Potential impacts of cropland expansion on threatened and endangered species in the United States

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The conversion of land to crop production in the United States may be adversely affecting threatened and endangered species and the federally designated critical habitat upon which they rely. The Endangered Species Act (ESA) requires establishing for each listed species an area of critical habitat that provides resources essential to the survival, reproduction, or recovery of a species. While several regional and species-specific case studies between agriculture and potential or listed threatened and endangered species have occurred (e.g. Poole & Downing, 2004; Runge et al., 2018), limited research has explored the potential scale and impacts of widespread land conversion on species of concern at the national scale. Thus, the overall impact of recent U.S. agricultural land use change on endangered species remains unknown.

Section 7 of the Endangered Species Act (ESA) requires federal agencies to consult with the Fish and Wildlife Service or the National Marine Fisheries Service to ensure that an agency's actions are not likely to jeopardize the existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat. Given the lack of assessment surrounding cropland expansion to date, there could be a number of agencies and associated policies implicated in the impairment of endangered species. As it currently stands, however, each forgone consultation represents a missed opportunity for possible inter-agency collaboration, improved conservation, or mitigation of potential harm to wildlife.

Cropland expansion near terrestrial critical habitat

To help species survive and recover, ESA designates areas of critical habitat that are essential for the species' reproduction, population stability, or distribution. Destruction or adverse modification of critical habitat could occur either through direct conversion of critical habitat or indirectly through conversion of nearby land. For example, conversion of land adjacent to critical habitat could decrease its functionality through landscape fragmentation, microclimate alteration, or encroachment and other proximity effects, and thereby alter the physical or biological features that were the basis for critical habitat designation. Thus, any critical habitat located in agriculturally active areas may be at risk of adverse modification from the expansion of crop production and the associated loss of grasslands and other natural or semi-natural areas.

We screened 359 endangered and threatened species for which federally-designated critical habitats exist to identify those that could potentially be affected by habitat modification, fragmentation, or water quality impairment due to their proximity to recent cropland expansion. Of the screened species, 93 of the 223 terrestrial or land-based species had conversion within 1 mile of their designated critical habitat. Of those, 41 species contained at least 10 acres of conversion directly within their critical habitat boundaries. **Figure 1**

provides an overview of the locations of assessed critical habitat and the concentration of land conversion in close proximity (within 1 mile) of the designated boundaries.

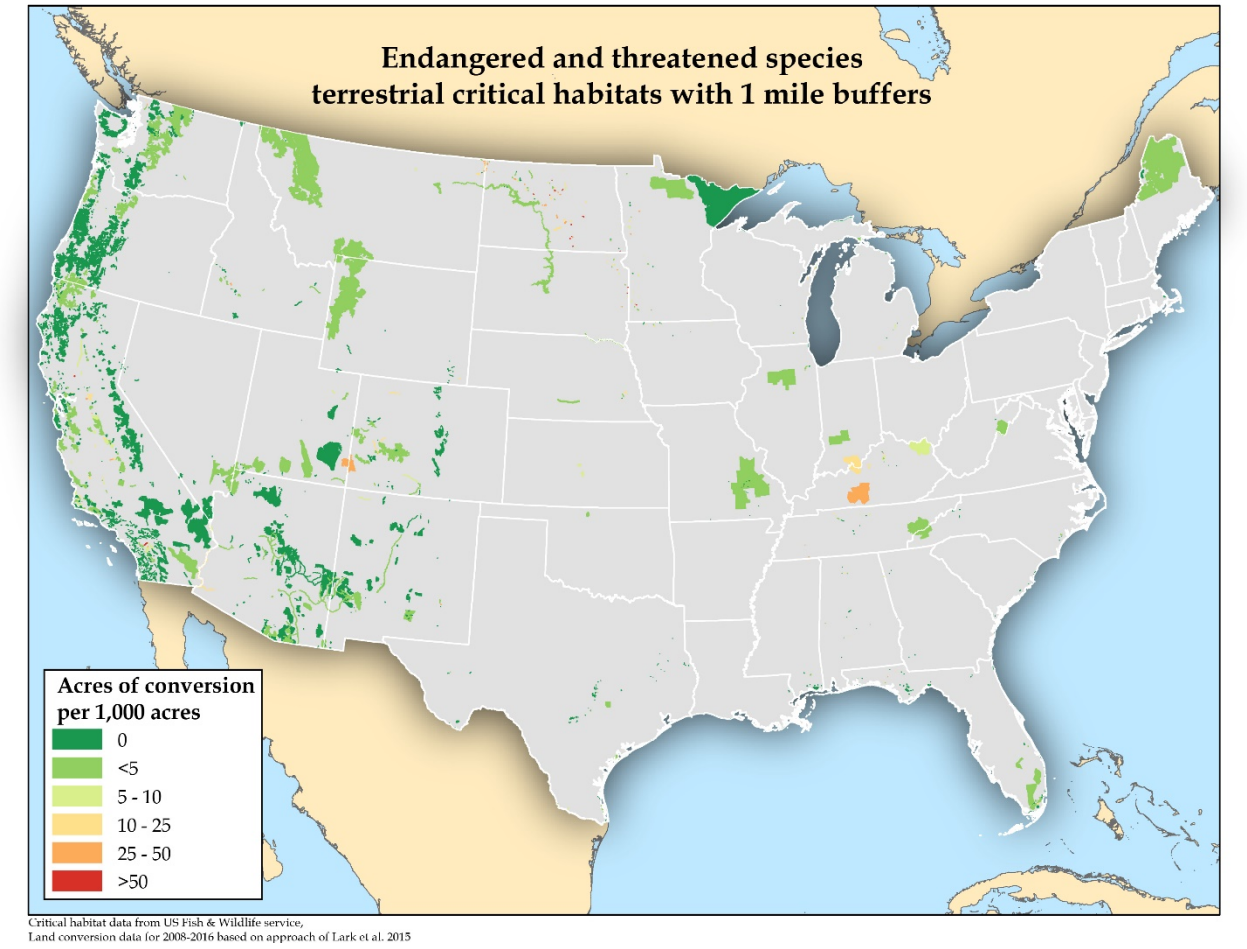

Figure 1: Designated critical habitats of terrestrial endangered and threatened species across the U.S. Each location is categorized according to the amount of conversion to cropland 2008-2016 that occurred within a 1 mile radius of the critical habitat boundary.

Potential impacts on terrestrial species

Given the vast number of species which may be affected by land conversion, we highlight here a limited selection to illustrate the range of taxonomical classes potentially impacted—including insects, birds, and mammals—as well as the variety of possible mechanisms of impairment.

Insects

Poweshiek skipperlings (*Oarisma poweshiek*) are endangered butterflies that inhabit tallgrass prairies in Minnesota, Wisconsin, North Dakota, South Dakota, and Iowa. Habitat fragmentation poses a key threat to the Poweshiek skipperling, and there are several instances where land has recently been converted to

cultivate either corn or soybeans within close proximity to its critical habitat in Minnesota, North Dakota, and South Dakota (see Appendix). Loss of habitat and especially tallgrass native prairie over the years reduced Poweshiek skipperling populations to isolated remaining pockets. This makes it difficult for them to recolonize, as they are only able to fly for short periods at a time and therefore are unable to travel necessary distances in search of a new home (Pogue et al., 2016). Furthermore, if the Poweshiek skipperling is lost in one locale, there are often no nearby populations to recolonize (USFWS, 2014). Adult Poweshiek skipperlings feed on nectar from prairie flowers, and thus the species may also be affected indirectly by cropland expansion due to the loss of nectar sources from the spraying of pesticides during crop production. Skipperlings may also be vulnerable to harm from airborne wafting pesticides, since the insects do not burrow into the ground in their larval stages (Federal Registrar, 2013). Other insects which could potentially be affected by cropland expansion via similar and/or other mechanisms of influence include the threatened Dakota skipper (*Hesperia dacotae*), the endangered Rusty patched bumble bee (*Bombus affinis*), the endangered Hine's emerald dragonfly (*Somatochlora hineana*), and the endangered Salt Creek tiger beetle (*Cicindela nevadica lincolniana*).

Birds

Whooping Cranes (*Grus Americana*) are endangered birds that inhabit prairie wetlands of North America and may be negatively affected by cropland expansion through the loss and fragmentation of habitat. There is substantial conversion of land to crops commonly used as biofuel feedstocks near the species' designated critical habitat in Kansas (see Appendix), as well as conversion to crop production adjacent to its critical habitat and wintering grounds on the Texas coast, which could adversely influence the conservation of the species and the effectiveness of its habitat. Furthermore, the Whooping crane frequently inhabits wetlands throughout its species range, and thus may be impacted by the widespread conversion and drainage of wetlands for crop production that has occurred throughout the region (Lark et al., 2015). Other examples of birds which may be impacted include the threatened Yellow Billed Cuckoo and the endangered Piping Plover.

The threatened Yellow Billed Cuckoo (*Coccyzus americanus*) is a medium-sized bird found in Texas, New Mexico, Arizona, Utah, Colorado, Wyoming, Nevada, Montana, Idaho, Oregon, Washington, and California. The Yellow Billed Cuckoo inhabits riparian areas especially under willows, cottonwoods, and woodlands. They use the vegetation underneath the trees to nest, breed, and search for food, and their threatened status is due in large part to the destruction of these habitats from anthropogenic activities, including agriculture. Pesticide use may also harm the yellow-billed cuckoo, as reproduction problems caused by eggshell thinning have been documented in the population (USFWS, 2014).

Piping Plovers (*Charadrius melodus*) are small shorebirds that live along the Atlantic coast, the Great Lakes, and rivers in the Northern Great Plains. They are threatened on the Atlantic coast and Northern Great Plains and are endangered in the Great Lakes region. These species could be affected by habitat fragmentation or water quality contamination. Piping plovers lay only a few eggs in shallow nests along shorelines, and rely on the associated wildlife and resources for both food and nesting material. Land conversion for crop production could affect this population, as disruption of plover habitat has specifically been shown to be destructive in the Great Lakes endangered population (Cohen et al., 2009), and human activity near the nest can cause abandonment or can interrupt incubation, resulting in egg mortality due to exposure (Fannin & Eamoil, 1993). There has been substantial conversion of land to corn and soybean production throughout the Piping plover's range, including the conversion of riparian areas along its designated critical habitat (see

Appendix). Agricultural pollution to waterways could also affect the species. Northern Great Plains Piping plovers frequently nest around small alkaline lakes, river islands, and other shorelines (Haig & Plissner, 1993), and pesticides or other contaminants from agricultural practices that have reached waterways could jeopardize the birds' egg survival near streams and open bodies of water (Fannin & Eamoil, 1993).

Mammals

Black-footed ferrets (*Mustela nigripes*) are mammals that have been listed as endangered across their entire range, which overlaps with substantial amounts of cropland expansion for corn production across the Great Plains (USFWS, 2018b; Lark et al., 2015). Although a critical habitat area has not been designated, the loss of habitat—including the conversion of native grasslands to agricultural land—has specifically been cited as a key risk to Black-footed ferrets (USFWS, 2018b). The conversion of grasslands to croplands also has been detrimental to populations of prairie dogs, a species upon which the Black-footed ferret is heavily reliant for both food and nesting habitat. Given the connection between cropland expansion and the conversion of grasslands to agricultural land within the Black-footed ferret's range, further assessment may be warranted.

Cropland expansion in critical habitat watersheds

Conversion of land to crop production is typically associated with adverse outcomes for water quality and thus may also affect aquatic species. The fertilizers and manure used to grow crops typically contain high levels of nitrogen and phosphorus, which are routed to waterways through surface erosion and runoff or can leach into groundwater. In surface water, this nutrient loading promotes the growth of plants and algae through eutrophication. This process can lead to dissolved oxygen depletion and thus hypoxia, making waterways inhospitable to many forms of life. Other effects of eutrophication and excessive nutrient loading include increases in algal toxin levels and the frequency of harmful algal bloom events (U.S. EPA, 2017a; Carpenter et al., 1998).

Nutrient runoff, eutrophication, and hypoxia due to increased crop production and the associated decreases in water clarity and oxygen content could jeopardize the health of federally threatened and endangered aquatic species. As of 2007, according to the U.S. Fish and Wildlife Service's endangered species database, 139 fish, 70 mussels, four crayfish, 23 amphibians, and one water dependent dragonfly had endangered or threatened status, and it was estimated that approximately 60 of these species are at least partially imperiled by eutrophication (Dodds et al., 2009). Species within the corn belt and other agriculturally intensive regions and their watersheds may be at greatest risk of impairment from increased crop production and associated land use changes.

We screened 136 aquatic species for potential impairment from water quality due to their proximity to cropland expansion. Of the critical habitats screened, 107 of had potential land conversion within their immediately adjacent watershed (HUC-12 subwatersheds). For the 16 aquatic species with the greatest amount of nearby land conversion, over 5% of the land in their surrounding watersheds was converted to crop production between 2008 and 2016 (**Figure 2**).

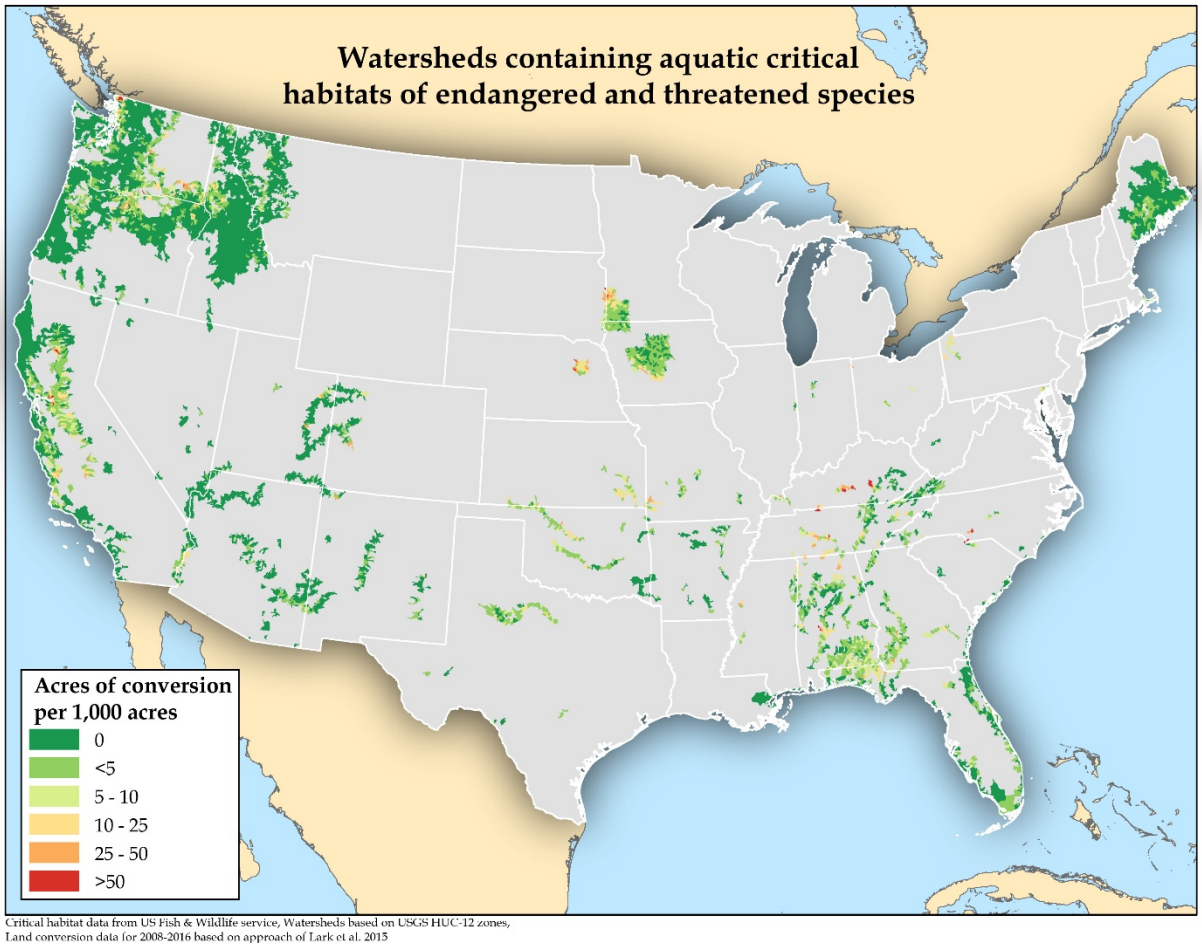

Figure 1: Critical habitat watersheds of aquatic threatened and endangered species across the U.S. The map shows the watersheds of all established aquatic critical habitats, such as freshwater rivers and streams. Each critical habitat is categorized according to the amount of conversion to cropland 2008-2016 that occurred within its HUC-12 sub-watershed.

Potential impacts on aquatic species

Freshwater Fish

The critical habitats with the greatest amounts of conversion within their watersheds contained several freshwater fish and mussel species that could potentially be impaired. For example, the Topeka Shiner (*Notropis topeka*) is a small endangered minnow that resides in prairie streams in the central United States where it is usually found in pool and run areas. Its range includes Iowa, Kansas, Minnesota, Missouri, Montana, Nebraska, and South Dakota (UWFWS, 2018). There has been substantial conversion of land to corn and soy production throughout the Topeka Shiner's habitat range as well as within the immediate vicinity of its designated critical habitat in southwest Minnesota and northwest Iowa (Lark et al., 2015, 2019), and agricultural activities that increase sedimentation or otherwise impact water quality are specifically listed

as threats that require special management in the species' critical habitat watershed (Federal Registrar, 2004). Given this impact mechanism, it is feasible that increased crop production could negatively affect the survival or recovery of this endangered species. A similarly impacted fish species is the Arkansas River shiner (*Notropis girardi*), a minnow found in Texas, New Mexico, and Oklahoma (see Appendix).

Mussels

Mussels can experience habitat fragmentation through the processes of sedimentation and impoundment. The sediment buildup that may occur due to an increase in agricultural activity can lead to the covering of mussels which may result in both resource deprivation as well as isolation of different populations (USFWS, 2018a). Excessive chemicals and nutrients in water systems are also a major threat to mussels such as the Purple Bankclimber due to its lifestyle as a filter feeder (McCann & Neves, 1992; Havlik & Marking, 1987), and the inflow of chemicals from nearby cultivated fields can be directly ingested by and harm these mussels. For example, ammonia is linked to fertilizers and is most often found in streams at the interface of the substrate and water, where mussels reside (Frazier et al., 1996), and ammonia has been shown to be lethal to mussels at concentrations of 5.0 ppm (Havlik & Marking, 1987). Young mussels are especially susceptible to these negative impacts (Robison et al., 1996), and deadly levels of pesticides and fertilizers from crop agriculture have been specifically reported in the Apalachicola-Chattahoochee-Flint river basin, which many mussels inhabit (Frick et al., 1998). Recent expansion of land used for crop production has also occurred in the region (see Appendix). Potential species impacted include the Fat Threeridge (*Amblema neislerii)*, Purple Bankclimber (*Elliptoideus sloatianus)*, Gulf Moccasinshell (*Medionidus penicillatus)*, Oval Pigtoe (*Pleurobema pyriforme)*, and Shinyrayed Pocketbook (*Lampsilis subangulata).* Fat Threeridges, Gulf Mocassinshells, Oval Pigtoes, and Shinyrayed Pocketbooks are all endangered mussels found in Georgia and Florida. Purple Bankclimbers are threatened mussels found in Georgia, Florida, and Alabama.

Marine species

The link between cropland expansion and hypoxia in the Gulf of Mexico has also been well established (Donner & Kucharik, 2008). The Gulf "dead zone"—a major hypoxic zone which forms seasonally in the northern Gulf of Mexico—is caused by the interaction of environmental conditions, water stratification, and excess nutrient pollution from the Mississippi River (National Oceanic and Atmospheric Administration, 2017). Corn and soybean cultivation is the greatest source of nitrogen loading to the Gulf of Mexico and contributes approximately half the total influx there (Alexander et al., 2008; Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2015). Harms to aquatic life in the "dead zone" include reduced growth and reproduction, habitat destruction, and death (National Oceanic and Atmospheric Administration, 2017; U.S. EPA, 2017b). The large seasonal dead zone in the Gulf may thus affect the critical habitat or migration and feeding ranges of any current and pending federally listed species which utilize the region, including the threatened Loggerhead Turtle, threatened Gulf Sturgeon, and endangered Sperm Whale.

Loggerhead sea turtles (*Caretta caretta*) spend the majority of their lives in coastal and offshore waters of the Gulf of Mexico, Caribbean Sea, and Atlantic Ocean. The nearshore waters of the Gulf provide valuable foraging habitat for juvenile and adult sea turtles, as well as important mating and inter-nesting habitat. Loggerheads in the near-shore northern Gulf of Mexico waters may be exposed to hypoxia (Hart et al., 2013) and thus could be affected by expansion of the Gulf hypoxic zone from increased crop cultivation. Indeed, the increased duration and extent of the hypoxic dead zone, as well increasing frequency of red tides and harmful algae blooms in the Gulf of Mexico, have been reported to both directly and indirectly affect sea

turtles (NMFS et al., 2011). Other species which may be impacted by similar mechanisms are the Gulf Sturgeon (*Acipenser oxyrhynchus desotoi*) and Sperm whale (*Physeter macrocephalus*). Gulf Sturgeons have designated critical habitat at the immediate mouth of the Mississippi river, and the species is vulnerable to low dissolved oxygen levels and hypoxia (USFWS & NMFS, 2003). Sperm whales (*Physeter macrocephalus*) are listed as endangered throughout their range, maintain a substantial year-round population in the Gulf of Mexico (NOAA, 2018, 2016), and may suffer a possible reduction in their food sources and sightings in this region due to the annual Gulf hypoxic zone.

Conclusions: More research needed

To date, little research has been performed regarding the potential impact of cropland expansion on federally threatened and endangered species. This initial assessment of the potential impacts of agricultural land conversion on critical habitat provides early insights into the wide range of possible impacts on animal wildlife species. Given the dearth of existing analyses on the topic and the potential mechanisms of influence highlighted here, further research could help improve understanding of the risks facing threatened and endangered wildlife as well as the opportunities available to help conserve these species and the habitat upon which they rely.

Methods

We used data from the U.S Fish and Wildlife Service to map the locations and extents of critical habitat for both threatened and endangered species for those which a critical habitat has been designated. We used land conversion data for 2008-2016 based on (Lark et al., 2015, 2017) to identify the amount of conversion directly within critical habitat as well as within 1 mile and 10 mile radii of critical habitat boundaries. For different species, different distances may represent appropriate radii of influence. For analysis and display, we chose the distance of 1 mile since it is large enough to capture adjacent land use change activity while remaining a small enough to be relevant to many of even the smallest species, including insects. For example, a radius of 1.5 km is often used in analyses of landscape composition on crop pests and predators (Werling et al., 2014).

Appendix

See appended figures for example maps of recent potential land conversion in close proximity to threatened and endangered species' critical habitats.

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