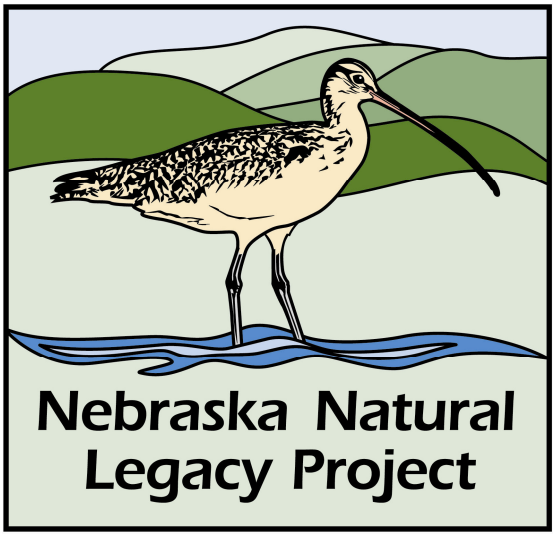
American Burying Beetle

(*Nicrophorus americanus*)

A Species Conservation Assessment
for
The Nebraska Natural Legacy Project



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The mission of the Nebraska Natural Legacy Project is to implement a blueprint for conserving Nebraska's flora, fauna, and natural habitats through the proactive, voluntary conservation actions of partners, communities and individuals.

Purpose

The primary goal in development of at-risk species conservation assessments is to compile biological and ecological information that may assist conservation practitioners in making decisions regarding the conservation of species of interest. The Nebraska Natural Legacy Project recognizes the American Burying Beetle (*Nicrophorus americanus*) as a Tier I at-risk species of high conservation priority. Indeed, the American Burying Beetle (ABB) is a species of conservation need throughout its range. Here, I provide some general management recommendations regarding ABB; however, conservation practitioners will need to use professional judgment for specific management decisions based on objectives, location, and site-specific conditions. This resource provides available knowledge of ABB that may aid in the decision-making process or in identifying research needs for the benefit of the species. Species conservation assessments will be updated as new scientific information becomes available. The Nebraska Natural Legacy Project focuses efforts in the state's Biologically Unique Landscapes (BULs), but it is recommended that whenever possible, practitioners make considerations for a species throughout its range in order to increase the outcome of successful conservation efforts.

Common Name	American Burying Beetle	**Scientific Name**	*Nicrophorus americanus*
Order	Coleoptera	**Family**	Silphidae
G-Rank G2G3	**S-Rank** S1	**Goal** 10	**Distribution** Limited
Criteria for selection as Tier I	State and federally listed as Endangered (July 1989), G2 (Federal Register 54:29652-29655)		
Trends since 2005 in NE	Fluctuating with drought		
Range in NE	North-central and southwest-central portion of the state		
Habitat	Wet meadows in Sandhills, open woodlands, loess canyons		
Threats	Eastern redcedar encroachment, drought, land development, light pollution, scavengers Climate Change Vulnerability Index: Highly vulnerable		
Research/Inventory	Determine specific habitat use; effects of land management practices; population sizes; conduct long-term monitoring of individual populations		
Biologically Unique Landscapes	Cherry County Wetlands, Elkhorn River Headwaters, Keya Paha, Loess Canyons, Middle Niobrara, Upper Loup Rivers and Tributaries, Verdigris-Bazile		

Status

ABB was state and federally listed as an endangered species on 13 July 1989, Federal Register 54:29652-29655 (USFWS 2012). The IUCN Red List Category is CR - Critically Endangered (NatureServe 2009). The state Heritage status rank of ABB is S1, U.S. national status is N2N3, and global conservation rank is G2G3 Imperiled (NatureServe 2009). The distribution of ABB in the state is limited. The Nebraska Natural Legacy Science Team set a goal of maintaining 10 populations in the state, assuming there is little movement between populations and fates of populations are not correlated. Moderate viability (40% chance of survival) of each population gives >99% probability of at least one population surviving 100 years (Morris et al. 1999).

Causes of Endangerment

The range-wide declines observed in populations of ABB are likely attributed to several causes. Some pesticide application practices can harm ABB (USFWS 1997, Perrotti 2012). The pesticide DDT may have extirpated populations (as reviewed in Sikes and Raithel 2002). Sharp declines in ABB have been positively correlated to the loss of the now extinct Passenger Pigeon (*Ectopistes migratorius*); this species of pigeon could have served as a suitable food source for ABB to rear offspring. Also, ABB is vulnerable to fragmentation of its habitat. Conversion and development of the landscape break up suitable habitat patches for not only ABB but also the species it relies on during its life cycle. In fact, ABB seems to be more responsive to carrion availability than vegetation type (NGPC and USFWS 2008), and ABB has to compete with scavengers, and possibly congeners, (as reviewed in Sikes and Raithel 2002) for carrion. Furthermore, developments are normally associated with an increase in night-time lighting and bug zappers that may disrupt the nocturnal behavior of ABB and directly harm the beetle (Perrotti 2012). Dogs and cats may prey on ABB that are attracted by lights into neighborhoods (W. W. Hoback, pers. comm.). As land is converted into new uses and developed, ABB is diminished or locally extirpated. There is also evidence that invasive woody plants such as eastern redcedar (*Juniperus virginiana*) encroach and degrade habitat for ABB (Walker and Hoback 2007). ABB is vulnerable to desiccation, and during drought years, it seems many ABB die (Bedick et al. 2005). A recent study conducted in Oklahoma by researchers from Augustana College, SD demonstrated that vibrations from wind turbines decreased the speed at which ABB could bury a carcass from 24.0 hrs to 51.1 hrs ($T = 3.43$, $df = 10$, $P = 0.006$), leaving them more vulnerable to competitors and predators (C. L. Hall, unpubl. data). A Climate Change Vulnerability Index assessed risk to ABB as highly vulnerable to climate change (Young et al. 2010).

Species Description

ABB is the largest member of its genus, earning it the alternate name of giant carrion beetle. It is similar to other beetles in genus *Nicrophorus* but can be identified by orange behind the head and an orange patch between the eyes. The body is shiny black with distinct orange bands on wings. The male's orange-red rectangular mark below the frons is larger than the female's mark, which is triangular. Length is 1.0–1.8 in (25–45 mm) (USFWS 1991); most adults are 1.2 in (30 mm) (NYDEC 2011).

Habitat and Range

Historically, ABB was recorded in 35 states of eastern and central United States (USFWS 2002). Today, it only occupies approximately ten percent of its former extent (USFWS 1991). In the Midwest, its decline was most evident in the central part of its range with most modern-day specimens collected from the periphery of its range (Ratcliffe 1997). In recent years, the beetle has been found in only seven states: Arkansas, Kansas, Nebraska, Oklahoma, Rhode Island, South Dakota, and Texas (Bedick et al. 2004). Nebraska and Oklahoma have the largest proportion of extant occurrences of ABB (USFWS 2008), but ABB in Oklahoma could be at risk from increased construction of oil and gas well developments in recent years (USFWS 2008). In southern parts of its range, ABB is also at risk of being displaced by red-imported fire ants (*Solenopsis invicta*) that compete for small vertebrate carrion and can feed on larvae of beetles (Scott et al. 1987, Trumbo 1990).

The insects' habitat requirements are not fully understood but appear to be somewhat general. Carrion availability is likely a limiting factor to ABB, but vegetation and soils can influence the prey food base (NYDEC 2011). In Kearney County, Nebraska, no correlations were found with soil type or land use and the presence of ABB specifically, but niche partitioning was observed for other carrion beetles (Bishop et al. 2002, USFWS 2008). In Oklahoma and Arkansas, ABB seemed to prefer sandy soils (i.e., >40% sand) (Backlund et al. 2008). Carrion beetle species have been trapped more frequently in lowland prairie than highland prairie (Rintoul et al. 2005). In Nebraska, ABB seem to prefer wet meadow (M. Fritz, pers. comm.) and clay-based, less rocky soils of Loess mixedgrass prairie (T. J. Walker, pers. comm.). Soil moisture content of 75–100% seems to be preferred (W. W. Hoback, pers. comm.). ABB can use agricultural lands when cropland comprises approximately <30% of the landscape (T. J. Walker, pers. comm.). ABB have generally been found in areas with little human development, including prairie, forest edge, and scrubland near Gothenburg, Brady, North Platte, and the north-central grasslands (Ratcliffe 1997, Schneider et al. 2011). Jurzenski (2012) found that "loamy sand, variable soil textures, wetland, and easting as a surrogate of precipitation were found to be positively correlated with ABB presence; whereas, loam soil, agriculture, woodland, and development were negatively correlated." Some evidence suggests that the encroachment of invasive eastern redcedar (*Juniperus virginiana*) can reduce habitat suitability (Walker and Hoback 2007).

In Nebraska, ABB concentrate in the Loess Canyons and Sandhills (Schneider et al. 2011). Inventory of ABB revealed that Blaine County, NE in the Sandhills had a large population of 56 individuals/km^2 (1,338 ± 272) in 2003 (Jurzenski et al. 2011). Models have been constructed to begin gaining a better understanding of ABB presence range, habitat suitability, and priority conservation areas; target areas occur in the Loess Canyons of Lincoln County and Sandhills (Holt, Rock, Garfield, and Wheeler counties) (See Jurzenski 2012). See Figure 1 for range of ABB within Nebraska. ABB is non-migratory (NatureServe 2009).

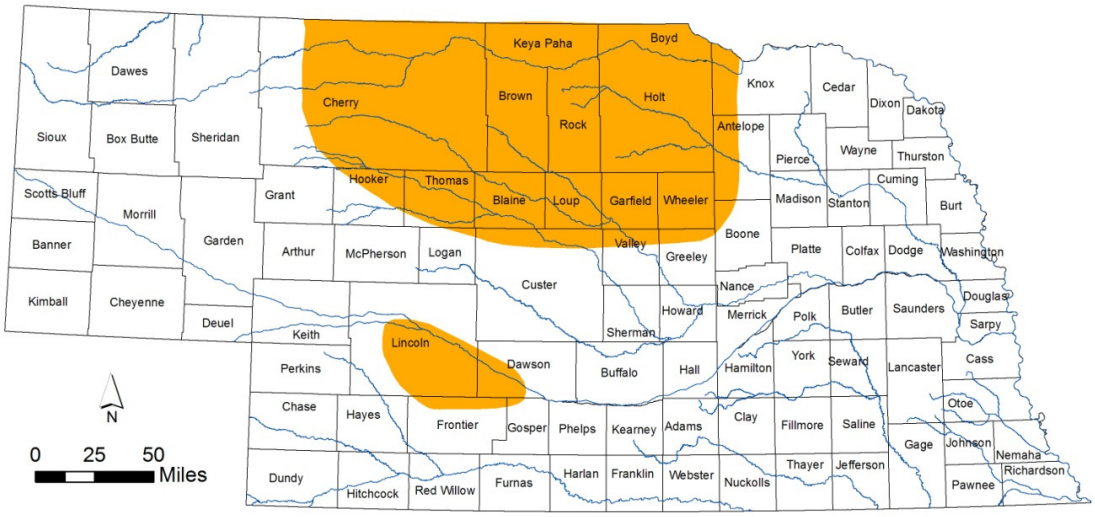

FIGURE 1. Current range of ABB in Nebraska based on field observations, museum specimens, and expert knowledge. Map courtesy of Nebraska Natural Heritage Program, Nebraska Game and Parks Commission.

Dispersal

Individual ABB have been documented to disperse 7.24 km/ night (4.5 mi) in Nebraska (Jurzenski et al. 2011). NatureServe (2009) indicates movements up to 13 km (8 mi). If ABB are aided by wind, they may travel over 29 km (18 mi) (Jurzenski 2012).

Diet

The beetle feeds mainly on a broad range of carrion (USFWS 1991) that it can smell as far as 2 mi away using olfactory organs of the antennae (Ratcliffe 1997, USFWS 2011). ABB feed on carcasses of all sizes, but carcass selection is more discriminating during brooding; with typical vertebrate carcass weights of 80–180 grams providing an adequate food source for developing larvae (Perrotti 2012). Pheasant and woodcock chicks are an adequate size; most mice are too small to be a suitable food source for brood rearing (NYDEC 2011). The food source is buried to limit competitive insects and scavengers from feeding on it (USFWS 2011). As the carcass is buried in soft substrate, it is rolled into a ball. An ABB pair can completely bury a carcass in just over an hour (W. W. Hoback, pers. comm.). Adult ABB will also prey on live insects (NYDEC 2011).

Life Cycle

ABB has been observed in Nebraska from 14 April - 29 October, but it has two peak periods of above-ground activity each year (NGPC and USFWS 2008). Typically in early summer (early June – early July) beetles emerge from hibernation. Later in July, beetles go underground again to raise their brood on a buried carrion item. Ten to thirty eggs are laid near carrion and hatch within 4 days (USFWS 2011). Both parents regurgitate to feed larvae from a

carcass up until the first instar stage (Raithel 2000). The number and size of larvae produced are positively correlated to carcass weight (Kozol 1990). A parent may consume some young if the food source is inadequate in supporting the entire brood. After larvae pupate, emerged adults live another 4–6 months (STLZOO 2011) but likely shorter in the wild (T. J. Walker, pers. comm.). The second period of above-ground activity is late summer (early August – early September) after the brooding cycle, when tenerals and older beetles occur above-ground. Early fall, new adults bury in the ground to hibernate over winter. Parents winter after reproduction or die (NYDEC 2011).

Research and Conservation Strategies

A multitude of factors should be considered before implementing any conservation actions for species. Within the guidelines of state and federal law, the Nebraska Natural Legacy Project recommends: 1) consider, but do not limit options to, scenarios that benefit both the species of interest and property owners, 2) consider species dispersal and landscape context, 3) plan for multiple years, and 4) do no harm.

Because ABB is a federally listed species, its "unauthorized taking, possession, sale, and transport" is prohibited; any management actions or manipulative research methods implemented for ABB are subject to policies of the Endangered Species Act of 1973 - ESA (16 U.S.C. 1531-1544, 87 Stat. 844), as amended – Public Law 93-20. ESA - Section 7 requires that "any action authorized, funded or carried out…is not likely to jeopardize the continued existence of listed species or modify their critical habitat" (ESA 1973). Furthermore, the Nebraska Game and Parks Commission (NGPC) has responsibility for protecting endangered and threatened species under authority of the Nongame and Endangered Species Conservation Act (NESCA),(Neb. Rev. Stat. § 37-801 to 37-811) (NESCA 1975). Nebraska Game and Parks Commission (NGPC) has entered into a Programmatic Agreement (PA) with the U.S. Fish and Wildlife Service (USFWS) to conserve threatened and endangered species (NGPC and USFWS 2008). In some cases, other agencies have developed PAs with NGPC for these species as well. Habitat work for the species must be in compliance with the most current PA, as amended. Any management actions outside the parameters of the PA that directly impact threatened and endangered species (e.g., ABB) require environmental review and approval from the NGPC Environmental Analyst. Refer to the PA and obtain appropriate approval and permits as necessary for management actions that may impact ABB.

The U.S. Fish and Wildlife Service American Burying Beetle Recovery Plan (USFWS 1991) recommended:

1. Protect and manage extant populations
2. Maintain captive populations
3. Continue Penikese Island reintroduction effort [off the coast of MA]
4. Conduct studies
5. Conduct searches for additional populations
6. Characterize habitat and conduct vertebrate inventories
7. Conduct additional reintroductions
8. Continue to conduct research into the species' decline
9. Conduct information and education programs

In Nebraska, conservation considerations should be made for ABB in at least seven Biologically Unique Landscapes: Cherry County Wetlands, Elkhorn River Headwaters, Keya Paha, Loess Canyons, Middle Niobrara, Upper Loup Rivers and Tributaries, and Verdigris-Brazile. These landscapes offer the best opportunities for conservation of ABB within Nebraska based on current knowledge. Given the identified causes of endangerment, conservation efforts for ABB may want to employ the following management strategies:

1. Some pesticide applications negatively impact ABB, leading to reductions, isolation, and extirpations of populations from direct exposure, reduced availability of live insects as a food source, or secondary exposure from feeding on dead insects exposed to chemicals (USFWS 1991). A particular threat may be chemical grasshopper control. Some of these substances degrade chitin of insects to increase mortality. ABB could be exposed to toxins when feeding on insect remains (M. Fritz, pers. comm.). Limit pesticide use. Treatments applied while ABB is underground are less likely to negatively impact the beetle. When pesticide use is planned, work with landowners and managers to choose options of least detriment to ABB.

2. Disturbances during certain times of the year in known locations of ABB have the potential to cause negative physical impacts to the beetles. Disturbance should be minimized during ABB's above-ground stage of life cycle. In some instances, permits will require the removal of ABB and the clearing of carcasses before planned disturbance actions. The exact timing of ABB emergence will vary based on locations and conditions. Typically disturbance (e.g., prescribed fire) in early spring (possibly March) would be appropriate. Soil disturbance that occurs from May - August in the range of ABB is subject to environmental review (NGPC and USFWS 2008). In general, do not burn and/or graze all areas simultaneously, thus ABB and other at-risk species can seek safe zones. Consult "Native Grassland Management Guidelines for Nebraska's Wildlife Management Areas" (Steinauer at al. 2011) for more detailed management strategies. ABB do not seem to be negatively impacted by haying (W. W. Hoback, pers. comm.), and habitat conditions resulting after prescribed fire and some level of disturbance are likely beneficial to ABB (T. J. Walker, pers. comm.). Beetles may colonize these cleared locations relatively quickly. Nevertheless, fire and grazing should be timed and planned judiciously.

3. Habitat fragmentation leads to greater competition for carrion from other scavengers such as raccoons and opossums (Perrotti 2012). Increased pressure may also raise predation rates on ABB from opossums (Jurzenski and Hoback 2011). At this time, there are no clearly-defined sizes recommended for habitat areas for ABB, but we do know that the burying beetles must search large areas in a variety of habitats to find adequate food (Lomolino et al. 2002). In general, try to maintain large, intact habitats with minimal development. Patch size limits are unclear (T. J. Walker, pers. comm.). It is also appropriate to manage for habitats sized suitably for small prey populations, but getting adequate measurements of the prey base for ABB is very difficult for researchers. Central to the survival of ABB is the fact that they seem to be most successful in landscapes with very little human disturbance (USFWS 2011). Conservation efforts scaled for native birds, mammals, and herpetofauna in landscapes shared with ABB can be designed to benefit the burying beetle as well.

4. Inevitably, conversion and construction projects have the potential to cause mortality of ABB. There are efforts that can be undertaken to deter ABB from occupying a

construction zone in order to avoid take. These strategies may involve heavy disturbance, such as overgrazing or mowing vegetation to a very short stature. In some cases, it may be appropriate to trap ABB using approved methods, and relocate them more than 2 mi away. Baiting away may increase predation and mortality (this ineffective strategy has been removed from federal guidelines) (W. W. Hoback, pers. comm.). Consult with the NGPC Environmental Analyst for more information on operating within the PA and obtaining appropriate permits for activities.

5. Biologists are hampered in their ability to effectively manage for ABB because information regarding details on where the beetles are moving across the landscape is often lacking. Identification of element occurrences of ABB in Nebraska has just developed in recent years. Appropriate permits are needed for capture and release. Pitfall traps baited overnight with carrion are a method of surveying for ABB (see Kozel 1990, Barnhart and Brown 2002, and Bedick et al. 2004 for detailed survey methods). Bedick and others (2004) recommend 18.9 liter bucket traps with soil. Figure 2a shows a biologist checking a typical pitfall trap to sample burying beetles in Nebraska. Captured ABB should be released into a shaded location under trees or shrubs or back into a shallow hole in the ground. One can use a garden spade or even a stick to create a small fissure in the ground for the release. Criteria set forth by the U.S.F.W.S. for a recovered population of ABB are: 1) each population consists of a minimum of 500 adults, 2) each population is self-sustaining for at least 5 consecutive years, and 3) ideally, each primary population contains several satellite populations to support dispersal and colonization (Backlund et al. 2008:10).

6. Research efforts may include mark-recapture and tiny transmitters to track movements and estimate populations. Any objects adhered to the body of an ABB for research purposes should not restrict flight or alter the profile of the beetle enough to impede movement through vegetation, burrowing activities, or reproduction (W. W. Hoback, pers. comm.; T. J. Walker, pers. comm.). University of Nebraska, University of Toronto, and the St. Louis Zoo have been involved in conservation research for ABB. Butler and others (2012) describe effective marking techniques for ABB. Butler and others (2012) found no significant differences in mortality of adult and teneral surrogate burying beetles among four different marking techniques (bee tags, enamel paint, elytron-clipping, and elytron-cauterizing). In general, avoid enamel paint because it may only last a week (Butler et al. 2012). If mark-recapture surveys are completed, a family of models can then be used to obtain population estimates (e.g., program CAPTURE) (Backlund et al. 2008). Butler and others (2012) demonstrated that cauterization of the elytra can be an effective means of marking burying beetles (Figure 2b). Use recommended methods and acquire appropriate permits.

7. ABB has been extirpated from much of its former range. Survey work may reveal that some locations may be appropriate for reintroductions. Captive-rearing may be a feasible option to assist colonization of ABB into available habitats. Based on research looking at alleles from five populations of ABB, no genetic concerns were yet identified that would suggest a limitation on colonization (Szalanski et al. 2000). Breeding programs have taken place at facilities such as the Cincinnati Zoo and Botanical Garden, Boston University, and Oklahoma Biological Survey (USFWS 1991), but the newly established population at Penikese Island, MA became extirpated within 9 years of release (USFWS 2008). We may be able to learn more from the on-going reintroductions of ABB in Ohio (USFS 2011) and the preliminary 5 June 2012 release of an experimental non-essential population into the over 3000-acre Wah'Kon-Tah Prairie

and the surrounding counties in Missouri (TNC 2012). Captive-rearing allowed for the establishment of an ABB population on Nantucket Island (Perrotti 2012). But broadly, it is unclear if most reintroductions are succeeding. Reintroduced populations need to be monitored in order to better understand their potential for success. Reintroductions have not been pursued in Nebraska, because the conservation of relatively large populations in current habitats is more important at this time. The Central Loess Hills BUL is a possible location that could be evaluated for re-introductions based on its landscape characteristics.

8. Artificial lighting may hamper nocturnal activities of ABB (USFWS 2011). ABB can be attracted to the lights and become disoriented (USFWS 1991). Sodium-vapor lamps that emit a yellowish light appear to be a better option in preventing disruption to ABB and causing light pollution (W. W. Hoback, pers. comm.). Look at lighting situation when considering any conservation effort or release site.

9. Because carrion that is sized adequately for ABB to rear young is limited, supplemental food sources may assist populations of ABB (USFWS 2002). Whole fish or waste fish parts may be an appropriate food item for ABB and also an organic fertilizer. Any fish used should be harvested and applied according to regulations. Invasive fish species could be investigated as an appropriate food source for ABB. Other sources of carrion may be appropriate as available and allowed. At this time, there are many unknowns regarding this concept, such as the possible increase in competitors that may arise from this strategy; therefore, supplemental feeding has not been advocated in Nebraska.

10. NatureServe's Climate Change Vulnerability Index tool (Young et al. 2010) evaluated ABB's exposure to, sensitivity to, and capacity to adapt to climate change, and found this species to be highly vulnerable to changes in climatic conditions (Schneider et al. 2011). *Nicrophorus* species, such as ABB, are susceptible to decreased humidity and drought conditions that can cause dehydration and mortality (Bedick et al. 2005, Schneider et al. 2011). Altered temperature and photoperiod have been shown to impact sexual maturity and lifespan of other *Nicrophorus* species (Hwang and Shiao 2010). Investigate and make considerations regarding climate change impacts on ABB. As climate changes, the survival of ABB in Nebraska, and elsewhere, may require assisted colonization into prime habitats of wet meadow and more suitable conditions if locations can be identified that are not too fragmented to support the beetle.

Information Gaps

A greater understanding of the response of ABB to land management practices is needed. Surveys would help researchers gain confidence in population size estimates, and long-term monitoring of individual populations would reveal trends.

a. b.

FIGURE 2. (a) Beetles are captured in a pitfall trap (i.e., baited bucket buried over the rim) to be marked (b) with a cauterizer for mark-recapture studies. Beetles marked in this particular study were a congener, *N. marginatus*, of ABB. Photos courtesy of W. Wyatt Hoback.

Considerations for Additional Species

At-risk species that share habitat with ABB or other species that may serve as good sources of carrion for brood-rearing (e.g., grassland and ground-nesting birds) should be considered in management plans for ABB. Specifically, Natural Legacy Tier I butterflies, Iowa Skipper (*Atrytone arogos iowa*) and Regal Fritillary (*Speyeria idalia*), are vulnerable to inappropriate overuse of fire. Plan accordingly and use rotational burns when fire is used as a management tool for habitats shared by ABB and these species. On-the-ground conservation for ABB may affect or be influenced by Natural Legacy at-risk species that can be found in the same Biologically Unique Landscapes as ABB. Table 1 lists a sample of at-risk species you may want to consider while planning habitat for ABB. This list will not apply to all sites that ABB occupies nor is the list all-inclusive.

TABLE 1. At-risk and other species identified in the Nebraska Natural Legacy Project that inhabit biologically unique landscapes with ABB (Schneider et al. 2011) may necessitate consideration in habitat management plans.

Animals

- Ghost Tiger Beetle (*Cicindela lepida*)
- Iowa Skipper (*Atrytone arogos iowa*)
- Married Underwing (*Catocala nuptialis)*
- Mottled Duskywing (*Erynnis martialis*)
- Ottoe Skipper (*Hesperia ottoe*)
- Regal Fritillary (*Speyeria idalia*)
- Whitney Underwing *(Catocala whitneyi*)
- American Woodcock (*Scolopax minor*)
- Bell's Vireo (*Vireo bellii*)
- Buff-breasted Sandpiper (*Tryngites subruficollis*)
- Burrowing Owl (*Athene cunicularia*)
- Greater Prairie-Chicken (*Tympanuchus cupido*)
- Loggerhead Shrike (*Lanius ludovicianus)*
- Long-billed Curlew (*Numenius americanus*)
- Northern Bobwhite (*Colinus virginianus*)
- Trumpeter Swan (*Cygnus buccinator*)
- Whooping Crane (*Grus americana*)
- Wood Thrush (*Hylocichla mustelina*)
- Bailey's Eastern Woodrat (*Neotoma floridana baileyi*)
- Northern River Otter (*Lontra canadensis*)
- Plains Pocket Mouse (*Perognathus flavescens perniger*)

Plants

- Blowout Penstemon (*Penstemon haydenii*)
- Hall's Bulrush (*Schoenoplectus hallii*)
- Large-spike Prairie-clover (*Dalea cylindriceps*)
- Prairie Moonwort (*Botrychium campestre*)
- Small White Lady's-slipper (*Cypripedium candidum*)
- Western Prairie Fringed Orchid (*Platanthera praeclara*)
- Wolf's Spikerush (*Eleocharis wolfii*)

TABLE 2. Summary of suggested management for ABB in Nebraska. The following should be interpreted as general guidelines based on the best available knowledge at the time of this publication. See Research and Conservation Strategies section of this document for more detail and Literature Cited section for sources of additional information.

FOCUS	STRATEGIES	MITIGATION and CONSIDERATIONS
Limit pesticide use	When pesticides are used, try to time applications outside of periods of peak activity for ABB	Insecticides that degrade chitin may impact ABB
Timing of disturbance	Aim to avoid ground disturbance when ABB has emerged; similar timing preferred for prescribed fire	Generally, do not burn and/or graze all areas at once where ABB are present, so the beetles may have better opportunities to seek safe zones
Unfragmented habitats are best for ABB	Use strategies to maintain and improve large, intact landscapes for ABB where they already occur	Consider managing for prey populations that meet brood-rearing size requirements; wind turbines may be detrimental to reproductive behavior
Prevent and reduce take of ABB	Deter ABB from occupying construction zones by overgrazing or mowing sites to remove vegetation (loss of vegetation reduces suitability of soil by lowering moisture content)	Obtain appropriate permits. Work with developers to find suitable mitigation sites. ABB are vulnerable to desiccation.
Inventory of ABB	Pitfall trapping at night from approximately 2200 to 0200 hrs via recommended methods.	Beetles active at night when temperature is above 55°F. Check traps as soon as possible and release under cover or in ground. Obtain permit.
Movements/dispersal research and population estimates of ABB	Document mark-recaptures and use data to estimate population.	Tiny transmitters are experimental. They could limit or prevent ability of ABB to dig or fly, particularly through vegetation. Bee tags may detach and negatively impact reproduction. Elytron-cauterizing has been effective. See Butler et al. 2012 for complete review of four marking techniques.

TABLE 2 (cont.)

FOCUS	STRATEGIES	MITIGATION and CONSIDERATIONS
Environmental Education and Outreach	Teach youth about the unique life history of ABB. Inform stakeholders of the benefits of the species.	Carcass burial reduces fly infestations and reduces the potential transmission of disease to livestock and humans.

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