FINAL REPORT

SASKATCHEWAN AGRICULTURAL WETLAND DRAINAGE: WILDLIFE HABITAT

Prepared for:

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EXECUTIVE SUMMARY

Saskatchewan's Water Security Agency (WSA) is developing a new wetland mitigation policy to support environmentally responsible agricultural development.

To achieve this goal, WSA is conducting multi-faceted evaluations of the costs and benefits associated with wide-ranging wetland retention scenarios. This report focuses on **wildlife habitat**.

A **qualitative review** of relationships between wetland and adjacent riparian habitat and wildlife populations indicated that accelerated wetland losses to drainage for cropland expansion:

- could reduce white-tailed deer and moose populations, with possible adverse impacts on hunting opportunities;
- would have negative effects on critical habitat and populations of several priority wetland bird and amphibian species, while
- populations of beneficial invertebrates (e.g., pollinators, pest predators) inhabiting wetland margins could also be negatively affected.

A **quantitative analysi**s incorporating wetland inventory and land cover data explored how wildlife habitat, bird abundances, and bird species richness could change in response to reduced levels of wetland retention (ranging from historic, through 10% decrements in wetland area, to the lowest retention levels on lands composed of protected areas and lands with low crop production potential). Modelling results indicated that:

- as expected, areas of remaining wildlife habitat declined quickly with progressive wetland reductions as wetland and natural upland habitats were converted to crop production;
- model-predicted wetland-associated bird abundances decreased in direct proportion to wetland retention levels;
- aerial insectivore (birds that capture flying insects) abundance also declined but at slightly slower rates than wetland birds relative to wetland loss.
- there was no clear indication that decreases in bird abundances became stronger or weaker as wetland retention levels declined (i.e., no threshold effects were evident).

Focused case-studies based on wetland inventory and land cover data for the Qu'Appelle River basin showed that:

- average bird species richness decreased gradually as wetland drainage and clearing of natural land cover progressed;
- preferentially draining smaller wetlands (e.g., Class III seasonal ponds) produced stronger decreases in wetland bird abundances especially during early phases of wetland loss (i.e., threshold effects were evident when wetland drainage was focused on seasonally-flooded ponds).

The predicted changes in wetland bird abundances associated with distinct wetland retention scenarios used in these analyses were consistent with expected patterns based on published reports for similar and other species in the Canadian and US prairies.

A review of the relationships between wetland retention scenarios and major environmental policies and agreements indicated that **removing wetlands to expand area of agricultural crop production is directly *contra*** a number of general and specific goals stated in:

- Saskatchewan's Growth Plan, as well as Saskatchewan's Game Management, Climate Change, and Protected Areas Plans;
- North American Waterfowl Management Plan and North American Bird Conservation Initiative;
- Canada's Species at Risk Act; and the
- International Convention on Biological Diversity.

Losses of wetlands and other natural habitats to expand agricultural crop production represent some of the greatest environmental threats to biological diversity – for game and nongame species alike - in Saskatchewan and world-wide.

Wetlands cannot be replaced by upland habitat due to the distinct functions of aquatic systems; whether wetland drainage impacts could possibly be partly mitigated by restoration of upland habitat is largely unknown.

Extensive losses of smaller wetlands such as seasonally-flooded Class III wetlands would be nearly catastrophic for Saskatchewan's wildlife; these Class III wetlands – as well as complexes of wetlands composed of varying size and permanence classes - must be conserved to safe-guard the large number of species that rely on these highly productive, unique systems.

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Glossary of Technical Terms

Ecological terms

Habitat ("habitat" terminology here and below is reviewed by Krausman 1999). The place where an animal lives, and includes the conditions and resources (e.g., food, cover, water) present in an area that are needed by an animal to survive and reproduce.

Habitat use. The way an animal uses the physical and biological resources in an area (e.g., for foraging, nesting, denning).

Habitat selection. An animal's decision processes involved in determining which habitat(s) to use, and when, and can result in avoidance (lower than expected use) or selection (higher than expected use) of available habitats. Typically, a selected habitat(s) is assumed to convey survival or reproductive benefits.

Habitat suitability index (HSI models). Commonly used to predict the suitability of a habitat (or area) for a species or group of species, and to derive species distribution patterns within a defined area. HSI models usually integrate multiple physical and biological characteristics of a habitat or area to predict the likelihood of a species occurring at a location(s).

Riparian (area or habitat). The uplands that occur alongside water bodies such as wetlands.

Species richness. The number of species.

Species abundance. The number of individuals of a species, for example, expressed as a count of individuals or as a density (i.e., number per unit area).

Wetland Class (see Stewart and Kantrud 1971 for complete definitions of Classes):

Class I, ephemeral pond.

Class II, temporary pond.

Class III, seasonal pond.

Class IV, semi-permanent pond.

Class V, permanent pond.

Statistical terms

Bootstrap procedure. The Bootstrap is a resampling method in which a pre-determined number of data points is selected, with replacement, from a larger data set. The new bootstrap samples can be used to calculate statistics such as sample mean, median and variance.

Median. A sample statistic that measures central tendency (similar to average or mean).

Root mean square error (prediction error). This quantity represents a standard way of measuring the error of a model in predicting quantitative data (e.g., bird abundance).

R^2. The percentage of variance (range: 0-100%) in a data set (e.g., bird abundance or number of species) explained by the explanatory variables (e.g., areas of wetland and upland cover) included in a statistical model.

GENERAL INTRODUCTION

Wetlands are among the most productive ecosystems in the world, and are “hotspots” of biodiversity (Hill et al. 2021). Freshwater systems including palustrine (non-lake) wetlands are under threat globally due to agricultural and urban expansion and pollution (Blann et al. 2009, Reis et al. 2017), leading to persistent calls for immediate actions to protect and restore these vital systems (Tickner et al. 2020). Similar threats and impacts to wetlands occur in Saskatchewan (Bartzen et al. 2010, Watmough et al. 2017, Doherty et al. 2018, Pattison-Smith et al. 2018), and other regions of the Great Plains. An estimated 40-70% of historic wetlands have been drained, mainly for agricultural development, in some parts of the Canadian prairies (Watmough and Schmoll 2007, Doherty et al. 2018), although the magnitude of wetland losses is highly variable across the region. Widespread concerns about these trends have triggered sustained conservation responses by diverse partner agencies across Canada and the US (Williams et al. 1999, Doherty et al. 2016, NAWMP 2018).

Despite numerous uncertainties about the full range of impacts caused by prairie wetland drainage, existing evidence indicates with high certainty that conversion of wetlands and their adjacent riparian areas to cropland has significant adverse impacts on regional wildlife habitat (reviewed by Baulch et al. 2021). Still, unlike several other prairie-based provincial and state jurisdictions, no regulations or laws protect small wetlands from drainage developments on private lands in a consistent manner in Saskatchewan watersheds. This has created wide-ranging disagreements between crop producers who engage in and benefit from regulated and unregulated wetland drainage and others who bear the direct (e.g., downstream and local flooding) and indirect (e.g., public disaster relief) costs of these activities (Breen et al. 2018, Minnes et al. 2020). To meet Saskatchewan’s agricultural development aspirations, a renewed, defensible approach is needed to better manage agricultural water resources. Saskatchewan’s Water Security Agency (WSA) is developing new guidelines and a wetland mitigation policy under its *Agricultural Water Management Strategy* initiative.

This report focuses on wildlife habitat, relationships between habitat and selected species, and examines some implications of retaining varying levels of wetland habitat in farmed areas of Saskatchewan where wetland inventories have recently been completed. The report is organized in three main parts, each corresponding to the principal objectives of this assessment. PART A focuses on use of wetland habitats by wild animals of management interest or conservation concern, with a focus on Saskatchewan. This involves a qualitative review of published research and other reports. PART B uses published quantitative models relating bird abundances to land cover features and wetland habitat to obtain preliminary estimates of the effects of varying wetland retention levels on wetland-associated and aerial insectivore bird species. This section also discusses possible alternatives to mitigate effects of reduced wetland retention levels. PART C places key findings from PARTS A and B in context of the goals of provincial, federal and international environmental goals, laws and agreements. Broad objectives of this report are to: (i) identify risks resulting from wetland drainage for selected species; and (ii) link wetland retention levels to wildlife habitat goals associated with provincial, national and international targets, laws and agreements. Revised wetland policies that consider size exclusions and best management practices are discussed briefly.

PART A –WETLAND FUNCTIONS AND USE BY SASKATCHEWAN WILDLIFE SPECIES: QUALITATIVE ASSESSMENTS

The main objective was to characterise habitat relationships (i.e., use and selection) of key Saskatchewan game species, species at risk, and other species of management or conservation interest, and then qualitatively assess the relative importance of wetlands, other natural habitats, and agricultural lands for these species. The importance of wetland margins for agriculturally beneficial insects was also examined briefly, as was the impact of aquatic food subsidies on terrestrial wildlife.

METHODS

A literature review was conducted to cover broad considerations about impacts of loss of wetlands and riparian areas, and conversion of natural areas to cropland. For general and species-specific information, published and unpublished information about habitat use and habitat selection was acquired for species, first, in Saskatchewan, and then the Canadian prairies, followed by the US Prairie Pothole Region. Studies were obtained using a combination of: (1) web-based search engines (Google, Scopus; using varied key words for focal species and habitats in the target regions); (2) direct communications with subject matter experts in Universities, non-governmental conservation organizations, and Saskatchewan and Canadian government personnel in wildlife management and conservation agencies; (3) personal library collections, and; (4) cross-references from published studies.

RESULTS AND DISCUSSION

WETLANDS AS REFUGIA FOR BENEFICIAL INVERTEBRATES AND INSECT FOOD SOURCES

Beneficial invertebrate pollinators and predators in wetland margins – Because wetland margins are often the only remaining natural terrestrial cover in many cropped landscapes, these margins represent important refuges for beneficial invertebrates such as pollinators, and predators and parasites of crop pests. There has been growing worldwide concern about the impacts of agricultural intensification (e.g., more crop monocultures with higher agrochemical inputs) on insects, generally (e.g., Sánchez-Bayo and Wyckhuys 2019), and specifically on insects that provide pollination or pest control services to agricultural producers (e.g., Goulson et al. 2008).

Wetland margins represent refuges for native bees in Alberta farmland, especially in cropped fields where bee abundance (and species richness) decreased with distance from wetland margin, whereas no such distance effects were detected for bees inhabiting fields composed of perennial grassland (Vickruck et al. 2019). Purvis et al. (2020) reported that native bees responded positively to restoration of grassland-wetland complexes within 5-10 years in Alberta, in large part due to the re-establishment of floral communities, and recovered bee communities resembled those of natural grassland-wetland sites. Native bees in North Dakota were more abundant, and both species and functional diversity were higher, in areas characterised by more land cover composed of wetlands (especially at smaller spatial scales near sampling sites), grasslands, bee-forage crops, and woodlands (Evans et al. 2018). Wetland margins and grasslands can also serve as seasonal refuges for some species of ground-dwelling arthropods that prey on canola pests, as reported by Robinson et al. (2021) for sites in Alberta. Native bee abundance declined as area of agricultural land cover increased in southern Manitoba (Olynyk et al et. 2021). Finally, results from a recent Saskatchewan study indicate higher abundances and diversity of beneficial insects (e.g., native bees) in wetland margins and grassy field edges than in cropped fields in agricultural landscapes (Morrice 2021). These results from Canada-US prairie studies are not unique. Other recent studies confirm the value of pond habitat and associated insects for crop production in Europe (e.g., Le Féon et al. 2010, Stewart et al. 2017, Walton et al. 2021). Wetlands, whether natural or restored, have potential to assist pollination services and thereby benefit crop producers.

Food web implications – wetlands are biodiversity and nutritional hotspots. Wetlands punch well above their weight in terms of exporting nutritious insect prey to higher consumers in adjacent terrestrial areas (Hixson et al. 2015). Aquatic algae (e.g., diatoms) are unique in producing highly unsaturated long chain omega-3 fatty acids (e.g., HUFA) - in some cases >10x more HUFAs than terrestrial insects when adjusted for biomass, which can improve growth, function, and survival of nestling birds (Twining et al. 2016, Twining et al. 2018), including several aerial insectivores (i.e., animals that capture flying insects in the air, like swallows, swifts, flycatchers, nighthawks, and bats). Abundance, survival, and reproductive rates of prairie waterfowl and other marsh birds are typically higher in years or multi-year cycles of abundant ponds (Bloom et al. 2013, Specht and Arnold 2018, Zhao et al. 2019), but there is recent evidence that such relationships can extend to some terrestrial species as well (e.g., Clark et al. 2018, Berzins et al. 2020, Berzins et al. 2021).

The net impact of these aquatic fatty acid subsidies to terrestrial consumers such as aerial insectivores has not yet been fully quantified but it is expected to be substantial (Génier et al. 2021, Shipley et al. 2022). For example, in intensively cropped areas of Saskatchewan where ponds remain abundant, the diets of adult and nestling tree swallows (*Tachycineta bicolor*) are composed mainly of aquatic-derived insects (Michelson et al. 2018). Indeed, breeding swallows travel farther from their nests only to access ponds, likely because food resources are more abundant or foraging for nutritious aquatic foods is more profitable near ponds when compared with cropped fields (Elgin et al. 2020). By contrast, in cropland areas with few ponds due to drainage, tree swallows breed later, and produce lower-weight nestlings, resulting in lower model-predicted first-year survival estimates (Berzins et al. 2022). Other evidence from Saskatchewan indicates that adult swallows work harder to raise nestlings with lower body mass on cropped sites, resulting in lower adult return rates than on grassland sites (Stanton et al. 2017). Recent work on bats in North Dakota indicates that ponds and wooded riparian areas surrounding ponds are important foraging habitats for big brown (*Eptesicus fuscus*) and little brown (*Myotis lucifugus*) bats (Nelson and Gillam 2020). Collectively, these general wetland-specific findings are important, given the current population status and declining trend of many aerial insectivores (Rosenberg et al. 2019), and proposed roadmaps to conserve this foraging guild (Nebel et al. 2020).

SASKATCHEWAN GAME SPECIES

This component of the assessment relies on published and unpublished reports, expert information communicated by Saskatchewan government and University personnel, and habitat suitability index model results obtained for selected game species in or near farmed areas. The main focus is on white-tailed deer (*Odocoileus virginianus*), moose (*Alces alces*), elk (*Cervus elaphus canadensis*), and non-native ring-necked pheasant (*Phasianus colchicus*) because of their importance to hunters and provincial hunting revenues. Furthermore, results of habitat suitability index (HSI) modelling are available for these species within the target regions of interest for this assessment (i.e., pothole or similar Saskatchewan landscapes); migratory waterfowl are addressed later in this report.

White-tailed deer – preliminary HSI models (D. Messmer, *personal communication*) based on data acquired from radio-tracked females in southeast Saskatchewan (e.g., Brewster and Longmuir 1994) and expert opinion, indicate that small wetlands ringed with willow (*Salix* spp.) and aspen (*Populus tremuloides*) provide critical wintering habitat, as do large (e.g., >30 ha) groves of aspen (or shrub). These small wetlands are also especially important as spring-summer habitats for females with fawns; in addition to forage, small tree-ringed wetlands provide thermal and escape cover. The HSI indicates higher suitability is expected with intermediate (40-60%) wetland cover, and higher (>60%) woodland, shrub and pasture cover.

Near Riding Mountain National Park, Manitoba, habitat selection patterns of radio-marked white-tailed deer varied with spatial scale and season (Laforge et al. 2015), with selection for wetlands only being detected at larger buffer sizes (e.g., >500 m) and wetland avoidance occurring at smaller scales. Furthermore, Laforge et al. (2015) reported that deer selected areas with higher habitat heterogeneity (i.e., more edge, and mixes of land cover).

Moose – moose distribution in Saskatchewan has changed in the past 15 years (Laforge et al. 2017), with much higher numbers now occurring in farmed areas, similar to moose expansion reported in Alberta (Bjorge et al. 2018). The only comprehensive habitat use study of Saskatchewan farmland moose indicates strong selection for wooded wetlands and remnant groves of trees by radio-marked females throughout the year (Laforge et al. 2016), as well as among females during birth and with young calves (Wheeler 2020). Wetlands and wooded areas provide shade in summer, and thermal and escape cover year-round.

Elk – elk occur in many farmed areas of Saskatchewan, and are more abundant near large protected areas and along the boreal-aspen forest fringe. In southern Manitoba, both elk and moose exhibited weak selection for wetlands at low population densities when compared with strong selection for mixed forest, and this wetland selection pattern weakened as ungulate population densities increased (van Beest et al. 2014); as elk populations increased, use of secondary, lower quality habitat (e.g., cropland) became more frequent. Among elk residing entirely on farmland areas of southern Manitoba, only forage crops were selected whereas pregnant female elk only selected remnant deciduous forest for calving (Brook 2010).

Ring-necked pheasant – the HSI model for pheasants indicates higher suitability in areas of higher cropland, and intermediate coverage of wetlands (1 km^2 scale; D. Messmer, *personal communication*). Wetlands and riparian areas along waterways embedded in cropland areas provide escape and roosting cover throughout the year.

Density dependent processes – density dependence affects survival and reproductive rates in most large ungulates (reviewed by Bonenfant et al. 2009), as well as habitat use as described above (e.g., van Beest et al. 2014, van Beest et al. 2016). Theory and empirical work suggests that higher animal densities result in higher disease transmission and impact, which can be challenging to resolve fully in wild animal populations (Lloyd-Smith 2005), and further work is needed regarding how such relationships might become more severe in human-altered landscapes where land use change alters animal densities and movements (Brearley et al. 2012). In Alberta, modelling of field data indicated that higher deer densities led to higher contact rates and potential for chronic wasting disease transmission (Habib et al. 2011) especially in areas with less natural cover and higher deer movement rates. Habitat loss could possibly also lead to higher frequency of competitive interactions between native and introduced animals (e.g., O'Brien et al. 2019), with possible disease consequences.

To conclude, small wooded wetlands provide important habitat for sustaining white-tailed deer and moose, and wetland habitat is also important for pheasants. This assumes that habitat suitability indices and habitat selection patterns generally reflect higher quality habitat where reproductive and survival rates support stable or growing populations. While uncertainties exist, interactions among habitat loss, animal movements, and disease transmission could also have serious implications for wild ungulates. Thus, the cumulative effects of draining and clearing small wooded wetlands are expected to have progressively detrimental impacts on white-tailed deer and moose populations, by reducing habitat area and connectivity, lowering reproductive success, increasing crowding, competition and predation, and possibly increasing risk of disease transmission and disease-related demographic impacts. Over time, these outcomes could become very likely in highly modified landscapes (with moderate-high certainty; https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/ch1s1-6.html). How this could eventually affect hunting opportunities for resident hunters and First Nations hunting rights is unknown.

PRAIRIE DUCKS AND OTHER WETLAND-ASSOCIATED BIRD SPECIES

Saskatchewan is probably the single most important jurisdiction in North America for production of common duck species. Conservation investments to protect and restore wetland and upland habitats in Saskatchewan exceed $550 million during 1986-2021 (North American Waterfowl Management Plan [NAWMP], Canadian NAWMP National Tracking System; D. Dixon, Canadian Wildlife Service, Edmonton, *personal communication*, May 2022), and the province also receives significant annual revenues from hunting tourism and licence sales. While exceptional flooding during 2008-2014 contributed to strong growth of most duck populations, and likely several other marsh bird species (Rosenberg et al. 2019), the long-term security of these populations is threatened by continuing land conversion to cropland following wetland drainage. Achieving long-term population goals for wetland-dependent species in Canada's prairies can only be made possible by having well-enforced wetland protection regulations across the region (Prairie Habitat Joint Venture 2014, 2021)). Fortunately, policies have been implemented to provide substantially improved protection for natural wetlands in Alberta (Alberta Wetland Policy [2013]; Alberta wetland policy - Open Government) and Manitoba (Sustainable Watersheds Act [2018]; amended Water Rights Act). Lacking similar wetland protection, Saskatchewan duck populations are expected to remain below conservation goals *over the long term* for two main reasons: (1) reduced habitat for breeding pairs due to ongoing drainage (Barzen et al. 2017, Watmough et al. 2017) and (2) lower breeding success due to conversion of natural habitats to cropland (Howerter et al. 2014, Zhao et al. 2019, Bortolotti et al. 2022). The combined effects of wetland drainage and climate change are also expected to accentuate challenges for sustaining and recovering populations of ducks and other wetland bird species in some prairie regions (Steen et al. 2014, Zhao et al. 2020, Zhang et al. 2021). Similar constraints will extend to priority songbird, shorebird, and marsh bird species (see Species at Risk and Priority Species below). Furthermore, for these species and ducks, it is unclear whether enhanced upland habitat amount or quality could increase breeding success, and partly offset the adverse effects of wetland losses on the capacity of Saskatchewan's landscapes to support wildlife population objectives.

WILDLIFE USE OF SMALL FARMED WETLANDS

Shorebirds and waterfowl make extensive use of farmed "sheetwater", ephemeral and temporary ponds, during spring and fall migrations; other wetlands within agricultural fields – temporary to permanent ponds – also provide food resources that are crucial for fueling waterfowl migrations (Janke et al. 2019). While small wetland basins that are tilled and cropped annually typically hold water for only short time periods in spring, they are often the first to provide food, water, and resting places for spring migrant and resident birds. For example, Niemuth et al. (2006) showed that migrant shorebirds in North Dakota selected for temporarily- flooded ponds, most in agricultural fields, but made less use of wetland basins with evidence of drainage (also see Kantrud and Stewart 1984). Using data from bird surveys in the US Prairie Pothole Region, Skagen et al. (2008) estimated that millions of shorebirds used ephemerally-flooded wetlands in agricultural fields during spring and fall migrations; such estimates are not available for Prairie Canada but are expected to be of similar magnitude. Unfortunately, despite the clear importance of small farmed wetlands to a range of wildlife at specific times of the year, especially in early spring, it is not yet possible to quantify changes in bird use or abundance at different wetland retention levels, as explored in Part B of this report, because there are no reliable data to inform predictive models.

COMMON FARMLAND SPECIES

Many wildlife species are well-adapted to agricultural environments, and continue to use areas converted from natural land cover and wetlands to cropland. This is especially notable among herbivorous and granivorous waterfowl, like resident Canada geese (*Branta canadensis*), and migrant sandhill cranes (*Grus canadensis*) and arctic-nesting geese. Likewise, grain and insect-eating crows (*Corvus brachyrhynchos*), magpies (*Pica pica*) and blackbirds (family Icteridae) are highly visible and often observed in crop fields. Species like white-tailed deer, moose and even small predators like fox (*Vulpes vulpes*), coyote (*Canis latrans*) and skunk (*Mephitis mephitis*) are often encountered in open farmland, as their visibility (detection) increases with less natural cover and where these animals are more mobile, moving frequently across large open areas to feed or access remnant patches of natural cover. And, while several bird species nest in croplands (e.g., horned lark [*Eremophila alpestris*], northern pintail [*Anas acuta*]), their overall abundance and species richness are much lower in croplands than in grasslands and pastures (e.g., Shutler et al. 2000, McMaster and Davis 2001), and breeding success is typically very low in spring-seeded cropland due to nest destruction by tillage or seeding operations and predators (e.g., Best et al. 1997, Tews et al. 2013, Devries et al. 2018).

SPECIES AT RISK and PRIORITY SPECIES

Species at Risk - Most species at risk in Saskatchewan are associated with areas dominated by grasslands rather than pothole wetland landscapes, but 22 species occurring in the focal region for this assessment are associated with wetland habitats during the breeding season or during migrations (Table 1). Nine species, including two bat and seven bird species, are aerial insectivores.

Of species that demonstrate some affinity to wetlands (Table 1), no single wetland class provides critical habitat for all species due to their varied species-specific requirements. Also, amphibians and some birds (e.g., grebes, rails, shorebirds) cannot acquire life-cycle needs without wetlands (i.e., wetland obligates) whereas others use riparian areas for breeding and(or) foraging (e.g., bats, aerial insectivores). Wetland obligate species cannot persist without wetlands, and abundances are expected to decrease significantly when distances between wetlands increase and individual wetlands become increasingly isolated. Thus, a complex of wetlands, representing basins of different classes, sizes, depths, and vegetation collectively form the critical habitat needed to support the full range of species at risk, and other wetland-associated species (Kantrud and Stewart 1984, Elliott et al. 2020).

Other priority species – In addition to species at risk, conservation agencies have identified bird species of high conservation concern due to decreasing population trends, relatively low populations, and the severity and spatial extent of threats to habitats and populations. Bird Conservation Region 11 (Prairie Potholes; see N.A. Bird Conservation Initiative [NABCI], BCR Map - NABCI (nabci-us.org)) has identified bird species of concern and the Prairie Habitat Joint Venture (PHJV) has developed habitat objectives to guide program delivery and help ensure that populations of focal species persist and grow, or do not become at-risk (PHJV 2021). In addition to bird species listed in Table 1, a further 22 resident breeding species (2 grebes, 7 shorebirds, 5 songbirds, 3 marsh birds, 2 terns, 1 gull, 2 raptors) and 9 migrant shorebird species are considered high priority (see Appendix 3 in Prairie Habitat Joint Venture 2021). To summarize, available evidence indicates with high certainty that expanded land clearing and wetland drainage to expand crop production would very likely result in lower populations of species at risk and species of concern (e.g., Stanton et al. 2018, Rosenberg et al. 2019).

Table 1. Saskatchewan species at risk that occur in the focal region of this assessment, classified as Endangered, Threatened, and Special Concern. Affinity to wetlands is indicated as √ (associated), √√ (strongly associated), and * (during migration). Also shown (√) are species in the aerial insectivore (AI) foraging guild. *Source*: Saskatchewan Conservation Data Center (2022).

Common name	**Scientific name**	**SARA schedule**	**Wetland affinity**	**AI guild**
Endangered				
Burrowing Owl	*Athene cunicularia*	Schedule 1		
Chestnut-collared Longspur	*Calcarius ornatus*	Schedule 1		
Piping Plover	*Charadrius melodus circumcinctus*	Schedule 1	√√	
Red Knot rufa subspecies	*Calidris canutus rufa*	Schedule 1	*	
Red-headed Woodpecker	*Melanerpes erythrocephalus*	Schedule 1		
Sage Thrasher	*Oreoscoptes montanus*	Schedule 1		
Whooping Crane	*Grus americana*	Schedule 1	*	
Little Brown Myotis	*Myotis lucifugus*	Schedule 1	√	√
Northern Myotis	*Myotis septentrionalis*	Schedule 1	√	√
Threatened				
Bank Swallow	*Riparia riparia*	Schedule 1	√	√
Bobolink	*Dolichonyx oryzivorus*	Schedule 1	√	
Chimney Swift	*Chaetura pelagica*	Schedule 1		√
Eastern Whip-poor-will	*Antrostomus vociferus*	Schedule 1		√
Hudsonian Godwit	*Limosa haemastica*	No schedule	*	
Lesser Yellowlegs	*Tringa flavipes*	No schedule	*	
Loggerhead Shrike	*Lanius ludovicianus excubitorides*	Schedule 1		
Thick-billed Longspur	*Rhynchophanes mccownii*	Schedule 1		
Short-eared Owl	*Asio flammeus*	Schedule 1		
Sprague's Pipit	*Anthus spragueii*	Schedule 1		
Special concern				
Great Plains Toad	*Anaxyrus cognatus*	Schedule 1	√	
Northern Leopard Frog	*Lithobates pipiens*	Schedule 1	√√	
Western Tiger Salamander	*Ambystoma mavortium*	Schedule 1	√√	
Baird's Sparrow	*Ammodramus bairdii*	Schedule 1		
Barn Swallow	*Hirundo rustica*	Schedule 1	√	√
Buff-breasted Sandpiper	*Tryngites subruficollis*	Schedule 1	*	
Canada Warbler	*Cardellina canadensis*	Schedule 1		
Common Nighthawk	*Chordeiles minor*	Schedule 1	√	√
Eastern Wood-pewee	*Contopus virens*	Schedule 1		√

Evening Grosbeak	*Coccothraustes vespertinus*	Schedule 1		
Ferruginous Hawk	*Buteo regalis*	Schedule 1		
Harris's Sparrow	*Zonotrichia querula*	No schedule		
Horned Grebe	*Podiceps auritus*	Schedule 1	√√	
Long-billed Curlew	*Numenius americanus*	Schedule 1	√	
Olive-sided Flycatcher	*Contopus cooperi*	Schedule 1	√	√
Red-necked Phalarope	*Phalaropus lobatus*	Schedule 1	*	
Rusty Blackbird	*Euphagus carolinus*	Schedule 1	*√	
Western Grebe	*Aechmophorus occidentalis*	Schedule 1	√√	
Yellow Rail	*Coturnicops noveboracensis*	Schedule 1	√√	
American Badger	*Taxidea taxus taxus*	Schedule 1		

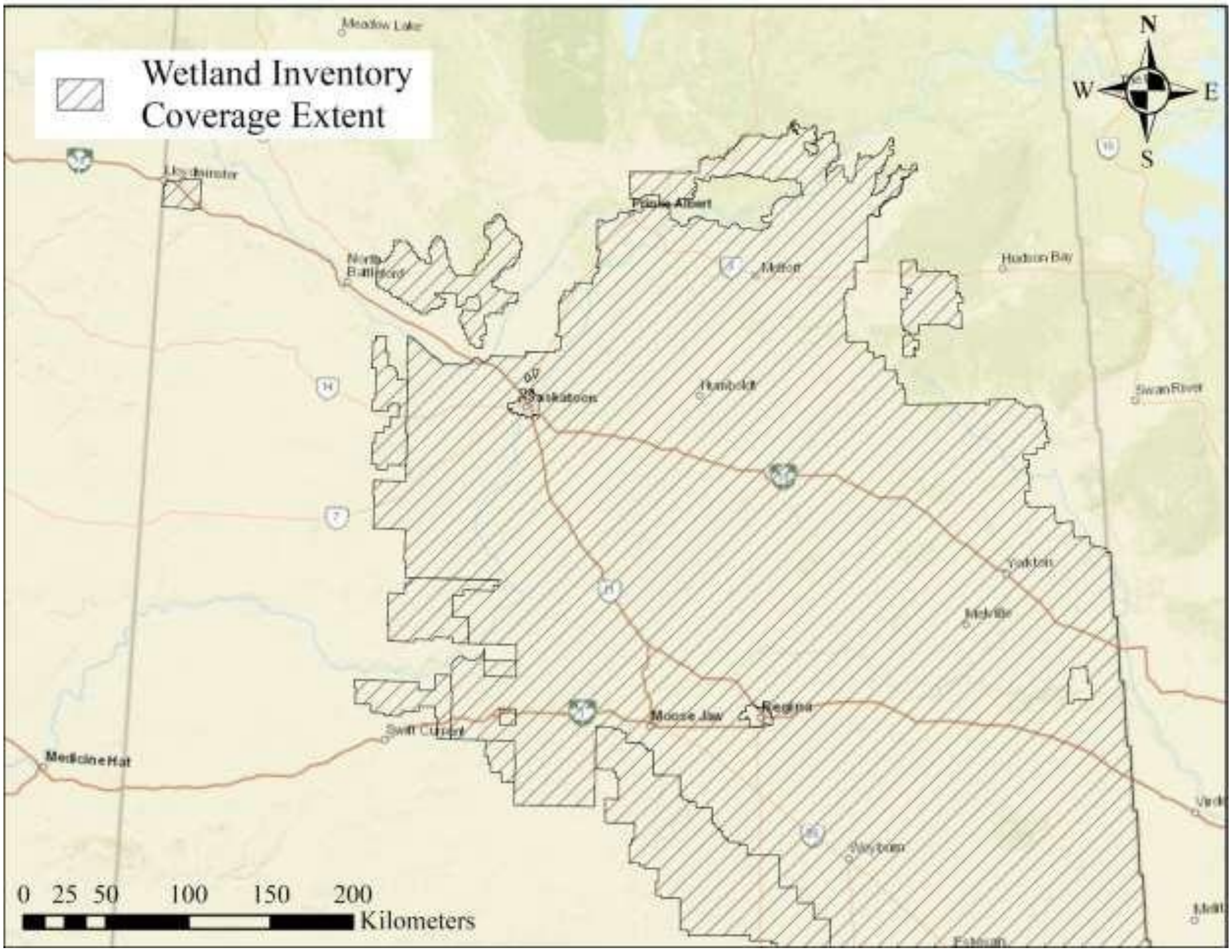
PART B – RESPONSES OF WETLAND-ASSOCIATED BIRDS AND AERIAL INSECTIVORES TO WETLAND RETENTION SCENARIOS: PRELIMINARY RESULTS OF PREDICTIVE MODELS

The main objectives of this section were to estimate changes in wetland and land cover areas associated with varying wetland retention levels, to determine how selected groups or guilds of birds might respond to subsequent landscape changes, and to assess how species richness (number of bird species) might respond to different wetland retention levels. Exploratory analyses were also performed to evaluate assumptions used to define wetland retention scenarios. Collective findings are summarized in terms of whether mitigation options exist to offset any adverse effects of wetland losses, and the implications of size exclusions for revised agricultural wetland management policies.

METHODS

WSA and partners acquired and processed aerial imagery for much of Saskatchewan's agricultural region, including the boreal transition zone, and completed a wetland inventory for much of the pothole region of Saskatchewan. The current extent of this wetland inventory constitutes the area of investigation for this study (Figure 1). This inventory information has been combined with geospatial data for soil classes and annual land cover obtained, respectively, from the Canada Land Inventory (CLI) and Agriculture and Agri-Foods Canada (AAFC).

Figure 1. Current extent of wetland inventory for the Province of Saskatchewan (courtesy of Holly Annand).



Wetland areas and impacts

Wetland inventory data were collected using digital orthophotos and a standardized interpretation guide (Boychuck et al. 2014). Date of imagery used depended on availability and quality of images but generally ranged from 2007-2015. During the inventory process, each wetland polygon was attributed with the area of each wetland and an impact code assigned: intact, partly drained, completely drained, partly filled, constructed, and farmed but not drained (CWI Data Model 2016). Wetland drainage associated with subtle land contouring may result in less area being attributed to ephemerally-flooded ponds but this area is expected to be small (Water Security Agency, *personal communication*) and, as explained below, does not affect analyses conducted in Part B.

For this study, large lake wetlands were removed, and partly drained (or filled) wetlands were assumed, for consistency, to retain 50% of the basin area and surface water storage capacity. This assumption has no impact on the wetland scenarios described below, but should be investigated more thoroughly if estimates of "current" wetland area (i.e., *circa* 2014-2019) are needed. Wetland basins were classified by area (1 acre is ~0.4 ha) into 7 size classes: 0-0.25 acres, 0.26-0.50 acres, 0.51-1.0 acres, 1.1-2.0 acres, 2.1-3.0 acres, 3.1-5 acres, and >5 acres. For a small portion of the wetland inventory (<3% of overall wetland area), very small wetlands appear as point features. These wetlands were assigned an area of 0.15 acres (0.06 ha) and given an impact code following Boychuk et al. (2014). A wetland area boundary was defined by the outer edge of the wet meadow/riparian vegetation zone, not by the wetland's topographic spill-point (Boychuk et al. 2014). An estimate of ***historic wetland area*** (i.e., as the reference for drainage scenarios defined below) was calculated by summing the area estimates for all intact wetland polygons and points, plus the entire area of polygons and points within the partly drained, completely drained, partly filled, and farmed impact categories; constructed wetlands were excluded.

Land cover and soil capability

Land cover data were acquired from AAFC's 2019 annual crop inventory products and data, generated using a combination of optical and radar imagery. This approach consistently produces a crop (land cover) inventory that achieves a minimum of 85% accuracy at a spatial resolution of 30 m (AAFC 2019). Areas of each land cover category were summarized by quarter section. Protected lands (e.g., parks, crown-owned and community pastures, Fish & Wildlife Development Fund lands) were identified. Note that while these land cover estimates were used to model bird responses in wetland retention scenarios (details below), these estimates represent conditions observed in 2019 and should not be considered "historic" estimates.

Soil suitability for agriculture was defined by seven categories using the CLI soil capability classes (CLI Agriculture classification). Class 1 soils have no limitations for crop production whereas class 6 and 7 soils indicate crop production is not feasible or possible, respectively. Areas of individual soil classes were mapped and quantified as % of area within each quarter section; for some analyses described below, the predominant soil class at the centroid of the quarter section was assigned to the entire quarter section.

Wetland retention scenarios

The historic wetland area (100% retention) estimate represents the starting or reference scenario. Then, wetland retention scenarios proceeded by incrementally removing 10% of the major river basin's wetland area, subject to the following decision rules:

- Wetlands in protected areas were not drained.
- Wetlands in CLI soil classes 6 and 7 were not drained.
- 90% of wetlands less than 0.25 acres (~1000 m^2) were not drained. Wetlands of this size often contain ephemeral or temporary ponds (Class I and Class II ponds; Stewart and Kantrud 1971), and these basins can be farmed without being drained. Evidence from wetland inventory data suggests that 90% is an appropriate assumption (Water Security Agency, *unpublished data*). When impacted by incremental wetland drainage scenarios in this study, these wetlands were designated as "farmed".
- Wetlands were drained, without regard to the location of outlets, and all water was exported from the watershed (i.e., no consolidation drainage occurred).
- Drained quarter sections were also cleared of all non-crop land cover, effectively eliminating all natural wildlife habitat on drained quarters to expand crop production.

By applying these rules, (1) wetlands were not subjected to drainage in protected areas or on quarter sections of land where crop production is not feasible, and (2) the 10% retention decrements from historical wetland area occurred on remaining quarter sections of land with feasible crop production capability (CLI soil classes 1-5). Specific methods regarding wildlife habitat components are described in the following sections.

Wetland retention scenarios and wildlife habitat changes

Grassland, pasture, shrub and woodland areas acquired from 2019 AAFC land cover data were estimated for selected wetland retention scenarios (70%, 50% and 30% of historic wetland area), for each Saskatchewan major river basin, separately, and all river basins combined. This was done by calculating the number of quarter sections that would be drained in each major river basin to attain the 10% decrement levels for each wetland retention scenario. Habitat areas were also estimated for non-drained quarter sections (i.e., Floor), as defined above. For historic, retention and Floor scenarios, the four land covers, and wetland areas, were estimated with a bootstrap procedure (Manly 2007) performed in the Statistical Analysis System (SAS, PROC

SURVEYSELECT; SAS Instit. 2016). The bootstrap involved randomly selecting quarter sections, with replacement, up to the number of quarter sections within each drained and non-drained category, 500 times. For each bootstrap sample (n = 500 samples), habitat areas in the drained and non-drained quarter section categories were summed to yield an area estimate for each habitat by major river basin. To generate estimates for the Floor, quarter sections representing protected areas, plus soil classes 6 and 7, were resampled in each river basin. Recall that the WSA wetland data allow an estimate of historic wetland area within each major river basin, but the AAFC data only provide an estimate of land cover *circa* 2019. Natural land cover conversion to cropland would have occurred, with or without wetland drainage, prior to 2019 (e.g., Hobson et al. 2002, Watmough and Schmoll 2007, Doherty et al. 2018).

Modelling bird responses to habitat changes

Modelling bird responses to changes in wetland and other habitats is challenging due to a lack of extensive community-level sampling at appropriate spatial scales to inform the development of robust statistical models. Furthermore, bird abundances are inherently variable and characterizing the main drivers of such variation can limit the reliability of model predictions. With these caveats stated, quantitative models were developed to link bird guild (and species richness [i.e., number of species]) responses to different levels of wetland retention described in the scenarios above. This is an active research area, and evolving statistical and spatial models of habitat-bird community relationships that would be highly appropriate for the current assessment are expected within 1-3 years.

The impacts of wetland retention levels on bird communities were estimated with statistical models initially developed using data and general methods described by Mantyka-Pringle et al. (2019); these data and models are the most comprehensive with respect to this assessment, and developed at a spatial scale (500 m radius) that nearly matches the scale used for wetland retention scenarios (quarter section). Specifically, these models relate bird abundances (and species richness) acquired from standard visual and acoustic surveys conducted by the Alberta Biodiversity Monitoring Institute (ABMI) to AAFC wetland and land cover data within 500 m of bird sampling sites.

New models were developed for this assessment using general linear models in SAS (PROC GLM; SAS Instit. 2016). Site-specific ABMI habitat data were inspected for extreme outliers (≥

3 standard deviations from the mean) and these sites were removed when found. Then, abundances of wetland-associated birds and aerial insectivores (birds that capture insects when flying) were modelled (species listed in Appendix A1), separately, in relation to wetland area (log transformed; see Bidwell et al. 2014) and percent cropland, pasture, shrub and wooded areas (following Elliott et al. 2020); grassland was strongly negatively correlated ($r < -0.70$; SAS, PROC CORR) with cropland and was excluded. Nonlinear (quadratic) relationships were examined for each land cover variable, and were retained when informative (based on Akaike's Information Criterion adjusted for sample size [AIC_c]; Burnham and Anderson 2002) and when the nonlinear term was estimated with precision, for use in multiple regression models.

Bird responses to wetland and land cover changes

The revised models developed specifically for wetland-associated birds and aerial insectivores using ABMI data were used to predict corresponding bird abundances in each quarter section of each major Saskatchewan river basin, assuming historic WSA wetland and 2019 AAFC land cover (i.e., cropland, pasture, shrub, wooded) areas. Ephemeral and temporary ponds (including small farmed wetlands) were excluded from quarter section wetland area estimates because predictive models were based on counts of birds detected during June-July at seasonal, semi-permanent and permanent ponds, according to ABMI protocols. Furthermore, there are no extensive field data that allow the development of predictive models about bird use of (1) ephemeral and temporary ponds during short periods in early spring or (2) farmed wetlands.

To estimate the impact of wetland retention scenarios on model-predicted bird abundances, the number of quarter sections on CLI class 1-5 soils that would be drained to achieve the target wetland area (i.e., 90%, 80%, etc.) was determined for each scenario in each major river basin. Then, a bootstrap procedure (SAS, PROC SURVEYSELECT; Manly 2007) was used to randomly select, with replacement, the number of undrained quarter sections corresponding to the scenario and major river basin, 500 times. The number of quarter sections that composed Floor values varied by major river basin but was fixed within each river basin, and also resampled 500 times. The predicted numbers of birds on undrained and Floor quarters were sorted and summed by bootstrap sample to generate 500 estimates of total numbers of birds for each river basin and scenario. Given that drained quarter sections were assumed to be completely drained and cleared of natural land cover for crop production, it was expected that no wetland birds or aerial insectivores would occur on drained quarters converted to 100% cropland.

However, in a separate analysis, it was assumed that *some* breeding birds from the wetland bird and aerial insectivore guilds could possibly occur on drained quarter sections, especially at higher wetland retention levels (e.g., >50% scenarios) due to spatial scale effects. For example, birds that occasionally use cropland as nesting cover (e.g., some ducks, songbirds or shorebirds; see Part A) or when foraging (e.g. blackbirds, swallows) could occur on drained quarters where wetlands are retained on *neighbouring* quarter sections. To explore this possibility, bird abundances on drained quarter sections were assigned random values based on distributions of bird abundances observed at ABMI sites with 100% cropland. Because fewer birds were detected at fully cropped ABMI sites, random values (25000 per guild) were generated from negative binomial distributions for wetland-associated birds (median = 1, mode = 1) and aerial insectivores (median = 1, mode = 0) and used within a bootstrap procedure to augment the model-predicted numbers of birds; this was done by adding randomly-selected bird abundances to the model-predicted bird abundances in each random sample (n = 500), by guild, for each river basin and scenario.

In all analyses described above, uncertainties in model-predicted bird abundances were quantified using guild-specific model root mean square error (i.e., prediction error) within the bootstrap frameworks. Model-predicted median bird abundances (and median errors) were retained for each random sample (n = 500) in each scenario by major river basin.

Case-study: wetland class, drainage risk and quarter-section-level drainage

The scenarios implemented above were based on guild-specific models derived via a single data set (i.e., ABMI). While this data set was appropriate for this assessment, it could be instructive to compare results from the analysis above with estimates obtained from other models. Also, scenarios were designed to remove all wetlands from quarter sections, whereas in some situations smaller wetland basins with seasonal ponds have higher risk of drainage than do larger wetlands. Field observations suggest that both occur: where feasible, entire quarters are drained and where this is not possible, individual wetlands may be drained. In wetland retention scenarios above, a central assumption was that all wetlands in a quarter section, regardless of permanence class, would be drained and pond water exported from the river basin. An important implication of using this approach is that the wetland size (area) distributions were consistent across all scenarios. However, field reports and other wetland data suggest that smaller wetlands may experience higher drainage risk (e.g., Bartzen et al. 2010, Serran and Creed 2016, Watmough et al. 2017; WSA, unpublished data). An important assumption, discussed previously and below, is that smaller wetland basins *tend* to contain Class III seasonally-flooded ponds when compared with larger Class IV (semipermanent) and V (permanent) ponds.

To explore the implications of (i) using another model to predict wetland-associated bird abundance and (ii) draining smaller wetlands before larger ones, pond-specific breeding pair abundances of mallard (*Anas platyrhynchos*), northern shoveler (*Spatula clypeata*), and three other duck species combined (blue-winged teal [*Spatula discors*], gadwall [*Mareca strepera*], northern pintail) were predicted using models developed by Bartzen (2008) and Bartzen et al. (2017) for the Qu'Appelle River basin, the largest (>80000 quarter sections) in the WSA data set. In the first analysis, wetland basins were drained by quarter section without regard to wetland area, as described above in the retention scenarios of the previous sections, and model-predicted numbers of ducks (and confidence intervals) were retained. Briefly, duck pair abundances were calculated for each wetland retention scenario, 500 times, using a bootstrap routine (SAS, PROC SURVEYSELECT).

In the second analysis, smaller wetland basins (<0.5 acre [0.203 ha]) were drained before any other size class, followed by progressively larger wetlands (e.g., <1 acre, <2 acre). Drainage was assigned to individual wetlands on the basis of area, with smaller wetlands being drained (in each 10% area decrement) before larger ones. Five wetland area categories were created, with the smallest wetlands (< 0.203 ha) always being drained before larger ones, in sequence, through the area categories. These categories are *arbitrary*, and used *only* to illustrate how estimates of bird (duck) abundances might be influenced by relative risk of drainage in relation to wetland area. Duck abundances were estimated using the retained wetlands in each 10% decrement, as before, but in this case without regard to quarter section affiliation. To be consistent with studies used to develop the guild-specific models above and the duck breeding pair abundance models (e.g., Bartzen 2008), shallow farmed wetlands and wetlands >3 ha were excluded in both sets of analyses.

Case-study: changes in species richness (number of species)

ABMI data (Mantyka-Pringle et al. 2019) were used to relate bird species richness (number of species) to wetland area ($\log_{10}$-transformed; see Bidwell et al. 2014) and percent area of cropland, pasture, shrub and woodland with a general linear model (SAS, PROC GLM); the final model was chosen using AIC_c, and when parameters were estimated with good precision ($P < 0.10$), as above for bird abundance models. Individual species of wetland birds and aerial insectivores could not be separated within guilds or from other species within the available ABMI data set, so all bird species were considered in this analysis. Again, wetland and land cover data for the Qu'Appelle River basin were used for this exploratory analysis to predict species richness in each retention scenario.

To evaluate changes in bird species richness for each wetland retention level, it is necessary to calculate mean species richness per quarter section rather than summed species richness. This is because, overall, species richness is not expected to change much within a major river basin across the wetland retention scenarios simply because most or all species could occur at least once on the quarter sections composing the Floor scenario. However, mean species richness per quarter section within a major river basin could potentially change considerably as wetlands and natural land cover are removed from the drained quarters being converted to 100% cropland.

To estimate the impact of wetland retention scenarios on model-predicted bird species richness, the number of quarter sections on CLI class 1-5 soils was determined for each scenario in the Qu'Appelle River. Then, species richness (± root mean square error) was estimated for all quarter sections based on modelling techniques (SAS, PROC GLM), and predicted values were resampled ($n = 500$) using bootstrap procedures (SAS, PROC SURVEYSELECT), as described previously. Shannon diversity index was also calculated from proportional areas of cropland, pasture, grassland, trees and shrubs, reasoning that higher land cover diversity (i.e., landscape heterogeneity) could contribute to higher bird abundances and species richness (Krebs 2014). However, this diversity index was positively correlated with shrubs, trees, and pasture (all $r > 0.32$, $P < 0.001$, $n = 335$ ABMI sites; SAS, PROC CORR) and moderately negatively correlated with cropland ($r = -0.27$, $P < 0.001$). Furthermore, adding the diversity index to models composed of wetland-land cover variables did not improve model fit, so it was not considered further.

For drained quarter sections converted to 100% cropland, a random value of species richness was assigned from a negative binomial distribution (n = 75000 samples; mode = 15 species, maximum = 42 species, based on ABMI data for 100% cropped sites) and resampled using a bootstrap (n = 500); lower and upper errors for random values were fixed to be proportionately the same as the model-derived root mean square error. For selected wetland retention scenarios, the predicted numbers of species on undrained, Floor and drained quarter sections were weighted by proportional area of these three categories within each major river basin, and then summed to calculate an area-weighted median species richness estimate for the entire river basin.

Comparisons with other bird-habitat models

Published models were reviewed for Canadian and northern U.S. prairie bird communities. The relative importance of wetland variables was described in terms of their effects on bird occurrence, abundance or species richness, as reported by the authors. Additionally, responses of birds to wetland and land cover characteristics obtained from models based on ABMI data were assumed to reflect responses by birds to habitat conditions in Saskatchewan. To evaluate this assumption, general (qualitative) comparisons were made between model parameters and predictions estimated in this assessment, and those obtained from published studies of other prairie wetland bird populations (e.g., Bartzen et al. 2017, Elliott et al. 2020).

RESULTS and DISCUSSION

Wildlife habitat changes with wetland retention scenarios

Changes in WSA wetland and 2019 AAFC land cover characteristics for all major river basins combined are shown in Table 2 (estimates for each river basin and scenario are shown in Appendix A2). As expected, land cover changes generally tracked the wetland drainage patterns as these habitats were assumed to be cleared and converted to crop production on drained quarters. Because Floor areas were protected or on low quality soils, relatively larger areas of shrub and woodland were present in low wetland retention scenarios but, regardless, the Floor area did little to retain substantial areas of either land cover or wetlands. Indeed, little area of natural land cover persisted across the river basins even at 50% wetland retention levels. Furthermore, because the AAFC data were acquired from 2019 imagery, substantial losses of natural land cover had already occurred prior to this recent assessment (e.g., Watmough et al. 2017). On the basis of the WSA wetland inventory data, and the untested assumption about pond areas within partly drained and partly filled wetland basins, the combined estimate of current wetland area is ~92.5% of historic wetland area.

Models for predicting abundances of wetland-associated birds and aerial insectivores

Predictive models developed for wetland-associated birds and aerial insectivores explained ~26% and ~33% of variation in respective abundances (Table 3) suggesting good model performance. All parameters were well-estimated, and while nonlinear effects were evident for wetland area (i.e., semi-log) in both models, non-linear (quadratic) terms for AAFC land cover variables were uninformative ($P > 0.10$) and not retained.. Model-specific root mean square error was used to characterize uncertainty (i.e., prediction error) when estimating abundances.

Table 2. Changes in absolute (%) and relative (Rel. %) areas of AAFC land cover and wetland areas in the combined Saskatchewan major river basins. Shown are estimates for Initial and Floor conditions, and median estimates obtained via bootstrap sampling (500 samples) for 70%, 50% and 30% wetland retention scenarios. Initial conditions refer to historic areas for WSA wetlands and 2019 AAFC areas for land cover. The Floor scenario was composed of quarter sections that were either protected or composed mainly of CLI class 6 and 7 soils. See Methods for details.

	Wetland		Grassland		Pasture		Shrub		Wooded	
Scenario	%	Rel. %	%	Rel. %	%	Rel. %	%	Rel. %	%	Rel. %
Initial	9.7	100	8.5	100	12.9	100	1.0	100	5.1	100
70% retention	6.8	69.9	6.2	72.6	8.8	68.6	0.8	78.1	3.8	73.9
50% retention	4.9	49.9	4.6	54.3	6.2	48.0	0.6	63.4	2.9	56.5
30% retention	2.9	29.9	3.1	36.0	3.5	27.2	0.5	48.8	2.0	39.1
Floor	1.0	10.2	1.6	19.2	0.8	6.2	0.4	37.5	1.1	22.2

Wetland area relationships were stronger for wetland birds and, for both guilds, the wetland area pattern indicated that bird abundances initially increased rapidly with wetland area and then progressively levelled off, as expected on the basis of theoretical and empirical studies (reviewed by Bidwell et al. 2014). A positive relationship between cropland and wetland birds could be related to effects of higher soil productivity in cropped areas, fertilizer inputs, or both, on wetland productivity; nonlinear relationships with cropland were not detected possibly because any negative effects of higher cropland area were channeled via bird responses to less wetland area (i.e., at higher cropland area there would necessarily be lower wetland area). To summarize, wetland bird abundance was higher at sites with greater area of wetlands, cropland, and pasture, and less woodland. Aerial insectivores were more abundant at sites with more trees, shrubs and wetland area.

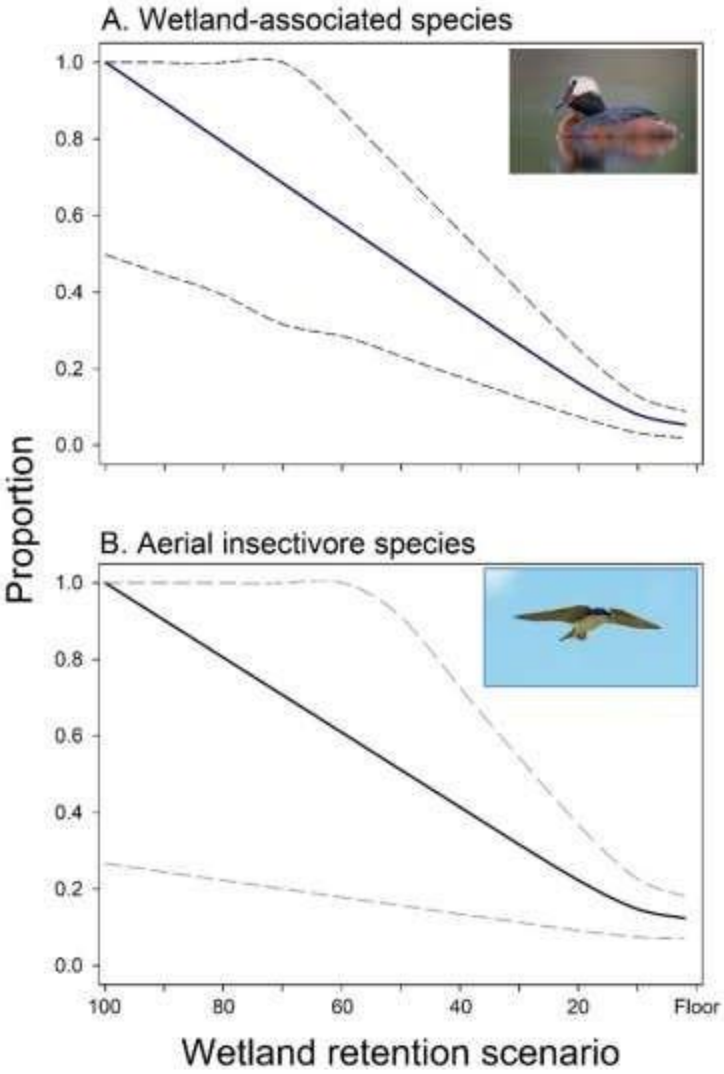
Table 3. Parameter estimates, standard errors (SE), and significance (P) from general linear models developed to predict wetland-associated bird and aerial insectivore abundances based on Alberta Biodiversity Monitoring Institute (ABMI) data. Also shown are model degrees of freedom (df), variance explained (R^2), and root mean square error (RMSE).

	Wetland birds			Aerial insectivores		
Parameter	Estimate	SE	P	Estimate	SE	P
Intercept	20.176	2.818	<0.001	3.039	0.297	<0.001
Wetland area (log10)	32.915	3.297	<0.001	1.012	0.581	0.082
Cropland (%)	0.138	0.036	<0.001	n/a		
Woodland (%)	-0.484	0.175	0.006	0.295	0.032	<0.001
Pasture (%)	0.142	0.060	0.018	n/a		
Shrub (%)	n/a			0.217	0.031	<0.001
df	4, 330			3, 331		
Model R^2	0.256			0.335		
RMSE	24.383			4.464		

Wetland retention scenarios and effects on selected bird guilds

Given inherent challenges and uncertainties in predicting bird abundances, comparing changes in abundance relative to historic levels rather than absolute numbers probably provides a more reasonable foundation for evaluating wetland retention impacts although both are reported here (for major river basin estimates, see Appendices A3 and A4). Wetland-associated bird and aerial insectivore relative abundances declined precipitously from historic levels as wetland retention decreased, a pattern that was evident whether breeding birds in these guilds were considered absent from drained and fully cropped quarter sections (Figure 2, Table 4) or randomly-assigned bird abundances were added to bird abundance estimates for drained-cropped quarters (Table 5; error estimates shown in Appendix A4). The decrease was less pronounced in aerial insectivores because the wetland parameter effect was weaker in this guild than for wetland birds (Table 3), and Floor quarters contained relatively more area of wooded and shrub cover (Table 2), land cover characteristics that had strong positive effects on this guild. Note that historic (100% retention) model-predicted abundance estimates for aerial insectivores, in particular, may be biased low because AAFC land cover data were acquired in 2019, after natural cover (e.g., trees, shrubs) had already been reduced by land conversion to varying extents in major river basins prior to 2019. Declines in model-predicted bird abundances occurred immediately in response to wetland drainage, with no indication that abundances would remain stable or decline more slowly at higher wetland retention scenarios before dropping off more steeply at some lower retention level (Figure 2). In short, such possible “threshold” patterns were not observed in these specific modelling results.

Figure 2. Relationships between *relative* abundances of wetland-associated birds (top, panel A) and aerial insectivores (bottom, panel B), and wetland retention scenarios for all Saskatchewan major river basins combined, assuming no birds in these guilds breed in 100% cropped quarter sections. Proportions of 1.0 signify predicted bird abundances at historic WSA wetland and 2019 AAFC land cover areas. Dashed lines represent ± prediction (root mean square) error for each guild-specific predictive model (Table 3). Horned grebe (*Podiceps auritus*) is shown in panel A, tree swallow (*Tachycineta bicolor*) in panel B.



Relationships between bird abundances and wetland retention scenarios were consistent across major river basins, with only relatively minor deviations due to river basin-specific differences in historic wetland and 2019 land cover areas, and characteristics of quarter sections within the Floor scenario (Figure 3). In several smaller river basins, the maximum number of eligible quarter sections on CLI class 1-5 soils had already been drained before target wetland areas ≤30% had been reached, as reflected in Figures 2 and 3, and Tables 4 and 5. Finally, the relationships between abundance and wetland retention scenarios were nearly linear before approaching Floor levels, likely because the wetland size distributions were not altered during the implementation of the wetland retention scenarios (see Methods for details). For instance, to develop these retention scenarios, all wetlands were removed from each quarter section and smaller wetlands (e.g., Class III seasonally-flooded ponds) were not deemed to be at higher risk of drainage in these scenarios.

It is also important to note that the models used here did not include spatial scale effects that could become evident as an increasing number of quarter sections are drained and converted to cropland. Specifically, as fewer wetlands are retained in the landscape, wetlands become more isolated and local complexes of wetlands needed to attract and support some bird species may become disfunctional (Fairbairn and Dinsmore 2001, Naugle et al. 2001, Blann et al. 2009). Wetland isolation might strongly affect species with relatively low mobility such as amphibians (Lehtinen et al. 1999, Environment Canada 2012 [leopard frog], Ruso et al. 2019). Importantly, these effects could accentuate biotic impacts and changes in community composition especially at lower wetland retention levels. For instance, assuming that some species are influenced by wetland area (or number) at both small *and* large scales, abundances might decrease very rapidly from higher retention levels before leveling off near lower levels. Only one spatial scale (500 m) was considered here because it was not possible to rigorously evaluate scale-related impacts with ABMI data available for this assessment, but this hypothesis should be tested when possible.

Figure 3. Relationships between model-predicted abundances of wetland-associated birds (top, panel A) and aerial insectivores (bottom, panel B), and wetland retention scenarios within each of nine Saskatchewan major river basins, assuming no breeding birds in these guilds occur on 100% cropped quarter sections. Proportions of 1.0 signify bird abundances estimated at historic WSA wetlands and 2019 AAFC land cover areas. Error estimates are shown in Appendix A3 for each river basin. Note that estimates level off at scenarios ≤30% in several major river basins because the maximum number of quarter sections with drainage potential in these river basins had already been drained for crop production.

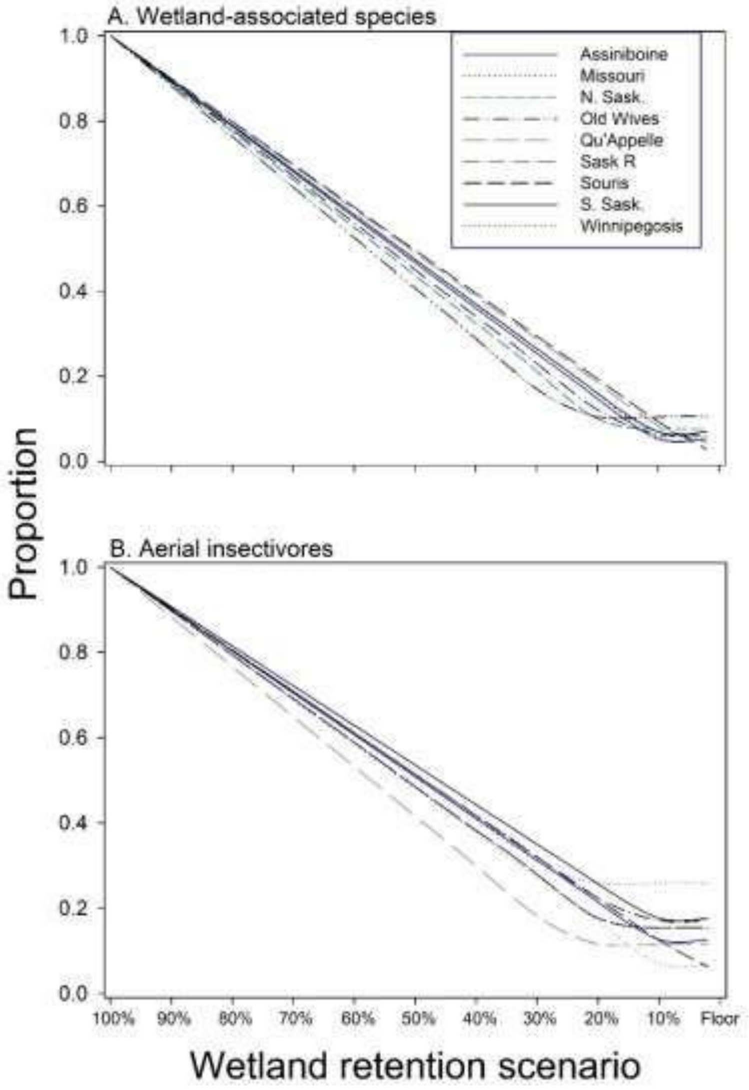


Table 4. Model-predicted abundances (N) of wetland-associated birds and aerial insectivores for all major river basins combined, with prediction errors (Lower, Upper), in relation to wetland retention scenarios (see Figure 2). Estimates assume that no breeding birds occur on quarter sections that were drained and converted to 100% cropland. Shaded values include Floor estimates (see Figure 3 caption). Wetland retention levels are shown in Table 5.

Retention scenario	Wetland-associated birds			Aerial insectivores		
	N	Lower	Upper	N	Lower	Upper
100%	11324004	5639382	17019089	1254523	334447	2295384
90%	10132439	5036569	15238390	1131948	306690	2064983
80%	8939735	4433326	13456015	1009366	279036	1834484
70%	7746979	3829709	11673857	886917	251507	1604177
60%	6554630	3226610	9892105	764573	223993	1373957
50%	5361896	2622789	8109969	641974	196302	1143520
40%	4169649	2019627	6328320	519571	168820	913238
30%	2977296	1416300	4546565	397117	141131	682936
20%	1836788	839716	2841866	279987	114864	462536
10%	907375	368628	1454034	185298	93886	283942
Floor	605974	215225	1004631	155674	87871	227217

Table 5. Model-predicted abundances (N) of wetland-associated birds and aerial insectivores for all major river basins combined, with prediction errors (Lower, Upper), in relation to wetland retention scenarios. Also shown is the proportion of birds relative to historic abundances (Prop.). Estimates include randomly-selected bird abundances added to quarter sections that were drained and converted to 100% cropland. Shaded values include Floor estimates (see Figure 3 caption).

Retention scenario	Wetland-associated birds				Aerial insectivores				Wetland	
	N	Lower	Upper	Prop.	N	Lower	Upper	Prop.	Area (ha)	%
100%	11324004	5639382	17019089	1.000	1254523	334447	2295384	1.000	1469433	100
90%	10164773	5174504	15260711	0.898	1159768	334539	2092784	0.924	1322389	90.0
80%	9003733	4595590	13510408	0.795	1065207	334875	1890326	0.849	1175171	80.0
70%	7842768	4016887	11760128	0.693	970573	335152	1687831	0.774	1028254	70.0
60%	6682933	3438793	10011210	0.590	875628	335046	1485052	0.698	881286	60.0
50%	5522789	2860479	8262012	0.488	780977	335320	1282513	0.623	734354	50.0
40%	4362177	2281914	6512290	0.385	686295	335506	1079962	0.547	587313	40.0
30%	3202275	1703845	4763199	0.283	591529	335631	877339	0.472	440519	30.0
20%	2069660	1122755	3069577	0.183	481224	316107	663778	0.384	300026	20.4
10%	1058744	544314	1605113	0.093	316424	225010	415074	0.252	185752	12.6
Floor	605974	215225	1004631	0.054	155674	87871	227217	0.124	149985	10.2

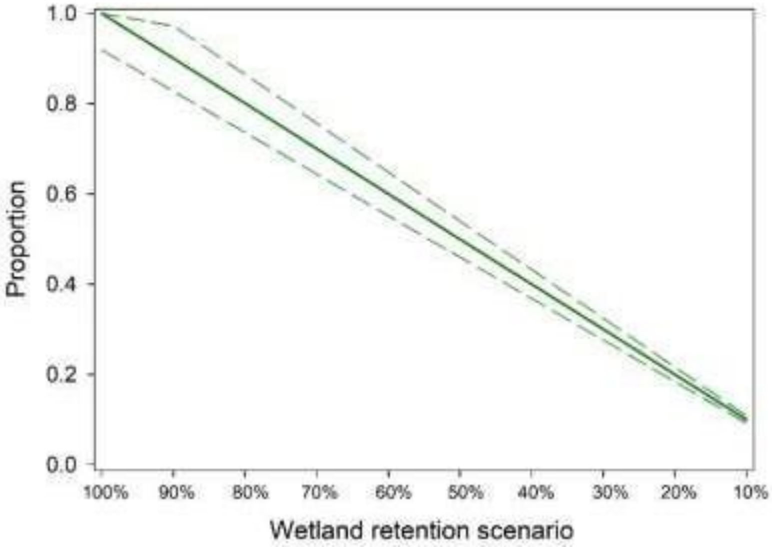
Case-study: Wetland class, drainage risk and quarter-section-level drainage

Duck pair abundances were estimated by species (or species combined) for individual wetlands and summed by quarter section, and then used to evaluate how relative pair abundances changed with wetland retention scenarios in the Qu'Appelle River basin (Table 6). Unlike the guild-specific predictive models above that included land cover data, models used to predict duck abundances were based solely on wetland area measurements. Nonetheless, the patterns of change in relative abundances of wetland-associated species and aerial insectivores (Figure 2) and ducks (Table 6, Figure 4) were similar despite different data collection methods, geographic extent, and distinct sets of explanatory variables. In short, changes in duck abundances closely tracked changes in wetland area retained (Table 5), as illustrated for mallard in Figure 4, and mirrored general patterns obtained for wetland-associated birds shown in Figure 2.

Table 6. Breeding pair abundance estimates (N) and 95% confidence intervals (Lower, Upper) for mallard and northern shoveler, and pair abundances of three other duck species and for all five dabbling duck species combined, by wetland retention scenario in the Qu'Appelle River basin. Estimates are based on square root of wetland area for mallard and shoveler, and (wetland area + square root of wetland area) for the other three species (Bartzen 2008). Shown are median estimates derived from bootstrap sampling (n = 500). Also shown is the proportion (Prop.) of duck pair abundance for each scenario relative to historic (100% scenario) wetland area values.

	Mallard				Northern shoveler				Other ducks		Dabbling ducks	
Scenario	N	Lower	Upper	Prop.	N	Lower	Upper	Prop.	N	Prop.	N	Prop.
100%	130348	119869	139211	1	62649	56392	68906	1	206970	1	399055	1
90%	117379	107943	126815	0.901	56416	50781	62050	0.901	186392	0.901	359369	0.901
80%	104391	95999	112782	0.801	50173	45162	55184	0.801	165759	0.801	319612	0.801
70%	91327	83985	98669	0.701	43895	39511	48279	0.701	144997	0.701	279585	0.701
60%	78251	71960	84541	0.600	37610	33854	41366	0.600	124255	0.600	239587	0.600
50%	65172	59933	70411	0.500	31324	28195	34452	0.500	103535	0.500	199587	0.500
40%	52162	47969	56355	0.400	25071	22567	27575	0.400	82818	0.400	159694	0.400
30%	39157	36009	42305	0.300	18820	16940	20700	0.300	62173	0.300	119876	0.300
20%	26072	23976	28168	0.200	12531	11279	13782	0.200	41406	0.200	79831	0.200
10%	13055	12006	14105	0.100	6275	5648	6901	0.100	20730	0.100	39966	0.100

Figure 4. Relative changes in model-predicted mallard breeding pair abundances (solid line) with 95% confidence intervals (dashed lines) versus wetland retention scenarios for the Qu'Appelle River basin, assuming all wetlands are drained within quarter sections. A proportion of 1.0 represents the historic estimate. Northern shoveler (and dabbling duck) pair abundance follows the same pattern of relative change as for mallard (see Table 6), and is not shown.

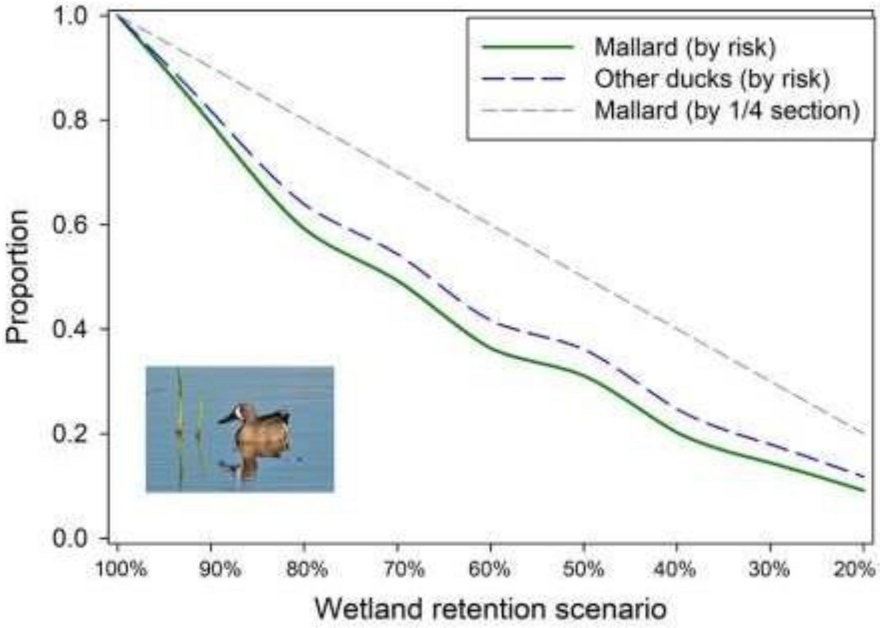


The preliminary assessment of how area-specific drainage risk might influence duck abundances indicated that initial decreases might be steeper if smaller wetland basins are drained before larger ones (Figure 5). This is because smaller wetlands are more abundant and have higher duck densities (i.e., pairs/hectare) than larger wetlands, so removing a greater proportion of smaller wetlands has a disproportionately larger impact on overall pair numbers. To further illustrate the relative impact of wetland area-specific loss, consider the following example. Predicted mallard pair abundance is 0.208 for a 0.1 ha wetland, 0.465 for a 0.5 ha wetland, and 0.931 for a 2 ha wetland; it follows then that pair abundance extrapolates to 4.163 pairs (=0.208*20) for 20, 0.1-ha wetlands, 1.862 pairs (=0.465*4) for 4, 0.5 ha wetlands, and 0.931 pairs (=0.931*1) for 1, 2-ha wetland (see Bartzen [2008] for parameter estimates, and Bartzen et al. [2017] for a similar example). Thus, total mallard pair abundance is ~2-4 times higher for 20, 0.1-ha wetlands than for either 4, 0.5-ha wetlands or a single 2-ha wetland, despite equivalent wetland area. Due to the nonlinear relationships between wetland area and bird abundances for other wetland species, reported above, the impact of higher drainage risk for small wetland basins extends more broadly than to just mallards or dabbling ducks examined here (also see Elliott et al. 2020). This result is also important when considering wetland size exclusions, as discussed briefly below.

Case-study: Changes in bird species richness (number of species)

Exploratory modelling of bird species richness (BSR) responses to AAFC wetland area and land cover (%) variation using ABMI bird species richness data incorporated the intercept ($\beta = 23.541 \pm 0.811$), positive relationships with $\log_{10}$-transformed wetland area ($\beta = 4.949 \pm 0.934$), pasture ($\beta = 0.081 \pm 0.018$), shrub ($\beta = 0.227 \pm 0.048$), and a nonlinear relationship with cropland (linear: $\beta = 0.122 \pm 0.043$; quadratic: $\beta = -0.0011 \pm 0.0004$). All parameters ($\beta$) were well-estimated and significant ($P < 0.01$), model fit was good ($r^2 = 0.235$; 5,329 degrees of freedom), and root mean square error was 6.872.

Figure 5. Relative changes in model-predicted duck abundances versus wetland retention scenarios for the Qu'Appelle River basin, weighted by risk of drainage based on wetland basin area. Proportion of 1.0 is the historic value. Shown are relative changes in mallard and other ducks (blue-winged teal, gadwall, northern pintail combined) for each scenario, weighted by area-risk category. Relative changes in mallard based on draining entire quarter sections (by ¼ section) are shown for reference, as in Figure 4. *Inset*: male blue-winged teal.



Preliminary model-predicted estimates for the Qu'Appelle River basin indicated an overall decrease in species richness below a 90% wetland retention scenario (Table 7). Approximately 24% of species had been lost, *on average*, at the 50% retention scenario relative to the historic level, and >40% of species had been lost at the 10% and Floor scenarios. Bird community composition presumably changed as well, with high turnover of species being possible, even likely, across the retention scenarios; unfortunately, the available ABMI data did not allow a rigorous assessment of this process. However, as wetlands and land cover were removed from progressively more drained and cropped quarter sections, fewer wetland, grassland and aerial insectivore species would be expected (see previous results) and common species that occur frequently on farmland such as corvids, horned larks and several small granivores (e.g., some sparrows, longspurs) would persist (reviewed in Part A). Furthermore, non-drained quarter sections (i.e., Floor) could provide suitable habitat for many species, as discussed previously.

Other field studies have reported that average species richness is lower (e.g., ~50%) at cropland than grassland sites (Shutler et al. 2000, McMaster and Davis 2001), and preliminary results presented here are consistent with these findings. Furthermore, Skinner and Clark (2008) found that overall bird species richness (and abundance) was highest in areas of southern Saskatchewan composed of more wetlands and diverse natural upland cover. While overwhelming world-wide evidence indicates significant biodiversity losses with agricultural expansion (see Part A of this report), a more refined and thorough evaluation of such impacts in Saskatchewan may be possible, and cover a wider range of biota.

Table 7. Preliminary estimates of median bird species richness (# Species) in relation to wetland retention scenarios, Qu'Appelle River basin. Proportion of 1.0 is set to predicted species richness at historic (100%) wetland values and 2019 AAFC land cover values. Median errors (Lower, Upper) were based on model root mean square error. All medians were weighted within the river basin by the number of quarter sections (i.e. area) in non-drained, drained-cropped, and Floor categories; see text for details.

Scenario	# Species	Lower	Upper	Prop.
100%	28.6	21.7	35.5	1.0
90%	27.2	20.4	34.1	0.952
70%	24.5	17.6	31.4	0.857
50%	21.8	14.9	28.7	0.762
30%	19.1	12.2	25.9	0.667
10%	16.3	9.5	23.2	0.571
Floor	15.8	8.9	22.7	0.552

Other models used to predict bird occurrences, abundances and species richness

In addition to Bartzen et al. (2017) and Mantyka-Pringle et al. (2019) cited above, at least six studies have modelled how occurrence or abundance of birds in distinct guilds vary with wetland characteristics in Canadian or northern US prairie regions (Table 8). Mantyka-Pringle et al. (2019) did not report a (significant) positive association between aerial insectivores and wetland area (Table 8), but they considered a larger number of explanatory variables in their modelling so a wetland effect may have been obscured or subsumed by these other variables. Most studies are consistent in reporting positive associations, as expected, between wetland area and occurrence or abundance of wetland-associated species. Furthermore, the diverse species-specific responses to wetland size, class, and numbers implies that a range of wetland sizes and permanence classes (i.e., complexes) are needed to accommodate wetland selection patterns within the wetland bird community (Kantrud and Stewart 1984, Elliott et al. 2020). Results for grassland birds are mixed, likely due to the affinity for large areas of dry grasslands exhibited by several species (Skinner and Clark 2008, Fedy et al. 2018). Saunders et al. (2019) also demonstrated that wetland occupancy among 8 of 9 breeding wetland bird species was negatively related to the proportion of either agriculture or developed land in the vicinity of wetlands; likewise, abundances of three species were highest where proportion of wetland area was greatest and agriculture had low-moderate land coverage. No studies were found to be specific to aerial insectivores so direct comparisons are not yet possible, but the wetland bird models seem highly consistent with the general findings reported in this report, in terms of wetland area effects on bird abundances and species richness.

Table 8. Summary of studies reporting effects of wetland characteristics (area, number) on bird communities in Canadian and US prairie landscapes. Shown are the species grouping, response variable reported (abundance, occurrence, number of species) and wetland effect as reported by authors. **Source** references corresponding to numbers (**1-8**) are listed in the footnote.

Source	**Species or functional group (# species)**	**Response variable**	**Wetland effect**
1	Waterbirds (5 species) and northern pintail	Abundance	Positively correlated with number of wetlands, all 6 species.
2	Ducks (4 species)	Abundance	Positive -- wetland area at all spatial scales (1k, 10k, 100k)
3	Ducks (5 species)	Abundance	Positive (area)
4	Grassland birds (15 species)		
		Occurrence	Positive (moderate) coefficient for 7 of 10 spp for # wetlands
			Negative (moderate) coefficient for 5 of 10 species for wetland area
5	Bird community		
	Aquatic and terrestrial invertivores (7)	Abundance	Positive (weak)
	Aquatic & terrestrial insectivores (3)	Abundance	ns
	Aquatic and terrestrial omnivores (4)	Abundance	Positive
	Aquatic carnivores (9)	Abundance	Positive
	Aquatic & terrestrial carnivores (2)	Abundance	Positive
	Aquatic invertivores (14)	Abundance	Positive

	Aquatic omnivores (19)	Abundance	Positive
	Aerial insectivores (21)	Abundance	ns
	Arboreal herbivores (2)	Abundance	ns
	Arboreal insectivores (18)	Abundance	ns
	Terrestrial omnivores (39)	Abundance	ns
	Arboreal omnivores (6)	Abundance	ns
	Terrestrial carnivores (1)	Abundance	ns
	Terrestrial insectivores (11)	Abundance	ns
	Terrestrial herbivores (11)	Abundance	ns
	Terrestrial invertivores (6)	Abundance	ns
	All groups (173)	Richness	ns
6	Wetland bird community (9 focal species analysed)	Occupancy, Abundance (3 spp)	Generally positive, but scale-dependent for wetland area.
7	Wetland bird community	Abundance (38 spp)	Overall, positive relationships with wetland area in all 38 spp modelled
		Species richness (57 spp)	Area models explained 7-63% of variation overall, and across guilds
8	Marsh bird community (8 focal species)		
	Grebes (3 spp)	Occupancy	Positive area and # basins (2 spp); positive basins, negative area (1 spp)
	Rails (3 spp)	Occupancy	Positive area all 3 spp; positive # basins: weak 2 spp, strong 1 spp.
	Other (2 spp)	Occupancy	Positive area both spp; negative # basins both spp.

1. Niemuth and Solberg 2003. Wetlands; **2**. Forcey et al. 2011. J. Biogeog.; **3**. Bartzen et al. 2017. Wildl. Soc. Bull.; **4**. Fedy et al. 2018. ACE; **5**. Mantyka-Pringle et al. 2019. Diver. & Distrib.; **6**. Saunders et al. 2019. Ornithol. Appl.; **7**. Elliott et al. 2020. Ornithol. Adv.; **8**. Bird Studies Canada (Kiel Drake, pers. commun.).

ADDITIONAL POLICY CONSIDERATIONS

Exclusions

Could wetlands of specific sizes or permanence classes be excluded (exempted) from overarching percentage-based wetland retention scenarios? For example, a policy option that requires 50% retention of historical wetland area, excluding wetlands 1 acre in size, would mean that <50% of historical wetland area would be retained because wetland drainage or filling would be permitted on wetlands <1 acre in size and these wetlands would not be counted in the wetland area retention requirement.

With respect to wildlife habitat, the answer to the question posed above is fairly straight-forward. Wetlands of all sizes are used by different animal species at various times of the year to fulfill life-cycle needs. This is why maintaining wetland complexes – landscapes composed of wetlands of varying size and permanence – is so critically important; wetland complexes may also provide resilience to future climate variability and change (Johnson et al. 2010). From an ecological perspective, therefore, no size or class exclusions can be justified. From a strictly pragmatic perspective, excluding Class I (ephemeral) and II (temporary) wetlands could be considered practical for producers and regulators; many wetlands in Classes I and II are already altered or farmed - although these ephemeral-temporary wetlands can still be important for some species, e.g., in early spring. Class III (seasonal) wetlands are highly productive due to frequent flooding-drying regimes, and they do not typically contain fish, so receive extremely high use by diverse aquatic biota during flood phases. Seasonal wetlands (Class III) cannot be defined exclusively by size category, due to a wide range of areas in this Class, but WSA wetland inventory data indicate that many wetlands <0.10 ha (<0.25 acres) are typically Classes I and II. An extremely careful examination of the existing data might provide deeper insights into defining sizes of Class III wetlands, and WSA should conduct a thorough assessment. However, ***the clear message is that excluding Class III wetlands from drainage restrictions would be nearly catastrophic*** for a diverse wetland-dependent community, including still-common and priority invertebrates, amphibians, birds and some mammals.

Best Management Practices (BMPs)

BMPs hold potential to improve environmental outcomes of selected wetland retention scenarios for some species. It is important to note that wetland habitat cannot be replaced with upland habitat; this is because no upland BMPs can offset negative impacts of wetland losses on obligate wetland species. Still, either protecting existing or restoring perennial upland habitat near wetlands could create favourable habitat conditions (quality and quantity) for some bird and game species that rely less on in-water resources and more on riparian or upland habitat. Vegetated buffers around wetlands could provide suitable habitat for a number of animal species, and also enhance water quality by reducing agrochemical inputs to wetlands (Main et al. 2015, Ruso et al. 2019). Protecting water quality could improve conditions for aquatic biota, and possibly reduce pesticide exports via emerging aquatic insects to terrestrial consumers (Kraus et al. 2021; also see Part A). For habitat-based BMPs to produce positive impacts needed to (partly) mitigate wetland loss would require relatively large areas of potential cropland, and this trade-off could impose a constraint for crop producers. Nonetheless, possible uses of upland habitat BMPs, and trade-offs involved in substituting wetland, upland and crop areas, probably warrants further consideration.

PART C – ACHIEVING GOALS OF SASKATCHEWAN, CANADIAN AND INTERNATIONAL POLICIES AND AGREEMENTS WITH RESPECT TO WETLANDS AND ASSOCIATED BIODIVERSITY

SASKATCHEWAN CONTEXT

Saskatchewan's Growth Plan 2020-2030 – this Plan sets out ambitious goals for growth and yet also seeks to conserve Saskatchewan's water and land resources, manage biodiversity risks, protect natural carbon sinks, and build resilience to extreme weather (https://publications.saskatchewan.ca/api/v1/products/103260/formats/114516/download). Encouraging the expansion of land area devoted to agricultural production by draining wetlands and reducing the area of other natural land cover will create serious trade-offs for conserving biodiversity; this is because wetlands and their unique functions cannot be replaced. Furthermore, wetland drainage and clearing of natural cover associated with wetlands could create challenges in building resilience to extreme weather events and in supporting Saskatchewan's approaches and objectives for addressing climate change (*next section*). None of the "30 Goals by 2030" refers to respecting and sustaining Saskatchewan's natural environment (30 Goals for 2030 | Saskatchewan's Growth Plan | Government of Saskatchewan) but the core Plan does refer to conserving land and water resources (page 50), and specifically recognizes the Game Management Plan (below) and Water Security Agency's (WSA) developing plans for agricultural water management. The Plan also aspires to "support and reward producers" who retain natural habitats on their lands (page 48); if implemented, this could be a highly strategic and environmentally favourable approach to protecting natural areas, including wetlands.

Prairie Resilience: A Made in Saskatchewan Climate Change Strategy (2017) – a cornerstone of the Provincial plan is building "resilience", implying that the province will be able to withstand climate change impacts, adapt appropriately to changing conditions, and recover quickly from climate stresses and change. To meet this challenge, the province has developed policies in four main areas: natural systems, physical infrastructure, economic sustainability and community preparedness. Within natural systems, the strategy states, "How we use our lands and our actions to *preserve and restore wetlands* builds resilience into our landscapes through greater ability to retain carbon and reduce the effects of flood and drought." And, in terms of supporting action(s), the plan proposes to, "Continue to implement Saskatchewan's agricultural water management framework in the province to help assure continued productivity, *enhance wetland habitat conservation* (*emphasis* added) and improve runoff management in times of both drought and flood.“ WSA's agricultural water management strategy should help to provide a more defensible and rational approach to farmland wetland drainage, and the climate change strategy clearly infers support for wetland protection and restoration. Clearly, better alignment of conflicting goals (i.e, development and conservation/resilience) within and among policies would be helpful. To conclude, expanding drainage and clearing natural areas for agricultural expansion seems entirely counter to the objectives of building resilience and conserving wetlands.

Saskatchewan's Protected and Conserved Areas Roadmap – the plan's vision is to have, "…a network of protected and conserved natural areas representing and sustaining the full range of habitat for wild species…" A principal goal is to protect and conserve 12% of Saskatchewan's land and water, using a range of land management mechanisms that provide varying levels of protection. Recent estimates indicate that of the major ecoregions within Saskatchewan's farmed landscapes, 15.6% of the mixed grassland ecoregion is protected in some manner (e.g., provincial, federal and community parks and pastures). Similar estimates for the moist mixed grassland and aspen parkland are 6.9% and 6.5%, respectively; these are the two ecoregions where wetland drainage impacts on wildlife habitat will be most severe due to continued and proposed agricultural development. Revised national and international protected areas targets (17%, 25% by 2025, 30% by 2030) are much more ambitious than Saskatchewan's stated 12% goal, and any future efforts to encourage further wetland drainage and clearing of natural lands for agricultural expansion will clearly undermine efforts to protect even 12% of Saskatchewan's unique wetland resources in agricultural areas.

Habitat Management Plan (HMP) – the HMP, in development, provides target habitats and proposed indicator species within each of Saskatchewan's ecozones. In the Prairie ecozone, the "priority conservation targets include grasslands, agricultural landscapes, natural tree cover, wetlands, lakes, rivers and streams. It is these conservation targets that the HMP seeks to affect, as measured using target indicators." To support the development of the HMP, the Ministry of Environment is completing habitat suitability model assessments for over 250 species in the province, and producing species distribution models by linking the probability of multiple species occurrences to habitat distribution across the Prairie ecozone, and classified by major habitat affinity (e.g., grassland, wetland, tree). In Agricultural Landscapes, pollinator access to crops and abundance of aerial insectivores are two indicators of ecological integrity. As explained in Part A, natural areas like wetland margins are important refugia for pollinators, and wetlands supply abundant and highly nutritious foods to insect-eating birds and bats. Extensive wetland drainage and habitat isolation are expected to create conditions well below the ecologically desirable state for these indicators. If wetland drainage is accompanied by loss of aspen woodland, similar adverse impacts will be evident for indicators of natural tree cover.

Several key wetland indicators are currently in development, including moose habitat suitability (discussed in Part A), wetland riparian health, and rate of wetland loss. A proposed indicator, occurrence of six marsh bird species, presumes that these species can be monitored during daylight in the breeding season using existing volunteer survey methods. Although spatially variable, wetland loss has been estimated at ~3% per decade for the prairies since the mid-1980s (Watmough et al. 2017). Another key goal identified in the HMP is to stabilize or decrease the rate of wetland loss relative to 2020 baselines. The implications of continued wetland drainage for marsh birds and other species were explored in Parts A and B, and population declines are expected in a wide range of wetland-associated species, and possibly among many tree-associated species, if this HMP goal is not achieved.

Game Management Plan (GMP), *2018-2028* – maintaining habitat to support wildlife populations is a core goal of the Game Management Plan (Outcome 1, Goal 1.1). Cumulative wetland drainage and land clearing for agricultural expansion will counter the GMP goals of maintaining key habitats and connecting habitats on Crown and private lands. Because 85% of land across the Prairie ecozone is privately owned, it is imperative to work with landowners to secure important habitat. However, while many non-governmental programs exist to protect wetlands, the use of NGO-landowner partnerships is constrained by provincial regulations concerning agricultural land ownership. Thus, a principle avenue for achieving wildlife habitat goals is to provide incentives to private landowners to retain existing natural habitats, as suggested in the Growth Plan (above).

NATIONAL AND INTERNATIONAL AGREEMENTS

North American Waterfowl Management Plan – Saskatchewan is a charter member of the Prairie Habitat Joint Venture (PHJV), the largest and most important Joint Venture for breeding waterfowl on the continent (PHJV 2021). Saskatchewan landowners and government receive significant funding for conservation projects across the prairies from private, NGO, and Canadian and U.S. federal and state sources. Also, as noted in Part A, the PHJV also delivers habitat conservation on behalf of the North American Bird Conservation Initiative (NABCI; Bird Conservation Region 11 – Prairie Pothole Region) which seeks all-bird conservation and recovery of species at risk. Despite conservation investments – which to date have had positive impacts on wetland habitats and birds - it will not be possible to achieve long-term NAWMP/NABCI goals for prairie-breeding waterfowl and other wetland birds without agricultural policies that provide significant wetland protection, including for complexes of wetlands composed of diverse sizes and permanency classes (e.g., Classes III-V). This is because the pace of delivery and spatial extent of conservation lands are more constrained than the losses of wetland and riparian habitats. Further details are provided in Part A.

International Convention on Biological Diversity (CBD) - Saskatchewan's main commitment is focused on CBD Target 1 which states: "By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably." This is important. It seems certain, however, that other key CBD Targets cannot be achieved by expanding agricultural production via wetland drainage, such as those aimed at protecting areas important to biodiversity (Target 11) and preventing extinction of threatened species (Target 12; Technical Rationale (provided in document COP/10/27/Add.1) (cbd.int)). As noted by Venter et al. (2017), evidence indicates that securing protected areas has been influenced more by avoiding places where agricultural development is planned than by selecting areas with greatest benefits for biodiversity. This conundrum describes the current situation in Saskatchewan.

CONCLUSIONS and CLOSING COMMENTS

Ongoing wetland drainage and land clearing to accommodate further agricultural crop development seems directly counter to stated objectives of several Saskatchewan policy initiatives (Table 9), including several components of the Growth Plan and Climate Change Plan, and major goals of the Game Management Plan (including the Habitat Management Plan, in development), and Protected Areas Plan. Such actions are also *contra* goals of national and international agreements for a range of species at risk, conservation of biodiversity and security of North America's avifauna.

Evaluating whether additional wildlife habitat and game harvest concerns exist as related to obligations regarding First Nations Rights and the reconciliation process was beyond the scope of this report, but this possibility should be thoroughly investigated. Respectful engagement would appear to be essential in this regard.

Finally, it is usually more cost-effective to retain existing wetlands than to restore them later, as is the goal of "keeping common species common". The costs of future interventions to recover species and critical habitats are not often fully integrated into economic assessments of development. Likewise, it could be instructive to determine whether environmental stewardship (i.e., via regulations that protect wetlands) could possibly help to retain or enhance market opportunities for commodity exports, a central goal of Saskatchewan's growth strategy.

Table 9. Environmental goals of major policies and agreements at provincial, national and international levels, and anticipated impacts of reduced wetland retention on achieving core goals of these initiatives.

Strategic Plans and Agreements	Vision or Goals (Environment)	Impacts of reduced wetland retention to expand cropland	Comments
Saskatchewan's Growth Plan 2020-2030	Conserving Saskatchewan's water and land resources; managing biodiversity risks; protecting natural carbon sinks; maintaining resilience to extreme weather.	Reduce water security; impact future market access (green certification).	SK Farm Stewardship Program (*contra* biodiversity maintained; minimizes environmental impacts and risks)
	Support landowners in maintaining wetlands and other natural habitats	Would reduce wetland loss especially in areas with lower crop production capacity.	This could be a favourable policy decision and *potentially* result in higher wetland retention.
Prairie Resilience: A Made-in-Saskatchewan Climate Change Strategy (2017)	Natural systems help to achieve resilience.	Converting natural uplands and wetlands to croplands releases C and reduces C storage capacity; increases hydrocarbon inputs.	*Contra* building resilience -- communities become more vulnerable to climate extremes
Protected and Conserved Areas Roadmap	A network of protected and conserved natural areas representing and sustaining the full range of habitat for wild species, unique physical features and ecosystem values that provide diverse benefits for Saskatchewan.	This goal cannot be achieved with reduced wetland retention for conversion to crop production.	Retention far more cost-effective than restoration
	Achieve Saskatchewan’s goal of 12% of Saskatchewan's land and water	(<7% of the aspen parkland and moist mixed grass prairie ecoregions are protected)	Outdated - note revised 17% goal (and proposed 25% by 2025 and 30% by 2030 initiatives)
Saskatchewan Habitat Management Plan (in progress)	Ecologically desirable states (based on robust indicators) are achieved for Agricultural landscapes and for Wetlands.	Negative impacts on indicators. Habitat loss and fragmentation; reduced connectivity.	Loss of habitat for key indicators including pollinators, pest predators, aerial insectivores.

Saskatchewan Game Management Plan	Key habitats are maintained for game species.	Reduces (selected) habitat for several big and small game species; conversion to cropland reduces availability of the most suitable habitats for most game species.	Implications for future hunting opportunities are uncertain.
Species at Risk	Critical habitat needs of listed species (schedules 1-3)	Habitat loss and fragmentation; reduced habitat connectivity.	See Table 1; amphibians, several bird species.
North American Waterfowl Management Plan (N.A. Bird Conservation Initiative)	Long-term sustainability of waterfowl and other priority bird species.	Negative impact. Breeding success is reduced; ability to meet goals is undermined	Reduces habitat suitability for target species, game and nongame. Reduced breeding success.
Convention on Biological Diversity	Target 11: By 2020, at least 17% of terrestrial and inland water areas ... especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape...	Negative impact. Areas under protection in pothole wetland landscapes are <7%.	Reduces diversity - aquatic and terrestrial.
	Target 12: By 2020, the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.	Negative impact. See Part A - species at risk and priority species.	

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APPENDICES

Appendix A1. Breeding birds and functional groups used for modelling bird responses to wetland drainage in Saskatchewan. See Mantyka-Pringle et al. (2019) for further details.

Common Name	**Scientific Name**	**Functional Group**[A]	**Family**	**Species at Risk in Canada**[B]
American Kestrel	*Falco sparverius*	Aerial carnivore	Falconidae	
Broad-winged Hawk	*Buteo platypterus*	Aerial carnivore	Accipitridae	
Burrowing Owl	*Athene cunicularia*	Aerial carnivore	Strigidae	Endangered
Eagles, Hawks and Allies[C]	*Accipitridae*	Aerial carnivore	Accipitridae	
Ferruginous Hawk	*Buteo regalis*	Aerial carnivore	Accipitridae	Threatened
Great Gray Owl	*Strix nebulosa*	Aerial carnivore	Strigidae	
Great Horned Owl	*Bubo virginianus*	Aerial carnivore	Strigidae	
Long-eared Owl	*Asio otus*	Aerial carnivore	Strigidae	
Merlin	*Falco columbarius*	Aerial carnivore	Falconidae	
Northern Harrier	*Circus cyaneus*	Aerial carnivore	Accipitridae	
Northern Hawk Owl	*Surnia ulula*	Aerial carnivore	Strigidae	
Red-tailed Hawk	*Buteo jamaicensis*	Aerial carnivore	Accipitridae	
Sharp-shinned Hawk	*Accipiter striatus*	Aerial carnivore	Accipitridae	
Short-eared Owl	*Asio flammeus*	Aerial carnivore	Strigidae	Concern
Swainson's Hawk	*Buteo swainsoni*	Aerial carnivore	Accipitridae	
Alder Flycatcher	*Empidonax alnorum*	Aerial Insectivore	Tyrannidae	
Bank Swallow	*Riparia riparia*	Aerial Insectivore	Hirundinidae	Threatened
Barn Swallow	*Hirundo rustica*	Aerial Insectivore	Hirundinidae	Threatened
Canada Warbler	*Cardelina canadensis*	Aerial insectivore	Parulidae	Threatened
Cliff Swallow	*Petrochelidon pyrrhonota*	Aerial Insectivore	Hirundinidae	
Common Nighthawk	*Chordeiles minor*	Aerial Insectivore	Caprimulgidae	Concern
Eastern Kingbird	*Tyrannus tyrannus*	Aerial Insectivore	Tyrannidae	
Eastern Phoebe	*Sayornis phoebe*	Aerial insectivore	Tyrannidae	
Great Crested Flycatcher	*Myiarchus crinitus*	Aerial Insectivore	Tyrannidae	
Hammond's Flycatcher	*Empidonax hammondii*	Aerial Insectivore	Tyrannidae	
Least Flycatcher	*Empidonax minimus*	Aerial Insectivore	Tyrannidae	
Mountain Bluebird	*Sialia currucoides*	Aerial Insectivore	Turdidae	
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	Aerial Insectivore	Hirundinidae	
Purple Martin	*Progne subis*	Aerial Insectivore	Hirundinidae	
Say's Phoebe	*Sayornis saya*	Aerial Insectivore	Tyrannidae	
Tree Swallow	*Tachycineta bicolor*	Aerial Insectivore	Hirundinidae	
Violet-green Swallow	*Tachycineta thalassina*	Aerial Insectivore	Hirundinidae	
Western Kingbird	*Tyrannus verticalis*	Aerial Insectivore	Tyrannidae	
Western Wood-Pewee	*Contopus sordidulus*	Aerial Insectivore	Tyrannidae	
Willow Flycatcher	*Empidonax traillii*	Aerial Insectivore	Tyrannidae	
Yellow-bellied Flycatcher	*Empidonax flaviventris*	Aerial Insectivore	Tyrannidae	
Great Blue Heron	*Ardea herodias*	Aquatic & terrestrial carnivore	Ardeidae	

Black Tern	*Chlidonias niger*	Aquatic & terrestrial carnivore	Laridae	
Common Yellowthroat	*Geothlypis trichas*	Aquatic & terrestrial insectivore	Parulidae	
Northern Waterthrush	*Parkesia noveboracensis*	Aquatic & terrestrial insectivore	Parulidae	
Sedge Wren	*Cistothorus platensis*	Aquatic & terrestrial insectivore	Troglodytidae	
Least Sandpiper	*Calidris minutilla*	Aquatic & Terrestrial invertivore	Scolopacidae	
Lesser Yellowlegs	*Tringa flavipes*	Aquatic & Terrestrial invertivore	Scolopacidae	
Red-necked Phalarope	*Phalaropus lobatus*	Aquatic & Terrestrial invertivore	Scolopacidae	Concern
Spotted Sandpiper	*Actitis macularius*	Aquatic & Terrestrial invertivore	Scolopacidae	
American Pipit	*Anthus rubescens*	Aquatic & terrestrial invertivore	Motacillidae	
Wilson's Snipe	*Gallinago delicata*	Aquatic & terrestrial invertivore	Scolopacidae	
Marsh Wren	*Cistothorus palustris*	Aquatic & terrestrial invertivore	Troglodytidae	
Ring-billed Gull	*Larus delawarensis*	Aquatic & Terrestrial omnivore	Laridae	
Arctic Tern	*Sterna paradisaea*	Aquatic & terrestrial omnivore	Laridae	
Bonaparte's Gull	*Chroicocephalus philadelphia*	Aquatic & terrestrial omnivore	Laridae	
Red-winged Blackbird	*Agelaius phoeniceus*	Aquatic & terrestrial omnivore	Icteridae	
American Bittern	*Botaurus lentiginosus*	Aquatic carnivore	Ardeidae	
American White Pelican	*Pelecanus erythrorhynchos*	Aquatic carnivore	Pelecanidae	
Belted Kingfisher	*Megaceryle alcyon*	Aquatic carnivore	Alcedinidae	
Black-crowned Night Heron	*Nycticorax nycticorax*	Aquatic carnivore	Ardeidae	
Common Loon	*Gavia immer*	Aquatic carnivore	Gaviidae	
Forster's Tern	*Sterna forsteri*	Aquatic carnivore	Laridae	
Red-necked Grebe	*Podiceps grisegena*	Aquatic carnivore	Podicipedidae	
Willet	*Tringa semipalmatus*	Aquatic carnivore	Scolopacidae	
Yellowlegs, Willet and Allies[C]	*Tringa*	Aquatic carnivore	Scolopacidae	
Black-necked Stilt	*Himantopus mexicanus*	Aquatic invertivore	Recurvirostridae	
Common Tern	*Sterna hirundo*	Aquatic invertivore	Laridae	
Eared Grebe	*Podiceps nigricollis*	Aquatic invertivore	Podicipedidae	
Greater Yellowlegs	*Tringa melanoleuca*	Aquatic invertivore	Scolopacidae	
Green-winged Teal	*Anas crecca*	Aquatic invertivore	Anatidae	
Horned Grebe	*Podiceps auritus*	Aquatic invertivore	Podicipedidae	Concern
Lesser Scaup	*Aythya affinis*	Aquatic invertivore	Anatidae	
Northern Shoveler	*Spatula clypeata*	Aquatic invertivore	Anatidae	
Pied-billed Grebe	*Podilymbus podiceps*	Aquatic invertivore	Podicipedidae	
Red Phalarope	*Phalaropus fulicarius*	Aquatic invertivore	Scolopacidae	
Ruddy Duck	*Oxyura jamaicensis*	Aquatic invertivore	Anatidae	
Semipalmated Plover	*Charadrius semipalmatus*	Aquatic invertivore	Charadriidae	
Solitary Sandpiper	*Tringa solitaria*	Aquatic invertivore	Scolopacidae	
Wilson's Phalarope	*Phalaropus tricolor*	Aquatic invertivore	Scolopacidae	

American Avocet	*Recurvirostra americana*	Aquatic omnivore	Recurvirostridae
American Coot	*Fulica americana*	Aquatic omnivore	Rallidae
American Wigeon	*Mareca americana*	Aquatic omnivore	Anatidae
Blue-winged Teal	*Spatula discors*	Aquatic omnivore	Anatidae
Canvasback	*Aythya valisineria*	Aquatic omnivore	Anatidae
Cinnamon Teal	*Spatula cyanoptera*	Aquatic omnivore	Anatidae
Common Merganser	*Mergus merganser*	Aquatic omnivore	Anatidae
Dabbling Ducks[C]	*Anas, Spatula, Mareca*	Aquatic omnivore	Anatidae
Ducks, Swans, Geese and Allies[C]	*Anatidae*	Aquatic omnivore	Anatidae
Gadwall	*Mareca strepera*	Aquatic omnivore	Anatidae
Marbled Godwit	*Limosa fedoa*	Aquatic omnivore	Scolopacidae
Northern Pintail	*Anas acuta*	Aquatic omnivore	Anatidae
Redhead	*Aythya americana*	Aquatic omnivore	Anatidae
Ring-necked Duck	*Aythya collaris*	Aquatic omnivore	Anatidae
Sora	*Porzana carolina*	Aquatic omnivore	Rallidae
Virginia Rail	*Rallus limicola*	Aquatic omnivore	Rallidae
Mallard	*Anas platyrhynchos*	Aquatic omnivore	Anatidae
Wood Duck	*Aix sponsa*	Aquatic omnivore	Anatidae
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	Aquatic omnivore	Icteridae
American Goldfinch	*Spinus tristis*	Arboreal herbivore	Fringillidae
Purple Finch	*Haemorhous purpureus*	Arboreal herbivore	Fringillidae
White-winged Crossbill	*Loxia leucoptera*	Arboreal herbivore	Fringillidae
Bay-breasted Warbler	*Setophaga castanea*	Arboreal Insectivore	Parulidae
Black and White Warbler	*Mniotilta varia*	Arboreal Insectivore	Parulidae
Blackpoll Warbler	*Setophaga striata*	Arboreal Insectivore	Parulidae
Blue-headed Vireo	*Vireo solitarius*	Arboreal Insectivore	Vireonidae
Cape May Warbler	*Setophaga tigrina*	Arboreal Insectivore	Parulidae
Golden-crowned Kinglet	*Regulus satrapa*	Arboreal Insectivore	Regulidae
House Wren	*Troglodytes aedon*	Arboreal Insectivore	Troglodytidae
Magnolia Warbler	*Setophaga magnolia*	Arboreal Insectivore	Parulidae
Mourning Warbler	*Geothylpis philadelphia*	Arboreal Insectivore	Parulidae
Orange-crowned Warbler	*Oreothlypis celata*	Arboreal Insectivore	Parulidae
Red-breasted Nuthatch	*Sitta canadensis*	Arboreal Insectivore	Sittidae
Red-eyed Vireo	*Vireo olivaceus*	Arboreal Insectivore	Vireonidae
Ruby-crowned Kinglet	*Regulus calendula*	Arboreal Insectivore	Regulidae
Tennessee Warbler	*Oreothlypis peregrina*	Arboreal Insectivore	Parulidae
Warbling Vireo	*Vireo gilvus*	Arboreal Insectivore	Vireonidae
Western Tanager	*Piranga ludoviciana*	Arboreal Insectivore	Cardinalidae
Yellow Warbler	*Setophaga petechia*	Arboreal Insectivore	Parulidae
Yellow-rumped Warbler	*Setophaga coronata*	Arboreal Insectivore	Parulidae
American Robin	*Turdus migratorius*	Arboreal omnivore	Turdidae
Black-headed Grosbeak	*Pheucticus melanocephalus*	Arboreal omnivore	Cardinalidae

Brewer's Sparrow	*Spizella breweri*	Arboreal omnivore	Emberizidae	
Cedar Waxwing	*Bombycilla cedrorum*	Arboreal omnivore	Bombycillidae	
Evening Grosbeak	*Coccothraustes vespertinus*	Arboreal omnivore	Fringillidae	Concern
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	Arboreal omnivore	Cardinalidae	
Black-capped Chickadee	*Poecile atricapillus*	Bark invertivore	Paridae	
Boreal Chickadee	*Poecile hudsonica*	Bark invertivore	Paridae	
Downy Woodpecker	*Picoides pubescens*	Bark invertivore	Picidae	
Hairy Woodpecker	*Picoides villosus*	Bark invertivore	Picidae	
Pileated Woodpecker	*Dryocopus pileatus*	Bark invertivore	Picidae	
White-breasted Nuthatch	*Sitta carolinensis*	Bark invertivore	Sittidae	
Woodpeckers^{C}	*Picinae*	Bark invertivore	Picidae	
Red-naped Sapsucker	*Sphyrapicus nuchalis*	Bark omnivore	Picidae	
Yellow-bellied Sapsucker	*Sphyrapicus varius*	Bark omnivore	Picidae	
Long-billed Curlew	*Numenius americanus*	Terrestrial carnivore	Scolopacidae	Concern
California Quail	*Callipepla californica*	Terrestrial herbivore	Odontophoridae	
Canada Goose	*Branta canadensis*	Terrestrial herbivore	Anatidae	
Clay-colored Sparrow	*Spizella pallida*	Terrestrial herbivore	Emberizidae	
House Finch	*Haemorhous mexicanus*	Terrestrial herbivore	Fringillidae	
House Sparrow	*Passer domesticus*	Terrestrial herbivore	Passeridae	
Mourning Dove	*Zenaida macroura*	Terrestrial herbivore	Columbidae	
Ring-necked Pheasant	*Phasianus colchicus*	Terrestrial herbivore	Phasianidae	
Rock Pigeon	*Columba livia*	Terrestrial herbivore	Columbidae	
Sharp-tailed Grouse	*Tympanuchus phasianellus*	Terrestrial herbivore	Phasianidae	
White-crowned Sparrow	*Zonotrichia leucophrys*	Terrestrial herbivore	Emberizidae	
Pine Siskin	*Spinus pinus*	Terrestrial herbivore	Fringillidae	
American Redstart	*Setophaga ruticilla*	Terrestrial insectivore	Parulidae	
Baltimore Oriole	*Icterus galbula*	Terrestrial Insectivore	Icteridae	
Brewer's Blackbird	*Euphagus cyanocephalus*	Terrestrial insectivore	Icteridae	
Connecticut Warbler	*Oporornis agilis*	Terrestrial insectivore	Parulidae	
European Starling	*Sturnus vulgaris*	Terrestrial insectivore	Sturnidae	
Grasshopper Sparrow	*Ammodramus savannarum*	Terrestrial insectivore	Emberizidae	
Killdeer	*Charadrius vociferus*	Terrestrial insectivore	Charadriidae	
Lincoln's Sparrow	*Melospiza lincolnii*	Terrestrial insectivore	Emberizidae	
Ovenbird	*Seiurus aurocapilla*	Terrestrial insectivore	Parulidae	
Palm Warbler	*Setophaga palmarum*	Terrestrial insectivore	Parulidae	
Sprague's Pipit	*Anthus spragueii*	Terrestrial insectivore	Motacillidae	Threatened
Northern Flicker	*Colaptes auratus*	Terrestrial invertivore	Picidae	
Rock Wren	*Salpinctes obsoletus*	Terrestrial invertivore	Troglodytidae	
Sandpipers, Curlews, Snipe and Allies^{C}	*Scolopacidae*	Terrestrial invertivore	Scolopacidae	Concern
Savannah Sparrow	*Passerculus sandwichensis*	Terrestrial invertivore	Emberizidae	
Swainson's Thrush	*Catharus ustulatus*	Terrestrial invertivore	Turdidae	
Upland Sandpiper	*Bartramia longicauda*	Terrestrial invertivore	Scolopacidae	

Bobolink	*Dolichonyx oryzivorus*	Terrestrial omnivore	Icteridae	Threatened
American Crow	*Corvus brachyrhynchos*	Terrestrial omnivore	Corvidae	
Baird's Sparrow	*Ammodramus bairdii*	Terrestrial omnivore	Emberizidae	Concern
Black-billed Magpie	*Pica hudsonia*	Terrestrial omnivore	Corvidae	
Blackbirds, Meadowlarks and Allies[C]	*Icteridae*	Terrestrial omnivore	Icteridae	
Blue Jay	*Cyanocitta cristata*	Terrestrial omnivore	Corvidae	
Brown Thrasher	*Toxostoma rufum*	Terrestrial omnivore	Mimidae	
Brown-headed Cowbird	*Molothrus ater*	Terrestrial omnivore	Icteridae	
California Gull	*Larus californicus*	Terrestrial omnivore	Laridae	
Chestnut-collared Longspur	*Calcarius ornatus*	Terrestrial omnivore	Calcariidae	Threatened
Chipping Sparrow	*Spizella passerina*	Terrestrial omnivore	Emberizidae	
Common Grackle	*Quiscalus quiscula*	Terrestrial omnivore	Icteridae	
Common Raven	*Corvus corax*	Terrestrial omnivore	Corvidae	
Dark-eyed Junco	*Junco hyemalis*	Terrestrial omnivore	Emberizidae	
Fox Sparrow	*Passerella iliaca*	Terrestrial omnivore	Emberizidae	
Franklin's Gull	*Leucophaeus pipixcan*	Terrestrial omnivore	Laridae	
Gray Catbird	*Dumetella carolinensis*	Terrestrial omnivore	Mimidae	
Canada Jay	*Perisoreus canadensis*	Terrestrial omnivore	Corvidae	
Gray Partridge	*Perdix perdix*	Terrestrial omnivore	Phasianidae	
Harris's Sparrow	*Zonotrichia querula*	Terrestrial omnivore	Emberizidae	Concern
Hermit Thrush	*Catharus guttatus*	Terrestrial omnivore	Turdidae	
Herring Gull	*Larus argentatus*	Terrestrial omnivore	Laridae	
Herring, Ring-billed, California and other gulls[C]	*Larus*	Terrestrial omnivore	Laridae	
Horned Lark	*Eremophila alpestris*	Terrestrial omnivore	Alaudidae	
Lark Bunting	*Calamospiza melanocorys*	Terrestrial omnivore	Emberizidae	Threatened
Lark Sparrow	*Chondestes grammacus*	Terrestrial omnivore	Emberizidae	
Le Conte's Sparrow	*Ammodramus leconteii*	Terrestrial omnivore	Emberizidae	
McCown's Longspur	*Rhynchophanes mccownii*	Terrestrial omnivore	Calcariidae	Threatened
Nelson's Sparrow	*Ammodramus nelsoni*	Terrestrial omnivore	Emberizidae	
Ruffed Grouse	*Bonasa umbellus*	Terrestrial omnivore	Phasianidae	
Rusty Blackbird	*Euphagus carolinus*	Terrestrial omnivore	Icteridae	Concern
Sandhill Crane	*Grus canadensis*	Terrestrial omnivore	Gruidae	
Song Sparrow	*Melospiza melodia*	Terrestrial omnivore	Emberizidae	
Spotted Towhee	*Pipilo maculatus*	Terrestrial omnivore	Emberizidae	
Swamp Sparrow	*Melospiza georgiana*	Terrestrial omnivore	Emberizidae	
Veery	*Catharus fuscescens*	Terrestrial omnivore	Turdidae	
Vesper Sparrow	*Pooecetes gramineus*	Terrestrial omnivore	Emberizidae	
Western Meadowlark	*Sturnella neglecta*	Terrestrial omnivore	Icteridae	
White-throated Sparrow	*Zonotrichia albicollis*	Terrestrial omnivore	Emberizidae	
Hummingbirds[C]	*Trochilidae*	Terrestrial pollinator	Trochilidae	
Ruby-throated Hummingbird	*Archilochus colubris*	Terrestrial pollinator	Trochilidae	

[A] A combination of dietary and foraging strategies recorded during the breeding season. Classified according to Sundstrom et al. (2012), the Cornell Lab of Ornithology Birds of North America (Poole 2005), and co-author (RGC, EMB) expertise.
[B] Designates the species' status according to the Committee on the Status of Endangered Wildlife in Canada (https://www.registrelep-sararegistry.gc.ca).
[C] Field observers could not identify the individual(s) to the species level.

Supplementary References

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Appendix A2. Areas (ha) of wetland and upland cover in each of nine Saskatchewan major river basins. Historic (100%) values are derived from Saskatchewan Water Security Agency wetland inventory data and from Agriculture and Agri-Foods Canada 2019 for major upland cover categories. For retention scenarios (70%, 50%, 30%, Floor), median area estimates were obtained from random sampling (n = 500 bootstrap samples). Also shown are the 5% and 95% values obtained from the bootstrap sample distributions.

	Assiniboine River			Missouri River			North Saskatchewan River			Old Wives Lake		
Wetland/land cover area	Median	5%	95%	Median	5%	95%	Median	5%	95%	Median	5%	95%
100%												
Wetland	193467			11847			114786			91457		
Grassland	78848			56481			134680			207070		
Shrub	5784			530			54243			2508		
Pasture	207151			20112			89263			145763		
Woodland	148692			649			27129			3979		
70%												
Wetland	134822	133309	136279	8302	7990	8587	80295	78270	82126	63896	62503	65277
Grassland	55741	54154	57621	39417	37883	40739	97140	94133	99918	140920	137615	144477
Shrub	4568	4198	4927	376	333	426	40302	39045	41624	1598	1519	1687
Pasture	141349	138022	144703	13560	12578	14485	58990	57101	60921	92512	89967	95325
Woodland	107850	105736	110157	468	421	518	19638	18776	20601	2781	2550	3011
50%												
Wetland	95653	94441	96891	5941	5654	6201	57213	55652	58849	45503	44196	46817
Grassland	40435	39059	41898	27937	26725	29196	72286	69983	74665	97000	94611	99682
Shrub	3766	3410	4109	277	237	318	30906	29918	32136	992	934	1053
Pasture	97498	94849	100153	9197	8421	10030	39072	37510	40603	57234	55286	59494
Woodland	80588	78728	82592	346	309	387	14679	13880	15539	1969	1778	2163
30%												
Wetland	56634	55531	57605	3573	3305	3829	34231	32881	35677	27112	25857	28263
Grassland	25115	24015	26154	16545	15628	17450	47354	45524	49143	52817	51070	54783
Shrub	2967	2624	3289	175	141	213	21594	20683	22765	384	351	432
Pasture	53585	51712	55366	4830	4229	5405	19001	17982	20073	21907	20654	23211
Woodland	53379	51863	54999	226	192	265	9695	8982	10397	1167	1005	1323
Floor												
Wetland	21430	20622	22259	1262	1019	1470	20257	19012	21660	21946	20780	23137
Grassland	11299	10582	11926	5324	4984	5648	32144	30637	33704	40498	39007	42110
Shrub	2234	1924	2562	77	50	108	15985	15142	16997	215	191	251
Pasture	14068	13200	14835	565	400	757	6809	6274	7429	11899	10998	12801
Woodland	28973	27773	30075	109	80	140	6689	6080	7275	940	790	1098

	Qu'Appelle River			Saskatchewan River			Souris River		
Wetland/land cover area	Median	5%	95%	Median	5%	95%	Median	5%	95%
100%									
Wetland	486170			111497			259170		

Grassland	362012			2535			271654		
Shrub	14679			9941			3628		
Pasture	679310			101119			476883		
Woodland	258352			99413			120172		
70%									
Wetland	340376	338322	342697	78048	76743	79504	181347	179848	182854
Grassland	270694	266280	275234	1750	1622	1892	197677	193801	201668
Shrub	12042	11240	12792	7225	6960	7498	2667	2537	2799
Pasture	474524	468456	480649	67971	65653	70340	335818	330771	341317
Woodland	192329	189108	195713	75077	73319	76995	87699	85132	89805
50%									
Wetland	243102	241372	245128	55795	54593	56948	129573	128258	131051
Grassland	209818	206129	214018	1230	1123	1356	148506	145156	151882
Shrub	10312	9521	11068	5405	5174	5627	2019	1918	2136
Pasture	337536	332908	343066	46052	44051	47962	241693	237294	246121
Woodland	148408	145442	151191	58871	57433	60524	65836	63781	68000
30%									
Wetland	145833	144212	147444	33441	32516	34695	77785	76775	78912
Grassland	148762	145901	152010	710	630	797	99080	96459	101723
Shrub	8613	7831	9320	3584	3390	3767	1374	1288	1463
Pasture	201550	197742	205921	24033	22695	25329	147605	144313	151061
Woodland	104157	101623	106614	42647	41172	44107	44091	42603	45881
Floor									
Wetland	29447	28436	30471	16409	15516	17340	9316	8698	9907
Grassland	75811	73526	77782	311	259	367	34127	32786	35536
Shrub	6515	5787	7213	2199	2040	2357	529	474	583
Pasture	38019	36786	39379	7187	6606	7769	23425	22384	24502
Woodland	51530	49766	53413	30254	29030	31454	15440	14464	16443

	South Saskatchewan River			Lake Winnipegosis		
Wetland/land cover area	Median	5%	95%	Median	5%	95%
100%						
Wetland	148427			52572		
Grassland	170230			5283		
Shrub	54176			2384		
Pasture	171303			47891		
Woodland	35981			72617		
7 %						
Wetland	103867	102329	105558	36846	35896	37750
Grassland	128481	125402	131608	3486	3193	3835
Shrub	44980	43452	46368	1708	1614	1807
Pasture	117605	114852	120969	31036	29452	32690
Woodland	27289	26260	28364	53842	52306	55532
5 %						
Wetland	74238	72764	75639	26296	25386	27136
Grassland	100627	98000	103089	2298	2062	2550
Shrub	38838	37330	40192	1264	1183	1341

Pasture	81944	79376	84190	19881	18791	20969
Woodland	21481	20584	22424	41371	40080	42785
3 %						
Wetland	44560	43179	45901	15779	15026	16518
Grassland	72623	70581	74837	1126	969	1269
Shrub	32656	31321	34003	819	751	876
Pasture	46014	44294	47788	8632	7935	9420
Woodland	15727	14946	16528	28952	27800	30033
Floor						
Wetland	16864	15713	17955	12996	12280	13676
Grassland	46607	45116	48353	802	697	922
Shrub	26945	25711	28138	700	641	755
Pasture	12617	11751	13399	5686	5132	6269
Woodland	10352	9625	11087	25657	24615	26661

Appendix A3. Model-predicted median abundances of wetland-associated birds and aerial insectivores by Saskatchewan major river basin for each wetland retention scenario, assuming no breeding birds from these guilds occur on drained quarter sections converted to cropland. Also shown are median values of prediction errors (Lower, Upper) based on ± model-specific root mean square error. Median estimates were derived by bootstrap techniques (n = 500 samples). Shaded estimates represent Floor values (see Results for details).

	Assin.[a]	Missouri	No. Sask.	Old Wives	Qu'App.	Sask. R.	Souris	So. Sask.	Winnip.
100%									
Wetland birds	1171138	99016	780936	647280	4039401	909973	2149846	1198595	327820
Lower	609529	50982	377959	347961	2000684	423902	1097590	581148	149628
Upper	1733256	147050	1187542	949576	6078475	1397138	3202275	1817475	506301
Aerial insectivores	157722	7905	90314	48993	427633	120129	214775	126001	61050
Lower	61610	138	25292	1217	100133	41032	46984	27401	30642
Upper	260556	16700	164127	103799	800928	209120	407434	239048	93672
90%									
Wetland birds	1046634	88559	693088	570678	3627840	810019	1933693	1072877	289052
Lower	544068	45548	334659	306650	1793190	376437	986053	518558	131406
Upper	1549648	131570	1054951	837620	5462831	1244640	2881520	1628631	446979
Aerial insectivores	142146	7085	81052	43262	386712	108439	193929	114288	55035
Lower	56111	128	23150	1100	91869	37784	42785	25678	28085
Upper	234166	14960	146694	91614	722617	187813	367436	215785	83898
80%									
Wetland birds	922000	78179	605278	493945	3216853	710023	1716476	946978	250003
Lower	478507	40190	291580	265251	1586292	328873	873948	455752	112934
Upper	1365910	116167	922399	725532	4847762	1092099	2559165	1439606	387375
Aerial insectivores	126626	6266	71698	37530	345864	96745	172929	102631	49076
Lower	50664	116	20957	989	83634	34574	38505	23996	25600
Upper	207825	13221	129147	79417	644411	166532	327184	192577	74169
70%									
Wetland birds	797034	67768	517129	417165	2805723	610035	1499901	821032	211193
Lower	412657	34803	248011	223765	1379269	281404	762251	392892	94657
Upper	1181842	100733	789508	613396	4232548	939567	2237720	1250533	328010
Aerial insectivores	111144	5442	62416	31796	305039	85059	152130	90894	42996
Lower	45261	103	18826	878	75449	31358	34406	22240	22988
Upper	181529	11478	111688	67208	566231	145226	287193	169293	64329
60%									
Wetland birds	672059	57370	429380	340494	2394581	510082	1283327	695313	172023
Lower	346821	29427	204930	182470	1172122	233865	650615	330292	76068
Upper	997763	85313	657016	501371	3617324	787069	1916276	1061687	268286
Aerial insectivores	95679	4621	53150	26071	264215	73377	131210	79201	37049
Lower	39859	93	16697	767	67273	28140	30157	20502	20506
Upper	155244	9737	94244	55017	488038	123954	247066	146032	54624
50%									
Wetland birds	547349	46967	341494	263948	1983080	409953	1066654	569304	133148
Lower	281173	24047	161651	141161	964721	186197	538707	267380	57753
Upper	813949	69886	524388	389470	3001740	634395	1594733	872551	208856

Aerial insectivores	80200	3801	43800	20343	223346	61738	110287	67484	30974
Lower	34446	83	14486	647	59023	24983	25918	18788	17928
Upper	128940	7998	76730	42819	409809	102716	206950	122764	44793
40%									
Wetland birds	422333	36560	253656	187238	1572032	310051	850104	443426	94249
Lower	215215	18663	118468	99822	757678	138776	427052	204595	39360
Upper	629829	54456	391808	277406	2386608	481949	1273314	683547	149402
Aerial insectivores	64753	2980	34507	14615	182483	50077	89480	55739	24935
Lower	29079	72	12364	533	50804	21787	21784	17034	15364
Upper	102661	6257	59265	30629	331594	81447	166937	99465	34982
30%									
Wetland birds	297535	26149	165772	110580	1160696	210085	633375	317743	55360
Lower	149588	13275	75175	58433	550378	91230	315194	141992	21034
Upper	445928	39023	259182	165392	1771190	329438	951716	494737	89959
Aerial insectivores	49226	2160	25237	8884	141692	38410	68518	44054	18937
Lower	23614	61	10198	424	42604	18571	17507	15312	12839
Upper	76328	4517	41826	18427	253431	60167	126775	76237	25229
20%									
Wetland birds	172834	15741	77779	67578	749618	110154	416800	191698	34586
Lower	83921	7889	31913	35250	343382	43739	203484	79017	11121
Upper	262124	23592	126447	102567	1156029	176962	630270	305565	58311
Aerial insectivores	33742	1337	15905	5678	100781	26767	47646	32356	15774
Lower	18211	49	8033	362	34337	15412	13345	13601	11515
Upper	50021	2774	24307	11593	175167	38923	86703	52982	20066
10%									
Wetland birds	61626	5777	59194	67578	338447	57186	200175	82805	34586
Lower	25347	2754	22749	35250	136290	18565	91714	24839	11121
Upper	98298	8801	98353	102567	540775	96149	308775	142006	58311
Aerial insectivores	19929	549	13898	5678	59983	20516	26763	22208	15774
Lower	13367	39	7543	362	26177	13655	9138	12090	11515
Upper	26578	1102	20564	11593	97005	27583	46620	32831	20066
Floor									
Wetland birds	61626	5777	59194	67578	175856	57186	61365	82805	34586
Lower	25347	2754	22749	35250	54435	18565	20166	24839	11121
Upper	98298	8801	98353	102567	297428	96149	102718	142006	58311
Aerial insectivores	19929	549	13898	5678	43794	20516	13328	22208	15774
Lower	13367	39	7543	362	22909	13655	6392	12090	11515
Upper	26578	1102	20564	11593	66032	27583	20868	32831	20066

[a] Major river basins are Assiniboine River (Assin.), Missouri River, North Saskatchewan River (No. Sask.), Old Wives Lake, Qu'Appelle River (Qu'App.), Saskatchewan River (Sask. R.), Souris River, South Saskatchewan River (So. Sask.), Lake Winnipegosis (Winnip.).

Appendix A4. Model-predicted median abundances of wetland-associated birds and aerial insectivores by Saskatchewan major river basin for each wetland retention scenario. Also shown are median values of prediction errors (Lower, Upper) based on ± model-specific root mean square error. Median estimates were derived by bootstrap techniques (n = 500 samples), and also include a random bird abundance value *added* to each quarter section drained and converted to cropland in each scenario. Shaded estimates represent Floor values (see Results for details).

Retention/response	Assin.[a]	Missouri	No. Sask.	Old Wives	Qu'App.	Sask. R.	Souris	So. Sask.	Winnip.
100%									
Wetland birds	1171138	99016	780936	647280	4039401	909973	2149846	1198595	327820
Lower	609529	50982	377959	347961	2000684	423902	1097590	581148	149628
Upper	1733256	147050	1187542	949576	6078475	1397138	3202275	1817475	506301
Aerial insectivores	157722	7905	90314	48993	427633	120129	214775	126001	61050
Lower	61610	138	25292	1217	100133	41032	46984	27401	30642
Upper	260556	16700	164127	103799	800928	209120	407434	239048	93672
90%									
Wetland birds	1049937	88834	695637	572484	3639362	812856	1939528	1076034	290101
Lower	560026	45911	341585	308854	1845451	393887	1006913	529867	142010
Upper	1552493	131845	1054052	836510	5474014	1246472	2887119	1630430	447776
Aerial insectivores	144898	7323	83143	44931	396364	110932	198879	117316	55981
Lower	58850	366	25246	2784	101534	40278	47752	28702	29027
Upper	236921	15198	148769	93278	732283	190297	372385	218802	84849
80%									
Wetland birds	928272	78748	609954	497902	3239011	715727	1727960	953835	252324
Lower	496403	40837	300321	269475	1646547	348276	899130	470498	124102
Upper	1371774	116737	923713	726642	4869620	1096912	2570481	1445125	389406
Aerial insectivores	132209	6740	76039	40876	365153	101766	182887	108533	51005
Lower	56237	591	25297	4334	102959	39578	48450	29898	27530
Upper	213405	13695	133497	82759	663702	171546	337145	198477	76100
70%									
Wetland birds	806678	68632	524450	422959	2838738	618685	1516942	831304	214380
Lower	432931	35753	259226	229899	1447752	302757	791714	410793	106061
Upper	1191050	101597	793549	616342	4265287	947365	2254583	1259456	330898
Aerial insectivores	119523	6152	68792	36793	333990	92626	166884	99843	45969
Lower	53643	814	25195	5875	104369	38893	49181	31197	25986
Upper	189893	12188	118076	72195	595205	152794	301949	178236	67294
60%									
Wetland birds	684730	58464	439049	348369	2438955	521561	1306314	708898	176593
Lower	369212	30593	218044	190500	1249409	257037	684643	351214	88141
Upper	1010023	86407	663512	506439	3661437	797805	1939113	1073890	272585
Aerial insectivores	106820	5564	61589	32751	302693	83326	150932	91103	40849

Lower	50994	1036	25147	7433	105735	38077	49888	32425	24310
Upper	166380	10681	102697	61706	526525	133911	266791	157943	58418
50%									
Wetland birds	563357	48362	353734	273548	2038941	424339	1095309	586491	138707
Lower	305876	25516	177100	151021	1050654	211350	577266	291555	70142
Upper	829575	71282	533592	396298	3057359	648144	1623212	888413	214136
Aerial insectivores	94133	4983	54366	28690	271426	74101	135039	82374	35863
Lower	48390	1265	25063	8996	107095	37349	50677	33686	22800
Upper	142872	9180	87294	51158	457901	115069	231704	137655	49678
40%									
Wetland birds	441721	38211	268348	198812	1638716	327074	884314	464082	100898
Lower	242259	20389	136009	111580	851896	165709	469872	232018	52182
Upper	648832	56108	403531	286264	2453042	498422	1307364	702947	155779
Aerial insectivores	81381	4404	47159	24622	240273	64956	119096	73636	30768
Lower	45717	1495	24992	10544	108567	36655	51421	34913	21202
Upper	119296	7681	71921	40639	389376	96310	196556	117373	40811
30%									
Wetland birds	320248	28079	182914	124077	1238445	230158	673616	341680	63058
Lower	178913	15277	94945	72144	653032	120170	362678	172425	34261
Upper	468262	40953	273409	176218	1848740	349020	991836	517402	97361
Aerial insectivores	68658	3819	39959	20564	209047	55737	103086	64914	25744
Lower	43058	1723	24923	12094	109989	35912	52104	36177	19650
Upper	95753	6177	56543	30113	320785	77502	161345	97092	32030
20%									
Wetland birds	198523	17965	97364	67578	838638	133043	462555	219409	34586
Lower	115261	10180	53758	35250	454607	74494	255192	112893	11121
Upper	287400	25816	143298	102567	1244840	199430	675885	332031	58311
Aerial insectivores	56006	3240	32756	5678	177816	46555	87235	56163	15774
Lower	40477	1950	24884	362	111384	35202	52930	37403	11515
Upper	72279	4677	41171	11593	252198	58707	126294	76793	20066
10%									
Wetland birds	61626	5777	59194	67578	438411	57186	251580	82805	34586
Lower	25347	2754	22749	35250	255889	18565	147801	24839	11121
Upper	98298	8801	98353	102567	640579	96149	360050	142006	58311
Aerial insectivores	19929	549	13898	5678	146597	20516	71275	22208	15774
Lower	13367	39	7543	362	112795	13655	53645	12090	11515
Upper	26578	1102	20564	11593	183619	27583	91137	32831	20066
Floor									
Wetland birds	61626	5777	59194	67578	175856	57186	61365	82805	34586
Lower	25347	2754	22749	35250	54435	18565	20166	24839	11121
Upper	98298	8801	98353	102567	297428	96149	102718	142006	58311

Aerial insectivores	19929	549	13898	5678	43794	20516	13328	22208	15774
Lower	13367	39	7543	362	22909	13655	6392	12090	11515
Upper	26578	1102	20564	11593	66032	27583	20868	32831	20066

[a] Major river basins are Assiniboine River (Assin.), Missouri River, North Saskatchewan River (No. Sask.), Old Wives Lake, Qu’Appelle River (Qu’App.), Saskatchewan River (Sask. R.), Souris River, South Saskatchewan River (So. Sask.), Lake Winnipegosis (Winnip.).