3	HM2
Eastern Cottontail	*Sylvilagus floridanus*	1	HM2
Eastern Woodrat	*Neotoma floridana*	11	HM2
Hispid Cotton Rat	*Sigmodon hispidus*	1, 2, 11	HM2
Hispid Pocket Mouse	*Chaetodipus hispidus*	1, 2, 11	HM2
House Mouse	*Mus musculus*	1, 2, 11	HM2
Prairie Vole	*Microtus ochrogaster*	1, 2, 11	HM2
Chimney swift	*Chaetura pelagica*	12	OB
Dove, rock	*Columba livia*	12	OB

Table 3. Beta animal guilds of the Tallgrass Prairie Preserve, OK (Cont.)

Common name	Scientific name	Source[a]	Alpha guild[b]
Disturbed Areas (cont.)			
Sparrow, house	*Passer domesticus*	12	OB
Coyote	*Canis latrans*	1, 2	OM1
Nine-banded Armadillo	*Dasypus novemcinctus*	1	OM1
Striped Skunk	*Mephitis mephitis*	1, 2	OM1
Deer Mouse	*Peromyscus maniculatus*	1, 2, 11	OM2
Fulvous Harvest Mouse	*Reithrodontomys fulvescens*	1, 2, 11	OM2
White-footed Mouse	*Peromyscus leucopus*	1, 2, 11	OM2

[a] Indicates source for both presence/absence and distribution. Sources: 1. Oklahoma Natural Heritage Inventory, 1993; 2. Nature Conservancy, 1993; 3. Myers et al., 2000; 4. McMillan et al., 1997; 5. McMillan and Kaufman, 1994; 6. Finck et al., 1986; 7. INHS, 1998; 8. Bockstanz and Cannatella, 2000; 9. LeClere, 2000; 10. Cossel, 1998; 11. Payne and Caire, 1999; 12. Zimmerman, 1993; 13. Hamilton, 1996.

[b] Key to Alpha Guilds:

HM1a	Herbivorous Mammals - grazers	CH1	Invertivorous Herptiles
HM1b	Herbivorous Mammals - browsers	CH2	Other Carnivorous Herptiles
HM2	Small Herbivorous Mammals	CB1	Invertivorous Birds
HB	Herbivorous Birds	CB2	Raptors
OM1	Large Omnivorous Mammals	CM1a	Fossorial Invertivorous Mammals
OM2	Small Omnivorous Mammals	CM1b	Other Invertivorous Mammals
OB	Omnivorous Birds	CM2	Large Carnivorous Mammals
OH	Omnivorous Herptiles		

Table 4. Dominant Plant Species at the Tallgrass Prairie Preserve, OK. Based on unbiased plots sampled throughout the entire preserve. Source: Palmer, unpublished data.

Species name	Frequency (% of plots occupied)	Average cover (%)
Andropogon gerardii	97.4	4
Sporobolus compositus	97.4	2.8
Oxalis dillenii	96	0.5
Ambrosia psilostachya	95.4	1.5
Asclepias viridis	92.1	0.5
Dichanthelium oligosanthes	91.4	0.5
Sorghastrum nutans	88.1	1.3
Panicum virgatum	87.4	0.7
Schizachyrium scoparium	86.8	2.3
Strophostyles leiosperma	83.4	0.4
Aster ericoides	80.8	0.5
Carex festucacea	79.5	0.4
Erigeron strigosus	78.8	0.4
Kummerowia stipulacea	77.5	0.5
Achillea millefolium	74.8	0.4
Carex microdonta	72.2	0.5
Ruellia humilis	71.5	0.3
Elymus virginicus	70.2	0.4
Vernonia baldwinii	67.5	0.5
Amphiachyris dracunculoides	66.9	0.4
Eragrostis spectabilis	63.6	0.4
Plantago virginica	61.6	0.3
Setaria parviflora	60.3	0.3
Solanum carolinense	60.3	0.3
Juncus interior	59.6	0.3
Paspalum setaceum	58.9	0.3
Poa pratensis	57.6	0.3
Ambrosia artemisiifolia	55.6	0.5
Salvia azurea	55.6	0.3
Cirsium altissimum	55	0.3
Conyza canadensis	55	0.2
Acalypha gracilens	54.3	0.2
Physalis pumila	52.3	0.3
Lespedeza procumbens	51.7	0.4
Sphenopholis obtusata	51.7	0.3
Oxalis violacea	51.7	0.2
Tridens flavus	51	0.3
Elymus canadensis	50.3	0.3
Ratibida columnifera	50.3	0.2
Digitaria cognata	50.3	0.2
Artemisia ludoviciana	49.7	0.4
Agrostis hyemalis	49.7	0.3
Croton monanthogynus	49.7	0.2
Solidago canadensis	49	0.6
Amorpha canescens	49	0.3
Psoralidium tenuiflorum	48.3	0.4
Carex bushii	48.3	0.2
Cyperus lupulinus	46.4	0.2
Dichanthelium acuminatum	46.4	0.2
Polygala verticillata	46.4	0.2
Lepidium virginicum	46.4	0.2
Physalis virginiana	45.7	0.2
Hordeum pusillum	45.7	0.2
Lespedeza virginica	45	0.2
Triodanis perfoliata	45	0.2
Bothriochloa saccharoides	43.7	0.4
Symphoricarpos orbiculatus	43.7	0.3
Carex gravida	43.7	0.2
Mimosa quadrivalvis	43.7	0.2
Callirhoe alcaeoides	43	0.2
Carex cephalophora	41.7	0.2
Cuscuta pentagona	41.7	0.2
Buchloe dactyloides	41.1	0.3
Bromus japonicus	41.1	0.3
Acalypha virginica	41.1	0.2
Rubus ostryifolius	40.4	0.7
Bouteloua curtipendula	40.4	0.3

Table 4. Dominant Plant Species at the Tallgrass Prairie Preserve, OK (Cont.).

Species name	Frequency (% of plots occupied)	Average cover (%)
Eleocharis montevidensis	40.4	0.3
Cirsium undulatum	40.4	0.2
Kummerowia striata	39.7	0.4
Fimbristylis puberula	37.7	0.2
Chamaesyce nutans	37.7	0.1
Ambrosia bidentata	36.4	0.2
Chaerophyllum tainturieri	33.1	0.1
Cyperus echinatus	32.5	0.2
Aster oolentangiensis	31.8	0.2
Panicum anceps	30.5	0.5
Sisyrinchium campestre	30.5	0.1
Hedeoma hispida	30.5	0.1
Medicago lupulina	27.8	0.3
Oenothera speciosa	27.8	0.1
Rudbeckia hirta	25.8	0.2
Erigeron philadelphicus	25.8	0.1
Linum sulcatum	25.8	0.1
Chamaecrista fasciculata	25.8	0.1
Rumex crispus	25.2	0.1
Desmodium sessilifolium	25.2	0.1
Geranium carolinianum	25.2	0.1
Gamochaeta purpurea	24.5	0.1
Monarda citriodora	23.8	0.2
Vernonia arkansana	23.8	0.1
Brickellia eupatorioides	23.8	0.1
Dalea candida	23.8	0.1
Dracopis amplexicaulis	23.8	0.1
Pyrrhopappus carolinianus	23.8	0.1
Baptisia bracteata	23.2	0.1
Coreopsis grandiflora	23.2	0.1
Tragia betonicifolia	22.5	0.1
Baptisia australis	21.9	0.1
Penstemon tubiflorus	21.9	0.1
Apocynum cannabinum	21.2	0.1
Silene antirrhina	21.2	0.1
Vulpia octoflora	21.2	0.1
Arnoglossum plantagineum	20.5	0.1
Euphorbia spathulata	19.9	0.1
Ulmus rubra	19.9	0.1
Melilotus officinalis	18.5	0.1
Eupatorium altissimum	18.5	0.1
Phalaris caroliniana	18.5	0.1
Valerianella radiata	18.5	0.1
Veronica arvensis	18.5	0.1
Andropogon virginicus	17.9	0.3
Krigia cespitosa	17.9	0.1
Antennaria neglecta	17.2	0.1
Xanthium strumarium	17.2	0.1
Scutellaria parvula	16.6	0.1
Dichanthelium sphaerocarpon	16.6	0.1
Stylosanthes biflora	16.6	0.1
Baptisia alba	15.9	0.1
Desmanthus leptolobus	15.9	0.1
Croton glandulosus	15.9	0.1
Nothoscordum bivalve	15.9	0.1
Desmanthus illinoensis	15.2	0.1
Juncus marginatus	15.2	0.1
Lithospermum incisum	15.2	0.1
Viola sororia	15.2	0.1

Table 5. Food relationships between the various alpha guilds at the Tallgrass Prairie Preserve, OK. An "x" denotes that a given prey species along the y-axis may be consumed by the corresponding predator on the x-axis.

		Predators															
		AI	BI	HM1a	HM1b	HM2	OM1	OM2	OB	OH	CH1	CH2	CB1	CB2	CM1a	CM1b	CM2
Prey	Plants	X	X	X	X	X	X	X	X	X							
	Detritus	X	X				X	X	X	X				X	X		
	AI	X					X	X	X	X	X	X	X	X		X	
	BI		X						X	X	X		X		X		
	HM1a						X										X
	HM1b						X										X
	HM2						X		X			X		X			X
	OM1						X							X			X
	OM2						X		X			X		X			X
	OB						X		X	X		X		X			X
	OH						X										X
	CH1						X	X	X			X		X			X
	CH2						X					X		X			X
	CB1						X		X	X		X		X			X
	CB2																
	CM1a						X					X		X			X
	CM1b						X							X			
	CM2																

Key to Alpha Guilds:

Plants	Plants and Fungi	OB	Omnivorous Birds
Detritus	Detritus and Carrion	OH	Omnivorous Herptiles
AI	Aboveground Invertebrates	CH1	Invertivorous Herptiles
BI	Belowground Invertebrates	CH2	Other Carnivorous Herptiles
HM1a	Herbivorous Mammals - grazers	CB1	Invertivorous Birds
HM1b	Herbivorous Mammals - browsers	CB2	Raptors
HM2	Small Herbivorous Mammals	CM1a	Fossorial Invertivorous Mammals
HB	Herbivorous Birds	CM1b	Other Invertivorous Mammals
OM1	Large Omnivorous Mammals	CM2	Large Carnivorous Mammals
OM2	Small Omnivorous Mammals		

Table 6. Metaguilds at the Tallgrass Prairie Preserve, OK. All guilds within each metaguild share either identical prey guilds, or identical predator guilds.

Predator Metaguild	**Constituent Guilds**	**Guilds used as Prey**
Herbivorous Mammals	HM1a, HM1b, HM2	Plants
Invertivores	CH1, CB1	BI, AI
Prey Metaguild	**Constituent Guilds**	**Guilds for which metaguild serves as prey**
Metaguild A	HM1a, HM1b, OH	OM1, CM2
Metaguild B	HM2, OM2, CM1a, CH2	OM1, OB, CH2, CB2, CM2
Metaguild C (Non-raptorial Birds)	OB, CB1	OM1, OB, OH, CH2, CB2, CM2
Metaguild D (Top Predators)	CB2, CM2	none

Key to Alpha Guilds:

Plants	**Plants and Fungi**	**OB**	**Omnivorous Birds**
Detritus	**Detritus and Carrion**	**OH**	**Omnivorous Herptiles**
AI	**Aboveground Invertebrates**	**CH1**	**Invertivorous Herptiles**
BI	**Belowground Invertebrates**	**CH2**	**Other Carnivorous Herptiles**
HM1a	**Herbivorous Mammals - grazers**	**CB1**	**Invertivorous Birds**
HM1b	**Herbivorous Mammals - browsers**	**CB2**	**Raptors**
HM2	**Small Herbivorous Mammals**	**CM1a**	**Fossorial Invertivorous Mammals**
HB	**Herbivorous Birds**	**CM1b**	**Other Invertivorous Mammals**
OM1	**Large Omnivorous Mammals**	**CM2**	**Large Carnivorous Mammals**
OM2	**Small Omnivorous Mammals**		

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Appendix A
Master Species List of the Tallgrass Prairie Preserve, OK

Table A-1. Master Species List of the Tallgrass Prairie Preserve, OK.

Common name	Scientific name	Trophic level[a]	Habitat[b]							Source[c]
			Deciduous riparian forest	Grassy riparian	Prairie	Upland deciduous forest	Rocky outcrops	Disturbed areas	Aquatic	
Mammals										
Bison	*Bison bison*	H	x	x	x	x	x	x		1, 2
Elliot's Short-tailed Shrew	*Blarina hylophaga*	H		x	x	x				1, 2, 3
Cow	*Bos* spp.	H	x	x	x	x	x			4
Coyote	*Canis latrans*	O	x	x	x	x	x	x		1, 2
Beaver	*Castor canadensis*	H	x	x					x	1, 2
Hispid Pocket Mouse	*Chaetodipus hispidus*	H					x	x		1, 2, 3
Least Shrew	*Cryptotis parva*	C			x			x		1, 2, 3
Nine-banded Armadillo	*Dasypus novemcinctus*	O	x	x	x	x	x	x		1
Kerr, Virginia Opossum	*Didelphis virginiana*	O			x					1, 2
Mountain Lion	*Felis concolor*	C	x	x	x	x	x			1, 2
Red Bat	*Lasiurus borealis*	I	x							1, 2
Black-tailed Jack Rabbit	*Lepus californicus*	H			x			x		1, 2
Bobcat	*Felis rufus*	C	x	x	x			x		1, 2
Woodchuck	*Marmota monax*	H	x			x				2
Striped Skunk	*Mephitis mephitis*	O	x					x		1, 2
Prairie Vole	*Microtus ochrogaster*	H	x	x	x			x		1, 2, 3
Woodland Vole	*Microtus pinetorum*	H			x					1, 2, 3
House Mouse	*Mus musculus*	H			x			x		1, 2, 3
Mink	*Mustela vison*	C	x	x					x	2
Eastern Woodrat	*Neotoma floridana*	H	x		x	x	x	x		1, 2, 3
Evening Bat	*Nycticeius humeralis*	I	x							1

Table A-1. Master Species List of the Tallgrass Prairie Preserve, OK (Cont.).

Common name	Scientific name	Trophic level[a]	Habitat[b]							Source[c]
			Deciduous riparian forest	Grassy riparian	Prairie	Upland deciduous forest	Rocky outcrops	Disturbed areas	Aquatic	
Mammals (cont.)										
White Tailed Deer	*Odocoileus virginianus*	H	x	x	x	x	x	x		1, 2
Muskrat	*Ondatra zibethicus*	H	x	x					x	2
Cotton Mouse	*Peromyscus gossypinus*	O	x			x				1, 2, 3
White-footed Mouse	*Peromyscus leucopus*	O	x	x	x	x	x	x		1, 2, 3
Deer Mouse	*Peromyscus maniculatus*	O		x	x	x	x	x		1, 2, 3
Raccoon	*Procyon lotor*	O	x	x		x				1, 2
Fulvous Harvest Mouse	*Reithrodontomys fulvescens*	O	x	x	x		x	x		1, 2, 3
Eastern Harvest Mouse	*Reithrodontomys humulis*	O			x					1, 2, 3
Western Harvest Mouse	*Reithrodontomys megalotis*	O			x					1, 2, 3
Plains Harvest Mouse	*Reithrodontomys montanus*	O		x	x					1, 2, 3
Eastern Mole	*Scalopus aquaticus*	I	x							1, 2, 3
Fox Squirrel	*Sciurus niger*	O	x							1
Hispid Cotton Rat	*Sigmodon hispidus*	H	x	x	x	x	x	x		1, 2, 3
13-lined Ground Squirrel	*Spermophilus tridecimlineatus*	O			x		x			2
Eastern Cottontail	*Sylvilagus floridanus*	H	x			x	x	x		1
Badger	*Taxidea taxus*	C			x			x		1, 2
Gray Fox	*Urocyon cinereoargenteus*	O	x		x	x				2

Table A-1. Master Species List of the Tallgrass Prairie Preserve, OK (Cont.).

Common name	Scientific name	Trophic level[a]	Habitat[b]							Source[c]
			Deciduous riparian forest	Grassy riparian	Prairie	Upland deciduous forest	Rocky outcrops	Disturbed areas	Aquatic	
Birds										
Blackbird, red-winged	*Agelaius phoeniceus*	O				SR				1, 2
Blue jay	*Cyanocitta cristata*	O	SR/WR			SR/WR				1, 2
Bluebird, eastern	*Sialia sialis*	O	SR			SR/WR				1, 2
Bluebird, mountain	*Sialia currucoides*	O					WV			1
Bobwhite	*Colinus virginianus*	O	SR		SR	WR				1, 2
Brown thrasher	*Toxostoma rufum*	O				SR	SR			1, 2
Bunting, indigo	*Passerina cyanea*	O	SR			SR				1, 2
Bunting, painted	*Passerina ciris*	O								2
Canada goose	*Branta canadensis*	O								1, 2
Cardinal	*Cardinalis cardinalis*	O	WR			SRWR	SR			1, 2
Catbird	*Dumetella carolinensis*	O				SR	SR			2
Chickadee, Carolina	*Parus carolinensis*	O								1, 2
Chimney swift	*Chaetura pelagica*	O						x		1, 2
Chuck-will's-widow	*Caprimulgus carolinensis*	O								1, 2
Coot, American	*Fulica americana*	O								2
Cormorant, double-crested	*Phalacrocorax auritus*	P								1, 2
Cowbird, brown-headed	*Molothrus ater*	O	SR/WR		SR	SR	SR			1, 2
Creeper, brown	*Certhia familiaris*	O								2
Crow, american	*Corvus brachyrhynchos*	O	SR/WR			SR/WR				1, 2
Crow, fish	*Corvus ossifragus*	O								2
Dickcissel	*Spiza americana*	O			SR					1, 2
Dove, mourning	*Zenaida macroura*	O			SR	SR				1, 2

Table A-1. Master Species List of the Tallgrass Prairie Preserve, OK (Cont.).

Common name	Scientific name	Trophic level[a]	Habitat[b]							Source[c]
			Deciduous riparian forest	Grassy riparian	Prairie	Upland deciduous forest	Rocky outcrops	Disturbed areas	Aquatic	
Birds (cont.)										
Dove, rock	*Columba livia*	O						x		2
Dowitcher, long-billed	*Limnodromus griseus*	O								2
Duck, ring-necked	*Aythya collaris*	O								1, 2
Duck, wood	*Aix sponsa*	O	SR							1, 2
Eagle, bald	*Haliaeetus leucocephalus*	C								2
Egret, cattle	*Bubulcus ibis*	I								1, 2
Egret, great	*Casmerodius albus*	P								2
Egret, snowy	*Egretta thula*	P								2
Falcon, peregrine	*Falco peregrinus*	C			M					2
Flycatcher, Acadian	*Empidomax virescens*	I								2
Flycatcher, alder	*Empidomax alnorum*	I								2
Flycatcher, great crested	*Myiarchus crinitus*	I	SR			SR				1, 2
Flycatcher, least	*Empidomax minimus*	I	M			M				2
Flycatcher, scissor-tailed	*Tyrannus forficatus*	I			SV					1, 2
Flycatcher, willow	*Empidomax traillii*	I				M				2
Gadwall	*Anas strepera*	O								2
Gnatcatcher, blue-gray	*Polioptila caerulea*	I	SR			SR				1, 2
Godwit, Hudsonian	*Limosa haemastica*	I								2
Goldfinch, American	*Carduelis tristis*	O				SR/WR				2
Grackle, common	*Quiscalus quiscula*	O	SV			SR				1, 2
Grackle, great-tailed	*Quiscalus mexicanus*	O								2
Great prairie chicken	*Tympanuchus cupido*	O			SR					1, 2

Table A-1. Master Species List of the Tallgrass Prairie Preserve, OK (Cont.).

Common name	Scientific name	Trophic level[a]	Habitat[b]							Source[c]
			Deciduous riparian forest	Grassy riparian	Prairie	Upland deciduous forest	Rocky outcrops	Disturbed areas	Aquatic	
Birds (cont.)										
Grebe, pied-billed	*Podilymbus podiceps*	P								2
Grosbeak, blue	*Guiraca caerulea*	O				SR				1, 2
Gull, Franklin's	*Larus pipixcan*	O			M					2
Gull, ring-billed	*Larus delawarensis*	O			M					2
Harrier, northern	*Circus cyaneus*	C			SR/WR	SR				1, 2
Hawk, broad-winged	*Buteo platypterus*	C								2
Hawk, Cooper's	*Accipiter cooperii*	C	M			M				1, 2
Hawk, red-tailed	*Buteo jamaicensus*	C	SR/WR			SR/WR				1, 2
Hawk, rough-legged	*Buteo lagopus*	C			WR					2
Hawk, sharp-shinned	*Accipiter striatus*	C	M							2
Hawk, Swainson's	*Buteo swainsoni*	C			SV					2
Heron, black-crowned night	*Nycticorax nycticorax*	P								2
Heron, great blue	*Ardea herodias*	P								1, 2
Heron, green-backed	*Butorides striatus*	P	SR							2
Heron, little blue	*Florida caerulea*	P								2
Horned lark	*Eremophila alpestris*	O			SR					1, 2
Hummingbird, ruby-throated	*Arcjilochus colubris*	O	SR							2
Junco, dark-eyed	*Junco hyemalis*	O	WR		WR	WR				2
Kestrel	*Falco sparverius*	C				M/WR				1, 2
Killdeer	*Charadrius vociferous*	I						x		1, 2
Kingbird, eastern	*Tyrannus tyrannus*	I			SR	SR				1, 2
Kingbird, western	*Tyrannus verticalis*	I			SV					1, 2

Table A-1. Master Species List of the Tallgrass Prairie Preserve, OK (Cont.).

Common name	Scientific name	Trophic level[a]	Habitat[b]							Source[c]
			Deciduous riparian forest	Grassy riparian	Prairie	Upland deciduous forest	Rocky outcrops	Disturbed areas	Aquatic	
Birds (cont.)										
Kingfisher, belted	*Ceryle alcyon*	P	SR/WR							1, 2
Kinglet, golden-crowned	*Regulus satrapa*	I	WR			M				2
Kite, Mississippi	*Ictinia mississippiensis*	C				M				2
Loggerhead shrike	*Lanius ludovicianus*	I			SR	SR				1, 2
Mallard	*Anas platyrhynchos*	O								2
Meadowlark, eastern	*Sturnella magna*	O			SRWR					1, 2
Merlin	*Falco columbarius*	C			M					2
Mockingbird	*Mimus polyglottos*	O					SR			1, 2
Nighthawk	*Chordeiles minor*	I			SR					1, 2
Northern flicker	*Colaptes auratus*	I	SR/WR			SR/WR				1, 2
Nuthatch, whitebreasted	*Sitta carolenensis*	O	SR/WR			SR/WR				1, 2
Oriole, Northern	*Icterus galbula*	O	SR			SR				2
Oriole, orchard	*Icterus spurius*	O				SR				1, 2
Osprey	*Pandion haliaetus*	P								1
Owl, barn	*Tyto alba*	C								2
Owl, barred	*Strix varia*	C	SR/WR							2
Owl, burrowing	*Athene cunicularia*	C			M					2
Owl, great horned	*Bubo virginianus*	C	SR/WR			SR/WR				1, 2
Owl, screech	*Otus asio*	C	WR			SR/WR				2
Owl, short-eared	*Asio flammeus*	C			M					2
Pheasant, ring-necked	*Phasianus colchicus*	O			SR		SR			2
Phoebe, eastern	*Savornis phoebe*	I	SR			SR				1

Table A-1. Master Species List of the Tallgrass Prairie Preserve, OK (Cont.).

Common name	Scientific name	Trophic level[a]	Habitat[b]							Source[c]
			Deciduous riparian forest	Grassy riparian	Prairie	Upland deciduous forest	Rocky outcrops	Disturbed areas	Aquatic	
Birds (cont.)										
Pintail, northern	*Anas acuta*	O								2
Plover, lesser golden	*Pluvialis squatarola*	O			M					2
Poorwill	*Phalaenoptilus nuttallii*	I			SR					2
Purple martin	*Progne subis*	I			SV					1, 2
Rail, king	*Rallus elegans*	O								2
Redhead	*Aythya americana*	O								1, 2
Robin	*Turdus migratorius*	O	SR/WR	SR/WR		SR				1, 2
Sandpiper, semipalmated	*Calidris pusilla*	I								1
Sandpiper, solitary	*Tringa solitaria*	I								1, 2
Sandpiper, upland	*Bartramia longicauda*	I			SR					1, 2
Scaup, lesser	*Aythya affinis*	O								2
Shoveler, Northern	*Anas clypeata*	O								2
Snipe	*Gallinago gallinago*	I								1, 2
Sora	*Porzana carolina*	O								2
Sparrow, American tree	*Spizella arborea*	O	WR		WR	WR	WR			2
Sparrow, chipping	*Spizella passerina*	O	M			M				1, 2
Sparrow, field	*Spizella pusilla*	O				SR				1, 2
Sparrow, grasshopper	*Ammodramus savannarum*	O								1, 2
Sparrow, Harris'	*Zonotrichia querula*	O	WR		SR	WR				2
Sparrow, Henslow's	*Ammodramus henslowii*	O			SR					2
Sparrow, house	*Passer domesticus*	O						x		1, 2
Sparrow, lark	*Chondestes grammacus*	O			SR	SR				1, 2

Table A-1. Master Species List of the Tallgrass Prairie Preserve, OK (Cont.).

Common name	Scientific name	Trophic level[a]	Habitat[b]							Source[c]
			Deciduous riparian forest	Grassy riparian	Prairie	Upland deciduous forest	Rocky outcrops	Disturbed areas	Aquatic	
Birds (cont.)										
Sparrow, Lincoln's	*Melospiza lincolnii*	O	M			M				2
Sparrow, savannah	*Passerculus sandwichensis*	O			M					1, 2
Sparrow, song	*Melospiza melodia*	O	WR			WR	WR			2
Sparrow, vesper	*Pooecetes gramineus*	O			M					1, 2
Sparrow, white-crowned	*Zonotrichia leucophrys*	O	M			M				2
Sparrow, white-throated	*Zonotrichia albicollis*	O	M			M				2
Starling	*Sturnus vulgaris*	O	SR/WR	SR/WR		SR/WR				1, 2
Summer tanager	*Piranga rubra*	O	SR							1, 2
Swallow, bank	*Riparia riparia*	I								1
Swallow, barn	*Hirundo rustica*	I			SV					1, 2
Swallow, cliff	*Hirundo pyrrhonata*	I			SV					1, 2
Swallow, rough-winged	*Stelgidopteryx serripennis*	I	SR		SR					1, 2
Teal, blue-winged	*Anas discors*	H								1, 2
Teal, green-winged	*Anas crecca*	H								2
Thrush, wood	*Hylocichla mustelina*	O	M							2
Towhee, rufous-sided	*Pipilo erythrophthalmus*	O	WR			SR/WR				2
Tufted titmouse	*Parus inornatus*	O	SR/WR			WR				1, 2
Turkey	*Meleagris gallopavo*	O	WR							1, 2
Vireo, Bell's	*Vireo bellii*	I					SR			2
Vireo, red-eyed	*Vireo olivaceous*	I	SR							2
Vireo, yellow-throated	*Vireo flavifrons*	I								1
Vulture, turkey	*Cathartes aura*	C			SV					1, 2

Table A-1. Master Species List of the Tallgrass Prairie Preserve, OK (Cont.).

Common name	Scientific name	Trophic level[a]	Habitat[b]							Source[c]
			Deciduous riparian forest	Grassy riparian	Prairie	Upland deciduous forest	Rocky outcrops	Disturbed areas	Aquatic	
Birds (cont.)										
Warbler, black and white	*Mniotilta varia*	I	SV			SV				1, 2
Warbler, Cape May	*Dendroica tigrina*	I								2
Warbler, Kentucky	*Oporornis formosus*	I	SR							2
Warbler, Northern parula	*Parula americana*	I								2
Warbler, yellow	*Dendroica petechia*	I	SV			SV	SV			2
Warbler, yellow-rumped	*Dendroica coronata*	O	M			M				2
Waterthrush, Louisiana	*Seiurus motacilla*	O	SR							1, 2
Waxwing, cedar	*Bombycilla garrulus*	O	M			M				2
Whip-poor-will	*Caprimulgus vociferus*	I	M							2
Widgeon, American	*Anas americana*	O								2
Wood-pewee, eastern	*Contopus virens*	I	SR			SR				1, 2
Woodpecker, downy	*Picoides pubescens*	I	SR/WR			SR/WR				1, 2
Woodpecker, hairy	*Picoides villosus*	I	SR/WR			SR/WR				2
Woodpecker, pileated	*Dryocopus pileatus*	O								1, 2
Woodpecker, red-bellied	*Melanerpes carolinus*	I	SR/WR			SR/WR				1, 2
Woodpecker, red-headed	*Melanerpes erythrocephalus*	O	SR/WR			SR/WR				1, 2
Wren, Bewick's	*Thryomanes bewickii*	I				SR	SR			1, 2
Wren, Carolina	*Thryothorus ludovicianus*	I	SR/WR							1, 2
Yellow-billed cuckoo	*Coccyzus americanus*	I	SR			SR				1, 2
Yellowlegs, greater	*Tringa melanoleuca*	I								2
Yellowlegs, lesser	*Tringa flavipes*	I								2
Yellowthroat, common	*Geothlypis trichas*	I			SR					1, 2

Table A-1. Master Species List of the Tallgrass Prairie Preserve, OK (Cont.).

Common name	Scientific name	Trophic level[a]	Habitat[b]							Source[c]
			Deciduous riparian forest	Grassy riparian	Prairie	Upland deciduous forest	Rocky outcrops	Disturbed areas	Aquatic	
Herptiles—turtles										
Midland Smooth Softshell	*Trionyx muticus*	O							x	2
Mississippi Map Turtle	*Graptemys kohnii*	O							x	2
Ornate Box Turtle	*Terrapene ornata*	O			x					2
Red-eared Turtle	*Trachemys scripta*	O							x	2
Snapping Turtle, common	*Chelydra serpentina*	O							x	2
Spiny Softshell Turtle	*Trionyx spiniferus*	O							x	2
Stinkpot	*Stermotherus odoratus*	O							x	2
Three-toed Box Turtle	*Terrapene carolina*	O	x			x				2
Herptiles—lizards										
Broadhead Skink	*Eumeces laticeps*	I	x			x				2
Eastern Collared Lizard	*Crotaphytus collaris*	C					x			2
Fence Lizard	*Sceloporus undulatus*	I				x	x			2
Five-lined Skink	*Eumeces fasciatus*	I	x			x				2
Great Plains Skink	*Eumeces obsoletus*	I			x					2
Ground Skink	*Scincella lateralis*	I	x			x				2
Six-lined Racerunner	*Cnemidophorus sexlineatus*	I			x		x			2
Southern Prairie Skink	*Eumeces septentrionalis*	I			x		x			2
Texas Horned Lizard	*Phrynosoma cornutum*	I								2
Western Glass Lizard	*Ophisaurus attenuatus*	C			x	x				2

Table A-1. Master Species List of the Tallgrass Prairie Preserve, OK (Cont.).

Common name	Scientific name	Trophic level[a]	Habitat[b]							Source[c]
			Deciduous riparian forest	Grassy riparian	Prairie	Upland deciduous forest	Rocky outcrops	Disturbed areas	Aquatic	
Herptiles—snakes										
Black Ratsnake	*Elaphe obseleta*	C			x	x	x	x		2
Broad-banded Copperhead	*Agkistrodon contortrix*	C			x	x				2
Brown Snake	*Storeria dekayi*	I	x	x	x	x	x	x		2
Bullsnake	*Pituophis melanoleucus*	C			x					2
Central Plains Milk Snake	*Lampropeltis triangulum*	C		x	x	x	x			2
Coachwhip	*Masticophis flagellum*	C			x		x			2
Common Garter Snake	*Thamnophis sirtalis*	C	x			x			x	2
Diamond-back Water Snake	*Nerodia rhombifera*	P							x	2
Eastern Hognose Snake	*Heterodon platyrhinos*	C	x			x				2
Flathead Snake	*Tantilla gracilis*	I					x			2
Gragham's Crayfish Snake	*Regina grahamii*	P							x	2
Great Plains Ratsnake	*Elaphe guttata*	C			x	x	x			2
Ground Snake	*Sonora semiannulata*	I					x			2
Lined Snake	*Tropidoclonium lineatum*	I			x			x		2
Massasauga	*Sistrurus catenatus*	C	x		x					2
Plain-bellied Water Snake	*Nerodia erythrogaster*	P							x	2
Prairie Kingsnake	*Lampropeltis calligaster*	C			x					2
Ringneck Snake	*Diadophis punctatus*	C								2
Rough Earth Snake	*Virginia striatula*	I								2
Rough Green Snake	*Opheodrys aestivus*	I	x							2
Speckled Kingsnake	*Lampropeltis getulus*	C				x				2
Timber Rattlesnake	*Crotalus horridus*	C				x	x			2
Western Ribbon Snake	*Thamnophis proximus*	C	x	x					x	2
Yellowbelly Racer	*Coluber constrictor*	C				x				2

Table A-1. Master Species List of the Tallgrass Prairie Preserve, OK (Cont.).

Common name	Scientific name	Trophic level[a]	Habitat[b]							Source[c]
			Deciduous riparian forest	Grassy riparian	Prairie	Upland deciduous forest	Rocky outcrops	Disturbed areas	Aquatic	
Herptiles—frogs and toads										
Blanchard's Cricket Frog	*Acris crepitans blanchardi*	I							x	2
Bull Frog	*Rana catesbeiana*	C	x	x					x	2
Cope's Tree Frog	*Hyla chrysoscelis*	I	x							2
Crawfish Frog	*Rana areolata*	C	x	x	x				x	2
Dwarf American Toad	*Bufo americanus*	I	x	x	x			x		2
Gray Tree Frog	*Hyla versicolor*	I	x			x				2
Great Plains Narrowmouth Toad	*Gastrophryne olivacea*	I	x	x	x		x			2
Plains Leopard Frog	*Rana blairi*	I	x	x	x				x	2
Southern Leopard Frog	*Rana utricularia*	I	x	x	x				x	2
Strecker's Chorus Frog	*Pseudacris streckeri*	I			x					2
Western Chorus Frog	*Pseudacris triseriata*	I	x	x	x					2
Woodhouse's Toad	*Bufo woodhousei*	I								2

[a] Trophic levels are as follows: C = carnivore; H = herbivore; I = invertivore; O = omnivore; P = piscivore.

[b] Habitat designations are as follows: x = present in habitat; blank = not present in habitat. Additional habitat designations for birds are as follows: SR = summer resident; WR = winter resident; SV = summer visitor; WV = winter visitor; M = migrant.

[c] Represents presence/absence data only. Refer to Tables 2 and 3 for sources of other species information. Sources: 1. Oklahoma Natural Heritage Inventory, 1993; 2. Nature Conservancy, 1996; 3. Payne and Caire, 1999; 4. Hamilton, 1996.

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Appendix B
Partial List of Animal Species of the Aquatic Systems at the Tallgrass Prairie Preserve, OK

Table B-1. Partial list of animal species of the acquatice systems at the Tallgrass Prairie Preserve, OK.

Common name	Scientific name	Trophic level[a]	Source[b]
Mammals			
Beaver	*Castor canadensis*	H	1, 2, 6
Mink	*Mustela vison*	C	2, 6
Muskrat	*Ondatra zibethicus*	H	2, 6
Birds			
Cormorant, double-crested	*Phalacrocorax auritus*	P	1, 2, 7
Egret, great	*Casmerodius albus*	P	2, 7
Egret, snowy	*Egretta thula*	P	2, 7
Grebe, pied-billed	*Podilymbus podiceps*	P	2, 7
Heron, black-crowned night	*Nycticorax nycticorax*	P	2, 7
Heron, great blue	*Ardea herodias*	P	1, 2, 7
Heron, green-backed	*Butorides striatus*	P	2, 7
Heron, little blue	*Florida caerulea*	P	2, 7
Kingfisher, belted	*Ceryle alcyon*	P	1, 2, 7
Osprey	*Pandion haliaetus*	P	1, 7
Herptiles—turtles			
Midland Smooth Softshell	*Trionyx muticus*	O	2, 4
Mississippi Map Turtle	*Graptemys kohnii*	O	2, 4
Red-eared Turtle	*Trachemys scripta*	O	2, 4
Snapping Turtle, common	*Chelydra serpentina*	O	2, 4
Spiny Softshell Turtle	*Trionyx spiniferus*	O	2, 4
Stinkpot	*Stermotherus odoratus*	O	2, 4
Herptiles—snakes			
Common Garter Snake	*Thamnophis sirtalis*	C	2, 4
Diamond-back Water Snake	*Nerodia rhombifera*	P	2, 4
Gragham's Crayfish Snake	*Regina grahamii*	P	2, 4
Plain-bellied Water Snake	*Nerodia erythrogaster*	P	2, 4
Western Ribbon Snake	*Thamnophis proximus*	C	2, 4

Table B-1. Partial list of animal species of the acquatice systems at the Tallgrass Prairie Preserve, OK (Cont.).

Common name	Scientific name	Trophic level[a]	Source[b]
Herptiles—frogs and toads			
Blanchard's Cricket Frog	***Acris crepitans blanchardi***	**I**	**2, 4**
Bull Frog	***Rana catesbeiana***	**C**	**2, 4**
Crawfish Frog	***Rana areolata***	**C**	**2, 4**
Plains Leopard Frog	***Rana blairi***	**I**	**2, 4**
Southern Leopard Frog	***Rana utricularia***	**I**	**2, 5**

[a] **Trophic levels are as follows: C = carnivore; H = herbivore; I = invertivore; O = omnivore; P = piscivore.**

[b] **Indicates source for presence/absence and aquatic character. Sources: 1. Oklahoma Natural Heritage Inventory, 1993; 2. Nature Conservancy, 1996; 3. Coppedge and Shaw, 1998; 4. INHS, 1998; 5. Bockstanz and Cannatella, 2000; 6. Myers et al., 1998; 7. Peterson, 1980.**

Appendix C
Areas of Further Research

Appendix C

Areas of Further Research

Depending upon the use of this trophic model, and the direction of future efforts relative to the larger project, several areas of further research may be appropriate.

C-1. Develop "Response Guilds"

Rather than divide guilds according to food consumption, it may be expedient to divide species on the basis of response to disturbance. This type of guild has been referred to alternately as a response guild (Wilson, 1999) or a management guild (Simberloff and Dayan, 1991). The alpha guilds used in this study, because of similar taxonomy, already offer some insight into response to disturbance; however, an explicit analysis would be more robust. This would allow the selection of endpoint species to provide increasingly consistent results when these species are used as indicators for the results of disturbance from contaminant spills. Such an undertaking may be more challenging, as response to disturbance, for many species, has been poorly studied compared with diet (Simberloff and Dayan, 1991).

C-2. Expand Species Information

As mentioned, this trophic model does not address issues such as population density of predators, quantity of prey consumed, ability to feed outside preferred resource classes, strictness of habitat requirements, and the portion or life-phase of prey consumed. All of this information may have significant bearing on community dynamics and the ability to use a particular species as an endpoint. Depending upon the level of resolution desired, increasing the amount of information that is incorporated into the trophic model may be appropriate.

Several key processes have also been neglected. First, symbiotic associations between mycorrhiza and plants are ubiquitous, and important in tallgrass prairie plant populations (Hetrick and Bloom, 1983), as has been documented at the Konza Prairie LTER (see Hartnett and Fay, 1998). Disturbances such as soil contamination from oil or brine, as well as other temporal variations and disturbance events, could significantly affect the mycorrhiza community, with impacts on plant diversity, primary productivity, and bottom-up effects on higher trophic levels. Second, the issues of disease and parasitism have not been considered; again, these could alter community dynamics. Finally, decomposers have not been granted a comprehensive treatment. However, Schoener (1989) asserts that decomposers are relatively isolated in most terrestrial food webs, and that their omission, therefore, is relatively unlikely to affect conclusions about food web interactions.

C-3. Include Temporal Variations

Disturbance events and cycles (including adjacent land uses), climatic variation, succession, fire, grazing, changes in management of the preserve, and intrinsic population dynamics may all play significant roles in structuring both community and ecosystem structure and function at the TPP (Collins, 1990; ONHI, 1993). In particular, the fire and grazing regimes at the preserve maintained by the Nature Conservancy represent the restoration of key disturbance cycles, the effects of which may have just begun. These two key components are thought to ultimately control the structure of the tallgrass prairie community (ONHI, 1993; Hamilton, 1996). By modeling the TPP system over a longer, specified time period, and incorporating these temporal issues into the analysis, more insight into the impacts of oil and brine contamination over time could potentially be gained.

C-4. Address Issues of Spatial Scale and Resolution

Several spatial issues may be relevant. To begin with, the beta guilds essentially treat the preserve as two-dimensional. Indeed, prairie ecosystems may be effectively regarded as two-dimensional until the spatial scale is very small (Knapp et al., 1998). However, three-dimensional aspects may be relevant in the forested areas of the TPP, and may also be important in the prairie guild when studying smaller animals such as insects or rodents. Many of these species interact with the TPP as a three-dimensional system by digging burrows and tunnels in which they store food, nest, and otherwise alter the underground ecosystem, creating small-scale disturbance and microsites for plant colonization and establishment (Hartnett and Fay, 1998). Above the surface, issues such as feeding height may be important to plant community structure, and even in the prairie, differences between the “canopy” and “understory” could be significant. Zimmerman (1993) has divided bird species into guilds based on nesting and feeding height in forested systems at the Konza LTER.

At a larger scale, topographic effects may be very important, as this generates a gradient upon which many (primarily plant) species ordinate. This could likely be addressed by geographic information systems (GIS) analysis using alpha and beta guilds.

Finally, the preserve boundaries may not represent the entire sphere of influence upon the TPP community. Typically, food webs do not neatly compartmentalize into independent units along spatial or temporal boundaries (Pimm, 1982). Species with large home ranges, such as birds or large mammals, may cause the effective boundary of the food web at the TPP to become much larger, having effects that are difficult to predict. Further, larger disturbances, such as climatic effects or adjacent land uses, may affect the community structure and function. Depending upon magnitude of influence, it may be useful to evaluate and incorporate these factors into the trophic model.

C-5. Utilize Statistical Techniques

Statistical techniques to divide species into guilds, and delineate relationships between and among these guilds, offer a method to ensure that the community structure and function found at the TPP is an empirical rather than a theoretical construct. This method for dividing guilds has been used in efforts such as the designation of intrinsic guilds, in which a statistical test is used

to determine if members of alpha guilds tend to exclude each other in the real community (Wilson, 1999). Such an increasingly data- and analysis-intensive approach may be appropriate, depending on the final use of the trophic model; it may be particularly useful for analysis of endpoint species and the interaction strengths between the species in the trophic pathways that they represent.

C-6. Explicitly Examine Ecosystem Dynamics

Finally, use of a trophic model may not be sufficiently comprehensive to fully understand the TPP ecosystem. Community structure and function may not always serve as a reliable proxy for ecosystem structure or function. Ecosystem management is a concept that is growing in popularity, and ecosystem approaches may prove to be extremely useful for evaluating the impacts of contaminant spills at the TPP. DeAngelis (1992) and others have performed extensive work linking community function to ecosystem function by examining nutrient and energy flows associated with trophic relationships, and adding abiotic fractions to the food web. Other important facets to an ecosystem analysis include the identification of key disturbances and driving variables, legacies of past human or natural disturbance, and changes in spatial mosaics over time. Such an analysis at the TPP could critically increase our understanding of the impact of oil and brine spills on ecosystem structure and function, and how this might relate to changes in community structure and function. Several different conceptual frameworks, such as the Legacy Framework (Vogt et al. in revision), provide relatively simple methods of ecosystem evaluation. GIS could also be used in conjunction with such an analysis as an effective platform for generating an ecosystem evaluation.

C-7. References

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Appendix D
References Used for Habitat Preference of Species at the Tallgrass Prairie Preserve, OK

Appendix D

References used for Habitat Preference of Species at the Tallgrass Prairie Preserve

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Appendix E
Trophic Pathways at the Tallgrass Prairie Preserve, OK

Appendix E

Trophic Pathways at the Tallgrass Prairie Preserve, Oklahoma.

All possible trophic pathways are traced, from basal species to top predator. *a.* through *c.* show trophic pathways beginning with aboveground invertebrates; *d.* through *f.* show trophic pathways beginning with belowground invertebrates; *g.* shows trophic pathways beginning with small herbivorous mammals; *h.* shows trophic pathways beginning with large herbivorous mammals; *i.* shows trophic pathways beginning with large omnivorous mammals; *j.* shows trophic pathways beginning with small herbivorous mammals; *k.* shows pathways beginning with omnivorous birds; *l.* shows trophic pathways beginning with omnivorous herptiles; *m.* shows trophic pathways beginning with raptors; *n.* shows trophic pathways beginning with fossorial invertivorous mammals.

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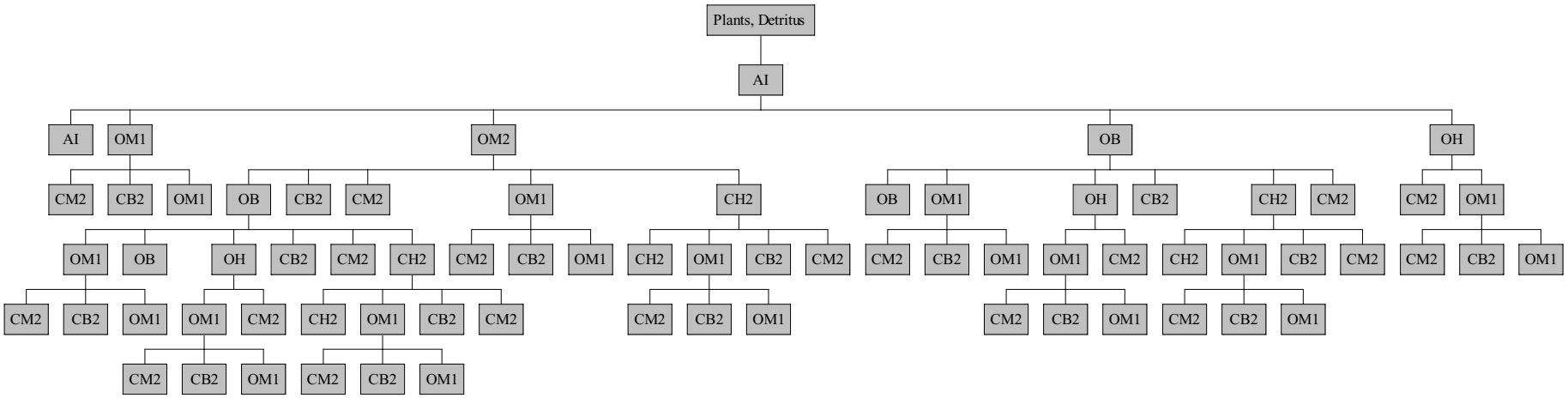

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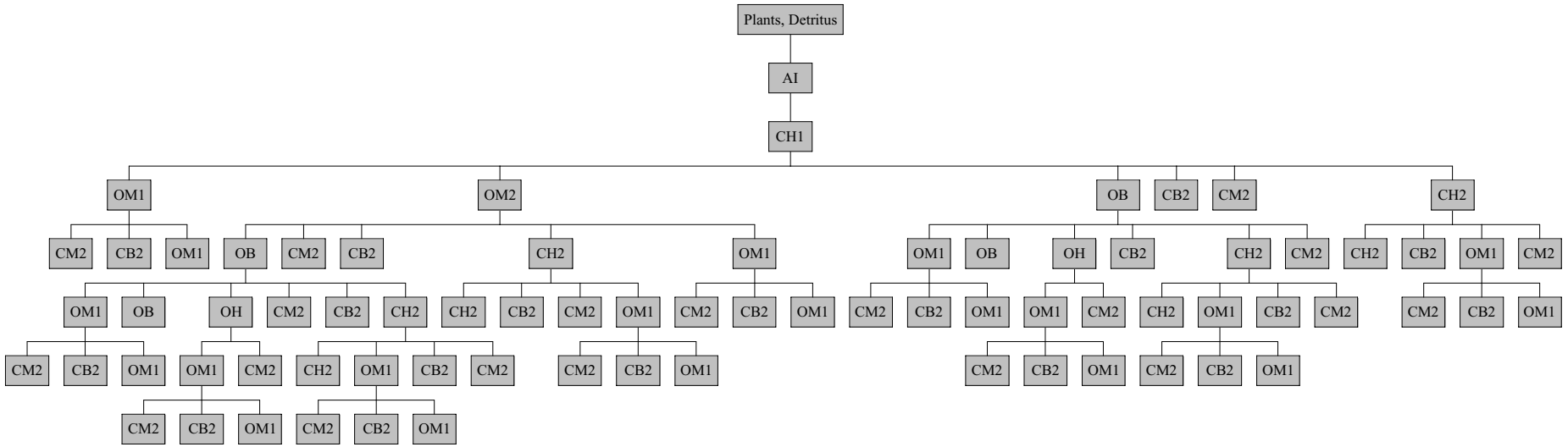
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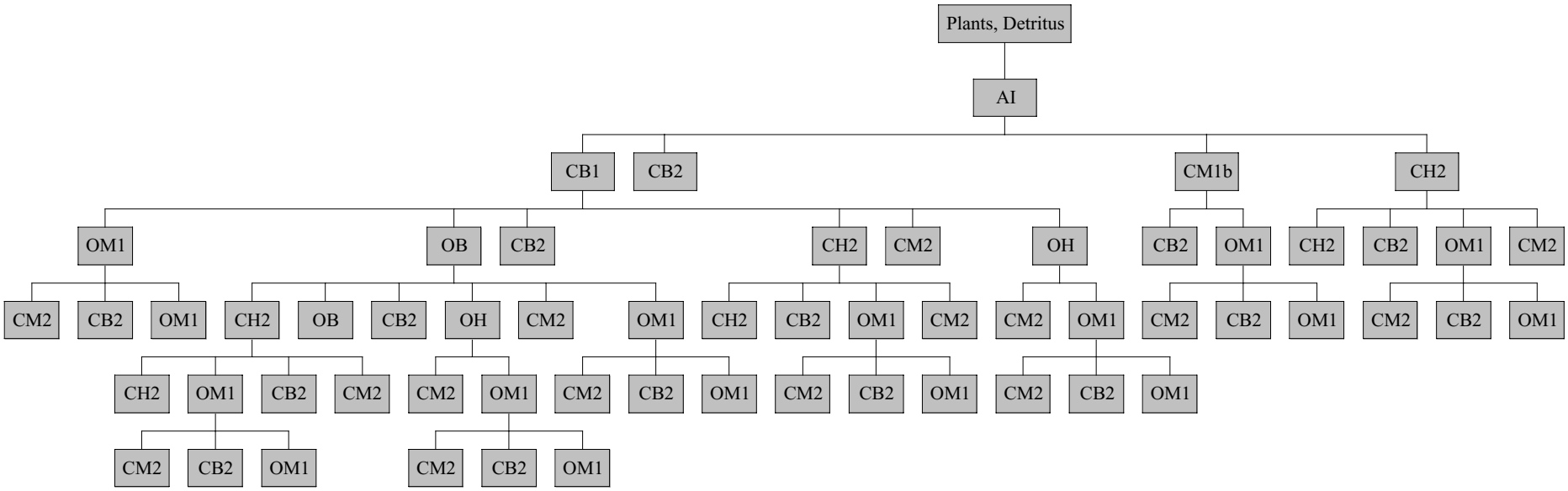
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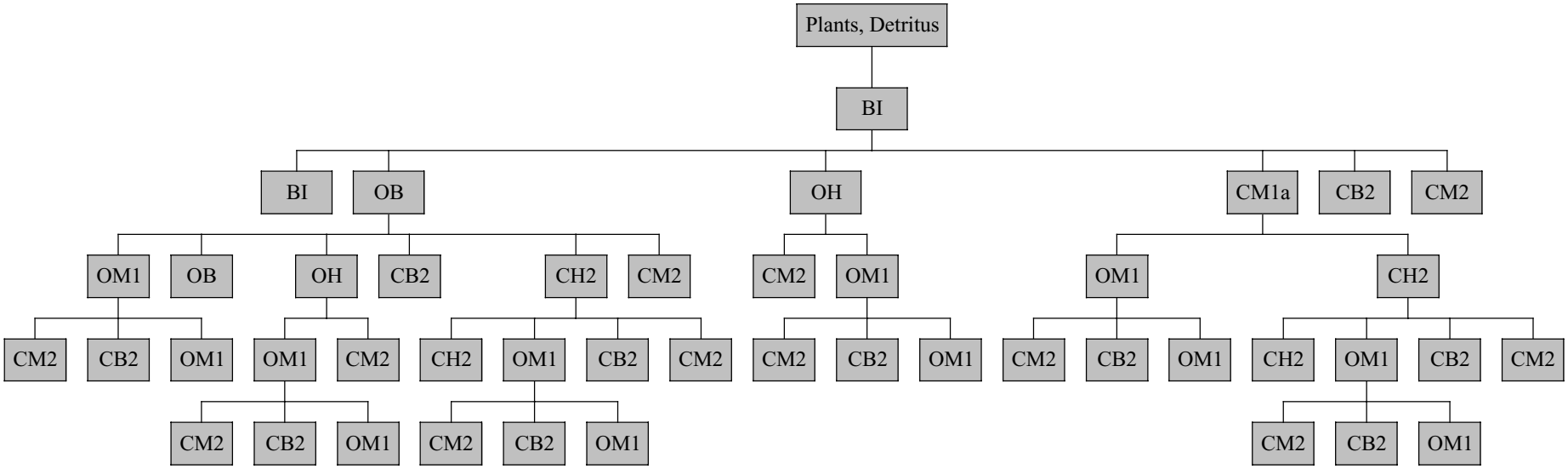
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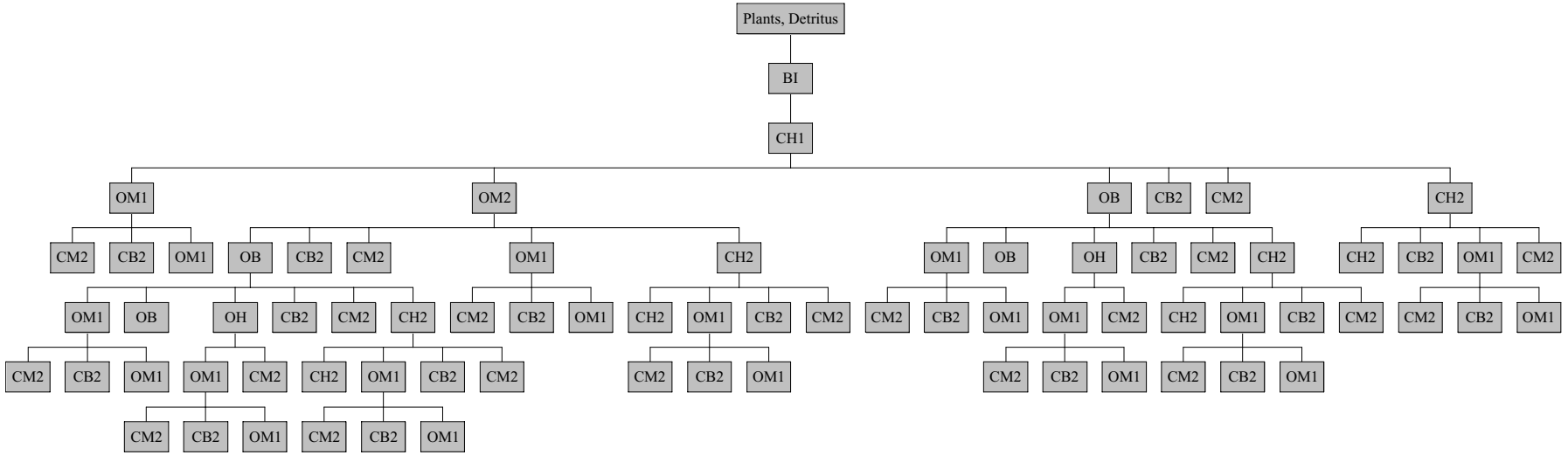
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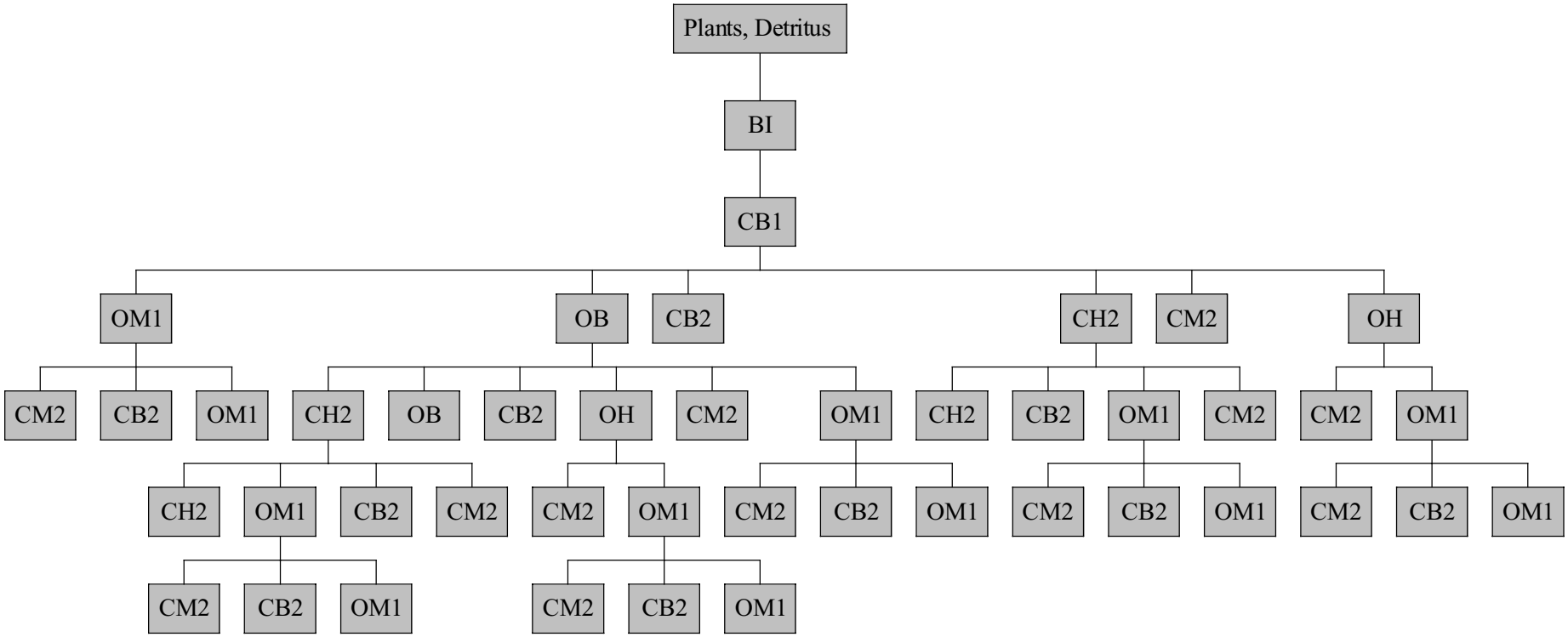
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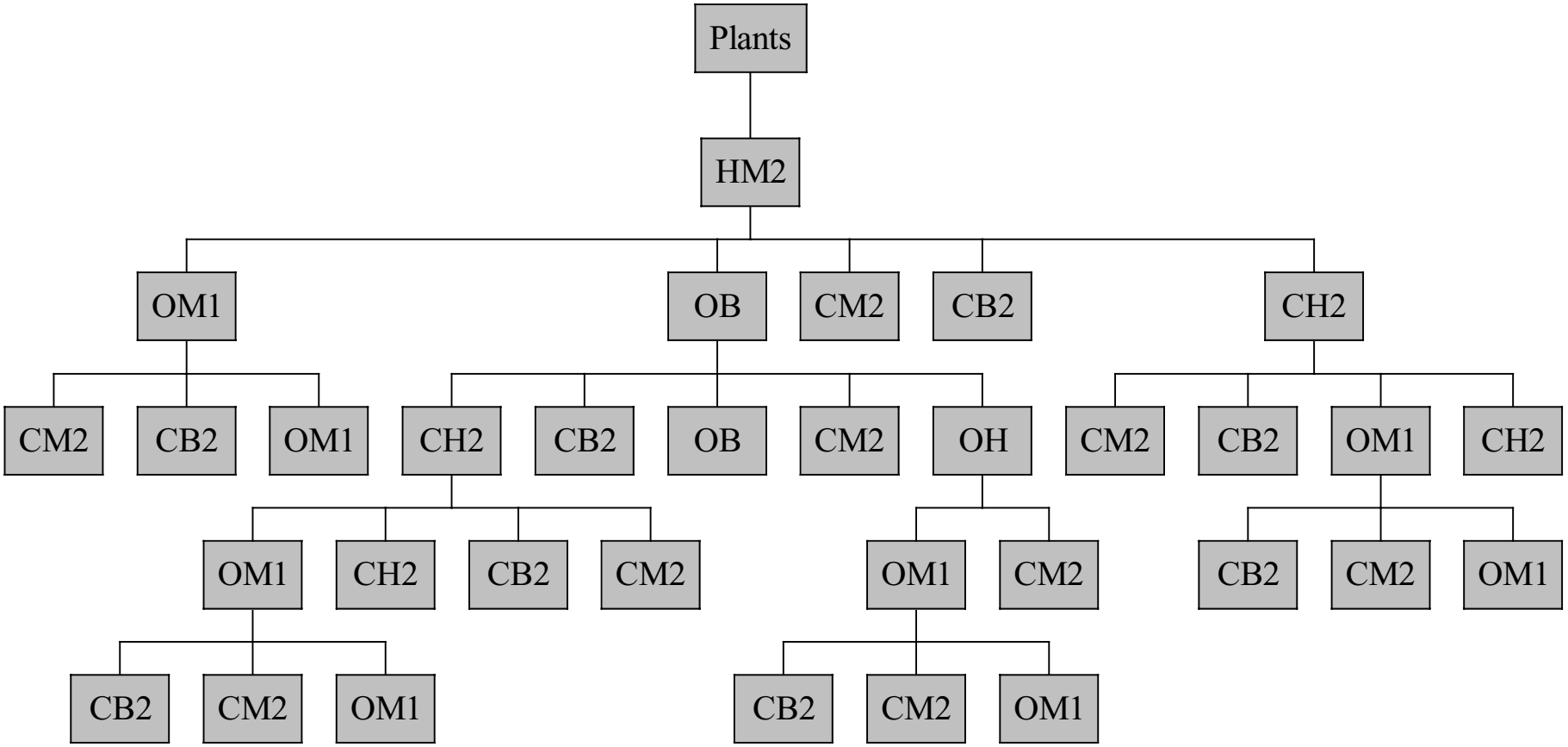
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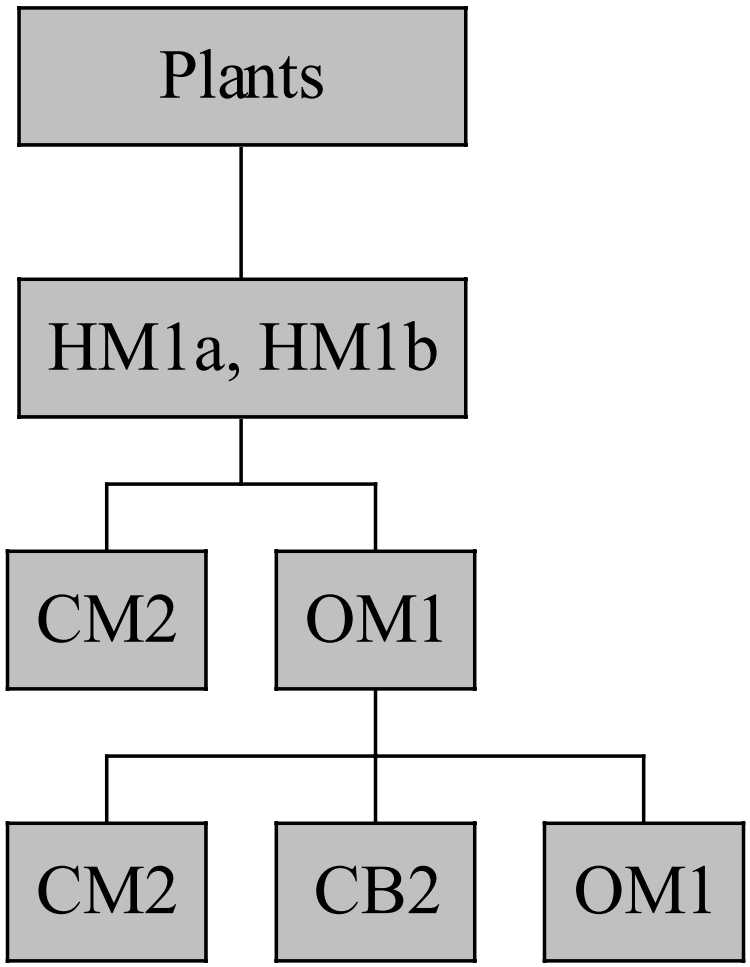
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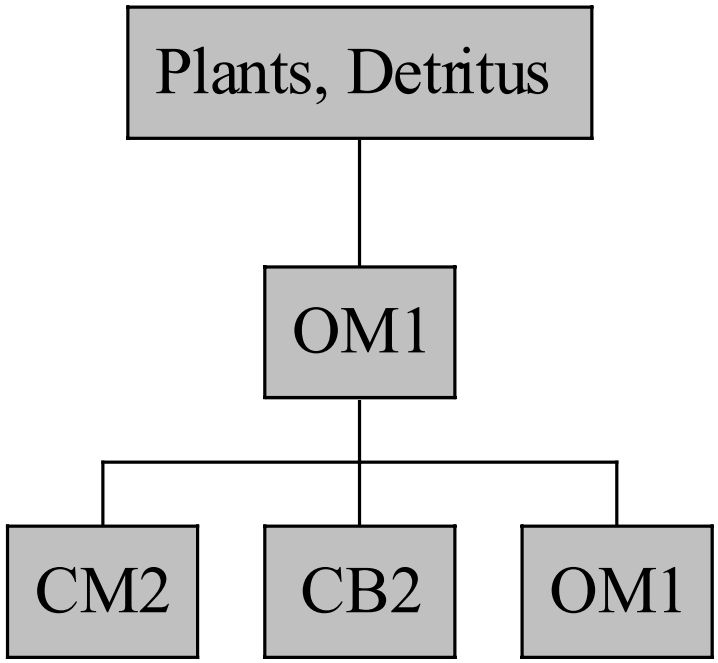
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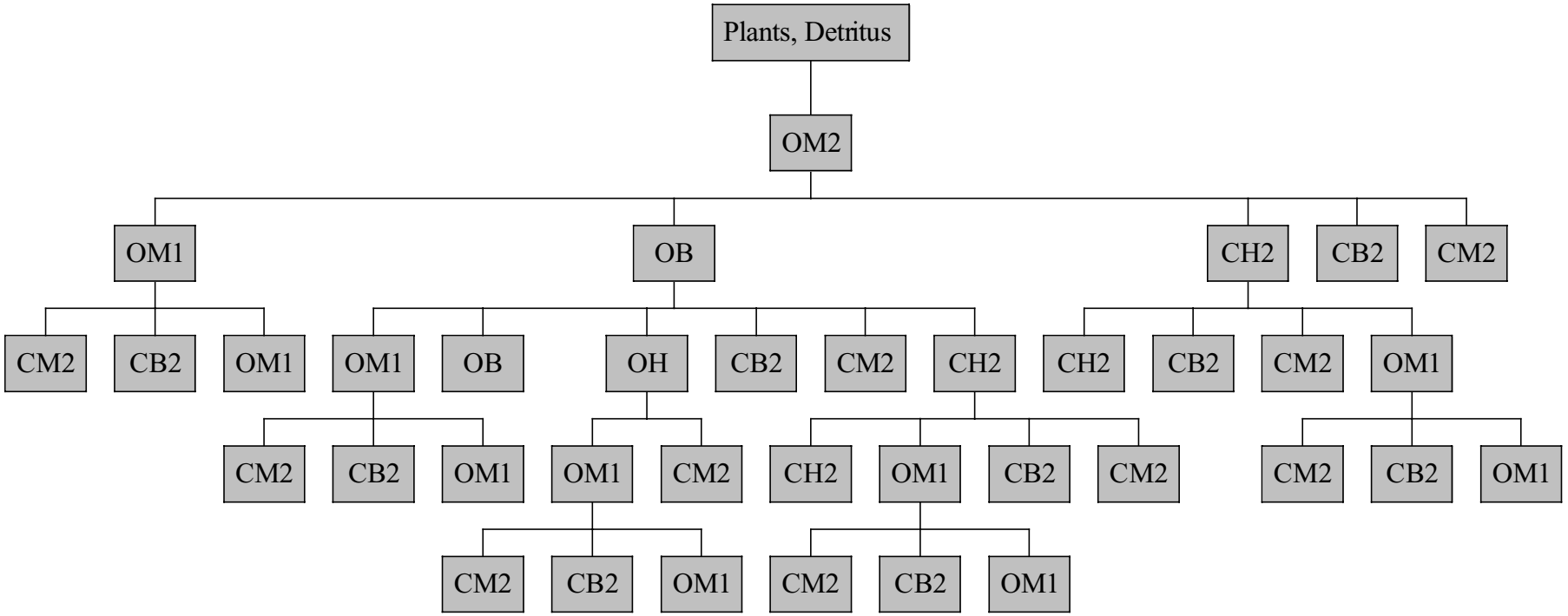
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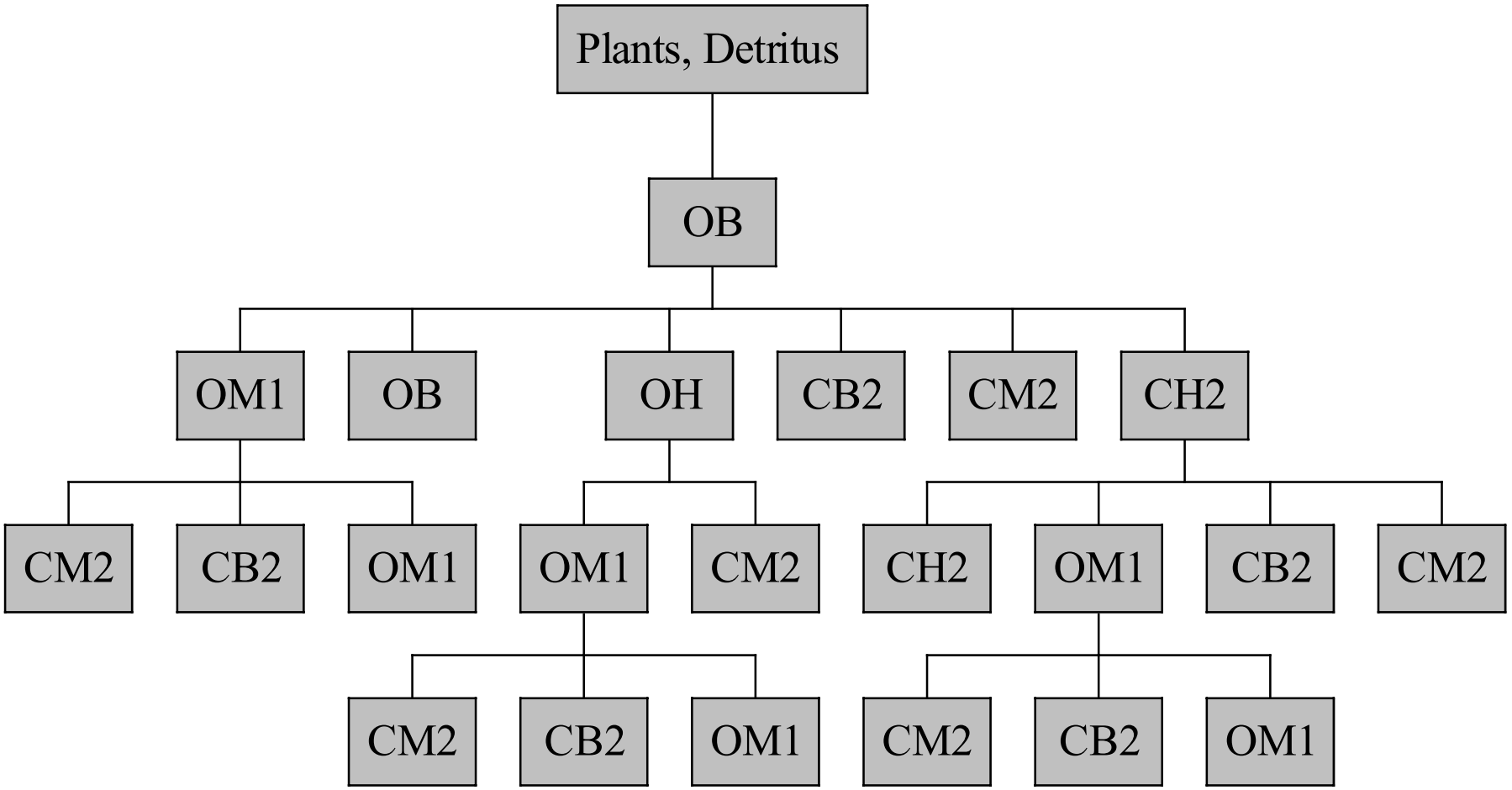
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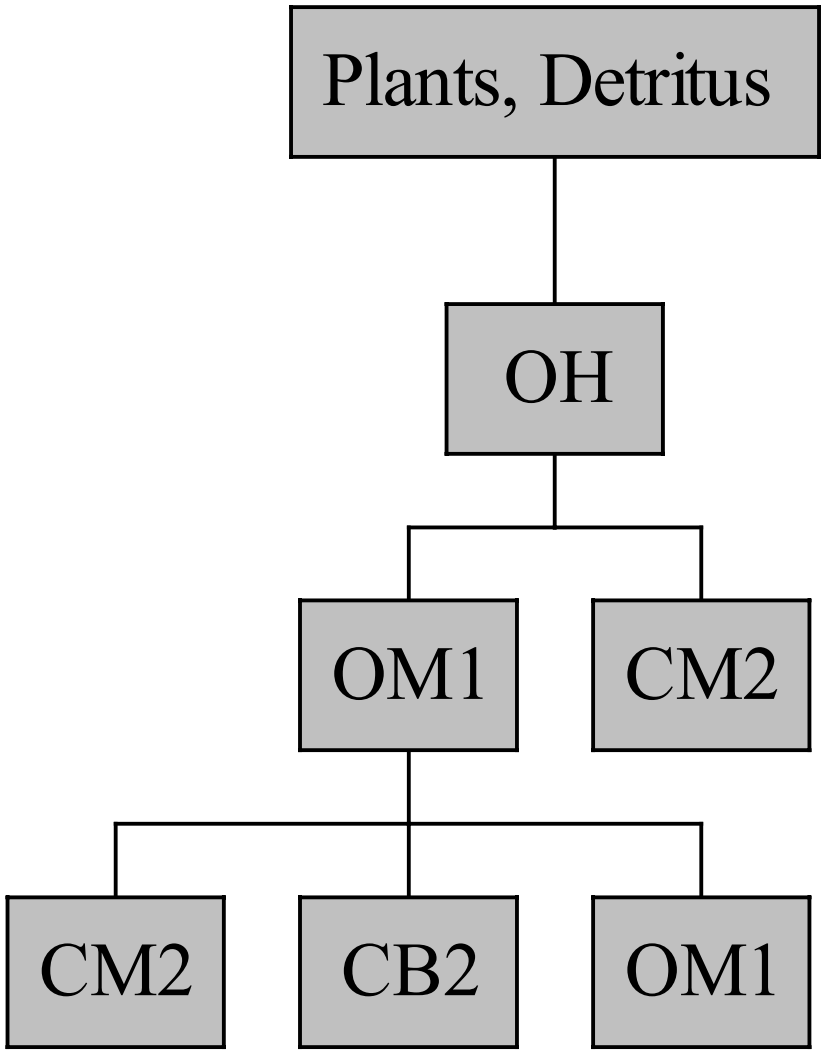
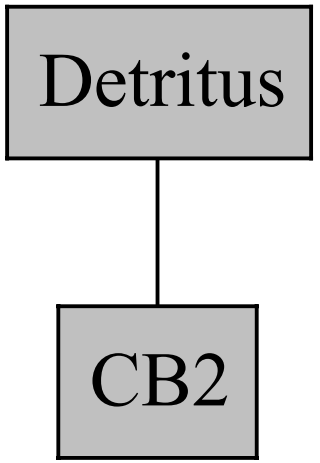
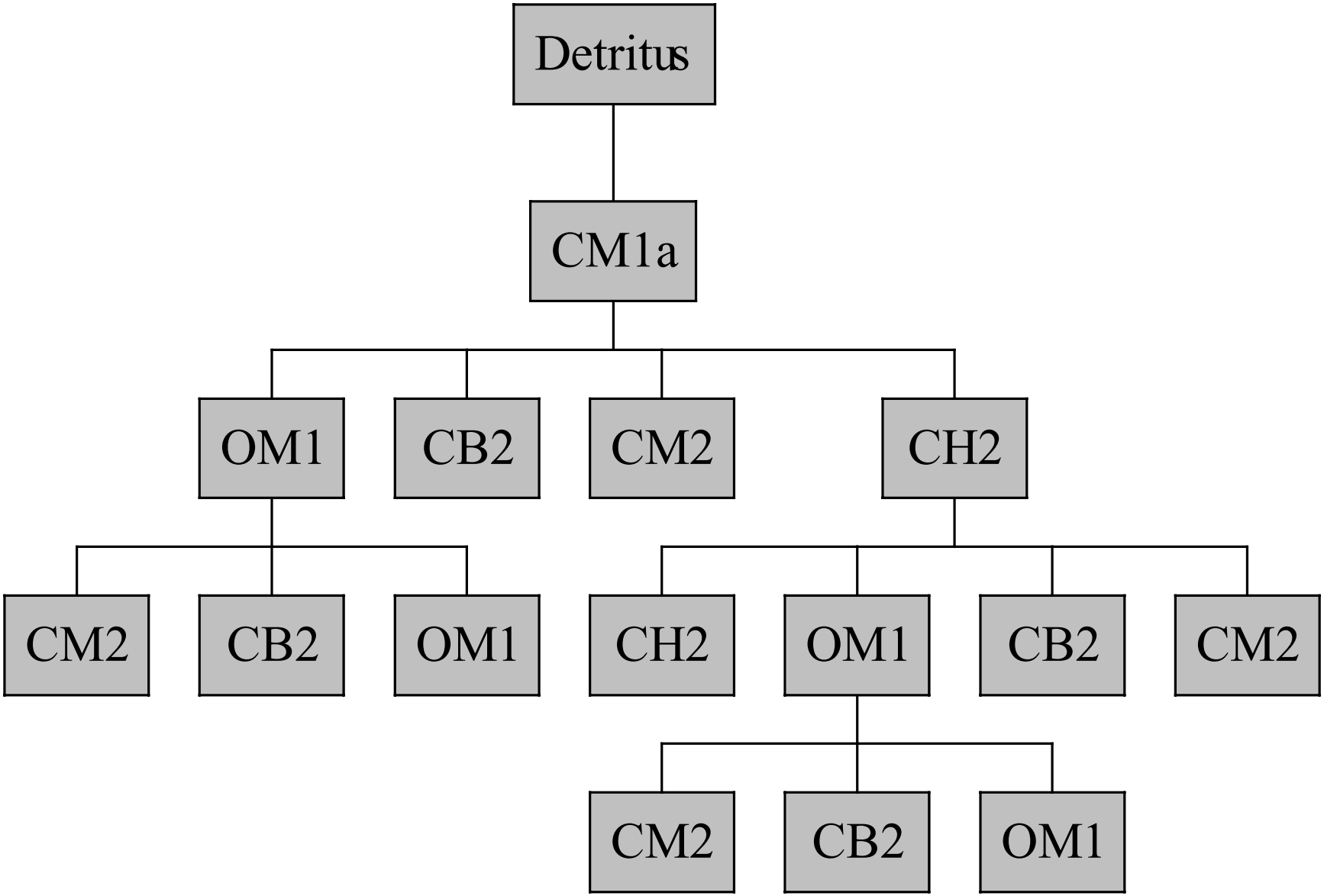


m.



n.


Detritus
CM1a
OM1
CB2
CM2
CH2
CM2
CB2
OM1
CH2
OM1
CB2
CM2
CM2
CB2
OM1

Appendix F
Glossary

Appendix F

Glossary

Basal Species: Species at the lowest trophic level; autotrophs, or primary producers.

Entomophage: Insect eater.

Folivore: An herbivore that feeds on foliage.

Fossorial: Describes species that are adapted to digging or burrowing.

Fundamental Niche: The range of environmental conditions within which a species could potentially be found.

Granivore: An herbivore that feeds on seeds/grains.

Herptiles: Amphibians and reptiles, collectively.

Invertivore: A species whose diet is restricted to invertebrates.

Lagomorph: Member of the order *Lagomorpha*; commonly refers to rabbits and hares.

Phytophagous: Plant-eating.

Realized Niche: The range of environmental conditions within which a species is actually found.