Perennial Herbaceous Biomass Production and Harvest in the Prairie Pothole Region of the Northern Great Plains

Best Management Guidelines to Achieve Sustainability of Wildlife Resources

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Though the use of biomass for heat and fuel production is not new in the United States, there has been a renewed interest in bioenergy production in response to increasing energy costs, dependence on foreign oil, greenhouse gas emissions and climate change. Recent legislation reflects the high level of interest. For example, the 2007 Energy Independence and Security Act (110 P.L. 140) raised the Renewable Fuel Standard (RFS-2) to require biofuels blending (with gasoline) of 36 billion gallons per year by 2022 of which 21 million are to come from non-corn sources with the focus on cellulosic materials. The northern Great Plains holds some of the greatest potential for the production of cellulosic biomass, but the region is also critical for wildlife producing 50-80% of waterfowl populations and providing breeding habitat for more than half of the bird species that breed in North America.

The Best Management Guidelines (BMGs) presented in this document were developed through a process that involved an advisory group of natural resource professionals with expertise in agronomy, production aspects of energy crops, wildlife (amphibians, birds, insects, mammals, reptiles), and native ecosystems. The following guiding principles helped define the uses and limitations of the BMGs:

- Integrate considerations that address biodiversity as an integral part of bioenergy sustainability
- Incorporate biodiversity when switchgrass or native warm-season grass mixes are established on marginally productive cropland (i.e., no conversion of native sod, wetlands, etc., is assumed)
- Provide a basis for development of site-specific practices that are tailored to local situations
- Balance environmental sustainability and the needs of production economics
- Must be feasible to adopt and include profit potential
- Intended for use by the bioenergy industry and biomass producers

Credit: Plains and Prairie Pothole Landscape Conservation Cooperative.
Although designed for the Prairie Pothole Region, the BMGs should be useful in adjacent geographies within the Northern Great Plains and elsewhere.

Two feedstocks were selected – switchgrass and a 3-species mix of big bluestem, indiangrass, and sideoats grama. These feedstocks are currently the focus of collaborative efforts funded by the U.S. Department of Agriculture to create a Midwestern regional system for producing advanced transportation fuels derived from native perennial grasses. Guidelines were designed to focus on site selection, planting design, establishment, management, and harvest of these feedstocks on wildlife and their habitats (i.e., food, water, cover, and space). Effects on grassland songbirds, waterfowl, shorebirds, mammals, amphibians, reptiles, insects, and aquatic organisms are discussed.

Wildlife management is complex. The effects of bioenergy production on wildlife will depend on the combination of several factors that influence both the wildlife and the habitat. Wildlife sustainability necessitates considering (in the context of the differing needs of individual wildlife species) the feedstock selected, the surrounding habitat, the habitat that is replaced, the method of establishment, how intensively the stand will be managed, what inputs (herbicides, fertilizers, etc.) will be used, how much area the feedstock occupies, and how it is to be harvested as well as the timing of those operations. The advisory group of natural resource professionals worked together to consider, sort out implications, and identify approaches that integrate a basic level of consideration of wildlife needs.

The following BMG’s reflect compromise in recognition of energy purposes and economic needs of industry and agricultural producers by focusing on the basic level of wildlife conservation needed to sustain species, not the maximum that is possible.

Best Management Guidelines (BMGs)

Landscape and Site Selection Considerations

- Do not convert prairie/sod, wetlands, or other rare native ecosystems.
- Plant biomass crops on existing cropland or other land with a cropping history.
- Plant biomass crops, as much as possible, on fields adjacent to native prairie/sod or established stands.
of native warm-season grasses to increase native ecosystem health (larger tracts of continuous grassland are better than smaller fragments).

- Use native grasses as biomass feedstocks. Locate big bluestem, indiangrass, and sideoats grama mixtures on drier sites and switchgrass on either dry or wet sites (depending on cultivar – upland or lowland) to take advantage of the range of growing conditions native grasses provide.

- Avoid tilling or ditching to drain water from land or in-field low areas that provide important wetland habitat in the early spring.

- Be aware of potential resources (food, water, cover) in the surrounding area and, as feasible, plant feedstocks that complement those resources.

- Consider using biomass plantings as conservation practices for existing cropland; for instance, place plantings along water bodies (streams, ditches, lakes, rivers, wetlands) to reduce erosion and chemical runoff, and on highly erodible soils to reduce erosion.

- In the event hybrid or genetically-modified varieties are considered for use, consult with the state fish and wildlife agency to determine potential risk to nearby native prairie/sod and develop a containment plan.

**Planting Design**

- Match the native grass feedstock to local/regional soil types and vegetation to enhance yield potential and ecosystem compatibility.

- Consider growing a diverse mixture of big bluestem, indiangrass, and sideoats grama as well as switchgrass to create diversity of habitat (structural and spatial) on the landscape and reduce risk to the producer through crop diversification.

- Create a native warm-season grass/forb buffer zone around potholes, wetlands or other bodies of water to provide habitat (pollinators included) and an agrochemical barrier. These buffers should be as wide as possible (100’ minimum recommended), seeded at the lowest NRCS rate, and include a 50’ unmowed area (closest to the pothole/wetland) with the remainder harvested at a height of 10” or higher.

- Establish native warm-season grass/forb field borders on portions of the field not connected with potholes/wetlands to retain inputs on site and provide additional wildlife habitat. These field borders should be wide enough to address site-specific wildlife needs (consult the state fish and wildlife agency to determine the appropriate width) and managed to create early successional habitat by burning, diskng, or haying every 3 to 5 years.

- Consider enrolling field borders and wetland buffers in wildlife-friendly conservation programs, which also provide a constant and dependable source of revenue.

**Establishment**

- Follow NRCS recommended seeding rates and do not exceed as doing so increases establishment cost and makes stands less desirable for ground-dwelling wildlife.

- Avoid the use of fertilizer during the establishment year to minimize excessive weed growth (which can slow growth of the grasses planted) and potential runoff into streams and wetlands.

- For fields that were planted to a winter cover crop the previous fall, prepare/plant fields as early as practical, but avoid planting during the peak nesting period. Check with the local NRCS office and state wildlife agency for local peak nesting seasons and dates.

- Plant no-till fields as late as practical to leave residual food/cover longer for wildlife

- Plant bare, conventional-tilled fields as soon as possible to reduce erosion and improve quality of water feeding wetlands/potholes.

- Use only the minimum rate of herbicides needed to establish biomass plantings and consider the alternative of mowing when weeds are about 12” tall (leave 6” stubble).

- Avoid the use of herbicide in field borders and wetland buffers.
Management

- Avoid use of fertilizer, herbicide, or mowing in core buffer areas around potholes, wetlands and other bodies of water and in unharvested field borders – manage upland buffers with prescribed fire or shallow disking (to set back plant succession) once every 3 to 5 years, prior to April 15 or after August 1 to avoid peak nesting season.

- With the technical assistance of NRCS, develop and follow an integrated pest management plan that takes advantage of avian and insect predators and minimizes the use of chemical pesticides.

- In the event chemical pesticides are necessary, consider withholding application in a buffer adjacent to wetlands/potholes (width determined in consultation with NRCS and the state fish and wildlife agency).

- Monitor fertility and minimize use of fertilizers through stand development and beyond with the aid of an NRCS precision nutrient management program plan designed specifically for perennial grasses, (saves cost, benefits water quality, and is easier on wildlife).

- Consider periodic spring prescribed burns (prior to peak nesting season) on portions of field with enough stubble residual from the previous year to carry a fire (stimulate grasses and benefit wildlife).

Harvest

- Add flushing bars to equipment to minimize bird injuries and deaths.

- Harvest fields from the interior of the field to the exterior to encourage wildlife to flush into surrounding areas.

- Leave at least 4” to 6” stubble after harvest to elevate windrows (aid airflow and speed up drying), and catch/retain snow to boost soil moisture. Higher stubble heights (>10”) are recommended to benefit wildlife.

- Leave wildlife cover in the form of taller stubble (10” or taller) after harvest on unproductive portions of fields (e.g., wet depressions, highly eroded areas) or adjacent to potholes/wetlands. This stubble will provide winter habitat and spring nesting cover – blocks are better than strips (5% of the total field area is recommended).

- Avoid harvest until after the first frost to avoid disturbance of nesting wildlife and improve quality of biomass (i.e., reduce moisture and nutrient content) for bioenergy production.

- Consider incremental harvest after the end of growing season (i.e., store portions of the biomass as a standing crop) versus harvesting all at once – this will leave some cover for wildlife.

We encourage the adoption and adaptation of these high-level guidelines to best benefit local conditions while minimizing negative impacts of bioenergy production on wildlife. It is hoped that the BMGs will make it easier for the bioenergy industry, agricultural producers, policymakers, and others to understand and integrate wildlife needs as bioenergy advances in the Prairie Pothole Region of the Northern Great Plains as well as in adjacent geographies.

Pothole. Credit: Cami Dixon, USFWS.
The decade of the 2000’s in the United States (U.S.) and globally brought a roller-coaster ride of concerns ranging from increasing energy costs, dependence on foreign oil, greenhouse gases and climate change, and concern over availability and cost of food. Interest in renewable energy, including bioenergy, escalated dramatically. The Farm Security and Rural Investment Act of 2002 (P.L. 171) was the first farm bill with an energy title and the first to authorize biomass harvest from Conservation Reserve Program lands. The Food Conservation and Energy Act of 2008 (P.L. 246) continued to focus attention to bioenergy with over $1 billion in mandatory funding for energy efficiency and renewable energy. The Energy Policy Act of 2005 (109 P.L. 58) created the Renewable Fuel Standard (RFS), which mandated the use of renewable fuels and the 2007 Energy Independence and Security Act (110 P.L. 140) raised the Renewable Fuel Standard (RFS-2) to require biofuels blending (with gasoline) of 36 billion gallons per year by 2022.

Humans have relied on combustible biomass for heat and energy ever since the discovery of fire. In recent years, both U.S. and global interest in generating heat and energy from biomass has been on the rise. This includes direct firing (biomass as the sole fuel), co-firing (biomass burned with coal), cogeneration (heat from burned biomass captured to produce more energy), and gasification (gas captured from heated biomass and then burned). The U.S. and Canada are the global leaders in export of wood pellets. In addition, crop residue, grasses, and many kinds of waste materials are increasingly pelletized for energy.

The history of ethanol is illuminated on the U.S. Energy Information Administration (EIA) website. The fuel for the internal combustion engine invented by Samuel Morley in 1826 was ethanol and the Model-T of 1908 was designed to use both ethanol and gasoline. Petroleum became the fuel of choice in the 1920’s but a resurgence of interest in ethanol in the 1930’s and early 1940’s (due to fuel needs tied to WW II) brought ethanol back into the spotlight. At the end of WW II, interest in ethanol waned until fuel shortages and escalating energy prices in the 1970’s turned public thoughts once again to ethanol.

Bioenergy has been a constant that society tends to rely on most strongly in times of uncertainty and crisis. The use of biomass to produce heat, whether through
In addition to the significant potential the Prairie Pothole Region holds for biomass production, it is a critically endangered ecosystem of immense importance to wildlife. Over half of the nation’s waterfowl are produced in this area and the region provides habitat for more than half of the bird species that breed in North America. In addition, the Prairie Pothole Region is immensely important to pollinators that provide many societal benefits.

A 1995 study listed the tallgrass prairie, including in the Prairie Pothole Region, as among the most diminished of ecosystems in the United States with a 99% loss east of the Missouri River and an 85% loss to the west. The United States Department of Agriculture Economic Research Service reported about 770,000 acres of grassland were converted to cropland between 1997 and 2007 and observed that high corn prices could be leading to grassland conversion. The United States Risk Management Agency map of crop indemnities for 2012 shows significant crop indemnity payments in the Prairie Pothole Region, suggesting that some of the rangeland converted to crop production may be, at best, marginally productive for production of food crops.

Although many parts of the United States are viewed as having significant potential for biomass production, the prairie regions of the Upper Midwest, including the Prairie Pothole Region of the Northern Great Plains, holds some of the greatest potential. The Prairie Pothole Region is also very important to biodiversity and wildlife. Over half of the nation’s waterfowl are produced in this area and the region provides habitat for more than half of the bird species that breed in North America. In addition, the Prairie Pothole Region is immensely important to pollinators that provide many societal benefits.

The Prairie Pothole Region is rich in grassland history and has a demonstrated ability to produce some of the best grasslands in the nation. However, many of the native grasslands have been converted to crops that can be prone to failure given the vagaries of the regional climate. Biodiversity has declined significantly as the great grasslands of the Prairie Pothole Region have been lost to other uses. The resurgence of bioenergy, interest in the production capacity of the Prairie Pothole Region, and potential to produce perennial, herbaceous energy crops on marginally productive cropland combine to offer opportunity to produce both biomass and contribute toward the conservation of biodiversity characteristic of the native ecosystem in which biomass is produced.

These Best Management Guidelines (BMGs) are intended to help bioenergy and agriculture producers to integrate fish, wildlife, and native ecosystem sustainability.

Perennial Herbaceous Biomass Production and Harvest - Best Management Guidelines
Although there have been very few research projects in the United States that specifically study the effect of energy crops on native ecosystems and the associated biodiversity, there is a large body of research regarding the effect of plant diversity, density, structure, and other factors on wildlife. The information in this BMG publication is based on the best available science and sense of the experts involved in this effort.

As biomass is produced in the Prairie Pothole Region and adjacent areas of the Northern Great Plains. The BMGs were developed through a process that involved an advisory group of natural resource professionals with expertise in agronomy and production aspects of energy crops as well as wildlife (amphibians, birds, insects, mammals, and reptiles) and native ecosystems that includes prairie/rangeland and wetlands. These experts helped to design the BMG document, conducted literature reviews, wrote content and, most importantly, ensured that the agronomy and biology in the document were grounded in the best available science and expert opinion. The following served as the guiding principles in crafting the BMGs and, therefore, define the uses and limitations of the publication:

- Integrate considerations that address biodiversity as an integral part of bioenergy sustainability.
- Incorporate biodiversity when switchgrass or native warm-season grass mixes are established on marginally productive cropland (i.e., no conversion of native sod, wetlands, etc., is assumed).
- Provide a basis for development of site-specific practices that are tailored to local situations.
- Balance environmental sustainability and the needs of production economics.
- Must be feasible to adopt and include profit potential.
- Intended for use by the bioenergy industry and biomass producers.
- Although designed for the Prairie Pothole Region, the BMGs should be useful in adjacent geographies within the Northern Great Plains and elsewhere.

In addition, several recent publications were very helpful and were consulted frequently. The first is one by The Wildlife Society9 (“Effects of Bioenergy Production on Wildlife and Wildlife Habitat”) and the second is an Association of Fish and Wildlife Agencies10 publication (“Assessment of the Bioenergy Provisions in the 2008 Farm Bill”). Both publications provided much information about the connection between bioenergy and fish, wildlife, and native ecosystem sustainability. These publications also contained BMGs that were developed as a national framework for tailoring to regional, state, and local levels. A third document (“Wisconsin Sustainable Planting and Harvest Guidelines for Non-Forest Biomass”) is the result of a collaborative effort among diverse stakeholders in Wisconsin that included the bioenergy industry.11 This publication illuminated what might be feasible in the nearby Prairie Pothole Region.

Although there have been very few research projects in the United States that specifically study the effect of energy crops on native ecosystems and the associated biodiversity, there is a large body of research regarding the effect of plant diversity, density, structure, and other factors on wildlife. The information in this BMG publication is based on the best available science and sense of the experts involved in this effort. As bioenergy continues to advance and evolve, it would be helpful if native biodiversity were fully incorporated into the concept of bioenergy sustainability and research pursued to better illuminate the effect of individual energy crops, and landscapes dominated by energy crops, on wildlife and the native ecosystem characteristics on which they rely.
As previously mentioned, the 2007 Energy Independence and Security Act (110 P.L. 140) requires the production of 36 billion gallons of ethanol by the year 2022; 16 million gallons of that production is supposed to come from cellulosic material. Furthermore, of the 1 billion dry tons of biomass targeted for production by 2030 by the U.S. Department of Energy, it is anticipated that about one-third of it will come from perennial crops. Though the addition of native cool-season grasses could benefit wildlife, native perennial warm-season grasses are the current prime candidates for cellulosic bioenergy production because of their high biomass yields, ability to capture and store carbon, tolerance to extreme climatic conditions, and compatibility with conventional farming practices. In addition, these native grasses, once established, usually have fewer input and maintenance requirements compared to more traditional crops. Two feedstocks – switchgrass and a 3-species mix of big bluestem, indiangrass, and sideoats grama – have been selected as central feedstock components of collaborative efforts funded by the U.S. Department of Agriculture to create a Midwestern regional system for producing advanced transportation fuels derived from perennial grasses grown on land that is either unsuitable or marginal for row crop production. These native warm-season grasses are components of the highly diminished tallgrass prairie ecosystems of the Northern Great Plains (including the Prairie Pothole Region) and restoration of some of this cover type could provide significant benefits to wildlife. Best management guidelines (BMGs) presented within this document will therefore focus on the establishment, management, and harvesting implications of these two native warm-season grass feedstocks on wildlife and their associated habitats.
...the deep, fibrous root systems of switchgrass have other environmental benefits including reducing runoff, increasing soil organic matter, and improving soil surface hydrology – all of which may improve stream and wetland quality for various wildlife and fish species.

Switchgrass

After evaluating 34 candidate species, the Department of Energy Bioenergy Feedstock Development Program chose switchgrass as its primary herbaceous bioenergy crop. Since then, there has been considerable focus by researchers, industry, and government officials to develop switchgrass for commercial bioenergy production. Commercial-scale, pre-operational testing of facilities that may use switchgrass as a primary fuel is already underway in numerous states (e.g., Alabama, Iowa, South Dakota, and Tennessee).

In addition to the political and economic drivers, sustainable production of switchgrass may have several environmental benefits when replacing traditional row crops such as corn or soybeans. Switchgrass is often used for reseeding cultivated lands to native grass because it is relatively easy to establish with proper seedbed preparation, stabilizes soils, and provides excellent winter cover for numerous wildlife species when mixed with cool-season grasses and other herbaceous flowering plants. Because it is related to the corn and sorghum family, switchgrass seeds are often highly desired by songbirds and upland game birds during portions of their life cycles. Furthermore, the deep, fibrous root systems of switchgrass have other environmental benefits including reducing runoff, increasing soil organic matter, and improving soil surface hydrology\(^9\) – all of which may improve stream and wetland quality for various wildlife and fish species. Best management practices (BMPs) have been developed for switchgrass bioenergy production in most regions of the U.S.
3-species mix (big bluestem, indiangrass, sideoats grama)

Though several studies have indicated that single-species plantings may have higher biomass yield when compared to multi-species plantings, there is some evidence that diverse mixtures of grasses may have other benefits for bioenergy production. Diverse mixtures tend to be more resilient and have reduced year-to-year variability of aboveground biomass. This, in turn, may lead to reduced dependence on external inputs and lower risk to the producer. In addition, research has shown that diverse mixtures may provide more usable energy, greater greenhouse gas reductions, and less agrichemical use while also increasing biomass productivity through time. More importantly for wildlife, diverse mixtures will improve the overall quality of habitat through the addition of vegetative structure and compositional diversity, which has been shown to increase biological diversity and ecosystem integrity.

Best management practices for establishing, managing, and harvesting diverse mixtures of big bluestem, indiangrass, and sideoats grama have been developed specifically for the Great Plains and Midwest making this diverse mix our second feedstock of choice. Mixing perennial grass species with different life cycles, nutrient, and growth characteristics reduces plant competition among species while maintaining overall biomass productivity and stability. Similar mixtures have shown high productivity in field tests. As a result, projects are underway to determine the feasibility of using this 3-species mix for large-scale bioenergy production. It is important to note that sideoats grama is in the mixture primarily to provide early cover to prevent erosion and serve as a nurse crop for the big bluestem and indiangrass, which take a little longer to develop. Over time, big bluestem and indiangrass will dominate the mix.

Noteworthy Differences Between Feedstocks

Cultural practices are similar for establishing all native warm-season grasses. However, the grasses have different herbicide tolerances, so weed control needs to be tailored to the species being planted. Specifically, indiangrass seedlings do not tolerate atrazine and switchgrass seedlings do not tolerate imazapic (Plateau), so care must be used when applying herbicides to mixtures containing both indiangrass and switchgrass. Choice of herbicide will also affect wildlife by changing food, cover, and shelter through the removal of vegetation. If pesticides are used, this can affect wildlife species by removing prey resources—especially insects for birds and small mammals—as well as threaten pollinators, which help pollinate over 75% of our flowering plants and nearly 75% of our crops making them critical components of healthy ecosystems. Agricultural runoff into aquatic areas such as streams and wetlands is also a concern. Guidelines specifically addressing any major differences in feedstock management and their resultant implications on wildlife and habitat will be highlighted throughout the document.
The Prairie Pothole Region is tremendously important to many species of wildlife. The Prairie Pothole Joint Venture described the area as having an unmatched (in North America) number of depressions that hold water (i.e., potholes), at an average of 83 per square mile. These potholes were historically imbedded in a landscape of tallgrass, shortgrass, and mixed grass prairie. Of the 800 species of migratory birds in the United States, 300 species rely on the Prairie Pothole Region for their lifecycle needs. There are 177 bird species that breed in the Prairie Pothole Region and 130 of those rely on the Prairie Pothole Region for feeding and resting while traveling to other places. These species don’t all need the same habitat components and seasonal needs of individual species can vary considerably. This is the complexity of wildlife biology. Discussion of species and habitat connections may help frame wildlife needs in the context of the Prairie Pothole Region and how biomass production could be most compatible with wildlife that depend on the region.

Cover, food, water, and adequate space are the four basic elements commonly recognized as wildlife “habitat.” This is wildlife biology at its simplest – the 30,000 ft. view so to speak. Looking at wildlife biology at this level is like looking at a forest from an airplane. The forest is obvious but what comprises it is not. It is the same for wildlife biology; the basic four elements are all wildlife need, but at that 30,000 ft. altitude the unseen parts are the “what, when, and where” of the four habitat elements. More specifically, the types of cover, food, water, and space can differ seasonally for each species and vary widely among species. The habitat, itself, also changes through time. It is important how all of these components interact to make a functional ecosystem. The type and quality of the food and cover, as well as how land is involved and how it is managed, determine sustainability of wildlife.

Although seasonal species needs are similar for some species, they can differ considerably among many species living on the same landscape. The bobolink and ring-necked pheasant provide a good case in point. Bobolinks winter on the grasslands and agricultural fields of South America but summer in the Prairie Pothole Region and adjacent areas where they prefer grasslands with some ground litter and standing grassland cover (absence of woody cover is a plus). In the fall, the bobolink moves to freshwater marsh habitat and seeks...
out feeding areas with annual seed crops. In contrast, the ring-necked pheasant is a non-native species that is economically important to the Prairie Pothole Region by way of the hunters that come to the area spending money on lodging, food, and other items. The ring-necked pheasant needs undisturbed grassy cover in the spring for nesting; in the summer they move to agricultural fields like those in alfalfa or small grains where their young can move about easily and find insects. In winter, pheasants tend to use woody or other tall vegetation (e.g., cattail sloughs) as a shield against extreme cold and heavy snow typical of the Northern Great Plains. The differences highlighted in the habitat needs of these two species – both of which depend on grasslands at some point during their life cycle – emphasizes the need to understand species biology and how management decisions may affect each.

Habitat required by individual species using the same cover type can be quite different as well. Contrasting habitat needs between the Henslow’s sparrow and horned lark provides a good example. A report provided by the Northern Prairie Wildlife Research Center in Jamestown, North Dakota, describes Henslow’s sparrow as preferring habitat that includes native grasslands with litter build-up, tall standing dead residual grass, the absence of woody material, and large grassland expanses even though individual birds have small home ranges. This species breeds in the prairie regions and migrates to winter habitat in the south. Another report by the Northern Prairie Wildlife Research Center provides habitat information for the horned lark, which prefers short, sparse herbaceous vegetation, interspersions of bare ground, and little or no woody cover. This species also prefers a larger habitat area but can do reasonably well on smaller patches of habitat and it stays in the same area year-round except in the most northern part of their range. The Henslow’s sparrow likes grassland sites with an unmanaged look imbedded within a larger grassland landscape whereas the horned lark prefers grassland patches that have a managed look and they are more flexible regarding the extent of surrounding grassland habitat. Differences between and among species are very common and can add complexity to wildlife conservation.

Another important difference in relation to the habitat needs of individual species goes to how well they respond to conversion or alteration of land cover in a native ecosystem that fragments the native cover and habitat normally available to wildlife dependent on that ecosystem. A report from the Northern Prairie Wildlife Research Center provides an excellent discussion of fragmentation as it relates to grassland birds. Importantly, there is a point at which the size of individual tracts or patches of remaining native habitat are too small and/or comprise too little a percentage of the larger landscape to maintain individual species. The northern harrier and bobolink as well as the Henslow’s, savanna, and grasshopper sparrows are examples.
Habitat specialists tend to do best when the native ecosystem is most intact and less well when it is fragmented or otherwise altered. Habitat generalists can usually make use of many kinds of habitat and can gain advantage over habitat specialists when ecosystems are fragmented. As long as the habitat is ecologically site-appropriate, both specialists and generalists should be able to survive and co-exist.

As long as the habitat is ecologically site-appropriate (e.g., native mixed grasslands in association with wetlands in the Prairie Pothole Region), both specialist and generalists should be able to survive and co-exist. However, when habitat change occurs, the balance can be upset to the point that some generalist species get the upper hand to the disadvantage of the specialists. The brown-headed cowbird provides an excellent example of how a habitat generalist species can gain advantage to the detriment of habitat specialists as ecosystems are fragmented. Cowbirds can be found in many kinds of habitat but particularly like transition areas (i.e., edge habitat) between cover types such as cropfield and prairie. The female cowbird destroys a host species’ egg and replaces it with its own egg. The cowbird egg hatches before that of the host species. The cowbird young are demanding and end up getting a greater share of food brought to the nest by the host species, which may cause the host species to abandon the nest and not make another nesting attempt that season.43 The brown-headed cowbird is native to the Prairie Pothole Region and gains advantage with the presence of woody cover and/or grass that is kept short.

The importance of habitat fragmentation is brought into focus by how it affects wildlife species that are habitat specialists and generalists. Habitat specialists are species that require a narrow range of habitat conditions in order to meet their needs whereas habitat generalists are those that can take advantage of many types of habitat. Habitat specialists tend to do best when the native ecosystem is most intact and less well when it is fragmented or otherwise altered. Habitat generalists can usually make use of many kinds of habitat and can gain advantage over habitat specialists when ecosystems are fragmented. Continuing with grassland birds as an example, the greater prairie chicken, upland sandpiper, dickcissel, and western meadowlark require mostly treeless grasslands for survival and are habitat specialists. A few habitat generalist bird species that commonly use grasslands along with other habitats are the song sparrow, red-winged blackbird, common grackle, and American goldfinch.42 All of these bird species are important to the overall biodiversity of North America but giving too much advantage to the generalists can, in some situations, contribute to the decline of specialist species. The issue is broader than birds and applies to all type of fish and wildlife – the needs of habitat specialist species should be addressed in addition to the habitat generalists if bioenergy is to be compatible with native biodiversity as a whole. The use of BMGs that incorporate specialist as well as generalist wildlife needs and consultation with fish and wildlife biologists can help ensure sustainability includes all native wildlife species.

The Prairie Pothole Region and wildlife that depend on the associated ecosystems, such as prairie grasslands and wetlands, do best when the ecosystems on which they depend are intact and fully functional.45 A 1995 study of ecosystems observed that ecosystems can become impoverished through loss of their structure, function, or composition. If the native cover is changed and/or other natural processes such as the water cycle are altered then the ability of the ecosystem to support wildlife diminishes as well.47

is how widely separated the patches are by cropland, introduced grasses, etc. The third is the extent of transition (edge) between two cover types such as native prairie and cropland because nesting and nest success of grassland habitat specialist species can be negatively impacted in edge areas.
Agroecosystem is a designation sometimes given to landscapes where the native ecosystem has largely been converted to agricultural production. However, it is not how the landscape is characterized that matters to wildlife. Rather, it is the cover chosen for the land and it is how that cover and other resources, such as water, are arranged and managed that will determine the health of wildlife native to the area. Wildlife will fare better when the cover and management of the land mimic the native ecosystem. Cover choice and management inconsistent with the native ecosystem usually results in declining native wildlife populations. The Environmental Protection Agency (EPA) reports that the leading way that species become threatened or endangered is through human activity that alters their habitat. The effort needed to recover the health of threatened or endangered species can lead to unproductive contention among stakeholder groups and be much more expensive than managing the land for sustainability of species in the first place. Despite the complexity of wildlife biology, integration of wildlife needs and production agriculture is achievable. It simply takes forethought and planning. Subsequent sections of this publication provide a walkway toward alternatives that can produce biomass and contribute to sustainability of America’s grassland biodiversity heritage.
When considering how biomass crops are managed, it is important to recognize the impacts on differing groups of species for many reasons. For one, some fish and wildlife species are important to local traditions or the local economy. An example would be the ring-necked pheasant and smallmouth bass, which are popular to those that hunt or fish. Other species have already experienced so much habitat loss that they are at risk of disappearing altogether. Still other species are important in ways that are sometimes overlooked – pollinators are among these. It is important for private landowners to have access to information that helps them recognize and understand the needs of wildlife in regard to the alternatives for managing their land. In fact, 96% of the Prairie Pothole Region is privately owned making collaboration between natural resource managers and private landowners essential in order to achieve wildlife conservation in the Prairie Pothole Region. The BMGs in this document are designed to help integrate wildlife conservation with production agriculture as biomass crops are produced.

**Grassland Birds**

Grassland birds associated with the Prairie Pothole Region include songbirds such as the bobolink, dickcissel, grasshopper sparrow, sedge wren, and meadowlark, as well as upland game birds including the ring-necked pheasant, greater prairie chicken, and wild turkey. Songbird response to biomass production will largely depend on vegetation structure (vertical and horizontal), size and fragmentation of grassland habitat, and the types of birds under consideration.

During the last 25 years, however, grassland bird populations have shown steeper, more consistent, and more geographically widespread declines than any other group of North American bird species due, in large part, to habitat alteration and agricultural intensification.
In addition, game birds will often be responsive to the geography on which the biomass plantings are located, the diversity of habitat types, and plant diversity within the biomass production area.

The Prairie Pothole Region of the Northern Great Plains provides breeding habitat for more than one-half of the grassland bird species breeding in North America. During the last 25 years, however, grassland bird populations have shown steeper, more consistent, and more geographically widespread declines than any other group of North American bird species due, in large part, to habitat alteration and agricultural intensification. Inappropriate or excessive use of pesticides, herbicides and fertilizer, removal of natural field edges, land drainage, harvesting or mowing earlier in the season when birds are still nesting or rearing broods, or harvesting needed winter thermal cover or early spring nesting cover could all negatively impact grassland birds. Expanding perennial grass bioenergy crop production may have positive or negative effects on grassland bird species depending on the land that is replaced. If bioenergy crops replace native habitat types, are improperly managed or harvested, or are planted to pure grass stands lacking forbs or to monocultures of introduced species (e.g., Giant Miscanthus), additional habitat could be lost and populations of native wildlife further diminished. However, if traditional row crops such as soybeans and corn are replaced with native perennial grasses (e.g., switchgrass, indiangrass, big bluestem, sideoats grama) – especially if done in mixtures – then suitable habitat may increase.

Biomass crops on agricultural lands are likely to be intensively managed and extensively harvested. No-till methods can increase bird diversity and are often recommended for native grass establishment of bioenergy crops, although Best (1986) noted that no-till fields may be an ecological trap for nesting birds attracted to high residue depending on the timing of management, including planting. Furthermore, these tillage methods rely on agrochemicals for weed and insect control that may affect birds through change in the vegetative structure and reduction in food (i.e., insects and seeds). Nesting success generally remains low for 1-2 years after planting due to limited cover for birds and their nests but increases as stands mature and overhead cover improves. Fertilizers applied in the second or third year after planting are often recommended to increase stand biomass, but this may limit movement of ground-nesting and dwelling species. Dense grass establishment after Years 3 to 5 causes a reduction in plant diversity and bird nesting cover and an increase in litter. During this period, bird use may shift as grass stands mature. In these cases, biomass harvest can be used to increase grass stand health, productivity, and species diversity if harvest mimics various stages of maturity and natural disturbance. Increasing site disturbance through occasional fire, disking, or other methods can increase bird use, because species that like open ground are quick to use newly planted or disturbed fields for feeding and brood rearing.

Harvest management and timing of harvest of perennial bioenergy crops will be critical. Landscape arrangement (i.e., how various habitats and land uses are arranged spatially) must be considered when planting and

Flying rooster. Credit: Tom Koerner/USFWS.

Ninety-six percent of the Prairie Pothole Region is privately owned making collaboration between natural resource managers and private landowners essential in order to achieve wildlife conservation in the Prairie Pothole Region. The BMGs in this document are designed to help integrate wildlife conservation with production agriculture as biomass crops are produced.
The mixture of wetlands and grasslands found in the Prairie Pothole Region is critical for waterfowl recruitment, producing 50–80% of the continent’s duck populations. In fact, the Prairie Pothole is so important for waterfowl production that it has been called the “Duck Factory” of the nation. Typical waterfowl species found there include blue-winged teal, mallards, canvasbacks, scaup, and northern shovelers.

The relative benefits of remaining stubble will depend on its height, how much residual there is and the targeted bird species.

Waterfowl and Shorebirds

The mixture of wetlands and grasslands found in the Prairie Pothole Region is critical for waterfowl recruitment, producing 50–80% of the continent’s duck populations. In fact, the Prairie Pothole is so important for waterfowl production that it has been called the “Duck Factory” of the nation. Typical waterfowl species found there include blue-winged teal, mallards, canvasbacks, scaup, and northern shovelers. In addition, thirteen species of shorebirds breed in the Prairie Pothole Region and require similar landscapes mixed with grassland and wetland habitats for nesting and brood rearing. Examples include piping plovers, killdeer, upland sandpipers, long-billed curlews, and common snipe.
As with grassland songbirds, expanding perennial grass bioenergy crop production may have positive or negative effects on waterfowl and shorebirds depending on the land that is replaced. For example, the U.S. Fish and Wildlife Service (USFWS) estimates that CRP has increased duck populations by more than 2 million birds per year in the Prairie Pothole Region since its establishment over 25 years ago. Because almost a quarter of the nation’s CRP is in the Northern Great Plains, even small, incremental reductions in wildlife benefits may have significant, continental impacts on duck populations. However, if more diverse bioenergy crops of native perennial grasses replace pure stands of corn or soybeans, then there may be a net increase in habitat and wildlife populations may benefit.

Many of the establishment issues that were pertinent for grassland birds (see “Grassland Birds” above) will also apply to waterfowl and shorebirds. Timing of no-till planting in the spring should take into consideration the early nesting season (mid-April through May) for waterfowl that may be attracted to high residue that remains on the field from the previous season. Minimizing the use of herbicides and pesticides will promote higher diversity of food sources – especially insects – on which many waterfowl rely following long migrations in order to physically prepare themselves for the breeding and nesting season. Small temporary or seasonal wetlands are often the first open water sources to thaw in the early spring making them critical feeding stopover points for waterfowl and shorebirds as they migrate north. In fact, more than 70% of the shorebird species found in the Northern Great Plains require water depths of less than 4 inches, and many are restricted to mudflat areas with water less than 2 inches and less than 25% cover. Because these areas will not produce high yielding biomass anyway, they should be retained whenever feasible to provide the wetland-grassland mosaic necessary for good waterfowl and shorebird production. Seven species of shorebirds nest in uplands near or adjacent to wetlands in short to moderate vegetation height. The overall height of vegetation used for nesting by shorebirds is much shorter than is used by most waterfowl.

As grass stands mature during the growing season, ducks shift from nesting to brood rearing. Good overhead cover provided by many perennial grasses will benefit young broods though most dabbling ducks move broods straight to wetlands after nesting and will spend very little time in the uplands. If grass stands become too dense, harvest can be used to open up the canopy and increase grass stand health, productivity, and species diversity. Late fall or early winter removal after the first hard frost causes less direct mortality than harvesting during nesting or brood rearing seasons; however, changes in vegetative structure the following spring and summer may affect breeding behavior of waterfowl. A recent study showed nest initiation was delayed a full month for hen mallards in fields that were harvested at 4-inches as opposed to leaving 10-inches of stubble or not harvesting at all. It is unknown whether those hens were renesting after a failed first or second nesting attempt and it is also unclear whether that delay in nesting may have larger consequences on the population as a whole (e.g., young birds may not be robust enough to successfully survive the fall migration). Though migratory waterfowl will not need winter cover, Ducks Unlimited recommends leaving 18-inches or more of residual stubble to provide some winter cover for other resident wildlife while also helping breeding waterfowl the following spring. Alternatively, non-harvested areas (i.e., buffers or patches) can be retained or portions of harvests can be deferred for a year.
observation has been supported in research, though no studies are specific to the Prairie Pothole Region. For example, the greatest mammal diversity occurred during the first 3 years after stand establishment of exotic CRP plantings in Texas, though these stands differed significantly from the surrounding short grass prairie. Another study found a greater abundance and diversity of small mammals in switchgrass compared to corn or hay in the fall, with maximum abundance in the third year after establishment. This indicates that periodic disturbance of perennial grasslands helps to maintain plant diversity and thereby benefit mammals that use early successional habitat.

Small mammals are sometimes overlooked, but they play an important role in several ecosystem services including predation of insect pests and weed seeds, nutrient cycling, and serving as a vital food source to avian, reptilian, and other mammal predators.

...periodic disturbance of perennial grasslands helps to maintain plant diversity and thereby benefit mammals that use early successional habitat. It should not come as a surprise that establishment, management, and harvesting techniques for producing bioenergy crops can affect mammal diversity and abundance. Effects will largely depend on the species, its individual food and other habitat requirements, and the season of year. Conventional tillage may benefit more disturbance-adapted species such as deer mice and house mice whereas no-till practices are generally better to improve small mammal habitat by providing additional food and cover. Reduced use of herbicides during

Mammals

Native perennial grass cover in the Northern Great Plains is used by a variety of mammals. These include larger game species such as white-tailed deer and pronghorn; predators such as coyotes, foxes, and raccoons; and numerous small mammals including deer mice, prairie voles, meadow jumping mice, and short-tailed shrews. Bats are also found in open prairies, but are usually associated with water bodies and woody vegetation.

Although few studies have directly investigated effects of bioenergy production on grassland-dwelling mammals, there is enough known about habitat use by wildlife to make pertinent inferences. For example, it is well known that many mammals prefer early successional habitat (e.g., habitat that has been recently disturbed through disking or prescribed burning). In fact, 56 of the 60 mammal species commonly found in the northeastern United States use early successional habitat. This
the establishment phase helps the high plant diversity characteristic of early successional habitat to last longer to the benefit of many mammal species. Waste corn, soybeans, and sorghum are high value food sources for a variety of resident wild mammals. Similarly, it is anticipated that seed-eating mammals may benefit from residual grass seed left in the field following harvest until heavy winter snow and ice makes it unavailable. Leaving residue in the field after harvest may increase cover and potential food sources (waste grain and insects) resulting in increased biodiversity overall, but further studies are needed.

Small mammals are sometimes overlooked, but they play an important role in several ecosystem services including predation of insect pests and weed seeds, nutrient cycling, and serving as a vital food source to avian, reptilian, and other mammal predators. Biomass harvesting for bioenergy production can expose small mammals and other prey species to predators. Several studies report negative effects to small mammal populations from haying tallgrass prairie. Companion strip and block plantings of wildlife-friendly grasses, legumes and other forbs and shrubs as well as unharvested areas can provide escape cover and safe travel lanes during harvest. These diverse native plantings provide year-round food and brood areas, travel/escape corridors, nesting material, and refuge sites during and after biomass harvest. Unlike other mammal species, management and harvesting of perennial grasses for bioenergy production would likely have an indirect effect on bats by changes in the diversity and abundance of their prey (e.g., insects) rather than have direct effects on cover they use.

**Amphibians and Reptiles**

The Prairie Pothole Region is rich in biodiversity, including reptile and amphibian species. Reptiles associated with the Prairie Pothole Region include species such as the northern prairie skink, western painted turtle, and western hognose snake. Amphibian species include the northern leopard frog and tiger salamander, among many others.

Reptiles are an important component of biodiversity in the region and can be negatively impacted by loss of habitat, cultivation, mowing, and application of chemicals, but amphibians are particularly important due to their abundance and role in predator-prey relationships and nutrient recycling. Reductions to amphibian populations can trigger a domino effect that alters the overall ecosystem. This is challenging in that over 30% of amphibian species are at risk of extinction. The loss of habitat has been cited as a primary cause of amphibian declines. In the Prairie Pothole Region, habitat alteration consists mainly of the conversion of native and restored grasslands and
Aquatic Resources

The prairie potholes are of glacial origin and were created about 13,000 years ago. The Prairie Pothole Region encompasses about 300,000 square miles and the potholes are supplied by surface precipitation such as rainfall and snowmelt. Water leaves the potholes mostly by seepage or evaporation and rarely by overflow. Because of this, dissolved salts tend to build up and create brackish water in potholes that rarely overflow. Potholes that overflow often tend to have fresher water. The Environmental Protection Agency characterizes pothole wetlands as having submerged and floating aquatic plants in deeper water and rooted plants, such as cattails and bulrushes, near the shore. Potholes are often bordered by wet, marshy areas that lead into the uplands. These prairie potholes absorb rain and snowmelt and thereby greatly reduce flood risk downstream. The region is often described as one of the most important wetland regions in the world and is home to over 50% of North American waterfowl.

Aquatic invertebrates, including insects such as the mayfly nymph and crustaceans like gammarus, provide a very important high-protein food source to wetland and non-wetland birds alike. Harsh winters limit fish from establishing in most prairie pothole wetlands, but this is a boon for bird species (especially waterfowl and shorebirds) that feed on the aquatic insects as the presence of fish would greatly limit invertebrate populations. In addition, the presence of fish would limit salamanders and frogs from communities that rely on these wetlands. Water in sufficient quantity and quality to recharge pothole wetlands and sustain the rich life associated with these aquatic habitats is extremely important to the biodiversity of the Prairie Pothole Region.

Invertebrates

Insects, centipedes, millipedes, crustaceans, spiders, and others encompass about 82% of all life forms on earth. Some of these can interfere with human health or activities through transmission of disease, crop damage, livestock health, and in other ways. But, invertebrates and their activities are more beneficial to people and ecosystems than is often recognized. Key benefits include: Cross-pollination of agricultural...
A recent study\textsuperscript{142} found that arthropod diversity and abundance was 230\% to 324\% greater in switchgrass and 750\% to 2,700\% greater in mixed-grass/forb prairie relative to energy crops such as corn. Importantly, another 2012 study of bioenergy crops in the Midwest\textsuperscript{143} showed that the type of bioenergy crop selected as well as placement on the landscape could reduce insect damage to adjacent food and forage crops as well as lessen the need to use agricultural insecticides. This is because perennial biomass crops could provide habitat for predatory insects that would suppress the normal pests associated with agricultural crops. Both studies point out the tremendous potential benefits of carefully selected and placed perennial biomass crops to agriculture, biodiversity, and native ecosystems in the Prairie Pothole Region.

The agricultural value placed on pollinators has been fairly steady at $10-15$ billion per year.\textsuperscript{139} The Xerxes Society\textsuperscript{140} sheds light on the importance of pollinators. Worldwide, over 2/3 of agricultural crops (about 100 in the U.S.) and about 70\% of flowering plants depend on pollinators. The fruits and seeds produced through the efforts of insect pollinators comprise much of the diets of 25\% or more of birds and mammals. Pesticide use, loss of habitat, and introduced diseases are mentioned as the primary risks to pollinators.

The Natural Resources Conservation Service (NRCS) provides information specific to South Dakota\textsuperscript{141} – the heart of the Prairie Pothole Region – that pollinators are of much value to nearly all native flowering plants (forbs, legumes, shrubs, trees, and many aquatic plants) as well as nearly 40 agricultural crop species. NRCS indicates that pollinators require reliable sources of nectar and/or pollen in their active period, which is late April to early October in South Dakota. Best habitat includes undisturbed areas for nesting with food sources (i.e., flowering plants) within 50 feet to ½ mile (up to ¾ mile for the European Honey Bee).

...invertebrates and their activities are more beneficial to people and ecosystems than is often recognized. Key benefits include: Cross-pollination of agricultural crops; aid decomposition of nearly 99\% of human and animal waste; recycle and return nutrients to the soil. Invertebrates are also vitally important to nearly every food-chain that exists and without them most terrestrial life could not exist.
Previous sections were intended to provide and illuminate the wildlife biology foundation as it relates to biomass production in the Prairie Pothole Region. The rationale for the two high-potential biomass crops selected for BMG development has also been addressed. It is time to put it all together and discuss how wildlife needs and biomass production can be integrated in mutually compatible ways. Implications and opportunities for wildlife conservation differ in each phase of production, so establishment, management, and harvest will be discussed individually.

Establishment

Selecting sites for biomass crop plantings is important to wildlife and conservation of the native ecosystem. Both switchgrass and the 3-species mix of big bluestem, indiangrass, and sideoats grama are warm-season grasses native to prairie ecosystems of North America. Establishment of native warm-season grasses on most marginal cropland sites in the Prairie Pothole Region would be compatible with wildlife as long as native sod or water flow/levels (aboveground or underground) are not altered. Plantings that restore marginal cropland to native warm-season grasses and extend the area of such cover on the larger landscape will favor species of conservation concern that have been on decline in the region. Permanent cover adjacent to prairie potholes is especially beneficial to aquatic and terrestrial species that depend on these habitat types in close proximity. Native warm-season grass plantings that link prairie and other permanent cover on agricultural landscapes provide a

Plantings that restore marginal cropland to native warm-season grasses and extend the area of such cover on the larger landscape will favor species of conservation concern that have been on decline in the region.
way for wildlife (especially small and less mobile species) to move from area to area as food, water, and cover quality and availability change throughout the year.

Native warm-season grasses like switchgrass, big bluestem, and indiangrass have a reputation for being challenging to establish. Historically, these grasses often required 2 or 3 years to establish a stand suitable for agricultural uses. However, this reputation may be somewhat unwarranted, largely due to establishment methods and stand development expectation differences between native grasses and the introduced European grasses that many U.S. agricultural producers are more accustomed to using. In addition, advancements in herbicides, cultivar development, cultivation methods, and planting equipment have dramatically improved the ease of establishment. Today, it is feasible to harvest 50% of the cultivar’s yield potential after frost in the seeding year. By the end of the first full growing season after seeding, it is feasible to produce and harvest 75% to 100% of the cultivar’s yield potential with many fields in the central Great Plains approaching full production of 5 to 6 tons per acre. If precipitation is adequate, warm-season grasses are readily established when quality seed of adapted cultivars are used in conjunction with the proper planting date, seeding rate, seeding method, and weed control.

The use of selective breeding and, more recently, genetic modification, to increase yield, endure climatic hardship, and improve establishment can be beneficial for production, but also adds characteristics that enhance the ability of these new varieties to compete with other plants. New varieties of switchgrass, for example—particularly those that are genetically modified—could outcompete native switchgrass and have a negative impact if they migrate into remaining native grassland ecosystems. In the case of high-yielding hybrid or genetically-modified varieties of native warm-season grasses, consultation with the state fish and wildlife agency to determine potential risk to native ecosystems is advised and development of a containment plan may be prudent.

In the central Great Plains and Midwest, warm-season grasses are usually planted 2 or 3 weeks before to 2 or 3 weeks after the recommended planting dates for corn, typically from mid-April to early June. In the Prairie
flush of vegetation may look weedy from an agricultural standpoint but is very beneficial to many species of wildlife that prefer plant diversity and patches of bare ground for nesting or brood rearing.

Warm-season grasses are normally seeded at 30 pure live seed (PLS) per square foot for optimum density for biomass production. Excellent results are obtained by planting after a soybean crop using a properly-calibrated no-till drill with depth bands that plant seeds 1/4" to 1/2" deep in 7.5 to 10-inch rows.150 Big bluestem and indiangrass seeds are fluffy and require a seed box equipped with an active seed flow mechanism. If warm-season grasses are planted after crops that leave heavy residue such as corn or sorghum, it may be necessary to remove the residue prior to planting. If the field is tilled, the seedbed needs to be packed to firm the soil as would be done for alfalfa. This seeding rate is intended to result in an optimum density for biomass production although as stand density increases, attractiveness to most species of wildlife declines. This is an especially important factor for the young of ground-nesting birds that have trouble moving through dense vegetation. Many species of wildlife (e.g., mammals, insects) prefer the more open ground and plant diversity that is prominent during the establishment period when the stand has the greatest plant and structural diversity; as the stand matures the composition of wildlife species present will also change. The addition of unharvested, wildlife-friendly field borders and buffers between the plantings and around prairie potholes and other bodies of water can add habitat that help offset the habitat loss associated with high stand density. Atrazine should not be applied adjacent to wetlands or other bodies of water. Weed competition is one of the major reasons warm-season grasses are slow to establish. Several herbicides are currently recommended to control weeds during establishment. All herbicides should be applied only as approved for the intended use and according to label instructions. A current recommendation for controlling weeds in a mixed planting of big bluestem, indiangrass, and sideoats grama is 4 ounces of imazapic (Plateau®) per acre plus glyphosate immediately after planting and prior to seedling emergence. For switchgrass, applying 8 ounces of quinclorac (Paramount®) plus 1 quart of atrazine per acre immediately after planting provides the best weed control and most rapid establishment for upland and lowland switchgrass ecotypes in Nebraska, South Dakota, and North Dakota, USA.151 However, in this same study, the use of quinclorac alone provided good weed control and will be a better choice for establishing switchgrass near wetlands where the use of atrazine should be avoided. Weed control usually accounts for about 5-10% of total establishment costs. After the establishment year, a successfully established warm-season grass stand requires limited herbicide applications. Mowing no shorter than 6" when weeds reach about 12" in height is an alternative to herbicide use.152

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There are tradeoffs regarding the use of herbicide versus mowing to control weeds as native warm-season grasses establish. Herbicides kill weeds and can harm wildlife - particularly in aquatic systems where they are known to harm invertebrates, amphibians, fish, and associated wildlife as well as the aquatic plant community. On the other hand, mowing during establishment means mowing during the peak nesting season and that can be detrimental to wildlife and their reproductive activities. Herbicide use can help the native grasses establish more quickly because it kills competing plants whereas mowing simply helps grasses gain the advantage. Use of mowing adjacent to water bodies and herbicide higher on the landscape can provide for a balanced establishment scenario that is kinder to wildlife than using only one or the other.

Successful stand establishment that occurs in the seeding year will be most economically viable for biomass producers. Failing to establish successful switchgrass stands in the seeding year can cost farmers more than $120 per acre. A stand frequency of 50% or greater (2 or more plants per square foot) indicates a successful stand, whereas stand frequencies from 25 to 50% are marginal to adequate, and stands with less than 25% frequency are a partial stand. Stand frequencies can be easily measured using a frequency grid. In a field study on 12 farms in Nebraska, South Dakota, and North Dakota, a switchgrass stand frequency of at least 40% in the seeding year was a stand threshold for identifying fields with successful post-planting year biomass yields. However, producers that can access programs like the USDA Biomass Crop Assistance Program (BCAP), and defray the cost of production forgone during establishment, can provide additional benefits to wildlife during a longer establishment period. In addition, even with herbicide, the vagaries of weather and other factors can lengthen the establishment but, with native warm-season grasses, patience will usually lead to a successful stand.

Managing Established Stands

Biomass yield is influenced by factors associated with the landscape chosen for the plantings (soil type, climate, water availability, etc.) and management practices such as ecotype, cultivar, fertilization, and harvest timing. Most of the research to date in the Great Plains and Midwest reports yields for warm-season grasses that were developed in the 1980’s or 1990’s for grazing or conservation. However, high-yielding cultivars developed specifically for biomass yield in the Great Plains and Midwest should be commercially available by 2015. For example, a biomass-specific switchgrass experimental cultivar developed by USDA-ARS at the University of Nebraska has a 3-year average yield of 8 tons per acre, 2.4 tons per acre greater than Shawnee, a switchgrass cultivar developed for grazing. Although bioenergy-
specific cultivars will have greater yield and stand density than cultivars most familiar to wildlife biologists, these differences will be most prominent for only a brief period in late summer and autumn. As previously mentioned, stand density can limit the ability of wildlife to enter stands and move about to feed and otherwise seek cover. This is particularly true for the young of ground-nesting birds. In addition, tall dense stands of grass tend to shade the ground and suppress shorter plants, including sideoats grama, a component of the biomass mixture. Dense stands with low plant diversity will be of limited benefit to many species of wildlife, including invertebrates that are an important food base for wildlife such as birds and amphibians. However, there are exceptions such as some species of mice and voles that prefer dense vegetation. Availability of different types of herbaceous cover across the greater landscape is the best scenario for wildlife. Use of both switchgrass and the native grass mixture for biomass crops in the same area could be helpful to diversify structure and food resources while minimizing risk to the producer through crop diversification. In addition, placement of less dense but unharvested, wildlife-friendly field borders (that include legumes and/or forbs to attract insects) and conservation of adjacent native sod, wetlands and other native cover would add wildlife benefits.

Biomass production fields will require fertilization. Site productivity, anticipated biomass yield, and time of harvest dictate switchgrass fertilizer needs. Although warm-season grasses growing in native grasslands and CRP tolerate low fertility soils, fertilization is required to optimize biomass, maintain stands, and replace nutrients in bioenergy production fields where large quantities of biomass are removed annually. The primary limiting nutrient for warm-season grass biomass is nitrogen (N). Biomass increases as N rate increases, but excessive fertilizer can result in N leaching or runoff and cause groundwater and surface water contamination, so the N rate must be carefully managed.

During the planting year, N application is not recommended because N encourages weed growth and increases establishment costs and residual N is present in land cropped with soybeans. Soil sampling to a depth of 1.5 m is needed since fertilizer rates are based on the difference between crop need and available soil N. Harvesting biomass removes N from the system and this N must be replaced to meet plant growth demands. Harvesting during the grass flowering stage removes more N from the system than harvesting after a killing frost, which is when we recommend harvesting biomass. For example, harvesting a switchgrass field after frost that produces 5 tons per acre of dry matter (DM) with a crude protein concentration of 4% (0.64% N) will remove about 64 pounds of N per acre. Not all removed N has to be replaced with fertilizer N because of atmospheric deposition and soil mineralization, but this will vary with location and soil. In general, for post-frost harvests, about 50 to 75 lbs of N per acre per year should be applied to meet anticipated yield goals. In Nebraska and Iowa, ‘Cave-In-Rock’ switchgrass yields increased as N rate increased from 0 to 270 pounds of N per acre, but residual soil N increased if more than 100 pounds of N per acre was applied. Switchgrass yield was optimized when 100 pounds of N per acre were applied, with about the same amount of N being applied as was removed by the crop. Soil testing should be conducted periodically to monitor soil N levels. Phosphorus (P) and potassium (K) are generally adequate for switchgrass


The use of buffer strips and unharvested field borders between biomass plantings and nearby water bodies can benefit aquatic species by keeping fertilizers out of the water and increasing habitat diversity.
It also merits mentioning that, although prescribed burning is counter-intuitive to use as a management tool for biomass crops, there may be times that there is enough material on the ground to do a spring prescribed burn. Prescribed burning can be used to return nutrients to the soil and stimulate growth that season.

Harvest and Storage Management

Harvesting perennial grasses for bioenergy production will present a few obstacles for wildlife populations, but many of these can be mitigated through careful planning by the producer. The greatest implications for wildlife will likely come through a loss of winter cover – especially for resident wildlife such as white-tailed deer and pheasants – and a change in the structure of the vegetation the following spring and summer, which will most significantly impact nesting and brood rearing by various species of grassland songbirds and some species of ducks and shorebirds. Proper use of highly diverse field borders and non-harvested buffer strips – especially around riparian areas – can help to offset some of the losses in vegetative structure that will naturally occur with harvest. Care must be taken to not make these areas too narrow, however, because several studies have shown narrow buffer strips and field borders can be detrimental to wildlife reproduction and survival.
...with the exception of a few species that prefer short stubble (e.g., house mice, killdeer, horned larks, prairie dogs) increasing stubble heights to 10-inches or more will improve habitat for wildlife by providing additional structure and material for nesting, additional substrate for insects and other prey sources, and increased overhead concealment from predators and inclement weather.

and non-harvested buffer strips – especially around riparian areas – can help to offset some of the losses in vegetative structure that will naturally occur with harvest. Care must be taken to not make these areas too narrow, however, because several studies have shown narrow buffer strips and field borders can be detrimental to wildlife reproduction and survival. Cattail sloughs provide good winter cover for several wildlife species, and shallow wetlands provide critical habitat for ducks and shorebirds in the early spring as well as amphibian populations.

Maximizing biomass recovery, matching feedstock quality to the conversion platform, ensuring a constant supply of biomass and maintaining productive stands are the primary feedstock harvest objectives for industry and the producer. Productive stands can be maintained indefinitely with proper harvest timing, cutting height, and adequate N fertility. In the Great Plains and Midwest, a single annual harvest to a minimum stubble height of 4” is recommended to optimize biomass and energy inputs and maintains stands. Harvest height is also important to avoid mortality of small and relative non-mobile species of wildlife such as turtles, salamanders and other species that can be found in fields during this time of the year. For example, in the first 9 years of a long-term study managed for biomass production, switchgrass biomass was greatest in plots fertilized with 100 pounds of N per acre and harvested at a 4-inch stubble height after frost. The combination of these management practices ensures carbohydrate translocation to the plant crowns for setting new tiller buds and maintaining stand productivity and persistence, even during drought. However, with the exception of a few species that prefer short stubble (e.g., house mice, killdeer, horned larks, prairie dogs) increasing stubble heights to 10-inches or more will improve habitat for wildlife by providing additional structure and material for nesting, additional substrate for insects and other prey sources, and increased overhead concealment from predators and inclement weather. Another option for the producer would be to harvest portions of the field at differing heights to create a mosaic for wildlife or, as previously mentioned, leaving unharvested areas (i.e., field borders, buffer strips, or alternate year blocks) that can act as refugia for wildlife.

Additionally, harvest timing is a major cultural practice affecting feedstock composition. Fortunately, harvesting is an area in which wildlife impacts can be minimized while still allowing the producer to maximize production. Harvesting after frost provides biomass with higher structural carbohydrates and lignin as well as lower protein and ash compared to earlier-harvested biomass – desired characteristics for bioenergy production. In addition, harvest at that time will be outside the primary reproductive season for grassland wildlife. The use of a flushing bar (particularly if harvest occurs during any portion of the nesting season for wildlife in the area) could help to move wildlife out of harm’s way as harvest takes place. In addition, harvesting portions of the field farthest from permanent cover toward permanent cover can help
move wildlife into protective habitat as in-field cover
is removed. Additionally, mature stands of bioenergy-
specific switchgrass cultivars will produce more than
500 pounds of seed per acre, which may provide a food
source for granivorous birds and small mammals through
the fall until snow and ice make it unavailable. However,
bioenergy facilities will likely need a year-round supply of
feedstock; as a result, there may be some cost tradeoffs
to biorefineries that could warrant harvesting in stages.
There is potential, therefore, to plan harvest in a way that
could benefit both the industry and wildlife production
simultaneously. Further research is needed in that area.

Switchgrass bioenergy Best Management Practices
(BMPs) and extension guidelines have been developed
for most agro-ecoregions, but most BMPs for other
native warm-season grasses have been developed
primarily for grazing, haying, and conservation. Commer-
cially available rotary-head harvesters and large round or rectangular balers can handle the
volume of material in harvesting and baling operations
in switchgrass fields producing 6-8 tons per acre.
A cutting height of 4" maintains stands and keeps the
windrows elevated to facilitate air movement and
more rapid drying to less than 20% moisture content
prior to baling. As previously mentioned, however,
leaving more than 10" is recommended to improve
wildlife habitat and could increase yields the following
year by capturing blowing snow and providing additional
moisture to the stand.

The goal for biomass storage is to preserve the biomass
so that it leaves the storage phase in the same condition
that it entered storage. This requires the biomass to
enter storage at low moisture levels (generally less than
18% is preferable) and to be protected from moisture
during storage. Research is limited on dry matter (DM)
damages during switchgrass storage but, in general, bales
stored inside can be stored indefinitely with minimal
DM losses (0 to 2%), regardless of bale type. However,
when bales are stored outside, differences in bale type
occur. Large round bales generally have less storage
losses, whereas rectangular bales tend to be easier to
handle and load on trucks for transport without road
width restrictions. Storage losses were greater for
tarped large rectangular bales than for tarped round
bales. Tarped and untarped large rectangular bales
had DM losses of 7% and up to 25%, respectively, after
6-months of storage in Nebraska. Large square bales
can spoil from the top and bottom and lose DM rapidly.
Wrapping big round bales with at least three wraps of
net-wrap maintains the structure of the bale and reduces
bale contact with the ground and tarping reduces dry
matter loss to less than 3% in 6-months. Improper
storage not only results in DM losses, but can change
the compositional characteristics of the biomass. For a
detailed review on harvest and storage management, see
Mitchell and Schmer (2012).

However, an alternative that can provide wildlife benefits
is to postpone harvest and temporarily store mature
biomass in the field. Depending on the length of time that
harvest is deferred, there may be some loss of material
(yield or quality) but native warm-season grasses tend
to be resistant to lodging and loss. In-field storage of
mature, standing biomass can provide wildlife benefits
even if only on a portion of the field and for a few
months. In this case, harvest could occur after snow
melt when the ground is still frozen, but prior to the
early nesting season (~April 1st). Given the challenges
of springtime weather in the Northern Great Plains,
however, greater benefits may accrue if some biomass
could be stored in the field until the end of the following
growing season. At that time, it could be harvested with
new growth and the ‘standing-storage’ approach could
be rotated to a different area. According to Harper and
Keyser (2008), deferring as much as 50 percent of a
field each year and harvesting on a biennial basis would
not amount to losing 50 percent of the field each year
because much of the yield from Year One is still present
in the field when harvested at the end of the second
growing season. In addition, letting biomass over-
winter and harvesting in spring reduces ash and protein
concentrations even more, but research has indicated
that yield can be reduced by up to 40%. How much
yield would be impacted by waiting to harvest until the
end of the second growing season is an area in need of
further research.
Based on the previous discussions of wildlife habitat, ecosystem integrity, and species-specific needs, the following BMGs have been developed to assist landowners and producers in establishing, managing, and harvesting biomass crops for bioenergy production in a manner that will be more compatible with wildlife resources. These are minimal, broad guidelines meant to incorporate a basic habitat foundation regarding sustainability of wildlife as based on expert opinion and the best available science; producers are encouraged to consult with their state fish and wildlife agency to further develop additional or more detailed wildlife-friendly practices for their local conditions.

**Landscape and Site Selection Considerations**

- Do not convert prairie/sod, wetlands, or other rare native ecosystems.

- Plant biomass crops on existing cropland or other land with a cropping history.

- Plant biomass crops, as much as possible, on fields adjacent to native prairie/sod or established stands of native warm-season grasses to increase native ecosystem health (larger tracts of continuous grassland are better than smaller fragments).

- Use native grasses as biomass feedstocks. Locate big bluestem, indiangrass, and sideoats grama mixtures on drier sites and switchgrass on either dry or wet sites (depending on cultivar – upland or lowland) to take advantage of the range of growing conditions native grasses provide.

- Avoid tiling or ditching to drain water from land or in-field low areas that provide important wetland habitat in the early spring.

- Be aware of potential resources (food, water, cover) in the surrounding area and, as feasible, plant feedstocks that complement those resources.

- Consider using biomass plantings as conservation practices for existing cropland; for instance, place plantings along water bodies (streams, ditches, lakes,
rivers, wetlands) to reduce erosion and chemical runoff, and on highly erodible soils to reduce erosion.

- In the event hybrid or genetically-modified varieties are considered for use, consult with the state fish and wildlife agency to determine potential risk to nearby native prairie/sod and develop a containment plan.

**Planting Design**

- Match the native grass feedstock to local/regional soil types and vegetation to enhance yield potential and ecosystem compatibility.

- Consider growing diverse mixture of big bluestem, indiangrass, and sideoats grama as well as switchgrass to create diversity of habitat (structural and spatial) on the landscape and reduce risk to the producer through crop diversification.

- Create a native warm-season grass/forb buffer zone around potholes, wetlands or other bodies of water to provide habitat (pollinators included) and an agrochemical barrier. These buffers should be as wide as possible (100’ minimum recommended), seeded at the lowest NRCS rate, and include a 50’ unmowed area (closest to the pothole/wetland) with the remainder harvested at a height of 10” or higher.

- Establish native warm-season grass/forb field borders on portions of the field not connected with potholes/wetlands to retain inputs on site and provide additional wildlife habitat. These field borders should be wide enough to address site-specific wildlife needs (consult the state fish and wildlife agency to determine the appropriate width) and managed to create early successional habitat by burning, disking, or haying every 3 to 5 years.

- Consider enrolling field borders and wetland buffers in wildlife-friendly conservation programs, which also provide a constant and dependable source of revenue.

**Establishment**

- Follow NRCS recommended seeding rates and do not exceed as doing so increases establishment cost and makes stands less desirable for ground-dwelling wildlife.
• Avoid the use of fertilizer during the establishment year to minimize excessive weed growth (which can slow growth of the grasses planted) and potential runoff into streams and wetlands.

• For fields that were planted to a winter cover crop the previous fall, prepare/plant fields as early as practical, but avoid planting during the peak nesting period. Check with the local NRCS office and state wildlife agency for local peak nesting seasons and dates.

• Plant no-till fields as late as practical to leave residual food/cover longer for wildlife.

• Plant bare, conventional-tilled fields as soon as possible to reduce erosion and improve quality of water feeding wetlands/potholes.

• Use only the minimum rate of herbicides needed to establish biomass plantings and consider the alternative of mowing when weeds are about 12” tall (leave 6” stubble).

• Avoid the use of herbicide in field borders and wetland buffers.

Management

• Avoid use of fertilizer, herbicide, or mowing in core buffer areas around potholes, wetlands and other bodies of water and in unharvested field borders – manage upland buffers with prescribed fire or shallow disking (to set back plant succession) once every 3 to 5 years, prior to April 15 or after August 1 to avoid peak nesting season.

• With the technical assistance of NRCS, develop and follow an integrated pest management plan that takes advantage of avian and insect predators and minimizes the use of chemical pesticides.

• In the event chemical pesticides are necessary, consider withholding application in a buffer adjacent to wetlands/potholes (width determined in consultation with NRCS and the state fish and wildlife agency).

• Monitor fertility and minimize use of fertilizers through stand development and beyond with the aid of an NRCS precision nutrient management program plan designed specifically for perennial grasses, (saves cost, benefits water quality, and is easier on wildlife).

• Consider periodic spring prescribed burns (prior to peak nesting season) on portions of field with enough stubble residual from the previous year to carry a fire (stimulate grasses and benefit wildlife).

Harvest

• Add flushing bars to equipment to minimize bird injuries and deaths.

• Harvest fields from the interior of the field to the exterior to encourage wildlife to flush into surrounding areas.

• Leave at least 4" to 6" stubble after harvest to elevate windrows (aid airflow and speed up drying), and catch/retain snow to boost soil moisture. Higher stubble heights (>10") are recommended to benefit wildlife.

• Leave wildlife cover in the form of taller stubble (10" or taller) after harvest on unproductive portions of fields (e.g., wet depressions, highly eroded areas) or adjacent to potholes/wetlands. This stubble will provide winter habitat and spring nesting cover – blocks are better than strips (5% of the total field area is recommended).

• Avoid harvest until after the first frost to avoid disturbance of nesting wildlife and improve quality of biomass (i.e., reduce moisture and nutrient content) for bioenergy production.

• Consider incremental harvest after the end of growing season (i.e., store portions of the biomass as a standing crop) versus harvesting all at once – this will leave some cover for wildlife.

• Consider leaving a portion of the field as a standing crop and delaying harvest until the end of the next growing season, at which time another area can be deferred.
The science behind the use of native perennial grasses for bioenergy production is still developing. Additional research will continue to discover better methods for planting and harvesting to increase biomass yields while also improving wildlife habitat. Some examples include:

### Landscape and Site Selection Research Needs

- Understanding the landscape-scale effect of bioenergy production on presence, diversity, and population health of wildlife and associated food webs and community structure.

- Assessing the “before-and-after” effects on wildlife of converting natural systems to bioenergy production over both the short- and long-term.

- Evaluating long-term response of wildlife use across varying feedstock production systems

- Using biomass sources that do not require a bigger agricultural footprint, such as from residues or other wastes.

- Evaluating the ecological impact of native grass feedstock varieties, hybrids, and genetically modified plants on remaining native grassland ecosystems and assessing the effectiveness of containment alternatives.

### Potential Future Improvements

Additional research will continue to discover better methods for planting and harvesting to increase biomass yields while also improving wildlife habitat.
Planting Design Research Needs

• Diversifying feedstocks and resulting implications for wildlife.

• Interseeding legumes into perennial grasses in biomass production fields to increase yield potential, minimize the need for external fertilizer, and provide additional wildlife habitat.

Establishment Research Needs

• Analyzing the impact of stand density on wildlife use and biomass production.

Management Research Needs

• Quantifying the response of bioenergy-specific cultivars to N, P, and K and resultant impacts on wildlife.

Harvest Research Needs

• Identifying, demonstrating, and refining biomass harvest strategies that provide the greatest benefits to wildlife and the industry (e.g., harvesting in stages).

• Researching the effects of harvest timing and frequency on crop yield and wildlife production.

• Analyzing the potential for delayed harvest and its effects on crop yield and wildlife production.

• Optimizing post-harvest stubble height for wildlife.

As interest in bioenergy from native warm-season perennial grass feedstocks continues to expand, sustainable production of these crops will become increasingly important in order to ensure long-term, healthy yields that minimize negative impacts on the environment. Producers and the bioenergy industry already recognize the potential for native warm-season grasses to reduce agricultural runoff, improve water quality and greenhouse gas emissions, and stabilize soils. In addition, advancements in herbicides, cultivar development, cultivation methods, and planting equipment have dramatically improved the ease of establishment and management of these feedstocks. The development and site-specific incorporation of the BMGs outlined in this document will serve to expand the definition of “sustainability” to include our wildlife resources and the many biological, economic, and social services they provide.
Endnotes


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South Dakota potholes. Credit: NRCS.