Cranes and Agriculture:

A Global Guide for Sharing the Landscape

Compiled and edited by

Jane E. Austin, Kerryn L. Morrison,

and James T. Harris

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International Crane Foundation and IUCN Species Survival Commission
Crane Specialist Group

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Front cover photo: Black-necked Cranes forage in a crop field while the farmer cultivates the field. Photographer: Zhou Qiuliang.

Back cover photos (clockwise from the top left): Sarus Cranes in Uttar Pradesh, India. Photographer: K S Gopi Sundar; Black-necked Cranes in Phobchika Valley, Bhutan. Photographer: K S Gopi Sundar; Grey-crowned Cranes in cattle pasture in Kenya. Photographer: Kerryn L. Morrison.

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Cranes and Agriculture: A Global Guide For Sharing The Landscape

Cranes have coexisted with agriculture for centuries in some regions and may often benefit from cropland or grazing. However, the rapid expansion and intensification of agriculture is leading to severe loss of wetland and grassland habitats important to cranes, thus increasing the conflicts between cranes and farmers. Agriculture has been one of the main drivers behind severe population declines for 11 of 15 species of cranes in the world, and affects all species in one way or another.

Cranes and Agriculture: A Global Guide for Sharing the Landscape synthesizes our current knowledge and experience about the interface between cranes and agriculture across different regions of the world, shares examples of both challenges and successes, and identifies potential solutions and opportunities.

This Guide is intended to serve conservation practitioners, decision-makers, communities, and farmers who want to enlarge their understanding of the crane-agriculture interface, so that they can develop more effective and sustainable approaches that address their specific local or regional challenges. Readers can draw on the information and experiences described in the chapters and case studies to develop a conservation program that addresses the conflicts or opportunities relevant to their area and situation, whether at a local, regional, or flyway scale.

KEY FEATURES:

Reviews the life history and feeding ecology of cranes as they relate to both natural and agricultural lands, explores patterns of agricultural development and change over the last 100 years, and explains how crane populations have responded.

Examines the conservation challenges of cranes related to agriculture – both crop cultivation and grazing – and provides a broad synthesis of the various threats and benefits that the crane-agriculture interface poses to cranes.

Reviews diverse approaches and methodologies used to prevent or mitigate human–wildlife conflicts that arise as a result of this interface, examines the situation from a farmer's perspective, and provides alternatives for developing programs at local, regional, and international scales.

Includes 18 case studies from 13 countries that contextualize many of the concepts outlined in the Guide and provide examples of the issues and the solutions from diverse areas.

Provides tables at the beginning of the Guide and the Case Study section that direct readers to the chapters or case studies that are of interest for their situation or questions.

Includes a Call to Action for Promoting Harmony between Cranes and Agriculture proposed for governments, IUCN members and commissions, conservation and practitioners, farmers and land users, and researchers.

Edited and written by 59 authors and contributors from 14 countries who are engaged in crane conservation.

This work was led by the International Crane Foundation and is a product of the International Union for the Conservation of Nature Species Survival Commission / Crane Specialist Group.

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[1]Dr. Lanovenko passed away in 2017.

In Dedication

James Thomas Harris

1950-2018

With grateful appreciation of Jim's 34 years of tireless service
to the cranes of the world
and his colleagues at the International Crane Foundation and abroad.

Jim's passionate commitment to safeguarding cranes and the places they live,
his overwhelming enthusiasm and eloquent words that inspired people,
his courage and perseverance in most difficult circumstances,
and his genuine interest in and care for those around him,
were admired and will always be remembered
by all who were fortunate to know him.

"The haunting calls of the world's cranes are sadder today because they have lost a devoted friend, and the conservation community has lost a true hero."
Kenneth Strom, National Audubon Society

On September19th, 2018 the Crane Specialist Group lost a dear friend and champion for the conservation of cranes and wetlands. Jim passed away peacefully surrounded by his family at his home in Baraboo, Wisconsin, USA after a valiant fight against liver and pancreatic cancer.

In 1984 Jim joined the International Crane Foundation (ICF) in Baraboo, Wisconsin as the Education Director. By the late 1980s, Jim served as Deputy Director expanding ICF's activities in Asia. In 2000, Dr. George Archibald stepped aside as ICF's President, and Jim succeeded him. Under Jim's leadership, ICF was directly involved in 45 projects in 22 countries around the world. In 2006, Jim decided to transition back to serve as director of ICF's East Asia program, while continuing as Vice-President. From 2006, he also oversaw ICF's Africa program, a post he held until just before his retirement in early 2018.

Jim was a journalist by training and an eloquent and prolific writer. He wrote lovely pieces detailing his experiences with people and cranes in Asia, featuring evocative descriptions of landscapes and their inhabitants.

As Co-chair of the IUCN Crane Specialist Group with George Archibald (1988-2008), then Chair (2008-2017) and Co-chair (2018) with Kerryn Morrison, Jim's vision for cranes and their landscapes has always been global in scale. He has adeptly integrated the expertise and passion of 350 members in over 50 countries. He led workshops, produced publications changing the course of how we address complex crane challenges such as agricultural land use and climate change, and brought diverse people together to find solutions to provide water for wetlands and cranes, whilst balancing human needs. His contributions are culminating later this year with the publication of the much-anticipated Crane Conservation Strategy that engaged over 150 crane specialists in a review of the status and trends for all 15 crane species. A comprehensive assessment of 19 direct threats identifies research needs and priority actions for the next five years, with measurable actions linked to diverse partners.

Jim's dedication, along with his wife Su Liying, to the cranes and wetlands of China, Russia, and beyond is well-known and greatly appreciated. He pioneered conservation work with a micro-lending program for farmers in return for crane habitat conservation in China, introduced improved water management techniques as part of reserve management plans in NE China, promoted sound science as a basis for improved management, organized highly popular and effective international nature schools and camps, and established monitoring networks.

Jim's infectious reverberating laugh, gentle smile and good sense of humor radiated an energy, positivity and sense of hope to everyone around him. Jim's insights, critical thinking and recommendations were always constructive and valuable. His wise counsel was often sought by partners throughout the crane world, in part because Jim was always so supportive and giving of his time.

As an incredible mentor, guide and confidant, Jim leaves behind many people, all over the world, who have benefited, flourished, and been inspired by his example.

Thank you, Jim, for decades of dedication and the legacy you have left for us all to continue forward for the conservation of the world's cranes. Thank you for your unfailing friendship to so many around the world.

Jim will be also remembered fondly for his passion for taking photos of the people, cranes and landscapes in the places he visited around the world. This photo, taken at Muraviovka Park in Far-eastern Russia captures his love for landscapes and the perfect shot.

Foreword

Agriculture has posed the greatest threat to terrestrial and freshwater habitats around the world, and current trends – rising human populations as well as increasingly intensive agriculture practices – mean that pressures on wild species will continue to grow. The charismatic family of cranes has suffered dramatically from habitat losses on all five continents where cranes occur. Agriculture has been one of the main drivers behind severe population declines for 11 of 15 species of cranes in the world and now threatened with extinction.

Remarkably, cranes have also benefitted from the vast open spaces created across agricultural landscapes as well as the bountiful waste grain left after harvest. The two most abundant cranes – the Eurasian and the Sandhill – have seen dramatic population increases across their wide ranges in large part due to utilizing croplands for foraging. Even threatened species of cranes – such as the Black-necked, Sarus, and Grey Crowned – now rely on farmlands for significant parts of their annual cycles.

The *Cranes and Agriculture: A Global Guide for Sharing the Landscape* has been prepared by the International Union for Conservation of Nature's (IUCN) Species Survival Commission (SSC) Crane Specialist Group. This publication explores the complex relationship linking lives of farmers and herdsmen with the lives of cranes. A great many of the Crane Specialist Group members helped assemble the latest in research and practical experience in addressing the challenges and opportunities for conserving cranes on productive lands, including in particular ways to reduce conflicts for example when cranes damage crops. Unfortunately such conflicts are growing in many areas as natural habitats diminish and crane numbers increase.

Cranes offer a striking example of how wildlife and agriculture can thrive together, and the lessons from cranes can contribute to conservation for other groups of wildlife. Let us hope that dialogue between species specialists, agriculture specialists, farmers and herdsmen can grow, as there is much to gain from exchange and cooperation.

Jon Paul Rodríguez
Chair, IUCN Species Survival Commission

Preface

Conservationists forever strive to minimize the negative impacts to wildlife from the extraordinary transformations that humans have brought to landscapes around the world. For the world's cranes, as for so many wildlife, the greatest threats to natural habitats have come from agricultural development. Yet the relationship between cranes and agriculture is remarkably complex.

Today, the world's fifteen species of cranes depend to varying degrees on croplands and pasturelands for survival. Cranes still need wetlands that offer shallow water roosting sites, providing safety for sleep or rest as well as for nesting and rearing of the young. Yet cranes now forage extensively on waste grain left after harvest. In some regions this benefit from agriculture has been evident for many decades. Less frequently, cranes consume seeds at or shortly after planting, or otherwise cause damage to crops and reduce harvests. Economic hardships to farmers, primarily those living close to wetlands favored by cranes, have led to harassment or killing of cranes.

Only in the last five years has the most aquatic of all cranes, the Siberian Crane (*Leucogeranus leucogeranus*), come to rice paddies, lotus ponds, and even corn and wheat fields to forage. We are able to observe this dramatic change in behavior happening right before us. The causes may relate to dwindling of natural foraging areas, and also a learning process – the Siberian Cranes mix with and follow the less aquatic species like the White-naped Crane (*Grus vipio*) and Eurasian Crane (*G. grus*) that have long utilized agricultural habitats.

This book had its genesis in the early 1990s, when ICF researchers together with colleagues from the Tibet Plateau Institute of Biology documented that most of the world's Vulnerable Black-necked Cranes (*G. nigricollis*) depended almost entirely during winter on the waste barley or the winter wheat growing in fields adjacent to suitable roosting sites in southcentral Tibet. We realized the future of this magnificent species would be determined in good part by agriculture practice.

Mindful of the threats to cranes from agriculture, as well as the remarkable benefits, the IUCN Species Survival Commission Crane Specialist Group convened a small workshop in June 2010 – 30 participants from 14 countries and five continents – hosted by Muraviovka Park for Sustainable Land Use in Russia. We talked about cranes, agriculture, and climate change. How should crane specialists of the world respond to the challenges and opportunities afforded by these immense changes happening around the world? We spent four days together at Muraviovka Park beside an extensive and diverse wetland with breeding Red-crowned and White-naped Cranes, surrounded by some of the richest farmland in far eastern Russia.

This publication was conceived during those discussions held with soybeans fields on one side, and wetlands on the other, the cranes flying overhead from one habitat to the other.

In late 2012, we followed up with a second, larger workshop, co-organized by Beijing Forestry University, China – the International Workshop on Crane Protection and Sustainable Agriculture. Eighty specialists from 11 countries came together for discussions in Beijing and a field trip to East Dongting Lake in the Yangtze River Basin of southern China. Many of the participants of that workshop have contributed to the contents of this publication. And many other specialists as well. The Call to Action, presented in this publication, was drafted as an output of that workshop.

Altogether, the authors and contributors to this book include 59 people from 14 countries. We also wish to thank many, many more researchers, managers, and conservation practitioners whose thinking and actions to solve conflicts posed by cranes and agriculture have contributed to the contents of this book.

Since cranes live in over 80 countries on five continents, adapted to an extraordinary range of conditions and an equally extraordinary diversity of agricultural practice, this Guide contains much but not all of the experience and lessons relevant to our objective – for cranes and people to live together and thrive across our agricultural landscapes. In addition, as crane behavior and agricultural practice change, we must learn to address new challenges. For example, agricultural poisons pose a growing threat to several threatened crane species. We hope this volume will inspire increased communications among conservationists, agricultural experts, and farmers – in particular, furthering dialogue among those who seldom interact. Through the Crane Specialist Group, we intend to continue the quest for productive co-existence of cranes and agriculture.

Cranes of course are not the only waterbirds to rely extensively on agricultural lands. Yet the charisma and cultural significance of cranes have inspired much attention in many countries to finding conservation solutions. Just as crane conservationists have learned from those working with other groups of animals, we hope our discoveries will benefit conservation of ducks, geese, and other species.

James T. Harris
International Crane Foundation

Acknowledgments

Many people have contributed to this publication. We are indebted to the many individuals and organizations who have given their time and knowledge to writing or reviewing, and to those who shared photographs, unpublished information, and observations. The reviewers for chapters and case studies are listed below. We thank participants of the Knowledge Café at the IUCN World Conservation Congress 2016 for their valuable suggestions for how to make the Guide materials more useful to a wider array of users. We are grateful to Hiroyuki Masatomi for contributing his extensive knowledge on artificial feeding of cranes in Japan. Elena Ilyashenko served as translator and liaison for two case studies. Staff at the International Crane Foundation contributed their expertise in many ways. Darcy Love created the elegant figures for Chapter 2. We thank Claire Mirande, Elena Smirenski, and Bev Pfister at ICF for working with authors and contributors, editing, proofreading, and formatting the documents for this publication.

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Fifteen crane species of the world. Painting by David Rankin

List of the 15 Crane Species, Recognized Subspecies, and Their Distributions

AF = Africa, AU = Australia, EA = Eurasian, EU = Europe, NA = North America, AS = Asia
Distribution maps are available at www.savingcranes.org/species-field-guide

Common name	Scientific name	Breeding distribution
Black Crowned Crane	*Balearica pavonina*	AF: northeast, central, western
Black-necked Crane	*Grus nigricollis*	AS: Tibet and west-central China
Blue Crane	*Anthropoides paradiseus*	AF: South Africa
Brolga	*Grus rubicunda*	AU: Australia and portions of New Guinea
Demoiselle Crane	*Anthropides virgo*	EA: southwestern Russia to northern China; northern Africa, eastern Turkey,
Eurasian Crane	*Grus grus*	EU: widespread
Grey Crowned Crane	*Balearica regulorum*	AF: east and southern Africa
Hooded Crane	*Grus monacha*	EA: southeastern Russia and northern China
Red-crowned Crane	*Grus japonensis*	EA: southeastern Siberia, northeastern China, Japan
Sarus Crane	*Grus antigone*	AS, AU: northern India, Southeast Asia, northern Australia
Sandhill Crane	*Grus canadensis*	NA: widespread
Siberian Crane	*Leucogeranus leucogeranus*	EA: northwestern and east-central Siberia
Wattled Crane	*Bugeranus carunculatus*	AF: DR Congo and Tanzania to Botswana; Zimbabwe and South Africa
White-naped Crane	*Grus vipio*	EA: se Siberia, ne Mongolia and ne China
Whooping Crane	*Grus americana*	NA: central Canada, central and east USA

Information about crane subspecies and their distributions can be found in the Crane Conservation Strategy (Harris and Mirande, in preparation) and online at https://www.savingcranes.org/species-field-guide/.

Abstract

Fifteen species of cranes (Gruidae) are found across the world, on all continents except South America and Antarctica. The landscapes and ecoregions important to cranes are also those areas most conducive to agriculture. Although cranes have had a close relationship with arable and pastoral agriculture that goes back hundreds and thousands of years, rapid changes in agriculture over the last 100 years have become a key threat to the world's cranes, primarily due to habitat loss but also other, indirect effects from agriculture such as poisons and power line collisions. As human populations and agricultural demands have expanded and intensified, conflicts between cranes and farmers are becoming more severe. Crane species most closely reliant on wetlands are the most threatened, whereas those more associated with grasslands have better adapted to open, productive landscapes. In a 2010 workshop, participants from 13 countries and five continents identified the need for a resource that synthesized information about the crane and agriculture interface that could help guide conservationists and other stakeholders. This Guide has gathered published information and personal accounts and experiences from around the globe. The document outlines the life history and feeding ecology of cranes as they relate to both natural habitats and agricultural lands; explores the patterns and drivers of agricultural development and change over the last 100 years and explains how crane populations have responded; examines the interaction between cranes and domestic animals; describes the various direct and indirect threats that the crane / agriculture interface poses to cranes; reviews the methodologies currently used to mitigate for human / wildlife conflicts that arise as a result of this interface; walks us through the situation from a farmer's perspective; and provides ideas for programmes that either mitigate for the conflicts that arise, or make use of the opportunity provided by the crane / agriculture interface. In addition, 18 case studies from 13 countries provide examples of issues discussed in the chapters. This Guide is intended as a first step in sharing knowledge and experiences of the crane / agriculture nexus from a diversity of situations, landscapes, flyways, and species, to find and disseminate ways to sustainably balance the needs of cranes and agriculture.

Introduction

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Cranes are ambassadors of nature, whose majestic appearance and distinctive calls encourage us to see that there are other unique beings in this world – beings that also have the right to exist.
— Carl-Albrecht von Treuenfels

Fifteen species of cranes (Gruidae) are found across the world, on all continents except South America and Antarctica. Their life histories and preferred habitats vary, from the small Blue and Demoiselle Cranes of semi-arid grasslands to the larger, more wetland-dependent Siberian and Whooping Cranes. All crane species rely on wetlands at some time during their annual life cycle, primarily for nesting but also for foraging and protective cover. Many species also have close affiliation with grasslands. However, wetlands and grasslands are the most vulnerable habitats to agriculture, and they have been greatly impacted, primarily by conversions to cropland but also other impacts such as intensive grazing.

Agriculture is involved in nine of the 19 threats to cranes identified in the IUCN/SSC Crane Conservation Plan, affecting all 15 species in some way (Harris and Mirande, in preparation). Crane species most closely reliant on wetlands are the most threatened whereas those more associated with grasslands are less threatened.

Cranes in Eurasia and Africa have coexisted with agriculture for thousands of years. They have proven surprisingly adaptable in many situations and able to sustain productive populations, particularly under traditional and low-intensity agriculture. Most crane species have adapted to using agricultural lands and crops in some way – consuming waste grains or other crops, feeding in rice paddies, or foraging in pastures. Crop fields provide abundant, predictable, and often high-energy foods that can be particularly valuable during migration and winter and have literally fueled growing populations and expanding ranges to new areas, particularly for Sandhill and Eurasian Cranes. Grazing, whether by native ungulates or by domestic livestock, is an important process for sustaining open and productive grasslands for cranes. Thus, cranes have at times

Key terms used in this Handbook

Agriculture: The science and practice of growing crops and rearing animals for human consumption; used here to encompass both crop cultivation and grazing activities.

Farmer: An individual who raises crops or livestock for human or livestock consumption.

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benefited from agricultural foods, lands, and practices, but conflict with farmers can arise when cranes damage the crops by consuming unharvested grains or vegetables like potatoes, uprooting young plants, trampling vegetation, or using crops to build nests.

This historic harmony between cranes and agriculture is increasingly in jeopardy. As human populations and their demands have expanded, conflicts between cranes and farmers are becoming more severe. The pace of agricultural change has greatly intensified since the early 1900s in nearly all parts of the globe, leading to major losses of natural habitats, increasing conflicts with farmers, and greater impacts on crane populations. In many regions, habitat loss, fragmentation, and degradation due to agriculture appear to be reaching thresholds beyond which crane populations can hardly be sustained. Five crane species are critically threatened by conversion of wetlands to agriculture or other development, and six species are critically threatened by dams and water diversions, which are often related to irrigation or hydropower (Harris and Mirande, in preparation). Other threats to cranes related to agriculture include unsustainable exploitation of wetland resources; human interference and disturbance, especially at nest sites; collisions and habitat loss associated with utility lines, which are often located between roost and feeding sites; poisoning by agrochemicals; and fires, which are often associated with agricultural activities. These threats are not static but continue to change over space and time, influenced by technical developments and socio-economic, political, and climatic drivers.

Given the overwhelming importance of agriculture to cranes globally, the Crane Specialist Group identified the need for a single resource that would synthesize our knowledge about the interface between cranes and agriculture across different regions of the world, share examples of both challenges and successes, and identify potential solutions and opportunities. This Guide is intended to serve conservation practitioners, decision-makers, communities, and farmers who want to enlarge their understanding of the crane-agriculture interface, so that they can develop more effective and sustainable approaches that address their specific local or regional challenges.

Why Cranes?

Cranes are one of many species of concern around the globe that are closely reliant on wetlands. Of the 15 species, 11 are listed as threatened under the IUCN Red List: one Critically Endangered (Siberian Crane), three Endangered (Grey Crowned, Red-crowned, and Whooping Cranes), seven vulnerable (Black Crowned, Black-necked, Blue, Hooded, Sarus, Wattled, and White-naped Cranes); the other four are listed as Least Concern (Brolga, Demoiselle, Eurasian, and Sandhill Cranes) (Harris and Mirande, in preparation). These crane species encompass diverse regions and landscapes, from the taiga to tropical broadleaf forest biomes. Cranes also are readily observable and charismatic because of their beauty, large size, and unique calls and behaviors. Moreover, cranes have a long heritage of cultural and spiritual values in many societies. These attributes – wide distribution, wetland affiliation, conservation status, and societal values at local to global scales – make cranes ideal models and ambassadors for conservation of healthy wetlands and grasslands across agricultural landscapes.

Cranes as a group also can serve a role as umbrella species at a broader ecosystem perspective. Societies around the globe have become increasingly aware of the value of biodiversity and healthy ecosystems, particularly related to wetlands. Societies are facing growing challenges due to expanding human populations (Russi et al. 2012). A major concern is water security, including quality and availability of water during extreme events (e.g., drought), as well as food security. Wetlands provide us with critical ecosystem services (Millenium Ecosystem Assessment 2005) at local to global scales: these habitats are essential in terms of water security, nutrient cycles and human food production (e.g., water for irrigation, rice production).

Wetlands are among the most biodiverse ecosystems in the world and provide essential habitats for many species (Russi et al. 2012). Therefore, wetland conservation and management activities for cranes can aid a diversity of other wetland species (Elphick 2010) while also contributing to healthy wetland function and broader societal interests. Similarly, improved conservation and management of grassland habitats for cranes can yield added benefits for other species and society (e.g., implementation of grazing systems to prevent overgrazing or soil erosion while improving forage production, biodiversity, and ecosystem function).

Finally, a focus on cranes for conservation can serve as a means to reconnect farmers and agricultural communities with nature (Pretty 2003), particularly where cranes hold a cultural or spiritual value. Cranes readily lend themselves to outreach and education programs that can help foster greater awareness, understanding, and appreciation of the wetland and grassland ecosystems that farmers share with cranes. Ecotourism developed around these observable and charismatic birds can further that awareness by providing opportunities for development, provoking tourists and the local community to critically examine human–nature relations, and demonstrating a value of nature within the broader community (Battacharya et al. 2005).

Origins and Intent of This Guide

This Guide originated in the workshop *Cranes, Agriculture, and Climate Change* (Harris 2012), at Muraviovka Park, Russia, in 2010. Thirty participants from 13 countries, representing five continents, attended the workshop by invitation of the Crane Specialist Group. Workshop participants identified the need for a document that would draw together and consolidate information on cranes and agriculture from around the world. Many of the workshop participants, as well as other conservationists from around the world, contributed chapters, case studies, published and unpublished information, and provided reviews.

In this Guide, we have gathered published information, personal accounts, and experiences around the nexus between cranes and agriculture. The first section of the Guide outlines the life history and feeding ecology of cranes as they relate to both natural habitats and agricultural lands, explores patterns of agricultural development and change over the last 100 years, and explains how crane populations have responded. The middle section examines conservation challenges: the interaction between cranes and domestic animals and, more broadly, provides a synthesis of the various threats that the crane-agriculture interface poses to cranes. The final section reviews the methodologies used to prevent or mitigate human-wildlife conflicts that arise as a result of this interface, examines the situation from a farmer's perspective, and provides ideas for developing programs that can mitigate for the conflicts that can arise, or make use of the opportunities provided by the crane-agriculture interface. In addition, 18 case studies from 13 countries provide examples of issues discussed in the chapters. All chapters and case studies were peer-reviewed and are cross-referenced.

Who Should Read This Guide?

- *Conservation practitioners and non-profit organizations* (NGOs) engaged in issues related to species conservation and wildlife-agricultural interactions in agricultural landscapes, wetlands, and grasslands, to gain a deeper understanding of the crane-agriculture nexus, enhance activities, program development, and communications, and to more closely integrate with waterbird conservation more generally.

- *Policy makers and organizations at the international level* engaged in issues of agriculture, wetlands, grasslands, and species conservation, to foster collaborations across countries and flyways and promote understanding of crane-wildlife interactions in multilateral environmental agreements through guidance documents and other communications.

- *Government authorities (local community to national) and others* that deal with policies and programs involving agriculture, wildlife, and environment (particularly related to water resources, wetlands, and grasslands).
- *Decision-makers at local and regional levels* involved with land use, water resources, wetlands, grasslands, and wildlife that wish for a better understanding of the crane-agriculture nexus, to ensure the best decisions are made to balance the interests of cranes and people.
- *Agricultural communities* where cranes interact with farming or grazing:
    - Organizations working with farmers and pastoralists,
    - Farming and community development organizations, and
    - Individual farmers with an interest in gaining a deeper understanding of their relationship with cranes so they can find solutions or opportunities appropriate to their situation.
- *Community organizations and the scientific community* interested in understanding, appreciating, and communicating the ecological and cultural significance of cranes and their interactions on the agricultural landscape.

How to Use This Guide

The Guide synthesizes our current understanding of the interface between cranes and agriculture around the world. The chapters can be read together or independently, with key concepts explained within the context of the relevant chapters across the Guide and sometimes appearing more than once. Case studies contextualize many of the concepts outlined in the Guide by providing actual experiences and stories from diverse areas. Chapters and case studies are cross-referenced to guide the reader to related information. Readers can draw on the information and experiences described in the chapters and case studies to develop a conservation program that addresses the conflicts or opportunities relevant to their area and situation, whether at a local, regional, or flyway scale.

Reading the Guide from the beginning to the end will provide the reader with a holistic understanding of cranes and agriculture. However, you can start with the chapter or chapters most relevant to your needs, and move around the Guide as desired. We suggest, though, that you start with the first chapter, which outlines the life histories and feeding ecology of cranes, for a foundational understanding of crane ecology and behaviour that ultimately explains why and how cranes and agriculture interact. The figure and Quick Guide table below provides an outline of the Guide chapters and guidance for its use.

The eight chapters are followed by 18 case studies, organized by season and type of agriculture, with their geographic location indicated on a global map. A table at the beginning of this section provides a guide for readers to determine which case studies are of interest for their situation or questions.

Appendices provide a list of all scientific names used in the Guide and a glossary of terms, in recognition of our global audience.

The final section is a *Call to Action for Promoting Harmony between Cranes and Agriculture*. Actions are proposed for governments, IUCN members and commissions, conservation and practitioners, farmers and land users, and researchers.

Quick Guide to the Eight Chapters

Crane / agriculture questions and information required	Guide chapter	Links to other chapters
• How and why do cranes interact with agriculture? • Why are some crane species more/less in conflict with agriculture? • How are agricultural crops and domestic grazers important to cranes?	**Chapter 1**: Linking crane life history and feeding ecology with natural habitats and agricultural lands	This chapter provides the understanding of why cranes are found in agricultural lands, and how cranes benefit or conflict with agriculturalists. **This chapter is the ecological foundation for the Guide**.
• How have the world's agricultural landscapes changed over the millennia, especially over the last 100 years? • What have been the key drivers of those changes?	**Chapter 2**: Regional and historical patterns of agriculture	To understand crane responses to these changes and patterns, see **Chapter 3.**
• How will a crane population potentially respond to changes you are seeing in the agricultural landscape in your area? • What are the agricultural factors contributing to a changing crane population status in your area?	**Chapter 3**: Crane responses to changes in agriculture	To better understand agricultural changes over time, see **Chapter 2**.
• How do cranes interact with domestic grazing animals? • How do cranes interact with other animals such as domestic waterfowl or dogs? • What impacts can domesticated animals have on cranes? • Is disease a concern for cranes' interactions with domestic animals?	**Chapter 4**: Interactions and impacts of domesticated animals on cranes in agriculture	

Table continues next page

Crane / agriculture questions and information required	Guide chapter	Links to other chapters
• What are the types of threats related to agricultural landscapes that cranes face, and where are they most problematic? • How and where does loss of wetland or grassland habitats to agricultural activities affect cranes? • How does fire and agricultural chemicals affect cranes? • How do farmers respond to threats to their crop caused by cranes?	**Chapter 5**: Threats to cranes related to agriculture	To learn more about mitigation methods to prevent or reduce crop depredation, and opportunities that could be used, go to **Chapter 6**.
		To better understand the farmers' perspectives on conflicts with cranes, and to explore ways to engage with key stakeholders in farming communities in mitigation efforts, go to **Chapter 7**.
		To explore partnerships, ecotourism, educational, and research opportunities in addressing conflicts and making use of opportunities in agricultural landscapes, go to **Chapter 8**.
• What methods are used to prevent or reduce human / crane conflict on agricultural lands? • What methods are best for the scale of my problem? • How can I solve the problems my cranes face?	**Chapter 6**: Methods to reduce conflicts between cranes and farmers	To understand why cranes are found in agricultural landscapes, read **Chapter 1**.
		To understand the different type of threats to cranes from agriculture, go to **Chapter 5**.
		This chapter should be read in conjunction with **Chapter 7** to better understand the perspective from a farmer's viewpoint and to understand the levels of engagement that could be important in mitigation action.
		This chapter should be read in conjunction with **Chapter 8** to understand the partnership, ecotourism and educational opportunities that exist for a conservation program aimed at either mitigating a threat or making use of the opportunity at the crane / agriculture interface.

Table continues next page

<table>
<tr><th>Crane / agriculture questions and information required</th><th>Guide chapter</th><th>Links to other chapters</th></tr>
<tr><td rowspan="5">What do farmers consider when they deal with conflicts between farming or grazing and wildlife?
How can I work with the local farming community to find solutions to crane-agriculture conflict and to identify opportunities to benefit both cranes and people?
What are some of the key elements I need to consider when developing a project with local farmers and communities?</td><td rowspan="5">Chapter 7: How do we improve conservation on privately owned lands?</td><td>For background information on why cranes are found in agriculture, read Chapter 1.</td></tr>
<tr><td>To understand the domesticated animal agriculture / crane interface, read Chapter 4.</td></tr>
<tr><td>To understand the threats to cranes in agricultural landscapes, read Chapter 5.</td></tr>
<tr><td>This chapter should be read in conjunction with Chapter 6, which outlines the methodology used to reduce crop damage.</td></tr>
<tr><td>This chapter should be read in conjunction with Chapter 8 to explore the development of a project which takes into account partnerships and the opportunities that ecotourism and education provide,</td></tr>
<tr><td rowspan="2">What are useful partnerships, agreements, and guidance documents at the national and international level?
How have different regions or areas developed partnerships to deal with crane-agricultural conflicts?
How can we engage agricultural industry or researchers to help resolve conflicts?
Who should I consider for building partnerships to mitigate threats or make use of opportunities?
How can I raise public awareness and support through ecotourism and educational programs?
How can I use research as an educational tool?
Why does cultural or spiritual values of cranes matter in conservation efforts?</td><td rowspan="2">Chapter 8: Strategies to manage the crane-agriculture interface using partnerships, ecotourism, and educational opportunities</td><td>This chapter should be read in conjunction with Chapter 6 to explore methods to mitigating the threats to cranes.</td></tr>
<tr><td>This chapter should be read in conjunction with Chapter 7 to better understand the farmer's perspective when developing a conservation project at local levels.</td></tr>
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CHAPTER 1

Linking Crane Life History and Feeding Ecology with Natural Habitats and Agricultural Lands

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Abstract: Most crane species are omnivorous and opportunistic. They have evolved in distinct habitats and their morphology and the digestive system show specific traits that are well adapted to foods and nutritional needs. They rely on a relatively wide spectrum of plant and animal food that varies depending on the season, habitat structure, and food availability as well as anthropogenic land use and intraspecific and interspecific competition. Cranes feed more on animal proteins during the egg-production period and for rearing offspring and more on plant foods during the non-breeding periods. Energy-rich plant foods are crucial during migration and winter when energetic demands are higher. Some crane species have morphologies and foraging strategies reflecting their adaptation to special habitats. Intensification of agriculture over the last 50–100 years in many areas and increase in concentrated and predictable food resources have resulted in greater abundance of food for many crane species, particularly harvest residues. Cranes also take advantage of newly sown, sprouted seeds that generally have a higher protein content than waste grains. Increased population sizes and declining availability of roost wetlands have led to increasingly large concentrations of some crane species during migration and winter, which can lead to crop damage. Farmers observe less damage if cranes feed on harvest residues, but they may suffer economic losses if cranes feed on newly planted seeds, new seedlings, or unharvested crops. As more sophisticated harvest machinery reduces the availability of harvest residues and timing of cropping changes, cranes may shift to newly planted seeds. Crop damage to plants can also occur due to up-rooting young plants and trampling. Understanding basic life history features and feeding ecology is key to developing effective approaches to prevent or minimize conflicts between cranes and agriculture.

Keywords: behaviour, crop damage, diet, feeding ecology, morphology, nutrition

As a group, cranes are cosmopolitan, occurring worldwide except for South America and the arctic regions. Most of the species prefer open landscapes with a wide range of visibility and shallow wetlands for breeding, feeding, and roosting. However, the degree to which cranes require and use wetlands varies widely among and even within species. For example, Demoiselle and Blue Cranes are least dependent on wetlands and are most commonly found in grasslands, whereas Siberian and Whooping Cranes forage mainly in wetlands (Harris 2012). During the breeding season, crane pairs defend their territories from conspecifics, but during the non-breeding season cranes can form very large flocks. All crane species are basically diurnal in their habits (Archibald and Meine 1996). Depending on the availability of food, cranes feed for extended periods in the early morning. Then they move to loafing areas to drink, preen, and engage in social displays. If temperatures are unusually hot, cranes may escape the heat by spiraling skyward on rising thermals or seeking shade under trees. Later during the day they return to feeding areas for foraging before moving into the roost sites at night.

Austin JE, Morrison K, Harris JT, editors. 2018. *Cranes and Agriculture: A Global Guide for Sharing the Landscape.* Baraboo, Wisconsin, USA: International Crane Foundation. 303 p.

Fig. 1. Grey Crowned Cranes forage in newly cultivated corn field (Photographer: James T. Harris)

Non-migratory cranes move relatively short distances between breeding and non-breeding areas and gather in large flocks during the nonbreeding season. These kinds of local and seasonal movements of varying length are typical of the lower latitude species, like crowned cranes, or Blue, Wattled, and Sarus Cranes, and the Brolga (Archibald and Meine 1996). Most of the northern crane species migrate, sometimes for thousands of kilometres, between breeding and wintering areas, and they may be confronted with broad deserts or high mountains during migration (e.g., Siberian, Demoiselle, Sandhill, or Eurasian Cranes).

The open landscapes typical of most agricultural fields, combined with the abundance of food resources in them even after harvest, make agricultural crops attractive areas for foraging cranes (Fig.1). To understand why, when, and where cranes feed and why they focus so strongly on agricultural crops, we review life history aspects of cranes as influenced through habitat changes and food selection in natural and human managed environments. As the different crane species have evolved in distinct habitats, their morphology and the digestive system show specific traits that are well adapted to foods and their nutritional needs. Their foraging behaviour depends largely on seasonal nutritional needs and food availability. The Sandhill, Eurasian, and Demoiselle Cranes are most abundant of all crane species; one likely reason is that they have managed to adapt to anthropogenic land use changes and are thus able to use croplands in much the same way as they used grasslands earlier (Harris 2012).

Morphology and the Digestive System Affect Foraging Behaviour and Diet

The morphology or shape of an organism reveals much about life strategies, in particular the strategy of obtaining food. The crane's physique is best suited for procuring food as a collector, unlike predators that lure their prey and suddenly strike it from a hidden place or that rush their prey over long distances. Instead, the large birds stride calmly with their long legs through the foraging grounds looking or probing for available foods. The crane's long neck and bill also enables it to strike very fast in cases when they come to prey by chance. Hooded, Siberian, Demoiselle, and Eurasian Cranes are diggers and probers. Red-crowned, Whooping, and Siberian Cranes feed in deeper water using a "walk-and-peck" feeding technique more than repeated probing and digging (Table 1).

Food size is generally limited to food items that can be swallowed whole. This includes seeds, tubers, small to medium-sized invertebrates, molluscs, crustaceans, fish, amphibians, reptiles, small mammals, or small birds (Johnsgard 1983, Archibald and Meine 1996). In light soil, they dig with a slightly opened bill whereas in dense soils they probe with a closed bill (Masatomi and Kitagawa 1975, Nowald 1994). When probing, cranes use certain digging techniques to move debris from the feeding site. This includes bill-flicking, bill-side-pushing, and bill-push-opening (Urbanek and Lewis 2015). In addition to probing for invertebrates, seeds, and tubers, they use their bill like tweezers, which is also ideal for picking up seeds from the ground.

Table 1. Breeding and nonbreeding season feeding habits of cranes (modified from Ellis et al. 1996).

Feeding Habitat	Breeding Season	Nonbreeding Season
Primarily feed in uplands	Demoiselle and Blue Cranes	Grey and Black Crowned, Demoiselle, Blue, Sandhill, and Eurasian Cranes
Feed in both uplands and wetlands	Grey and Black Crowned, Sandhill, Sarus, Eurasian, White-naped, Black-necked, and Whooping Cranes, Brolga	Sarus, White-naped, Red-crowned, Black-necked, Hooded Cranes, Brolga, and Whooping Cranes
Primarily feed in wetlands	Wattled, Siberian, Hooded, Red-crowned, and Whooping Cranes	Wattled and Siberian Cranes

Cranes swallow food items by bobbing the head, which can be used to determine what they are feeding on in agricultural fields. If cranes forage on seeds in newly sown fields, the birds bob the head regularly due to the equal distribution of the seeds. But if they forage on invertebrates they bob the head irregularly (Nowald 1994). Head bobbing by cranes and many other birds species is a terrestrial locomotion behaviour related to compensatory effects of vision and coordination during foraging which comprises a hold and thrust phase (Nyakatura and Andrada 2014). Moving the head forward through series of fixed positions helps to stabilize visual fields preventing motion blur of the retinal image (Cronin et al. 2005), whereby the head bobbing frequency depends on the walking speed which varies between 0.4 and 0.8 m/sec (Cronin et al. 2007). The head is stabilized through most of each foot step, but short head-bobs have also been observed when cranes lower the head towards the ground for food.

The behaviour and technique of drinking water does not seem to differ among crane species. As described for Sandhill Cranes, the birds fill the bill with water by submerging the lower mandible and raising the head to swallow (Tacha 1988). Wintering Sandhill and Whooping Cranes drink water with salinities up to 20–23 parts per thousand (ppt) (Haley 1987, Urbanek et al. 2010); they spent around 0.2% of the day drinking. When salinity levels in coastal waters reach 23–24 ppt, Whooping Cranes shift to inland freshwater ponds for drinking (Urbanek and Lewis 2015).

The digestive tract of a crane is shown in Figure 2. Unlike geese, cranes have a poor ability to break down high-fiber plant foods (consisting of non-starch polysaccharides such as cellulose, arabinoxylans, and lignin) due to the lack of particular enzymes in their digestive system and the lack of long appendices (colic caeca or diverticular) with appropriate symbionts (Bergmann 1987). Thus, they are dependent on lower fiber, high-energy plant food such as seeds and berries or tubers. As cranes do not have a crop, the food passes through the esophagus directly into the complex stomach consisting of a small glandular (proventriculus or true stomach) and large muscular (gizzard) portion. In the gizzard, the food is ground up with previously swallowed stones or grit through muscular contraction. Mundy and O'Donoghue (2000) found many small stones within the gizzard of an adult Grey Crowned Crane, most likely ingested to help break down the hard and fibrous plant material they feed on. Then the gizzard passes the food back to the true stomach, the secretory part, and foods circulate between the two portions until it is passed into the small intestine where the ingested food undergoes further enzymatic processes. In feeding experiments with Whooping Cranes, passage of plant food from consumption to defecation took seven hours (Urbanek and Lewis 2015). Foods that had low fiber and high ash and calcium content (e.g., clams) had much shorter passage time, likely due to the foods' higher digestibility (Nelson et al. 1997).

Although all crane species have some feeding traits in common, distinct differences in morphology and foraging strategies exist for crane species that are primarily dependent on wetland habitats (e.g., Siberian and Whooping Cranes) and those species that have adapted to dry grassland habitats (e.g., Demoiselle and Blue Cranes; see Table 1). The latter species have much smaller bills (Fig. 3) and are adept at picking up smaller food, like small insects or grass seeds, but they are able to probe less deeply (maximum 3-5 cm) into the soils of their grassland habitats than cranes with longer bills. Sandhill Cranes, in contrast, can penetrate 5–7 cm into the ground while probing for tubers and ground-dwelling insects or earthworms (Walkingshaw 1973).

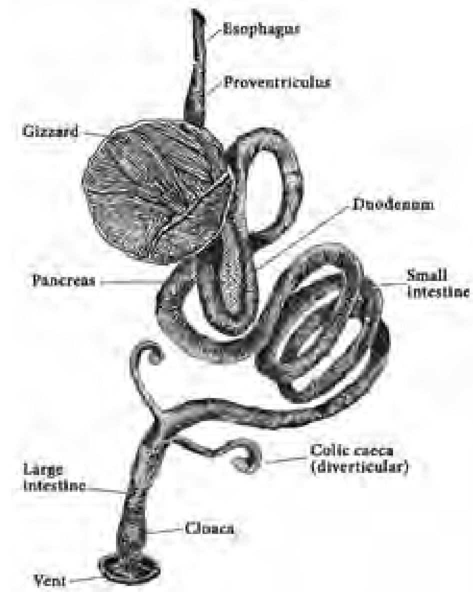

Fig. 2. Simplified diagram of the digestive organs of a crane. Drawing by Darcy Love

With their head lowered, upland feeders like Black and Grey Crowned Cranes hunt and peck while stamping on the ground to scare up and catch insects like grasshoppers. Stripping and plucking seeds of grasses from the blade with a slightly opened bill (Archibald and Meine 1996) have been observed in a goose-like manner with Black and Grey Crowned, Demoiselle, Hooded, Black-necked, Eurasian, and Sandhill Cranes.

Cranes that often feed in wetlands have long, powerful mandibles that are used to capture animals in the water or substrate, to excavate tubers and roots from muddy soils in shallow water zones, or to poke holes around aquatic plants to expose the tubers (Fig. 4). For example, Sandhill Cranes wintering in New Mexico probe soils in flooded areas for below-ground insects and tubers such as chufa (*Cyperus esculentus*) (Taylor and Smith 2005). The Siberian Crane has the longest bill (Fig. 3) and is especially well adapted to wetlands; they feed on the tubers and parts of certain aquatic plants (e.g. wild celery *Vallisneria* sp.) as well as animals. Urbanek and Lewis (2015) describes the behaviour of Whooping Cranes while feeding in dryland habitats and in water. Dragonfly nymphs (*Aeshna* sp. and *Libellula* sp.) were the predominant food items during the breeding season and made up 88% of known foods (Bergeson et al. 2001). But in all seasons they also stab large food items such as blue crabs (*Callinectes sapidus*) or snakes, probe substrate for tubers or grubs, peck to grasp grain seeds or wolfberries (*Lycium carolinianum*), or nibble to remove parts of a large food item. They have been observed shaking snakes violently with their bill before striking it against the ground to immobilize it. Allen (1952) observed Whooping Cranes in pastures turning cattle dung to obtain beetles, as do Sandhill Cranes and likely other crane species. Further, Whooping Cranes, Eurasian Cranes, and other crane species breeding in wetlands also eat mussels (Fig. 5), small fish, and egg masses of frogs and toads in shallow water areas (Prange 1989, Urbanek and Lewis 2015).

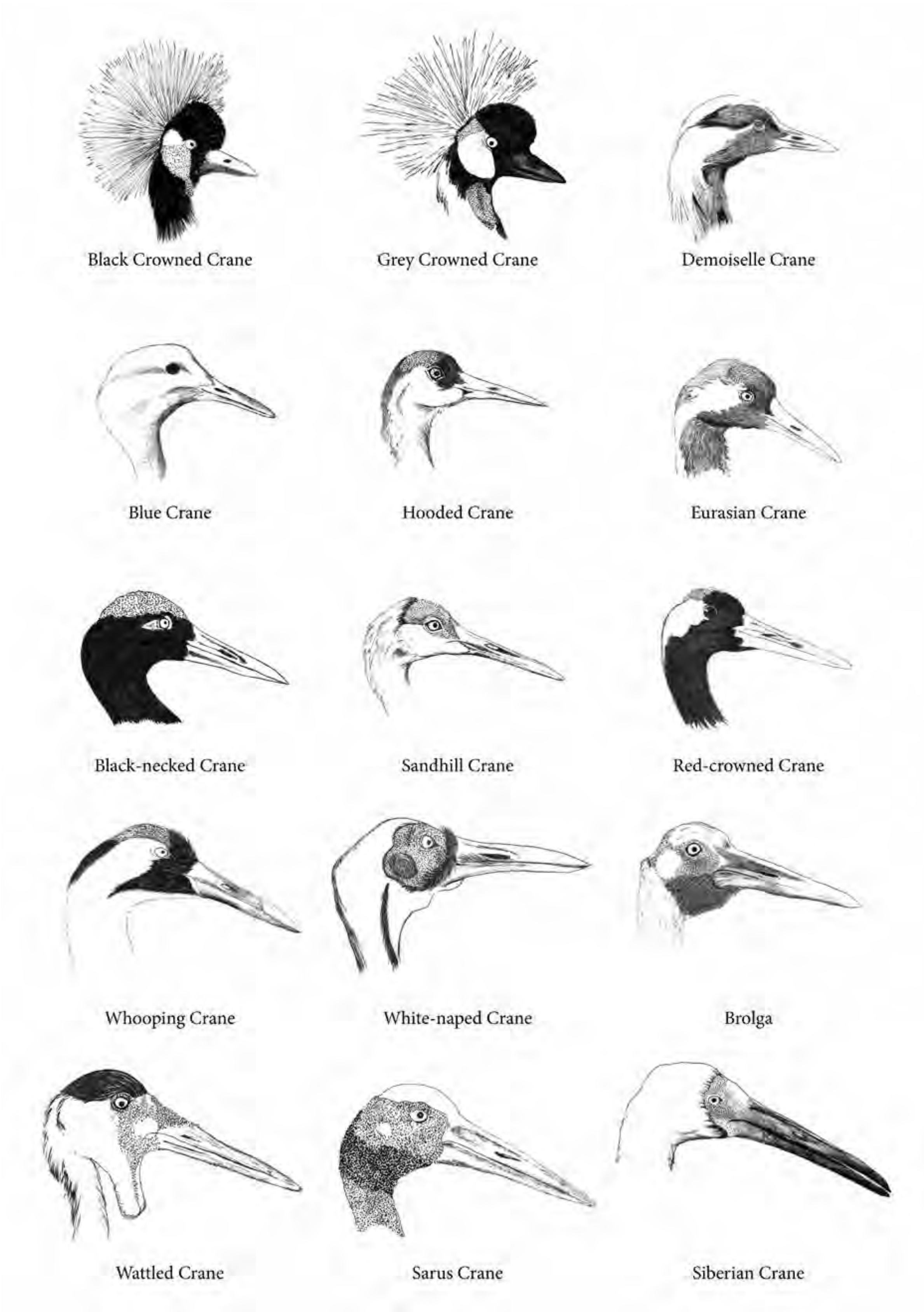

Fig. 3. Differences in bill morphology among crane species. Drawing by Darcy Love

Fig. 4. The long bills of Wattled Cranes allow them to probe deeply in wetlands (Photographer: Daniel Polpire)

Fig. 5. Whooping Crane handling a small mussel (Photographer: Ted Thousand)

Seasonal Changes in Foraging Ecology

Cranes are omnivorous and opportunistic, but their activity patterns and diets change over the year with changing nutritional needs and seasonal and local changes in food availability. Animal foods are rich sources of protein and are most crucial to cranes during the breeding season. Egg-laying females need to obtain the essential amino acids, sugars, proteins, calcium, and other nutrients for egg formation (Ellis et al. 1996), and growing juveniles need protein and a higher calcium/phosphorus ratio in their food than non-breeding adult cranes because of mineral demands for bone and feather growth (Ellis et al. 1996). Macroinvertebrates such as snails, Odonate nymphs, and Orthoptera are valuable sources of protein and are most abundant in the warm season when cranes are breeding. Small birds, amphibians, reptiles, and fish are also part of the diet for many breeding cranes.

Protein-rich foods are found primarily in natural rather than agricultural habitats, hence cranes tend to use agricultural fields least during the breeding season. Eurasian Cranes, for example, prefer natural habitats for rearing their flightless offspring between May and July. In Germany, they walk up to 30 km per day inside their about 80-ha territories seeking natural foods (Nowald 2003). Demoiselle Cranes also can cover considerable distances in the search for insects and other food items during the pre-fledging period (Archibald and Meine 1996). Whooping Cranes feed more heavily on aquatic animal matter during the breeding season than the non-breeding season (Serafin and Archibald 1977 unpublished report, *in* Ellis et al. 1996). Cranes breeding in tropical and subtropical regions (crowned cranes, Blue and Sarus Cranes, and the Brolga) usually breed on seasonal wetlands that provide protection against predators and abundant animal and plant food resources. However, extensive farming practice in artificial wetlands, like rice (*Oryza sativa*) fields can provide animal food, (e.g., for Sarus Cranes). Cranes that use paddy systems (e.g., rice and shrimp farming) during the breeding season are more likely to overlap or potentially conflict in agricultural activities than those relying on natural wetlands or uplands for food. Diets of non-breeding cranes during summer likely are similar to diet of breeding cranes during late summer but again influenced by food availability and habitat preferences.

In northern regions, cranes shift towards more herbivorous diets between late summer and winter and tend to gather in big flocks for feeding. Many seeds and berries ripen during late summer and autumn, and tubers of sedges and other plants are at their maximum nutritional quality and availability in autumn and winter. These foods are rich in carbohydrates and fats. Migratory species seek foods rich in carbohydrates and fats to store energy as fat for autumn migration. During the non-breeding season, cranes prefer to forage as close to the roost site as possible. As food is depleted near the roosts by large foraging flocks, cranes will fly farther to find productive feeding habitats (Hamilton and Watt 1970). Such seasonal changes in flight distance have been observed for Eurasian Cranes in the area of the Laguna de Gallocanta, a wintering ground in Spain (Alonso et al. 1984), and for Sandhill Cranes in the staging areas on the Platte River, Nebraska, USA (Pearse et al. 2010, Sherfy et al. 2011). Alonso et al. (1994) found that the midwinter Eurasian Crane population in Gallocanta is limited by the carrying capacity (i.e., food resources) of the area. The density of the cranes in 10 study zones was approximately proportional to the amount of available food resources, with some over-representation in zones with highest food densities (Bautista et al. 1995). Those findings indicate wintering cranes select patches with the best food availability. Similar results were found by Nowald's (1996) investigations in the Rügen-Bock resting area in Northeast Germany, where cranes selected the feeding habitat in accordance with optimal foraging theory (McFarland and Stahnke 1989). Also, feeding rate was related to food abundance; on newly sown summer barley (*Hordeum vulgare*) fields with 190 kg seeds per ha, Eurasian Cranes swallowed 21 seeds per minute whereas in fields with 160 kg seeds per ha they took only 17 seeds per minute (Nowald 1994). Thus, cranes can more quickly meet their energy needs in densely sown fields.

In contrast to Eurasian and Sandhill Cranes, Siberian Cranes roost and feed in large, isolated wetlands on migration and wintering grounds and do not use agricultural areas. They instead feed on roots, bulbs, tubers (especially of sedges), rhizomes, sprouts and stems of aquatic plants, and aquatic animals (Del Hoyo et al. 1996). On the wintering grounds in China, Siberian cranes of the Eastern population feed primarily on pondweed *(Potamogeton malainus)*, stems and tubers of wild celery (*Vallisneria spiralis*), and small freshwater clams (Liu and Chen 1991).

In areas of the southern hemisphere having distinct annual seasons, the frequency of habitat use of Blue Cranes also varies according to the time of the year and food availability, comparable to the Eurasian Crane. Principal food items are seeds of sedges and grasses (Fig. 6), waste grains (mainly wheat [*Triticum aestivum*], barley, and maize [corn, *Zea mays*]), insects, and small vertebrates (Archibald and Meine 1996). Australian Sarus Cranes, in contrast, do not seem to have any preferences to foods in any season (Archibald et al. 2003).

Fig. 6. Blue Crane pair forages in short sedges and grass of a wetland (Photographer: Daniel Polpire)

Cranes of the more subtropical or tropical zones gather in large flocks during the dry season. The Eastern Sarus Crane in Cambodia and Vietnam and the Brolga in Australia congregate on dry coastal wetlands where they forage on the tubers of the bulkuru sedge (*Eleocharis dulcis*) (Archibald et al. 2003). Black Crowned Cranes can be considered both year-round residents and local migrants, flocking, often occurring in large numbers during the dry (non-breeding) season, and moving from large permanent wetlands to smaller temporary wetlands during the rainy season (Archibald and Meine 1996).

Migrating cranes will forage heavily on staging areas to acquire the necessary energy (fat stores) to fuel their long flights. The increase of body mass of staging cranes is highly variable and depends on the arrival date to the staging area, food availability, local weather, competition with migratory waterfowl, and the number of cranes in the area (Krapu and Johnson 1990). Feeding on waste grain of maize along the Platte River Valley in Nebraska, adult females and males of the Mid-Continent Sandhill Crane population increased body mass by 17% and 20%, respectively, during fall migration (Krapu and Johnson 1990) and by 30% and 34%, respectively, during spring migration (Krapu et al. 1985). Eurasian Cranes consumed about 4% of their body weight per day following autumn and spring migrations (Halibey 1979 unpubl. *in* Ellis et al. 1996). Shortly after arriving at the wintering site of the Laguna de Gallocanta in Spain, they consumed up to 350 g cereal per day in November to increase their body weight following migration. By the end of winter, until March, food ingested had decreased to 96 g per day (Alonso and Alonso 1992), but near the end of spring migration in northeastern Germany it increased again to 290 g wheat per day in order to deposit fat for the subsequent reproduction season (Nowald 1999). During spring staging migration, food consumption and daily energy requirements are influenced by ambient temperature as well as age and sex (adult females acquiring more fat reserves than males to support later reproductive efforts; Reinecke and Krapu 1986). For example, maximum food requirements for immature Lesser Sandhill Cranes staging on the Platte River in spring were 16% higher at -4.4°C than at 13.6°C (Reinecke and Krapu 1986). Sandhill Cranes there feed extensively on maize fields, providing high-energy food, but invertebrate foods in native grasslands and alfalfa (lucerne, *Medicago sativa)* fields were good sources of protein and calcium. For Whooping Cranes, Kang and King (2014) estimated that for survival, a crane needed to maintain a balance between daily energy expenditure (DEE, e.g., winter season: 604.2 ± 9.93 kcal) and daily energy intake (DEI). They calculated Crane Use Days (CUD), derived from the number of cranes that can be sustained in a given habitat for a given amount of time:

$$\text{CUDs} = \frac{\text{Digestible energy density (Kcal/m}^2\text{) * habitat size (m}^2\text{)}}{\text{Daily energy requirement (Kcal/ day)}}$$

Although use of agricultural grains tends to be highest during migration and winter, diets continue to be influenced by availability of agricultural and natural foods and species preferences. The diet of wintering Sandhill Cranes consists largely of agricultural grains, but those wintering in the South Texas Plains make greater use of seeds and tubers of nut grass (*Cyperus rotundus*), chufa, and other tuberous species (Guthery 1975, Ballard and Thompson 2000). Migrant Whooping Cranes forage in both crop fields and wetlands but, unlike Sandhill Cranes, do not feed in large flocks, although some may feed in crop fields association with Sandhill Crane flocks (Austin and Richert 2005).

Whooping Cranes wintering on the Gulf Coast in the Aransas National Wildlife Refuge, Texas, forage in brackish bays, estuarine marshes, and tidal flats where they prey upon blue crabs but also on clams (*Ensis* sp.), fiddler crabs (*Uca* spp.), shrimps (decapod crustaceans), other aquatic invertebrates, and small vertebrates. Additionally, they feed on acorns and wolfberry, foods that are rich in ascorbic acids, iron, calcium, and essential amino acids (Hunt and Slack 1989). Little is known about how other crane species obtain such nutrients or their significance for health or subsequent breeding success.

Adapting to Agricultural Foods

Anthropogenic food sources like seeds of maize, wheat, barley, broomcorn (*Sorghum bicolor*) or millet (e.g., *Pennisetum glaucum, Eleusine coracana*) as well as ground nuts (*Arachis hypogaea*), soy beans (*Glycine max*), potatoes (*Solanum tuberosum*), or even rice provide high energy in form of carbohydrates and fats, which are important factors to enhance fitness of migrating and wintering cranes. Additionally, food is distributed more equally across large agricultural fields than it is in patchy natural habitats. Hence, several crane species have readily adapted to these food sources. With the conversion of many grasslands and wetlands to agriculture (see Austin 2018b, Ilyashenko 2018), cranes have shifted to feed on more on agricultural foods than in remaining native habitats during migration and winter (Fig. 7). Indeed, many authors see waste grain from agricultural crops as the most important source of energy for cranes during migration and winter, and also for resident species during the non-breeding season (Iverson et al. 1987, Tacha et al. 1985, Prange 1989, Nowald 1996). Use of agriculture or natural foods also depends on the carrying capacity of an area, which may vary within and among years (Bautista et al. 1995). Beside harvest residues, cranes also use other anthropogenic food sources, for example ground nuts in the Hula Valley of Israel or in northern India. In the Extremadura of Spain, before the agricultural intensification and restructuring, wintering Eurasian Cranes foraged in open forests with Holm oak (*Quercus ilex*) and Cork oak (*Quercus suber*), eating acorns and lily (*Lilium* spp.) tubers. Today, the majority of cranes wintering in the Extremadura are instead foraging in rice paddies and on maize stubble fields. But they also probe for seeds in freshly sown fields, or feed on ground nuts, potatoes, or other crops shortly before harvest. The more omnivorous crane species often feed on tuber-producing plants, so transitioning from native tuber-producing plants like chufa or sedge tubers to human-cultivated tubers such as potatoes or ground nuts may have been quite easy. Cranes foraging on agricultural lands may also dig or probe for invertebrates or weed seeds and tubers. For example, in northeast Germany during spring migration cranes have been observed probing for invertebrates in fields of oilseed rape (*Brassica napus*) (Nowald 1994). Wintering Sandhill Cranes in New Mexico similarly probe for invertebrates and chufa tubers in moist areas of alfalfa fields; this foraging behaviour can lead to crop damage as crop plants are torn off or trampled (Taylor 1999, Austin 2018a).

Fig. 7. Sarus Crane family foraging in harvested wheat field, India (Photographer: K S Gopi Sundar)

Fig. 8. Eurasian Cranes feeding on agricultural fields (Photographer: George Archibald)

Availability of agricultural crops and their vulnerability to damage by cranes is influenced by agricultural practices. In Europe, cranes have been foraging on agricultural lands for at least 200 years, but conflicts with farmers rarely occurred because the cranes fed on the stubble fields after harvest in autumn (Salvi 2010). During the last four decades, agricultural practices have changed, with a shift from spring-sown summer crops to fall-sown winter wheat. Further, all over Europe harvested fields are increasingly plowed shortly after harvest, leaving less residual grain on the field. As a consequence, the birds are concentrating more on fields with newly sown winter crops (Nowald et al. 2001) or feed along the border of standing crops (Günter Nowald, personal observations) (Fig. 8). In South Africa, the preferred planting times of barley and wheat are in fall (April to June) and grain is harvested and harvest residue is available for cranes in spring (October and November). Timing of sowing and harvest will vary for each region depending on weather and seasonal effects. In the cooler areas of southern Queensland, barley planting can occur into July (mid-winter), and spring wheat is planted from August to September.

In India and Vietnam, flocks of the non-migratory Sarus Cranes forage in rice fields, which largely have replaced natural wetlands (Sundar and Subramanya 2010, Sundar 2018), where they feed on aquatic plants such as tubers of sedges (like *Eleocharis* spp.), grains, invertebrates, and small vertebrates. In the South Korean Civilian Controlled Zone (CCZ), Red-crowned Cranes forage during the day in rice fields and at night they roost in the undisturbed natural wetlands inside the Demilitarized Zone (DMZ) (Kim et al. 2011). In comparison to other wildlife, Red-crowned Cranes are perceived in a positive way by the farmers as it is considered a "culturally important species" and supposedly only feeds on waste grains of rice (Kim et al. 2011). In two different wintering sites in China, Eurasian Cranes consumed more cereals (crop seeds) (76.4 % of diet, primarily maize and broomcorn), although their diet additionally consisted of eight natural plant species (Zhan et al. 2007).

The increase of the Eurasian Crane during the last 40 years was related to considerable restoration of breeding habitats (Mewes et al. 2013) but has also been partly dependent on the increasing cultivation of maize for livestock feed (Nowald et al. 2001). Nowadays, maize is increasingly cultivated for the production of biofuel; those fields provide no foods for cranes because the plants are harvested before seeds are ripe. At this time we have to deal with increasing numbers of cranes on the one hand and on the other hand with more intense agricultural land use, including winter crops. These fields are prone to be damaged by cranes because the birds are instead congregating on agricultural sites with germinating winter cereals where they easily can fill up energy balances. This might lead to a growing potential of conflicts between farmers and crane conservationists.

In other regions of the world, similar situations can be observed with conflicts already being quite severe, and may be economically significant; many examples are provided in the case studies. For example, farmers have been complaining about crop damage to seeded corn fields by the eastern population of the Sandhill Crane (*Grus canadensis tabida*) since the 1980s (Barzen et al. 2012, Lacy 2018). In the western United States, Sandhill Cranes also can damage mature grain and chilie (*Capsicum* spp.) crops if other foraging habitat is limited (Austin 2012; Austin 2018a); in the middle Rio Grande Valley, New Mexico, they can damaged newly planted alfalfa fields by probing for invertebrates and chufa tubers (Austin 2012). In the Daurian steppe zone in south eastern Siberia (Transbaikal Region), six species (Siberian, Red-crowned, White-naped, Eurasian, Hooded, and Demoiselle Cranes) of non-breeding cranes spend the summer. They are all regularly found foraging on crop fields, with Demoiselle Cranes being the most numerous (about 67,000 individuals) (Goroshko 2012). This leads to considerable crop damage – often up to 50 % – through feeding on ripe wheat and trampling down the wheat ears.

The Grey Crowned Crane that occurs in the southern and the south eastern parts of Africa also forages frequently in agricultural lands, including pastures, irrigated areas, fallow fields, recently harvested fields, and newly planted cereal crops (Pomeroy 1980, Gichuki and Gichuki 1992, McCann and Wilkins 1995, Morrison 1998, Gichuki 2000, Muheebwa 2004, Muheebwa-Muhoozi 2001, Van Niekerk 2018). They especially prefer soy beans, ground nuts, millet, potatoes, and maize (Pomeroy 1980, Muheebwa-Muhoozi 2001). Further, the Grey Crowned Crane in East Africa (Pomeroy 1987) and the Blue Crane in the Western Cape of South Africa (Kerryn L. Morrison, personal comm. 2016) both have been observed feeding on standing wheat, plucking seeds of standing crop. As a result, conflicts with farmers arise; however, the perceived damage caused to crops often is higher than the actual damage (Katondo 1996, Smallie 2000).

Unusual Food Sources

Cranes can adapt to unusual food sources where habitat loss is severe and most natural habitats are no longer available. For example, in Izumi, southern Japan, the wintering crane population decreased rapidly during and after World War II (Ohsako 1983). To support the cranes, during 1962–1963 the authorities of Izumi City and towns of Takano and Noda began to put wheat out at special feeding places close to the roost sites. As a result, the wintering population increased to 10,000 Hooded and 2,500 White-naped Cranes (Nara 2008). Even today, there are still high numbers of cranes in the area, but wetland losses and construction of greenhouses on historic foraging grounds have left little natural habitat for cranes, and they have become dependent on the artificial feeding. On Hokkaido in northern Japan, wintering Red-crowned Cranes have been fed with fish and maize in a snow covered and frozen landscape. Due to this extensive winter feeding the population increased from 33 Red-crowned Cranes in 1952 to 1,250 birds in 2008 (Koga 2009) and the birds now depend entirely on the artificial winter feeding (Momose 2009). Two other examples include the feeding of more than 10,000 overwintering Demoiselle Cranes in the middle of Kheechan, a small village in Rajasthan (India) (Jain et al. 2010), and feeding of 20–40,000 Eurasian Cranes in the Hula Valley in Israel (Shanni et al. 2018). It seems that if food is limited, especially during winter, cranes are more disposed to approach buildings. Further discussion about artificial feeding is covered in Austin and Sundar (2018).

The Grey Crowned Crane's generalist foraging strategy has allowed them to adapt to human settlement, and they are often seen in human-modified environments (Meine and Archibald 1996, McCann and Wilkins 1995). This has even extended to Kampala's main rubbish dump in Uganda, where a flock of up to 95 Grey Crowned Cranes has been feeding daily in recent years (Nachuha and Quinn 2012, Ndibaisa 2013).

Conclusions

The feeding ecology of cranes varies among species, ranging from the more aquatic Siberian and Whooping Cranes to dryland foragers such as Blue and Demoiselle Cranes. The diets of most cranes change with season and local food availability. Cranes generally select places that provide the highest food availability, best energy and nutritional content, and shortest handling time. Habitat loss, especially the loss of shallow wetlands important for roosting, can induce bigger concentrations around remaining roost areas. Cranes frequently occur in large numbers on agricultural lands during the non-breeding season. In most of the crane species, especially in Africa and Asia, more research is needed to describe and to understand why, when, what, and where cranes feed in natural and anthropogenic landscapes. Even for well-studied species like the Sandhill and Eurasian Crane, there remain gaps in knowledge because results obtained in one part of their range are not always applicable in other places. Understanding basic life history features, resource needs, and feeding ecology is key to developing effective approaches to prevent or minimize conflicts between cranes and agriculture.

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CHAPTER 2

Regional and Historical Patterns of Agriculture

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Abstract: Cranes have had to adapt to many anthropogenic changes, particularly in agriculture, over thousands of years. Historically agriculture development has contributed to significant reduction and degradation of natural habitats important to cranes while also providing new food resources and, sometimes, breeding habitats. Agriculture and its effects on the landscape have been driven by a range of geographic, political, socio-economic, and technological factors. This chapter briefly describes geographic influences affecting agriculture and cranes, and historical changes in agriculture relative to cranes in different regions. In particular, it focuses on the last 100 years, a period of rapid agricultural expansion, contraction, intensification, and market changes, which have had both positive and negative effects on cranes or changes to their behavior. A sound understanding of the socio-economic, political, scientific, and climate factors influencing agriculture is important for planning and implementing effective conservation strategies for cranes.

Keywords: agricultural development, agriculture practices, arable agriculture, geography, habitat loss, historical perspective, land use, markets, pastoral agriculture

Cranes have survived and adapted to many natural and anthropogenic changes over thousands years, including the expansion and intensification of agriculture. Agriculture affects the environment more than any other component of human activity because it involves vast areas. A 2010 study by the International Resource Panel of the United Nations Environment Programme (UNEP 2010) reported that agriculture and demands of growing human population for food are two of the most important drivers of environmental pressures, particularly habitat change, climate change, water use, and toxic emissions. Approximately 25% of Earth's terrestrial surface is now occupied by cultivated systems (Archer et al. 2008). Food production will need to increase by about 70% by 2050 to cope with human population increases, which in turn will increase competition for land and water resources (Galluzi et al. 2011). These realities of current and future agricultural pressures have critical implications for the conservation of cranes around the world.

Changes in agriculture over the past several hundred years have led to the most substantial impacts to cranes. In many areas settled by humans, crane numbers have been severely diminished, especially in crane breeding areas where natural habitats have been lost or degraded (Austin 2018). Numerous staging and wintering areas also are no longer used by cranes because of impacts to their habitat. However, most crane species show some ability to adapt to landscape change and to human activities (Nowald et al. 2018). The length of interaction between cranes and agriculture is an important consideration in the evolving relations between cranes and humans and agriculture (Harris 2012). African and Asian crane populations have had the longest co-existence with agriculture, and cranes there tend to be integrated and adapted to subsistence farming. In North America and Australia, agriculture has had a shorter history and cranes had little exposure to subsistence types of agriculture. As the extent of cereal grain cultivation has grown in many regions, migrating and wintering cranes have adapted to take advantage of those new food resources.

Austin JE, Morrison K, Harris JT, editors. 2018. *Cranes and Agriculture: A Global Guide for Sharing the Landscape.* Baraboo, Wisconsin, USA: International Crane Foundation. 303 p.

As noted in Chapter 1 (Nowald et al. 2018), the interactions of the 15 crane species with agriculture vary relative to their habitats requirements and historical ranges. Those interactions also are affected by both abiotic (e.g., water, soils, landform, and climate) and anthropogenic (internal and external political issues, socio-economic, technical, scientific, and cultural) factors that influence agricultural development. This chapter provides a perspective from the human and agricultural side – how these drivers interact to influence agricultural patterns and development, and how these changes in land use, water management, agriculture practices, and crop species affect landscapes and resources important to cranes. Understanding how such factors influence agriculture will be critical to finding ways to take advantage of their positive impacts to cranes and minimize negative ones into the future. Chapter 3 (Ilyashenko and King 2018) describes how cranes have responded to some of those changes, and Chapter 5 (Austin 2018) provides more details about habitat losses and other threats related to agriculture.

As societies change with time, their influences on agricultural systems also change. Therefore, any assessments of the economic, social, and political drivers affecting agricultural systems are time-specific. This chapter gives a brief description of geographic influences affecting distribution of agricultural types and cranes as well as historical aspects of crane co-existence with agriculture during its development. A particular focus is on the last 30–100 years, as this period experienced very rapid socio-economic, technical, and scientific developments that have led to significant changes in agriculture and exploitation of natural resources. Agricultural development during this period has been uneven among countries, thus the impact of agricultural changes to cranes varies among the different parts of the world.

Geographical Influences to Agriculture and Cranes

Broad patterns of agriculture, as well as crane distributions, can be seen at the biome scale. Here, interactions between cranes and agriculture are considered using the World Wildlife Fund's biomes (Olson et al. 2001). Biomes that are the largest and the most important for both cranes and agricultural crops are the boreal forest/taiga; temperate broadleaf and mixed forest; temperate grasslands, savannas and shrublands; tropical and subtropical grasslands, savannas, and shrublands; montane grasslands and shrublands; Mediterranean forests, woodlands and shrubs; and tropical and subtropical moist and

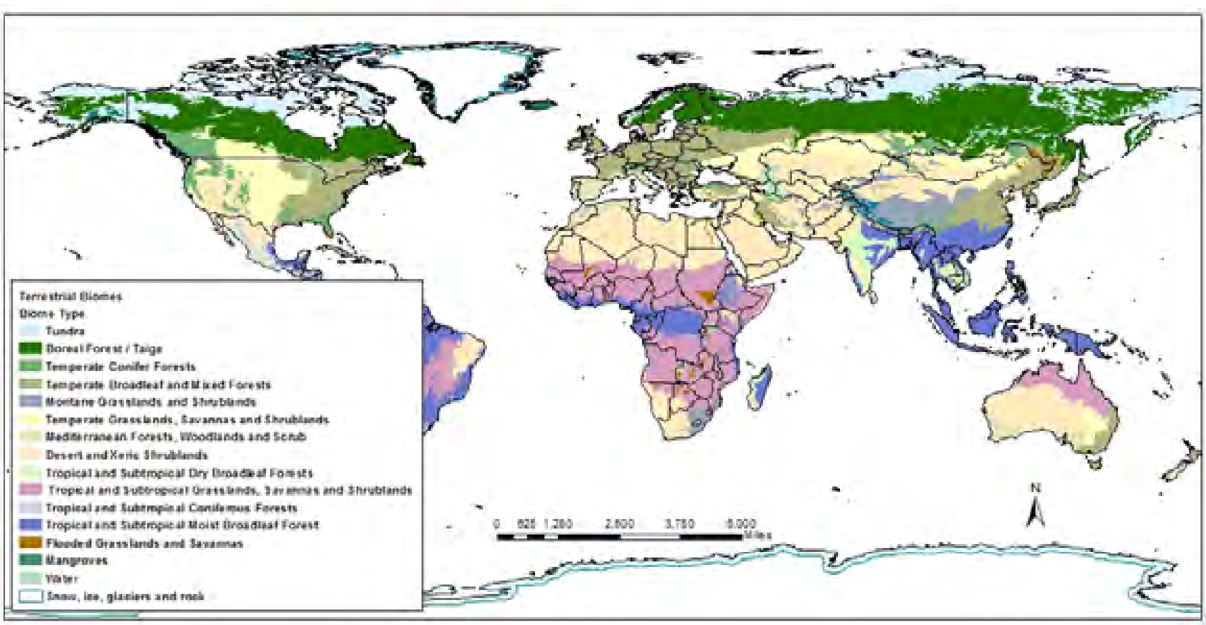

*Fig. 1. Terrestrial biomes of the world. From World Wildlife Fund (*www.worldwildlife.org/biomes*).*

dry broadleaf forests (Fig. 1; Olson et al. 2001; www.worldwildlife.org/biomes). The relationship of cranes and agriculture within each of these biomes is summarized in Table 1 and described below.

The *boreal forest/taiga biome* occupies the vast areas in the north of Eurasia and North America where northern portions of the breeding ranges of Sandhill and Eurasian Cranes as well as Whooping and Hooded Cranes are located. Major limitations for agriculture include short, cool growing seasons (not enough time to mature or to produce high yields of harvestable crops), long and/or unfavorable winter weather that can limit survival of many perennial crops, often poor soils, and high moisture stress in some areas. Crop types are limited; the biome is most suitable for growing barley (*Hordeum vulgare*), oats (*Avena sativa*), potatoes (*Solanum tuberosum*), green peas (*Pisum sativum*), and in some areas wheat (*Triticum aestivum*) (Juday 2005). Cranes mainly rely on natural habitats during the breeding season but may feed on early ripening barley and wheat fields for a short time during autumn staging; cranes sometimes damage standing grain or grain swaths by trampling before harvest is complete (Lundin 2005, Khokhlova et al. 2007).

The *temperate broadleaf and mixed forest biome* has a distinct warm and cool season, creating moderate annual average temperatures and relatively warm and rainy climates. An estimated 46.6% of this biome has been converted to human-dominated uses (Hoekstra et al. 2005). In areas with suitable soils and topography, most natural habitats have been converted into agricultural lands. Wheat, corn (maize, *Zea mays*), and soybeans (*Glycine max)* are widely cultivated as cash crops; other common crops include barley and rye (*Secale cereale*). These cereal grains produce good yields as they grow well in a temperate climate even in areas with a moderately short growing season. They are highly favored by birds and support Eurasian and Sandhill Cranes during migration and wintering, especially in Western and Central Europe and east of the Rocky Mountains of North America where "grain belts" of mass arable farming are located. There is potential for conflicts between farmers and these two most numerous crane species because the cranes often gather in huge flocks at staging areas and stopovers. Grain fields in Japan and South Korea support large parts of the world populations of Red-crowned, Hooded, and White-naped Cranes with food during winter.

The *temperate grasslands, savannas, and shrublands* are key areas for cranes and agriculture. The climate is temperate and ranges from semi-arid to sub-humid. Temperatures are warm to hot in summer and often cold to freezing in winter, and areas can be vulnerable to drought. Precipitation and periodic fire historically limited occurrence of forests. The biome is characterized by generally open, flat to rolling topography and historically was dominated by grasses. An estimated 45.8% of this biome has been converted to human-dominated uses (Hoekstra et al. 2005). Most of this biome was converted to cultivated agriculture where soils were suitable. Conditions allow a high diversity of crops, including those favored by cranes (corn, wheat, barley, potatoes, dried beans) as well as those inedible for cranes (e.g., soybeans, beets [*Beta vulgaris*], rapeseed [*Brassica napus*]). However, limited precipitation and water resources often require irrigation to support crop production. Most water-limited are the steppes and shortgrass prairies in semi-arid climates in the south of Russia, Kazakhstan, Central Asian countries, Mongolia, northwestern China, Turkey, and some other countries. Historically, these areas were used for livestock, but since the mid-1900s large portions have been converted to cultivated crops. These semi-arid areas are important breeding habitats for Demoiselle Cranes and the more aquatic White-naped Cranes, both of which have adapted to living in grazed pastures. Where pastures were converted to arable agriculture with the development of irrigation systems, the Demoiselle Crane has adapted to breed on agricultural fields. Demoiselle, Hooded, White-naped, Eurasian, and sometimes Siberian Cranes now use cereal crops (wheat, rye, and barley) during migration. Tallgrass and mixed-grass prairies of the Great Plains in central North America have moderate rainfall and generally rich soils that make them ideally suited to extensive agriculture. These grassland regions include some of the most productive grain-growing (mostly wheat and corn) regions in the world. The main migration routes of the Endangered Whooping Cranes and the Mid-continental Population of Sandhill Cranes pass through the Great Plains of North America, where both species benefit from the abundant grain crops. The temperate savannas in southeastern Australia are breeding habitats of Brolga. Much of the savanna has been converted to pasture (southern portion of the region) or wheat lands (northern portion), contributing to a significant reduction of the south-eastern population of Brolga.

The tropical and subtropical grasslands, savannas, and shrublands are also dominated by grasses and are characterized by low annual rainfall levels (~600 mm on average), although there may be great seasonal variability in soil moisture. This biome is widespread in Africa and throughout South Asia, northern Australia, and the southeastern United States. An estimated 23.6% of this biome has been converted to human-dominated uses (Hoekstra et al. 2005). Plowing, overgrazing by domestic livestock, and excessive burning led to rapid degradation and alteration of natural communities in many areas. In Africa the diets of both Grey and Black Crowned Cranes are broad and their flexible feeding strategy allows them to exploit food resources produced by people. In pastures they feed on insects associated with grazing animals such as cattle (*Bos taurus*), sheep (*Ovis aries*), and donkeys (*Equus asinus*) (Pomeroy 1987). Alteration of surface water patterns (Austin 2018) for arable agriculture has had significant negative impacts on breeding populations of the more aquatic Wattled Crane, which are listed as vulnerable in IUCN Red List. In Australia, savannas and shrublands provide breeding habitats for the northern population of the Brolga and for the Sarus Crane. Both species are expanding their range, benefitting from clearing of woody growth for pastures and increasing arable agriculture (Meine and Archibald 1996, Tim Nevard, personal comm.). In the United States, >99% of the coastal prairies of Louisiana and Texas have been converted to arable agriculture, including rice (*Oryza sativa*) cultivation (Grace et al. 2000). Once an important region for wintering Whooping Cranes and a non-migratory population (Ilyashenko and King 2018) reintroduced Whooping Cranes are now using working wetlands – rice and crawfish agriculture – in the historical Cajun Prairie region of southwestern Louisiana (Harrell and Bidwell 2015).

The montane grasslands and shrubs include high elevation (montane and alpine) grasslands and shrublands, including steppes of the Tibetan plateaus. Only 12.7% of this biome has been converted to human-dominated uses (Hoekstra et al. 2005), mainly in foothill valleys. The Black-necked Crane, which breeds in high-altitude wetlands of the Qinghai-Tibetan Plateau in China, overlaps with agriculture only during the wintering season, when it moves down to low-elevation agricultural valleys and forages mainly in cultured pastures and crop fields (barley, wheat, corn, and oats in China and rice in northeast Bhutan) (Meine and Archibald 1996).

Mediterranean forests, woodlands, and shrubs are characterized by hot and dry summers, while winters tend to be cool and moist. Only five regions in the world experience these conditions: the Mediterranean (Portugal, Spain, France, and Morocco), where wintering grounds of the Western Eurasian Crane population are located; the fynbos of southern Africa, the primary breeding grounds of the Blue Crane; and California, USA, wintering grounds for Sandhill Cranes. With its long history of human habitation, many areas in this biome have suffered extensive degradation and habitat loss through logging, overgrazing, conversion to agriculture, urbanization, and introduction of exotic and invasive species (Cody 1986). The regions around the Mediterranean basin have been particularly affected by human activity and have experienced extensive loss of forests and soil erosion (García-Ruiz et al. 2013). In California, many wetlands have been lost or converted to intensively managed rice. However, arable agriculture in the Mediterranean basin and California (mainly corn, wheat, and rice) provides food for wintering Eurasian and Sandhill Cranes respectively. South Africa's fynbos, a unique ecosystem, underwent rapid conversion to an agricultural landscape especially since the early 1990s; this transformed landscape has led to a changing distribution of breeding Blue Cranes within its range, with the species taking advantage of open croplands for nesting (Morrison et al. 2012).

The tropical and *subtropical moist and dry broadleaf forests* are two biomes located at tropical and subtropical latitudes. The moist forest experiences a perpetually warm, wet climate that promotes more explosive plant growth than in any other environment on Earth, while the dry forests have dry seasons that last several months, and agriculture is driven by seasonal rainfall patterns. An estimated 48.5% of the tropical dry broadleaf forests and 32.2% of the tropical moist broadleaf forests have been converted to human-dominated uses (Hoekstra et al. 2005). The main cash crops are rice and wheat, and in Africa sorgo (*Sorghum* varieties grown for sugars and fodder) and millet (*Panicum miliaceum*) that are grown mainly by small-scale farmers for their own needs. In the Indo-Malayan region, more than 95% of natural habitats have been degraded or converted into agriculture, and settlement areas have dense human populations that have been present for thousands of years. These changes have affected breeding populations of the Eastern Sarus Crane in Vietnam and Cambodia. In India, forests were cleared to make way for flooded rice fields and the floodplains opened up, likely improving conditions for Sarus Cranes and for wintering Demoiselle and Eurasian Cranes. Cranes and small-scale farmers here have coexisted for an extended period of time (Sundar 2018).

The major cultivation zones of the world lie in regions with agriculturally productive soils and adequate climate conditions: the grain belt of the United States, the prairie regions of central United States and Canada, the wheat-corn belt of Europe, the paddy systems in the Ganges flood-plain in India, the wheat- and rice-growing regions of eastern China, and the wheat belts of Australia (Ramankutty et al. 2002). In addition, large sections of Africa are characterized by low- to moderate-intensity subsistence agriculture. It is in these areas where changing agriculture has had the greatest influence on crane populations.

Changes in Agriculture Over the Centuries

Arable and livestock agriculture started about 12,000 years ago with the domestication of animals and plants. From ancient Africa and Asia cereals (mainly wheat, rice and millet) were spread around the world and fortuitously also provided easy accessible and energy-rich food beneficial to cranes. Cranes generally took advantage of small-scale, subsistence agriculture and were able to use crop fields and pastures for breeding, roosting, and wintering. For instance, the region south of the Himalayas in India was converted almost entirely to small-scale rice paddies as far back as 300 years ago (Sundar 2018), and Sarus Cranes there have come to coexist with farming and agricultural practices. Cranes also co-occurred with nomadic pastoralism in two important regions: the Eurasian steppes stretching from the Hungarian Plain to Manchuria (Russia, Ukraine, Kazakhstan, Mongolia, Central Asian countries, and China) (Fig. 2), and the tropical savannahs of eastern and central African grasslands. Demoiselle Cranes in the Eurasian steppes and crowned cranes in Africa have co-existed for thousands of years with grazing livestock, which provide several benefits to cranes, including livestock watering sources and control of vegetation structure and woody encroachment.

In the 15th and 16th centuries, increasing exploration and trade led to the "Columbian exchange" of plants, crops, animals, plants, culture, human populations, technology, and ideas between the American and Afro-Eurasian hemispheres (Nunn and Qian 2010). Crops edible by cranes included corn and potatoes from South America and cereal grains, oats, rice, and soybeans from Eurasia. European settlers to the New World started in Mexico in the 1500s and along the coasts of the United States and Australia in the 1600s. In both North America and Australia, European settlements and populations rapidly increased in the 1700s and expanded, particularly in the 1800s. Agriculture in

Fig. 2. Black-necked Cranes forage in sheep pastures (Photographer: George Archibald)

these "new" worlds was based largely on capitalistic economies with individual land ownership.

Massive changes in agriculture occurred in the 18th to 20th centuries in two distinct periods. The First Industrial Revolution (Deane 1979) started in Britain in the third part of 18th century and through the first half of the 19th century spread to continental Europe and North America. Its main feature was the transition from agrarian to industrial economies, including conversion from hand production methods to machines, new chemical manufacturing and iron production processes, improved efficiency of water power, development of machine tools, and the rise of the factory system; coinciding with these developments were rising human populations and rapid declines in biodiversity and natural habitats. The First Industrial Revolution evolved into the Second Industrial Revolution (Landes 1969) in the latter half of the 19th century up to World War II, when many regions experienced expansion of railroads, widespread use of machinery in manufacturing, greatly increased use of steam power, and corresponding effects for moving and marketing agricultural products and large-scale production. Farming in the more developed countries (Britain, Germany, and the United States, but also in France, the Low Countries of Europe, and Japan) became more intensive with input of capital, hired labor, and use of farming machines, pesticides, and fertilizers. In the Great Plains of the United States and Canada, agricultural expansion during 1860s–1920s was fueled by government grants to settlers for lands west of the Mississippi and Red rivers and new access provided by an expanding railroad system. By 1930, cultivation began in southwestern Australia and grazing continued in other parts of the country. The rest of the world gradually intensified its cultivation during this time. Subsistence farming became more intensive in East Asia and India, although some cropland abandonment also occurred in India. In Africa, intensification of agricultural production only took root at a substantial scale in the second half of the 20th century; agriculture remains dominated by low-input, small-scale production mostly for home consumption, with approximately 40% of the total agricultural area consisting of farms smaller than 2 ha and 67% under 5 ha (Lowder et al. 2014)

Although expansion and increases in crop production around the world increased food availability for many crane species (excluding the more specialized Siberian and Wattled Cranes), the expansion of agricultural lands came at the cost of wetland and grassland habitats important to cranes. Those habitat losses, combined with people taking cranes for food, contributed to reduction or disappearance of crane populations. Greater intensity of wetland use affected natural habitats used by Red-crowned Cranes in China and Japan and Sarus Cranes in South Asia and India. The disappearance of Eurasian Cranes as a breeding species in western and southern Europe, Balkan Peninsula, and southern Ukraine occurred more than 200–400 years ago (Prange 1994) and coincided with the beginning of industrial civilization development. The Demoiselle Crane was extirpated from the Iberian Peninsula, Balkan Peninsula, Moldova and Southwestern Ukraine mainly in late 19th–early 20th centuries, a period of increasing of human disturbance, steppe plowing, and mass use of pesticides (Andryuschenko 1997, Nankinov 2009). The range of the Whooping Crane, which never was numerous, shrank rapidly in the second half of the 19th century, and by the 1940s the species was extirpated from much of its historic range (Allen 1952). Numbers of Sandhill Cranes in many parts of United States also declined markedly from the mid-1800s to mid-1900s due to shooting and habitat changes (Meine and Archibald 1996). In Australia, the southern population of Brolga along the southeast coast, where conditions for agriculture development were more favorable, declined significantly following European settlement (Meine and Archibald 1996). More details about impacts upon and responses of crane populations and their distributions are provided in Chapter 3 (Ilyashenko and King 2018).

Changes in Agriculture Since the Mid-20th Century

While the direction of change in agricultural development remained the same, its pace has dramatically accelerated since the mid-1900s, influenced by socio-economic, political, and technical drivers as the world seeks to provide food for a rapidly growing human population. As described above and in Austin (2018), these forces have resulted in huge losses of natural habitats and extirpation or declining populations of many animals. Some more specialized species, including several crane species, have had little time to adapt to rapid changes in their environment, while other crane species or populations were able to take advantage of some changes, using crop fields and pastures for breeding and feeding (see Ilyashenko and King 2018). Here, four aspects of agricultural change in countries encompassing crane ranges are described: expansion of agricultural lands, decline or contraction of agricultural lands, agricultural intensification and industrialization, and market forces.

Expansion of Agricultural Lands

In the last 30-50 years, expansion of land in agricultural use has continued mainly in the developing countries in sub-Saharan Africa (FAO 2013) and South and Southeast Asia. These regions combine ample land resources with potential for crops, food demands of rapidly increasing human populations, and limited access to modern technology that could increase productivity on land already in agricultural use (Alexandratos and Bruinsma 2012). In most of Africa, agricultural expansion accelerated with the turn into the 21st century in the small-scale agriculture sector (Phalan et al. 2013), driven by population growth and increased investments in large-scale commercially oriented operations. The greatest cropland expansion occurred in South and Southeast Asia; 11% and 18% of their total land area, respectively, were cleared for cultivation during the 20th century. In these regions, cropland areas since have increased exponentially, matching an exponentially growing population (Ramankutty et al. 2002).

In more developed nations, the main drivers of expansion were advances in scientific and technological achievements in mechanized machinery, pesticides, and fertilizers, combined with growing human populations and expanding markets. These factors contributed to the expansion of arable agriculture to marginal and non-fertile lands through new technologies, such as breeding herbicide-resistance crops that are suitable for lands where they could not be grown previously (Alexandratos and Bruinsma 2012). Improvements target resistance to pests, diseases, or drought, or developing regional types better adapted to different season length or environments. For example, in North America corn and soybeans varieties have been developed that can be successfully grown in cooler climates and shorter growing seasons, allowing the expansion of these crops further to the north of the Great Plain, partially supplanting other crops such as wheat.

In the Soviet Union, the greatest expansion of cropland areas occurred following World War II. Arable agriculture expanded very rapidly in the 1950s–1960s, mainly through the "Virgin Lands Campaign" that occurred in the south of European Russia, Siberia, and Russian Far East, as well as in Kazakhstan and Central Asia (Frenken 2013, Ilyashenko 2018). This expansion of cultivated lands across huge areas of the Eurasian steppe belt came at the expense of grasslands where Demoiselle, White-naped, and Grey and Black Crowned Cranes historically co-existed with nomadic pastoralism – trading one agricultural use for another, far more intensive. These policy decisions had the greatest impact on the Demoiselle Crane, especially in the northern and central regions of Kazakhstan, where about 25 million ha of steppe were plowed between 1954 and 1960; this significantly decreased the extent of pasture, and in turn contributed to overgrazing and soil erosion (Kamp et al. 2011). During the same period, cropland area expanded in India and China, although some cropland abandonment has also occurred in the northeast and the southeastern coastal regions of India (see below; Ramankutty et al. 2002).

Demand for agricultural production led to expanding agriculture into more arid zones using irrigation systems. In the 1920s in Australia, irrigation allowed the expansion of arable and livestock agriculture from coastal zones, where it had been concentrated during early European settlement, to interior dry lands (Fig. 3). In Central Asia, while some areas have been irrigated for centuries, during the 1950s–1980s Soviet central planning created many new irrigation schemes in desert or steppe areas. Hundreds of thousands of people moved to the irrigated areas to work in agriculture, mainly for the production of cotton (*Gossypium*), but also wheat, fodder, and pastures (Frenken 2013). Water allocation and irrigation system infrastructure were maintained and operated with massive funding from the central government of the Soviet Union. Since independence in 1991, the political transition from a planned to a market economy introduced 'new' concepts such as land tenure, water rights, and different kinds of ownership. While most irrigated schemes are still operated, many small private farmers do not have the capacity or resources to afford the energy required for pumping water or irrigating land on an individual basis (Frenken 2013). Lack of resources led to declining water infrastructure and increasing competition between human uses (livestock grazing, industrial and urban use) and cranes. Irrigated agriculture is well developed in Asian countries and accounts for some 40% of their harvested area under cereals. Nearly one half of the irrigated area of the world's developing countries is in India and China (Alexandratos and Bruinsma 2012). In Africa, however, irrigated agriculture remains largely under-developed. In general, the area under irrigation is projected to increase by 20 million ha over the period from 2005/2007 to 2050, nearly all of it in the developing countries of East and South Asia and East/North Africa, while for developed countries only a very marginal expansion of the irrigated area is foreseen (Alexandratos and Bruinsma 2012).

Generally croplands, including cultivation on irrigated lands, expanded by 50% during the 20th century, from roughly 1,200 million ha to 1,800 million ha, with abandonment of 222 million ha since 1900 (Ramankutty et al. 2002). By some estimates, there has been greater expansion of cropland areas since the mid-1900s, following World War II, than during the 18th and early 19th centuries combined (Richards 1990). On average at the global level, 4 million hectares of arable land were added annually over the period of 1961 to 2007 (Alexandratos and Bruinsma 2012). FAO projections indicate that while the most gains in production (around 90%) will be achieved by raising productivity through increasing yields and cropping intensity, it is still expected that the area of arable land will be increased by around 70 million hectares globally by 2050 (Galluzzi et al. 2011).

Fig. 3. Brolgas foraging on winter wheat field under large spray irrigation system in Australia (Photographer: Tim Nevard)

Loss of Agricultural Lands

While agricultural lands continues to expand in some areas, its extent shrank in others due to diverse interacting forces – socio-economic (conversion to urban and industrial uses, declining rural populations, economic crises, global and national markets, surplus production), agricultural mismanagement (over-exploitation or overgrazing leading to desertification, salinization, and soil erosion; poor water management), and politics (political changes, policy decisions, armed conflicts). These factors have often interacted to increase their negative impact on agriculture.

In the 1960s–1990s, cropland expansion continued in northeast China, India, and Southeast Asia, but slowed in the United States and stabilized and even decreased in northern Europe, and in some regions of China (Ramankutty et al. 2002). In particular, the expansion of 176 million ha between 1961–1963 and 2005–2007 was the result of two opposite trends: an increase of 230 million ha in the developing countries and a decline of 54 million ha in the developed countries (Alexandratos and Bruinsma 2012). Since 1990, an estimated 40% of global cropland area has been withdrawn from production (Ramankutty et al. 2002). Net losses of lands in agricultural use mean that less land is available for food production in the future (Galluzzi et al. 2011).

Socio-economic drivers such as urbanization and industrialization are a major contributor to declining agricultural lands in some regions. Most of the urban centers were established close to prime cropland areas. With exploding urban population growth, human settlements are now encroaching on regions with the best climate and soils for growing crops, pushing agriculture into more marginal lands (where more inputs have to be applied to be productive) and thus into more fragile environments. The greatest loss of large areas of prime farmlands to urbanization and industrialization have occurred in the United States and China (Ramankutty et al. 2002).

Economic drivers, influenced by policy decisions and advancing technologies, are key forces in urbanization trends, as occurred during the 20th century with the industrialization in developed countries such as the United States, Canada, and Australia (Archer et al. 2008). Despite government support for farmers in these developed countries, rural populations continue to decline. Greater mechanization has reduced the number of farm workers needed. Of special concern is the loss of interest in agricultural careers by younger generations, and the strong attraction of modern possibilities and jobs in urban areas. In Russia, even during periods of relative stability in agricultural development with heavy state support for farmer collectives, permanent outflow of the most active, hard-working part of rural people occurred during the 1950s–1980s due to great differences in life style between villages and towns. Economic crises and reorganization of the agricultural system after the USSR dissolution strengthened this rural depopulation trend further (Nefedova 2014).

Changes in human life style are another social driver affecting land uses and agricultural practices. A highly visible example is the change from a nomadic to a sedentary life style by inhabitants of the Eurasian steppes (Kazakhstan, Mongolia, and China) and grasslands of sub-Saharan Africa (Sahel region, Eastern and Southern Africa), where people were historically dependent on the vast grasslands for their livelihood. Socio-economic, political, and climatic events have led to many nomadic people leaving their traditional nomadic lifestyles behind.

In Mongolia, systemic factors during the last two decades such as the country's recent transition from Communist control to a market economy, global warming, and desertification have reshaped daily life in the countryside (Chen et al. 2015). The majority of the pastoral households began settling around permanent towns or immigrating to large urban centers starting in the 1990s. In the 2000s, as a consequence of climate extremes (30% of the national herd perished due to the consecutive summer drought events of 2000–2002 and the severe winters of 2009 and 2010) and the 2007 global finance crises, national policy stipulated the relocation of rural herdsmen into urban areas. As a result more than 50% of the national population now resides in the three largest cities and more than one-third of rural lands have been placed under preservation. Livestock production has become increasingly hard to sustain due to new land policies and long-term drought. Many former herders, especially young generations, have started to diversify their ways of earning a living by exploring new business opportunities and using technology to link up with new markets as well as cope with market fluctuations (Chen et al. 2015). Also, since the mid-1990s, domestic livestock grazing has been concentrated within a 10-km radius around settlements (Kamp et al. 2011). The change to a more sedentary life style and reduced grazing areas has led to constant grazing pressure on the same pastures with no rotation to allow the steppe plants to recover. These pressures in turn have led to deterioration of livestock food resources, grassland conditions, and soil erosion. Such changes affect the crane species that historically depended on grazed grasslands, reducing quality of breeding grounds and feeding resources or changing breeding behavior (see Ilyashenko and King 2018). In addition to these stressors, pastoral land-use change is expected to also be impacted by mining in upcoming decades because the region is recognized for its rich minerals (Chen et al. 2015).

Political decisions following the disintegration of the USSR in 1991 led to significant changes in policies, economy, and society, with the transition away from a planned to a market economy in former soviet republics. The collapse of collective farming and subsidized production in Russia after 1990 and the subsequent economic crisis led to the abandonment of more than 45 million ha of arable lands (23% of Russia's agricultural area). This transformation was the most widespread and abrupt land-use change in the 20th century in the northern hemisphere (Kurganova et al. 2014) and influenced Eurasian Crane redistribution among staging areas during pre-migratory period (Ilyashenko and King 2018). This transition also led to massive declines in livestock and wild ungulate numbers, changes in grazing patterns, and the abandonment of vast areas of arable land in the steppe zone of south Russia and Central Asia. Since about 2000, many of the post-Soviet trends in agriculture have been reversed, with expansion and intensification of agriculture in the steppe zone of Kazakhstan and new increases in livestock numbers.

Agriculture mismanagement (over-exploitation, soil degradation, salinization, etc.) also led to agricultural decline, especially in arid and coastal zones. Roughly estimated, 2 to 5 million ha of global arable land have been lost annually through soil erosion and another 3 million ha have been lost annually to severe land degradation (Alexandratos and Bruinsma 2012). While irrigation projects sometimes provided cranes with new water resources and associated foods (see Ilyashenko and King 2018), without appropriate management they have only short-term positive effects. For instance, in Uzbekistan, intensive development of new irrigated areas for cotton production in the 1960s–1980s caused land salinization, waterlogging, land degradation, and increased discharge of highly saline drainage water into the Amu Darya; total area salinized by irrigation in 1994 was 2,141,000 ha, and currently waterlogging and salinization affect 50% of the irrigated areas (Frenken 2013). The intensive extraction of water for irrigation from both the Syr Darya and the Amu Darya continuously reduces the volume of these rivers and their discharge into the Aral Sea. As a result, the level of the Aral Sea has fallen by 17–19 m and reduced the volume of its water resources by 75 percent. The environmental crisis of the Aral Sea basin is a major disaster that has affected all Central Asia countries located in the Aral Sea basin, contributing to declining agricultural lands, pollution, human health problems, and biodiversity loss.

Abiotic factors, particularly related to soils and water resources, can also contribute to loss of agricultural lands, particularly when agricultural practices are mismatched to environmental conditions. Extended droughts or warming climate in semi-arid areas can result in wind erosion, salinization, and declining productivity to the point of land abandonment (e.g., changes in steppes of central Asia described above). Another instructive example is the American Dust Bowl of the 1930s, where socio-economic factors led to cultivation and overgrazing of marginal grasslands in the Great Plains and agricultural mismanagement that, when hit by severe drought, triggered major social and environmental calamities (McLeman et al. 2014). Conversely, severe flood events may strip away soils, or contaminate flooded areas with salts. Predictions of climate changes in northern India suggest an increased rate of loss of agricultural lands, forced by sea-level rise in the coastal zone and increased aridity and salinity in surrounding regions and countries (Sundar 2011).

Agriculture Intensification

Agricultural activities have continued to intensify over the last 50–70 years, driven by advances in mechanized equipment, chemical fertilizers and pesticides, crop breeding, irrigation technologies, remote sensing, and computers. Science–based agriculture was adopted in different sequences in different parts of the world and has led to phenomenal increases in yields in some parts of the world (McCalla 2001). Global gains in crop productivity were most striking during the "Green Revolution" of the 1960s–1990s. Since the mid-1900s, intensification of cultivated systems globally has contributed almost 80% to increased production output (Cassman et al. 2005), and this trend is foreseen to continue. Alexandratos and Bruinsma (2012) estimated that intensive farming prevented the transformation of more than 80 million ha of natural habitats to agricultural lands during 1960–2000. The higher yields of crop per unit land area has helped to satisfy demand of growing human populations but also has provided more abundant food for cranes during migration and wintering in some areas (Ilyashenko and King 2018).

However, intensification and industrialization of farming through high energy inputs also has resulted in a substantial decline in biological diversity (Bignal and McCracken 2000). Agriculture depends far less on qualities of the existing landscape and its ecological functions, such as natural control of pest species. Modernization has contributed to increasing farm size, loss of small farm operations, crop specializations, and monocultures. Large-scale, intensified farming often has led to simplification of the cropland landscape, reducing or eliminating natural habitat patches or edges, and greater control of weeds, all of which can reduce the diversity and abundance of foods available to cranes. Larger and more powerful farm machinery enables farmers to cultivate field's edge-to-edge and cultivate grassland or wetland patches they once avoided (Fig. 4). Tractors and other heavy equipment can remove rocks and install irrigation systems or drainage tile, permitting more complete cultivation of field areas. While crop yields have increased, more efficient harvesting equipment and intensive tillage practices can reduce the amount of waste grain left in the field and in turn reduce food availability for cranes and other wildlife (Sherfy et al. 2011, Ilyashenko and King 2018).

Increased cropping intensity has been achieved by agricultural practices such as reduction in fallow periods and cultivation of another crop immediately after the first (sequential farming system). This practice reduces time for cranes to feed on stubble fields and may push them to newly sown crops that in turn can increase conflicts with farmers (Ilyashenko and King 2018). However, with techniques such as minimum- or no-till (seeding directly into the previous year's stubble), waste seed remains more available for cranes.

Fig. 4. Traditional methods of cultivating fields with oxen have lower impacts to the landscape than large-scale mechanized cultivation methods (Photographer: George Archibald)

Advances in crop breeding have led to development of crop varieties that are more tolerant of diseases, drought, or saline soils, which has further increased cropping intensity. In the Indian subcontinent, in response to greater need for food and changes in rainfall regimes, an important advance has been the development of rice varieties that need less water and are adapted to higher salinity (Sundar and Subramanya 2010). Development of genetically modified crops that are resistant to herbicides can lead to greater use of herbicides and reduction in weeds in crop fields and margins, which in turn reduces the abundance of weed seeds and tubers and in turn reduces food diversity available to cranes and other wildlife.

Modernization and intensification of agriculture, driven in part by world and national market forces, has led to marginalization of landscapes sustained with traditional agriculture systems, which co-existed with cranes over hundreds of years. Traditional small-scale, low-production, and self-sustaining agriculture systems, such as small-scale rice paddies in India and South Asia (Fig. 5) or some traditional landscapes in Europe, are valuable for cranes but are unable to win markets for themselves; such systems are gradually being abandoned or replaced by more intensified agricultural systems (Meeus et al. 1990).

Market Forces

A cash crop is an agricultural commercial crop that is grown for sale to return a profit, while subsistence crops are grown by farmers to support their own needs. Cash crops occupy most arable

Fig. 5. Planting young rice plants with small mechanized planter (Photographer: George Archibald)

lands in the world. The cash crops of wheat, rye, corn, rice, and barley are valuable foods for cranes during staging, migration and wintering, while the other cash crops such as beets, rapeseed, cotton, olive (*Olea europaea*), sugar cane (*Saccharum officinarum*), fruits, most vegetables, and flowers are not used by cranes (Nowald et al. 2018). Wheat is widely cultivated as a cash crop because it produces well in a temperate climate even with a moderately short growing season. The other main cash crop is corn, which is grown mostly in North America and Europe for human and livestock food, alternative energy (biofuels), and other commercial purposes, as well as in Mexico, South European countries, China, and India. In Central and Western Europe as well as in North America, these two main cash crops are rich food sources for migrating and wintering cranes. Corn is also the staple food crop in most of sub-Saharan Africa. However, a substantial part of the production there is under smallholder management for providing the farming household with food. The majority of agricultural production (around two-thirds of total area) in sub-Saharan Africa comes from plots ranging in size from below one hectare to about 5 ha (Lowder et al. 2014) with corn as the dominant crop in most places.

Rice is grown widely around the world in countries with suitable conditions – subtropical climate, flooded areas, and high humidity. It is mainly cultivated by small-scale farmers in Asia and Africa as well as a cash crop in large farms in central California and some southern states of the United

States. Developing countries account for 95% of the total rice production, with China and India alone responsible for nearly half of the world output. In many rice-producing countries (Japan, China, South Korea, Iran), harvested rice paddies may be the main feeding habitat for migrating and wintering cranes. In South Asia, Sarus Cranes have adapted to breed on rice paddies in lieu of natural wetlands (Sundar 2018).

National or regional market forces are important drivers in the shift from subsistence to cash crops or from crops favored by cranes to those unfavorable and vice versa. One example is the San Luis Valley of southeastern Colorado, USA, an important staging area for Sandhill Cranes. There, the combination of shrinking water resources and market forces have led to a 36% decline in barley production and 73% decline in wheat production over the last 15 years as farmers switch to higher-value potatoes and fallow more land annually to save water (National Agriculture Statistics Service 2014). At a more global scale, a major factor in the price rise for some crops has been the sudden spurt in demand caused by the diversion of significant quantities of land for the production of the biofuel crops like corn and rapeseed (Alexandratos and Bruinsma 2012). In recent years, due to increasing demands for biofuel in some countries, especially in Europe, rapeseed has become the main cash crop, substantially displacing other crops used by cranes (Galluzzi et al. 2011). Leading producers include the European Union, Canada, the United States, Australia, China, and India. In India, rapeseed is grown on 13% of cropped land. In Germany, the area planted with corn, the favored food of cranes, has declined from about 15% to 5% of the region while the area planted to winter rapeseed increased from 10% to more than 20%, due to European Union legislation. The European Union supports rapeseeds as a sustainable vegetable product for oil production (energy) (Nowald 2016). In the United States the demand for biofuels and federal subsidies have been important drivers in the expansion of corn planting and corn prices. Hence, markets interacting with other factors such as climate and socio-political factors can have far-reaching effects on the landscape and cranes.

Crop change can be driven by national or regional policies which can include decisions to provide governmental subsidies or payments to keep crop cultivation. As part of the planned economy of the USSR, all Central Asian republics located in the arid zone were designated for increased cotton production, based on natural economic zones and regions. All suitable and even marginally suitable lands were used to grow cotton, often involving the construction of irrigation canals with centralized governmental financial support. Cereal crop production was limited to dryland areas without irrigation. Since the 1990s, after the USSR dissolution, newly independent countries have changed the structure of agriculture significantly. In Uzbekistan and Turkmenistan, the main state policy in the agricultural sector was to reach "wheat independence" even though wheat growing in irrigation areas was not profitable. Nevertheless, it was decided to reduce areas under cotton production, increase corn and rice lands, and to use nearly a million hectares for growing wheat. Such agricultural changes together with climate warming have led to favorable condition for Eurasian Cranes wintering in Amudaria Valley (Lanovenko 2018).

Conclusions

In the 20th and early 21st centuries, changes in land use and agricultural practices as described here have led to substantial changes in the habitats and foods available to cranes. Cranes have often shown some level of adaptability in the face of landscape change, and even have benefitted from such changes, such as feeding on the rich abundance of waste cereal grains in migration corridors and wintering areas. Cranes still continue to benefit from low-intensity or sustainable agricultural practices and small-scale farming in the developing world, which provide a greater diversity of habitats and foods and tend to be less damaging to surrounding natural ecosystems. Examples include the Black and

Grey Crowned Cranes in African countries and Sarus Cranes in India and South Asian countries (see also Patterson-Abrolat et al. 2018). Sustaining traditional cultural and religious beliefs may help to support traditional ways of agriculture and conserve cranes, but such places have become less and less common (Sundar 2011). Further intensification of agriculture to meet demands of the growing human population for food may limit or reverse what benefits cranes have gained in food availability from agriculture. Traditional or low-intensity farming practices are increasingly being replaced by more modern, intensive, and mechanized farming systems, which often do not sustain agro- and natural biodiversity.

To sustain cranes in transforming landscapes, it is necessary to find balance in agriculture practices that enhance sustainability of agricultural production – including both agricultural diversity and natural biodiversity – while meeting demands for increased output and efficiencies. Around the world, there is growing interest in finding alternatives to the intensive farming methods that have emerged during the 20^{th} century. The deleterious effects of pesticides, inefficient fossil fuel usage, chemical fertilizer inputs, genetic monocultures, and factory farming of livestock have become increasingly apparent (Matson et al. 1997). Conversely, there is increased recognition for the need to integrate biological diversity into existing modern commercial agricultural systems (Galluzzi et al. 2011, Sundar and Kittur 2013). Combining the productivity of modern systems, sustainable aspects from more traditional practices, and deeper ecological knowledge of agricultural systems could help to preserve biological diversity and feed a growing human population with less damage to the environment and wildlife. Understanding how such new developments in agriculture will influence crane life history and behavior deserves further consideration and research.

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Table 1. Connections between cranes and agriculture in terrestrial biomes. Seasonal importance to cranes refer to breeding (B), migration (M), wintering (W), or throughout the annual life cycle (A) for non-migratory populations.

Biome	Primary crane species (season)	Conditions for agriculture	Benefits for cranes	Threats for cranes	Agricultural conflicts
Boreal forest/ taiga	Eurasian (B) Hooded (B) Sandhill (B)	Cold climate; short growing season, and often poor soils limit agriculture	Vast size, low human disturbance; abundant wetlands; largely undisturbed breeding habitats	Insufficient agricultural food resources during pre-migratory season	Very limited; some conflict with grain crops during early fall migration
Temperate broadleaf and mixed forest	Eurasian (B, M) Sandhill (B, M) Red-crowned (B,W)	Few limitations; favorable climate and soils conditions for arable agriculture	Vast size; abundant agricultural food resources	Extensive conversion to human uses, high level of disturbance from human activity	Crop conflicts with large migrant flocks
Temperate grasslands, savannas and shrublands	Brolga (B) Demoiselle (B, M) Eurasian (M) Hooded (M) Sandhill (M) Siberian (M) White-naped (B, M) Whooping (M)	Favorable conditions for arable agriculture and livestock grazing, where soils and water appropriate for agriculture; insufficient water resources in some regions	Vast size; abundant agricultural food resources; livestock grazing sustains open grasslands; agricultural practices created new breeding habitat in some areas	Extensive loss and degradation of natural habitats; limited number of wetlands, high disturbance from livestock	Crop conflicts with large migrant flocks
Tropical and subtropical grasslands, savannas, and shrublands	Brolga (B) Black Crowned (A) Grey Crowned (A) Sarus (A) Wattled (A) Whooping (W)	Favorable conditions for livestock grazing and rice cultivation in some regions; often insufficient water resources, climate change impact	Vast size; sufficient agricultural food resources; some agricultural activities (e.g., rice growing and grazing) create new breeding habitat	Breeding habitat loss and degradation; limited number of wetlands; overgrazing, increased disturbance from agricultural activity	Crop damage mainly to smallholders
Montane grasslands and shrublands	Black-necked (A)	Cold climate and short growing season limit agriculture to grazing and some grains	Sufficient food resources; low human impact; largely untouched breeding habitats	Small range; changing agricultural practices and increasing human activity alter food resources; increasing disturbance on migration and winter areas	Very limited
Mediterranean forests, woodlands and shrubs	Blue (B) Eurasian (W) Sandhill (W)	Favorable climate and soil conditions for arable and livestock agriculture where soils and water appropriate for agriculture; dry summers	Abundant agricultural food resources; agricultural practices created new breeding habitat for Blue Cranes	Extensive conversion to cropland, habitat loss and degradation from overgrazing, soil erosion	Crop damage mainly to smallholders
Tropical and subtropical moist and dry broadleaf forests	Demoiselle (W) Eurasian (W) Hooded (W) Sarus (B) White-naped (W)	Favorable climate for agriculture where soils and water appropriate; agriculture in dry forests driven by seasonal rainfall	Creation of new foraging habitat (rice paddies, co-existence of cranes with small-scale farming); sufficient agricultural food resources	Extensive conversion to cropland, habitat loss and degradation; increasing human disturbance	Crop damage to smallholders

CHAPTER 3

Crane Responses to Changes in Agriculture

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Abstract: Changes in agriculture during last 30–50 years, as described in the previous chapter, have induced varying responses among crane species, largely as a result of a species' degree of biological specialization and the species' ability to adapt to transformed environments. More aquatic species such as Siberian, Wattled, Whooping, and Red-crowned cranes have declined precipitously and have been listed as threatened. Other species, such as Eurasian and Sandhill cranes, have experienced stable or increased population growth as they have more readily adapted to altered landscapes and shifting agricultural food resources. In this chapter we review distribution, demographic, and behavioral responses of crane populations to changes in agriculture. Overall, crane responses to agriculture can be positive or negative and can vary among species depending upon the effects on food availability, disturbance frequency, and the amount and spatial distribution of other critical habitats.

Keywords: land use changes, agriculture practices, crane responses, distribution, food availability, population trend, adaptations

Virtually all species of cranes are affected during at least a portion of their life cycle by agriculture. Numerous examples exist of the positive or negative effects of agriculture on cranes during the breeding and non-breeding seasons. In some instances, cranes (e.g., Hooded, Black-necked, Blue, Grey Crowned Cranes) have persisted with lower intensity traditional agricultural practices for decades or centuries and may be dependent upon these practices for survival (Wright et al. 2012, Nowald et al. 2018). While agricultural practices can be compatible and/or beneficial to crane populations, the type and timing of agricultural practices, the distribution of agriculture relative to other critical habitats, and the species of crane act synergistically to create varying responses, such as changes in distribution and migration and wintering patterns, population trends, and breeding success, to any given agricultural situation. World food needs are expected to greatly increase by 2050 (Galluzzi et al. 2011); thus a greater understanding of past responses of cranes to various agricultural scenarios is needed to understand their potential future responses and opportunities or challenges for conservation.

Global agricultural changes, as described in the previous chapter (Ilyashenko 2018b), have directly or indirectly affected cranes and their habitats through two main avenues: 1) changes in land use (expanding or declining cultivated lands) and water management (irrigation and drainage) that impact habitats important to cranes at both local and landscape scales, and 2) changes in agricultural practices, including intensification and mechanization, the application of new methods and shifts in crop types, that affect agricultural and natural foods available to cranes (mainly during migration and wintering) or the amount of energy needed to be expended to acquire those resources. These two processes vary among countries depending upon the socio-economic conditions; therefore, their impact to crane biology also varies. Furthermore, crane species differ in their biological specialization and in their ability to adapt to new habitats (Nowald et al. 2018). Populations of the more aquatic specialized species, such as Siberian, Wattled, Whooping, and Red-crowned Cranes, have declined precipitously and have been listed by the International Union for Protection of Nature as threatened (www.iucn.org; see also Harris and Mirande, in preparation), while other crane species or their populations can more easily adapt to altered landscapes and shifting agricultural food resources.

Changes in Land Use

Responses to Agriculture Expansion

In the 20th century, extensive agriculture development resulted in fragmentation and degradation of breeding and roosting habitats (Austin 2018) and the local extirpation of some crane populations, such as isolated non-migratory populations of the Demoiselle Crane in the Atlas Mountains in northern Africa (Meine and Archibald 1996, Ilyashenko and Ilyashenko 2011, Geer Scheres, personal communication 2010), threatened isolated populations (subspecies) of Eurasian Crane in the Tibetan Plateau and in Eastern Turkey and Transcaucasia (Ilyashenko et al. 2008, Ilyashenko and Belyalov 2011), and the Demoiselle Crane in Turkey (Akarsu et al. 2012). Expansion of cultivated lands by draining wetlands led to fewer suitable roosting sites available to cranes during the non-breeding season. Usually distance between feeding and roosting sites does not exceed 30 km, and under optimal conditions (great food availability and lack of disturbance) cranes feed in the closest fields (1–2 km from roosting sites) to save energy (Prange 2010, Anteau et al. 2011, Markin 2013, Nilsson et al. 2016). A limited number of suitable roosting sites may force cranes to concentrate in a few large wetlands which can increase conflict with farmers in nearby fields (Bouffard et al. 2005, Nowald and Mewes 2010).

Not all crane responses to agricultural expansion are negative. In fact, some crane species or their populations adapted by increasing their use of expanding crop fields or pastures both for feeding and breeding. Species that are less specialized for aquatic environments, such as Sandhill, Eurasian, Demoiselle, Hooded, White-naped, Black-necked, and Black and Grey Crowned Cranes have proven to be more adaptable to agricultural expansion than more aquatic cranes. These species have historically adapted to use croplands for feeding, particularly during the energy-demanding migration and wintering periods, and have responded positively to the extensive areas of agricultural fields now available to them (Meine and Archibald 1996, Nowald et al. 2018). For example, in the United States the Sandhill Crane nearly disappeared from Wisconsin and neighboring states during the early 20th century. Over the last 70 years, however, the species has made a dramatic recovery due to the crane's adaptation to feeding across agricultural landscapes as well as strict protection from hunting and the restoration and protection of wetlands. From less than 100 cranes in Wisconsin in the 1930s, the population has grown to well over 13,000 birds (Barzen et al. 2012).

Some crane populations have also had success breeding in expanded agricultural areas. In Central Eurasia, since the 1950s, the Demoiselle Crane expanded its breeding area to the north with the development of arable agriculture and cattle grazing in the north steppe of Kazakhstan and high grass steppe of south Russia (Ilyashenko 2018a). These agricultural changes led to formation of more open landscapes with low and sparse grass cover favored by cranes. In the Western Cape region of South Africa, fynbos, the natural shrublands or heathland vegetation, historically limited Blue Crane habitat. However conversion of the fynbos to wheat fields in the 1990s created favorable breeding habitat conditions for this species and rapidly changed its distribution and demographics in the country (Fig. 1). In the early 2000s this core area supported 47.4% of the national population, although it comprises only 7.6% of the total Blue Crane range (Scott and Scott 1996, McCann et al. 2007).

Fig. 1. Nest of a Blue Crane in a wheat field in the Western Cape, South Africa (Photographer: Wicus Leeuwner)

In some instances, the initial period of agricultural development had positive effects on crane populations, but further intensification had negative effects. For example, since the 1970s in north central Florida, pine (*Pinus* spp.) woodlands have been cleared to create grasslands and expand prairies for cattle grazing. These activities provided additional breeding and wintering habitats for the non-migratory Florida Sandhill Crane (*Grus canadensis pratensis*) and initially led to increases in crane populations (Lewis et al. 1977). However, intensification of arable farming and livestock grazing in combination with human population growth in the area eventually led to a 42% reduction in suitable natural habitats over 30 years. As a result, Florida Sandhill Crane populations declined by 36%, from 6,000–7,000 in 1970s to about 4,500 by 2003 (Nesbitt and Hatchitt 2006). Similarly, agricultural-related clearing of highland forests and woodlands in African countries and their conversion to grasslands for cattle grazing that began early in the 20th century led to an increase in the area of breeding habitats suitable for the grassland-dependent Grey and Black Crowned Cranes and in turn increased crane numbers (Pomeroy 1987). Recent expansion of cultivated fields and increased human activity in these important grasslands and wetlands, however, reduced crane breeding habitats and the frequency of disturbance. For example, in Zimbabwe in the Driefontein Important Bird Area, large commercial cattle ranges were compatible with wetland and grassland habitats used by Wattled and Grey Crowned Cranes. But since 2000, the governmental Fast Track Land Resettlement program changed the land use systems to increase cropland and woodland areas, thus reducing the number of suitable crane breeding sites (Fakarayi et al. 2015).

Responses to Losses of Agricultural Lands

The loss of agricultural lands due to urbanization, industrialization, and soil erosion, as well as abandonment of cultivated lands because of social, political or climatic factors, has affected cranes, especially species that depend on agricultural landscapes for breeding or foraging habitats.

Cranes that are dependent on agricultural habitats for breeding, often do so because the agricultural wetlands replaced natural wetlands, thus the loss of these agricultural wetlands can be particularly severe. In India, for instance, demand for industrial land is increasing rapidly, and some states like Haryana and Gujarat have experienced large-scale conversions of agricultural and other lands to industrial uses. Sarus Cranes breed in rice paddies and populations of Sarus Cranes were once abundant in some of these states. However, it is believed that land-use changes are contributing to population declines (Sundar 2018). In Etawah and Mainpuri districts of Uttar Pradesh in the upper Gangetic floodplains in India, expansion of towns permanently displaced 0.7% of pairs of the Sarus Crane annually. It is relatively low, but a continuation of this rate is adequate to halve the breeding population within a decade (Sundar 2011). The effects of industrialization are not limited to breeding habitats, but also to habitats used in the non-breeding season. In Ethiopia, where wintering grounds of the Eurasian Cranes are located, many regions underwent rapid changes during 2008–2011. A large number of foreign investors facilitated rapid expansion of trading and manufacturing enterprises and the heavy-load traffic multiplied to support these industries at the expense of natural wetlands and agricultural lands. A new asphalt road to Addis Ababa was built across the "Chelekleka Chefe" wetlands, the main crane roosting site. As a result, these wetlands are now subjected to a higher level of disturbance and the number of cranes using this roosting site decreased from more than 17,000 in February 2009 to only 250 in January 2011 (Nowald 2011).

Political and economic drivers can reduce the amount of land in agriculture (Ilyashenko 2018b) and lead to broad-scale changes in crane behavior and distribution and food availability. Crane responses to these changes vary among species and between breeding and non-breeding seasons. For instance, as described in the previous chapter, agricultural lands were abandoned after the collapse of the USSR because of the economic crisis and reorganization of the agricultural system. The economic crisis led to decreasing food availability for staging and migrating cranes due to the decline of cultivated fields and their uneven distribution among waste lands. In European Russia, it resulted in the redistribution of Eurasian Cranes among a reduced number of sites with suitable feeding and roosting conditions, changes in duration of staging (shorter time in the north of the region with lesser cultivated fields and conversely longer time in the south with more productive arable agriculture) and forced cranes to concentrate in larger numbers at rich food sites. As a result, conflict with farmers increased (Ilyashenko 2018a). Reduction of food availability, especially in the northwestern part of the region, led to a westward shift in crane migration routes. In the two European flyways, the westward shift of cranes combined with other factors such as food abundance, climate change and conservation measures, significantly increased crane numbers.

Results from monitoring of banded cranes indicated that 30% of the cranes in the 1980s came from the east, but by the 2000s 60% were from the east (Prange 2015). Changing of staging and migration behavior of Eurasian Crane in the European part of Russia, not only created potential conflict with farmers in Russia, but the increased numbers from the westward shift also aggravated crane/farmer conflicts in Western Europe. A similar redistribution of Eurasian cranes among staging areas occurred in Ukraine for the same reasons (i.e., the economic crisis and reorganization of the agricultural system). For instance, the number of cranes at protected roosting sites in Askania-Nova Nature Reserve and in adjacent agriculture fields increased from 5,000 in late 1980s to 20,000–45,000 in 2010s, while their numbers decreased in other areas with waste fields (Redchuk et al. 2015). The increased numbers of cranes resulted in damage to crop fields surrounding the nature reserve and a conflict with farmers and increased poaching of cranes during migration (Andryuschenko 2011). In southeast Siberia in Russia, the area of arable agriculture declined in the 1990s due to the economic crisis in combination with a long-term drought since the early 2000s. As a result, cranes nearly disappeared from their pre-migratory staging area near the Torey Lakes. In the 1980s and 1990s, nearly 40,000 cranes had gathered there, including large numbers of Demoiselle Cranes as well as Hooded, White-naped, Eurasian, and sometimes Siberian Cranes (Goroshko and Tseveenmyadag

2002). Starting in early 2000s, the number of cranes at this staging area decreased and no cranes were observed there from 2006 to 2008 when fields were not planted because of the intense drought (Goroshko 2011). Since 2009, precipitation has started to increase again, and agriculture has begun to slowly recover. As a result, by 2012 the number of Demoiselle Cranes had increased to 3,500, although other crane species were still in small numbers (Goroshko 2015).

As we described above, loss of agricultural lands can reduce breeding habitats and food availability for cranes, but also can lead to recovery of natural habitats. In Western Europe, the planned withdrawal from economic use of agricultural fields as a response to surplus agricultural products since the 1960s (Meeus et al. 1990) contributed to an increase in suitable habitat of the Eurasian Crane in the breeding and non-breeding periods. For example, in Germany, the restoration of recently drained wetlands increased the availability of breeding sites (Mewes et al. 2013) and was one of several factors that assisted the breeding population growing from 700 pairs in the 1970s to 7,800 pairs in 2011 (Mewes 2012).

Responses to Changes in Water Management

Given the importance of water and wetlands to cranes (Nowald et al. 2018), reductions in water availability related to agriculture activities can significantly affect crane populations (Austin 2018). However, agricultural expansion in arid areas is usually accompanied by the development of irrigation systems, including canals, reservoirs, artificial ponds, and artesian wells, which can subsequently provide greater availability of water for cranes and contribute to an expansion of their distribution. For example, this type of water-infrastructure development in Central Eurasia facilitated enlargement of the breeding range of the Demoiselle Crane south into semi-desert and desert zones, following irrigation canals and artificial ponds created for livestock grazing and arable agriculture (Berezovikov 2002, Kovshar and Berezovikov 2001). Although the historic range of the Brolga overlaps with that of the Australian Sarus Crane, the latter species is more aquatic and did not expand their range into this region. However, in India, Sarus Cranes appear to be spreading to new locations (Sundar 2018) along irrigation canals in Gujarat following the construction of the massive and controversial Narmada irrigation dam. The canals provide water to previously arid regions, and Sarus Cranes now are using these new areas for nesting, at least in limited amounts. Similarly, Sarus Crane populations using canals have been present in several locations in the semi-arid regions of Rajasthan state, likely expanding its breeding area to these locations (Sundar 2018). Such attraction of irrigation canals for breeding was recently noted for the Eurasian Crane in southern European Russia (Bukreeva 2003, Victor Belik, personal comm. 2015).

Construction of dams has created numerous problems with crane habitats (Sundar 2018). But sometimes dams can increase area of sites suitable for birds. For instance, in West Africa, climatic aridity has increased since the early 1970s under a drought characterized by its unusual length, severity and large geographical coverage (Treca 1996). It led to substantial mortality from human starvation and forced the region to develop dams and irrigation systems to retain floodwaters and support irrigation across a huge area for agricultural development, including numerous rice schemes that often were created in existing wetlands. Since that time, year-round water availability for irrigation of rice fields provides good habitat for Black Crowned-crane during the non-breeding season in the rice fields and remaining wetlands (Treca 1996).

Sometimes appropriate water management can support existing crane habitats. In northeastern China, the installation of extensive, branched irrigation networks, including dams and canals, to support farming activities and other needs, combined with intensive drought in the 2000s, reduced available wetland habitats in almost all refuges used by Siberian Cranes during migration. Zhalong, Xianghai, and Keerqin National Nature Reserves (NNR) received little use by Siberian Cranes due to limited fresh water and some drying of reed marshes (Pang et al. 2005). Momoge NNR increased in importance during this period in part because of the artificial flooding of wetlands through the UNEP/GEF Siberian Crane Wetlands Project (SCWP) (2003–2009). About 3,000 Siberian Cranes (about 90% of the world population) have used Momoge NNR during migration (Hongxing 2010). Continuous flooding of Momoge's most important wetland, Eutapao, from irrigation releases is, however, currently causing a degradation in wetland quality (Sammy L. King, personal comm. 2016), although efforts have been initiated to improve management of irrigation water. In Africa, recent management of large river systems that address multiple socio-economic and ecosystem objectives and programs to restore seasonal river flows have shown substantial promise in addressing water conflicts between cranes and agriculture. For example, Black-Crowned Cranes declined from 10,000 to 2,500 following dam construction in Waza-Logone River in 1979, but in 1994 a pilot-study was initiated that re-flooded the area to improve crane habitat. The species, which depends on perennially flooded grasslands, responded positively (Scholte et al. 2000).

Changes in Agricultural Practices

Intensification

The intensification of agriculture refers to the increased production per operation unit (a piece of land, a herd of cattle, and so on) (Meeus et al. 1990). It is attributed to modern agricultural equipment, various practices to improve yields, changes in agricultural methods, pest and weed control, and scientific achievements. The effects of intensive agriculture on cranes depend upon numerous factors including the types, if any, of habitats lost; the types of crops grown; how efficiently the crops are harvested; and when the crops are harvested relative to crane life history (Ilyashenko 2018b). Therefore intensified agriculture can have varying impacts to crane biology, connected mainly with food availability, either increasing or reducing its abundance and quality during staging, migrating, and wintering periods.

In most developed countries increased grain production due to intensification provided abundant food for cranes at their resting and wintering sites, such as for Eurasian Crane in Europe, and Sandhill Crane in the United States and Canada (Fig. 2). Agricultural intensification, in conjunction with climate change and nature conservation measures, has led to population growth for these species (Krapu et al. 2004, Nowald and Mewes 2010, Nowald 2012, Salvi 2012, Prange 2015). The increased production of energy-rich crops along the migration route of the mid-continent population of Sandhill Cranes (*Grus canadensis*) in the central US and south-central Canada has presumably sparked a population increase and range expansion. The population in Russia increased from 20,000 in the early 1980s (Kishchinsky et al. 1982) to 140,000 in the early 2000s (Krapu et al. 2011a). The breeding range of this population has been expanding westward in East Siberia, Russia (Krapu et al. 2011a), and eastward through Alaska, US, and the boreal and prairie-parkland areas of central Canada, and into western and northern Ontario (Krapu et al. 2011b, Dubovsky 2011). Similarly, in Central and Western Europe the increase in corn (maize; *Zea mays*) production has corresponded with a generally greater number of Eurasian Cranes at staging and resting areas and an increase in the Central European migratory population from about 40,000–45,000 in 1980s to 350,000 birds in winter 2014/2015 (Prange 2015). Homologous with the population increases described in Germany above (see chapter Responses to Losses of Agricultural Lands), population increases of Eurasian Cranes are known, for example, from Sweden (from 12,500 in 1980 to 30,000 breeding pairs in 2010) (Lundgren 2013), Denmark (from 3–5 pairs in 1990 to 120-130 pairs in 2010) (Tofft 2013), Estonia (from about 300 pairs in 1970 to 7,500 pairs in 2011) (Leito 2014), and some other European countries. In Germany the breeding areas were doubled by expanding in the last three decades to the north (50 km), the south (60 km), and particularly to the west (240 km) (Mewes 2010). Such increases in crane populations can also raise conflicts with farmers along flyways, both in developed and especially in developing countries where human food is more limited.

Fig. 2. Whooping Crane defends space against Sandhill Cranes feeding in a wheat stubble field (Photographer: Jim Hudgins, U.S. Fish and Wildlife Service)

However, changes in agricultural practices (duration of fallow period, crop changes) and the application of modern techniques (using scientific and technical achievements) to increase yields also can lead to reduction of availability of crop foods for cranes. Reduction in waste grains can cause rapid food depletion in fields located close to roosting sites and force cranes to seek new food sources at greater distances from roost sites. This can result in a negative energy balance and reduce crane lipid reserves and potentially lead to lower reproductive success and ultimately a lower population size (Anteau et al. 2011). For more vulnerable species with a limited number of wintering sites, such as Red-crowned, White-naped, Hooded, and Black-necked Cranes, reduction of food availability due to changes in agriculture practices can cause an insufficient accumulation of energy during the non-breeding period. Reduced energy during the non-breeding season can lead to reduced breeding success and, ultimately, to population declines.

Mechanization

Agricultural productivity no longer depends strictly on inherent productivity of the existing landscape as modern machinery, water, and fertilizer applications allow increased production on marginal lands (Bignal and McCracken 2000) and increased food availability for cranes. On the other hand, recent improvements in harvest equipment and harvest efficiencies have reduced the amount of waste grain left in the field and in turn have reduced food availability for cranes in some areas. For example, in Central Nebraska, USA, the energy demand needed for a hypothetical 60-day staging period for cranes has increased by 87% from 1970s until the early 2000s, primarily because of increasing Snow Goose (*Chen caerulescens*) and Sandhill Crane populations (Pearse et al. 2010). Improved efficiency in combine headers increased harvesting efficiency from 96% to 98% from 1978 to 1998 increase total yield by 20%. This increased in efficiency decreased post-harvest waste corn by 47% (1978 – 333 kg/ha; 1998 – 177 kg/ha) (Krapu et al. 2004). In Western Europe in the 1970s and 1980s, approximately 3–5% of cereal grains and 5–10% of corn remained in the field post-harvest and was available for cranes. More recently, only 1–2% cereal grains and 0–1% of corn remained in the field post-harvest (Lundin et al. 2005, Nowald 2012). The lower food availability has led to increased conflicts with farmers as cranes instead seek food in newly sowed fields (Nowald et al. 2018). In addition, many cranes compensate for lower food densities by flying to more distant fields to seek food and, as a result, lose energy necessary for successful migration (Prange 2010).

Duration of Fallow Period for Harvested Fields

In many countries, intensified agricultural practices have shortened or entirely eliminated fallow periods (period between harvesting and plowing or disking), the period when cranes may safely use waste grains. For example, in south Germany, fields were historically plowed in the spring and cranes could use the fields in late autumn and throughout the winter. More recently, farmers began plowing fields in the fall to control weeds and insects, break up residual crop material, and promote more rapid warming and drying of soil in the spring. When corn fields are disked or plowed, about 77–97% of the waste corn becomes unavailable to wildlife (Krapu et al. 2004). With stubble fields now more often plowed immediately after harvesting, thus burying residual grain, cranes can feed only a short time (Prange 2012). As a result they may move to newly sown winter crops, causing conflicts with farmers (Nowald and Mewes 2010, Nowald 2018). In south-central Tibet, the Black-necked Crane also has been affected by similar changes that reduced the availability of barley and spring wheat grain after fall harvesting, which are principal winter food for this species (Bishop 1991, Meine and Archibald 1996).

Use of modern practices such as no-till agriculture can benefit cranes by reducing tillage and thus increasing food availability in harvested fields. In no-till agriculture, which is designed to conserve soil resources, seeds are sown directly into the previous year's stubble, increasing the time that waste grain is available for cranes during winter. But while the no-till practice has many environmental benefits, it requires more integrated farming practices and different planting equipment (Lal et al. 2007). For example, in Russia using modern no-till technology led to indiscriminate multiple insecticide and pesticide treatments, which significantly decreased biodiversity and poisoned cranes (Malovichko 2011).

The sequential farming practice (cultivation of another crop immediately after the other) also reduces time when food is available for cranes. For instance, in the wintering grounds of Eurasian Cranes in Lake Tana, Ethiopia, the land is cultivated for other crops immediately after harvest, severely limiting the time available for cranes to feed on residual grains. To adapt, the cranes have shifted to newly sowed crops such as chickpea (*Cicer arietinum*) fields, which can be grown with only limited moisture; cranes can cause damage by picking and pulling out seeds and seedlings (Aynalem et al. 2018). In South Korea, multiple changes in agricultural practices on the main wintering grounds of the threatened mainland population of the Red-crowned Crane and the vulnerable White-naped Crane at Civil Control Zone of Cheorwon have reduced food availability for cranes (Lee 2010). In 2002, waste grains in harvested rice-paddies averaged 212 kg/ha (around 3% of total rice production) and provided a critical food resource for cranes during the winter. Since that time, agricultural methods and crops have changed. Farmers now plow rice paddies soon after harvest to increase decomposition of rice straw. Vegetables and flowers are now also grown in green houses in dried paddies after rice harvesting to improve agricultural returns, and the area of agricultural lands covered with green houses in the winter time has increased annually. This practice reduces food availability for wintering cranes and increases their disturbance by farmers who visit greenhouses daily (Smirenski and Smirenski 2007, Lee Kisup, personal comm. 2009).

Crop Change Impacts to Food and Habitat Resources

Changes in the types of crops grown can be forced by numerous factors including socio-economic, political, and climatic factors (Ilyashenko 2018b). Sometimes shifting to cash crops, many of which are favorable for cranes, can increase food availability. For example, economic profits from tourism and social factors stimulated crop changes in the Gallocanta Valley in Spain, which serves as migration stopover and wintering ground for the Eurasian Crane in the Western-European flyway (Alonso et al. 2018). This crop change in the Jiloca River in the Gallocanta Basin began attracting cranes and coincided with the site becoming an important crane wintering ground 30 years ago. Wheat and barley (*Hordeum vulgare*) cultivation now are the most important crops in the valley, replacing sugar beets (*Beta vulgaris*) and other vegetables. Cranes use cereals until the middle to the end of January, after which most stubble fields are plowed and short-season cereal (mainly barley) is sown. These resources contribute enough food for cranes until they start their spring migration in the middle to the end of February (Pueyo et al. 2011).

In France, as well as in most European countries, since the middle of the 20th century, corn agriculture has dramatically expanded from the southwest of the country to all other regions (Salvi 2012). This factor, along with climate warming and wetlands restoration, led to an increase in the number of wintering cranes by about 150,000 (more than one third of cranes used the West European Flyway) and resulted in cranes shifting their wintering grounds northward (Salvi 2015). In the Hula Valley in Israel, cotton (*Gossypium* spp.) was the primary crop until the mid-1990s, and Eurasian Cranes were uncommon in winter during that period. Low cotton prices and exchange rates stimulated major changes in agricultural practices in the 1990's. Instead of a single cotton crop which was of no value to cranes, there was an increase in crop varieties including peanuts (*Arachnis* spp.), corn (for seed), sunflowers (*Helianthus annuus*), potatoes (*Solanum tuberosum*), carrots (*Daucus carota* subsp. *sativus*), and peas (*Pisum sativum*), which provided food resources for people throughout the year (Carmi 2012). As a result, the changes in agricultural practices along with restoration of Agamon Lake led to an increase from a few hundred migrating cranes in the Hula Valley in the 1990s to 80,000 migrating cranes. About 35,000 cranes stayed for the winter in 2010 (Shanni et al. 2012).

Changes in crops in the former Soviet republics in Central Asia (Uzbekistan and Turkmenistan) after the collapse of the USSR were driven by political decisions, such as an achievement of "wheat independence" (Lanovenko 2018). Eurasian cranes migrating to wintering grounds in India took advantage of wheat and rice crops that replaced cotton plantations in Amudaria River Valley in the 1990s. Some of the cranes started to winter there and warmer winters facilitated this strategy (Lanovenko et al. 2008). The number of wintering cranes has increased from 12,000 in the beginning of the 2000s to 30,000 in the winter of 2010/2011 (Lanovenko and Kreuzberg 2003, Sorokin et al. 2011).

Crop changes driven mainly by economic factors such as national or regional markets can shift crops edible by cranes to inedible crops whose nutrition structure is not suitable for cranes. For example, in Germany, due to growing demand for biofuel and the European Union supporting rapeseeds (*Brassica napus*) as a sustainable vegetable product for oil production (energy), the area planted with corn, the favored food of Eurasian cranes has declined from about 15% to 5% of the region while the area planted to winter rapeseed increased from 10% to more than 20%. This has been detrimental to cranes because of the low nutritive quality of rapeseeds and its dense growth, which restricts its use by cranes (Nowald et al. 2018).

In the middle Rio Grande Valley of New Mexico, the important wintering grounds for the Rocky Mountain population of Sandhill Cranes, the amount of corn on private lands declined from >2,000 ha in 1981 to <600 ha in 1997 because farmers shifted from production of grains to alfalfa (*Metacago sativa*) and silage grains, to support an expanding dairy industry, or to chili (*Capsicum* spp.) and cotton crops. This shift led to crop damage to alfalfa fields in late fall when newly planted fields were irrigated and arriving cranes probed for invertebrates and chufa (*Cyperus esculentus*) tubers in the fields. Chilies and silage corn (in feedlots) were the other primary crop-damage complaints from farmers in the valley (Austin 2012).

In the Republic of Korea, ginseng (*Panax* spp.) agriculture is impacting crane foraging habitats in the mountains. Ginseng agriculture is increasingly common in the middle or top of the steep southern slopes of the mountains, where it supplants the fields of the grass Job's Tears (*Coix lacryma-jobi*), the seeds of which Red-crowned Cranes eat in winter (Lee Kisup, personal communication, 2009).

Crane species with less specialized feeding habits have often adapted to, and benefitted from, various crops that replaced their natural habitats (Nowald et al. 2018). For example, cranes eat chili plants and alfalfa tubers (the southwestern United States and Mexico) (Taylor 1999; Austin 2012), soybeans (China, African countries) (van Niekerk 2018), peanuts (Israel) (Shanni et al. 2018), and some other domestic plants. In Europe, in spring, cranes often forage in harvested potatoes fields (Prange 2012) and in Spain, they eat also oak (*Quercus* spp.) acorns, competing with the Iberian breed of pigs (*Sus scrofa*)(Pueyo et al. 2011).

Changes to some marketable agricultural products can reduce food resources as well as negatively affect crane breeding habitats. During the past few decades in India, economic decisions of farmers led to a replacement of rice agriculture with cash crops such as cotton, sugarcane, and tobacco (*Nicotinia* spp.), thereby eliminating breeding habitat of cranes (Borad and Mukherjee 2002). In the eastern states of the Gangetic floodplains in India the illegal conversions of traditional rice paddies to cultivation of water crops like water chestnut (*Trapa* spp.) makes wetlands unsuitable for waterbirds. Here, Sarus Cranes and community wetlands are now exceedingly rare (Sundar 2018). Since 1970–1980s, the Demoiselle Crane adjusted to breed on crop fields in the great part of its breeding range (Kovshar and Neufeldt 1991). Changes from crop fields to rice paddies, vegetables, and fruit plantations reduces area of breeding habitats, especially in the west of the breeding range (Andryushchenko 2015).

Weed and Pest Control

Weed and pest control allows increased crop production and consequently increased food for cranes. On the other hand, widespread or more effective use of herbicides, including the use of genetically modified crops that are resistant to herbicides, results in reduction in weeds in crop fields and margins, and in turn reduces the availability of weed seeds and tubers that cranes and other birds often feed on (Krapu et al. 2004). For example, Sandhill Cranes forage on chufa tubers in the southwestern USA (Austin 2012), on weed seeds and grass roots in potato fields in Idaho, and staging cranes (mainly Demoiselle, but also White-naped, Hooded, and Eurasian) feed on seeds of foxtail (*Setaria viridis*) in non-harvested wheat fields in Southeast Siberia in Russia (Bouffard et al. 2005). Finally, using pesticides decreases biodiversity in agricultural areas and also reduces the availability of protein and other nutrients and vitamins.

Conclusions

There are two main processes in agriculture development that influence cranes: 1) changes in land use (expanding or declining cultivated lands) and water management (irrigation and drainage), and 2) changes in agricultural practices. Overall, crane responses to agricultural development can be positive or negative and can vary among species depending upon the effects on food availability, disturbance frequency, and the amount and spatial distribution of other critical habitats.

Cranes can adapt to breed in agricultural landscapes that replace natural habitats or even increase their breeding range following expanded arable agriculture and livestock grazing. Often, however, such adaptations are tenuous, as crane nesting becomes vulnerable to further intensification of cultivated lands, to the reduced area of the agricultural landscape, or to the alteration of agricultural crops/practices.

Cranes, particularly Eurasian and Sandhill Cranes, benefit from increases in food availability resulting from agricultural expansion and its intensification. However, further intensification can lead to reduced food quantity and availability and increased conflict between cranes and farmers, and potentially result in population declines of vulnerable and threatened crane species. Reduced food quantity and availability can be caused by changes in agricultural practices, such as improved harvesting efficiencies, shortening or elimination of the fallow period of harvested lands, burial of remaining foods with organic fertilizer or by plowing, as well as by degradation of agricultural lands due to mismanagement, pesticide and herbicide use, urbanization, industrialization, soil erosion, water pollution, and long-term drought due to global warming.

Water resource development and use for agriculture can negatively impact crane breeding and feeding habitats due to changes in hydrology and pollution. However, appropriate water management, water availability, and improved water quality can provide additional breeding and feeding habitats for cranes.

Shifts in crop types to those preferred by cranes can benefit cranes and have at times resulted in breeding range expansion and/or population increases. However, food quantity or availability can also be reduced by crop changes because new crops may be inedible for cranes or of low nutrition. Furthermore, agricultural practices with new crops, such as crop density and the use of greenhouses, may be incompatible for crane use.

Positive crane responses to expansion and intensification of agriculture show the importance of food availability during migration and wintering to crane energetics and that adequate agricultural food availability can lead to increased reproductive success and population increases. However large populations of several species of cranes stimulated by population growth from past agricultural practices may create more conflicts with farmers as food availability is reduced in the future due to further agricultural intensification and changes in crop types. To build and/or sustain support for crane conservation with farmers, appropriate management efforts will need to be implemented to allow the coexistence of cranes and people (see chapters Alternate Methods and Awareness/programs).

Knowledge Gaps

- For developed countries:
    - Find balance between growing populations of numerous crane species and capacity of agricultural land;
    - What is the limit of crane population growth considering the reduced area of agricultural lands and continued agricultural intensification? and
- What is the limit of crane opportunism in adaptation to transformed habitats both in breeding and non-breeding seasons?

Recommendations

- Organize monitoring of breeding, roosting, stopover, and winter habitat conditions to provide the knowledge necessary for legislation and conservation measures in the field;
- Work with farmers and other stakeholders to identify practices in traditional agriculture that can be incorporated into more intensified agriculture for the mutual benefit of cranes and farmers; and
- Encourage proper management of wildlife conservation areas used by cranes during migration and wintering to ensure availability of food and to secure roosting areas.

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CHAPTER 4

Interactions and Impacts of Domesticated Animals on Cranes in Agriculture

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Abstract: Affiliations of most cranes to humans and agriculture means they often interact with a variety of domestic animals. Those interactions can be beneficial or neutral when domestic animal densities and their impact on wetland or grassland systems are low to moderate, as found in more traditional agricultural practices. The most common interaction is with grazers, primarily domestic ungulates such as cattle, horses, and sheep. Cranes can benefit from the rapid recycling of grassland nutrients, maintenance of open areas, and invertebrate foods that grazers facilitate. Examples of the close interactions among cranes and grazers are found in South Africa, Central Eurasia, China, India, and North America. Overgrazing and direct disturbances from domestic livestock are usually detrimental to cranes and interact with other factors such as altered wetland hydrology, fire, and changing climate. Cranes are most likely to interact with domestic birds in wetlands (ducks and geese) or farm areas (poultry) where they are attracted to areas where the domestic birds are being fed and maintained in large open areas. Risks of disease transmission between domestic birds and cranes are the greatest concern. Dogs associated with humans and agricultural activities are generally a threat where cranes are raising their chicks nearby.

Key words: disturbance, dogs, grazing, livestock, poultry, waterfowl

The frequent affiliation of most cranes with humans and agriculture means proximity to domestic animals such as cattle (*Bos taurus*), buffalo (*Syncerus caffer* and *Bubalus bubalis*), yaks (*Bos grunniens*), horses (*Equus ferus caballus*), sheep (*Ovis aries*), goats (*Capra hircus*), dogs (*Canis lupus familiaris*), ducks (Anatini), geese (Anserini), and poultry (*Gallus gallus*). Such close association often benefits cranes, but also may come with some risks, particularly disturbance and disease. As with other types of agriculture, the interactions of cranes with domestic animals can be beneficial or neutral when domestic animal densities and their impact on wetland or grassland systems are low to moderate, as found in more traditional agricultural practices. Problems are most likely to arise when domestic animal densities are high. In this chapter, we review how cranes relate to three broad groups of domestic animals in agriculture: grazing mammals (ungulates), birds (including poultry, waterfowl, and ostrich [*Struthio camelus*]), and domestic dogs.

Grazing Mammals

Herbivorous hoofed mammals (ungulates) evolved on open grasslands, and hence share an evolutionary history with many crane species. The crane species most closely associated with grasslands are the Blue Cranes, which inhabit the grassland of South Africa, and Demoiselle Cranes on

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the steppes of Central Asia. Wattled Cranes are strongly associated with the large herbivores of Africa floodplains (Howard 1992). In North America, migrating Sandhill Cranes once shared grasslands with the large herds of wild bison (*Bison bison*) that roamed the American West. Cranes undoubtedly benefited historically from consequences of the grazing and dung from large herds of wild ungulates: reduction in plant density and height, new plant growth, loosening of soil by hooves, and proliferation of invertebrate life from dung. In most regions such herds have been replaced by herds of domestic ungulates such as cattle, horses, sheep, and goats.

Domestic ungulates generally serve as ecological replacements for wild herbivores. Periodic grazing disturbance is important to the healthy functioning of most grasslands and some wetlands (West and Nelson 2003): consuming or trampling live and residual vegetation, turning over nutrients, stimulating new growth and productivity, and suppressing growth of woody vegetation (shrubs and trees). The low vegetative structure maintained by grazing allows cranes easier access to foods and better visibility to watch for predators and disturbances. Stimulation of new growth, both above (shoots and grain) and below ground (tubers) provides foods for cranes. Dung colonized by insects provides another valuable source of food. Cranes are frequently observed foraging in association with cattle and other domestic ungulates (Fig. 1). Cranes may also benefit from ranchers controlling mammalian predators (e.g., coyotes [*Canis latrans*]) that threaten their livestock, but can also be important predators of crane eggs and chicks.

Cranes clearly benefit from the rapid recycling of grassland nutrients, maintenance of open areas, and invertebrate foods that are the consequence of grazing. For example, non-migratory Sandhill Cranes in Florida often forage in pastures and use the associated wetlands for roosting (Nesbitt and Williams 1990). In the western United States, 72% of breeding Greater Sandhill Cranes in California and Oregon are found on private ranches used for livestock grazing, and others are found on grazed lands in national wildlife refuges (Gary Ivey, personal comm. 2016). Eurasian Cranes in Europe and Black-necked Cranes in Tibet often forage in grasslands heavily used by domestic animals (Fengshan Li, personal comm. 2016). The pattern of cranes benefiting from domestic grazing is repeated in Hokkaido, Japan, where Red-crowned Cranes that formerly fed in wetlands now also feed in pastures and croplands that border the wetlands. Cranes are strictly protected in Japan and have become very accustomed to the livestock; some pairs even enter dairy barns and frighten the cows!

Watering sources developed to support domestic grazers can also benefit cranes by providing a source of fresh water. Ranchers may maintain or create ponds or wetlands for livestock, which may then be useful to cranes for foraging or roosting. The relationship between livestock water sources and cranes is particularly apparent where natural water sources are very limited. For example, territories of Blue Crane families are directly influenced by the proximity of artificial water sources developed for livestock (Bidwell 2004). Overgrazing or

Fig. 1. Grey Crowned Cranes forage alongside cattle (Photographer: George Archibald)

heavy trampling around water sources, however, can degrade such wetlands for cranes by reducing water quality, protective vegetative cover, or availability of other foods such as seeds, invertebrates, and amphibians. For example, hoof shear from grazing sheep in some Mongolian wetlands, important to White-naped Cranes, has damaged the organic soil layer, lowering moisture levels in the soil and leading to reductions in wetland vegetation species (Voorhis and Gurrieri 2015). Such damage can be controlled through judicious use of fencing to allow cattle to access only portions of the wetland or by piping water from the wetland into a trough set away from the wetland. Water troughs established for livestock can provide a source of drinking water for cranes, but the troughs need to have some means for chicks to easily climb out to minimize the risk of drowning.

The importance of grazing to maintain grassland habitat for cranes is evident where removal of livestock has resulted in declines or losses of cranes. In the highlands of eastern South Africa, a formerly unknown population of Wattled Cranes was discovered in the mid-1970s breeding in small wetlands and wide surrounding pastures. A core area was identified with as many as 18 pairs of Wattled Cranes, 53 pairs of Blue Cranes, and unknown numbers of Grey Crowned Cranes. In an effort to protect the endangered Wattled Cranes, the government purchased the core farms, removed hundreds of domestic cattle and horses and thousands of sheep, and proclaimed the area the Verloren Valei Nature Reserve. The removal of the grazing mammals and abandonment of a regular burning regime, compounded by the poisoning of cranes in nearby areas where cranes inflicted crop damage, resulted in a reduction to one pair of Wattled Cranes and three pairs of Blue Cranes in the protected area. Similarly, when another important wetland and grassland complex – Umgemi Vlei in Kwazulu-Natal – was protected for cranes, domestic grazers were removed and periodic burning eliminated, and the number of breeding pairs of Wattled Cranes plummeted from seven to just one. After managers implemented a more frequent fire regime (areas burned every second year) and re-introduced livestock grazing, the number of active Wattled Crane pairs attempting to breed on Umgeni Vlei increased to four pairs by 2004 (Kevin McCann, personal comm. 2016). While these management changes provided some benefits for cranes, it is important to recognise that there may be limited opportunities in protected areas to use cattle as a management tool, and that where cattle grazing is allowed, it needs to be subject to strict guidelines (stocking rates, grazing system, season) and closely linked to the conservation objectives of the area.

As described earlier in Ilyashenko (2018), the Demoiselle Crane population on the steppes of Central Eurasia declined in the 1990s because of the agricultural crisis that followed the collapse of the Soviet Union. With the collapse came reductions in livestock farming, decline of irrigation systems, neglect of artesian wells near shepherd camps, and transformation of abandoned pastures and crop fields into tall, rank growth susceptible to damaging wildfires (Kamp et al. 2011). Grazing was forbidden in the system of strictly protected areas created in the Soviet Union and in some of the new nations after the Soviet Union collapsed. For example, once grazing was prohibited in the Askania-Nova Nature Reserve, Ukraine, the resulting tall, dense vegetation deterred breeding by Demoiselle Cranes, which prefer short cover (Yuriy Andryushchenko, personal comm. 2015). Since the beginning of the 2000s, agriculture has been recovering in north Kazakhstan and in Ciscaucasia in Russia, and crane numbers have been increasing (Fedosov and Malovichko 2008, Bragin 2011, Kamp et al. 2011). However, in the Caspian area (Kalmykia and Volgorad Region), livestock farming still is greatly reduced from earlier levels and crane numbers continue to decline (Bukreeva 2003, Chernobai 2011).

Benefits of grazing disturbance for crane habitat are not limited to grasslands. High in the Himalayas, Bhutan's Phobjikha Valley supports in winter a population of approximately 350 Black-necked Cranes on that nation's largest wetland. The predominant vegetation in the wetland is a type of bamboo that can grow to the height of several meters. However, in summer several thousand cattle and horses graze on the bamboo and reduce the plants to mere stubs projecting from the wetland soils. In autumn the keepers move their herds to lower and warmer altitudes just as the cranes start arriving at Phobjikha Valley from their breeding ground in nearby Tibet. Throughout the winter the bamboo produces a plethora of new shoots that constitute a primary food for the cranes. If the wetlands were not heavily grazed in summer, the cranes' access to the bamboo shoots in winter would be very limited.

Light grazing likely contributes to the use of shallow wetland areas by breeding Brolgas in northern Victoria, Australia. The wetlands were constructed or highly modified and managed for irrigation storage, but shallower wetland zones that experienced ephemeral flooding provided attractive habitat for nesting and foraging. Wetlands that received at least some level of grazing by sheep or cattle were used by breeding Brolgas, but wetlands grazed too intensively or grazed when flooded had little vegetation and hence little value to cranes (Herring 2005).

In England, resident Eurasian Cranes that do not have juveniles often forage in fields with domestic livestock. However, cranes with young prefer to pick invertebrates from ungrazed wetland vegetation. Studies there have demonstrated that an ungrazed fen has a larger biomass of invertebrates than a grazed fen and therefore provides more food for the cranes. However, it was noted that low intensity grazing by domestic animals may be important in maintaining a mosaic of open areas easily used by cranes (Buxton et al. 2011).

Grazing is often just one of the factors affecting grassland or wetland ecosystems for cranes. The last flock of Siberian Cranes wintering in India largely resided in the Keoladeo National Park, Bharatpur, Rajasthan, located in north-central India. Established in 1982, the park encompasses extensive wetlands of a former floodplain. Cranes there foraged primarily in shallow wetlands on tubers of sedges and other plants and on large snails (Sauey 1985). Before the national park was established, domestic water buffalo grazed in the emergent vegetation during the winter flooding season, which helped to keep wetlands open for aquatic birds and facilitated water movement. Wild geese also grazed on wetland plants and help to maintain openings (Middleton et al. 1991). Grazing by domestic livestock and most other human activities were banned in 1983, resulting in accumulation of deep litter, more frequent fires, and dense stands of grasses (primarily knotgrass *Paspalum distichum,* a perennial amphibious grass; Gopal 1991). Total plant cover varied seasonally in relation to monsoonal flooding patterns but was always highest in ungrazed *Paspalum*-dominated areas (89–98% during January/March 1985) compared to grazed areas during that same period (10–50%; Middleton et al. 1991). Plant diversity was also higher in grazed areas. The dense grass cover prevented use by cranes. By the 1990s, diversion of water used for irrigation, changing monsoonal flooding patterns (Middleton et al. 1991, 2009), and management interventions to remove *P. distichum* have greatly altered that wetland system. Unfortunately, Siberian Cranes no longer visit India due to other factors, and no further studies have been conducted in the park.

While periodic or light grazing can benefit cranes, overgrazing and disturbances from domestic livestock are often detrimental to cranes, other birds, grazers, and their habitats. Overgrazing can seriously degrade grassland health and productivity, compact soils, contribute to soil erosion, and degrade food and cover conditions important to cranes, as well as cause excessive disturbance. Reduced cover may be of particular concern for nesting (nest-building material and protective cover) and chick survival. Examples of where degradation of the habitat and disturbances from overgrazing have been identified as a problem for cranes include the Xianghai National Nature Reserve, Jilin Province of China (Red-crowned Cranes; Oyun-Erdene 1998, Ren et al. 2007); Ruoergai National Nature Reserve, Sichuan Province of China (Black-necked Cranes; Scott 1993); various areas in Cuba (Cuban subspecies of Sandhill Crane; Aguiler and Chavez-Ramirex 2010); and the Boye wetland of southwestern Ethiopia (Black Crowned Crane; Mekonnen and Aticho 2011). During the breeding season, grazing animals can directly harm cranes by trampling nests or young chicks and therefore should be kept out of potential nest and brood-rearing areas (e.g., flooded areas and ponds within breeding territories). White-naped Cranes avoided the proximity of livestock herds while foraging (Bradter et al. 2007) and preferred to nest in wet areas where grazing pressure was low and vegetation provided good nest concealment (Bradter et al. 2005); however, grazing intensity was not correlated with hatching success or chick survival to four weeks of age. In South Africa Blue Cranes are able to defend their nests from being trampled by sheep except in cases when sheep are herded accidentally over nests (Kevin Shaw, personal comm. 2016). Although requiring further investigation, there seems to be a relationship between cranes and the various livestock types present as it relates to both the cranes' ability to prevent trampling of eggs or nests and the vegetation structure that results from either more selective or bulk grazing. For example, Blue Cranes seem to nest more readily and are potentially more productive in areas where sheep are grazed than where cattle herds are managed (Kerryn L. Morrison, personal comm. 2016).

Overgrazing can have cascading effects on the ecosystem, resulting in other negative consequences for cranes. Overgrazing can increase soil compaction, making probing for tubers or insects more difficult; shift the plant community toward species that may not provide useful foods for cranes (e.g., loss of *Cyperus* or other tuberous species) (Zhang et al. 2011, Teuber et al. 2013); and increase soil erosion, leading to degraded quality of uplands and sedimentation in wetlands. In more arid regions, it can lead to grassland desertification. One example of such consequences for cranes is the Ruoergai Plateau Marshes of Sichuan Province of China, an area important for breeding Black-necked Cranes. Extensive overgrazing and wetland drainage since the 1970s combined with warming climate have led to degradation of grassland cover, grassland desertification in local areas, and shifts in the grassland plant community (Tiefeng 2010). Domestic livestock (primarily yaks, but also cows, sheep, and goats) now spend longer periods grazing in wetlands due to deterioration of the less resilient upland dry pastures, thereby degrading wetland quality for foraging and nesting Black-necked Cranes (Kong De-Jun, personal comm. 2015). Increases in rodent populations, apparently related to changes in the grassland plant community and agricultural practices, led farmers to use pesticides to control rodents. Rodents, however, are one of the food items of cranes, and rodent control efforts could lead to increased risk for poisoning.

Grazing management that sustains the long-term health of the ecosystem will in turn help to sustain its value for domestic grazers as well as for cranes and other birds. A short period of intensive grazing, or combination of controlled burning and grazing, can be useful to restore overgrown grasslands or control encroachment of woody plants. Prescribed burning can be useful to remove residual vegetation and provide a flush of new growth for livestock, but judicious use is important (see also chapter 5, *Threats to Cranes Related to Agriculture: Fire*). Grassland burning during the dry season in parts of Africa for this purpose often coincides with and hence threatens nests and chicks of Wattled Cranes (McCann and Wilkins 1995). In the floodplains of Africa, almost 100% of the floodplain outside of national parks is burned annually. The absence of managed burning or managed grazing regimes in Zimbabwe too often results in devastating fires in the Driefontein Grasslands. In South Africa, uncontrolled or escaped prescribed fires also threaten nesting cranes.

Cranes may come into direct conflict with herders or ranchers where livestock are fed grains or processed feed. For example, in the Western Cape Province of South Africa, Blue Cranes are attracted to feed troughs used to feed sheep (Kerryn L. Morrison, personal comm. 2016). This conflict was readily solved by placing a low barrier wire around feeding troughs or adapting the troughs by adding a roof. The sheep are short and can pass naturally under the wire or roof whereas the cranes will not bend down to get under the wire or roof to the food. Grey Crowned Cranes also are often found in affiliation with dairy cattle, both on irrigated pastures or in more confined areas where cattle are herded just prior to and after milking (Kerryn L. Morrison, personal comm. 2016).

Livestock fencing is often part of grazing management and can effectively result in habitat fragmentation (Fig. 2). Collisions or entanglements with fencing can be a significant source of crane injuries or mortalities, particularly for juveniles (White 1983, Drewien et al. 1995, Fanke et al. 2011). Fanke et al. (2011) identified collisions with wire fences as the second most frequent cause of mortality for Eurasian Cranes in Germany. Juvenile Sandhill Cranes were found entangled in barb-wire fences (Braun et al. 1978, Drewien et al. 1995). The Australian Crane Network provides information to landowners to minimize risks of fence collisions or entanglements for Brolgas and Sarus Cranes (Australian Crane Network 2014). For large livestock, risks from fences can be reduced by simplifying the fence structure to 2–3 strands; replacing multi-strand fences with single electrified strands; or shifting fence lines away from high-risk areas. Single electrified strands have the added benefit of being easily moved, allowing the landowner to better manage their livestock forage or to temporarily protect crane nests or chicks from livestock. Solutions have yet to be found that can prevent chick entanglement in the types of fencing required for sheep.

Fig. 2. Woven-wire fence prevents safe movement of Black-necked Cranes with chicks between pastures (Photographer: Dai Qui)

The use of baled dry fodder on livestock feeding sites also may pose risks of injury to cranes. In most cases the fodder is held together with baling twine, which is not removed to reduce wastage from livestock trampling the bales. The bale feeding sites can attract cranes, which then often get the twine wrapped around their legs (Kevin Shaw, personal comm. 2016). This situation can result in either amputation of the leg or death if the trailing twine becomes entangled in fence lines or vegetation. Such risks of entanglement to cranes and other wildlife could be reduced by frequently inspecting bale sites and removing loose twine or other binding materials.

Domestic Birds

Cranes are most likely to interact with domestic birds where they utilize the same areas where the domestic birds are being fed and maintained in large open areas, whether in wetlands (ducks and geese) or farm areas (poultry or ostrich). If cranes are consuming the same foods as the domestic birds (e.g., grains), farmers are more likely to discourage their presence. In a more unusual situation, Blue Cranes in South Africa take advantage of feeding troughs set up for domestically raised ostriches (Kerryn L. Morrison, personal comm. 2016). That conflict was readily controlled by raising the height of the feeding troughs so they were inaccessible to the cranes. The conflict still, however, exists on farms that raise young ostriches of the same height or smaller than Blue Cranes and, where farmers feed ostriches by scattering the food on the ground.

While cranes may find some benefit by feeding in association with domestic birds, there are serious concerns regarding the potential for disease transmission (e.g., avian tuberculosis, cholera, and avian influenza) from wild cranes to domestic species. For example, nearly four million chickens are farmed on the Izumi plain in southern Japan, where over 12,000 Hooded and White-naped Cranes winter, accounting for 80–90% of the world's Hooded Cranes and up to 50% of the White-naped Cranes. There is risk of a significant disease outbreak with the dense concentration of birds in the feeding areas. In winter 2010–2011, at least 28 cranes were found dead at Izumi associated with highly pathogenic avian influenza (AI) infection in waterbirds (Fukui 2013). Although this incident did not develop into a significant mortality event and currently cranes appear to be less at risk from AI than some other avian species, it is a reminder of how vulnerable these populations could be to a more virulent AI or other infection. Regulatory authorities are very concerned about the presence of any infectious disease in the Izumi cranes and the resulting possible risks to the area's poultry industry; this could result in negative feelings and pressure for alternative management for the cranes. In the Western Cape, the ostrich industry is plagued by outbreaks of avian influenza, and embargos are periodically placed on the export of ostrich products to other countries. This problem may result in landowners taking action against perceived carriers of avian influenza, which could have severe consequences for the Blue Crane population (Kevin Shaw, personal comm. 2016).

At the same time, domestic waterfowl pose potential threats of transmitting disease to cranes. In China, India, and Iran cranes frequently have contact with large flocks of domestic ducks and geese. There is circumstantial evidence that domestic waterfowl infected by Newcastle disease might have infected Black-necked Cranes at Cao Hai Nature Reserve in western China (Li and Li 2005) and Grey Crowned Cranes in South Africa (Kerryn L. Morrison, personal comm. 2016). Overall, although the potential of serious disease problems in cranes related to domestic birds appears high, there have been relatively few documented incidents. Likely more significant for cranes, however, is the increased human disturbance related to managing waterfowl flocks, and the deterioration of wetland quality where high densities of domestic waterfowl are kept.

Domestic Dogs

Dogs are generally a threat wherever cranes are raising their chicks nearby, whether the owners area farmers, suburban residents, or military personnel. Although cranes do defend themselves and their chicks against dogs by threat postures and jabbing with their bill, dogs can be serious predators of cranes, especially of flightless juveniles and molting adults. Dogs have been reported as major predators of pre-fledged Black-necked Cranes in India and in China (Pankaj Chandan and Fengshan Li, personal comm. 2016). Domestic dogs were considered one of the primary causes of mortality of Lesser Sandhill Crane chicks in rural residential areas of Homer, Alaska, USA (Edward Bailey, personal comm. 2016) and were documented killing adults and juvenile Sandhill Cranes in Mississippi, USA (Butler 2009). In Ladakh, India, eggs and chicks of Black-necked Cranes were taken by feral dogs and dogs owned by nomadic herders or the armed forces (Chandan et al. 2006). In the Kulen Promtep Wildlife Sanctuary, Preah Vihear Province, Cambodia, local people reported incidents of domestic dogs having eaten Sarus Crane eggs; this caused cranes to move their nest to a different, smaller wetland the following year (Tran Triet, personal comm. 2016). In wintering areas of the Demoiselle Cranes in Tekeze River Valley, Ethiopia, Gebremedhin et al. (2009) noted that there were a number of stray dogs which hunted and killed cranes. On the breeding grounds of the Demoiselle Crane on the Central Eurasian steppes, herding dogs are considered the main cause of disturbance during the breeding season, and many pre-fledged cranes are killed (Andryuschenko 2011, Malovichko 2011).

Knowledge Gaps

- Direct and indirect effects of grazing, and grazing intensity/seasonality, by different types of domestic ungulates on crane food resources and habitat, and ultimately crane productivity;
- Interactions of grazing with fire, changing wetland water regimes, and changing climate as they affect crane food resources and habitat conditions;
- Factors influencing risks of disease transmission among wild cranes, wild waterfowl, and domestic birds;

  Effective methods to minimize risks of disease transmission between cranes and domestic birds;
- Effective means of minimizing mammalian predation on both cranes and livestock;
- Impact of livestock fencing types on cranes (injury, mortality, habitat use) and implications of fencing in different environmental situations; and
- The relationship between cranes and the impact that livestock have on the vegetation structure.

Alternative Actions to Prevent or Minimize Negative Impacts

- Provide resources and information to communities and individuals to help restore overgrazed areas;
- Encourage restoration and implementation of sound grazing practices in protected areas where appropriate that benefit cranes and other waterbirds;
- Protect or enhance the availability of shallowly flooded wetland zones, and use fencing or appropriate grazing regimes to avoid overgrazing or breeding-season disturbance;
- Encourage design and management of modified or constructed wetlands to provide ephemeral or seasonally flooded zones beneficial to cranes and other wild waterbirds;
- Encourage ranchers to use fencing or other methods to minimize negative impacts of livestock around water sources;
- Provide information and encourage ranchers/herders to provide means for chicks to exit water troughs to prevent drowning;
- Monitor health of domestic birds that associate with cranes and implement appropriate control measures to minimize disease transmission to wild cranes;
- Minimize risks of disease transmission by prohibiting people from releasing domestic waterfowl into protected wetlands with concentrations of waterbirds;
- Control domestic and feral dog populations and movements where they are impacting crane breeding success or survival; and
- Where livestock guard dogs are used to protect herds from mammalian predators, educate and encourage herders to control and train the dogs to avoid cranes.

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CHAPTER 5

Threats to Cranes Related to Agriculture

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Abstract: The greatest threats to cranes worldwide are related to agricultural activities. They include direct losses of wetlands or grasslands; altered wetland hydrology due to water control systems such as dams or irrigation ditches; fire; direct and indirect impacts from agricultural chemicals; human disturbances; disease risks where cranes congregate in high densities on crops or in association with domestic birds; and collisions with power lines in cropland areas. Loss and degradation of wetland and grassland habitats by conversion to agriculture pose the greatest threats to all crane species. However, some agricultural uses of these ecosystems, such as paddy wetlands and grazing, can be beneficial to cranes and allow sustainable use by both cranes and farmers. Effects of agricultural burning on crane habitats can vary widely depending on fire severity, timing relative to plant growth and its response to burning, environmental conditions during and after fire, impact on predators and alternative prey, and relation of these factors to life-history stage for cranes. Cranes are increasingly exposed to agricultural chemicals that may affect them directly, through consumption of contaminated foods, or indirectly, through loss of important foods, or altered habitats. Cranes in agricultural areas can be intentionally or unintentionally disturbed by normal farming activities; where they directly threaten crops, farmers may destroy nests or kill birds. Birds may become habituated to some disturbances, but repeated, intensive, or targeted disturbances can result in reproductive failure, abandonment of breeding territories, or avoidance of roost or foraging areas. Dense congregations of cranes on crops increase risks of rapid spread of infectious diseases. Widespread concerns about avian collisions with power lines, a leading source of mortality or injury for some crane populations, have led to various approaches to reduce or prevent avian mortalities in problem areas. Alternative actions or programs that could help prevent or mitigate these threats are outlined.

Keywords: agricultural chemicals, disturbance, fire, grasslands, habitat loss, habitat degradation, power lines, wetlands

Agricultural activities over the past 50–75 years have greatly expanded and intensified in nearly all regions (Ilyashenko 2018b), substantially altering the landscape and causing extensive losses of wetland and grassland habitats critical for cranes. Agricultural expansion also comes with other, often interrelated threats to cranes and their habitats. Water supplies needed to sustain agriculture in arid and semi-arid regions via irrigation have altered the hydrology and function of wetlands, often degrading their value for cranes. The combination of growing human populations in rural areas and efforts to improve their standard of living means more families seek to make a living on the land, and their expectations are higher. Farmers have increased the intensity of their agricultural activities by increasing the proportion of their land-holding under cultivation and increasing their reliance on commercial fertilizers and pesticides to improve crop yields. Traditional practices that had benefitted cranes are shifting to new practices and crops that are often detrimental to cranes. As expectations and input costs rise, and space to expand becomes more limiting, farmers' tolerance for crop damage, real or perceived, declines. These pressures are breaking down the historic harmony that often existed between farmers and cranes, when farmers tolerated and in some cultures revered cranes.

This chapter discusses sources of threats associated with agricultural activities and how those sources affect cranes. Threats examined here include loss of wetland, grassland, and some agricultural habitats; fire; agricultural chemicals (poisoning and indirect effects on ecosystems); disturbances and intentional killing related to agricultural activities; disease risks of birds congregating at high densities on agricultural crops or in association with domestic birds; and collisions with power lines associated with agriculture. Some alternative programs and actions are identified that conservationists and decision-makers could use to prevent, mitigate, or ameliorate conflicts between cranes and farmers. More detailed assessment of threats, their effect on individual species, and priority conservation actions can be found in the *Crane Conservation Strategy* (Harris and Mirande, in preparation).

Habitat loss

Loss and degradation of wetland and grassland habitats pose the greatest threats to all crane species, and indeed to many associated wetland and grassland birds. Conversion of these habitats to agricultural uses has been on-going for hundreds of years, but the rate of loss has intensified over the last 50–100 years as human populations have grown and food demands increase (Ilyashenko 2018b) (Fig. 1). Cranes have proven to be adaptable to many changes to their habitats over the years, as demonstrated in many species by use of agricultural fields and many types of crops and some tolerance for human disturbances, even during nesting in some areas (Nowald et al. 2018, Sundar 2018). However, habitat fragmentation and losses in many regions appear reaching a threshold where crane populations are difficult to sustain. Remaining habitat patches may be too small to sustain breeding pairs or support non-breeding birds, and cranes may be forced to move into marginal habitats, often with negative impacts to their breeding success and survival. Equally if not more important, is the reduction in amount and distribution of habitats. Historically, many populations bred, staged, or wintered across many different areas or across a contiguous range of habitats. Such distributions allowed populations to survive natural variations in climate and events such as floods and droughts. Fragmentation and losses of habitat have resulted in cranes concentrated on fewer and often smaller areas of lower quality, which are more vulnerable to ecological and human disturbances. Reduction in number of areas available to cranes makes them much more vulnerable to further changes in climate or habitat losses.

Fig. 1. Extensive wetland drainage in the Quill Lakes area of Saskatchewan, Canada (Photographer: Chuck Deschamps, Ducks Unlimited, Canada)

Wetlands

Most crane species rely on the vegetative cover, security, and aquatic foods provided by wetlands at some time during their annual cycle, usually during nesting and brood-rearing. Availability and quality of wetlands influences crane distribution, migration, and reproductive success. Hence, wetlands are the most critical habitat for cranes, yet they are at risk from agricultural and other human activities. The top three threats to cranes globally are wetland related: dams and water diversions (changes in quantity, timing, and quality of water), conversion of wetlands for agriculture and other land development, and unsustainable exploitation of wetlands, including grazing and harvest activities (Harris and Mirande, in preparation). These threats are also among the top threats to global biodiversity (Salafsky et al. 2008). Most wetlands losses have been attributed to drainage for dry-land farming or conversion to water-dependent crops such as rice (*Oryza sativa*; OECD 1996, Finlayson and Spiers 1996, An et al. 2007, Junk et al. 2013; Aynalem et al. 2018). Agricultural activities also can markedly alter wetlands' natural hydrology, functions, and biotic communities, and in turn their value to cranes. Loss and degradation of wetland habitat are considered a primary factor in population declines of many crane populations (Meine and Archibald 1996, Aryal et al. 2009, He et al. 2009, Su and Zou 2012).

Wetland losses are believed to be substantial in many regions, but systematic quantifications are largely unavailable. Assessing loss or remaining wetland resources is challenging because of lack of historic data, difficulties of defining extent and type of wetlands, and their temporal variability. In the Organization for Economic Co-operation and Development (OECD) report (1996), it was estimated that by 1985, 56–65% of available wetland had been drained for intensive agriculture in Europe and North America, 27% in Asia, 6% in South America, and 2% in Africa, totaling 26% loss to agriculture worldwide. Wetland losses to agriculture have been ongoing for hundreds of years in Asia, Middle East, and Europe. The overall rate of wetland loss, however, is estimated to have been 3.7 times faster during the 20th and 21st centuries, with an estimated 64–71% of wetlands lost since 1900 (Davidson 2014). An et al. (2007) estimated that China lost 23% of freshwater swamps, 16% of lakes, 15% of riverine wetlands, and 51% of coastal wetlands; 82% of the total area was lost to drainage or conversion for human uses. In Sanjiang Plain of northeastern China, a critical breeding area for Red-crowned and White-naped Cranes, approximately 67% of wetlands were lost between 1975 and 2004 to agriculture. Tidal wetlands on the Chongming Island of China have experienced repeated losses, with about 200 km^2 lost since 1990, and further losses are anticipated; these wetlands are considered the last natural wintering area for Hooded Cranes (Ma et al. 2003). In Russia, wetland drainage for agriculture began in the 17th century and continued until the collapse of the Soviet Union, but information about wetlands is very limited (Robarts et al. 2013). In the United States, freshwater wetlands declined by 79% between the 1950s and 2004; an estimated 75% of those losses were attributed to drainage for agricultural (Dahl 2005). Wetland losses in the United States continue, albeit at much lower rates than historically, despite federal and state regulations. Wetland inventory data for Africa and Russia are very limited and rarely have been measured or losses recorded (Finlayson and Spiers 1996). Most recently and dramatically, the loss of the historic Mesopotamian wetlands in Iraq during the 1990s likely displaced thousands of Eurasian Cranes in the Middle East. Despite limited data, it is very apparent that wetland loss to agriculture and other uses is continuing and intensifying, particularly in regions such as Asia and Africa.

While many wetlands have been entirely lost to agriculture or development, the function and quality of remaining wetlands have often been substantially altered by changes to hydrology; inputs of chemicals, nutrients, or sediments; and increased exposure to disturbance. Foremost among these impacts is altered hydrology – altering amount, distribution, and temporal patterns of flooding. Such changes affect the community and productivity of plants and animals, often altering food resources and vegetative cover important to cranes. Seasonal flood pulses can be particularly important as they affect water levels, import nutrients, and may flush out salts or contaminants. Flood pulses also may bring in fish and other animals, providing additional foods for cranes. Flood pulses are often markedly altered by water-control systems. Such impacts to wetlands occur at a watershed scale (e.g., dams) or at more local scales (e.g., holding ponds and irrigation canals or ditches). Water diversions and impoundments also can flood wetlands too deeply or too long to be useful to cranes. The impact of such hydrological changes and the associated biotic changes will depend on how changes affect crane food availability, nesting conditions, exposure to predation, and disturbances.

Water allocation and distribution, most often for flood control and irrigation via dams and irrigation systems, are inextricably linked with the rate and extent of wetland loss and degradation worldwide (Speiers 1996). At a watershed scale**,** dams impact water and riparian wetlands by flooding out existing wetlands, controlling seasonal flood pulses, and often diverting water for use beyond the riparian ecosystem (Wood et al. 2000, Graf 2006). The impacts of dams on riparian ecosystems are complex and varied, depending not only on the dam structure and its operation but also local sediment supplies, geomorphic constraints, climate, and the key attributes of the local biota (McCartney et al. 2000). Diversion of water to irrigation systems often causes wetlands downstream to shift to shallower water regimes or upland conditions. Large dams and other large water developments in sub-Sahara Africa have caused fundamental changes in the expansive floodplain habitats important to Wattled Cranes, and their most important food source, *Eleocharis*, and have degraded habitats important to Black Crowned, Demoiselle, and Eurasian Cranes. Construction of dams on the headwaters of the Hadejia River in Nigeria have led to reduced discharge, loss of seasonal flooding of once-riparian fed wetlands, deeper incising of the river channel that in turn lowered groundwater levels and flood depths, and reduced recharge of groundwater. These impacts, combined with greater agricultural activity and groundwater extraction by small water pumps, have contributed to the decline of the Hadejia-Nguru wetlands in northern Nigeria, home to Grey Crowned Cranes (Olofin 1996). In China, increased withdrawal of water from Huolin River for irrigation reservoirs and fisheries has reduced water available for wetlands downstream, reducing and fragmenting wetland habitat for Red-crowed Cranes (He et al. 2009). Diversion of water from the Wuyuer River for "changing dry land to paddy" has markedly altered the hydrology of the Zhalong Wetland, an area important to six crane species (Li and Wu 1998). In the central United States, dams and heavy irrigation usage along the central Platte River have markedly altered the seasonal flood pulses critical to the creation and maintenance of open sand bars, used as roost sites by migrant Sandhill and Whooping Cranes (National Research Council 2005). Approximately 80% of all Sandhill Cranes of the Midcontinental Population utilize a 120-km stretch of the Platte River in spring migration; it is also designated as critical habitat for the endangered Whooping Crane (Krapu et al. 2011).

New or proposed dams threaten riparian habitat for cranes elsewhere. Development of dams to prevent flooding of croplands or to supply water for irrigation facilitates further growth and development of human communities and irrigation systems in lowland areas, and contributes to further loss of natural wetland and grassland habitats. Conversely, recent evolution of environment flow management for large, dammed river systems, addressing multiple socio-economic and ecosystem objectives, and programs to restore seasonal flows have shown substantial promise in addressing water conflicts between cranes and agriculture. For example, a pilot-study water release in the Logone floodplain of northern Cameroon showed positive results for Black Crowned Cranes, which depend on perennially flooded grasslands (Scholte et al. 2012). In South Africa, however, Grey Crowned Cranes appear to have adapted to breeding at dams and feeding on agricultural crops (Okes et al. 2008). These human-made habitats have facilitated range expansion in a region where much of their lands after their traditional marsh habitat was lost. In the semi-arid Saurashtra Region of Gujarat, India habitats created by the Ghee Dam and associated irrigation infrastructure support large numbers of staging Demoiselle and Common Cranes (Mukherjee and Wilske 2006). Densities of Sandhill and Whooping Cranes staging on the central Platte River have substantially increased over time (Krapu et al. 2011), in large part due to the high availability of corn (*Zea mays*) and other foods on adjacent croplands, which are supported by irrigation from the dammed river system.

Wetland hydrology and function also are altered at more local scales by drainage and irrigation systems. Such systems may be quite simple, operating at a small scale and shallow depths via gravity feed, to large and more complex systems with large reservoirs, pumps, and control structures that can rapidly flood or dewater fields. Systems can be very beneficial to cranes if the hydrology is managed in a way that produces food resources for cranes (e.g., seeds, invertebrates, mollusks, small vertebrates) or that provides secure nesting habitat. Canals and ponds can provide valuable foraging habitat for cranes during the dry season and thereby may improve breeding success and support cranes in drier regions. Most hydrological impacts of drainage and irrigation systems, however, tend to be detrimental to cranes. With diversion of surface flows from wetlands, surface flooding shrinks, wetland habitat can become fragmented and, over time, may be lost entirely. For example, diversion and impoundment of the Huolin River has shrunk and fragmented reed habitat in the Xianghai Wetlands of China, especially during years of water shortage (He et al. 2009). Reeds (*Phragmites* spp.) are the favored nesting habitat for Red-crowned Cranes, and the resulting fragmentation and loss of reed habitat threatens breeding success. Wetland fragmentation is also apparent in the Sanjiang Plain of northeastern China, an area used by eight crane species. That landscape has changed from one dominated by wetlands in the 1980s to one characterized as agricultural fields dissected by a network of canals and ditches with a mosaic of wetlands and grasslands. Conversion of wetlands for aquaculture also can directly fragment and alter wetlands. In the Yancheng Biosphere Reserve in China, some tidal wetlands used by wintering Red-crowned Cranes have been fragmented and converted to fish or shrimp ponds, salt works, or agricultural fields (Ma et al. 1999). In the Liaohe Delta of northeastern China, the southern-most breeding area for Red-crowned Cranes, dikes through tidal wetlands for development of aquaculture caused marked declines in molluscs and crustaceans and also contributed to eutrophication and pollution (Duning et al. 1996). Such altered wetlands could be managed to provide productive foraging habitat during most of their working cycle and allow cranes and agricultural activities to co-exist. High levels of agricultural activity during the breeding season, however, may cause nest abandonment or loss of eggs or chicks to predators.

Traditional irrigation systems in Asia, the Middle East, and Africa are generally small in scale, with holding ponds (tanks) and a series of earthen canals or ditches to direct water into shallowly flooded paddies. In traditional paddy agriculture (temporary wetlands that are intensively cultivated for rice), a single crop of rice or combined rice and fish is raised annually, with a long fallow period (Wood et al. 2010). Such systems are most extensive and intensive in areas where rice, shrimp, or fish are the predominant crops. Cranes and other waterbirds benefit from the residual seeds and aquatic biota supported in the ponds, paddies, and seepage areas along the earthen ditches. Often the paddy wetlands provide the best remaining wetland habitat for cranes. Paddy systems are important to cranes for breeding, migration, and wintering habitat throughout Asia and Africa as well as in California, where few unmodified wetlands remain. In Gujarat, India, distribution of the Sarus Crane is largely in the agricultural landscape and is positively correlated with area under paddy cultivation and canal irrigation (Borad et al. 2002, Mukherjee et al. 2002). Indeed, paddy systems can coexist with and function as productive wetlands, provided that the spatial and temporal variability in the water needs of the wetland and farmers are understood and accommodated into planning and management at both local and watershed scales (Galbraith and Huber-Lee 2005). Paddy systems, however, can be a "double-edged sword for waterbird conservation" (Elphick 2010). Creation of new paddy systems contributes to further losses of natural wetlands. Crane reliance on paddies increases probability of disturbance, and crop damage from cranes trampling or consuming grains increase tensions with farmers (see Disturbance section below). As paddy management intensifies to provide greater crop productivity, farmers often use more agricultural chemicals (Cassman and Pingali 1995 and section below) and may be less likely to tolerate crane use of their fields. Such trends can be combated via programs that encourage less intensive chemical inputs, or organic farming, such as have been successfully implemented at Dongting Lake, China (Mingqi et al. 2011; see also Austin and Sundar 2018).

Traditional paddy management, however, may be unable to meet rising demands for crop production and farmers' income. Expansion and intensification of crop production have coincided with increasing demand for water and the infrastructure to control water distribution. Globally, the proportion of cropland that was irrigated has expanded by 72% between 1966 and 1996 (Wood et al. 2000). China and India represented 39% of the global irrigated area; regions with the greatest dependency on irrigation are South Asia (35% of the region), Southeast Asia (15%), and East Asia (7%). These also are regions with the most threatened crane species. Water for these irrigated areas is increasingly dependent on dams. An et al. (2007) estimated that the area of irrigated croplands in China increased by 340% from 1950 to 2000. Water demands also are pushing operators to improve efficiencies of water distribution systems. Non-governmental and government organizations have supported projects to improve water delivery systems and reduce leakage. Efforts to improve efficiencies can ease water-use conflicts between agricultural and conservation uses (Wu et al. 2011). However, in some situations it may also result in eliminating crane habitats. Improvements such as hard-lining irrigation canals eliminate the biota of open earthen canals and seepage wetlands, which provide additional habitat for cranes. In India, such improvements have threatened the feeding and breeding habitats of Sarus Cranes, which relied on the traditional open canals (Aryal et al. 2009). Mitigation programs may be needed if wetland foraging habitats for cranes are lost due to such improvement projects. In parts of Asia, a different threat is the conversion of wetlands traditionally managed as rice paddies to greenhouses. In Korea, conversion of rice paddies and crop fields to greenhouses effectively eliminated habitat for staging and wintering Hooded Cranes (Kim et al. 2003).

Rice production techniques also are changing (Cassman and Pingali 1995). Some producers are producing multiple crops, which require greater input of fertilizers and pesticides, and different flooding regimes and depths, or producing rice with much shorter flooding periods; such practices can limit or eliminate the value of those fields to cranes. These trends in rice agriculture will likely intensify as water becomes a more limited commodity due to growing demands for agricultural and community uses and as changing climate alters water availability. Joint projects between farmers and conservation groups can be useful to demonstrate alternative rice-paddy management approaches that can benefit both cranes and farmers. For example, in the Winter-flooded Rice Paddy Project, in the Kabukuri-numa wetland of Ohsaki City, Japan, farmers were able to improve crop productivity by flooding paddies during winter while also creating new crane roosting sites, dispersing over-concentrated waterbird populations, and increasing biodiversity (Kurechi 2011).

Increased irrigation use fed by diverting surface inflows or pumping groundwater can ultimately lead to the extinction of wetlands. Exploitation of groundwater worldwide for agriculture, industrial, and municipal uses has exploded in recent decades (Lemly et al. 2000, Konikow and Kendy 2005), with depletions most critical in parts of northern India; also of concern are deficits in groundwater estimated for central plains of the US, much of Mexico, portions of China and southern India, and portions of the Middle East (Wada et al. 2010). Wetlands in the Chihuahuan Desert of central Mexico, historically important to wintering Sandhill Cranes, have shrunk or disappeared due to groundwater extraction (Calderon-Aguilera et al. 2012). In coastal Texas, the sole wintering home for the extant population of Whooping Cranes, withdrawal of underground water and oil and gas has resulted in the submergence of substantial area of estuarine marshes (White and Tremblay 1995). As noted above, groundwater extraction in the Hadejia-Nguru wetlands of Nigeria contribute to degradation of wetlands important to Grey Crowned Cranes (Olofin 1996). The magnitude of groundwater use and depletion, and the implications to wetland conservation are poorly understood in many areas, but may become a critical issue as many regions face changing climate regimes.

Wetland habitats also have effectively been lost due to conversion from crops friendly or useful to cranes, such as rice paddies, to crops or habitat conditions not usable by cranes, whether due to absence of foods or altered vegetation structure. For example, wetlands in the Krishnagar, Rupandehhi, and Nawalparasi districts of south-central Nepal have been converted to sugarcane production, fuelled by cash incentives from the sugar cane (*Saccharum officinarum*) industry (Aryal et al. 2009). High-plateau wetlands critical to Black-necked Cranes have been degraded or shrunk due to conversion to fish farms, pastures, or cropland; on some wintering areas the concentration of birds on remaining habitat has intensified conflicts with farmers (Song et al. 2014). Sarus Cranes no longer breed in the Krishnagar area, and the other regions are similarly threatened. Subsistence farmers in parts of Africa convert seasonally flooded wetlands into vegetable gardens to take advantage of the better soil moisture and fertility compared to dry grasslands, particularly during the dry season (Aynalem et al. 2018).

Wetlands have long provided rural communities with valuable natural resources such as reed or robust grasses for thatch or building materials; fodder for livestock; and human food resources such as fish, crustaceans, and aquatic plants such as water chestnuts (*Trapa natans*) and lotus (*Nelumbo* spp). These resources often still serve an important role in subsistence economies in parts of Asia and Africa (Ambastha et al. 2007). If over-exploited, however, human use can reduce their availability for crane nesting cover or food and result in excessive disturbance to cranes. For example, reed beds may be burned in spring to improve density of reeds and later harvested for thatch or other purposes, reducing habitat available for breeding cranes. Draining reed beds for harvest may also result in reduced food resources for cranes and lack of water during winter or spring. Sarus Cranes in India reduce their use of wetlands when water chestnuts (*Trapa natans*) are harvested (K S Gopi Sundar, personal comm.). Over-harvest of fish or crustaceans in natural wetlands and estuaries also may deplete important food resources for cranes and may not be sustainable over long periods. However, with carefully balanced management of the wetland's hydrology and natural resources, multiple uses can be sustained for both people and wildlife.

Grasslands

Grasslands are used by many crane species for foraging but are critical habitat for the specialists of dry grasslands, the Demoiselle Cranes of Eurasia and Blue Cranes of southern Africa. Grasslands have long been the first habitat to be converted to cultivated cropland, so estimates of historic grasslands are difficult to determine in parts of Africa and Eurasia that have long histories of agriculture. Extent and distribution of grassland cover has been dynamic over the last century, influenced by changing wars, socioeconomics, land-tenure systems, urbanization, and agricultural practices (Fuchs et al. 2015). Nonetheless, grasslands are considered among the most devastated biomes of the world (Olson and Dinerstein 1998). In North America, surveys suggest that 82–99% of grasslands of the central Great Plains have been lost since European settlement, largely to agriculture (Sampson and Knopf 1994) (Fig. 2); this region serves as the main migration corridor for Whooping Cranes and the Midcontinent Population of Sandhill Cranes. Extensive areas of steppe were converted to arable land by the state in China and the former Soviet Union, with the greatest losses in Ukraine (Werger and van Staalduinen 2012, Dengler et al. 2014, Andryushchenko 2018). Kovshar et al. (1995) noted declines in the populations of Demoiselle Cranes that coincided with plowing of the Eurasian steppes in the 1960s as remaining native steppe areas in European areas were cultivated, during the 1970s when irrigated fields replaced dry steppe, and during further grassland losses in the 1980s.

However, land abandonment with the collapse of the Soviet Union in the early 1990s has resulted in natural restoration of some steppe areas (Kamp et al. 2011, Andryuschenko 2018, Ilyashenko 2018a,

Fig. 2. Plowing up native grassland for crops in North Dakota, USA (Photographer: Scott Stephens, Ducks Unlimited, Inc.)

b). Commercial afforestation (planting of trees in grassland areas) also has consumed native grasslands important to Blue, Wattled, and Grey Crowned Cranes in Africa (McCann and Benn 2006, McCann et al. 2007) and the Mississippi Sandhill Crane in the southeastern United States. In the Western Cape Province of South Africa, Blue Cranes have benefited from an artificial landscape of wheat (*Triticum* spp.) and pastures that developed after World War II (Morrison et al. 2012). That landscape, however, is threatened by climate change, which is anticipated to reduce extent of land suitable for wheat production and reduce water availability to livestock (Morrison et al. 2012). Breeding White-naped Cranes in eastern Mongolia preferred areas with low human and livestock pressure, and higher wet-meadow vegetation (Gilbert et al. 2016).

The value of grasslands to cranes can be threatened by overgrazing and fragmentation. Intensive grazing reduces vegetative cover and species diversity important to sustain native invertebrates (e.g., grasshoppers, beetles) and for crane nest sites; impacts seed and tuber production; and compacts soils, which affects soil invertebrates and probing abilities of cranes (Bradter et al. 2005, Khishigbayar et al. 2015). Heavy grazing also reduces vegetative cover that provides cover from predators and, for chicks, from adverse weather. Crane habitat may be especially at risk in regions where precipitation is highly variable among years but grazing is sustained at high levels. In arid and semi-arid grasslands, mismatch of grazing pressure with precipitation and forage production can result in changes in rangeland vegetation which may or may not be reversible (Khishigbayar et al. 2015). Increased livestock numbers and change from semi-nomadic to more sedentary lifestyle in grassland regions such as the Mongolian steppe may lead to long-term degradation of crane habitat and increased potential for conflicts near settlements (Bradter et al. 2005, Khishigbayar et al. 2015). As evidenced by changes in Mongolia and China over the last 30 years, land tenure policies (e.g., communal vs. private ownership), human population growth, markets, and warming climate are important drivers affecting grassland condition, grazing pressure, and opportunities for sustainable management (Bradter et al. 2005, Ling et al. 2011, Khishigbayar et al. 2015). Fragmentation of grasslands exposes cranes to increased human disturbances and to predators that focus on habitat edges. Degraded or fragmented habitat may also cause cranes to expand their territories. Wattled Cranes had larger home ranges in areas that had reduced availability and greater fragmentation of grasslands and wetlands due to cropland (McCann and Benn 2006).

Fig. 3. Blue Crane killed after becoming entangled in a barb-wire fence (Photographer: Wicus Leeuwner)

Livestock fencing is often part of grazing management and habitat fragmentation. Collisions or entanglements with fencing can be a significant source of crane injuries or mortalities, particularly for juveniles (Fig. 3). Fence design has to balance minimizing risks to cranes with its function for livestock control (Austin and Sundar 2018). Risks from fences used for larger livestock can be reduced by simplifying the fence structure to 2–3 strands, replacing multi-strand fences with single electrified strands, or shifting fence lines away from high-risk areas. Single electrified strands have the added benefit of being easily moved, allowing the landowner to better manage their livestock forage or to temporarily protect crane nests or chicks livestock.

It is important to recognize that maintaining grazing as the primary land use is more beneficial to cranes than most alternative land uses. Grazing provides income to the landowner and helps to prevent the grasslands from being converted to cropland or other land uses. In addition, water sources developed or maintained for livestock, such as impounded drainages or small ponds, can provide water for drinking water and wetland foods for cranes.

Preventing or Reducing Habitat Losses

Conservation efforts have been successful in identifying and protecting many important areas for cranes (Meine and Archibald 1996). Research and monitoring, using techniques such as satellite telemetry, have helped to better understand species' flyways and identify important breeding, migration, and wintering areas for conservation. For example, a network of protected areas has been identified for the protection of Siberian Cranes across their flyway from Russia to China and Iran (Mirande and Prentice 2010, Secretariat of the Convention on the Conservation of Migratory Species of Wild Animals 2011, Convention on Migratory Species 2013). Implementing some form of habitat protection to prevent further loss or degradation will be important for conserving crane populations over the long term. An array of approaches are available, ranging from more traditional protection in nature reserves to programs that aid farmers and communities to reduce their impact on the ecosystem. In arid and semi-arid grasslands, policies and programs that support nomadic cultures may be most effective. Moreover, traditional knowledge such as that held by nomadic herders, developed over generations to adapt to variable and often severe environments, can be a valuable resource to guide management of arid and semi-arid grasslands. Creation of nature reserves or parks is a traditional method of protecting habitat and associated fauna and is most often done in undeveloped areas. Regulations limit or prohibit many human activities, including residency, farming, or hunting. Although protected from conversion, reserves are impacted by surrounding land uses, particularly water use that may affect wetlands within the reserve. To sustain ecosystem health and value of the area to cranes and other native fauna, some level of management is often needed, such as periodic grazing, burning, or water manipulations. Monitoring to track changes in climate, forage resources, or other habitat conditions at district or regional levels can directly inform management decisions at and avoid undesirable impacts to habitat and the agricultural community (Khishigbayar et al 2015).

Treaties, regional and international conventions and agreements, and collaborative programs can provide the resources to implement protection or restoration of habitats. Where habitat protection via reserves is not feasible, community or government programs may provide valuable alternative approaches for conserving crane habitat by helping farmers minimize impacts to the local ecosystems while sustaining their livelihoods (Li 2018, Sundar 2018). For more details, refer to Patterson-Abrolat et al. (2018) and Austin and Sundar (2018).

Alternative Programs and Actions

- Develop and sustain global- and national-level inventories of wetlands as a means for monitoring wetland status and where losses to agriculture are occurring, and provide information for conservation planning and agricultural programs;
- Develop and sustain grassland monitoring programs to track changes in climate, forage, grazing pressure, and other habitat attributes, which will provide useful information to guide community-based management of grasslands;
- Develop long-term international strategies, policies, and programs to protect existing and new crane habitats from agricultural impacts at the local, national, and flyway levels;
- Collaborate with governments and non-governmental organizations (NGOs) to enact stronger wetland conservation policies and legislation at local, national, and regional levels to reduce or mitigate losses to agriculture;
- Strengthen watershed-level approaches to wetland management that balance human uses, including agriculture, with wetland and waterbird conservation;
- Encourage water conservation and wise use programs to reduce impact of human water usage on crane habitats, including improved irrigation systems and groundwater extraction;
- Request or require mitigation for wetland loss in government agricultural programs and NGO programs that affect water control systems and wetlands;
- Develop and implement plans for the restoration of degraded wetlands and adjacent uplands;
- Strengthen requirements for environmental impact assessments in the planning of development projects related to agriculture that would affect wetlands and other crane habitat;
- Assess and ameliorate to the extent possible pressures from dams or other large infrastructure related to large-scale agriculture development;
- Encourage development of environmental flow management of impounded rivers to sustain wetland habitats critical to cranes;
- Strengthen management and enforcement in existing protected areas, including actions such as development and implementation of comprehensive management plans, assessment of the effectiveness of present boundaries, impact of land use in the surrounding watershed, and improved effectiveness of law enforcement;
- Develop special buffer zone programs for landowners and villages near protected areas to strengthen management programs and to harmonize conservation and development goals;
- Develop and implement integrated, community-based land-use programs to promote conservation

of cranes and crane habitats among farmers and other private landowners. Included in such programs would be: participation of landowners in surveys and inventories of wetlands used by cranes; incentives for setting aside suitable nesting habitat; monitoring and assessment of planned or possible land use changes that threaten breeding sites; identification and adoption of agricultural practices that improve habitat conditions; dissemination of information on habitat protection and management practices; and reimbursement programs for landowners in areas where crop damage occurs. The Cao Hai case study (Li 2018) provides an example of such programs;

- Develop conservation programs for grazing lands that encourage grassland and wetland conservation and healthy conditions while providing sustainable livelihood for ranchers/herders;
- Encourage reduced fencing where feasible or replacement of fencing types with those that minimize potential injuries to cranes; and
- Increase awareness and knowledge of stakeholders of ecosystem function and services, and how they can be managed for multiple uses, including crane conservation.

Fires related to agricultural activities

Global Patterns in Fires Related to Agriculture

Burning is a common agricultural practice for a variety of crop types in many regions. Farmers burn agricultural fields to clear crop residues following harvest or in preparation for planting, return nutrients to the soil, and control weeds and insect pests. Grasslands are burned to remove decadent material and to enhance forage quality and productivity. The use of remote sensing to monitor fire, as in Korontzi et al. (2006) and the Fire Information for Resource Management System (http://earthdata.nasa.gov/data/near-real-time-data/firms), can help conservationists gain a broader understanding of when and where cranes may be most at risk from fires in croplands and grasslands. Agricultural fires accounted for 8–11% of the annual global fire activity during 2001–2003 but were substantially more important in some regions (Korontzi et al. 2006). Seasonal, annual, and regional patterns of fire activity reflected crop types, cropping practices, and weather conditions. Globally, peak fire activity occurred in April-May (associated mainly with burning croplands in Eastern Europe and Russia) and in August (mainly burning grain residues across central Asia and Asiatic Russia).

The highest concentration of agricultural fires extended across Russia and its border with China (latitude 45–55° N) during April, and in Eastern Europe in August. In Europe and European Russia, cropland burning accounted for 48–73% of all fire in various land-cover types, although cropland burning has been banned in many western European countries. In China, fire in croplands accounted for 30–40% of all fires detected, and fires in savanna accounted for 13–16% of fires. In Southeast Asia and India, savanna fires accounted for 28–30% of fire activity, and agricultural burning accounted for 16–20%, with most burning concentrated in December-April. In Africa, most burning was in savanna (75% in the north, 80% in the south); agricultural burning accounted for just 1–2% of fire activity. Cropland fire coincided with burning savannas. In northern Africa, most fire activity occurred during November-February and in southern Africa fire was more common during the late dry season (July-October). The relatively consistent patterns of agricultural fires over space and time suggest the significance of fire related to cropping practices. Perhaps most significant to breeding cranes, fires in Heilongjiang Province and in east-central China (Hebei, Shanxi, Shandong, and northern Henan provinces) were common during April-June, when cranes would be initiating breeding, or during January-March (Korontzi et al. 2006: Figure 13). West of the Heilongjiang Province, Goroshko (2010) estimated that 60–70% of the wetland breeding habitat important to Red-crowned Cranes on the Russian part of the Argun River valley was burned each spring.

Direct Effects

Fires during the nesting season can destroy nests and eggs of many crane species, although published reports are limited. Fire may cause direct mortalities of pre-fledged chicks or increase chick mortality indirectly by reducing vegetative cover and increasing exposure of chicks to predators (Smirenski and Smirenski 2012). No mortalities of adult cranes due to fire have been reported. Where fires are frequent or extensive in scale, their effects can have long-term consequences to breeding crane populations. In the steppes of northern Mongolia, Goroshko and Tseveenmyadag (2002) estimated that in most years 30% of White-naped Crane pairs lost clutches or chicks or did not attempt to breed due to fires.

Severity and impact of fires on breeding birds vary with timing relative to the breeding effort, vegetation phenology, and environmental conditions. More severe fires are likely during dry periods and would be more likely to destroy nests than fires under wet conditions, when fuel moisture and water surrounding nests prevent direct nest destruction. Accidental or intentional setting of grass fires during the dry season frequently killed pre-fledged chicks of Wattled Cranes, while non-seasonal fires set in wetlands and floodplains were identified as a threat to successful breeding (Johnson and Barnes 1991).

Indirect Effects

The greatest impacts of agricultural burning are indirect, affecting vegetative cover and associated food resources important to cranes. Effects of burning on crane habitat can vary widely depending on fire severity (extent of vegetative removal and mortality), timing relative to plant growth and its response to burning, environmental conditions during and after fire (e.g., wetland or soil water conditions), impact on predators and alternative prey, and relation of these factors to life-history stage for cranes (nesting, brood-rearing, non-breeding) and vegetation phenology. Depending on fire severity, burning can remove some or all standing live and residual vegetation and may kill woody vegetation. Burns may temporarily increase accessibility of foods such as insects, seeds, and tubers by removing residual cover. In northern regions, blackened soils in burned sites tend to thaw earlier, facilitating earlier availability of invertebrates and high-protein vegetation for foraging cranes. Small-scale, patchy burns can provide enhanced foraging opportunities while maintaining some cover for nesting and chick-rearing. More severe or extensive fires, however, can remove so much vegetative cover that the area becomes effectively unusable for cranes that season. On the breeding grounds, one of the most critical effects of fire is the temporary reduction in nest-building materials and cover to protect nests and chicks from predators and exposure. For example, a March fire in the Zhalong Natioanl Nature Reserve resulted in Red-Crowned Cranes nesting away from their usual core nesting sites that year (Liu et al. 2009). Absence of residual vegetation from the previous growing season may prevent cranes from building nest platforms in more deeply flooded areas that provide more secure nesting; instead, they may have to build nests in remaining patches of unburned emergent vegetation or in less secure sites in shallower water. In agriculture areas in the south of Zeya-Bureya Plain of Russia, wildfires from burning grasslands or croplands to remove crop residuals can reduce nesting activity and success (Smirenski et al. 2018).

Burning is sometimes used by ranchers to maintain grazing or haying fields, and by land managers of conservation lands to manage grasslands and wetlands. In the US, autumn burning did not affect the following year's nest success for Sandhill Cranes in Idaho (Austin et al. 2007), but spring burning (before nesting) did cause decline of nest success in that year for Sandhill Cranes in Oregon (Ivey and Dugger 2008). In both areas, only portions of the breeding areas were burned each year and cranes usually had some cover remaining in or near their territories.

In northeastern China, a series of large, severe fires during August-October 2001 and March 2002 burned 50% of the core area of the Zhalong Nature Reserve, a critical breeding area for Red-crowned Cranes. Much of the reeds, the preferred nesting vegetation, was lost and cranes nested in 'secondary' habitat that provided poorer hiding cover and may also have provided reduced food resources (Kong et al. 2007). Cranes that did nest delayed nest initiation by 4–5 days (Jialong 2004). The breeding population declined for several years following the fire (Kong et al. 2007). Here, the large scales and timing of the fires and very limited availability of secure nesting habitat were likely contributing factors to the long-term negative effects to the population.

Fire on areas used by non-breeding cranes have generally been beneficial, particularly during the first few weeks or months after the fire. By reducing standing vegetation and litter cover, fire can enhance access of cranes to a variety of foods; cranes forage on both live and burned animals as well as new vegetative shoots that emerge soon after a fire. Sandhill and Whooping Cranes have often been observed foraging in recently burned grasslands and wetlands (summarized by Stone 2009) and appear to prefer recently burned habitats for foraging. In Florida, numbers of greater Sandhill Cranes in prairie grasslands were much greater following winter prescribed burns than before the burns (Wenner and Nesbitt 1987).

It is important to recognize that many of the wetland and grassland habitats important to cranes have evolved with natural disturbance events such as fire. Fire can be important for maintaining healthy ecosystem function and the more open habitats preferred by cranes. A combination of periodic fires and other defoliating disturbances such as grazing or mowing can be effective at sustaining the ecosystem's productivity, suppressing encroachment of woody vegetation, or controlling invasive species. For example, prescribed burning has been effective in controlling para grass (*Urochloa mutica*) in Australian wetlands used by breeding Brolga Cranes (Grice et al. 2010). Moreover, prescribed burning is an important management tool for reducing risk and severity of wildfires or fires that escape intentional burning (Smirenski et al. 2018) (Figs. 4 and 5). Smaller-scale, controlled burns are desirable for all stakeholders. Understanding the ecological and economic implications of fire, and improving farmers' knowledge about fire and fire management, will be key to finding the appropriate balance and making judicious use of fire for cranes, agriculture, and ecosystem health.

Fig. 4. Jeb Barzen instructs a local fire fighter how to effectively use fire-fighting equipment for conducting safe prescribed burns at Muraviovka, Russia (Photographer: Sergei Smirenski)

Fig. 5. Fire crew uses drip torch to light grasslands in a prescribed burn (Photographer: Tom Lynn)

Alternative Programs and Actions

- Use prescribed burning to reduce risks of wildfires and to maintain desirable habitat conditions of cranes; and
- Provide training and resources to farmers, local agencies, and conservationists for improved understanding and implementation of safe and appropriate use of prescribed burning for land management:
    - Improve knowledge of farmers and land managers about the ecological role of fire in wetland and grassland habitats;
    - Encourage use and maintenance of fire breaks to reduce unintentional spread of fires; encourage burning smaller patches and burning at times that minimize risks to cranes and benefits the habitat; and
    - Encourage farmers and land managers to avoid burning when nests, chicks, or flightless cranes are present.

Agricultural Chemicals

Intensification of agriculture around the world has been accompanied by greater use and diversity of chemicals used to fertilize crops and control plant and insect pests. Increased chemical use in agricultural systems has broadly affected both upland and wetland ecosystems, through contamination of the food web, changes in the trophic structure, and eutrophication. Cranes living in association with agriculture are therefore increasingly exposed to chemicals that may affect them directly, through consumption of contaminated foods, or indirectly, through loss of important foods (e.g., aquatic invertebrates, weed seeds) or altered habitats. Crane mortalities have been linked to a range of chemicals, with organophosphates and carbamates appearing most commonly in reports. Cranes also are expanding the types of habitats they use and foods they consume, which could expose them to novel chemicals or chemically treated situations. The additional investment made by farmers in agricultural chemicals also may contribute to reduced tolerance of farmers for real or perceived crane damage to their crops. Impacts of pesticides on cranes may be more prevalent in paddy agriculture than other agricultural systems because of the intensive farming effort, often higher pesticide use, and more direct interactions and conflict for crops between farmers and cranes (Borad et al. 2002, Huang et al. 2003, Parsons et al. 2010).

In developed countries, application of more toxic agrochemicals has declined as the most toxic chemicals were banned, formulations were improved for greater efficiency, and farmers' understanding of applications improved. However, use continues to grow in developing countries (Ecobichon 2001). Risks to cranes and their habitat from misuse or illegal use of agrochemicals are higher in developing countries where governments lack regulatory, registration, and educational systems for proper usage.

Poisoning

Cranes have been killed through both intentional and unintentional poisoning from agricultural chemicals, primarily pesticides. Poisoning is also a serious threat to global biodiversity (Salafsky et al. 2008). Crane species known to have suffered from chemical poisoning include Black Crowned, Blue, Brolga, Eurasian, Demoiselle, Grey Crowned, Hooded, Red-crowned, Sarus, Sandhill, and White-naped Cranes. Documentation of poisoning can be problematic because of lack of reporting and limited resources for testing to verify the cause of death. Incidents involving a few birds often go unnoticed, but mass mortalities receive more attention and may reflect the severity of the problem.

The large number of reports and range of species indicates poisoning by agrochemicals remains a serious problem, although chemical regulation has improved in many areas.

Accidental or incidental poisoning usually occurs when timing or location of chemical applications to crops coincide with crane foraging activities. Poisoned cranes often have consumed planted seeds that have been treated with pesticides. At the Yancheng Biosphere Reserve, China, more than 20 Red-crowned Cranes were poisoned and seven died from feeding in wheat fields; thereafter, use of agrochemicals and pesticides were banned on the reserve (Ma et al. 1999). Monocrotophos pesticide used on wheat seed was responsible for the deaths of 13 Sarus and two Eurasian Cranes at the Keoladeo National Park, India; this mortality represented 15.5% of the population of globally threatened Sarus Cranes using the park (Pain et al. 2004). Siberian Cranes previously wintered at the park but have not been observed since ca. 2002; the cause of the disappearance is unknown but may be linked to pesticide poisoning. Earlier mortalities at the Park included 43 Sarus Cranes, three Eurasian Cranes, and two reintroduced Siberian Cranes, likely poisoned by the organophosphate insecticide chlorpyrifos (Gargi 2001, cited in Pain et al. 2004). Another poisoning incident occurred in Mongolia in 2002, when about 3,500 km^2 of steppe were treated with the rodenticide bromadiolone, following a population explosion of voles (Cricetidae). No monitoring of non-target mortality was conducted, but ecologists working in the area noted more than 340 dead or dying birds at several localities, including 145 Demoiselle Crane and large raptors such as Steppe Eagle (*Aquila nipalensis*) and Saker Falcon (*Falco cherrug*) (Natsagdorj and Batbayar 2002, cited in BirdLife International 2004). The true scale of the mortality was presumably much larger than was observed.

Given the fidelity of migrant cranes to breeding and wintering areas, large or repeated mortality events such as these may eliminate that portion of a population that returned to an area. Rapid, local declines of Blue Cranes in South Africa during the 1980s and 1990s coincided with many reported cases of poisonings from all parts of the country (McCann et al. 2001) (Fig. 6). In China, evidence

Fig. 6. Poisoned Blue Cranes found on a farm in the Western Cape of South Africa (Photographer: Wicus Leeuwner)

of high adult mortality and large number of poisoning incidents reported for Red-Crowned Cranes on their migration and wintering areas (Su and Zou 2012) suggests poisoning remains an important source of mortality for that endangered species. Particular effort may be needed to minimize pesticide exposure of cranes that feed on private lands around protected areas. Protected areas attract and hold concentrations of cranes that are often very important to the conservation of the population; those cranes may then be exposed to treated crops when they leave the protected areas to feed in the surrounding agricultural fields.

Agricultural chemicals have been implicated in intentional efforts to kill or deter cranes and crane families that were damaging crops, although direct proof is usually lacking. Borad et al. (2002) reported mortality of a Sarus chick and an entire Sarus family in a paddy crop ecosystem in India. Breeding Sarus Cranes are closely associated with paddy cultivation and canal irrigation, using the agricultural fields for nesting and foraging. Damage from cranes nesting and feeding in the paddy crop fields contributes to conflicts with farmers. Although farmers usually resort to relocating nests or scaring cranes from their fields, poisoning and other means of killing cranes have been identified as likely factors contributing to the decline of the Sarus population in this area.

Some pesticides have demonstrated particularly severe impacts on birds. Poisoning of Sarus Cranes in Keoladeo National Park, Bharatpur, India, coincided with the application of aldrin in the crop fields around the park in winter, when the birds were present (Muralidharan 1993). Aldrin, an organochlorine pesticide, was used to treat soil and seeds such as wheat, mustard (*Brassica* and *Sinapis* spp.), and pea (*Pisum sativum*), against termites (Isoptera) and was once widely used. It is now considered by the World Health Organization (WHO) as an obsolete or discontinued pesticide, in part because of many bird mortalities. Monocrotophos is a broad spectrum, systemic organophosphate insecticide used on a range of crops. Its use has resulted in a large number of cases of poisoning of non-target species, particularly birds, including Sarus and Eurasian Cranes in India (Pain et al. 2004). Carbofuran (also known as Furadan [Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government]) is a carbamate insecticide and nematicide which is used to control insects in a wide variety of field crops and also has been responsible for many bird mortalities around the world. Its use was banned in Canada and European Union and is highly restricted in the United States, but it continues to be widely used elsewhere. Many species of birds in Kenya have suffered extensive mortalities from carbofuran (Richard 2011), and its use threatens Grey Crowned Cranes. Although the manufacturer repurchased Furadan 5G from distributors and retailers in Tanzania, Uganda, and Kenya in 2010 in response to wildlife problems, the chemical remains locally available and is still used by farmers and by poachers. Other agrochemicals have been used in bait to kill pest species or for illegal harvest of birds and resulted in cranes deaths. For example, 37 White-naped Cranes and 11 Hooded Cranes in Korea were killed after consuming rice grains soaked in phosphamidon used for illegal harvest of wild ducks (Kwon et al. 2004).

Some crane mortality occurs from naturally occurring toxins in moldy crops such as peanuts (groundnut; *Arachis hypogaea*), corn, and cereal grains left on the field after harvest. Wintering Sandhill Cranes in south-central US have been killed in several events from mycotoxin poisoning from moldy peanuts in the field. Mortality events usually occurred in association with cold weather in winter that is favorable for toxin production. Between 1982 and 1987, an estimated 9,500 Sandhill Cranes died in Texas and 470 Sandhill Cranes died in New Mexico from mycotoxins in peanuts (Windingstad 1988). Exposure of cranes to mycotoxins and aflatoxins can be reduced or prevented by immediately deep-plowing fields after harvest to bury the contaminated foods.

Indirect Effects to Ecosystems

Wetland and grassland ecosystems can be substantially impacted by agrochemicals, reducing habitat quality for cranes and in particular reducing their food resources; wetland systems seem particularly vulnerable. Herbicides can kill vegetation needed for protective cover for nests or chicks. High inputs of nitrogen and phosphorus in runoff and groundwater due to overuse of fertilizers have led to eutrophication of many wetlands around the world, altering wetland function and trophic structure. With repeated or intensive use, pesticides can substantially alter the trophic structure of both wetlands and uplands by killing organisms such as invertebrates, amphibians, snails, fish, or Orthoptera that are often important crane foods. For example, Black Crowned Cranes may be directly poisoned by consuming sprayed locusts and face a much reduced food supply after spraying programs. Tréca (1992) implicated aerial spraying to control locusts (Orthoptera) in west and central Africa to declines in the population of this species. Farmers in less developed nations often have had little or no training in the safe and appropriate use of chemicals and are unaware of the ecological implications of misuse. Inappropriate and often heavy use of agrochemicals has been cited as a serious ecological and human-health concern for India (Huang et al. 2003, Abhilash and Singh 2009).

For many agrochemicals, most effects are short-lived and invertebrate or plant populations recover in weeks or months once treatment is ended, but repeated applications, or persistence of chemicals can have lasting impacts. Most pesticides cited above have short lives in water and soils and have low potentials for bioaccumulation. However, some agrochemicals that have been banned from sale such as DDT and aldrin are still in use in some rural areas in developing countries. These chemicals bio-accumulate, leaving long-lasting legacies of risks to cranes. Heavy metals from agricultural chemicals (e.g., mercury, commonly used in seed fungicides) accumulate in water and soils and then bio-accumulate in animal tissues that are then consumed by cranes and other waterbirds. Toxic effects from mercury were identified as a serious issue for cranes in Japan (Teraoka et al. 2007).

Alternative Programs and Actions

- Provide training and information resources to farmers to increase awareness of toxicity of chemicals to birds, and the side effects to wetland systems, to reduce unintended poisoning of cranes and other wildlife and their wetland ecosystems;
- Provide training and information resources to farmers to improve pesticide application methods to reduce exposure of wildlife and humans to chemicals and runoff of chemicals into wetlands;
- Develop and encourage non-chemical approaches to control pests or improve field nutrients, such as biocontrols, composting, and other more organic farming methods;
- Develop strategies to help farmers deal with crop damages from cranes so they are not compelled to poison birds intentionally;
- Work with pesticide manufacturers, national, and local stakeholders to reduce the use and environmental impacts of chemicals toxic to birds;
- Improve regulation and enforcement of chemical use to prevent incidental and intentional misuse; and
- Improve reporting and documentation of poisoning events to more effectively address emerging problems.

Disturbances and Intentional Killing Related to Agricultural Activities

Birds in agricultural areas can be intentionally or unintentionally disturbed by normal farming activities, such as planting or plowing near nesting pairs, or harvesting, as well as by foot and vehicle traffic. Suitable use areas may be effectively lost due to high levels of human activities. Human interference or disturbance is considered among the greatest threats to cranes globally (Salafsky et al. 2008, Harris and Mirande, in preparation). Birds may become habituated to some disturbances. However, repeated, intensive, or targeted disturbances can result in reproductive failure, abandonment of breeding territories, or avoidance of roost or foraging areas. Disturbances on foraging areas also may reduce foraging time and food acquisition, force birds to feed on poorer quality sites, or take more risk to feed (Luo et al. 2012). During the breeding season, human disturbances may keep adults off the nest or away from young chicks, providing greater opportunities for predation by feral dogs, native mammals, and corvids. Dogs can be serious predators of cranes, especially of flightless juveniles and molting adults (Farrington and Xiulei 2013, Austin et al. 2018). Human disturbance may be most problematic in paddy agrosystems where breeding cranes are in close proximity to frequent agricultural activities (Sundar 2018).

Farmers use various tactics to keep cranes out of their crops, including scaring away territorial pairs, deploying flags, dogs, and other deterrents; removing eggs; and moving or destroying nests (Austin et al. 2018). Farmers also intentionally take adults for food. Effects of such disturbances are most deleterious for breeding birds. Eggs and chicks of Sarus Cranes in south-central Nepal were taken by children for both food and fun. Conflicts between farmers and Sarus Cranes in paddy agro-systems are a likely cause of population decline for this species in the Kheda district of Gujarat, India (Borad et al. 2002). In Uganda, most reports of threats to Grey Crowned Cranes occurred at breeding sites, and the most common threat was nest destruction by farmers (Olupot et al. 2009).

A special case related to human disturbance is the Demilitarized Zone (DMZ) between North and South Korea, and the associated Civilian Control Zone (CCZ) buffer zone. Human activities to the 4-km wide DMZ are severely restricted, and farming and residential activities in the CCZ also are very limited. Since their establishment in 1953, the DMZ has provided secure nocturnal roosting habitat for wintering Red-crowned and White-naped Cranes, while the CCZ has provided low-disturbance wetland and cropland for foraging. The area is threatened with development and increased farming intensity (John et al. 2003), which would result in direct habitat loss and increased infrastructure development (e.g., roads, power lines) as well as indirect loss through disturbance effects. Farmers consider cranes as a potential threat to their livelihood, and landowners support development programs. Efforts to guide policies and program development to recognize ecosystem values (including tourism) along with agricultural uses may provide a critical tool to balance economic well-being with ecosystem health and protection of this critical area for cranes.

In many areas, cranes traditionally held cultural value and were protected as sacred or desired animals and people avoided disturbing them (Meine and Archibald 1996, Didrickson 2010). For example, in areas of southern Nepal that were dominated by the Hindu religion, the presence of Sarus Cranes was believed to improve crop production, whereas areas dominated by Muslim religion lacked such cultural value of cranes. Other values, traditional or more recent, may encourage consumptive use of cranes rather than protection. In Uganda, rural communities valued cranes as a source of food, medicine, and decorative material, as well as egg sales to tourists. Where cranes had traditionally been revered and protected, encouragement of such cultural values may provide an important tool to continue to protect cranes from disturbances and harassment. Communities also may be simply unaware of the protected status of cranes.

Buffer zones around core conservation areas can serve to minimize disturbances from human activities while also providing a controlled balance of habitat use between farmers and cranes. Some conservation reserves in Eurasia have designated buffer zones around the core protected area where certain types of human activities are allowed, such as grazing, reed harvesting, or fishing. Li et al. (1999) demonstrated a decision-analysis approach to determine appropriate widths of buffer zones around core conservation areas. Widths of buffer areas may need to vary relative to landscape context, such as nature and disturbance levels of human uses (e.g., tourism, traffic, harvesting of plants or animals) and pollution (e.g., sedimentation or chemical runoff).

Understanding crane behavior and sensitivity to types of disturbances can help farmers adjust their activities to minimize the effects of their activities on cranes. Effective distances for minimizing disturbance effects will vary with the local situation, taking into account habituation of cranes to human activities; landscape (e.g., nature buffer areas or tall vegetation that can screen cranes from human activities); and whether they are nesting, with chicks, or non-breeding. Effective distances may be as little as 50 m or as much as 600 m (Li et al. 1999, Austin and Buhl 2008). Increasing farmers' understanding of crane behavior and needs can help farmers observe and determine appropriate buffer distances between cranes and their activities. Understanding how landscape features influence disturbance distances can also be important to protecting important roosting areas. In the central Platte River, Nebraska, roosting Sandhill Cranes generally showed stronger selection for wider channels with shorter bank vegetation situated farther from potential disturbance features such as roads, bridges, and dwellings (Pearse et al. 2018). Cranes were more resilient to nearby disturbances when roost sites had wide channels with short bank vegetation than sites had more narrow channels with taller bank vegetation.

Alternative Programs and Actions

- Improve farmers' awareness about cranes' legal status, ecology, and cultural value through media, cultural, and agricultural programs;
- Encourage farmers to establish or maintain patches of uncultivated marsh areas for breeding cranes. Such habitat-focused conservation would also foster other biodiversity on the landscape;
- Provide compensation to farmers who allow a pair to raise its brood successfully in their field;
- Develop alternative strategies to help farmers deal with damages from cranes that do not impair cranes' reproductive success;
- Improve legal protections to cranes and cultural values of wild birds while eliminating markets for live birds, eggs, cranes as bush meat, or crane feathers;
- Provide support for cultural totem attitudes;
- Involve local communities in monitoring crane population to enhance awareness; and
- Support development and enforcement of effective buffer zones for human activities around important wetlands and conservation areas.

Disease Risks From Concentrating Birds on Crops

Cranes can reach high densities on agricultural fields in migration and wintering areas because of the superabundance of easily-obtained foods. Those situations also contribute to high densities on associated roost sites. High densities are often found on artificial feeding sites, many of which are crop fields. These conditions are ideal for rapid spread of infectious diseases that may weaken or prove fatal to individuals. When combined to stressful conditions associated with long-distance migration, severe weather, and overcrowding, disease may pose a significant threat to the health of individuals and to wild crane populations.

Build-up of parasites and bacteria from heavy fecal contaminations has been documented on roost or feeding areas where cranes congregate in high densities. Coccidia (*Eimeria* spp.) have been found in various crane species, including Red-crowned Cranes at winter feeding station at Hokkaido, Japan. Oocysts of the coccidia parasites are shed in feces and can rapidly build up in environments when birds are overcrowded and use an area for prolonged periods. Crane coccidian species, *Eimeria gruis* and *Eimeria reichenowi*, differ from other *Eimeria* species in that they multiply systemically in both digestive and respiratory tracts and cause disseminated visceral coccidiosis, which is often lethal to young birds (Novilla and Carpenter 2004). High loads of coccidian, trematodes, or other parasites can weaken birds and make them more susceptible to other diseases. Avian tuberculosis (*Mycobacterium avium*) has been identified in Eurasian Cranes and a high proportion of free-ranging Whooping Cranes. This bacterial disease can survive for long periods in the environment and also builds up with repeated site use; outbreaks have been associated with waste-water discharges high in organics. Infections of *Salmonella* bacteria have been found in Hooded Cranes in the Izumi area of Japan, where thousands of cranes roost in tight quarters (Fig. 7). Although mortalities have not been documented from *Salmonella*, such high concentrations of birds and *Salmonella* pose a risk to crane health.

In North America, two diseases associated with large concentrations of staging or wintering waterfowl have also resulted in mortality to Sandhill Cranes that intermix with them. Avian cholera

Fig. 7. Dense flock of Hooded and White-naped Cranes gather on grain provided to winter flocks in Izumi, Japan (International Crane Foundation)

is a highly contagious disease of the bacteria *Pasteurella multocida*; it is readily transmitted through environmental contamination of air and water from body discharges from diseased birds. It has caused large die-offs of geese and ducks and sometimes substantial numbers of Sandhill Cranes since the 1960s. Avian botulism (type C) results from ingesting a toxin produced by *Clostridium botulinum*. It has resulted in mortalities of Sandhill Cranes in Arizona and Nebraska, including the Platte River, an important staging area for the large Midcontinent Population of Sandhill Cranes, Whooping Cranes, and many snow geese (*Anser caerulesens*; Windingstad 1988) (Fig. 8). For both diseases, it is the super-abundance of crop foods that attracts and supports large concentrations of birds, and can put substantial numbers of birds at risk of mortality.

Several species of cranes are concentrated in situations where disease from domestic birds, such as avian influenza, avian cholera, and *Salmonella*, could have profound impacts on survival. In Hokkaido, Japan, resident population of Red-crowned Cranes feed on human-provided corn, cereal grains, and fish in close association with livestock. At the Izumi Feeding Station in Japan, Hooded and White-naped Cranes occur in high concentrations also in response to artificial feeding. The Izumi area also has poultry farms holding more than 28 million chickens. Highly pathogenic H5N1 avian influenza (AI) has been documented periodically in wild birds, including cranes, at both Hokkaido and Izumi, since 2008 (World Health Organization 2012). In January 2011, 28 cranes were found dead in associated with an AI outbreak in wild birds in Izumi (International Crane Foundation, unpublished data). Regulatory authorities are very concerned about the presence of any infectious disease in the Izumi cranes and the resulting possible risks to the poultry industry, while crane conservationists are very concerned about the risks of disease transmission from poultry. The wintering population of

Fig. 8. Sandhill Cranes share a wetland with Snow Geese (Photographer: Ryan Hagerty, U.S. Fish and Wildlife Service)

Hooded Cranes at Izumi represents about 85% of the world population, and hence such disease risks represent a serious threat to their population.

Alternative Programs and Actions

- Reduce risks of disease transmission by providing a diversity of feeding and roosting areas to prevent dense concentrations of birds;
- Monitor concentrations of cranes for signs of disease; if an outbreak occurs, disperse birds from infected areas or treat area and birds as needed to reduce spread of disease;
- Develop strategies to promote dispersal of cranes from historic concentration areas (e.g., Hooded Cranes at Izumi) or areas most at risk of disease transmission from livestock and domestic birds; and
- Continue research into the environmental conditions that promote spread and lethality of disease.

Power Lines Related to Agriculture

Power lines pose significant risks of mortality or injury to cranes. Crane collisions with power lines are a problem in many regions of the world (review by Jenkins et al. 2010). Both larger high-tension transmission lines and local supply lines can be hazardous to birds, particularly large-bodied birds such as cranes. Cranes may be killed outright by the collision or by the fall or injured when a wing or leg strikes a line. Here, we focus on the risks of crane injury and mortality due to collisions with electrical power lines as related to agriculture: co-occurrence of power lines in areas of high crane concentrations on crop fields, and power lines associated with small farm dams or irrigation systems.

Fig. 9. Blue Cranes fly close to power lines in South Africa (Photographer: Wicus Leeuwner)

Many of the crane mortalities from power line collisions occur in areas where migrant or wintering cranes congregate to feed on crops or are moving between roost and cropland feeding areas. Primary examples are the frequent collisions with transmission lines by Sandhill Cranes staging along the Platte River (Wright et al. 2009, Murphy et al. 2016) and Eurasian Cranes staging on a large wetland in Spain (Janss and Ferrer 2000). Local supply lines that supply power to irrigation pumps often are located within or along the edge of crop fields. Those single, low-level lines can be hard for cranes to detect when making short, low flights between fields.

Cranes seem particularly vulnerable to collisions due to their larger body size, flight behavior, angle of vision (Martin and Shaw 2010), and habitat use patterns. Cranes often fly in family groups or small flocks at heights similar to that of smaller, lower supply lines when moving short distances between roost sites and nearby agricultural fields or between fields, and at heights similar to that of larger transmission lines when making longer movements. Cranes are most at risk of collision when power lines are located within breeding territories, cross wetlands important for roosting, or lie between roost wetlands and nearby feeding habitats (often agricultural fields) (Figs. 9 and 10). Topography or tall vegetation may divert birds toward more open areas maintained along power lines. On breeding territories, breeding adults and pre-dispersed juveniles are exposed only to lines within their territory, and the adults are familiar with line locations. Power lines at edges of breeding territories also may result in higher risk of mortality because of aggression between territorial pairs (Sundar and Choudhury 2005). Young fledged cranes tend to be more at risk of collision because of poorer flight agility and lack of familiarity with power line locations. In contrast, non-breeding birds, which move widely, are exposed to a greater numbers of lines that occur within or between their movement areas, and may be less familiar with line locations. Many collision events occur when cranes are flushed (particularly from night roosts) due to disturbances by humans or predators (Murphy et al. 2016).

Mortalities due to collisions can have significant impacts on crane populations, particularly for small and non-migratory populations (e.g., non-migratory Whooping Cranes, Blue Cranes) or highly concentrated during one season (e.g., wintering Red-crowned Cranes in Hokkaido). Power-line collisions are believed to be one of the most important sources of mortality to migrating Whooping Cranes (Stehn and Wasserich 2008), non-migratory Whooping Cranes in Florida (Folk et al. 2008), Red-crowned Cranes wintering in Hokkaido (Masatomi 1987), and Sarus Cranes in south-central Nepal (Aryal et al. 2009). Collision-rate estimates for Blue Cranes in South Africa suggested approximately 12% of the total Blue Crane population in the Overberg area were killed annually, an unsustainable rate (Shaw et al. 2010), and collisions are considered the main threat to Blue Crane populations as a whole (K. Morrison, Endangered Wildlife Trust, personal comm.). Estimates of annual mortality rates are 2.4–5.9 cranes/km power line for Eurasian Cranes in Spain (Janss and Ferrer 2000). In most cases, mortality rates are unknown, and incidental reports of mortalities only suggest the extent of the problem.

Widespread concerns about avian collisions have led to various approaches to reduce or prevent avian mortalities in problem areas (Jenkins et al. 2010). Most commonly, existing power lines are marked at intervals with tags or other devices to increase the visibility of lines. Luminescent line markers show promise where collisions occur at dusk or after dark near roosts. Moving or burying lines may be feasible in limited areas of very high bird use but is very expensive. Feeder lines serving irrigation pumps may be removed during the seasons when they are not in use. Other potential actions include manipulating habitat to reduce bird flights over lines, using vegetation and topographical features to encourage birds to fly above lines, and reducing human disturbance.

Fig. 10. Blue Crane killed by collision with a power line (Photographer: Jon Smallie)

Demand of electrical resources is increasing worldwide, but the need is greatest in rural areas. A report by the International Energy Association (Kato 2002) indicated that 85% of people lacking access to electricity live in rural areas; about half of those lacking electricity access reside in South Asia, 30% live in sub-Saharan Africa, and a further 15% in East Asia. India alone comprises 35% of those lacking access to electricity. Given the significance of rural electrification to societal and economic development, many nations and international organizations are actively working to increase electrical distribution systems, particularly in rural areas. With more extensive rural electrification, farmers will have new opportunities to power their water pumps and irrigation systems, which likely will lead to expanding the supply lines into crop and paddy fields that may be used by cranes.

Given the anticipated growth of power lines in rural areas, it will be important to work with utility companies and decision-makers involved with strategic planning and regulation to develop guidelines and regulations for new power-line and wind farm developments. In the United States, the Avian Power Line Interaction Committee (APLIC), composed of nine investor-owned electric utilities and the USFWS, was established in 1989 to address the issue of collisions with Whooping Cranes and other birds. Voluntary guidelines for avoiding avian collisions with power lines were developed by the APLIC for use by the industry (APLIC 1994). Work in South Africa (Antal 2010, Jenkins et al. 2010, Jordan and Smallie 2010) provides examples of how conservation organizations and utilities can work together to minimize risks of electrocution and collisions of birds with electrical infrastructure. Further collaboration to share information and lessons learned are underway by the Power Line Working Group of the Crane Specialist Group.

Alternative Programs and Actions

- Work in partnership with utilities and conservation organizations to assess risks to birds and mitigation options for existing and planned electrical infrastructure;
- Develop geo-referenced databases in collaboration with utilities and conservation organizations to share information on planned developments and report information on bird interactions with electrical infrastructure;
- Work with governments, communities, and utility companies to increase awareness of risks of power-line strikes and significance to crane populations;
- Provide recommendations and guidelines on placement (preferably as early in the network planning process as possible) and marking strategies for new power lines to reduce risks to cranes;
- Encourage marking lines in high-risk areas and the development of new, more effective and inexpensive marking techniques for power lines of all sizes;
- Develop more effective mitigation devices for detection of power lines during daylight and low light conditions; and
- Encourage removal of power lines during periods when electrical supply is not needed (e.g., irrigation pumps not in use).

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CHAPTER 6

Methods to Reduce Conflicts Between Cranes and Farmers

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Abstract: Alternative methods to reduce conflicts between cranes and farmers range from relatively simple, inexpensive disturbance methods to changes in land use at a landscape scale. Visual and acoustics disturbance methods can be useful for small fields or gardens but require frequent changes to prevent habituation by the cranes. Changes in farming practices can be implemented by individual farmers and matched to the local situation. By altering timing of seeding and harvest, harvest methods, and other management practices, farmers can minimize the vulnerability of the crop or its attractiveness to cranes. Crop damage can be reduced by strategically locating high-risk crops away from crane roosts or high-use areas. Diversionary fields, where cranes can forage on nutritious, preferred foods near their roost without disturbance, are one of the more effective methods to reduce crop damage. Artificial feeding may be appropriate as a temporary measure but its long-term use should only be a last option where no alternative wintering areas or food resources are available or restorable. Chemical treatment of seeds can deter cranes from taking newly sown seeds and seedlings. Conflicts with farmers can be mitigated by financial or other compensation, or through conservation approaches. Financial mechanisms should be used cautiously as they can dilute or corrupt local traditions of tolerance. An integrated approach, using several methods, is more likely to be effective in the long term. Farmers and communities are more likely to embrace alternative measures if they understand basic crane ecology and if the measures are clearly beneficial to the farmers. Developing a broader range of tools to better understand the conflict, to understand farmer perceptions of cranes, and to help implement strategies to improve positivist attitudes is necessary. Multi-disciplinary approaches that incorporate social, economic as well as ecological aspects of the issue are very rare, and much needed to develop workable solutions.

Keywords: disturbance, farming practices, chemical seed treatment, compensation programs

The history of interactions between birds and farmers is long and likely dates back to the earliest efforts to cultivate grains or root crops that were attractive food for cranes. When large areas of natural habitat remained available to cranes and farming activities were small in scale and intensity, conflicts between cranes and farmers – primarily cranes damaging crops – were likely limited. However, as described in earlier chapters, crop types, cropping practices, and scale of agriculture have changed dramatically in many regions, increasing the potentials for conflict. Such changes often have affected the effectiveness of traditional approaches to deal with conflicts, such as scaring (e.g., Sugden et al. 1988). Seriousness of conflicts with cranes in subsistence farming likely has also increased in the recent decades, as human population have grown and economic pressures have intensified. Seemingly small damage to a crop can have substantial economic implications for subsistence or small-scale farmers (van Niekerk 2010).

Austin JE, Morrison K, Harris JT, editors. 2018. *Cranes and Agriculture: A Global Guide for Sharing the Landscape.* Baraboo, Wisconsin, USA: International Crane Foundation. 303 p.

Scarce but desirable resources might receive brief but intense use by the cranes, whereas more abundant resources may receive chronic use and damage. Viable solutions can be created based on an understanding of the life history of cranes and some innovation and flexibility in farming practices and among farm communities. Key to successful application of methods is understanding what food resources are most desired by cranes, what areas are most likely to be used, under what conditions, and when.

Alternative methods to reduce conflicts between cranes and farmers range from the simplest and most direct (hazing or harassment type disturbances) to changes in land use at a landscape scale. Methods will be more effective when tailored to the local situation, taking into account the life history of cranes and natural foods they use (Nowald et al. 2018), the changing seasons, crops, and farming practices, and a careful balance between the needs of cranes and farmers. Often the best approach is an integration of different methods, as no one method will be effective all the time. The sections below provide descriptions of different approaches, ranging in scale from local fields (disturbances) to landscapes (conservation programs). Table 1 provides an overview of the different method types, situational suitability for application, issues, and cautions or caveats.

Visual and Acoustical Disturbances

Visual or acoustical disturbances of feeding birds are the most direct methods to reduce crop damage by cranes. Disturbance methods are matched to the timing and duration of the birds' presence or interest in the crop and to scale (flock size and field size). If cranes are responding to short-term availability of foods or moving quickly through an area, only one or two disturbances at the right time and place may be adequate to deter them and move them elsewhere. For longer periods of potential conflict, repeated disturbances and a variety of methods may be necessary. Cranes can become habituated to disturbances, so some type of variation – frequency, magnitude, location, appearance, or type – is usually needed for these approaches to remain effective for a prolonged period. The effectiveness of one disturbance type can be reinforced by periodic additions of other disturbance types. For example, trained dogs or human patrols provide an animated visual dimension to the aural disturbance provided by crackers or propane cannons.

In small crop fields or gardens, cloth strips, scarecrows, or brightly colored balloons can be placed in fields to deter cranes from entering the field (Fig. 1). These passive visual disturbances are inexpensive and have proven useful in Zimbabwe (Fakarayi et al 2018). Periodically moving the location, animating, or periodically changing the appearance of these devices is needed to prevent cranes from habituating to them. Incorporating some means of movement to the scaring device, such as having the scarecrow rotate in the wind or be mechanically animated (e.g., pop-up scarecrow; Cummings et al. 1986), can enhance its efficacy. Such scaring devices are probably most effective for breeding pairs or small groups where the scaring device is within or very close to crop fields.

Tape or flags with reflecting surfaces have been used as a visual deterrent in smaller fields to discourage birds from damaging a wide range of crop types (Bruggers et al. 1986). The tapes are often silver on one side and colored on the other and flash brightly in sunlight and wind; in South Africa, the tape has alternating red and white bands. The tapes may be strung between poles or attached at only one end to move freely in the wind. When strung between poles, it can pulsate and produce a fluttering or humming sound in the wind that adds to the visual deterrence. Farmers in Uganda have used tape from old compact cassette tapes, strung between poles against the predominant wind direction, for similar visual and sound effects. Tape has also been used in Gujarat, India to prevent Common and Demoiselle Cranes depredating peanuts (groundnuts, *Arachis hypogaea*).

Table 1. Summary of methods to deter or prevent crop damage by cranes. Methods are most effective when intermixed with other methods. See text for details and full references.

Method	Suitable conditions for application	Cautions and caveats	Examples
Visual and audible			
Scarecrows or balloons	Small gardens or fields where people can frequently attend to them	Habituation by cranes unless items are moved or animated, or their appearance periodically altered	Gardens and crop fields in Zimbabwe
Reflective flagging or tape	Small gardens or fields where wind keeps the material in motion	Habituation by cranes	Small gardens and fields in South Africa and Uganda
Green laser beam	Roost areas	Effective only during low light or night or low-light conditions indoors (e.g., livestock barns); habituation possible	Airports and urban areas in Canada and USA
Noise-making devices (pyrotechnics, propane cannons, guns)	Small to medium fields or roost sites	Disturbance to livestock, people, or other wildlife; habituation by cranes unless intermixed with other disturbances; may require permits	Use of propane cannons in crop fields on staging and wintering areas in New Mexico, USA, and South Africa
Physical barriers			
Fencing	Very small fields, gardens, or livestock feeding sites	Requires careful design and placement to be effective and prevent injuries to cranes from entanglement	Fencing around livestock feed troughs in South Africa
Suspended horizontal wiring	Small roost ponds; small fields, or gardens with highly attractive foods	May be expensive to build and maintain; needs to be highly visible to birds to prevent collisions	Deterred Canada Geese from using roost ponds in Virginia, USA
Farming practices			
Timing of planting	All areas	Gauge timing of crop vulnerability with chronology of crane activity; timing options may be constrained by soil and weather conditions that are best for cropseed germination	Earlier planting and mat-uration of alfalfa in New Mexico, USA

Method	Suitable conditions for application	Cautions and caveats	Examples
Pattern of harvesting	All areas	May be constrained by field variability in crop maturation	Grain fields in Idaho, USA, and southeastern Russia
Direct grain harvest	All areas	Availability of equipment may be limiting for some areas or crops	Direct combining grains instead of windrowing in Saskatchewan, Canada
Post-harvest field treatment	All areas	May constrain farmers' ability to prepare field for next crop	Delayed plowing of crop fields in Hula Valley, Israel; Laguna de Gallocanta, Spain; and Civilian Control Zone (CCZ) area of South Korea
Cropping practices (rotation, no-till, fallow)	All areas	Loss of production from fallowed fields; fallowing or rotating crops often a short-term solution	Rotation of corn with other crops not attractive to cranes
Leave some waste grain	All areas	Small reduction in amount harvested	Managed fields in national refuge, New Mexico, USA
Crop varieties	All areas	May limit farmers' choice of crop varieties	Switch from summer to winter cereal grains, Germany
Mowing	Grasslands, hay land, or harvested crops with tall or rank vegetation	Do not apply where vegetation provides valuable cover for breeding cranes	Managed wet meadows in national refuge, Oregon, USA
Graze or burn	Grasslands or rice fields with tall or rank vegetation	Do not apply where vegetation provides valuable cover for breeding cranes	Managed wet meadows in national refuge, Oregon, USA
Altering crop location	All areas	Options for moving crop fields may be limited for individual farmers, but may be more feasible at a community level	Crop fields moved 5–15 km from roost areas; Daurski, Russia and Idaho, USA
Diversionary fields	Areas near roost or sensitive crops	Lost productivity (income) and land for crop that will not be harvested or only partially harvested. Funding, management, and locating diversionary field may be most effective when done at a community level.	Public and private fields, Idaho and New Mexico, USA, and Mecklenberg, Western Pomerania, Germany

Method	Suitable conditions for application	Cautions and caveats	Examples
Artificial feeding	Focal areas where and cranes congregations have developed but that provide insufficient natural food (staging or wintering area) and alternative habitats are lacking	Encourages high densities of cranes, putting them at risk of stress, disease outbreak or other catastrophic event; increases habituation to people; may reduce likelihood of protecting or restoring nearby natural habitats.	Izumi and Hokkaido, Japan
Chemical seed treatment	Newly planted seeds	Chemical should be approved for use on crop and cranes, and be non-toxic to other wildlife. Few chemicals available and approved for use (primarily Avipel® for field corn in the USA; not approved in Europe). Approved uses vary by state or nation, crop, and bird species covered.	Field corn seed treated with Avipel® in Wisconsin and some other states, USA
Compensation for damaged or partially harvested crops	All crop types, best focused on areas most critical for cranes	Requires funding source and administration. May dilute or even negate prevailing attitudes toward wildlife; farmers may come to expect compensation	Crop damage payments, New Mexico, USA; compensation for leaving unharvested grain, Aquitaine, France
Conservation programs			
Zoning (e.g., buffer zones)	Areas around roost sites or critical nesting habitat	Limits ability to use land; often comes with no compensation for lost or reduced agricultural use	Buffer zones limited land use activities at Yancheng Biosphere Reserve, China
Easements	All areas	Limits ability to use land, but usually involves compensation	Easements protecting wetlands or grasslands, USA
Habitat restoration	Habitats most critical for cranes, and more marginal for crops	Cost may be high depending on extent of damage or total area needing to be restored	U.S. Fish and Wildlife Service and U.S. Department of Agriculture
Incentives to maintain habitat or farming practices beneficial to cranes	Habitats most critical for cranes	Cost and administration; tailor to balance needs of cranes and agricultural livelihoods	Subsidies for creating crane habitat, European Union

Fig. 1. Cloth strips tied to stakes are used to try to deter Grey Crowned Cranes from feeding in a field (Photographer: Kerryn L. Morrison)

Other shiny objects such as aluminum foil plates can also be suspended on lines so they flash in the wind. Effectiveness as a deterrent is influenced by placement and density of reflective materials. Reflective tapes or objects have given mixed results but may be most effective in smaller areas and short-term situations, such as a ripening crop.

A more technical approach to visual deterrence is the use of Class IIIB lasers, which have a power rating between 1 and 500 mW (Sherman and Barras 2004, Baxter 2007). Moving green laser beams have been shown to be an effective deterrent for many bird species, including Sandhill Cranes, in the USA (Blackwell et al. 2002). Birds perceive the bright green beam as a long, moving stick sweeping across the field. Commercially available devices range from hand-held laser devices to large, programmable, stationary systems used primarily at airports and urban areas to prevent bird-aircraft collisions. Effective ranges vary from 100 to 3,000 m. The laser devices developed for bird deterrence are silent, non-lethal, and are generally considered safe to eyes. The method is most effective between dusk and dawn or during overcast, rainy or foggy weather conditions, but it is not effective during bright light conditions. Hence, it may have most value in deterring cranes from using certain roost sites. As with other visual deterrents, some birds can become habituated unless used with other deterrents. Portable lasers above 5 mw are prohibited from use in the USA, Canada, and many other countries.

Devices that create loud noises are useful across a range of flock sizes and situations (Gorenzel and Salmon 2008). Noise-makers include rifles and shotguns firing live ammunition or blanks; shotguns and flare pistols that shoot exploding or noisy projectiles; pyrotechnics such as shell crackers, bird bombs, bird whistles, whistle or racket bombs; and propane cannons. These tend to be most useful in situations where crops need to be protected for days or a few weeks, and louder methods can be effective at deterring large flocks. Most of these are manually operated devices, are relatively inexpensive, and can be used when and where needed, allowing much flexibility. However, the effect is usually of short duration, necessitating repeated visits to keep birds away. Other devices can be set up on a site to generate noise autonomously. Propane cannons are a scaring device commonly used to disperse birds from crops or high-risk areas in North America, Europe, and South Africa (Austin 2018) (Fig. 2). Cannons have been effective at distances of >600 m, so they can deter flocks from large areas. The cannons run autonomously by gas pressure and can be set to produce a loud blast at a set or random frequency. Birds can become habituated to such automated noise devices unless the sound changes its magnitude, pitch, or time interval. Hence, moving their location or integrating with other disturbance methods may be needed for longer periods. Use and placement of noise-making devices should consider possible negative effects on livestock and irritation to neighbors. Also, in many situations, permit or authorization may be required before using such methods. Ultrasonic devices are ineffective because birds do not hear on an ultrasound level. Noise-making devices may be the only deterrent method for crops such as potatoes in large fields where other methods (e.g., approved chemical repellent) are not available.

Several drawbacks of disturbance methods limit their use. Cranes often habituate to the same disturbance types and ignore disturbances at some distance away, so efficacy is best in small fields and gardens. Unless alternative fields are available for the cranes to move to, using disturbances to push

Fig. 2. Propane cannon set up to deter cranes from a field in Eastern Cape, South Africa (Photographer: John Smallie)

cranes off one field will just move the problem to new locations. Hence, a larger-scale or community-based approach, incorporating diverse methods, will be more likely to succeed in reducing overall conflicts with farmers. In addition, disturbance methods targeting cranes also will likely disturb other wildlife, which may not be desired. Selection and application of methods also should be done with consideration to the effects to other species.

The direct threat of mortality, combined with the human and noise disturbances associated with the effort (i.e. shooting), can be effective in the most problematic situations in deterring further bird use of those fields for that season and can make other non-lethal acoustical devices effective for longer periods (Baxter and Allen 2008). Shooting cranes is only legal in parts of the USA and Canada (only Sandhill Cranes, where their populations are quite large and are not threatened). In these countries, federal and state regulations allow limited, targeted lethal control of migratory birds where problems persist and are very localized. Such permits are carefully regulated and very limited in use. Landowners may obtain a crop depredation permit from the U.S. Fish and Wildlife Service, allowing them to shoot and kill a specific number of birds that are damaging crops in specified crop fields. Permission is given only after non-lethal management proves unsuccessful, and the individual is expected to continue to integrate non-lethal techniques when implementing any lethal measures.

Physical Barriers

Physical barriers such as fences, suspended wires, or netting are intended to prevent birds from walking or flying into a field. Given cranes' flight abilities, use of physical barriers is necessarily limited to small areas or to situations where cranes are flightless when the crop is most vulnerable. Where physical barriers are used, consideration and care should be applied to minimize the potential for collisions, entanglement, or entrapment of cranes or other wildlife. High visibility materials can minimize potential for collisions by cranes or other wildlife; careful structure of fences or overhead grids can prevent entanglement; and frequent monitoring can prevent prolonged entrapment if a bird does manage to get in.

Fences may be useful in some situations where cranes are most likely to walk in from another field or water area. A single wire strand has been successfully used around feed troughs to keep Blue Cranes from consuming livestock feed (sheep [*Ovis aries*] can fit under the wire but cranes will not bend to get under the wire to eat). A fence structure that is highly visible (stands out against the landscape or adjacent habitats) will serve as a visual deterrent as well as help to minimize potential for collision by flying birds. A variety of fence types may be applicable depending on materials available and the situation, including woven wire, wooden slats, plastic snow fence, chicken wire, or netting. Electric fences with multiple strands have proven effective in excluding wading birds at aquaculture ponds (Mott and Flynt 1995) and could prove useful for cranes in certain situations. Structure of the fence also is important to prevent entanglement, which can be a significant source of mortality and injury to cranes (Allen 1996, Fanke et al. 2011). Cranes can entangle their legs between strands when they make low, short hops or flights over multi-strand wire fences.

An alternative physical barrier is a horizontally suspended 'fence.' A grid or closely-spaced set of lines (wire, rope, twine, or reflective tape) is suspended over the area to be protected on a set of poles. Such barriers have been used to keep birds out of fish hatcheries, water bodies, gardens, and smaller farm fields. An overhead grid of wires was effective at deterring non-migratory Canada Geese (*Branta canadensis*) from using urban ponds, which led to the birds abandoning the area (Lowney 1995). The system requires a robust structure capable of supporting the weight of the lines without sagging and periodic maintenance to ensure it continues to hold up. As with vertical fencing, high visibility of the lines against the water or vegetation beneath is important, as is the spacing between the lines. Effective spacing is usually related to the bird's wingspan but likely is also influenced by bird behavior. The protected area may also have to be fenced to prevent cranes from walking in from the sides. Such a barrier may be useful for some types of intensive, subsistence agriculture.

Farming Practices

Cranes prefer to feed in open areas with low-growing or minimal vegetation, and thus are more attracted to newly sown, harvested, or plowed fields that can be easily probed than areas with standing crops or tall vegetation (Nowald et al. 2018). Crane use also is influenced by availability of food, whether the crop itself or other foods such as weed seeds, tubers, and invertebrates. Farmers can affect food availability and hence crane use by modifying their planting and harvest cropping practices. Some of the practices described below may not be feasible in areas where strong seasonality affected by climate or weather, such as the monsoon, prevents shifting of timing or some other practices. Targeted research on the ecology, habitat preferences, and behaviors of cranes relative to crops and farming practices would help to refine these approaches and develop more innovative means to balance farming activities and economic considerations with crane use, and consideration of impact to other wildlife.

Experience from a range of regions and crane species indicates the following methods can be effective in deterring crane use or attracting them to other, less vulnerable crops or fields:

- *Time the planting of crops so vulnerable seeds or germinating plants occur before cranes are present.* For example, wintering Sandhill Cranes in New Mexico, USA, are attracted to chufa tubers (*Cyperus esculentus*), which thrive in moist, disturbed soils. Such moist-soil areas in crop fields may support other natural foods attractive to cranes such as beetles and other invertebrates. Farmers had the most alfalfa damage in low-lying areas that had chufa tubers in alfalfa; cranes trampled or pulled up young alfalfa plants while probing for the tubers (Taylor 1999). However, if alfalfa was planted a few weeks earlier so it was more mature then wintering cranes arrived, damage to the more mature alfalfa plants was minimal. Planting crops so that they are mature enough to sustain probing or trampling (e.g., robust root and stem systems) can help mitigate such site-related problems.

- *Harvest vulnerable fields closest to the roost first.* Cranes prefer to feed close to their wetland roost and will range farther from their roost as foods in nearby fields are depleted. This strategy proved effective in reducing crane damage to standing wheat crops at Daurski State Biosphere Reserve in southeastern Russia (Oleg Goroshko, personal comm. 2016). This area provides breeding, summer, or autumn staging habitat for Demoiselle, White-naped, Eurasian, Red-crowned, Siberian, and Hooded Cranes; all regularly forage in crop fields.

- *Directly harvest standing crop where feasible, rather than windrowing.* In situations where availability of waste grains and weed seeds is low, cranes may feed on windrowed crops; windrows can also attract invertebrates and small mammals that then attract cranes (Fig. 3). On a major autumn staging area in

Fig. 3. Swaths of windrowed grains can be vulnerable to crane damage (Photographer: Jane Austin)

Saskatchewan, Canada, cranes appeared to prefer to feed in harvested areas of the field rather than the windrows, where grains could be more easily handled (Sugden et al. 1988). If crops have to be first windrowed to finish curing, crane use could be deterred for a short time using disturbance methods such as propane cannons.

- *Don't disk or plow harvested fields until all vulnerable crops in the area have been harvested.* Disking or plowing buries a large proportion of unharvested grains and weed seeds but can also expose some seeds, tubers, and invertebrates previously hidden in the soil. Cranes and other birds can respond rapidly to the newly exposed foods, and then move on to other areas as those foods are depleted. In the Hula Valley, Israel, autumn-staging Eurasian Cranes are allowed to forage in fields where there is least potential for damage and are hazed from unharvested fields; cranes feed on waste peanuts and corn (maize; *Zea mays*) (Shanni et al. 2018). In Laguna de Gallocanta, Spain, plowing of harvested fields reduced food availability to Eurasian Cranes through winter and could delay the shift to foraging on newly sown grains (Alonso et al. 1994, Alonso et al. 2018). In the Cheolwon area of the Civilian Control Zone (CCZ) of South Korea, Red-crowned and White-naped Cranes spent more time foraging on the few unplowed rice (*Oryza sativa*) fields than in adjacent plowed fields, indicating greater food availability in unplowed fields (Lee et al. 2007). Due to its limited development, the CCZ is one of the most critical migratory habitats for these threatened cranes. Farmers in the CCZ now plow most of their fields after the autumn harvest rather than in the spring as they did previously. Cranes observed on the few remaining unplowed fields in the CCZ spent more time foraging than cranes on adjacent plowed fields.

- *Use crop rotation, no-till practices, and fallow fields to attract cranes to fields with less vulnerable crops or to unused fields.* In Wisconsin, USA, nonbreeding Sandhill Cranes preferred to forage in soybean (*Glycine max*) and fallow fields that had been planted to corn the previous year and still had waste corn available (Su 2003). The use of no-till practices left corn stalks and other residual plant material on the surface that contained invertebrates. Cranes foraging in no-till fields that had been corn previously benefitted from both invertebrates and waste corn kernels. Fallow fields that have abundant weed seeds such as foxtail grass (*Setaria viridis*) or waste seed from the previous crop also can provide attractive foraging opportunities for cranes and other granivorous birds. Crop-rotation, no-till, and fallow fields can serve the same function as diversionary fields (see below) by providing attractive, alternative foraging areas and a combination of native and agricultural foods. Farmers may also benefit by cranes consuming unwanted seeds and insects. However, fallowing or rotation of vulnerable crops may provide only a short-term solution for a particular field, and thus farmers may need to integrate these practices with other approaches.

- *Leave some grain in the field during harvest.* Increased efficiencies of modern combines have substantially reduced waste grain left in harvested fields, leaving little for foraging birds (see Ilyashenko and King 2018). Similar to practices suggested above, slight reductions in combine efficiency for portions of a field or for selected fields may leave sufficient waste grain in harvested fields to keep cranes from seeking unharvested or newly sown fields.

- *Select crop varieties that can be planted or harvested outside the time frame of most crane activity.* Disconnecting the period of crop vulnerability from the time most cranes are present can be effective in avoiding conflicts. For example, grain varieties that mature early can be harvested earlier, before concentrations of staging cranes threaten crops. Farmers in Germany experienced less crop damage when they switched from summer to winter cereal grains (Nowald 2013).

- *Mow tall grasslands or haylands to remove tall vegetation.* Mowing taller vegetation helps to improve availability of natural foods (seeds, tubers, insects, small vertebrates). Mowing can be timed to attract cranes to particular areas, such as along the edges of diversionary-crop fields or near roost wetlands. This method is usually applied in staging and wintering areas, where mowing is unlikely to affect nesting birds. Tall vegetation may provide valuable cover to other wildlife species, such as bitterns (Ardeidae) or rails (Rallidae), so its application should consider potential effect on other wildlife species of concern.

- *Graze or burn grassland areas or flood rice fields.* Grazing and light burning of grassland areas or flooding harvested rice fields can improve availability of natural foods or waste seeds for cranes by removing standing vegetation and residual litter (Bouffard 1993). These disturbances also stimulate new productivity on those fields, enhancing their value in the long term. Dung from livestock grazing provides additional natural invertebrate foods (e.g., dung beetles, fly larvae) attractive to cranes. Crane usage is usually short and intense, but these practices may be useful to attract cranes away from vulnerable crops. However, such practices probably should not be used where the vegetative cover is important to breeding cranes, or important to other wildlife species of concern.

Altering Crop Location Relative to Crane Use Patterns

Location of crop fields relative to roosts is one of the most important factors influencing field use by cranes (van Niekerk 2010, Austin 2013). If farmers can identify those areas of their farms that are most susceptible to crane damage, they can focus their deterrent efforts more efficiently. Breeding cranes forage within or very close to their breeding territory; foraging area will expand as chicks become more mobile with age. Nonbreeding cranes range more widely, often up to 30 km from roosts (Sugden et al. 1988, Alonso et al. 1994; Alonso et al. 2018). At autumn staging areas or on wintering grounds, cranes may shift to new roosts and foraging areas as foods are depleted in one area or new, more attractive food resources appear. High densities of cranes lead to greater competition among individuals and also can cause cranes to forage farther from roosts or shift to new areas. These considerations may not be helpful in situations where farmers control very limited areas, particularly small holders, and only some farmers may have fields at risk. Consideration and planning of crop location and vulnerability at the landscape scale may be coordinated at the community level (e.g., rental trades or agreements).

Given cranes' foraging activities relative to roost sites, the most vulnerable crops should be grown farthest from roosts and breeding territories. Crops at higher risk of damage are better placed farther from roosts or in areas that have other attributes that would deter crane use, such as higher levels of human disturbance or very tall vegetation or topography that limits visibility for cranes. In the Daurski State Biosphere Reserve, Russia, crop damage to wheat fields was reduced by moving that crop to areas 5–15 km away from the Torey Lakes. Crane foraging use on the distant fields was 3–7% of the level in fields located ≤1 km from the lakes (Oleg Goroshko, unpublished data). In South Africa, however, crop damage by Grey Crowned Cranes within a 5-km buffer of study sites was not affected by distance from wetlands (van Niekerk 2010), which suggests the distances considered may have been too small to be effective for deterring damage. At Grays Lake National Wildlife Refuge (NWR) in Idaho, USA, managers largely eliminated damage to barley (*Hordeum vulgare*) crops by autumn-staging Sandhill Cranes by moving the barley fields >5 km away from roosts (Austin 2013). The new field locations were on higher grounds and barley matured earlier; therefore, the barley could be harvested earlier than the original fields in the cooler valley bottom.

Aspects other than the crop itself may attract cranes to or deter cranes from using a crop field. Fields located near frequent disturbances, predator threats, or limited visibility (e.g., surrounded by trees or abrupt topography) tend to be avoided by cranes, and may be lower-risk sites for planting vulnerable crops.

Diversionary Fields

Diversionary fields are fields or crops that are managed to attract cranes away from other crops, providing them with preferred, alternative foods and a place where they are allowed to feed undisturbed. Diversionary fields may be planted crops, fallow fields, or managed grasslands that have abundant weed seeds or natural foods. The more effective diversionary fields are those that match preferences and nutritional quality sought by cranes, are situated in areas of high use by cranes and, for farmers, provide positive benefits relative to their cost and trade-offs.

A number of the farming practices as described above can be applied to diversionary fields. The diversionary or luring effect may be short term, through a management action (e.g., flooding harvested rice fields or burning grasslands), or longer term by planting a crop intended to be left for birds. Mowing or flattening standing crops can enhance food availability and accessibility to cranes at strategic times (Fig. 4). Strategic placement of diversionary crops near roost sites or areas that traditionally receive high crane use can effectively intercept cranes from flying to other fields to feed. Hazing or intentionally disturbing cranes from vulnerable crops is often integrated with diversionary fields to get cranes to find the diversionary crop fields more rapidly. If diversionary fields are available before at-risk crops, cranes may not bother the at-risk crops.

Fig. 4. A mown strip in a barley field on Grays Lake National Wildlife Refuge, Idaho, USA, was used to divert Sandhill and Whooping Cranes from damaging private barley fields in the area (Photographer: Steve Bouffard, U.S. Fish and Wildlife Service)

The implementation of diversionary fields has proven effective at reducing conflicts in many areas. In Mecklenberg-Western Pomerania, Germany, financing diversionary-crop fields by provincial governments and non-government organizations have proven to be more successful in reducing conflicts between cranes and farmers than compensation payments for crop damage (Nowald 2013). Since the guidelines were remitted in 1996, farmers have established up to 20 feeding sites for cranes in the Rűgen-Bock area; those sites in turn have become valuable for tourism (see Patterson-Abrolet et al. 2018). At the Hortobágy National Park, Hungary, the park directorate manages 50 ha of corn fields for Eurasian Cranes, geese (Anserini), and ducks (Anatini) during autumn migration (Végvári and Hansbauer 2018). In southeastern Idaho, USA, diversionary fields planted to barley have been effective at reducing crop damage to unharvested or windrowed wheat (Austin 2013); barley matured earlier and had higher yields than the wheat it protected. Diversionary crops were planted on public lands near roost wetlands or, through subsidized means, on private lands. At Bosque del Apache NWR, New Mexico, corn is planted on refuge lands and periodically mown or knocked down during the winter to provide new pulses of food for wintering Sandhill Cranes (Austin 2013, Austin 2018). At Daurski State Biosphere Reserve, long narrow diversionary fields were placed close to the Torey Lakes and planted to millet (*Panicoidea* spp.) (Oleg Goroshko, personal comm. 2016). Millet was inexpensive, preferred by cranes, and also self-seeded, so it was abundant in those fields left fallow the following year. In the Hula Valley, Israel, Eurasian Cranes are allowed to land and forage freely on a “between fields” strategy during the autumn stopover period, allowing them to use those fields where there is no potential damage; cranes are simultaneously hazed from vulnerable crops (Shanni et al. 2018).

Diversionary fields require an investment of land, time, and often seed. Diversionary fields, whether planted or left fallow for cranes, incur a cost of not producing a harvestable crop. If planted, seeds have to be acquired and time spent planting or tending it. Seed for some diversionary crops are inexpensive compared to crops they are intended to protect (e.g., millet vs. wheat). Farmers may find that an investment in diversionary crops is relatively small compared to the costs of crop damage and therefore be willing to accept those costs themselves. In many situations, however, farmers may need financial or other means of support or encouragement to create diversionary fields. Those resources may be provided through a collective (e.g., from the community or group of impacted farmers), from a government agency, or from a conservation organization. Alternatives can be crafted to best match the situation and the interests of the farmers. At the community level, a local cooperative could be formed to share in expenses and to identify the most appropriate fields among participating farmers. Free seeds or farming assistance could be provided to help farmers plant or manage their own diversionary fields. Private lands could be leased for diversionary crops or fallowing. Similar financial agreements may be made to manipulate cropland to function as a diversionary field (e.g., delaying plowing or to flood harvested rice). Diversionary crops are often placed on publicly owned or conservation lands; these crops often are closest to roosts and breeding territories and can be integrated with their other land management (Austin 2018). Cost of planting diversionary crops on private or public lands can also be defrayed by share-cropping arrangements: a farmer agrees to raise a crop on designated land and harvests a portion of the crop, leaving the remainder for wildlife. Alternatively, a farmer may receive other compensation for planting a diversionary crop on their own or other lands, such as receiving farming opportunities elsewhere. As farmers gain experience with integration of diversionary crops into their farming practices and see their effectiveness, they may become more willing to take on the costs themselves.

Kubasiewicz et al. (2016) outlined four key issues to consider when developing an effective approach using diversionary methods. Careful consideration for these issues can inform choices about when, where, and how to implement diversionary feeding. A fifth issue, from the farmers' perspective, is whether land is available for use of this practice. Monitoring is key to evaluating whether the method is effective in reducing conflict with farmers and meeting objectives.

1) Is there sufficient information on the target species?
    a) Is the population food limited?
    b) Is damage caused by a subset of the population?
    c) How will the target species respond to diversionary food?
2) What spatial distribution of diversionary food should be used?
    a) How will the food be distributed?
    b) Where should feeding stations [fields] be located?
3) Does feeding have detrimental effects on the target species or surrounding area?
    a) Does feeding create dependency for the target species?
    b) Is feeding detrimental to the health of the target species?
4) Have effects on habitat conditions and non-target species been evaluated?

Artificial or Supplemental Feeding

Artificial or supplementary feeding is the intentional provision of easily accessed foods (usually harvested grain) to wild cranes. Artificial feeding is used 1) to divert cranes away from crops, as a means to reduce crop damage, as described earlier in this chapter, 2) to sustain the health and survival of cranes where the availability and quantity of natural foods are very limited, and 3) to attract cranes

Fig. 5. Grain is distributed by tractor to support large flocks of wintering Eurasian Cranes in the Hula Valley, Israel (Photographer: Efi Naim)

to certain areas for tourism. Most artificial feeding of wild cranes occurs on staging and wintering areas when birds naturally congregate around food resources. Though in some cases one individual, one family, or a small number of individuals of wild cranes may be fed by people, large foraging flocks are commonly formed around the artificial feeding sites developed to reduce crop damage or sustain cranes. Best known examples are the large concentrations of Red-crowned, White-naped, and Hooded Cranes at feeding sites in Hokkaido and Izumi, Japan (Amano 2009), and Eurasian Cranes in the Hula Valley, Israel (Shanni et al. 2018).

Artificial feeding can be critically important for sustaining some populations during the nonbreeding season when habitat and foods have become very limiting, or as a valuable method to minimize crop damage in the face of growing populations and limited habitat. For example, in the Hula Valley, Israel, artificial feeding has become an important and heavily used means to minimize crop damage during winter and spring for an expanding population of Eurasian Cranes (Shanni et al. 2018) (Fig. 5). The Red-Crowned and Hooded Cranes populations wintering in Japan have become heavily reliant on artificial feeding because most of the historic wintering wetlands there were lost to intensive agriculture or human development (Ohsako 1987, Amano 2009). Today, more than 80% of Hooded Cranes winter at the Izumi Feeding Station on the Japanese island of Kyushu. One of the greatest conflicts with agriculture is with dairy farmers; cranes may consume foods intended for livestock or bring infectious bacteria into barns, and cranes walking into barns can agitate livestock, reducing milk productivity (Hiroyuki Masatomi, personal comm. 2013). Cranes also may peck holes in the covers of compost and hay rolls, preventing maturation of fermentation. To prevent such risks to cranes and conflicts with dairy operations, farmers could employ methods that alter cranes' behavior so they revert back to more natural aversion to humans in those situations, such as visual and noise disturbances. However, the foods that attracted them in the first place will need to be removed or shifted away from problem areas.

The distributions and unnaturally high concentrations of cranes resulting from artificial feeding increases stresses from conspecific interactions and puts populations at risk of disease outbreaks and catastrophic events (e.g., severe storms) that could decimate the population. The most worrisome aspect of artificial feeding is the increased risks of infectious disease due to the high densities of birds. Under such conditions, viral and bacterial diseases and parasites can quickly spread through the flock through respiratory droplets and accumulated feces (Watanabe et al. 2003). Foods scattered on the ground or snow attract not only for cranes but also swans, ducks, and many terrestrial birds, which may transmit diseases to cranes. At feeding sites at Hokkaido, large numbers of Whooper Swans (*Cygnus cygnus*), which are susceptible to avian influenza, comingle with Red-crowned Cranes on the feeding grounds during winter, which raises serious concerns about the spread of the disease from migrant swans to cranes. In the winter of 2010–2011, avian influenza H5N1 was found in waterfowl at Izumi, where a mixed flock of about 13,000 cranes consisting of Hooded, White-naped, and a few Eurasian Cranes were wintering, but fecal samples of Hooded Cranes all tested negative for the disease (Otsuki et al. 1987, Chen et al. 2006).

The habituation and increased use of human-dominated areas by cranes also pose greater risks of exposure to agrochemicals (particularly poisons used to control rodents or insect pests), dogs (*Canis lupus familiaris*), and power lines (see Ilyashenko 2018), and collisions with vehicles. Further, artificial feeding to replace lost habitat requires substantial economic and logistical commitments year after year, which may not be sustainable. However, if carefully managed, feeding stations can provide communities with additional income from tourism and opportunities to educate the public about cranes.

Two of the greatest risks from artificial feeding is that it pulls cranes away from natural habitats that may be nearby and provides a false sense that wetlands and other natural habitat are not important for conserving cranes. By removing the necessity of habitat protection, cranes can become increasingly dependent on feeding stations, with their diets less varied and their conservation status actually deteriorating. In such situations, cranes may survive but the numerous other, conservation relevant waterbird species that normally co-exist with cranes may be left without either habitat or food.

Effects on Vital Rates, Population Dynamics, and Distribution

Where natural foods are limiting, artificial feeding can alter cranes' health, distribution, survival, and potentially their productivity. Artificial feeding at stopovers in spring and autumn is believed to be an important factor in the maintenance or increases in some crane populations, including Red-crowned Cranes in Hokkaido, Japan (Masatomi et al. 2007), Hooded and White-naped Cranes in Japan and Korea (Davis 1998), and Eurasian Cranes in Europe. Flock sizes and densities are often higher at artificial feeding sites than on croplands or natural habitats because of the high density of foods available (usually grains). The larger flock sizes resulting from artificial feeding can provide greater levels of vigilance against predators and disturbances (Masatomi 2000). Artificial feeding of wild cranes, however, rarely occurs just before or during breeding, so effects of winter artificial feeding on reproduction may be indirect by affecting body condition. Unfortunately, no studies as yet have compared body condition, health, survival, or reproductive success of cranes that have had access to artificial food resources compared to those that rely on natural foods and habitats.

Nonbreeding cranes move to areas where food availability is high, and they may abandon traditionally used areas when foods become scarce. This adaptability has served them well in dealing with natural variations in food availability. Where natural habitat and food resources have become highly limited, artificial feeding has altered crane distributions and densities. In Khichan, India, located in the Thar Desert, organized feeding of Demoiselle Cranes has resulted in attraction of >6,000 cranes during the winter, instead of fewer than 100 reported historically (Pfister 1996). While this has enhanced opportunities for tourism, the village is extremely divided about the feeding since the farmers endure substantial losses due to cranes feeding on their crops. As crane numbers grow the problem is exacerbated; effective solutions are needed to balance interests of stakeholders and cranes. In China, numbers of wintering Red-crowed Cranes gradually declined at traditional wintering sites such as lakes along the Yangtze River while their numbers gradually increased at the Yancheng Nature Reserve since the 1980s (Ma et al. 1998). Those congregations may have been caused not only by environmental deterioration along the Yangtze River and in lands surrounding the reserve, but also by the effects of artificial feeding and abundance of natural foods within the core areas of the nature reserve. Red-crowned Cranes in Hokkaido also are extending their distribution areas in both breeding and wintering seasons (Hiroyuki Masatomi, personal comm. 2013). In the Kushiro marshes, Japan, some people recently started offering foods during the breeding season to a few pairs of Red-crowned Cranes at the peripheral areas of the main breeding grounds. This activity may promote expansion of their breeding distribution in Japan (Hiroyuki Masatomi, personal comm. 2013).

Artificial feeding may be appropriate as a temporary measure, such as attracting birds into a new area where natural habitat and food resources for cranes are being developed. However, artificial feeding is not desirable as a long-term conservation method As such, artificial feeding should be considered only a last option where no alternative habitat or food resources are available or restorable.

Seed Treatments to Prevent Damage to Newly Sown Crops

Cranes can damage newly planted fields by eating planted seeds or the young seedlings. Such damage has been reported most often for wheat, corn, rice, and oats (*Avena sativa*) but also can damage young alfalfa fields. Economic damages can be particularly significant for small farmers (van Niekerk 2010). Cranes may be attracted to the fields specifically for the sown seeds or because the cultivation has enhanced the availability of other foods such as weed seeds, tubers, or invertebrates. Seeds and seedlings are most vulnerable in the first three weeks after sowing, and crane use usually ends when seedlings are 5–10 cm tall (Littlefield 2002, Lacy 2018) (Fig. 6).

Fig. 6. Uprooted corn plant with germinated seed still intact (Photo: International Crane Foundation)

The most effective method of deterring cranes and other birds from newly planted fields is chemically treating the seeds with a taste repellent before planting. Seedlings usually can also be sprayed with the same formulations to deter crane feeding (e.g., on alfalfa). Avipel® (Arkion Life Sciences) is a formulation of anthraquinone, a naturally occurring, nontoxic substance that has proven to be an effective avian foraging repellent for both seeds and plants (Fig. 7) and that has very low toxicity for other wildlife (any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government). Use of Avipel® has been successfully demonstrated and applied in Wisconsin, USA, to deter Sandhill Cranes from pulling up corn kernels and emerging corn plants (Lacy 2018). In the United States, it is currently registered and approved for use only on field corn, rice, and sunflowers (*Helianthus*); it is not authorized for use in the European Union. Protection of a cornfield with repellent-treated seed did not shift the problem to another field but caused the cranes to select other foods in the same field. However, as use of the chemical deterrent increases in an area, crane use of remaining untreated fields may increase. Responses elsewhere will likely depend on alternative foods available in the treated fields or other nearby fields. ReJeX-iT AG®36 is a methyl anthranilate-based formulation approved in the United States and Canada as a bird repellent; it deterred captive

Sandhill Cranes from eating corn kernels (Blackwell et al. 2001), but it has not been tested for efficacy in the field for cranes and is not approved for use on cranes in the United States.

Fig. 7. Effectiveness of the seed treatment, Avipel®, to deter Sandhill Cranes from damaging seeded corn fields is demonstrated in this field. The dotted line demarks the untreated (left) and treated portions of the field (Photographer: Anne Lacy)

Chemical seed treatments for avian deterrence are often inexpensive relative to financial losses incurred by crop damage and have shown to be readily accepted by commercial farmers once provided with information and demonstration. Some seed treatments that may deter bird damage may have undesirable effects on other wildlife or the environment. Application of any chemicals to deter avian use should consider environmental toxicity, be approved for bird use, and follow approved application methods. Anyone considering use of chemical repellents to reduce crop damage by cranes should carefully study and follow current regulations in their area for approved uses, including crop type, species covered, and application methods, to ensure safe and legal use.

Financial or Other Compensation for Damaged or Partially Harvested Crops

Several publications on seed treatment have been published since this chapter was completed. The deterrent, 9-10 anthraquinone, was effective in comparison to methyl anthranalate and limonene (Lacy et al. 2018). The ecological scale of effective deterrence for 9-10 anthraquinone effectively separated planted corn kernels from other food items located within the same field (Barzen et al. 2018). Finally, landscape implications of using a deterrent have been identified (Barzen and Ballinger 2018).

Farmers can be compensated for damaged crops by direct payments, replacement crops, or alternative compensation, such as opportunities to farm other lands. Compensation alleviates the immediate economic impact to farmers, which can be especially important for subsistence or small-scale farmers. However, compensation programs need a source of funding and an administrative mechanism to make assessments and payments. Credible measurements of actual crop damage and valuation of the loss are often difficult, and damage perceived to be done by one species may in fact be due to another species or other factors (van Velden et al. 2016). Individuals may become accustomed to being paid rather than seeking alternative solutions that may be more sustainable in the long term. Compensation programs can have other unintended consequences. Farmers may take more risks (e.g., putting high-risk crops in high-risk areas) or be more willing to plant at-risk crops in marginal farmland (e.g., wetland margins) because they are likely to be compensated. Implementation of economic compensation for crop loss also can dilute or even negate prevailing attitudes toward wildlife and should be avoided (Bulte and Rondeau 2005). Bulte and Rondeau recommended implementing more sustainable alternatives, such as compensating communities and landowners for ecological services (e.g., not converting native habitats).

Benefits of compensation programs are highest when subsidies or compensation are focused on areas of most important crane habitats, such as those close to breeding territories and important staging and wintering roosts. Landowners can be compensated to not cultivate, to accept partial losses, to leave land untilled or partially unharvested, or to leave some waste seed (e.g., reduce harvest efficiency, or allow more weed seed production). For example, farmers in Aquitaine, France are offered 5-year contracts by the government to maintain 80% of their existing corn fields and leave corn stubble unplowed into the winter (Gallato 2003, Salvi 2012). In other areas of France where the main damage is to newly sown crops, they also may be given crop damage payments. The Dazhanhe National Nature Reserve in China, an important breeding area for Hooded Cranes, encourages and rewards farmers to leave enough corn on arable lands to provide food for the cranes (Guo et al. 2005, cited in Luo et al. 2012). In the United States and Canada, integrated crop-depredation programs include crop compensation payments where other approaches (e.g., scaring devices and diversionary fields) were unsuccessful in keeping cranes from depredating crops (Mitchusson 2003, Austin 2013).

Conservation Programs to Sustain Crane Habitats and Agricultural Livelihoods

Many of the conflicts between cranes and farmers have evolved as agriculture has shifted from traditional, low-intensity agricultural practices and land uses to more intense use of the landscape with concurrent losses of natural habitats. Hence, programs that restore or sustain low-intensity land uses, or that restore and protect crane habitats, can help alleviate conflicts or prevent them from intensifying. Options include zoning, easements, support for habitat restoration, and subsidies or incentives to maintaining habitat or specified land use practices. Like compensation programs discussed above, resources to support such programs can come from the community, government, or conservation organizations, or from partnerships involving multiple groups.

Government policies and zoning laws can be designed to limit land uses that would degrade natural habitats or create disturbances that deter crane use. In the United States, federal and state policies protect many wetlands from drainage or filling while maintaining grazing, cropping, or other uses. While such policies may not target specific species, the natural resources provided through those protected habitats or working lands can serve to provide alternative foods and attract cranes away from crops. In the USA, the Department of Agriculture's (USDA) Wetland Reserve Program is a voluntary program designed to assist and compensate farmers for conservation or protection of wetlands; this and other USDA programs have protected thousands of hectares important to staging and wintering Sandhill and Whooping Cranes (Hohman et al. 2018). Conservation designations can also be used as part of conservation policies to constrain human activities. For example, buffer zones around conservation reserves may be designed to allow limited settlement and agricultural activities. Landowners retain rights and ability to use the land in the zone (e.g., grazing, cultivated crops, fishing, harvest of plant material), but regulations limit types, intensity, and sometimes seasonality of use. Cranes then have a larger area of secure foraging and are less likely to conflict with farming activities. Buffer zones controlling human activities have been established at the Yancheng Biosphere Reserve, China, for Red-crowned Cranes (Li et al. 1999). Buffer zones can be a key aspect in reserve management because they provide a link between the reserve managers and local inhabitants. Local communities are more likely to accept and cooperate with the management of buffer zones or other conservation designations if landowners have been informed of the ecological significance of the area and species, and how the designation will affect their livelihoods (Kim et al. 2011).

Alternative approaches to laws and regulations, which usually provide no compensation to those affected, include easements, subsidies, or incentive programs. An easement is a certain right to use the real property of another without possessing it. Easement rights may be purchased from private landowners to allow, limit, or prevent certain activities or land uses. For example, the U.S. Fish and Wildlife Service purchases easements to prevent wetlands from being drained or grasslands from being converted to cropland. Incentives or subsidies can be used to direct or encourage land uses that sustain both agricultural livelihoods and wildlife. The European Union has implemented agri-environmental schemes to facilitate habitat restoration in less productive areas. Among the programmatic tools are specific subsidies for creating habitats for crane and geese in Hungary (Vegvari and Hansbauer 2018). In Lorraine, France, programs provide support to landowners to restore and maintain traditional uses of grasslands (Salvi 2012). In South Africa, agencies are exploring the potential of using carbon offset credits to protect peatlands, which provide critical habitat for Blue Cranes (Kerryn L. Morrison, personal comm. 2016). Agencies there also may offer technical assistance to agricultural producers through the Biodiversity Stewardship program to improve their productivity and income in trade for conserving habitat (Franke and Theron 2018).

Habitat restoration programs, supported by direct payments or subsidies, can be implemented to restore wetland and grassland habitats. This approach may be most attractive to landowners on marginal lands, where intensive inputs are needed to sustain crop production. The restored habitats may still be used for grazing or periodic haying. For example, wetland restoration programs of the U.S. Fish and Wildlife Service and U.S. Department of Agriculture help to keep ranchers on the land by providing improved water resources for livestock. Similar programs are funded by Ducks Unlimited in the United States and Canada.

Ecological effects of conservation programs in farmed areas are a function of resulting ecological contrast, agricultural land-use intensity, and landscape context (Kleijn et al. 2011). Given the political and financial commitments of such conservation approaches, it is important to evaluate their effectiveness as to what extent they improve habitat conditions, survival, and reproductive success for the targeted species group relative to conventionally managed habitat. Kleijn et al. (2011) focus on European programs to counteract biodiversity declines, but they raise important questions about conservation programs that are also appropriate for target species such as cranes: 1) What are the effects of conservation initiatives on the demography and population dynamics of species? 2) How do effects of local conservation initiatives scale up to national or continental trends? 3) What part of species richness responses to conservation initiatives are caused by behavioral responses and what part by population-level responses? And 4) How significant are effects of conservation initiatives compared with effects of land-use change resulting from autonomous processes (e.g., the introduction of new [varieties of] crops, new harvesting techniques or ongoing intensification) in the wider countryside that is used by the target species? Monitoring and assessment of conservation programs will be valuable for improving development and implementation of more effective and feasible approaches to conserve cranes and biodiversity while sustaining farming economies and culture.

To encourage involvement and support, and to prevent skepticism or mistrust, design and implementation of conservation policies or programs need to make sense to the community, be biologically and socially sound, be as unbiased as possible, and engage the local community from the start. Social and economic considerations include minimizing constraints on farmers' abilities to sustain a livelihood, and minimizing impact on property values (Kim et al. 2011) and community and landowner rights (Campese et al. 2009).

Developing New Approaches

Understanding how to ensure persistence of cranes alongside farming is currently limited by lack of targeted research and monitoring, particularly in landscapes where traditional, subsistence, or low-intensity farming dominates. Not surprisingly, the vast majority of research and knowledge about methods to deter crane damage to crops relate to migrating or wintering cranes in large flocks. Observations and research related to resident crane populations, such as the crowned cranes in Africa and Sarus Cranes in India, have been minimal but greatly needed. More robust monitoring and research studies are important to understand of whether – and how – the application of a practice or program is working, its economic effectiveness and social acceptance, and to note if undesirable unintended consequences are emerging (like in the case of Khichan, India). These monitoring and research needs apply to all scales, from methods implemented by individual farmers to landscape- and regional-scale conservation programs (Kleijn and Sutherland 2003). One powerful but simple research approach for investigating the effectiveness of new methods or programs is a before-after design. Ideally, studies should include collection of baseline data, incorporate control sites (similar to sites where the method is applied in every respect but the applied method), and both control and method-application sites should be sufficiently replicated.

New explorations in previously unstudied landscapes are showcasing how even very high degrees of human use of habitats embedded within agricultural landscapes do not necessarily deter their use by cranes and other diverse species (Sundar and Kittur 2013). Developing a broader range of tools is necessary to understand conflict as well as farmer perceptions of cranes, and to help implement strategies to improve positivist attitudes. Multi-disciplinary approaches that incorporate social, economic as well as ecological aspects of the issue are very rare, and much needed to develop workable solutions.

There is increasing evidence that conflict is perceived differently by different cultures, and in some areas, regular occurrence of aspects such as crop depredation (for food and for nests) appears to be tolerated by farmers. Economic approaches currently dominate literature due to their predominance in the developed world. However, technical approaches to deter cranes (e.g. use of propane exploders, chemical taste deterrents) often are not feasible in areas of small-holder farming systems as farmers have no money to invest in such technologies. Careful scrutiny of local practices in regions where societies are not entirely monetized should prove invaluable to understanding how conflict situations can be eased.

Farmers around the world have used a variety of traditional methods to keep birds away to reduce damage, but there has relatively little attention accorded to these methods. There also is minimal understanding of the social and attitudinal characteristics of farmers on these landscapes that disallows a broader conceptualization of potential solutions to other landscapes. Working with sociologists and anthropologists to capture examples of traditional method may provide inexpensive and locally-relevant solutions that are as yet unrecognized.

Cross-sectoral discussions, for example between agriculturists and conservationists, are rare in most areas important for cranes. This situation has prevented early interventions during planning stages that could potentially help reduce future conflicts, particularly situations involving government programs or policies. More cross-sectional dialogue early in the process allows for adjustment of plans before full implementation and minimize potential detrimental impact to crane habitats and populations (Elphick et al. 2018). Improving engagements between crane conservationists with governmental departments responsible for agriculture and water use is therefore vital.

Conclusions

A range of alternatives is available for reducing conflicts between cranes and agriculture. These alternatives range from relatively simple, inexpensive scaring methods appropriate to small fields to changes in farming practices that individual farmers can implement, to more complex landscape-scale programs. Conflicts are more readily contained or prevented if a program is started before birds find the crop. Experience and investigations into efficacy of the different approaches show that an integrated approach, using more than one method, is more likely to be successful than reliance on any one method. Which methods will be most effective will depend on the scale of the problem and the environmental, social, and economic situations? Given the range of alternatives, an integrated program can be developed at the level of an individual farmer, the community, or the region to address problems. Involvement and planning at the community level help to coordinate efforts and share information (Hake et al. 2010) and to prevent problems from being pushed onto neighboring farms or areas. Education of farmers and communities is an important component (see also Patterson-Abrolat et al. 2018). Farmers and communities are more likely to embrace alternative measures if they understand why and when cranes damage crops, why some areas or crops are most vulnerable, the real extent of damage, and the ecological significance of habitat and cranes. Understanding basic crane ecology also can help farmers create new alternatives that are appropriate to their crops and local situation.

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CHAPTER 7

How Do We Improve Conservation on Privately-Owned Lands?

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Abstract: Worldwide, most land is privately owned or controlled. Most private land, in turn, is used for agricultural purposes. It follows that, to solve land-based environmental problems and to reduce conflicts between agriculture and wildlife, it is necessary to work more closely and effectively with private landowners than previously accomplished. Such work can succeed but requires stronger and more diverse collaborations that create ecologically effective solutions (solutions that address a species biological needs and will persist as a result), place these solutions in a marketplace such that they are economically sustainable (i.e., simultaneously meeting human needs), and allow for individual landowner input. Further, accomplishing these objectives requires a process that augments traditional methods and follows three steps. First, find commonly held values that can help divergent stakeholders convene. Second, pursue multiple iterations aimed at problem-solving and that build trust by allowing visions underlying objectives among diverse stakeholders to merge. Third, keep outcomes (the things that you achieve rather than your goals or objectives) open so that accomplishments more accurately reflect the diverse stakeholders involved.

Key words: sustainability, economic incentives, wetland, watershed, conservation, private land ownership

Globally, local human communities control approximately 65% of the earth's surface even though most governments do not recognize this less-tangible manner of control or ownership (Wily 2011). Agriculture (mostly defined by use of row crops rather than forestry and grazing) is the predominant land use on 37% of the earth's land surface (World Bank 2016). In the United States, where the concept of private ownership is more tangibly codified, 60% of land is privately owned (U.S. Bureau of Census 1991, p. 201). In some U.S. states, private ownership is as high as 98% (e.g., Kansas). If you define private land as land that is controlled by people living on or adjacent to that land, this high ratio of private to public ownership in the U.S. approximates global ownership patterns, although 52% of U.S. land is used for the production of food, fuel, fiber, or medicine (Nickerson et al. 2011), higher than the global average. Concomitantly, most global environmental problems require solutions that are ultimately land-based. To reduce the hypoxic zone in the Gulf of Mexico, for example, soil erosion and excess nutrient input must be controlled on agricultural lands in the Midwest (Scavia et al. 2003). More broadly, if we want to solve environmental problems through conservation we will need to succeed at linking private landowners, the majority of whom use their land for agriculture, with the needs of society and of other species that share the same habitats. That linkage, however, will require that the economics of any solution for both landowner and society are sustainable.

The presence of wildlife on private land can incur both costs and benefits to the private landowner as well as to society. Wildlife often damage crops, attack livestock, or damage infrastructure (Hygnstrom et al. 1994). 'Beyond economic costs to the landowner, conflicts between wildlife and landowners can induce animosity by landowners towards wildlife, and this conflict can undermine broader

Austin JE, Morrison K, Harris JT, editors. 2018. *Cranes and Agriculture: A Global Guide for Sharing the Landscape.* Baraboo, Wisconsin, USA: International Crane Foundation. 303 p.

conservation goals (Treves et al. 2009, White and Ward 2011). For example, before efforts to solve crop damage problems were developed (Lacy et al. 2013, Lacy 2016), the damage caused by Sandhill Cranes (*Grus canadensis*) that ate sown seeds from crop fields, often elicited calls from farmers to instigate a crane hunting season, even though hunting would not solve their problems (Barzen 1997, Barzen and Ballinger 2017). Yet conservationists often do not fully engage the agricultural audience when devising solutions for human/wildlife conflicts (Treves et al. 2006, White and Ward 2011) and can sometimes work at cross purposes (Bulte and Rondeau 2005). When devising solutions to other environmental problems arising from agricultural lands, similar lack of integrating ecological, social, and agricultural sciences often occurs (Duff et al. 2017).

To be effective for any population of wildlife, and for any community of people, a successful solution to human-wildlife conflict is defined by a process that is effective, adapts to the target economic system, allows for individual control, and is implemented at landscape scales (i.e., landscapes appropriate to the solution). Treves et al. (2009) defined feasibility with measures focused on cost-effective design, wildlife specificity, and socio-political acceptance. Importantly, we often think the primary barrier to success is lack of education on the part of the farmer. The reality is often more complicated, and landowners often have valuable insight to offer conservationists. Agricultural producers on any continent are often fully aware of the need for a sustainable solution but lack the proper tools that can be used to resolve conflicts, while the conservation communities in those same places are often unable or unwilling to supply those tools (Cuizio et al. 2013).

The goals of this chapter are two-fold. First, I seek to define the context that non-farmers need to understand to effectively work with farmers. Using issues primarily related to wildlife-human conflicts, I explore the importance of 1) developing effective solutions, 2) describing how solutions must meet simple sustainable economic metrics so they more likely will be adopted by growers, and 3) engaging individuals directly. These solutions pertain to an agricultural landscape but also reflect a more general process of working with private landowners regardless of how they use their land. Second, I seek to define a process for collaboration that helps to engender effective solutions, individual incentive and active participation that is relevant for private landowners worldwide because both problems and solutions are human-based. As such they tend to be independent of culture.

Developing Effective Solutions

When organizations work to increase wildlife populations through conservation efforts, they should prepare for unintended consequences of success. Burgeoning Common Crane populations, for example, can mean an increase in crop damage complaints (Salvi 2012) that organizations who promote crane recovery bear some responsibility to solve. So far conservationists have a mixed track record in solving wildlife conflicts (Hygnstrom et al. 1994). For example, deer management in the U.S. has dramatically increased white-tailed deer (*Odocoileus virginianus*) populations, but crop damage caused by growing deer herds has not been resolved (Craven and Hygnstrom 1994). Conversely, crop damage solutions applied to a growing Sandhill Crane population in the north-central US have been successful (Lacy et al. 2013, Barzen and Ballinger 2017). Solutions tend to be successful when they target the actual individuals in a wildlife population that are creating the problem. With cranes for example, territorial birds often do not cause significant damage to newly planted corn (maize; *Zea mays*) but non-territorial birds do (Barzen and Ballinger 2017). The reverse is true in other situations, such as where territorial cranes bloody themselves on windows while non-territorial cranes are uninvolved (Barzen and Ballinger 2017). Research is usually required to understand exactly what individuals are responsible for most of the agricultural damage that wildlife cause before solutions can be considered, implemented, and evaluated.

Once problematic individuals in a wildlife population are identified, it is important to seek an ecological context within which a solution can be deployed effectively. With cranes damaging newly-planted corn in Wisconsin, we found that solutions designed to move birds from one field to the next invariably failed because the habitat selection for corn fields that the birds preferred was so strong that birds had a large incentive to learn that deterrents like propane cannons were harmless (Barzen and Ballinger 2017). Attempts to improve deterrents that prevented bird use of whole fields tended to focus on making deterrents more lifelike or more unpredictable – like adding pyro-techniques to cannons, for example – but these efforts also inevitably failed because they were operating at a spatial scale of selection that favored adaptation by long-lived, highly philopatric, intelligent cranes (see also chapter *Methods to Reduce Conflicts between Cranes and Farmers* on disturbance methods). Instead, deterrents that were deployed at a different spatial scale of selection (Johnson 1980) were effective – cranes were prevented from feeding on planted corn seeds within a field but allowed use of other dietary items within the same field (Lacy et al. 2013). By deploying deterrents among food items within a field, deterrence of crane damage to planted corn has been effective for more than a decade and > 40,450 ha have been treated in four of the last five years (2012–2016, Barzen and Ballinger 2017). The ecological context here is the spatial and temporal scale (when seeded and newly sprouted seeds are available) at which habitat selection occurs. With Sandhill Cranes, removing whole fields from crane use would not work but removing one dietary item, which is a temporary resource to begin with, would work. Planted seeds exhaust their endosperm within two weeks after germination and, once the endosperm is gone, are no longer food for cranes, so our solution to damage mimics a situation that the birds already face in their environment. Solutions applied to large mammals have not been as effective nor have they been deployed over as large of scale (Distefano 2005).

Economical Solutions in Agriculture

In their review of human-wildlife conflicts, Treves et al. (2006) identified an approach to reduce conflicts through creating a transparent process that 1) provides needed baseline research to clarify both problem and appropriate solutions, 2) supports participatory planning by relevant stakeholders, and 3) monitors results of solutions that are implemented. This excellent review also argues that social sciences, when coupled with wildlife science, are needed to assure economic feasibility and long-term sustainability, lowered resistance to conservation measures, and a process through which human behavior can change. Yet in their review, and in other reviews of human-wildlife conflicts (Distefano 2005), no examples that have met these criteria have been identified. Furthermore, few studies have been implemented that are both effective and have eventually been implemented at a large enough geographic scale to be considered sustainable for human and wildlife populations. To illustrate an example that does meet Treves et al. (2009) criterion, I focus on one broad example on bird deterrence.

To succeed at a broad scale, any sustainable solution to wildlife damage, or to environmental problems on farms, requires that solutions ultimately accommodate the farm budget. An agricultural solution can be highly effective but, if too expensive, the solution may not be adopted unless it is accompanied by new income streams (e.g., government subsidy or adopting new products such as selling carbon credits). Solutions that pay for themselves are more likely to be widely adopted. For example, rice (*Oryza sativa*) farmers in the U.S. can seed their fields at lower rates when they use a taste deterrent on the seed because bird herbivory is prevented; the cost of lower seeding rates breaks even with the cost of treatment (Ken Ballinger, personal comm. 2016). As a result, virtually all aerial-seeded rice fields in Louisiana (81,000 ha) are treated with the taste deterrent each year and this cost is born by individual growers (Ken Ballinger, personal comm. 2016). Most programs that have subsidized solutions have tended not to persist because inevitable budget cuts occur or because wildlife populations grow beyond the capacity of the subsidy to pay for damages (Barzen and Ballinger 2017). Compensation for damage may also have unintended consequences of allowing growers to take more risks (Bulte and Rondeau 2005, *Methods to Reduce Conflicts between Cranes and Farmers* chapter) because compensation will pay for the cost of ventures that fail. Alternative approaches that compensate landowners or communities for ecological services or for damage abatement (instead of damages that occur) have been proposed (Bulte and Rondeau 2005) but, if not linked to the market place, may not be sustainable in the long-term because they ultimately rely on government funding to persist.

Weaving solutions seamlessly into the agricultural system is as important as fitting the solution into a farm budget. For example, to successfully apply a taste deterrent to planted corn, it was necessary to provide both powdered and liquid formulations of the product. The powdered formula was designed to mix into a hopper box at planting so that a grower could decide if they wanted to treat their corn at the last minute. The challenge to a powdered treatment was to coat all of the seed with an effective concentration of deterrent. The liquid treatment was formulated to be used by seed distributors who would treat their seed prior to selling it. This application more readily coated all the seed but was less flexible at planting time. Though preferred by farmers, the first formulation of powdered deterrents created several problems in the planting system. Powder treatments worked well with mechanical planters but performed poorly with planters that used optical scanners to count seeds. The powder coated the sensor and interfered with its operation. Powdered formulations also had difficulties adhering to the seeds at sufficient concentrations to provide deterrence. Yet growers greatly preferred the flexibility that the powdered hopper-box treatment offered so growers tended to feel that the deterrent was ineffective when, in reality, it simply wasn't working in the system correctly. It took several years to formulate a powder that could adhere to the seed well enough to reach effective concentrations and not interfere with advanced optical sensors on planters (Ken Ballinger, personal comm. 2016). Once the powdered treatment was perfected, sales and use of the repellent rose sharply (Barzen and Ballinger 2017).

To persist in the marketplace, or to be applicable widely if subsidized, any developed solution will need to not only be ecologically effective but it will need to be safe to the user and to the environment, simple to use, easy to obtain, understandable to the user, and economical to use under a wide range of market fluctuations. Importantly, in non-subsidized environments, if a grower cannot make a profit while using a product they will not use it. If they do, they risk insolvency and may lose their farm to someone who may not pursue wildlife-friendly practices.

Since wildlife conflicts vary with the size of wildlife populations, and since wildlife populations vary over time, the suitability of a solution is critical as a response to conflicts of varying severity and distribution. The value of market-based solutions is that they allow for effective solutions to adjust to whatever scope is appropriate for level of damage inflicted. If a solution works well in a particular environment, it can be used as broadly as the conflict demands. Alternatively, subsidized crop-damage approaches tend to be limited by the availability of government funding, pre-defined spatial scale of the need, or the length of time deterrence will be needed, none of which may be readily adaptable to changing conditions.

For taste deterrents, an additional advantage of solutions that are developed in an ecological context is that they can often be economically deployed on other crops and for other damage-causing species. For example, 9,10-Anthraquinone was developed to deter seed herbivory by cranes feeding on corn (Lacy et al. 2013) but was quickly adapted to other crops such as sunflower (*Helianthus annuus)* and rice, and to other bird species causing damage to planted seed such as Ring-necked Pheasants (*Phasianus colchicus*) and blackbirds (Icteridae; Werner et al. 2009) because other bird species respond similarly to 9,10-Anthraquinone (Cummings et al 2011, Werner et al. 2015). In another example of ecological context, use of domestic, trained dogs to deter lion depredation of livestock in South Africa may work as effectively to deter wolf depredations in North America (Treves and Karanth 2003).

Government subsidy or incentive may be valuable in cases of subsistence agriculture where there is no other way to alter the farmer's agricultural budget to cover the cost of implementing effective deterrence programs. In this case, subsidies of effective deterrents would provide relief *until* more sustainable approaches could be developed. This highlights the importance of linking subsidy programs with research and development to ensure long term solutions (Treves et al. 2009).

Self-Developed Solutions From Individual Farmers

Self-developed solutions work to a grower's strength because they arise from experience of the person or people who know their land intimately. As such, self-developed solutions to wildlife conflicts are influenced by the nuances of the landscape within which the farm is located (Treves et al. 2006). It also means that growers are influenced, for better or for worse, by the culture of the farming community that surrounds them. In market-based or subsistence agricultural systems, farmers tend to be independent-minded and they desire solutions that they can evaluate and deploy on their own. Any wildlife conflict or environmental solution that is developed will need to meet this demanding (and sometimes biased) form of evaluation.

That said, outside sources are important because no farmer is all-knowing. Universities, conservation groups, and government agencies can contribute important resources. In the United States, the extension system has a long, rich history of linking universities with agricultural and non-agricultural communities (David et al. 2016). To contribute to the process, outside organizations do not always need to lead but they do need to engage productively to help address problems that inhibit advancement such as limited technical knowledge or funding. At Cao Hai, the International Crane Foundation (ICF) partnered with the Trickle Up Program (TUP) of New York and other non-governmental organizations, county, provincial, and national governments to implement TUP's micro grants program and later to develop Community Trust Funds (CTF) (Li 2018) by providing staff, technical expertise, and matching grants. In a different example, as part of a program primarily led by the growers themselves, universities aided the Healthy Grown Potato Program® in Wisconsin by conducting needed research that tested growers' new ideas for sustainability (Lynch et al. 2000, Zedler et al. 2009, Duff et al. 2017).

In another example from Asia, the Khmer tradition of weaving with vegetation harvested from local wetlands provided important knowledge and skills to researchers as poverty alleviation schemes were being devised at Phu My (Tran et al. 2007). Unlike at Cao Hai, where ideas for new businesses were needed, the gaps at Phu My involved learning how to add value to an already-existing tradition that was not economically lucrative in the original form. To change the economic model at Phu My, Tran et al. (2007) merged weaving traditions found elsewhere with traditions found at Phu My to develop new crafts that would sell for higher prices in international markets and then trained people in their manufacture. Khmer traditions also taught researchers nuances of wetland management related to production of weaving materials (*Lepironia* sp.), such as the benefits of pulling vegetation out when harvesting as opposed to cutting it; cut vegetation re-sprouted poorly whereas plucked vegetation re-sprouted vigorously (Tran et al. 2007). Likewise, with Sandhill Cranes and treating planted corn in Wisconsin, farmers taught researchers that chemical deterrents placed on planted corn would work. The researcher's role was to describe how the farmer-developed technique worked ecologically and then find a substance that was both economical and environmentally safe (Jeb Barzen, unpublished data).

The Process of Collaborating For Private Landowners Worldwide

Finding solutions that are effective, economical, and have the potential to be self-developed is challenging because they require the application of skills found in ecological, agronomical, economic, and sociological disciplines. Developing integrated, multi-disciplinary teams is clearly needed to advance such collaborations. The process for how to develop multi-disciplinary teams that include farmers, and which work worldwide, is relevant for both agricultural and non-agricultural private landowners alike (Margoluis et al. 2009, Treves et al. 2009, Converse et al. 2013).

Conservation projects that link poverty alleviation and wetland conservation for cranes has been well-documented in Vietnam (Tran et al. 2007) and China (Hong et al. 2001, Li 2018). The long-term association between cranes and agriculture has also been described in the chapters and case studies in this publication. In addition, many new programs seek to link conservation and agriculture in innovative ways (Elphick et al. 2018, Franke and Theron 2018, Lacy 2018). For example, the description of ICF's approach to working with local people (i.e., farmers or other private landowners) in China and Vietnam has been thorough, and each effort has proposed how tools such as handicraft business (Vietnam) or micro-grants and loans (China) can be applied elsewhere. Extrapolating from lessons learned is important but can also be formulated at a scale that is larger than these individual tools themselves and may be more inclusive of a diverse array of people.

What are the broader lessons that extend beyond the individual tool deployed and might it be independent of geographic origin? Is there a specific culture that unites divergent peoples and forms a basis for any process seeking to link conservation and agriculture? If it exists, what might we learn about a process deployed among the diverse experiences on private lands in Wisconsin, China, Germany, Ukraine, South Africa, or Vietnam as illustrated in this publication? By focusing on the process, and not the tool (e.g., handicraft businesses or TUP grants), it is possible to show how a broad method of working with farmers or private landowners can be effective.

Assessing the case studies presented here and in other published work (Lynch et al. 2000, Tran et al. 2007, Zedler et al. 2009, Duff et al. 2017), I argue that three recognizable steps exist in common among these diverse projects. First, for people with divergent perspectives to convene they need to **have something which they all value.** Second, once convened, it is necessary to **merge visions through iterative steps** that incrementally **build trust** and understanding among these divergent groups. And third, for partnerships to succeed it is necessary to **keep outcomes open**.

Have Something in Common

It is a deeply ingrained part of human nature to distrust strangers. People tend to worry that the intentions of outsiders are manipulative even if assurances indicate otherwise. This basic component of humanness can make it difficult to convene groups that have divergent experiences and yet convening people with different perspectives and skills is necessary to solve most difficult problems that confront conservation and agriculture on private land. This surely is the case when foreigners work in any country, such as with ICF's work at Cao Hai. It is often equally true when farmers work with conservationists in the same county as the cultures of these two groups, even if living in the same geographic area, are often so fundamentally different that the two groups view each other as antagonists. Having something in common among divergent groups can thus bring people together at the proverbial table so that it is possible to contemplate partnership.

Farmers and conservationists, for example, may both value cranes and be willing to discuss what might be done to allow cranes to persist or even flourish. The wetlands that cranes and people share may also serve as such a point of common interest. Often farmers and conservationists both consider themselves as good stewards of the land, and the mutual value of stewardship can provide positive things to discuss, even between opposing groups.

Generally, the broader the context where interests overlap between groups, the more likely it is that substantive discussions can follow and outcomes can be more productive. For example, when antagonists both like cranes it is possible to find simple ways of meeting crane needs. Protecting nesting areas, for example, may solve a problem. Often, however, cranes indicate a broader problem that may be missed if the focus is primarily on one species. Where ecosystems can serve as a rallying concept, it is easier to discuss solutions that are longer lasting or that address the real issues at hand. Ecosystems, however, are not understood equally by all. Increasing nesting wetlands for cranes will also increase pollinator habitat and ground water recharge, something that might be important to farmers as well. Cranes, however, are simple to understand while ecosystems are often more complex and less readily defined. Farmers, for example, may speak of managing their farms as a whole while ecologists may speak of ecosystem services when, in actuality, both groups mean the same thing. These similar ideas, masked by divergent terminology, suggest the next step in the process.

Merge Visions and Build Trust through Iterative Steps

Once at the table, people will not remain for long if they see no hope in meeting their own needs. Solving your partners needs before addressing your own is a good way to begin a partnership which will, in turn, keep your partners engaged and at the table, ready to address your problems next. After it is clear that your partnership is ready to grapple with real issues, it is important to evolve from a partnership focused on solving individual problems to a partnership that seeks overall consensus of action.

But action to what end? Though we often use words that have common definitions among diverse groups of people, the visions that we attach to those words can differ so much as to have opposite meanings. Returning to the Healthy Grown example, Wisconsin farmers attached substantial negative feedback to the word 'ecosystem' even though it seemed clear that there was no disagreement about our objective to restore grasslands and wetlands. Through listening more carefully it became clear that the growers used the words 'whole farm' in the way that I used 'ecosystem.' To the growers, ecosystem was a term used for government programs with which they had unproductive experiences. 'Whole farm', in contrast, meant that growers understood that their farm was defined by more than the summation of their individual fields. Whole farm management embraced the concept of ecosystem very well so we used it instead. Now, a decade later, growers use 'ecosystem' and 'whole farm' interchangeably but 'ecosystem' is no longer the impediment to communication that it once was.

The process of discovering workable solutions that meet the needs of a diverse group of collaborators is thus one of slowly allowing the visions that people hold to merge. Merging visions takes numerous steps and cannot be rushed. The value of this approach, however, is that trust is strengthened with each small step and new ideas can emerge as people understand each other better. With greater trust between collaborators, more risk can be taken in advancing sustainability or larger goals can be addressed. For Healthy Grown, farmers changed their input from establishing food plots for deer to implementing restoration of prairie and wetland ecosystems. For me, as the implementing ecologist, I learned about the difficulty in taking an idea from concept to implementation in a complicated agricultural system.

Keep Outcomes Open

Though seemingly simple, leaving outcomes open is perhaps the most difficult among these three steps. "Outcome" here means an approach or action used to achieve the group's goals; examples of outcomes include testing farmer-derived solutions to crop damage, developing new businesses so that people have alternative jobs and zinc smelting remains closed, adding value to traditional woven products to improve livelihoods before asking for help in protecting a wetland, or making filter strips economical. Starting a project where you do not know what actions will be acceptable and effective requires faith in the process and in the people that you are working with. Yet it is by leaving outcomes open that you can discover directions or endpoints that were unknown or unimaginable at the beginning of the process.

Case study from Cao Hai

To illustrate the three-step process proposed here, it is useful to re-examine the case study from Cao Hai National Reserve (CNR) in Guizhou Province, China (Li 2018). At Cao Hai grants were provided to farmers as capital they could use to develop alternative businesses that would be more compatible with the conservation goals of CNR within which they lived (TUP funds, Song et al. 2001). In addition, Community Trust Funds (CTF) were designed to create long-term solutions to poverty by providing low interest loans to people who would not normally have access to bank loans (Guan and Deng 2001). Both TUP and CTF were very successful at Cao Hai and collectively created a model that can be, and has been, readily deployed to other situations (Shi 2001). My focus here on CNR is to describe the process through which the tools of TUP and CTF were deployed successfully, not the tools themselves.

In 1993, our project represented the first time that the Guizhou Environmental Protection Bureau (GEPB) or CNR had ever implemented an international project, and it was ICF's first attempt at a project that linked poverty alleviation with conservation. For all parties there was much discussion and negotiation about how TUP and CTF grants should be distributed, who should get the grants and what we sought to achieve. It was eventually agreed that recipients should be among the poorest people and be people who lost land when the nature reserve raised water levels to restore the Cao Hai wetland. To link poverty alleviation with conservation, we also decided that our goal was to help people switch from land use that was harmful to CNR (i.e. conversion of wetland to farmland or overgrazing by pigs) to land use or businesses that were consistent with goals of the nature reserve within which people lived. The first TUP round was distributed to farmers scattered throughout the 98-km^2 watershed of the reserve in 1993 because we wanted to expose people in CNR to the project as widely as possible.

<u>First Round</u>: In 1994, we evaluated the project after three months of operation and learned that, of the twelve grants that had been awarded in eight villages, eleven of these grants were going well. Yet many of the participants were unhappy with the process because friends of the reserve director received most of the grants. Compared to people living in the large city nearby (Weining), all participants receiving TUP grants were poor. Compared to compatriots within their own villages, however, TUP recipients were relatively wealthy. Recipients were also connected to the director and most recipients wanted to raise pigs, threatening to exasperate the serious overgrazing problem that existed. Providing grants to wealthy and connected people as well as encouraging more grazing violated the rules that had been painstakingly negotiated and bilingually recorded. Were the rules disregarded and had the project failed? After long discussions, however, an alternative, less polar explanation emerged.

Wealthy and connected people disproportionately received grants because everyone wanted this important project to succeed. Guaranteeing success meant that you provided grants to people whom you knew and trusted. Most grants were successfully fulfilled so this logic was reasonable but the target audience was, never-the-less, not reached. Grants were also provided disproportionately to pig-raising businesses because that is the business that people were familiar with. Why take risks with new, untried businesses? After extensive discussion to clarify the rules, and to emphasize that it was okay if some novel businesses failed, we agreed to conduct another round of TUP grants.

Second Round: The next group of grants was given to 20 TUP groups in Xi Hai Village. This time friends of the reserve director did not receive grants and new businesses were created; high-quality tofu was made with clean water collected from Cao Hai. Another new business involved sugar extraction from buckwheat (*Fagopyrum esculentum*) seedlings and then, as an example of value-added economics, used to coat walnuts (*Juglans*) and sold in the market for a good profit. A third business idea involved the crafting of cooking stoves from 55-gallon oil drums. Yet amid a growing diversity of alternative businesses, all was not well. Most the groups who received grants in Xi Hai were still relatively wealthy. The coordinators for the village who were trained and tasked with helping implement TUP projects were not helpful to the other grant recipients because they focused on succeeding at their own TUP grants instead. Village coordinators were also friends of CNR. Explanations for why wealthy groups received second round TUP grants had changed some but not a lot; people wanted to use this great opportunity to succeed and wealthy people knew how to administer money so they were chosen to receive TUP grants. The visions of what success meant to each of the partners had consolidated but were not yet the same.

Still, important lessons had emerged. Some of the businesses created were novel (tofu, sugared walnuts, and stove-making) and no longer harmed the reserve. In fact, the sugar extraction produced by-products that were fed to the pigs (*Sus scrofa*) – a process that *lessened* grazing pressure and improved husbandry (because pigs did not roam the countryside for food) while it simultaneously provided economic gains. Perhaps most importantly, towards the end of the process of choosing TUP recipients at Xi Hai, the reserve staff, who were responsible for administering the TUP program, began to gain confidence in the project's approach.

During interviews with people in Xi Hai to determine who should receive TUP grants, reserve staff noticed that many wealthy people were listed again. Knowing that funding the poorest people in the village was the goal, they began to ask follow-up questions. "Who was the poorest person in the village?" Amazingly, each Xi Hai resident that was interviewed identified the same family as being the poorest: Miao Fu Yong's family. According to respondents, Mr. Yong's family members begged for food in Weining and were lazy. Most residents advised the CNR team to choose anyone in Xi Hai for TUP grants except them because Mr. Yong's family was certain to fail. They were just too poor. Song Tao and Huang Mingjie (CNR staff) had the courage to conclude the opposite and provided Miao Fu Yong a TUP grant, who then used TUP funds to purchase tools and raw materials to make stoves. When we returned to evaluate, Miao Fu Yong's group had made the largest profit of any group in Xi Hai! Over the next year Mr. Yong was so successful that he became the next TUP coordinator for Xi Hai and was admired for his excellent coordination. So, though many of the grants in Xi Hai had still gone to the wealthier people of the community, we now could show that giving grants to the poorest of the poor could succeed. Visions of success continued to merge.

Third Round: When we began the third round of grants in 1994 we thought that all misunderstandings had finally been resolved. In our evaluation of the next 23 TUP grants in Hai Bian Village (fall, 1994), we anticipated that all would be running smoothly. The village coordinator, Mrs. Guan Er Ying, had visited the TUP grantees often and was very helpful. Chosen TUP projects were diverse and projects tended to go to poorer people in the village. Few pig-raising businesses had been proposed and the county government had begun to provide helpful technical assistance.

Yet demonstrations that opposed the TUP grants had erupted in Hai Bian. Mrs. Guan's relative had his corn field vandalized. When we interviewed people in Hai Bian, the reasons given for the demonstration were that our team was not implementing poverty alleviation fairly. Fair dissemination of poverty alleviation funds was defined as equal distribution to all people in any village regardless of an individual's economic status. In contrast, we were targeting only poor people with TUP grants. Our success was seen as unfair to those who did not receive TUP grants.

We explained that our project was a collaboration between the Chinese Government and two foreign nongovernmental organizations (ICF and TUP), making our rules very different. We also explained that CTF funds, which would be established in the villages early in 1995, would be available to a broader range of village members. People listened and visions continued to merge.

<u>Fourth Round</u>: In 1995 we were working on providing grants to Yun Long Village and planning to expand TUP grants for two other villages (Dong Shan and Bai Ma), essentially circumnavigating the perimeter of Cao Hai wetland as well as beginning the CTF program. Though there were still communication problems to solve, and though we still needed to increase the capacity of coordinators, CNR staff and county technical advisors were reaching out to a growing number of TUP projects and we anticipated no major problems.

Yet two significant issues arose. First, a major donor for our work questioned the continuation of funding for our project because our project was proceeding more slowly than they anticipated. Second, we had not yet clearly linked poverty alleviation to conservation at CNR.

Our focus on Yun Long was an interesting coincidence because people in the village lived near the outlet of Cao Hai and were quarrying rock there. Quarrying was done by detonating dynamite to loosen the limestone bedrock, a technique that threatened to undermine the entire outlet and perhaps drain the wetland. We had been discussing the cessation of quarrying with Yun Long Village since 1993 but had as yet reached no agreement. Now, with TUP programs coming to Yun Long, local residents linked TUP with the quarry. Not all the residents of Yun Long lived within the watershed of Cao Hai, the boundaries of our project. Yun Long proposed that, if everyone in Yun Long village, within and outside the watershed, were eligible to receive TUP grants, they would stop quarrying. Though we needed to find additional funding to support additional grants, this was a reasonable compromise. We obtained additional funds and the TUP grants were distributed. The quarrying stopped. Both our donors and ICF participants began to see the unexpected ways that poverty alleviation was linked to conservation. After two years of implementation and four rounds of evaluating TUP grants, the visions held among all members of the collaboration were finally close to parity.

<u>Subsequent Rounds</u>: Demonstrating the linkage between poverty alleviation and conservation was perhaps our greatest challenge. Was the resolution of the quarry issue at Yun Long coincidence or did it exemplify the linkage that we sought? By 1996, our efforts to establish a community forest nursery, which would provide trees and shrubs for people to revegetate their denuded landscape, had failed. We had anticipated that the TUP grants would help make the tree nursery a success but this did not occur. Had we succeeded in alleviating poverty only to fail at solving pressing conservation issues?

Other linkages between poverty alleviation and conservation, which we did not anticipate, arose and suggested that solutions could come from our partners instead of the conservation groups alone.

Tertiary zinc smelting had occurred in the watershed for decades. These activities were polluting Cao Hai and were creating unhealthy conditions for smelting plant workers. GEPB had tried many times to close the smelters, but those efforts tended to be temporary. After a few months of quiescence, closed smelters would quietly resume operation. After TUP and CTF activities were in place, however, GEPB again closed the smelters but this time the smelters remained closed. In our Participatory Rural Appraisals it became apparent that one reason for the success in keeping smelters closed was that the unemployed workers now saw alternative businesses that they could create; in addition, they had access to affordable loans (CTF) or grants (TUP) to pursue those changes.

In another example, people in Yang Guan Shan Village had angrily demonstrated against CNR during 1993 when reserve staff had tried to enforce the seasonal closure of fishing to protect spawning adults. In 1994, people in Yang Guan Shan had received TUP grants and in 1995 they had received CTF funds. CNR had also responded favorably to a proposal by Yang Guan Shan to convert a sub-station building, owned but not used by the reserve, into a school. Yang Guan Shan would provide the teachers if the reserve provided the building. In 1996, Yang Guan Shan proposed to self-enforce CNR fishing regulations and encouraged other villages in CNR to do the same. In other villages, people had dramatically reduced their fishing because they made more money in their TUP or CTF activities than they did with fishing. Poverty alleviation was making it more feasible to implement conservation strategies for CNR.

Finally, after 1997, input from villages surrounding Cao Hai was sought by CNR to develop a village management plan designed to benefit both villages and CNR. One result of this input was for villagers of Bai Ma Village to cooperate in demarcating a zone in the wetland where vegetation would not be collected. Better wetland vegetation, in turn, would increase nesting habitat for wetland birds. The village also jointly built an observation tower to view birds in the habitat zone to promote more ecotourism (Li 2018). Though our preconceived notions of how conservation and poverty alleviation would be linked were unsuccessful, the collaboration was successful in developing many powerful linkages that were developed by our collaborators in the watershed of Cao Hai.

Still, there were limits to our success. Even though over 20,000 trees were planted by people in the villages and though other plantings were done to reduce erosion, soils in the watershed were not yet stabilized. Further, drawdowns of Cao Hai, a necessary tool to maintain high productivity in wetland systems (Johnson et al. 2010), had not yet been attempted. With the work of TUP and CTF it should have been possible to risk the renewed conversion of wetland to agriculture if water levels were temporarily reduced to see if a drawdown would improve wetland productivity; but this has not yet been done. In both of these examples, although the social cohesion might have existed to solve these problems, the technical abilities had not yet been marshaled for such a focused attempt at solving a larger problem. The potential, however, was great.

Conclusions

In the case study from Cao Hai, the three steps of collaboration were very clear. Black-necked Cranes and the Cao Hai wetland itself were valued by all the participants who came to the table. Yet poor people, who were further impoverished when they lost land due to restoration efforts at Cao Hai, would not remain at the table long if their pressing problems remained unsolved. Yet the lessons from different rounds of evaluating TUP grants illustrated that the simple concept of providing money to the poorest and most affected people was difficult to implement but not because people objected to the idea. Instead, the idea of distributing money to the poorest people in the community was challenging because there were many visions behind what success really meant and how success would best be achieved. Even when most people in Xi Hai village agreed that Miao Fu Yong's family was too poor to trust with a TUP grant, they were wrong. Even though ICF and CNR staff thought that community tree nurseries were a good idea (and we had previous literature to support our contention), we were wrong.

Many iterations and the long unfolding of the Cao Hai project suggested that we were inefficient in implementation. I argue, however, that all parties involved were competent and that the many small steps reflected both the challenge and the power of gradually merging visions which occurred at each round of evaluation that we took – the incremental learning used by Harris (2001a). Li et al. (2001, p. 280) further stated that "[l]ocal participation in Cao Hai conservation is a process of understanding, establishing trust, and problem solving." Importantly, this process does not invalidate or compete with important tools like open standards (Margoluis et al. 2009). Instead, having something in common, relying on iterative steps to gain trust and merge visions, and keeping outcomes open are simple steps to create the feedback loops necessary to strengthen and engage local people effectively. Such engagement, in turn, is necessary for open standards (or other planning tools) to be effective. Finally, in retrospect, the linkages between poverty alleviation and conservation were most powerful in situations that arose directly from input of our local collaborators rather than from what ICF and CNR had planned. Keeping options open allowed these alternatives to unfold.

The cost of the process, of course, is measured by the amount of effort required for numerous iterations to occur. Often large donors wish to spend significant sums of money quickly to come up to scale – to show a big impact and measurable success. Our experience, however, was the opposite. It cost large amounts of staff time to spend relatively small amounts of money effectively. Scaling up was possible but it took much longer than anticipated to reach our goals. We eventually reached over 572 groups with TUP (Song et al. 2001, Li and Song 2007) and over 1,499 households with CTF (Guan and Deng 2001, Guan and Song 2001) in the Cao Hai watershed. The time (10 years) and effort (staff time for ICF, TUP, CNR, Weining County Government, and village coordinators for TUP and CTF) to reach this point was extensive but produced a growing population of wintering cranes and a collaborative relationship between CNR and people living beside Cao Hai.

Another challenge with this approach lies in keeping your options open. Allowing collaborators to create their own solutions is perhaps the biggest asset in conservation management that we found (Harris 2001b, Li 2018, Lopez 2001), but it is challenging to implement a program that has undefined or vague outcomes at the start. This uncertainty was what made our donors consider withdrawing funding from us.

Is that effort and uncertainty worth it? The experience with Cao Hai (Hong et al. 2001), and the experience in Wisconsin (Zedler et al. 2009, Duff et al. 2017), suggest through divergent examples that it is possible to accomplish important conservation goals in agricultural landscapes if this simple but challenging process is pursued. Once the process is chosen, solutions for agricultural environments will need to be ecologically effective, economically sustainable, and they will need to be open to input by individual landowners.

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CHAPTER 8

Strategies to Manage the Crane-Agriculture Interface Using Partnerships, Ecotourism and Educational Opportunities

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Abstract: Adaptation by cranes to the expanding agricultural landscape has been a mixed blessing to both cranes and farmers. The loss of natural food resources led to cranes utilizing farmer's crops or pasturelands for food – providing ready access to food for cranes, but sometimes resulting in economic losses to farmers. The presence of cranes allowed farmers to generate income in the form of ecotourism, but in some cases, this activity resulted in disturbance to cranes during critical life stages such as breeding. The strategies needed to address these seemingly dichotomous advantages and disadvantages have differed from place to place; some strategies worked better than others. It is therefore essential to share ideas and the lessons learned from a wide range of sites. This experience sharing is best done through partnerships that can work across boundaries and at a multitude of levels to ensure effective communication and collaboration among the various stakeholders. At the international level, numerous treaties, conventions, and agreements exist to facilitate and guide the establishment and format of guidance bodies and systems. These approaches are generally multi-phased in nature and work towards the benefit of cranes, livelihoods, and education, often mobilizing large-scale financial resources in the process. At the national and regional level, projects and efforts become more focused and specific and see the development of steering committees and management plans that incorporate a wide range of stakeholders such as conservation officials, non-government organizations, farmers, tourist operators, and local businesses owners. Effort may also be given to securing habitat through interventions such as stewardship programs or conservancies, as well as legislation to support these initiatives. In an effort to boost local economies, cranes have been encouraged to return to many of their historical staging or feedings grounds through the provision of food and the planting of diversionary crops by local farmers. Their presence has allowed local communities to come together to work on crane-related projects, and bolster ecotourism ventures. Ecotourism opportunities, in the form of guided tours, information centers, photographic outings, and workshops have been well received by the public. Subsidiary industries such as transport operators, lodging and restaurant owners, and curio retailers have also benefited from the presence of cranes. Successful efforts have resulted in mutual benefits for community members and cranes. Similarly, partnerships with industry have led to a variety of technological advances which have contributed to the successful implementation of a number of projects. Some facilities have also provided in situ research opportunities to crane conservationists and scientists in the form of access to study subjects, and internship programs. Such research has focused on both the bird's biology as well as crop-damage mitigation strategies. In some countries, for example Uganda, such research has been instrumental in furthering efforts to gain the support of local communities in terms of crane conservation efforts. The spiritual and symbolic values of cranes are deep rooted in many cultures and provide valuable opportunities to engage people in conservation.

Keywords: community, conservation strategies, cultural value, education, ecotourism, industry, international agreements, partnerships

Since ancient times cranes have relied on natural landscapes across the continents of Africa, Australia, Eurasia, and North America for food, breeding sites, and refuge (Nowald et al. 2018). As humans have increasingly dominated the environment, many of the wetland and grassland ecosystems on which cranes depend have been converted for agricultural uses – cropland or pastures. Although cranes have adapted to co-exist with agrarian human societies, this adaptation has come with both positive and negative implications for the ongoing persistence of cranes.

Wetland habitat loss and degradation caused by agriculture, urbanization, infrastructure development (i.e., roads, dams, power lines, wind turbines), and water pollution have impacted negatively on breeding, staging and wintering sites for cranes (Austin 2018). The loss of natural food resources has led to cranes utilizing farmer's crops or pasturelands for food. While this behavior has led to conflict with farmers on one hand, it has also presented opportunities for farmers, and other stakeholders (such as local hotel owners) to invest in alternative income-generating strategies such as ecotourism. The concentration of cranes around agricultural areas has also presented opportunities for furthering conservation efforts, environmental education, and raising the awareness of the plight of cranes among farming communities and the public.

A variety of strategies have been applied worldwide to draw cranes to certain areas (for ecological and/or economic reasons) and to encourage tourists to visit these regions to see the cranes. It has quickly become apparent that some strategies work better than others and that the success of some examples are situation dependent. It is therefore essential to share ideas and the lessons learned from a wide range of sites.

While the crane/agricultural interface has become increasingly significant for crane status and conservation, agricultural issues interact with other human activities that together contribute toward the future for cranes. Solutions to conflicts and emerging threats must reach beyond single issues toward holistic, multi-faceted programs. Accordingly, conservation responses to impacts from agriculture have much to gain from a broader context.

This chapter aims to be a catalyst for robust and inclusive strategies to address the threats to cranes related to agriculture, and more generally to promote harmonious coexistence opportunities that contribute to healthy crane populations. Such strategies include building partnerships, developing ecotourism and educational opportunities, furthering research, and sustaining the cultural and spiritual values of cranes. There is a fundamental need to develop awareness and extension programs that take into consideration both crane conservation and human economic development.

Building Partnerships Among Stakeholders

Cranes undertake local movements or migrate long distances between non-breeding and breeding areas, often crossing national, regional, or continental boundaries. These movements naturally bring them into contact with a variety of human cultures and land-use types (e.g., agricultural fields, conservation areas, urbanized areas) with varying levels of protection. Partnerships that can work across boundaries are therefore critical at a multitude of levels to ensure effective communication and collaboration among the various stakeholders (e.g., farmers, community members, interest groups, environmental educators, local and national nature conservation officials, non-government organizations (NGOs), and the staff of conservation treaties and conventions).

Conservation actions in one place or country – such as reducing hunting pressures or protecting habitat – may lead to population increases or altered crane distributions that in turn affect other areas. For example, the restoration of Eurasian Crane breeding and staging habitats, coupled with abundance of agricultural foods, has led to a dramatic increase in the populations of this species in Europe (Prange 2012, Ilyashenko 2018a). These changes, however, have led to increased conflict with landowners on the cranes' wintering grounds in Morocco and Algeria, where agriculture is small-scale and often at a subsistence level. Similar situations have been reported between other range states that are signatories to the African-Eurasian Migratory Waterbird Agreement (AEWA), where the creation of bird sanctuaries and reduced hunting pressure in some states have led to conflict in areas experiencing intensified agriculture and aquaculture (AEWA 2005).

Partnerships are a critical tool to address and better encompass the often wide range of issues and interests at hand. At local, regional, national, and international levels, cooperation between farming, nature conservation, and economic development agencies can be the most important means to solving conflicts between farmers and cranes. Partnerships provide the platform to explore different opportunities and approaches to finding the balance between crane conservation needs and the socio-economic needs of communities and societies (Fig. 1). Even for conflicts that appear at the local level, partners from distant places may contribute toward and gain from effective solutions.

Fig. 1. Workshop with Chrissiemeer farmers in South Africa to develop a management plan to balance the needs of agriculture and crane conservation (Photographer: Ursula Franke)

Numerous publications give guidance on how to form and maintain partnerships. Detailed information is beyond the scope of this Guide; we recommend several resources on this topic such as those provided by BirdLife International (2008), Poulsen (2009), Herbert et al. (2013) and *EcoAgriculture Partners and IDH, the Sustainable Trade Initiative* (2012). Table 1 gives a brief synopsis of steps to effective partnerships, adapted from The Nature Conservancy (available online at https://www.conservationgateway.org/ConservationPlanning/partnering/cpc/Pages/step5.aspx).

Table 1. Steps to building effective partnerships. Adapted from The Nature Conservancy (2017).

Steps in the Strategic approach to partnerships	**Discuss and/or Consider….**
Prepare	Consider why you want / need a partner Consider the type of partnership needed
Select	Who do I need to work with Narrow the list Are all sectors represented
Negotiate	Lay the foundations for the partnership Set structures to manage the relationship Consider legal aspects of importance Plan for dispute resolution
Manage	Develop operational manuals (with roles and responsibilities) Set work plan with built in monitoring components
Measure	Assess the partnership for effectiveness
Conclude or Adapt	Highlight lessons learned and successes Amend aspects that are not working Implement changes

Partnerships at an International Level

The majority of international conventions and agreements on wildlife focus on the conservation status of species and/or the habitats in which they live, for example, the Convention on Biological Diversity (CBD), Nature 2000 (the network of protected areas in the territory of European Union), the Convention on Migratory Species (CMS), and other bilateral conventions on migratory birds (Table 2). Apart from the Convention on Wetlands (Ramsar Convention) and the African-Eurasian Migratory Waterbirds Agreement (AEWA), only a few of these agreements specifically consider the direct threats that biodiversity, for example waterbirds, face in agricultural landscapes, and in turn, the impact of cranes, waterbirds and other biodiversity on farmers' livelihoods. However, international cooperation is required to address the conflict situations (AEWA 2005).

AEWA and Wetlands International published the *Guidelines on Reducing Crop Damage, Damage to Fisheries, Bird Strikes and Other Forms of Conflict between Waterbirds and Human Activities* (AEWA Guidelines No. 8) in an effort to maintain the conservation status of migratory waterbirds while providing guidance on methods to minimize or prevent damage to agricultural crops, fisheries, or aircraft (AEWA 2005). The Guidelines propose a multi-phase approach which starts with identifying the source of conflict (e.g., crop damage), and then moves on to assembling a multidisciplinary team to investigate and propose measures to reduce the conflict, as well as identifying a national focal point of AEWA who is responsible for coordinating all activities relating to conflicts between waterbirds

Table 2. List of international and regional partnerships involved in the conservation of migratory birds and their habitats.

Name	Region	Focus	URL
African-Eurasian Migratory Birds (AEWA)	Africa and Europe	Intergovernmental treaty dedicated to the conservation of migratory waterbirds and their habitats across Africa, Europe, the Middle East, Central Asia, Greenland and the Canadian Archipelago	www.unep-aewa.org/
Central Asian Flyway (CAP)		Regional cooperative partnership among the Central Asian Flyway states to promote the conservation of migratory waterbirds and their habitats	www.cms.int/en/legalinstrument/central-asian-flyway
Convention on Biological Diversity (CBD)	Global	Global agreement to develop national strategies for the conservation and sustainable use of biological diversity	www.cbd.int/
Convention on Migratory Species of Wild Animals (CMS)	Global	Intergovernmental treaty to conserve terrestrial, aquatic and avian migratory species throughout their range	www.cms.int/
Convention on Wetlands (Ramsar)	Global	Intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources	www.ramsar.org/
East Asia-Australasian Flyway Partnership	East Asia and Australasia	An informal and voluntary initiative, that aims to protect migratory waterbirds, their habitat and the livelihoods of people dependent upon them. Partners include governments, inter-governmental agencies international non-government organizations and international business sector	http://www.eaaflyway.net/
Natura 2000	European Union	Coordinated network of nature protection areas in the territory of the European Union	ec.europa.eu/environment/nature/natura2000/index_en.htm
North American Waterfowl Management Plan (NAWMP)	North America (Canada, United States, and Mexico)	International partnership working towards conserving wetlands to benefit migratory waterfowl and other wildlife, and achieving broad benefits to biodiversity, ecosystem processes, and the people of North America. Partners include federal, provincial/state and municipal governments, non-government organizations (NGOs), private companies, and many individuals	http://www.fws.gov/birds/management/bird-management-plans/north-american-waterfowl-management-plan.php

and human activities. Such teams may include 1) stakeholders, 2) representatives and/or experts from appropriate national or international agencies, 3) other experts such as ornithologists and specialists in the assessment of crop damage, and 4) professional advisers (e.g., socio-economists, representatives of national and international conservation agencies such as NGOs and research institutes) (AEWA 2005). Ideally the local public should also be included to ensure public awareness is raised. Engaging the local public can be done though the inclusion of local interest or birding groups.

Across Europe, the emphasis has been on building partnerships between government institutions and farmers, using various sets of guidelines, ministerial acts, and laws. This model has, in many instances, enabled the mobilization of financial resources to compensate farmers for impacts such as crop damage, in exchange for voluntarily engagement in agro-environmental initiatives such as supplying food for cranes (Lundin 2005, Austin and Sundar 2018).

The 5th European Crane Conference in Sweden in April 2003 established *The European Crane and Agriculture Specialist Group* to solve conflicts between Eurasian Cranes and farmers. Although there are many similarities in the type of crop damage taking place across Europe, differences in patterns should not be overlooked and causal factors may vary greatly within a region, particularly when it comes to climate, farming regulations, and cultural differences. The above-mentioned group plays a critical role in information exchange, and collective experience and lesson sharing within Europe as well as with other regions (Lundin 2005).

Partnerships at National and Regional Levels

The AEWA Guidelines guide the establishment of partnerships at the national and at the regional level between countries, aimed at mitigating conflict between cranes and farmers. Situations and outcomes will vary according to the level of economic development, public awareness, and the support available, for example, nature conservation organizations (AEWA 2005).

An excellent example of cooperation between national and regional stakeholders is the Crane Management Project in Israel that aims to create co-existence between farmers, tourism, and the environment, and to prevent crop damage from the thousands of wintering Eurasian Cranes in the Hula Valley (Shanni et al. 2018). This project is driven by a steering committee of farmers, a municipal council, Keren Kayemet L'Yisrael (Jewish National Fund), Agamon-Hula Park, Nature and Parks Authority, and the Society for the Protection of Nature in Israel. The project's management plan includes a monitoring protocol and various research projects aimed at providing scientific information and knowledge to improve the management activities. The combination of representative stakeholders is critical for maintaining long-term sustainability of the Crane Management Project (Bonneh 2012).

In South Africa, the International Crane Foundation (ICF) / the Endangered Wildlife Trust (EWT) Partnership promotes the Biodiversity Stewardship Program among landowners in order to secure critical habitat for threatened crane species (Grey Crowned, Blue, and Wattled Cranes) in two critical crane sites, Chrissiesmeer and the southern Drakensberg. This program was enabled by the National Environmental Management Act (Act 107 of 1998), which provides the opportunity for legally binding contracts to be drawn up between landowners (most frequently farmers) and the state to secure land for conservation. The program provides the long-term capacity for conservation agencies to assist farmers and other landowners with the implementation of a systems-driven management plan, including incentives while ensuring the sustainability of the program (Franke and Theron 2018). Similar tools for wetland conservation are to be considered for wetlands and surrounding catchments of particular importance for cranes across Africa. This approach will rely on in-country legislation, the importance given to the wetlands and conservation agreements that are developed between local communities and relevant NGOs or government departments, in which rural communities will derive benefits based on conservation action they implement (Morrison 2012).

In the 1970s, conflicts among water users (farmers and power companies), conservationists, and state and federal agencies intensified over water and land use along Nebraska's Platte River, USA, a critical migratory staging area for hundreds of thousands of Sandhill Cranes (Krapu et al. 1982) and the Endangered Whooping Crane (Echeverria 2001). The Platte River Whooping Crane Critical Habitat Maintenance Trust (now the Platte River Trust) (Lingle 1992) was established in 1978 as an agreement between the state of Nebraska, National Wildlife Federation, and the Missouri Basin Power Project; it has since developed into a partnership of more than 18 state, federal, academic, and non-governmental organizations. Its mission is to protect and maintain the physical, hydrological, and biological integrity of the Big Bend area of the Platte River so that it continues to function as a life support system for Whooping Cranes, Sandhill Cranes, and other migratory bird species, while also sustaining irrigation supply for the region's agriculture. The Trust has purchased and continues to manage and restore habitat on >4,050 ha (10,000 ac) for cranes and other migratory birds (Lingle 1992); it also contributes surveys, research, and expert knowledge for regional decision-makers.

Partnerships at the Community Level

Conservationists in both governmental and non-governmental organizations can assist in resolving conflict experienced by farmers who may bear economic losses from cranes or disturbances from tourists in search of cranes and the ultimate crane experience (Nowald 2012). Conservationists can also assist with developing community pride among those communities that are benefiting, or could benefit, from ecotourism opportunities.

Since 2000, Ligue pour la Protection des Oiseaux (LPO, Birdlife International in France) and the Regional Park in Luc du Der have worked together to publicize and showcase wintering cranes throughout the Landes de Gascogne. To promote knowledge sharing they have been encouraging the landlords of local tourist lodging houses to attend an instructional program and have developed an annual training plan for nature trips that prevent disturbance whilst maximizing sightings (Petit and Couzi 2005).

In Finland, working groups have come together to design mitigation strategies for crop damage at migration stopover sites for cranes. West Finland's Regional Environment Center led this initiative involving representatives of farmers, regional administration, and ornithological societies. It resulted in greater cooperation, in more effective conservation lobbying with the Ministry of the Environment and in organizing crane seminars (Lundin 2005).

The ICF has worked with China's Cao Hai Nature Reserve (CNR), the Trickle Up Program (TUP; which focuses on poverty alleviation), Guizhou Environmental Protection Bureau, and Yunnan Rural Development Research Center, for over 15 years. This collaboration has focused on integrating community development and wildlife conservation, and emphasized the participation of local villagers (most of them farmers) in the design, development, and the implementation of activities (Li 2018). It has become a model for management initiatives for nature reserves. In 1993, ICF and TUP implemented a joint program offering US $100 grants to villager-groups towards starting and/or expanding small businesses that are compatible with the reserve's conservation goals. Over 550 small businesses were started, including small vending businesses, raising livestock or poultry, stove making (with recycled oil barrels), bicycle repair, and paddle boat rides for tourists to view the area's waterfowl. Two years later Community Trust Funds (CTFs) were established to build upon similar guidelines but at a larger scale. Since 2005, partners have been working to establish a NGO, the

Farmers' Conservation and Development Association, to increase local community capacity and enhance community participation in decision-making. The Farmers' Conservation and Development Association was formed in 2007 to organize and structure community activities, including the building of drinking wells and biogas stoves (Barzen 2018, Li 2018).

Partnerships with Industry

Building partnerships with industry facilitates the production and distribution of appropriate, biologically safe, deterrent techniques such as Avipel® (a taste deterrent for crops), as well as the development and installation of safety devices such as bird flappers on powerlines.

The ICF has been involved in long-term research focused on the use of crop deterrents in conjunction with a consortium of individuals and organizations at local, state, and federal levels (Lacy 2018). This research included Arkion Life Sciences, University of Wisconsin – Extension Service, United States Department of Agriculture (USDA) Wildlife Service, Wisconsin Department of Natural Resources (WIDNR), and over 50 farming families. This group of partners identified and tested Avipel® to ensure that it is an economically viable, non-toxic chemical, compatible with farmer's machinery and planting methods, persistent on the seeds while they are vulnerable, and effective on deterring crane herbivory (Barzen et al. 2012, Barzen 2018). A similar partnership is currently under development in South Africa between the International Crane Foundation, Endangered Wildlife Trust, Ecoguard (an agrochemical company), and farmers (Kerryn L. Morrison, personal comm. 2017).

The Endangered Wildlife Trust has been working closely with Eskom, South Africa's national energy producer, to mitigate the negative effects of electricity infrastructure (e.g., power lines and substations) and renewable energies on birds and other species. Cranes often traverse energy infrastructure, increasing their potential for collisions, as they move between roosting and foraging sites and between foraging sites in agricultural landscapes. The partnership between the two organizations now ensures that proactive environmental assessments are conducted prior to construction of new infrastructure, taking into account cranes and their use of the agricultural landscape; research into the relevant issues is conducted; wildlife interaction training is provided; analysis of wildlife interaction incidents is recorded; reactive and proactive mitigation of existing infrastructure is completed; and reporting systems are in place (K. Morrison).

Raising Public Awareness and Support Through Ecotourism

Cranes' use of crops and the reliability of their presence on agricultural lands at certain times of the year (Nowald et al. 2018) provides an ideal opportunity for ecotourism. In a small number of locations around the world, Eurasian or Sandhill Cranes gather in large flocks during migration and wintering. Here their uniqueness and behavior attract substantial interest from tourists who enjoy watching crane interactions and dancing in the fields, as well as their flying formations against the background of a rising or setting sun as they vocally move between roosting and foraging sites. The existence and maintenance of these unique areas provides a solid base for the development of ecotourism opportunities, which in turn provides economic benefits to landowners and farmers.

In places such as Europe and the United States, dramatic transformations in landscapes and agricultural practices, coupled with climate change and increased crane populations, have resulted in increasing concentrations of birds at a decreasing number of locations (Salvi 2012). The man-made narrowing of the Central Flyway at the Platte River Valley in Nebraska, USA, forces over 500,000 Sandhill Cranes (80% of the world population; Krapu et al. 2011), and a large percentage of the 300 remaining Whooping Cranes (Canadian Wildlife Service and U.S. Fish and Wildlife Service 2005) into dense concentrations along a 125–128 km-wide corridor, which is an important staging location during the cranes' migration (Taddicken 2012). Crane-related tourism became popular here in the mid-1970s due to the realization that there are finite limits on natural resources, and the fact that it is one of the USA's most spectacular and accessible natural phenomena.

In Central Europe, crane tourism started two decades ago due to increased crane numbers. At the turn of the century, only a few birders went to see cranes flying to the roosts in the shallow lagoon landscape of the National Park (*Vorpommersche Boddenlandschaft*) on northeast Germany's Baltic coast. The establishment of the Crane Information Center has resulted in roughly 15,000 tourists visiting the area annually, as single visitors, in small groups, or in groups organized by travel agencies (Nowald 2005). Economically, this provides a "fifth season" to tourism organizations in the Rugen-Bock Region. A similar development is documented for other important crane resting areas in agricultural landscapes of Germany, for example, the Rhin-Havelluch and the Diepholzer Moorniederung regions (Nowald 2012).

However, poorly organized and unmanaged tourism can harm both cranes and agricultural production, and cause frustration and mistrust among the tourism industry and local people. It is thus essential to share the accumulated experience and lessons learned from well-managed tourist areas for uptake by areas where ecotourism is still in its infancy, or not generating the desired results.

One such lesson that can be shared is the common technique of planting diversionary crops (Austin and Sundar 2018) to encourage cranes to remain in an area. This practice may benefit conservation and ecotourism development by attracting larger numbers of cranes, but usually involves financial support from federal and provincial government bodies as well as NGOs. For example, the provincial government of Aragon Province in Spain has recognized the Eurasian Crane wintering grounds in Gallocanta Basin Lake as an important tourism site and, over the last 30 years, encouraged farmers to switch from vegetables to wheat and barley, in order to attract an increasing number of wintering cranes, and hence a greater number of tourists (Pueyo et al. 2011, Alonso et al. 2018).

In Sweden, Eurasian Cranes staged on potato (*Solanum tuberosum*) fields near Hornborga Lake until potato cultivation ceased in the 1950s. With crane populations having dropped from 6,000 to <10, farmers planted barley (*Hordeum vulgare*) to attract the cranes back to the area. By the 1980s, the population had increased to 13,000 (Swanberg 1987) and today 250,000 tourists visit the lake annually (Lundin 2005).

The provision of artificial feeding sites is another commonly used technique to attract cranes to certain areas, and thus tourists to see them (Austin and Sundar 2018). Changing land use patterns may attract large numbers of cranes to an area resulting in potential damage to crops that would be unsustainable for farmers. The creation of artificial crane feeding sites at traditional wintering and migration sites not only distracts cranes from the surrounding agricultural fields, thus reducing possible damage to crops, but also provides valuable opportunities for tourism development as cranes congregate in these areas. In Izumi, Japan, crane feeding was organized to support up to 12,000 wintering cranes (90% and 40% of the world's Hooded and White-naped Crane populations respectively) at their traditional wintering site so as to decrease the pressure on nearby agricultural fields (Anonymous 2011). Similarly, an endangered non-migratory population of Red-crowned Cranes (Koga 2007) is supported by artificial feeding sites at Hokkaido, Japan.

At Khichan in Rajasthan State, India, residents of the small and isolated village began using their own food to feed wintering Demoiselle Cranes for religious purposes. Word soon spread and crane feeding is now supported by tourists who give donations for the purchase of grain; the cost of which is now also supported by local governmental and NGOs. As a result, Demoiselle Crane numbers increased from 200–250 in 1982/83 to 6,000–7,000 in 1996/1997 (Pfister 1996) and nearly 9,000 cranes by 2015, supported by >5,000 kilograms of bird seed every day (Neema et al. 2012 *in* Laladhas et al. 2017).

The feeding of cranes can contribute to broader management objectives for both cranes and the community. Yet artificial feeding can lead to negative situations. A significant concern is the potential for artificial feeding to excuse or lead indirectly to reductions in natural habitats. Uncontrolled sites where farmers feed cranes specifically to attract tourists and add to their own income may create unexpected problems such as traffic blocking roads, the use of unauthorized roads, and interference with farming activities (Kunikazu Momose, personal comm. 2017). In a few instances, the planting of crops or provision of artificial feeding sites for cranes has led to the situation where there are too many cranes for the resources available. High concentrations in artificial feeding sites also raise concerns about disease (Austin and Sundar 2018). Changes in land use, crops grown, limited water supplies (Shanni et al. 2012, 2018), and even climate change, need to be considered when planning ecotourism ventures. For crane projects to be sustainable, these issues must be dealt with in a proactive, responsible way, which should include the investment of resources for developing and implementing long-term management plans (Artzi 2012). The actions taken both by development and conservation driven stakeholders may intensify the antagonism between conservation efforts and local peoples' needs, resulting in intensified waterbird hunting, farmers encroaching into the wetlands, and changes in water use systems (Li 2018).

Benefits to the Broader Society

Crane tourism also contributes to the development of alternative livelihood projects for local people to prepare souvenirs and other materials for tourists, employ staff for tourist services (hotels, restaurants, tour boats, etc.), and protect crane roosting and "pre-sleeping" sites that are more sensitive to human disturbance. Crane tourism allows volunteers from local bird associations and the general public to serve as guides during crane counts. Also crane tourism contributes to the increase of wide-scale awareness and knowledge level of the general public.

Tourism above a certain volume can help raise money for programs aimed at reducing crop damage, including compensation to farmers for crop damage by cranes. For example, in the Gallocanta Basin in Spain, the government of Aragon Province applied a program of agri-environment measures in 1994, which at first was established with only the economic support of the autonomic administration, but has since 2000 been funded by the European Agriculture Fund for Rural Development (EAFRD) and Community Regulation. By 2013, during the 20 years with the agri-environment program in place, 2.5 million Euros had been provided to more than 900 beneficiaries (Munilla 2014).

In the United States, local economic revenue was bolstered by over US$4 million in 2004 through recreational visits (nearly all non-consumptive wildlife tourism) in Bosque del Apache National Wildlife Refuge (Austin 2012). The tourism industry on the Platte River, with annual visits of over 35,000 people from all over the world, brings over US$10 million to the local economy during a two-month period each spring (Taddicken 2012). Income from crane-related tourism can be used for social needs, such as clinics and schools, and conservation needs, benefitting the farmers and other local people. Similarly, tourism in Israel's Hula Valley has been reported to bring in an estimated income of US$25 million a year to the region (Shanni et al. 2012, 2018).

Emerging Opportunities

The relatively stable agricultural systems of the former USSR republics were reorganized in the 1990s to early 2000s, resulting in a vast increase in abandoned fields (Ilyashenko 2018b). These changes influenced the Eurasian cranes' pre-migratory behavior resulting in their redistribution among pre-migratory autumn staging areas (Ilyashenko and King 2018). The cranes stopped using sites with limited food and concentrated on the fields of the successful agricultural enterprises, increasing pressure on these farmers (Ilyashenko and Markin 2013). More recently, the recovery of agriculture and general trend of increasing Eurasian Crane numbers (Prange 2012) has in some cases led to conflict between the cranes and stakeholders (Ilyashenko 2018b). Ecological tourism programs should be developed for these areas. Similarly, opportunities may exist elsewhere along the paths cranes follow and should be mapped out in order of priority to ensure effective crane conservation and ecotourism opportunities for farmers.

Even in areas where crane numbers are low, the cranes' opportunistic behavior of selecting agricultural lands can lend itself well to tourism opportunities. In Chrissiesmeer, South Africa, for example, the annual Chrissiesmeer Crane Festival relies on the Grey Crowned Cranes congregating in flocks on agricultural lands in the winter months to provide the visiting public an opportunity to view these endangered birds. The festival includes crane viewing trips onto private land, talks on various environmental topics, night tours to see the area's nocturnal wildlife, a central meeting point for the local community to sell their handicrafts and food, and also presents cultural events such as traditional dancing. This festival has increased the awareness of this location as an important crane and biodiversity area, causing the number of tourists visiting the area to rise throughout the year, hence contributing to the overall local economy.

Balancing Ecotourism, Cranes, and Communities

Although ecotourism can be good for local or regional development, education, and mitigation of crop damage, a constantly growing number of tourists can lead to problems. Adequate planning and budgets are needed to ensure tourism benefits farming communities while at the same time enhancing conservation. Again, experience elsewhere can be instructive for partnerships or communities attracted by tourism opportunities. For instance, several NGOs and the authorities of the federal state of Brandenburg, Germany, are working on nature and crane conservation at the Rhin-Havelluch area. With more and more cranes stopping at this site (>100,000 individuals in the mid-2000s) and an increasing number of local tourists visiting the area, crane conservationists are battling to raise funds sufficient for the construction of observation platforms and organization of excursions, exhibitions, and presentations (Gunther Nowald, personal comm. 2015).

Other concerns stemming from the rapidly developing crane tourism industry is the disturbance tourists can have on cranes. Tourists naturally want to approach cranes as closely as possible to take better pictures and/or to enjoy the magnificence of the cranes (Fig. 2). Most of the well-managed sites have observation towers and/or blinds for crane watchers and photographers, and tourist groups are accompanied by trained staff in order to ensure appropriate tourist behavior (e.g., no loud voices or flash photography).

Disturbance from uncontrolled tourists mostly exists on cultivated lands when visitors drive by car to look at the feeding cranes and take pictures. Roads leading to roosting sites may need to be closed to the public (Seeger and Rauch 2005). In Rugen-Bock, trained rangers from the Crane Information Centre are dedicated to reducing disturbances by directing visitors to places with fenced-off observation facilities (Nowald 2005). Balloons and drones are posing a new threat to Germany's Rhin-Haveluch area as they fly at low altitude over "forbidden areas" to capture photographic and video footage and can cause a panic reaction amongst the cranes (Seeger and Rauch 2005).

Fig. 2. Photographers gather to watch and photograph Siberian Cranes at Poyang Lake, China (Photographer: George Archibald)

The well-managed tourist site of Hornborga Lake in Sweden offers well-developed infrastructure and basic services around the lake and in three surrounding towns in the form of restaurants, cafes, hotels and youth hostels, shops, and supermarkets. Bird-watching sites and observation towers give a good opportunity to study different biotopes and cranes (Lundin 2005). Conversely, the small village of Linum (Rhin-Havelluch, Germany) is visited by many hundreds of crane tourists in October each year, but currently lacks adequate infrastructure to support the demands of so many visitors (Seeger and Rauch 2005). This problem has resulted in negative attitudes towards tourists and cranes from local people and farmers. Similar problems have been experienced in Khichan, India, where tourism has developed spontaneously but without supportive infrastructure (Pfister 1996).

Raising Public Awareness and Support Through Education

Although market forces are particularly important drivers in the agricultural sector, societal values for clean water and wildlife conservation in more developed nations have served to temper economic pressures. Today, NGOs as well as state and federal agencies are taking an increasingly active role in environmental education targeting the public and decision-makers. Improving public understanding of conservation issues, including those related to ecosystem services, is critical to getting both social and political support for conservation actions in agricultural landscapes.

Almost all well-managed crane tourist sites have information centers where information, interactive games, and specialized lectures and tours are provided. Such centers provide opportunities to reach a wide range of people though environmental education programs. For example, the Crane Park in Izumi, Japan, hosts a collection of crane exhibits and educational programs about cranes (Parilov 2004, Yuko Haraguchi, personal comm. 2016).

In central Nebraska, USA, the National Audubon Society raises world-wide awareness of the cranes and the threats to the Platte River. Audubon has led public sentiment to move the agricultural and conservation communities to work together for solutions, and has inspired Kearney, Nebraska, USA, a rural farming community in the central United States, to proclaim themselves the "Sandhill Capital of the World" (Taddicken 2012).

The annual Crane Festival in the Crane Homeland Wildlife Refuge, Moscow region, and Muraviovka Park, Amur Region, Russia has been running since the 1990s. About one thousand students from adjacent towns and villages take part in various activities that include bus tours to watch cranes in the fields. "Sowing crane fields" was pioneered there as an educational event, using ancient hand-sowing methods and involving students, local administrations, protected area staff, and spiritual leaders (Grinchenko 2002). The matured grains are not harvested but left as food for cranes in autumn. Recently a visitor center was built with the support of Naturschutzbund Deutschland (NABU) and other sponsors, where tourists can learn more about cranes, wetlands, and local wildlife. Similarly, Muraviovka Park of Sustainable Land Use (Russian Far East), bases its research and operations on the co-existence of cranes and people within an agricultural landscape. They provide practical examples of land management that benefits both people and nature. Due to the Park's environmental education program, which is closely interwoven with conservation, sustainable agriculture, and nature tourism projects, the Park has managed to significantly raise awareness of threats to cranes and wetlands and the direct impacts of farming practices on wildlife (Smirenski et al. 2018). As a result, more and more people are getting involved in conservation throughout the Amur Region (Moskaleva 2012).

Israel's Hula Valley offers a mobile crane blind (Fig. 3), photography workshops for beginners and professionals, sunrise and sunset tours, art workshops, a Crane Run, a local Winter Bird Festival and an International Bird Festival. Hotels, tourism sites and local attractions create events and products based on cranes such as weekend crane packages, exhibitions, tours, lectures, and musical performances (Semerano 2012).

In addition to the regular activities during the tourist season, many tourist centers organize special events to attract more people. Examples include the spring "Wings Over the Platte" celebration (Grand Island, Nebraska, USA), the "Rivers and Wildlife Celebration" (Kearney, Nebraska, USA), and the autumn "Festival of the Cranes" at Bosque del Apache National Wildlife Refuge (New Mexico, USA), all of which have specialized/tailored information and tours with experienced guides. The "Week of the Cranes" in the last week of September in the Rugen-Bock of Germany has numerous events, slide

Fig. 3. Mobile viewing stand for tourists allow close viewing of Eurasian Cranes wintering in the Hula Valley, Israel (Photographer: Zeb Labinger)

shows, as well as boat trips to the shallow night roosting areas of the lagoons in the national park Vorpommersche Boddenlandschaft (Nowald 2012). The "Crane Days" in Hortobagy National Park, Hungary, includes specialized talks and a tour to watch the crane roost flight (Vegvari 2005). The "Kruu-Fest" in Crane Homeland Wildlife Refuge, Russia, has bus tours for crane watching, numerous master classes, souvenir stalls, applied crafts, farm products, wood-burning samovars, tea made with local herbs, homemade jam, children's playgrounds, a colorful cultural program with the participation of local folklore ensembles, folk choir and the local theater group (Grinchenko 2014).

In Gallocanta, Spain, the Nature Guides Company organizes two crane celebrations each year (Pueyo et al. 2011). The first, the "Welcome Festival for Cranes", is held during the first weekend of October and consists of activities such as guided excursions and music concerts. The second event, the "Crane Weekend," is held during the last week of January and focuses on talks on crane behavior and migrations. Both events are well publicized and represent just a sampling of tourism activities that have developed around concentrations of cranes that also provide opportunities for environmental education.

Crane education and awareness on agriculture landscapes can be provided even without tourist development. The Crane Working Group of Eurasia has initiated a large-scale program to raise public awareness about cranes through mass media and special actions such as an annual Crane Celebration. The celebration is organized in autumn and winter (depending on the location and the country), when cranes can be observed gathering on agricultural landscapes (Moore and Ilyashenko 2009).

Using Research as an Education Tool

The presence of cranes across agricultural landscapes present valuable opportunities for research and education to be conducted in situ. Much of this research has focused on crane biology and the development of crop-damage mitigation strategies to reduce human-wildlife conflict. Results from such research has, in many instances, led to changes in land use that favor cranes, and has also decreased the economic losses experienced by farmers. In almost all cases, such successes have depended on cooperative efforts engaging the farmers impacted by cranes.

The ICF used its proximity and existing research program in Wisconsin, USA, to highlight research efforts to test the mitigating effects of Avipel® (outlined above) for crop depredation by Sandhill Cranes, using specially guided tours. Furthermore, ICF trains interns and hosts a number of national and international researchers each year who join ICF staff in their field research and/or conduct their own studies. ICF also plays a mentoring role for graduate students. In addition to fostering professional research, this same site provides an opportunity to introduce the public, ICF members and supporters, as well as the media, to applied crane conservation.

The African Crane Conservation Program, a partnership between the ICF and the Endangered Wildlife Trust, is exploring opportunities to study crop depredation in East Africa involving various prevention methods such as Avipel®. Communication with small-scale farmers is critical to assess the impact of cranes on maize (corn, *Zea mays*), ground nut (*Arachis*), pea (*Pisum sativum*), and other crops. Research in Uganda found that communicating the ICF's experiences with local communities is particularly important for public relations, noting "It is important for the farmers to know that there is a possible solution to the crop depredation by cranes… and it gives hope rather than to assume we are only interested in crane number increases, not the farmers' plight when their crops are damaged" (Jimmy Muheebwa, personal comm. 2012).

In 2010, a team of BirdLife Zimbabwe Officers tested the use of scarecrows on globally threatened Wattled and Grey Crowned Cranes to reduce crop damage (mostly on maize at germination stage and rice, *Oryza sativa,* at milk stage) by cranes and improve their conservation through mitigating the human-crane conflict. The scarecrow models tested in this project worked effectively and the method was well received by local villagers. Local communities in Zimbabwe's Driefontein area were also trained on the use of the scarecrows and awareness on crane conservation was successfully raised (Fakarayi et al. 2018).

In California's Central Valley, USA, a coalition of conservation organizations (Audubon California, Point Blue Conservation Science, and The Nature Conservancy), the California Rice Commission, and individual farmers have been working together to enhance intensively farmed rice fields for a wide range of wetland-dependent bird species. This project provides a model for local solutions that increase farmland's conservation value without seriously affecting food production. The consultative workshop model that this project employed ensured that very different perspectives were put on the table for discussion. It results in learning both for the 'conservationists' and the 'farmers/industry.' Possible solutions were discussed for a range of perspectives, practicalities addressed, and solutions found (Elphick et al. 2018).

Crane Conservation Germany conducted research on how crane feeding behavior was affected by agriculture intensification, in an attempt to find preventative measures to mitigate human-wildlife conflict. Their research raised awareness among an extensive number of farmers in methods to reduce crane damage through changes to agricultural processes. Techniques included leaving grain stubble-fields unplowed as long as possible, sowing of 10–20% more winter seeds, and sowing grain at times when cranes are absent. As a result, the damage caused by cranes has been reduced in the area and the increasing crane population now lives compatibly with the intensive land use of the area (Nowald et al. 2010).

In Russia, the challenge of reducing crop damage by cranes was investigated between 1994 and 2002 in Daursky State Nature Reserve (SNR) in the steppes of South-East Transbaikalia. Croplands (mostly oats, *Avena sativa*, and wheat, *Triticum aestivum*) attract staging cranes, geese, and ducks that have roosting sites in the reserve. Up to 42,000 Demoiselle and nearly 1,000 Hooded Cranes feed in fields neighboring the reserve and cause significant damage (up to 70% in some wheat fields). Using various methods to reduce crane depredation, experimental trials were conducted in collaboration with farmers. Methods included moving croplands further from roosting sites; using diversionary crops (usually millet, *Panicum miliaceum*, as it is a relatively cheaper crop, but attractive to cranes); and changing agricultural practices. All of these methods had good results and helped solve the crop depredation problems – at the same time improving knowledge and appreciation of crane ecology in the local community, conserving crane populations, and improving relationships between farmers and Daursky SNR (Goroshko et al. 2008, Goroshko 2012).

An increasingly popular technique to engage local communities, interest groups and tourists, is citizen science. While the use of members of the public to contribute to science (citizen science) is not entirely new, technological updates in the form of smart phones and similar devices, has created many new opportunities to not only collect information, but also for researchers and scientists to provide information to empower citizens (Dillon et al. 2016). Such programs can be as simple as members of the public submitting sighting information, to more complex ones that see stakeholders (including the public) contributing to policy formulation and development.

Sustaining Cultural and Spiritual Values of Cranes

Most of the successful partnerships presented in this chapter have brought very different stakeholders together. An important aspect of developing partnerships is the discovery of common or shared values. Crane conservationists are fortunate in that cranes have special cultural significance in many regions. When seeking to reach out to new partners, practitioners should consider carefully the culture of cranes and draw on local traditions in the process of exploring cooperative strategies.

Cranes are among the most spectacular, elusive, and beautiful birds on earth, with a heritage that goes back to prehistoric times. Their resounding voices are trumpets from the past. Over the centuries, cranes have been symbols that speak to the human heart. They figure prominently in the artwork, dances, poetry, and folk tales of many cultures. Cranes are universal symbols of longevity, monogamy, and good luck due to their long life spans and mate fidelity.

Ancient Sanskrit literature dating from the first or second century provides the first reference to what can be recognized as Sarus Cranes. Their stature, unison calls, and lively dancing are among the features that have rooted cranes in local culture and folklore. Indeed, many South Asian cultures today consider it a crime to kill a crane and believe such an act will bring bad luck (Sundar 2018). Modern Pueblo cosmology, mythology and ceremonialism dates back to the 14^{th} century. The kiva murals at Pottery Mound, New Mexico, USA, depict a number of birds most closely associated with fertility, control of the weather, and well-being of the community; Whooping Cranes appear among these depictions (Eckert and Clark 2009).

Similarities exist with many Ethiopian cultures where the killing of a crane for food is taboo (Aynalem et al. 2018). The Zulu people of southern Africa revere the Blue Crane, and the feathers of this crane are reserved for use only by the royal family. The feathers are thought to bestow powers to predict the weather. The Xhosa people associate the Blue Crane with brave warriors and their feathers were only used during battle. The killing of Blue Cranes is taboo and thought to bring very bad luck (Didrickson 2010).

Many cultures around the world have various crane species as totems. For example, the Diedhiou people in the Casamance in southern Senegal use the Black Crowned Crane as their totem. As a result, the species is strongly protected in the area, with local communities noting that no crop damage is caused to ripening rice fields of the Diedhiou people, despite the species' presence (Idrissa Ndiaye, personal comm. 2016). Many North American tribes are known to have crane totems, crane clans, or feature cranes in their origin stories. Since totems are considered a symbolic protector, such reverence affords cranes protection from persecution (Didrickson 2010).

In Extremadura, Spain, cranes are a symbol for the beginning of winter, which is why the annual "Crane Day" takes place the first Sunday in December to celebrate their arrival. Likewise, the annual Black-necked Crane Festival in the Phobjikha Valley, Bhutan, in November is an occasion for the local residents to rejoice at the arrival of the treasured birds and celebrate the king's birthday. Black-necked Cranes are protected in Bhutan due to the local people's traditional and religious attitudes toward all living beings.

Cranes are national birds for several countries in Africa. In Uganda, the Grey Crowned Crane is highly regarded by many of the country's inhabitants, due to its national bird status. The Blue Crane, the national bird of South Africa, is also well known, and is highly regarded by the country's Zulu people. Sadly, the Black Crowned Crane, the national bird of Nigeria, is functionally extinct in the country, with only a few occasional visitors.

Sundar (2018) suggests that in areas where the ranges of cranes are expanding quickly, local people have not had time to fully incorporate cranes into their culture, which could lead to conflict. He also suggests that typical conservation methods are unlikely to work in areas that are not fully monetized. For example, paying farmers compensation for damage could be viewed negatively, or even considered corruption. The conservation strategies employed in an area need to take local attitudes and culture into account in order for them to be adopted by communities.

Knowledge Gaps

- In many places where crane-linked conservation projects are present or needed, there is inadequate understanding of the perspectives and socio-economic factors that influence attitudes of farmers and local communities towards cranes and conservation actions;
- Effective and inexpensive approaches for reducing crop depredation and negative attitudes towards cranes and nature conservation are required for subsistence and small scale agricultural landscapes;
- Cultural beliefs and the stories about cranes in agricultural landscapes often reside with the elders of communities and are being lost over time; and
- There is a lack of understanding of the process required to entrench crane conservation into local culture to ensure the uptake of conservation efforts in agricultural landscapes.

Recommendations

- Ensure effective and appropriate partnerships exist at strategic sites, drawing on experience with successful partnerships elsewhere;
- Build and expand partnerships on local, national, and international levels between farmers, administrations, hunters (where relevant), and nature conservationists, as well as with the agricultural industry, to develop measures to prevent and reduce crop damage by cranes. To enable this, a stakeholder assessment, that identifies each of the potential partners and stakeholders in the area and their respective roles and responsibilities, is encouraged. From this assessment, the relevant partners should be consulted in the development of a strategic plan for the region, from which a communications and engagement strategy that supports the plan can also be developed;
- Seek opportunities to engage in collaborative research with the agricultural industry to develop more effective farming practices and technologies that minimize negative impacts to cranes;
- Accumulate and share existing experiences and learn lessons on reducing crop damage in consultation with people around the world who are also working on this issue;
- Involve farmers in studies on how to mitigate conflict between cranes and agriculture through reducing crane damage to crops;
- Provide education and public awareness activities using nature scenarios of migrating and wintering cranes on agricultural landscapes to increase the knowledge among farmers, other community members, and tourists;
- Develop guidelines and recommendations for crane ecotourism to ensure effective management of disturbances to cranes, farmers, and the wider community;
- Promote the development of educational components and outreach programs;

- Increase the dissemination of knowledge to the public and agricultural community about crane ecology and conservation, crane-agriculture relationships, and effective strategies for minimizing conflicts with farmers via the internet;
- Use social media tools to communicate with farmers and communities to spread the word about crane ecology and movements, educational opportunities (e.g., crane festivals, workshops), and positive solutions and mitigation measures to resolve conflicts;
- Strategically identify new areas that can be used for ecotourism and educational opportunities, as well as the infrastructure needed to support such efforts;
- Collect crane stories from the elders in areas where cranes are highly revered and ensure that they are shared across the local community;
- Develop a range of tools (e.g., guidelines) and techniques (e.g., lobbying strategies) for use by partnership bodies; and
- Understand how large-scale developments (e.g., the man-made narrowing of the Platte River Valley) will impact on socio-economic livelihoods to ensure proactive planning is conducted and mitigation measures implemented.

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CHAPTER 9

Synthesis

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Cranes have a close relationship with arable and pastoral agriculture that goes back hundreds, presumably thousands of years. The landscapes and ecoregions important to cranes are also those areas most conducive to agriculture. Thus, cranes and humans are attracted to the same landscapes and will therefore have futures that remain co-mingled. As such, agriculture can both benefit and inhibit crane populations. Agriculture can often benefit cranes, such as cropland that provides predictable and concentrated food sources for migrating and wintering birds or grazing that maintains open and productive grasslands that are required by territorial pairs. However, agriculture has changed significantly over the past century in extent and intensity and will continue to change rapidly into the future. Agriculture has become a key threat to the world's crane species through the direct loss of wetland and grassland habitats and the indirect impacts of agricultural practices. Agriculture has become a key driver of crane population dynamics.

Increasing demands for food production to meet growing human populations across the globe, particularly in Asia and Africa, are causing continued threats to remaining natural habitats as well as leading to changes in agricultural practices that are less beneficial to cranes. Some experts estimate that the human population will need 50% more food by 2030 and a doubling of food production by 2050. We therefore anticipate increased pressure on cranes and their habitats as agricultural land use intensifies that will result in growing conflicts between cranes and agriculture. The challenges are great! Although the future challenges are great, so are the opportunities. Cranes and agriculture are linked and people, for myriad reasons, find value in cranes. In addition, land use that benefits cranes can also benefit the agricultural model. Hence, these graceful ambassadors can provide divergent cultures with metrics for success.

Ideally, sustainable agriculture needs to be viable in three arenas: economic, environment, and social. These components, though, are often not weighted equally. The need to address resilience and scale in farming practices has become ever more critical in a changing climate and human-dominated world. Unfortunately, this trend often leads to a disproportionate focus on economic sustainability at the cost of environmental or social sustainability. The changes that we see in the agricultural landscape will vary considerably around the world, dependent on a multitude of factors including climate change, adoption of new technologies, socio-economic factors, energy supply, consumption patterns, water supply, and government policies. These considerations, as key drivers for agriculture, therefore need to be addressed through projects or policies developed to improve the interface between cranes and agriculture. Regrettably, the greatest short-coming we face in providing a more balanced and sustainable system is poor development and transfer of tools to those landowners who desire to pursue sustainable systems. Too few actual examples of a balanced sustainable system that have been successfully deployed are available or have not been broadly shared.

Austin JE, Morrison K, Harris JT, editors. 2018. *Cranes and Agriculture: A Global Guide for Sharing the Landscape.* Baraboo, Wisconsin, USA: International Crane Foundation. 303 p.

To ensure the sustainable future of cranes, we seek to integrate knowledge of crane ecology with agricultural systems and cultures. We often lack sound, evidence-based knowledge and solutions to the challenges we face at the crane – agriculture nexus. Yet we can recognize and build upon the benefits that agriculture provides to cranes and other wildlife, while learning from our efforts to minimize potential negative impacts on cranes and the agricultural sector. This balance can be achieved through strong collaborations that draw on literature outlined in this Guide, lessons learned from around the world, and the expertise on best practices from conservationists, farmers, researchers, and government representatives. Such broad collaborations can more effectively mitigate conflict situations or make use of opportunities that the nexus provides.

Although we have a broad understanding now of the crane – agricultural interface, as outlined in this Guide, there remain many gaps in our knowledge. These uncertainties challenge our ability to clearly identify the problem at the appropriate scale – whether at the scale of a local field or an entire flyway – and in turn our ability to identify opportunities and develop effective solutions. Cranes have proven to be adaptable over the centuries to gradual changes in agriculture, but to what extent can cranes adapt to more rapidly changing agricultural land uses, crops, and practices? What may the tipping points look like, and can they be predicted and circumvented? For example, over half a million migrating Sandhill Cranes (and millions of other waterbirds) in central Nebraska rely on irrigated crop fields. Efforts to increase crop production, benefitting both farmers and cranes, may come at the cost of greater water use and reduced river flow and groundwater recharge, which in turn may diminish roosting habitat. If we are to be successful in sustaining the crane-agriculture nexus, a sustainable model means that myriad resources arise from the same fields and challenges must be grappled with simultaneously rather than serially.

More simply, one key to successful solutions is understanding the role of agricultural foods in the dietary and bioenergetics needs of cranes across different parts of their life cycle and relative to reproduction and survival. Better delineation of flyways, important stopover areas, habitat connectivity, and patterns of habitat loss in relation to agriculture and human pressures will be critical to targeting conservation actions. Identifying spatial and temporal risks from fire, agricultural chemicals, power lines, and diseases from domestic animals will aid in the development of policies and methods to mitigate those risks.

Our understanding of socio-economic factors in the agricultural-conservation nexus is particularly limited but critical to developing policies and programs that are accepted and sustainable on a broad enough geographic scale to successfully benefit entire populations of cranes and people. Addressing these and other issues as discussed in this Guide will then provide us with a more holistic understanding of how to balance crane conservation needs with those of agricultural communities for a mutually beneficial trajectory. Given the complexity of the issues across ecological, social, and economic realms and rapidly changing environments, adaptive, multi-disciplinary approaches must be founded on sound research and monitoring. For truly adaptive management approaches, we need data (such as population and vital rate data) that clearly demonstrate cause and effect and can prove efficacy of interventions.

At the heart of the challenge for cranes globally are habitat loss and degradation. This is also a major threat to people and agriculture as well. Addressing this threat at any scale will require buy-in and commitment from farmers, conservationists, and governments. This is both our strength (because there is common purpose) and our weakness (because we have few existing models to easily deploy). Multi-sectoral and multi-stakeholder approaches and partnerships will often be necessary to achieve success. Improved legislation and enforcement as well as expanded resources are required to secure natural habitats, strengthen management of landscapes and protected areas, and restore degraded habitats. But also important will be integrated, community-based land-use programs that promote conservation of cranes and crane habitats among farmers and other private landowners.

Sharing knowledge and experience from diverse situations, landscapes, flyways, and species is key to developing a broader toolset for balancing the needs of cranes and agriculture. This Guide is a significant step in that effort. Among the next steps are finding the most appropriate mechanisms and approaches for distributing the information contained within this Guide and from model projects to the diverse stakeholders involved. We look toward all interested and affected stakeholders to build and share our knowledge and capabilities in ways that make a difference to the world's 15 crane species and the agricultural landscapes on which they depend.

Call to Action: Promoting Harmony Between Cranes and Agriculture

SERVING as models and ambassadors for wildlife conservation across agricultural landscapes, cranes are good indicators and flagships for integrating biodiversity conservation into agricultural practices;

ACKNOWLEDGING that cranes are well adapted to utilizing many agricultural landscapes and that this interface has become a key driver in global crane population dynamics;

UNDERSTANDING that the life histories of cranes are closely tied to wetlands and grasslands, which are the most vulnerable ecosystems to agricultural conversion, overexploitation, and other impacts;

UNDERSTANDING that the intensification of agriculture over the last 50-100 years in many cases has resulted in a greater abundance of food for cranes, whilst rapid agricultural expansion, contraction, intensification, and market changes have had both positive and negative effects on cranes;

RECOGNIZING that sustainable agricultural development, in concert with wetland conservation, can harmonise the growing need for food production with ensuring a future for wetlands and cranes in an era of climate change and declining food and water security;

NOTING that affiliations of most cranes to humans and livestock farming activities means that cranes often interact with a variety of domestic animals, benefitting primarily from the rapid recycling of grassland nutrients, maintenance of open areas, and invertebrate food sources that grazers facilitate, but threatened by overgrazing, direct disturbances and altered habitats;

KNOWING that food production will need to increase by about 70% by 2050 to cope with human population increases, which in turn will increase competition between humans and wildlife for land and water resources;

CONCERNED that the greatest threats to cranes worldwide are related to agricultural activities, including direct losses of wetlands and grasslands; altered wetland hydrology due to water control systems such as dams or irrigation ditches; fire; direct and indirect impacts from agricultural chemicals; human disturbances; disease risks where cranes congregate in high densities on crops or in association with domestic birds; and collisions with power lines in cropland areas;

CONCERNED that conflicts between cranes and farmers are now occurring at an escalating rate, increasing the risk of persecution and negative impacts;

RECOGNIZING that alternative methods to reduce conflicts between cranes and farmers are available, ranging from relatively simple, inexpensive disturbance methods to changes in land use at a landscape scale;

ACKNOWLEDGING that in most instances, an integrated and landscape level approach is required to resolve conflict, and that solutions will be situation-specific;

RECOGNIZING that worldwide, most land is privately owned or managed and that most private land is used for agricultural purposes, therefore, to solve land-based environmental problems and to reduce conflicts between agriculture and wildlife, it is necessary to work closely and effectively with private landowners;

RECOGNIZING that many societies value cranes for their cultural and spiritual significance, and that cranes can inspire understanding and action to enhance both natural and artificial ecosystems, with widespread benefits to numerous other species and to humanity;

The IUCN Species Survival Commission Crane Specialist Group:

CALLS ON all stakeholders to:

better understand the crane – agriculture interface through reference to the *Cranes and Agriculture: A Global Guide for Sharing the Landscape.*

CALLS ON governments to:

a. Acknowledge that crane – human conflicts arise within agricultural landscapes, often resulting in the persecution and negative impacts on cranes;

b. Recognize the interrelationships among agricultural, socio-economic, and environmental policies in their influences on crane-agricultural interactions and conflicts;

c. Work with conservation practitioners, agricultural experts, and other key stakeholders to explore effective solutions to mitigating human-crane conflicts occurring in agricultural landscapes;

d. Adopt and enforce policies that sustain biodiversity values within agriculture landscapes, including protection of wetlands and other ecologically important lands from encroachment and runoff, and regulation and safe use of pesticides that do not threaten ecosystem health or cranes; and

e. Disseminate information to farmers and land managers about sustainable farming, sound water use, and methods to avoid conflicts with wildlife in areas significant to cranes or other wildlife.

URGES IUCN members and commissions to:

a. Use the crane-agricultural experience as a model and cranes as an ambassador for wildlife conservation across agricultural landscapes; and

b. Share lessons learned and experiences in the wildlife-agricultural landscape so that other IUCN members and groups can draw from them.

CALLS ON conservation practitioners to:

a. Find the balance in agriculture practices that enhances sustainability of agriculture and natural biodiversity while meeting demands for increased agricultural output and efficiencies;

b. Consider a successful solution to human-wildlife conflict being defined by a process that is effective, adapts to the target economic system, allows for individual control, and is implemented at appropriate scales;

c. Undertake cross-sectoral discussions between agriculturists and conservationists, and conservationists and government departments responsible for agriculture, to encourage the co-creation of early interventions that could potentially help reduce future conflict situations;

d. Develop partnerships at various levels to mitigate for the conflict that arises between cranes and people and to make use of the opportunities around ecotourism and research created through cranes reliably occurring in agricultural landscapes;

e. Use multi-disciplinary approaches that incorporate social and economic as well as ecological aspects of the crane - wildlife - agriculture interface to develop workable solutions; and

f. Consider alternative methods to reduce conflicts between cranes and farmers, recognizing that methods will be more effective when tailored to the local situation, taking into account the changing seasons of cranes and their life histories, the natural foods of cranes, the crops and farming practices most suitable to the area, and a careful balance between the needs of cranes and farmers. Acknowledging that often the best approach is an integration of different methods, as no one control method will be effective over the long term, and the situation may change over time.

ENCOURAGES farmers and land users to:

a. Explore mitigation options available before persecuting cranes and other wildlife;

b. Improve their understanding of crane biology to identify the best approaches in each situation to prevent or mitigate conflicts;

c. Collaborate and partner with conservation practitioners and other stakeholders in the development and implementation of effective strategies that will mitigate human – crane conflict in agricultural landscapes;

d. Consider using agricultural practices that benefit cranes by increasing food availability to cranes, without incurring negative impacts to agricultural livelihoods; and

e. Consider alternative methods to reduce conflicts between cranes and farmers, recognizing that methods will be more effective when tailored to the local situation, taking into account the changing seasons and life histories of cranes, their natural foods, the crops and farming practices most suitable to the area, and a careful balance between the needs of cranes and farmers, and acknowledging that often the best approach is an integration of different methods, as no control method will be effective over the long term, and the situation may change over time.

REQUESTS researchers to:

a. Improve our understanding of how to ensure persistence of cranes alongside farming, particularly in landscapes where traditional, subsistence or small-scale farming dominates;

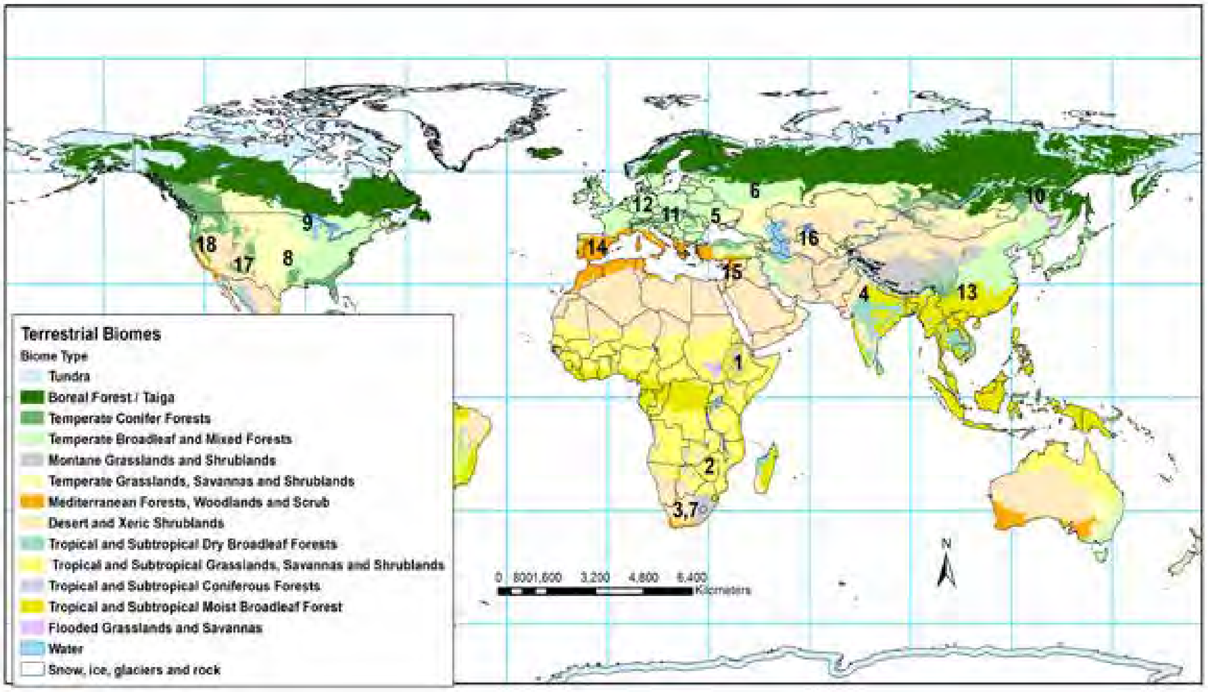
b. Develop a sound understanding of community perceptions, socio-economic, political, scientific, and climate factors influencing agriculture, to help inform planning and implementation of effective and sustainable conservation strategies for cranes;

c. Develop ecologically viable approaches based on crane life histories to help implement more effective strategies to reduce human – crane conflict; and

d. Engage agriculturalists and agricultural communities in the development of studies examining alternative management practices that better address their concerns and situations, and that would more likely lead to practices benefitting both agriculturists and cranes.

White-naped Cranes share a pasture with cattle (Photographer: Andrew Holman)

Case Studies



No.	Country	Case Study Title
1	Ethiopia	Black Crowned, Eurasian, and Wattled Cranes and agriculture expansion at Lake Tana, Ethiopia
2	Zimbabwe	Mitigating human-crane conflict in Driefontein Grasslands, central Zimbabwe: a test of scarecrow methods
3	South Africa	Quantifying crop damage by Grey Crowned Crane in the North Eastern Cape, South Africa
4	India	Sarus Cranes and Indian farmers: an ancient coexistence
5	Ukraine	Preliminary review of co-existence and conflict of cranes and agriculture in southern Ukraine
6	Russia	Changes in distribution and populations of Eurasian and Demoiselle Cranes in response to agricultural changes after the Soviet Union Collapse
7	South Africa	South African Crane Conservation case studies: Experiences and observations
8	USA	Opportunities For crane conservation through U.S. Department of Agriculture Conservation Programs
9	USA	Developing anthraquinone (AQ) as a crane deterrent
10	Russia	Agriculture program of Muraviovka Park: Integrating wetland conservation with farming
11	Hungary	Stopover management for the Eurasian Crane in Hortobagy National Park, Eastern Hungary
12	Germany	Development of Stop-Over Area for Eurasian Cranes and the Influence of Agriculture in the Rügen-Bock region in Northeast Germany
13	China	Integrating conservation with rural development in Cao Hai, China
14	Spain	A Review of the Crane-Agriculture Conflict at Gallocanta Lake, Spain
15	Israel	A review of the crane-agriculture conflict, Hula Valley, Israel
16	Uzbekistan	Relationship between Eurasian Cranes and farmers at wintering ground in Upper Amudaria River Valley, Surkhandaria Province, Uzbekistan
17	USA	Resolving conflicts between Sandhill Cranes and agriculture in the Middle Rio Grande Valley, New Mexico, USA
18	USA	Wetland bird conservation in California rice fields

A Guide to Case Studies from Around the World

Case studies are organized and color-highlighted by season, type of agriculture, and scale of each case study. A check mark in columns indicates the aspects of the crane-agriculture nexus covered. See map on previous page for geographic reference.

Case study title	Season	Type of agriculture	Scale	Wetland focus	Conservation areas & habitat programs	Financial compensation programs for crop loss	Lure fields & artificial feeding	Other methods	Tourism & Education	Damage to seeded crops	Impact to breeding birds	Long-term patterns of agriculture & cranes
1 – Black Crowned, Eurasian, and Wattled Cranes and Agricultural Expansion at Lake Tana, Ethiopia	All	Traditional	Landscape	✓						✓	✓	
2 – Mitigating Human-Crane Conflict in Driefontein Grasslands, Central Zimbabwe: A Test of Scarecrow Methods	All	Traditional	Landscape					✓		✓		
3 – Quantifying Crop Damage by Grey Crowned Crane in the North Eastern Cape, South Africa	All	Traditional	Landscape					✓		✓		
4 – Sarus Cranes and Indian farmers: An Ancient Coexistence	All	Traditional	Region	✓							✓	✓
5 – Preliminary Review of Co-Existence and Conflict of Cranes and Agriculture in Southern Ukraine	Breeding and Migration	Modern	Region		✓						✓	✓
6 – Changes in distribution and populations of Eurasian and Demoiselle Cranes in response to agricultural changes after the Soviet Union collapse	All	Modern	Region									✓
7 – South African Crane Conservation Case Studies: Experiences and Observations	All	Modern	Region		✓				✓			
8 – Opportunities for Crane Conservation Through US Department of Agriculture Conservation Programs	All	Modern	Region	✓	✓			✓				
9 – Developing Anthraquinone (AQ) as a Crane Deterrent	Breeding	Modern	Landscape					✓		✓		
10 – Agriculture Program of Muraviovka Park: Integrating Wetland Conservation with Farming	Breeding	Modern	Landscape	✓	✓		✓	✓	✓			✓
11 – Stopover Site Man-age-ment for the Eurasian Crane in Hortobágy National Park, Eastern Hungary	Migration	Modern	Landscape	✓	✓		✓					✓
12 – Development of Stop-Over Area for Eurasian Cranes and the Influence of Agriculture in the Rügen-Bock region in Northeast Germany	Migration	Modern	Landscape			✓	✓		✓	✓		✓
13 – Integrating Conservation with Rural Development at Cao Hai, China	Migration & Winter	Traditional	Landscape	✓	✓			✓	✓			
14 – A Review of the Crane-Agriculture Conflict at Gallocanta Lake, Spain	Migration & Winter	Modern	Landscape		✓	✓			✓	✓		✓
15 – A Review of the Crane-Agriculture Conflict in the Hula Valley, Israel	Migration & Winter	Modern	Landscape		✓		✓		✓			
16 – Relationship Between Eurasian Cranes and Farmers at Wintering Ground in Upper Amudaria River Valley, Surkhandaria Province, Uzbekistan	Winter	Modern	Landscape					✓				✓
17 – Resolving Conflicts Between Sandhill Cranes and Agriculture in the Middle Rio Grande Valley, New Mexico	Winter	Modern	Landscape		✓	✓	✓	✓	✓			✓
18 – Wetland Bird Conservation in California Rice Fields	Winter	Modern	Landscape	✓	✓			✓	✓			

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CASE STUDY

Black Crowned, Eurasian, and Wattled Cranes and Agricultural Expansion at Lake Tana, Ethiopia

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Abstract: Four species of cranes occur in Ethiopia, three of which occur in the Lake Tana area: the resident Black Crowned Crane (*Balearica pavonina*) and Wattled Crane (*Bugeranus carunculatus*), and the Palaearctic migratory Eurasian Crane (*Grus grus*). The distribution and population of each of the four species in Ethiopia is quite variable, with total population numbers estimated after several years of crane monitoring of 1,071 Black Crowned Crane, 110 Wattled Cranes, > 20,000 Demoiselle Cranes (*Anthropoides virgo*), and >60,000 Eurasian Cranes. The Lake Tana area has recorded 94% of the population of Black Crowned Cranes and 36% of Eurasian Cranes and is a breeding area for Black Crowned Cranes and Wattled Cranes and a wintering site for Eurasian Cranes. Availability of food and secure wetland habitat for Black Crowned Cranes and Wattled Cranes in the area has become a challenge for these species to survive. This study was initiated to provide an overview of possible conflicts between cranes and agriculture and was conducted in three major parts of Lake Tana. Although cranes could cause damage to crops in the area, killing or poaching of birds was scarce here due to religious beliefs and cultural taboos. Cranes, however, are threatened directly or indirectly by agricultural practices such as the increased use of mobile water pumps for farming and the resulting loss of habitat, especially wetlands. In addition, sequential (multiple) cropping systems and human population pressure on the land have significantly influenced the Eurasian Crane's feeding behavior. Conservation challenges at crane breeding, feeding, and roosting sites, mainly in and around the wetlands, can only be resolved through community and stakeholder participation, cooperation with regional government, proper planning, environmental awareness creation, and implementation of appropriate problem-solving, community based conservation projects to ensure sustainable development in harmony with the environment.

Keywords: agricultural practices, Black Crowned Crane, Demoiselle Crane, Eurasian Crane, Wattled Crane, Ethiopia, Lake Tana, wetland loss

Background

Four species of cranes occur in Ethiopia: the resident Black Crowned (*Balearica pavonina*) and Wattled (*Bugeranus carunculatus*) Cranes, and the Palaearctic migratory Eurasian (*Grus grus*) and Demoiselle (*Anthropoides virgo*) Cranes. The distribution and population of each species is variable. The Black Crowned Crane is resident throughout the western highlands and the Rift Valley lakes and rivers. In 2007, 1,071 individuals were observed during crane monitoring in Ethiopia, with 94% of

Fig. 1. A Black-crowned Crane nest in the north of Ethiopia close to Lake Tana (Photographer: Shimelis Aynalem)

Fig. 2. Black-crowned Cranes roosting in vicinity of Jimma, Ethiopia (Photographer: Günter Nowald)

the population sighted in the Lake Tana area. The total population of Wattled Crane in Ethiopia is estimated at 200–250. During the 2011 crane monitoring, around 110 Wattled Cranes were recorded, of which more than 66% were located in the Rift Valley areas. However, no breeding pairs were observed except at Lake Tana (2 juveniles) and Lake Boyo (adult with juveniles). The locations of Wattled Cranes are restricted and isolated. Eurasian Cranes stay in Ethiopia from October to March and are distributed throughout the country except for the Northeast and drier areas elsewhere. They favor the western highlands and Rift Valley. During the 2009 crane monitoring, a total of 59,008 Eurasian Cranes were recorded, with over 36% in the Lake Tana area. The distribution and status of Demoiselle Cranes in the country is not well known; however, 21,500 birds were sighted during a field expedition at Kafta-Sheraro National Park (Gebremedhin and Demeke 2011).

Only Wattled, Eurasian, and Black Crowned Cranes occur in different sites around Lake Tana, which supports breeding and feeding sites of Black Crowned Cranes (Fig. 1 and 2) and Wattled Cranes (Fig. 3), and a roosting and feeding site for Eurasian Cranes (Nowald et al. 2010, Shimelis et al. 2011). The food availability and the requirement of secure wetland habitat for Black Crowned and Wattled Cranes in the area have become a challenge for these species' survival here as people compete for similar resources.

Farming practices have influenced breeding, feeding, and roosting sites of cranes. When the rainy season ends, farmers usually cultivate most of the roosting sites and some of the breeding areas of cranes. In addition, farmers use the wetlands for grazing because the areas are communal land. They cultivate crops and vegetables using the remaining moisture, and some of them use mobile water pumps to irrigate adjacent farm lands. This investigation was initiated with the objective of providing an overview of the conflicts between cranes and agriculture at Lake Tana, Ethiopia.

Description of the Study Area

Lake Tana is located at 1,800 m above sea level and is the largest lake in Ethiopia, with an estimated surface area of 3,200 km^2 and a watershed of 16,500 km^2. It forms the head water of the Blue Nile, which carries more than 86% of the total volume of the Nile River at Khartoum, Sudan (Zurich ETH and Arsano 2007).

The study was conducted in three major parts of Lake Tana: the southern part (Zegie and Chimba), the north (Gorgora), and the eastern part (Fogera Plain). The topographic features of the area are variable depending on vegetation cover, land use, and slope. The major wetland is found at the southern part of the lake, whilst the eastern part, particularly Fogera Plain, is undulating and regularly flooded by the Gumara and Rib Rivers. The northern part, adjacent to Dembia Plain, has similar features to the Fogera Plain.

The area supports two Important Bird Areas – Bahir Dar-Lake Tana and Fogera Plain – because it possesses globally threatened species such as Wattled Crane, Lesser Flamingo (*Phoeniconaias minor*), Rouget's Rail (*Rougetius rougetii*), Pallid Harrier (*Circus macrourus*), and Greater Spotted Eagle (*Aquila clanga*). In addition, the area is estimated to host water bird populations that are likely to exceed 150,000 seasonally. Nineteen highland biome bird species have also been recorded in the area, including Abyssinian Long-eared Owl (*Asio abyssinicus*), White-backed Black Tit (*Parus leuconotus*), White-throated Seedeater (*Sporophila albogularis*), and Banded Barbet (*Lybius undatus*) (EWNHS 1996). However, the area is under threat, particularly from agricultural encroachment.

Agriculture Conflicts

Local people follow traditional farming systems in which rainfall is the main basis for crop farming. Irrigation schemes, however, have recently been established in some areas where rivers and wetlands are located. Cranes and some other waterbirds are considered to be agricultural pests at Lake Tana; Eurasian Cranes for instance can strip bare fields of varieties of sorghum crop (*Eragrostis tef*; EWNS 1996). Due to religious beliefs and cultural taboos, however, the killing and poaching of birds for food is scarce in Ethiopia, except francolins (*Francolinus*) and guineafowl (Numididae) in some places. Hence, it is common to see cranes and other birds feeding close to or within farmlands even with the farmers present. Farmers want to prevent the crop damage but have not yet used poisoning of birds.

The conversion of wetlands to agriculture and sequential farming (cultivation of another crop immediately after the other) is a major challenge for cranes. Due to draining and pumping wetlands

Fig. 3. Foraging Wattled Crane pair at Lake Zway, Ethiopia (Photographer: Günter Nowald)

dry out relatively quickly after the rainy season because these areas are immediately used for cultivation of the next crop. As a result, cranes will be forced to leave the area in search of water and suitable foraging sites. In addition, the sequential farming system has an effect on the feeding behavior of cranes because cranes do not have the opportunity and enough time to feed on the fallen grains that are shattered or left in the farmland immediately after harvest.

Agriculture Conflicts with Breeding Grounds of Cranes

Due to human population pressure, wetlands are being converted to agriculture. This conversion totally or partially destroys the breeding grounds of Black Crowned and Wattled Cranes. As a result, breeding productivity has declined, with few juveniles observed, particularly at the Yiganda wetland. Generally, the occurrence of large populations of cranes during the dry season has decreased. This trend is either a result of cranes migrating to other suitable wetlands or a decreasing population; further research is required to fully understand the situation. The wetlands of the southern part of Lake Tana, the most important breeding area for both species, are under particular threat. Between September 2009 and August 2010, over 30% of the area was given to landless young farmers. Consequently, these wetlands are being destroyed by rooting out the vegetation, burning, and then digging and draining to ready the land for cultivation. The papyrus (*Cyperus papyrus*) vegetation has been completely removed except for some fragmented remnants. Most of the converted to agriculture land has been prepared for rice (*Oryza sativa*) cultivation, with some areas also used for potato (*Solanum* spp.) and maize (*Zea mays*) production. Previously, the crane breeding sites had never been used for such intensive agriculture.

Agriculture Conflicts with Crane Feeding Sites

Cranes are known pests for chickpea (*Cicer arietinum*), finger millet (*Eleusine coracana*), sorghum, or "teff," and rice. Until recently, however, most farmers made little effort to kill or scare away cranes from their agricultural lands. Scarecrows are usually placed in the middle and along the borders of the farms, but after a few days birds become accustomed to them, aware that they do not pose a threat, and return to feed in the fields.

The sequential cropping system has brought a significant change in land use and has had a big influence on the Eurasian Crane's feeding behavior. It prevents cranes from feeding efficiently on waste grain, as the land is cultivated for other crops immediately after harvest. Then cranes shift to feed on chickpea fields, which can be grown with only limited moisture. The cranes have been observed to pick and pull out seeds and sprouts. Such crane activities are creating conflict with farmers.

It is common practice in northern and eastern parts of the lake to drain wetlands and pull up vegetation as water recedes, to dry out wet areas for new cultivation. In addition, the diversion of major rivers from their normal outflow during the wet season affects the flood pattern, particularly when the dry season comes. This phenomenon has happened around Shesher and Wallala area, main roosting site of Eurasian Cranes. The area supported more than 21,000 Eurasian Cranes in 2011 and 2012. The Rib River flows through Shesher and Wallala and also through the villages. These areas were inundated and flood water remained until the end of March, just before the beginning of the rainy season. The recent diversion of this river, however, has changed the function of the floodplain, shortening the amount and the duration of flooding. Farmers utilize the diverted flood water for irrigation. These practices dry out the wetland and impact the main roosting sites of Eurasian Cranes as well as feeding and roosting sites used by Palearctic waterfowl.

Conclusions

The resident Black Crowned Crane and Wattled Crane, and the Palearctic migratory Eurasian Crane occur at Lake Tana, which supports breeding, feeding and roosting sites for these species. Cranes damage a variety of crops in the area, including chickpea, finger millet, sorghum, teff, and rice. The recent sequential cropping practice has had a significant influence on crane feeding. Conversion of wetlands for rice production has recently become a big threat to breeding cranes at Lake Tana; however, destruction of breeding and feeding habitats due to the conversion of wetlands to new cultivation is more significant. The conservation of breeding, feeding, and roosting sites of cranes in and around the Lake Tana wetlands can only be solved through community and stakeholder participation, cooperation with regional government, proper planning, creation of environmental awareness, and through implementation of an appropriate problem-solving community-based conservation project to ensure sustainable development in harmony with the environment.

The following recommendations should be addressed urgently:

- Introduce site protection measures and community-based wetland management practices that prevent extermination of crane breeding sites, particularly in the southern part of Lake Tana;
- Carry out impact assessments on crop losses caused by cranes, and then develop and implement appropriate measures that would benefit cranes on their wintering ground in the area;
- Prevent further construction of greenhouses for growing flowers close to shallow wetlands like Shesher, and restrict increased use of mobile water pumps for farming that can cause rapid and dramatic changes to the wetlands, negatively affecting crane habitats; and
- Appropriate socio-economic-cultural studies should be conducted to understand the real impact of the agricultural system on cranes and wetlands.

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CASE STUDY

Mitigating Human-Crane Conflict in Driefontein Grasslands, Central Zimbabwe: A Test of Scarecrow Methods

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Abstract: The Driefontein Grasslands, an Important Bird Area located on Zimbabwe's central plateau is an important habitat for Zimbabwe's two crane species, the Wattled Crane *Bugeranus carunculatus* and the Grey Crowned Crane *Balearica regulorum*. These globally threatened crane species were reported to damage crops in the Driefontein Grasslands, resulting in conflict with farmers. The major crops damaged by cranes were maize (*Zea mays)* at germination stage and rice (*Oryza sativa*) at milk stage. A method of using scarecrows to reduce crop damage by cranes was tested using eight field sampling plots at two villages in the area. A combination of human and dog models, and plastic balloons were erected in the sampling plots during wet and dry planting seasons. No crop damage was recorded in crop fields where scarecrows were erected, while crop damage by cranes was recorded in sampling plots without deterrents. The scarecrow models tested in this project worked effectively and the method was well received by local villagers as it proved to be environmentally friendly. There is a need to scale up the project and cover other areas to expand these mitigation efforts.

Key words*:* Grey Crowned Crane, Wattled Crane, Driefontein Grasslands, scaring methods, Zimbabwe

Background

The Driefontein Grasslands (19˚23'S 30˚47'E) is an Important Bird Area defined by the land between Chivhu, Mvuma, and Felixburg on Zimbabwe's central plateau, covering an area of 1,600 km². It is an important habitat for Zimbabwe's two crane species, the Wattled Crane (*Bugeranus carunculatus*) and the Grey Crowned Crane (*Balearica regulorum*), both of which are globally threatened. The Driefontein Grasslands support total populations of about 100 and 200 Wattled and Grey Crowned Cranes, respectively. The flat landscape is characterised by extensive expanses of open wet grasslands where soaks, seeps, and depressions collect water and form many seasonally and intermittently flooded wetlands, both natural and impounded by dams. The cranes are highly dependent on the wetland habitat for foraging and breeding. The area is not part of the protected area system of Zimbabwe; therefore, the survival of cranes largely depends on land use practices and the attitude of the local communities who live in the area and share wetlands with cranes. Before 2000, the area was used for commercial cattle ranching only. Land use has since changed to mixed farming by small-scale farmers who were resettled in the area during the land resettlement programme of 2000. Both small-scale farmers and cranes rely on the same wetlands and grasslands for survival, as farmers use the area for crop production and livestock grazing. Therefore, the wetlands in the Driefontein Grasslands are important for ecological conservation and socio-economic production purposes.

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As more land was opened up for cultivation by subsistence farmers, Wattled and Grey Crowned Cranes have adapted to the changes in land use in the Driefontein Grasslands. Cranes are now using the croplands as part of their foraging grounds. The cranes are attracted to newly plowed fields where they can easily feed on tubers, mainly of a perennial sedge (*Cyperus esculentus*) and other rhizomes found from the turned soils (Fig. 1). However, the cranes were reported to damage crops, resulting in conflict with the farmers. The major crops damaged by cranes were maize (corn, *Zea mays*) at germination stage and rice (*Oryza sativa*) at milk stage. Farmers therefore viewed these birds as crop pests. In 2010, a team of BirdLife Zimbabwe officers won a 2010 Future Conservation Leadership Award from the Conservation Leadership Programme (CLP) and tested methods of using scarecrows to reduce crop damage by cranes. The overall goal of this project was to improve conservation of cranes through mitigating the human-crane conflict in Driefontein Grasslands. The methods and the results are outlined in this case study.

Description of the Method

Several scarecrow methods were tested during the wet and dry seasons in Driefontein Grasslands (Fig. 2). Eight field sampling plots were selected from Shashe and Chinyaure villages.

Fig. 1. Cyperus esculentus *tuber (Photographer: Togarasei Fakarayi)*

Fig. 2. Scarecrow in maize field (Photographer: Togarasei Fakarayi)

The sampling plots were cooperative community gardens and individual crop fields. The Shashe sampling plots were located at the edge of a large seasonally flooded wetland, about 100 m from a crane foraging and roosting site. The sampling plots at Chinyaure Village were located at a distance of about 500 m from the crane foraging, breeding and roosting grounds and were also at the edge of a large, seasonally flooded wetland. The crane scarers, in the form of human and dog models and plastic balloons of about 30-cm diameter of different colours, were set up in crop field sampling plots. Scarecrows were erected in two distinct sampling plots in each of the planting seasons. The dry-season study sites were communally owned maize gardens and the wet-season sites were individual maize crop fields. The estimated size of the community garden sampling plots was about 10 ha and the individual crop field about 6 ha. The scarecrows were put up in sampling plots at germination stage of the maize crop; usually these plants are vulnerable to damage by cranes for about two weeks after germination. For each season, two crop garden sites (during dry season) and two crop field sites (during wet season) without deterrents were selected and used as control sites. The human model scarecrows were covered with clothes and dog models were left uncovered. The clothes on the human model scarecrows and their positions were changed every two days. Plastic balloons that were blown off were replaced in the mid-mornings and evenings. The scarecrows were placed in crop fields for a period of three weeks from the onset of germination of maize crop. Observations in crop fields to determine effectiveness of scarecrows and role of crane species in crop depredation were carried out in the mornings as early as 0500 hrs until mid-morning and evenings from sunset until dark, when cranes were most likely to use the field. The local communities were trained in the use of the scarecrows and awareness on crane conservation was raised throughout the Driefontein area.

Results

No crop damage was recorded in crop fields and gardens where scarecrows were erected. The cranes were mostly scared by the human models and plastic balloons scarecrows. Most Grey Crowned Cranes flew over the sampling plots with scarecrows and landed at a distance outside the plots. However, on two occasions two Grey Crowned Cranes flew into one garden with scarecrows but restricted themselves to the edges and did not forage on crops. If deterred from entering crop fields, the birds would not come back until towards sunset when they were on their way to roosting sites. In the control sampling plots, flocks of Grey Crowned Cranes were recorded and crop damage was noted. One of the control sampling plots at the Shashe garden was completely destroyed by a flock of Grey Crowned Cranes and the maize had to be replanted. The Grey Crowned Cranes were observed digging and picking up food (presumably root tubers) from the gardens. They also uprooted and consumed germinated maize seeds, thus destroying the plant. Very few cranes of either species were observed in crop fields and no observations or crop damage was reported during the rainy season. No Wattled Cranes were recorded in crop fields during either season. The Wattled Cranes were observed foraging entirely in wetlands and uplands, at some distance from the crop fields. Observers also saw bird and small mammals, such as Spur-winged Goose (*Plectropterus gambensis*) and spring hare (*Pedetes capensis*) which might cause significant crop damage using the crop fields, although this possibility needs further investigations.

Discussion

The absence of cranes in sampling plots with scarecrows showed that the cranes were deterred by the scarecrows. This study also showed that the problem of crop damage by cranes is at its peak in crop gardens cultivated during the dry season and was mainly caused by Grey Crowned Cranes. Wattled Cranes occurred in crop fields only infrequently. During the rainy season, there appeared to be plenty of food and water areas available, and cranes had a wide range of foraging habitats available besides crop fields. There were few observations of Grey Crowned Cranes during this season and they were thought to be breeding at hidden places. During the dry season, when the areas surrounding crop gardens are dry, availability of wetlands and other water sources are limited, and the ability of cranes to penetrate the soil in other foraging grounds is low. The plowed crop gardens located at the edges of wetlands that are close to human settlement are also used as foraging grounds by cranes during this season as they have high soil penetrability. The Grey Crowned Cranes appear in large numbers of about 67 in a big flock and medium size flocks of about 30 during the dry season. The magnitude of crop damage by such large flocks is extremely high. A large flock can uproot nearly a hectare per day.

Although literature on the use of scarecrows in southern Africa is generally scarce, the various scarecrows that have been tried showed limited success for deterring cranes. In contrast, the scarecrow models tested in this project seem to work effectively, probably because we clothed the scarecrows and changed their clothes every 2–3 days, and changed their positions and postures as well. The scarecrows were designed to look like real humans and sized as human beings. We also attached balloons to the scarecrows, and the balloons moved around. Due to all these adjustments the birds did not perceive scarecrows as immovable objects.

The project needs to be scaled up to cover the entire project area to expand these mitigation efforts. The subsistence farmers in Driefontein Grasslands plant their crop gardens at different times of the season. Therefore, if the method is to be tested in the larger area, the scarecrows should be set up in crop gardens when the crops are most vulnerable to damage by cranes. Cranes will have options to feed in croplands without deterrents or where deterrents have been removed after crops have completed the vulnerable stage (e.g., three weeks after maize germination). The method was viewed as environmentally friendly and was well received by local villagers. A request for more scarecrows from villagers living outside the study areas showed the success of the methods and high level of community support. The program also was successful in generating more interest for crane conservation in the Driefontein Grasslands.

Conclusions

The findings from this study have indicated that the problem of crop damage by cranes is high during the dry season. Although the two crane species were accused of damaging crops, the finding from the study shows that the Grey Crowned Cranes caused much greater crop depredation in crop fields than Wattled Cranes. However, if deterred from entering crop fields they would not come back until towards sunset (evening) when they were on their way to roosting sites. The key crop destroyed by cranes was maize at germination stage. There was strong evidence that the scarecrow models tested in this project were effective in reducing crop damage by cranes. The project received overwhelming support from the local communities, and generated great interest for crane conservation in the area. There is a need to scale up the project to cover other areas to expand these mitigation efforts.

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CASE STUDY

Quantifying Crop Damage by Grey Crowned Crane *Balearica regulorum regulorum* in the North Eastern Cape, South Africa

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Abstract: Complaints of crop damage by cranes on planted maize in the North Eastern Cape, South Africa, have been increasing since the mid-1990s, and in some instances severe losses have been reported. Crop damage by the Grey Crowned Crane *Balearica regulorum regulorum* near the town of Maclear (31°04´S 28°22´E) has been quantified over two growing seasons, and assessed relative to losses caused by foraging Cape Crows *Corvus capensis* and other feeding damage assumed to be caused by insects. Twelve fields were selected based on previous patterns of crop depredation. Maize seed in seven of the fields were treated with the chemical 'Gaucho' and five were planted with untreated maize. In order to determine the source of losses, 20 quadrats (4 m x 4 m) randomly distributed within each field were visited on average every second day, for a period of up to 28 days. Results indicate that seed treatments do act as a deterrent to feeding by both cranes and crows, but crane damage is generally insignificant compared to other sources of damage. Conclusions provide direct input into the management of agricultural areas by enabling landowners to take steps to mitigate crop damage. These mitigation measures may involve either application of seed treatments, or planting of low risk crops in high risk areas. Future studies should consider possible detrimental effects of chemical seed treatments on crane biology.

Key words: *Balearica regulorum regulorum*, crop damage, Gaucho, Grey Crowned Crane, Maclear, maize

Study Area

The study area is located in the Maclear district at the southern end of the Drakensberg mountain range in the North of the Eastern Cape Province in South Africa (32° 42' to 32° 21'S; 27°55' to 28° 30'E). It consists of five quarter-degree square map units, covering an area of ~3,400 km². The study area is situated in a grassland biome, consisting of a complex mosaic of mainly pine plantation blocks, cultivated land (chiefly maize [*Zea mays*]), and montane grassland that is used for formal (managed) and informal (normally intensive) grazing.

Background

All species of cranes, except for the Siberian Crane (*Leucogeranus leucogeranus)*, occasionally or regularly feed on crops such as wheat, maize, rice, soya, and oats at certain times of the year (Allan and Ryan 1993). Exploitation of these unnatural foods is most common during the non-breeding period in most wetland- dependent species. Of the cereal crops, maize in particular is a preferred food for cranes in many parts of the world. This habit has obvious economic, conservation, and management implications for the species. Crop damage is of particular concern to farmers in many regions. For example, Lockman et al. (1987) found that complaints of crop damage attributed to Sandhill Cranes (*Grus canadensis)* were reported to be rising concomitantly with an increase in crane

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population numbers in the United States. Blackwell et al. (2001) reported that from 1992 to 1996 the United States Department of Agriculture received 670 reports pertaining to depredating Sandhill Cranes in Wisconsin, with reported damages exceeding US$80,000. Crane damage to newly planted maize in Wisconsin was reported to be increasing since the mid-1960s, and severe damage had been documented in some areas.

While foraging by cranes in fields may be beneficial to farmers by removing invertebrate pests and waste grain, cranes can uproot newly sprouted maize plants and feed on the attached kernel. Mackworth-Praed and Grant (1957) stated that Grey Crowned Cranes (*Balearica regulorum*) can cause considerable damage to young crops in East Africa. Pomeroy (1980) mentions that damage to crops by Grey Crowned Crane in Uganda can be extensive. This is particularly the case with annual crops; however, no attempt was made to quantify the damage caused by the birds. Pomeroy (1980) also stated that damage to crops is often indirect, as when the birds trample cotton while displaying, or when seedlings are dug up in search of insects.

The North Eastern Cape of South Africa is historically an isolated agricultural district, dependent on rangeland stock farming using winter pastures, as well as on maize and potato crops. Since 1990, large areas of the North Eastern Cape have been afforested with pine (*Pinus*) and gum (*Eucalyputus*). As of 2008, maize production within the Eastern Cape region has also increased according to the South African Grain Laboratory.. Further increases are likely as agricultural production will need to expand by approximately 3% per annum in order to meet the demand for food in South Africa. This increase in production will in itself lead to more conflict with species that share the resources and therefore crop damage complaints are likely to increase.

Complaints of crop damage by cranes on planted maize in the North Eastern Cape have been increasing since the mid-1990s, and in some instances severe losses have been reported. Damage by Grey Crowned Cranes (Fig. 1 and 2) is primarily a result of pulling of the maize seedling and consuming the maize kernel. Foraging activity within the field does, however, often also result in the trampling of the germinating maize seedlings.

My preliminary investigations and observations by farmers also suggested that a chemical, Gaucho, may act as a deterrent to crane feeding. 'Gaucho'™ (Bayer Crop Science 2010) is a seed treatment registered for the control of *Astylus atromaculatus* larvae, black maize beetle (*Heteronychus arator*), rootworm (*Buphonella* spp.), false wire worm (Family: Tenebrionidae), ground weevil (*Protostrophus* spp.), and leafhopper (*Cicadulina mbila*). Farmers have been using this chemical in the Maclear area for at least the last 5–7 years, although the exact start of use is uncertain. Treating maize seed with Gaucho causes a physical change to the seed, resulting in the seed taking on a blue appearance. It is unclear whether the colouration of the seed has any influence on feeding behaviour or whether this is due to chemical deterrence. Although implicit reports indicated that seed treatments may reduce damage to planted maize seed, a detailed study was needed to confirm these observations.

Objectives

The main objectives of my study were as follows:

- To determine whether Grey Crowned Cranes were responsible for crop damage to maize in the North Eastern Cape and quantify the damage caused by the birds.

- To determine the age at which maize plants were most susceptible to crop damage. This information would affect potential mitigation measures structured to focus on when maize plants are the most susceptible.

- To determine whether seed treatments used in the control of insect pests on maize may influence crane feeding behavior. A pilot study (van Niekerk 2011) and landowner observations suggested that cranes avoided treated maize seedlings; however, it was unlikely that any quantified assessments to support these observations had been undertaken.

Fig. 1. Crop damage by Grey Crowned Crane on maize seedlings of 10 days. (Photographer: Mark Harry Van Niekerk)

Fig. 2. Probe holes by Grey Crowned Crane. (Photographer: Mark Harry Van Niekerk)

Materials and methods

In order to determine the damage to maize seedlings, I assessed crop damage in the North Eastern Cape using multiple quadrats randomly distributed over seven farms. This technique was developed primarily from the work of McIvor and Conover (1994), Lacy and Barzen (2005), and a combination of the aforementioned studies.

Three study sites, consisting of six fields, were initially selected within the Maclear area for the 2005 planting season. Ten quadrats of 10m x 10m were randomly placed within each field. A total of 60 quadrats were sampled: 30 quadrats were planted with maize seeds treated with 'Gaucho' and 30 quadrats were planted with untreated maize seeds. Within each quadrat, each maize plant was counted every second day to determine the cause of damage. The type of damage (caused by crane, crow, unknown cause, and feeding and trampling by other animals) was recorded. Plant damage was assessed by documenting damage on each plant within a 4m x 4m quadrat and extrapolating the damage to the entire field.

For the 2006 season, the sample size was increased to 260 quadrats with four additional study sites. This increase, based on the central limit theorem, reduced the variance and provided more of a representative sample within the fields. The quadrat sizes were reduced to 4 m x 4 m and 20 quadrats per field were sampled. Among these quadrats, 131 quadrats were planted with seed treated with 'Gaucho' and 129 quadrats were planted with untreated seed.

Results

In the 2005 season, mean crane damage on untreated fields amounted to 4.10% (624 plants) of the total of 15,223 plants sampled (Table 1). Overall damage from all the crop damage classes (crane, crow, unknown, other feeding and trampling) amounted to 6.77% of the total of 15,233 plants monitored. On the treated fields, damage by cranes accounted for 0.23% (34 plants). Overall damage for the treated crop was recorded as 1.22 % of the total plants. The Chi Squared (χ^2) test using the number of plants damaged by cranes in both treated and untreated fields relative to the number of plants not damaged by cranes showed that treating crops with Gaucho had a significant impact on reducing crane damage in 2005 (χ^2= 543.661, df=1, P < 0.001).

For the 2006 season, mean crane damage on untreated fields amounted to 3.06% (296 plants) of the total of 9666 plants counted (Table 1). Overall damage from all the crop damage classes amounted to 7.32% (339 plants) of the total of 9666 plants monitored. On the fields treated with Gaucho, crane damage accounted for 0.91% (94 plants) of the total of 10312 plants. Overall damage for the treated crop was recorded as 3.29% of the total of 10,312 plants. The Chi Squared (χ^2) test using the number of plants damaged by cranes in both treated and untreated fields relative to the number of plants not damaged by cranes showed that treating crops with Gaucho had a significant impact on reducing crane damage in 2006 (χ^2= 120.6, df=1, P < 0.0001).

Table 1. Number of plants sampled for untreated and treated quadrats in 2005 and 2006

Type of Observation	Total treated plants damaged (2005)	Total untreated plants damaged (2005)	Total treated plants damaged (2006)	Total untreated plants damaged (2006)
Crane Damage	34	624	94	296
Crow Damage	13	7	75	261
Unknown Damage	19	236	8	17
Other Feeding	49	156	148	128
Trampling	65	7	14	6
Undamaged Plants	14,545	14,193	9973	8958
Total Plants Sampled	14,725	15,223	10,312	9666

Conclusions

Crop damage by the Grey Crowned Crane has been quantified over two growing seasons and assessed relative to other forms of loss. This method of sampling provided the quantitative data necessary to draw conclusions regarding crop damage by Grey Crowned Crane on maize and provided accurate qualitative data necessary to determine the economic value of crop damage by the cranes.

Grey Crowned Cranes are responsible for crop damage on commercial farms within the North Eastern Cape of South Africa. Cranes select young maize as soon as the plumule appears above the soil surface and feed on these seedlings for up to 16 days after appearing above the surface (Fig. 1 and 2). After this period the cranes no longer feed on the plants, since the maize kernel has been significantly reduced in size.

When viewed critically, however, crop damage by Grey Crowned Crane was not seen to be economically important relative to the losses that may be incurred as a result of possible insect damage. Insect damage will occur throughout the growing period; however, monitoring of plants only took place for a period up to 28 days, therefore the extent of insect damage was not reflected in the methodology.

Small amounts of crane damage may not be inconsequential elsewhere in Africa where small scale subsistence farming is the norm, and where any loss may be significant in terms of the expected yields of the farms. Mitigation measures which focus on the susceptible period up to 16 days would significantly reduce conflict with the species.

Gaucho was shown to significantly affect crane feeding behaviour in both 2005 and 2006 and effectively reduced the relatively high rate of depredation during the early stage of plant development. Gaucho-treated seed does act as a deterrent to crane feeding. It is unclear whether avoiding seeds treated with the chemical has or will become learned behaviour by the birds. Further toxicology tests are needed to ascertain the extent, to which this chemical may affect cranes. Feeding trials with captive Grey Crowned Crane, possibly in collaboration with zoo establishments, would clarify this aspect and could establish whether the blue colour attributed to seed treatment by Gaucho has any effect on feeding preferences by Grey Crowned Cranes.

In South Africa, political pressures for land reform and agricultural intensification may result in smaller farms and fields, increased human densities and anthropogenic disturbance, and the introduction of new crops. Studies from Europe and India demonstrate that certain forms of agriculture can benefit some threatened birds but that highly intensified agriculture has led to the collapse of farmland bird populations (Donald et al. 2001, Sundar and Subramanya 2010). It would be important to determine to what extent Grey Crowned Cranes are able to benefit from, or adapt to, agricultural transformation. Establishing the benefits of cranes to agriculture would further support conservation efforts of the species, for example. assessment of the contribution of agricultural pest insects to crane diet.

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CASE STUDY

Sarus Cranes and Indian farmers: An Ancient Coexistence

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Abstract: Sarus Cranes (*Grus antigone*) in India have benefited from long-standing cultural and traditional values of farmers. Substantial breeding populations persist even on landscapes entirely converted to human-dominated croplands. Four distinct population-level behaviors are recognized. Prominent growing conservation challenges for Sarus Cranes are highlighted. These include localized threats like egg mortality and land use change, and broader threats like pesticide-related mortality, industrialization, land use change, and changing climate. Challenges to Sarus Crane conservation are enormous, but persisting traditional agriculture and positive farmer attitudes offer considerable advantages. Framing and developing initiatives around these advantages will be critical to executing efficient and long-term conservation interventions.

Key words: Central Gujarat, conservation agriculture, cultural values, Gangetic floodplains

The Indian subcontinent has wintering populations of Demoiselle Cranes (*Anthropoides virgo*) and Eurasian Cranes (*Grus grus*), a small population of Black-necked Cranes (*G. nigricollis*) that summer in the high Tibetan Plateau, and resident Sarus Cranes (*G. antigone*). Until 2002–2003, the central population of Siberian Cranes (*Leucogeranus leucogeranus*) migrated to wintering grounds in north-central India. Scientific and conservation attention to cranes and wetlands in the region has been sparse, and literature on Sarus Cranes dominates. In this case study, I detail historical and cultural contexts that interlink to provide unique landscapes where cranes and people have coexisted for centuries in India. I base this report on published work, and hence focus on Sarus Cranes. I use lessons learned so far to sketch a basic outline for future research and conservation actions that are necessary for cranes and wetlands in the region.

Culture and agriculture

With an agricultural history spanning several centuries, and landscapes dominated by very high human populations, Indian floodplains and wetlands have experienced human use for centuries. Archeological and paleontological evidence point to the region south of the Himalayas as being among the first to experience formal flooded-rice (*Oryza sativa*) cultivation. Forests were cleared to make way for flooded-rice fields, and the floodplains opened up likely improving conditions for Sarus Cranes, and the wintering Demoiselle and Eurasian Cranes. Evidence shows that the region was converted almost entirely to smallholder cereal farmland for much further than 300 years ago, but verifiable information from before that period is absent. Cranes and farmers here therefore have had occasion to learn to coexist for an extended period of time. In addition to the tenure, local belief systems about cranes and traditional land use have facilitated continued presence of Sarus Cranes.

The earliest literary reference to Sarus Cranes is in ancient Sanskrit literature – in the Hindu Epic, the Ramayana. Referred to as the *krauñca*, the narrative in the first book (dated at between *circa* 2nd century BC to 2nd century AD) describes two large birds that have life-long pair-bonds, with sufficient detail to be recognized as Sarus Cranes (Sundar and Choudhury 2003). The commonality of cranes in the Gangetic floodplains, their size, unmistakable call, and legends of permanent bonds of paired Sarus Cranes have found them a prominent place in local culture and folklore. It is still considered a crime and bad luck to kill Sarus Cranes in most parts of their distribution range in South Asia. Figures 1 and 2 show two locations in Uttar Pradesh where Sarus Crane flocks and territorial pairs use crop fields with minimal disturbance from farmers.

Despite the landscape having been converted largely to open cereal croplands, village councils maintain small patches of habitats (grasslands, scrublands, wetlands, woodlots) for common use in the northern floodplains. These common use wetlands, despite heavy human use, continue to be refugia to hundreds of bird species including Sarus Cranes (Sundar and Kittur 2013). In addition, individual farmers retain very small patches of wet areas in which to grow fodder for cattle. This tradition spans centuries, and has been responsible for the current mosaic patchwork of cereal croplands in India that favors the use of these landscapes by an impressive diversity of birds (Sundar and Subramanya 2010, Sundar and Kittur 2012). In combination, the folklore built around Sarus Cranes and continuing traditional land use methods stand the species in good stead today. The state of Uttar Pradesh has a human density of over 800 people km^2, yet the landscape continues to host the largest known, very productive population of Sarus Cranes (Sundar and Choudhury 2003, Sundar 2011).

Sarus Crane ecology

Research on Sarus Cranes has been sporadic yet geographically well distributed, covering nearly their entire distribution range in South Asia. Some key findings are condensed here to consider and plan crane research and conservation. Four distinct population-level behaviors, as it were, can be categorized. *The first* is winter use of wetland areas by Sarus Crane flocks ("wintering population"). This behavior appears to be restricted to very small numbers of cranes, and to cropland-wetland mosaic in the Punjab. Sarus Crane flocks, frequently with newly-fledged yearlings, use some areas in the Punjab as wintering grounds (Bal and Dua 2010). Their source is unknown but suspected to be the growing population from the floodplains of Himachal Pradesh in the lower Himalayas. *The second* is that Sarus Cranes appear to be spreading to locations that are relatively new to this species ("expanding populations"). A few breeding pairs were discovered in the newly-converted cereal fields of river valleys in Kulu in Himachal Pradesh in the late 1990s. This population now appears to be growing with increasing amounts of rice cultivation in the region (personal observation). Another growing population may be the pairs being seen recently along the irrigation canals in Gujarat following the construction of the massive and controversial Narmada irrigation dam. The canals provide water to previously arid regions, and Sarus Cranes now appear able to use new areas for nesting. Similar canal populations have been present in several locations in the semi-arid regions of Rajasthan state, likely expanding to these locations following expansion of irrigation systems (Kaur et al. 2008). *The third* is represented by populations with regular seasonal movements prompted by drying up of wetland areas during the summer months ("seasonally migrating populations"). Two areas with such populations – central Gujarat and Bharatpur Park in Rajasthan – have been studied extensively. Breeding pairs here set up territories during the rainy season when flooded-rice crops dominate the landscape, and with drying of the landscape in late winter and summer, undertake seasonal movements to flock in artificially managed wetlands and reservoirs (Mukherjee 1999, Kaur et al. 2008). Finally, *the fourth*, or "perennially resident population" of western Uttar Pradesh was discovered relatively recently where breeding pairs maintain year-long territories and non-breeding birds reside in the larger wetlands as flocks frequently foraging in crop fields (Fig. 1; Sundar 2009, 2011). Fluctuations in rains and sporadic changes in cropping patterns cause variations to these broad behaviors, but formal documentation of factors causing variations in behaviors and local numbers is very sparse.

Threats and changing landscapes

Threats to Sarus Cranes and conservation requirements vary with location and the population-level behavior. Wintering populations do not appear to be facing immediate threats, though the reason for winter movements requires attention. Expanding crane populations are beginning to face farmer resistance to crop depredation. Given the relatively short interaction time in the newer areas of crane expansion, it appears that cultural belief systems have not been strengthened adequately. Break-downs in local traditional thinking have been apparent in other locations with established crane populations. In the canal populations of Rajasthan, near-complete nest mortality due to egg removal by itinerant laborers for food has prompted physical guarding of nests by hired locals to facilitate Sarus Crane breeding success (Kaur et al. 2008). The seasonally migrating populations are threatened at their breeding grounds by farmers causing mortality of eggs to prevent crop damage by cranes. The ability of this population to find safe water bodies to roost and forage during the summer is also declining due to expanding agriculture in reservoir areas, and increased use of the reservoirs by people during the summer. The resident populations appear to be the least threatened. However, changes in land use and increasing pressure on existing wetlands, leading to increasing human disturbance and prompting conversion of wetlands to other uses, is causing steady attrition of breeding and roosting areas (Sundar 2011, Sundar et al. 2015).

Notwithstanding crane behavior, some threats are common to all populations, and land use changes affect large parts of the Sarus Cranes' distribution range. A prominent well-recorded threat has been pesticide-related mortality where mortality occurs due to spraying of crops prior to the harvest. This problem is widespread and several instances of mass-mortality have been recorded. These deaths are likely reducing local populations significantly, especially in semi-arid areas where entire populations are forced to use areas with remnant wetlands in the summer. Demand for industrial land is increasing in India, and some states like Haryana and Gujarat have experienced large-scale conversions of agricultural and other lands to industrial uses. Sarus Crane populations in some of these states used to be relatively high, suggesting that land-use changes have contributed to population declines. Use of community lands by farmers varies from public open-use to illegal conversions to cultivation of water crops like water chestnut (*Trapa* sp.) and aquaculture that render wetlands unsuitable for waterbirds (Sundar et al. 2015). In the past, wetland conversions were encouraged by state and federal governments that classified marshlands and wetlands as a category of wastelands. Illegal transfers of community lands have increased in the recent past, but traditional use of these areas prompted farmers to resist, resulting in a legal order by the Supreme Court of India disallowing further conversions and mandating restoration of converted community lands. While there is now a legal recourse to disallow conversions, increase in human populations places enormous pressure on community lands. In the eastern states of the Gangetic floodplains, for example, human densities exceed 1,100 people/km^2. Here, Sarus Cranes and community wetlands are now exceedingly rare (Fig. 1).

Fig. 1. A flock of non-breeding Sarus Cranes use multi-cropped fields in western Uttar Pradesh where they are seldom persecuted by local farmers (Photographer: K S Gopi Sundar)

Looming challenges and opportunities

Sarus Cranes proliferate in landscapes dominated by flooded rice-paddies and farmers who revere cranes and wetlands. Industrialization and urban development pose significant threats to such landscapes in the near future. Legally, farmlands cannot be converted to other land uses, but effective practice of the law on the ground faces considerable challenges related to governmental ability, corruption, and pressure for development. Change in management regimes of wetlands from community-owned public-access areas to single uses such as pisciculture leads to severe attrition of Sarus Crane populations. Traditional land use practices and farmer attitudes have served as buffers against globalization and market forces, and continue to provide the best hope for preventing large-scale conversions of land and value systems. Impending and ongoing changes in rainfall and temperature regimes, likely due to global warming, also pose considerable threats to the farmers' and cranes' futures. Predictions for the Gangetic floodplains suggest increased annual rainfall, but occurring within a shorter time frame each year. This pattern may be inadequate for traditional rice farming that requires flooding for several months. If farming practices change to similar crops, for example rice varieties capable of quicker growth, the future of Sarus Cranes is safe yet. If farmers shift to crops that require drier conditions – e.g. corn – we will witness drastic declines in crane populations. Other parts of India with Sarus Cranes have less definitive climate change predictions though parts of the Sarus Crane range are expected to face increased aridity. Some predictions suggest mass human immigration from nearby coastal countries whose agricultural areas will be reduced due to sea-level rises. Such immigrations may result in accelerated urban development, which is currently the most serious threat to breeding Sarus Crane populations, even more important than variations in rainfall.

Conservation planning under such uncertainty and enormous challenges is very difficult and compounded by lack of detailed ecological information of Sarus Cranes from most locations. Immediate research requires investigating pesticide-related mortality and exploring the use of alternate chemicals. Movement patterns, age-related survival, long-term monitoring, understanding factors affecting distribution, and health and disease aspects should be researched. Research also should expand beyond wildlife ecology, especially to understand institutional structures in village communities that have allowed preservation of wetland areas and bird diversity. Traditional cultivation in Sarus Crane areas of South Asia is referred to as "conservation agriculture" for its ability to retain soil fertility and soil flora and fauna. New research is documenting the advantages of land use here for improved biodiversity resilience, underscoring the ability of the system to retain species while catering to hundreds of millions of farmers. Opportunities to interlink understanding from these and other facets of the landscape into regional policy are immense. It is critical to facilitate retention of long-standing values that are congruent with conservation goals.

Conservation effort in areas with Sarus Cranes in South Asia will fare poorly with the classical wildlife areas / site-based ethos. Economic models are also unlikely to succeed since, like many other tropical countries, human societies in Sarus Crane landscapes are not fully monetized. Practices are infused instead by dominating cultural traditions and religious beliefs. Traditional economic conservation strategies (compensation, ecosystem service payments, etc.) here may therefore serve to dilute and corrupt ongoing practices. Strategies likely to withstand growing globalization over the long-term are those focused on retaining and strengthening cultural values in farmers and cropping patterns matched with local weather also conducive to requirements of Sarus Cranes.

The landscapes of India can be learning grounds for how to improve conditions for crane and wetland survival in other parts of the world where development and burgeoning human populations are increasing, necessitating very expensive conservation intervention strategies. Persisting ancient farming methods and deep-rooted cultural practices offer novel advantages to conservation practitioners. Conservation interventions tuned to these conditions will best serve the coexistence of farmers and cranes here (Fig. 2).

Fig. 2. A pair of territorial Sarus Cranes indulge in a unison call while a farmer watches. Such coexistence can be continued if conservation interventions are able to incorporate local traditions alongside needs of the cranes (Photographer: K S Gopi Sundar)

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CASE STUDY

Preliminary Review of Co-Existence and Conflict of Cranes and Agriculture in Southern Ukraine

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Abstract: Populations of Demoiselle (*Anthropoides virgo*) and Eurasian Cranes (*Grus grus*) in Ukraine have greatly declined over the last 50 years; their breeding ranges have been reduced by more than half, and substantial portions of their steppe and wetland habitats have been converted into anthropogenic landscapes. Today, the Azov-Black Sea region in the southern part of Ukraine encompasses almost all of the breeding range of the Demoiselle Cranes and serves as the largest staging area and migration stopover of the Eurasian Crane. Suitable conditions for stopovers by migrating Eurasian Cranes were formed in this region in the middle of last century. This shift in distribution and increasing use of agricultural fields by cranes were influenced by several factors: changes in crops and crop growing locations along the traditional migration routes and around roosting sites, which provided more accessible and abundant foods for cranes; development of large irrigation systems that led to intensification of cultivation for winter cereals, cruciferous crops, and rice; and flushing of rice fields that reduced salinity of wetlands and improved their value for cranes. However, since the 1990s, large concentrations of Eurasian Cranes began to shift from the shallow coastal wetlands of Sywash Bay to adjoining small wetlands in the Biosphere Reserve Askania-Nova and adjacent agricultural fields due to high disturbance levels. Demoiselle Cranes inflict only minor damage to crops because of their low numbers, short-time pre-migratory gatherings, and the start of autumn migration out of the area before crop ripening. Crop damage by staging Eurasian Cranes, however, has substantially increased due to decline in the area of cultivated crop lands, which concentrates cranes on the remaining fields. Increases in hunters and poachers also caused cranes to concentrate their feeding in fields near protected areas, resulting in greater crop damage in those areas. In addition, winter crops have a shorter period of protection from snow cover due to longer and warmer autumn weather. To reduce conflicts, relationships between cranes and landowners need to be improved, hunting and poaching controlled, and adaptive management practices developed for croplands and grazing lands.

Key words: agricultural practices, Demoiselle Crane, Eurasian Crane, habitat use, staging, Ukraine

The Importance of Azov-Black Sea Region of Ukraine for Cranes

Demoiselle (*Anthropoides virgo)* and Eurasian (*Grus grus*) Cranes, previously widespread and numerous in Ukraine, have decreased in numbers almost everywhere in the country except in some steppe regions of Crimea Peninsula for the Demoiselle Crane, and in the south and west of the country for the Eurasian Crane. Both species are listed in the Red Data Book of Ukraine (Andryuschenko 2009, Fesenko 2009).

The Demoiselle Crane is a breeding and migratory species in Ukraine, with a population of 600–700 birds during the reproductive season, including 200–250 breeding pairs. The breeding range of the

Eurasian Crane in Ukraine covers most areas in the forest and forest steppe zones, with a current population of 900–1,300 individuals that includes up to 400 breeding pairs (Andryushchenko and Gorlov 1999, Gorlov 2012).

During the 20th century, especially in the last 40–50 years, the situation for both Demoiselle and Eurasian Crane populations has worsened: their breeding ranges shrunk by more than half, and substantial portions of their habitats have been converted into anthropogenic landscapes. Unfortunately these trends are continuing. Most breeding grounds, staging areas, and migration stopover areas of the Demoiselle Crane are located outside of protected areas (except for a few small nature reserves), in landscapes with intensive economic development and high human population density. In steppe nature reserves and national parks, the Demoiselle Crane does not breed or congregate because exclusion of grazing by hooved animals has resulted in high, dense grass. Most portions of the Eurasian Crane breeding grounds and migratory stopover areas also are not protected (Andryushchenko and Gorlov 2001, Andryuschenko, 2015).

Most of the important habitats for both crane species in Ukraine are located in the Azov-Black Sea region in the southern part of Ukraine. This region includes almost all of the breeding range of the Demoiselle Cranes as well as the largest staging areas and migration stopovers of the Eurasian Crane. Two flyways for the Eurasian Crane cross at the Sivash Bay and adjacent areas in the south of Kherson Region and in the north of Crimea. One flyway extends from the Dnepr River through Crimea to Asia Minor, and the second flyway goes along the north and north-west coast of the Black Sea to the Balkan Peninsula (Gavrilenko 1995).

Before intensive plowing of grasslands and development of land reclamation and irrigation systems, crane numbers were regulated by natural factors in spring and autumn. At that time, cranes made only short spring migration stopovers there due to insufficient food supplies. During autumn migration, cranes fed mainly in virgin grasslands and wetlands and used coastal wetlands of the Azov and Black Seas for resting and drinking. Plowing the steppe for cereal grains provided benefits to cranes and allowed longer stop-overs because the crop fields provided abundant food during both migration seasons.

In the early 1990s, large congregations of the Eurasian Crane (57,000–60,000) gathered mostly in shallow coastal wetlands of Sivash Bay and adjacent lakes. In the early 2000s, a significant redistribution of staging areas occurred, and the largest numbers of cranes began to use night roosts in the "Askania-Nova" Nature Biosphere Reserve, feeding in adjacent agricultural fields. In 1990, 8,000 Eurasian Cranes staged there, but by October 2009 their numbers had increased to 44,000 (Gavrilenko 1995). Concurrent with these changes, some cranes crossed the southern Ukraine without stopping or they rested further west in Central Europe because of increasing disturbance from hunters and poaching pressure in southern Ukraine. Other threats for staging cranes are pesticides and shortage of safe roosting sites.

Impact of Changing Agriculture on Cranes

Before humans, the breeding grounds of the Demoiselle Cranes must have been steppe pastures grazed by wild herbivores, e.g., wild horses, antelope saiga (*Saiga tatarica*), wild bison (*Bison bonasus),* until the wild herbivores were depopulated by people. Usually the wild herbivores moved from place to place across the steppes to find sufficient forage. Later, nomadic people with domestic livestock also moved constantly from place to place to find adequate forage and avoid overgrazing. Development of arable farming resulted in changing peoples' life-style from nomadic to settled, and increased human populations caused significant reductions in pastures as well as greater overgrazing. Combined, these resulted in degradation of steppe pastures and significant declines in the numbers of cranes that used these habitats for breeding and feeding. After the collapse of the USSR in the 1990s and the resulting agricultural crisis, overgrazing was reduced temporarily; however, in recent years overgrazing has begun to increase again (see also Ilyashenko 2018).

Today in the Azov-Black Sea region in southern Ukraine, the Demoiselle Crane breeds in agricultural lands; 28.3% of nests were found in virgin steppe used for livestock grazing; 22.4% in waste lands; 15.9% in crop lands; and 3.3% in fallow lands (Fig. 1). On sites within the region used for summer and pre-migratory gathering, cranes feed mostly in pastures and harvested fields and drink in ponds, small rivers, artesian wells, and flooded areas created by water escaping from irrigation canals (Andryuschenko 2011).

Area of fallow lands has increased significantly since the mid-1990s. Fallow lands become suitable for the Demoiselle Crane breeding within 2–3 years after cultivation, when grass is still sparse. Later, fallow lands become overgrown with high weeds and cannot be used by cranes for nesting. After lying fallow for 8–10 years, however, the native steppe plants become dominant in the fallow lands due to succession processes, and steppe conditions are restored. Such restored lands, especially when they are moderately grazed, become suitable again for the Demoiselle Crane breeding. Unfortunately, there was a tendency to convert the fallow lands back to crop fields.

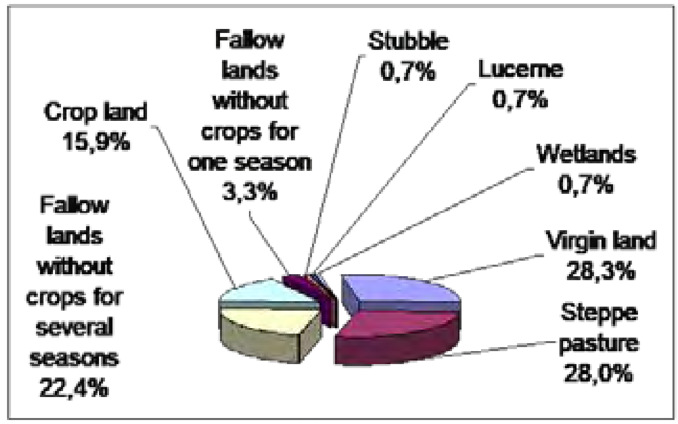

Fig. 1. Distribution of Demoiselle Crane nests on different agricultural fields and virgin steppe in southern Ukraine

In agricultural lands, especially with cereal crops, human disturbance to cranes is relatively low. From the second 10 days of April to the middle of June (from egg laying to chick rearing), such fields are not visited by people or cattle. The one exception is mechanized fertilizer application, which is not done on all fields and usually done only once or twice during this period. Also, agricultural machinery itself is rarely the cause of clutch destruction or chick mortality. Therefore, cranes are exposed to fewer threats in crop fields than in pastures and during hay mowing. Disturbance from frequent use of machines, however, can cause breeding pairs to reduce their time attending nests and chicks, resulting in egg and chick mortality from cooling or predation.

Stubble fields are used by Demoiselle Cranes in the post-breeding period, where they feed on waste grain. Before the winter season, stubble fields are plowed, and in recent years even burned to control pest insects, contrary to nature conservation regulations. Unplowed and unburned stubble fields supply cranes not only with waste grain, but also with sprouted seeds, which appear after autumn rains. They provide a good food source for both Demoiselle and migrating Eurasian Cranes. In the past, corn (*Zea mays*) was also a favorite food of Eurasian Cranes, but in the last 20 years corn cultivation has practically ceased due to the high cost for irrigation in the more arid regions of the southern Ukraine.

Causes of Conflict Between Cranes and Agriculture

Demoiselle Cranes do not damage crops because of their low numbers, short duration of pre-migratory gathering (end of July – August), and the start of autumn migration out of the area before crop ripening. At the same time, Eurasian Cranes, migrating through the south of Ukraine, can do significant damage to sprouted seeds of winter crops. In the 1990s, the area of winter crop fields was reduced significantly due to the agricultural crisis after the collapse of the USSR, and cranes began to gather in huge numbers on leftover winter crops in the autumn and on summer crops in the spring. Of areas in the southern Ukraine, agricultural fields around the Askania-Nova Biosphere Nature Reserve, where Eurasian Crane roosting sites are located, receive the greatest damage from cranes.

The main factors contributing to increasing use of agricultural fields by Eurasian Crane during migration are the following (Andryushchenko and Gorlov 1999, Gavrilenko and Listopadsky 2010):

- Location of crop fields along traditional migration routes and around roosting sites provides more accessible and abundant foods for cranes;
- During 1976–1990, the area of intensive cultivation for winter cereals, cruciferous crops, and rice increased after the construction and operation of two of the largest irrigation systems in Europe: North-Crimean and Kakhovka; and
- Watering of rice fields has led to desalination of previously saline water bodies (lakes, estuaries and other coastal wetlands) and to an increase in suitable drinking water for cranes.

The main causes of increasing crop damage by Eurasian Cranes are the following:

- Since the 1990s, the area of cultivated crop lands greatly decreased and cranes became more concentrated on the remaining sown fields;
- Increased numbers of well-equipped hunters and poachers caused cranes to concentrate around protected areas (nature reserves and national parks), resulting in increasing crop damage to fields located around these protected areas; and
- The length of the staging period during autumn migration has been prolonged due to global warming. Data from the Askania-Nova Weather Station indicates that the mean autumn temperature has increased by 0.8°C during the last 30 years, and as a result the winter crops are not protected by snow cover for as long a time in autumn.

Recommendations for Reducing Conflicts Between Cranes and Agriculture in Azov-Black SEA Region in Ukraine

- Conduct regular monitoring on status of crane populations and their habitats in agricultural landscapes, study features of crane biology and ecology connected with agriculture, and develop recommendations for crane conservation in agricultural landscapes based on scientific data;
- Work to optimize the relationship between land owners and cranes in agricultural landscapes to decrease uncontrolled hunting and poaching;
- Adapt agriculture management with the following measures (Andryuschenko and Gorlov 1999):
    - Create fields with lure crops (millet [*Panicum miliaceum*], sunflower [*Helianthus annuus*], and corn) around or close to roosting sites of migratory cranes;
    - Create a mosaic of available agricultural types on the landscape through alternation of crops with different density, heights, and dates of sowing, ripening and harvesting, as well as a mix of pastures, hay fields, and crop fields; and

- Develop guidelines to reduce grazing pressure based on scientific research for restoration of breeding areas of the Demoiselle Crane

- Provide education and public awareness for farmers (Andryuschenko and Gorlov 1999, Gavrilenko and Listopadsky 2010):
    - Provide publications and distribute posters and booklets, conduct surveys, and broadcast on television a popular film about the need to protect the cranes, including agricultural land;
    - Establish recommendations for scaring cranes away grain fields; and
    - Create and protect (by banning hunting) new roosting sites for a wider dispersal of cranes in the south of Ukraine, and a decrease in their concentration in Askania-Nova.

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CASE STUDY

Changes in Distribution of Eurasian and Demoiselle Cranes in Response to Agricultural Changes After the Soviet Union Collapse

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Abstract: In the Soviet Union in the 1960s–1980s, agriculture was fully developed and relatively stable with large, mainly mechanized collective and soviet farms. During that time the Eurasian Crane pre-migratory staging areas were consistently used and distributed evenly among vast areas of plowed fields that covered almost all woodless lands. Cranes had abundant food in crop fields after harvesting, and rural people were very loyal to them due to near absent crop damage. The massive changes in economy and society following the dissolution of the Soviet Union in 1991 and the subsequent transition from a planned to a market economy severely affected the state-controlled agricultural system in the former USSR countries. Agriculture in Russia went through the crisis after the collapse of the USSR in 1991 to a slow recovery in some regions since early 2000s. Three main processes affected agricultural changes in the EPR during the transition period, which had substantial impacts to the number and distribution of the Eurasian Cranes and their staging areas: 1) geographical (north/south) and 2) administrative (periphery/center) polarizations of agricultural development and 3) dispersion and fragmentation of once large, contiguous areas of crop fields. Changes in numbers of used staging areas and distribution of cranes correspond to these three main processes. Cranes stopped using some staging areas in the Northwestern and Central Federal Regions due to decline in grain production. In some provinces of Central and Volga Federal Regions the number of staging areas increased due to dispersion of previously large flocks among the mosaic of cultivated fields. In the South and Volga Federal Regions, both crane numbers at staging areas and duration of their stay at migratory stopovers had increased. Cranes started to concentrate at the few agricultural fields around large cities and administrative centers, sometimes causing conflicts with farmers. The agricultural crisis in the former Soviet republics (Ukraine, Kazakhstan) and in southern Russia led to destabilization, redistribution, and declining numbers of Demoiselle Cranes in some parts of their breeding range, especially in the south of European Russia and in the south, south-east and east regions of Kazakhstan.

Key words: Eurasian Crane, Demoiselle Crane, Russia, reorganization of agricultural system, economic crisis, agricultural practices, crane redistribution

Changes in Agriculture After the Soviet Union Collapse

Agricultural patterns and practices went through different phases under the administration of the Soviet Union. After the October Revolution in 1917, lands were nationalized and collective and soviet forms established in the old cultivated agriculture area. In 1950s, due to acute food shortage after the Second World War, the mass Virgin Lands Campaign was organized to develop virgin and fallow lands and increase agricultural production. The agriculture lands were expanding greatly, including zones of "risky" agriculture in the cold northwest and dry southeast areas of the European part of Russia, in Siberia and Russian Far East in the Asian part of Russia, and steppe zone in other Soviet Republics, especially in Kazakhstan and Ukraine. In the 1960s–1980s, agriculture was fully developed and relatively stable with large, mainly mechanized collective and soviet farms. This stability had been achieved by centrally planned management of agriculture system and large state investments, especially for remote collective and soviet farms which were largely unprofitable due to some social issues such as mass moving of rural people to towns, poor mechanization, and undeveloped transport system (lack of good roads) (Nefedova 2014).

The massive changes in economy and society following the dissolution of the Soviet Union in 1991 and the subsequent transition from a planned to a market economy severely affected the state-controlled agricultural system in the former USSR countries (Kamp et al. 2011). Agriculture in Russia went from the period of relative stability in the late Soviet era of the 1980s, through the crisis after the collapse of the USSR in 1991, to a slow recovery in some regions since early 2000s. The deepest collapse occurred in the late 1990s – early 2000s. By the end of the transition period of the 1990s, the total volume of agricultural production dropped by 40%; in the collective sector it had dropped by 60% due to institutional changes, unstable economic conditions, and depopulation (Nefedova 2008). According to Russian Statistical Yearbook (2009), cultivated areas in Russia decreased from 117.7 million hectares in 1990 to 76.93 million hectares in 2008; areas planted with crops decreased from 63.068 million hectares in 1990 to 46.74 million hectares in 2008.

The 1990s crisis also led to massive declines in livestock and changes in grazing patterns (Kamp et al. 2011). Livestock experienced a particularly deep decline – its part in the gross agriculture production decreased from 63% in 1990 to 44% in 2000, and 46% in 2009. Cattle numbers decreased from 57 million in 1990 to 20.1 million in 2011 (Nefedova 2014).

Since the early 2000s, many of the post-Soviet trends in agriculture have reversed, with renewed expansion and intensification of agriculture, but these processes have occurred only in some regions and mainly around large administrative centers (Kamp et al. 2011, Nefedova 2008).

Changes in the Distribution of Eurasian Cranes Among Pre-Migratory Staging Areas in the European Part of Russia

Changes in the numbers of autumn pre-migratory staging areas and distribution of Eurasian Cranes (*Grus grus grus*) among them were determined using two questionnaire surveys given to hunters, rural teachers and students, and professional ornithologists. They were asked to identify staging areas, including feeding and roosting sites, and to estimate the maximum crane number in the staging areas. The first survey was conducted in 1982 and 1983 to identify autumn (mid-August – early October) crane pre-migratory staging areas and migration stopovers in 50 administrative provinces of the Russia Federation. Those data were used to create a Catalogue of the Eurasian Crane Staging Areas of the Russian Federation, which included 460 staging areas having 30–3,000 cranes (Markin 2013). Mapping of the Eurasian Crane staging areas from the survey data indicated that the area of autumn pre-migratory staging areas coincided with cultivation of the main cereals used by cranes – wheat (*Triticum aestivum*), rye (*Secale cereale*), and barley (*Hordeum vulgare*) (Fig. 1; Markin 2013). This survey was conducted in the period of relatively stable agriculture and during a time when crane pre-migratory staging areas were consistently used and distributed evenly among vast areas of plowed fields that covered almost all woodless lands. Cranes had abundant food in crop fields after harvesting, and rural people were very loyal to them due to near absent crop damage. At that time the use of staging areas by cranes depended mostly on availability and safety of wetlands for night roosts (Markin et al. 1982).

The survey was repeated 25 years later in 2007, based on the earlier Catalogue in the same administrative provinces of the Russian Federation, with the goal of determining changes in the numbers of staging areas and crane distribution among staging areas, as well as crane numbers at staging areas connected with changes in agriculture. Those 25 years included the phase of relative stability of agriculture in 1980s, the crisis of the agricultural system due to its reorganization and economic decline after the USSR collapse in 1990s–early 2000s, and the period of slow recovering since early 2000s.

Although the surveys covered the whole Russia, the comparative analyses of two surveys were done only for the European part of Russia (EPR), which is the area with high human density and where changes both in agriculture and crane behavior are more apparent. The EPR covers 3,960,000 km^2 and represents 25% of Russia and 40% of Europe. This part of Russia spreads from Russian western borders to the Ural Mountains in the east, which divide European and Asian parts of Russia, and to the national border with Kazakhstan in the south. This region is very developed and has a high human population density, containing 78% of the entire Russian population (www.ru.wikipedia.org). The EPR includes several federal regions: Northwestern, Central, Volga, and the Southern and North Caucasus Federal Regions, which in turn include several administrative provinces (Fig. 2).

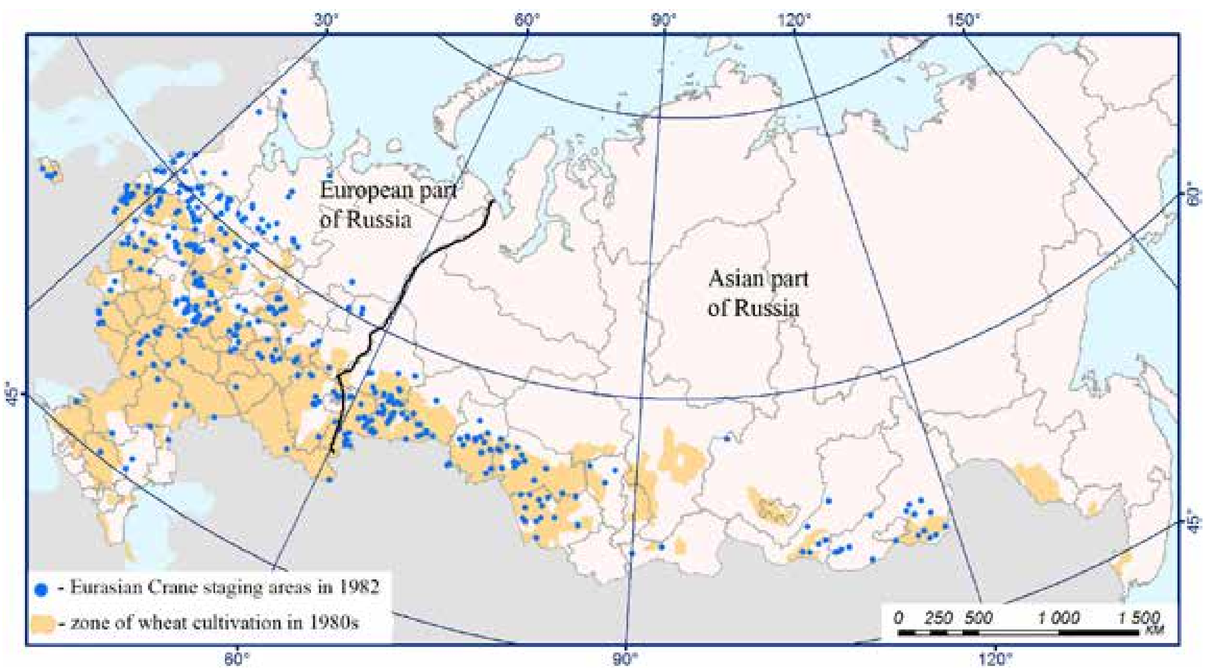

Fig. 1. Distribution of autumn pre-migratory congregations of Eurasian Cranes in Russia in 1982 relative to zones of wheat cultivation in 1980s (from Atlas of the USSR, 1984)

The two conducted questionnaire surveys cannot provide fully comparable estimates of crane numbers and population trends in as large an area as the EPR. Changes detected may be results of 1) general population growth trend of the Eurasian Crane numbers (Prange 2012), 2) stronger efforts to reach people for the second survey (higher numbers of involved organizations and people), and 3) a higher percentage of returned completed questionnaire forms in 2007. This type of survey, however, is the most feasible means to identify changes in crane distribution among staging areas, and its association with agricultural changes, over such an extended area as the EPR over the 25-year period.

The estimated numbers of cranes at staging areas in the EPR increased from 46,800 to 78,400 between the early 1980s and 2007 (Ilyashenko and Markin 2013). Analyses of survey results, count data at some sites with regular crane monitoring, and published literature indicate that these changes in numbers of used staging areas and distribution of cranes correspond to two main processes that have occurred since 1991 in agriculture – a geographic (north/south) polarization of agricultural development, and the dispersion and fragmentation of crop fields due to administrative (center/periphery) polarization and concentration of agricultural space around large cities and administrative centers (Nefedova 2014).

Crop production either stopped or substantially decreased mainly in the Northwestern and Central Federal Regions, creating a north-south polarization of crop fields. The agricultural crisis had the deepest impact in northern areas, a so-called "risky" agriculture zone that had few scattered crop fields and poor harvests even in the Soviet time (Fig. 3). As a result of reduced availability of crop foods, cranes either stopped using staging areas in the most northern and some central provinces or redistributed among them (Ilyashenko and Markin 2013;Fig. 2, Table 1). For example, in Arkhangelsk Province in the Northwestern Federal Region, the area planted with crops declined by 42% from 2002 to 2003. As a result, the large staging area in Arkhangelsk Province, where up to 10,000 Eurasian Crane gathered in 1980s, was entirely abandoned by cranes (Anzigitova 1998, Khokhlova et al. 2007). Reduction of crop fields and resulting loss of food resources on staging areas in the north and northwest parts of the EPR can lead in turn to shifts in crane migration routes to the west to European countries, where crops are abundant. This likely is one of the main reasons for the increasing numbers of Eurasian Cranes (from near 50,000 in 1980s to 250,000 in 2000s) in Central Europe along with other contributing factors (Prange 2012).

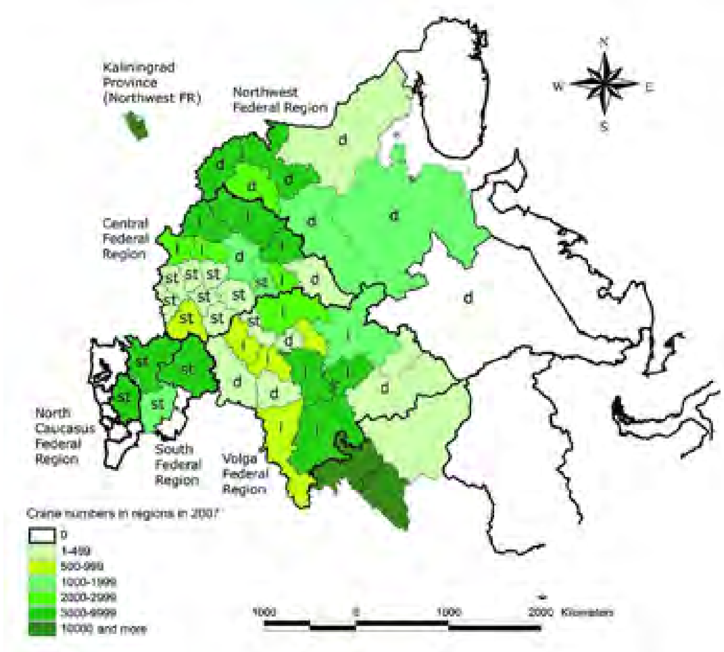

Fig. 2. Changes in maximum numbers of Eurasian Cranes at pre-migratory autumn staging areas in the European Part of Russia during a 25-year period (1982–2007): i – increase; d – decrease; st – stable

Table 1. Changes in the number of staging areas with varying numbers of cranes in the European Part of Russia, 1982 and 2007.

Federal Regions of the European Part of Russia	Numbers of cranes										General tenden-cy
	30-99		100-299		300-999		More than 1,000		Total		
	1982	2007	1982	2007	1982	2007	1982	2007	1982	2007	
Northwestern Federal Region	61	42	33	24	12	14	5	0	194	97	Decrease
Central Federal Region	49	121	33	57	4	43	1	7	132	279	Increase
Volga Federal Region	45	85	17	9	7	13	0	3	134	193	Increase
Total	155	248	83	130	23	70	6	10	460	569	Increase

Areas with more successful agricultural development and recovery are located mainly in the South, North Caucasian, and Volga Federal Regions, where most migration stopovers are located (Fig. 3). Official statistics indicate that in 1997, up to 82% of agricultural enterprises in the Southern Federal Region were unprofitable, but by 2000 almost half had achieved profitability (Nefedova 2014). The Stavropol and Rostov provinces in the South Federal Region are currently the leaders in agricultural production volume in the EPR. Due to more favorable grain availability in these provinces, cranes arrive at migration stopovers earlier and stay longer (1–1.5 months) compared to the Soviet time when cranes stopped only for a short time (Alexander Lipkovich and Victor Belik, personal comm.). At the same time, in some more arid provinces of the South Federal Region that are considered zones of "risky" agriculture, crop fields were abandoned, and cranes stopped using them as migration stopovers. Only few cranes now rest on Elton Lake in Volgograd Province due to the cessation of arable agriculture and destruction of irrigation systems; 3,000 cranes had used this area in 1980s (Chernobai and Guguyeva 2008).

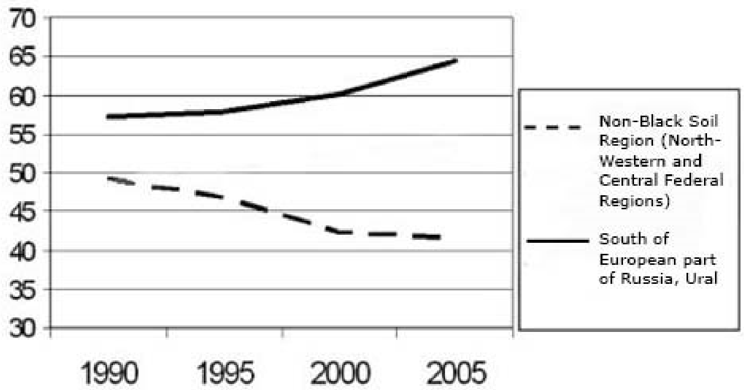

Fig. 3. Changes in percentage of cereals (%) in the cultivated area in the different regions of the EPR from 1990 to 2005 (from Nefedova 2008)

In addition to the geographic polarization of agricultural changes, the pattern of crops on the landscape has become more dispersed and fragmented. Due to insufficient capacity for development (in terms of labor, money and transport), the former vast agricultural fields turned into a mosaic of small scattered crop fields within expanded areas of abandoned land (Nefedova 2008). Concurrent with these agricultural changes, some large crane staging areas of the 1980s turned into a mosaic of smaller ones dispersed among the fragmented small crop fields, resulting in increase in the number of staging areas in the Central (from 132 to 279) and Volga (from 134 to 193) Federal Regions during that 25-year period (Table 1; Ilyashenko and Markin 2012). For example, an important site is the Crane Homeland Wildlife Refuge (Moscow Province of the Central Federal Region), which served both as a staging area for local cranes and as a migration stopover for cranes from the north. In the 1980s, nearly 5,000 cranes gathered there; by 2005 the cranes had divided into three smaller congregations (Grinchenko and Sviridova 2008).

Area planted with crops decreased mainly in the periphery of administrative provinces resulting in administrative (center/periphery) polarization, driven by depopulation and discontinuation of state agricultural investments into unprofitable peripheral enterprises; this is especially noticeable in the Central Region. In some peripheral areas, 30% to 80% of agricultural fields were not cultivated since mid-1990s; many of them were abandoned and became overgrown with brush and trees (Nefedova 2014). On the other hand, in landscapes with greatly dispersed mosaic of crops there are a few successful agricultural enterprises and private farms, mainly around large cities and in some more developed provinces in Volga and South Federal regions (Nefedova 2014). Cranes started to concentrate at the small number of well-developed agricultural enterprises and farms in huge flocks, moving there from other staging areas with less favorable feeding conditions. This shift has caused increased conflict between cranes and farmers (Ilyashenko and Markin 2013). The process of concentration of agricultural space will continue with disappearance of agriculture in the periphery and development of fewer large agricultural enterprises, mostly around big cities (Nefedova 2014), with predictable consequences of increasing conflict between cranes and farmers. This problem is only in its early stage and deserves further study.

Changes in the Breeding Distribution and Populations of Demoiselle Cranes

The current breeding range of the Demoiselle Crane (*Anthropoides virgo*) in Eurasia extends from the Ukraine through the south of Russia, Kazakhstan, Kyrgyzstan, and Mongolia to China, covering steppe and semi-desert zones of Central Eurasia. There are six breeding populations and four of them are located in the former USSR republics: 1) Eastern (south part of South-Eastern Siberia in Russia [Transbaikalia], Mongolia and northern China); 2) Central Asian (south of Western and Central Siberia in Russia, Kazakhstan and partly Kyrgyzstan); 3) South of European Russia including three breeding flocks: Caspian, Middle Don and Volga-Ural (Russia and Western Kazakhstan); and 4) Azov-Black including two breeding flocks: Crimean and North Azov (Fig. 4).

The middle of 20th century was a period of depressed populations for the Demoiselle Crane due to extensive plowing in steppe zone in Ukraine, Russia and especially in Kazakhstan, where about 25 million ha were plowed between 1954 and 1960 during the Virgin Lands Campaign (Kamp et al. 2011). Other threats accompanied the campaign (high levels of disturbance due to large numbers of people, machinery, construction of new settlements, electric power lines, and industrial buildings, and mass poaching) greatly affected cranes, especially in Kazakhstan where human densities had previously been low. As a result, cranes were displaced to the less suitable habitats in semi-deserts and deserts and their number decreased (Kovshar and Berezovikov 1990).

By the 1970s–1980s, due to their ecological and ethological flexibility, cranes adapted to breed in agricultural landscapes both in arable lands and pastures. The cranes started to expand their range to the north in high grass steppe and forest-steppe in the north of Kazakhstan and the south of Ural and Siberia in Russia, following the emerging open cultivated fields and grazed grasslands. They also moved to the south and southeast into arid zones of semi deserts and deserts in Volga-Ural Region of Russia, and to the west, south, and south-east areas of Kazakhstan, following artificial irrigation systems constructed for livestock grazing and irrigated agriculture (Berezovikov and Kovshar 2006, Bragin 2011, Davygora and Gavlyuk 1991, Zavialov et al. 2003). Total numbers of Demoiselle Cranes there had increased in early 1990s to an estimated 200,000–240,000 individuals (Meine and Archibald 1996).

Fig. 4. Distribution of the Demoiselle Crane areas in the south of the European part of Russia (according to Belik et al. 2011). Border legend: a) populations and flocks; b – countries; c – administrative provinces. Populations: 1) Azov-Black Sea population (a – Crimean flock, b – North-Azov flock); 2 – South of European Russia population (a – Middle Don flock, b – Caspian flock; c – Volga-Ural flock)

Since 1991, the economic crisis and reorganization of agricultural system in the former Soviet republics led to rapid decline of arable agriculture and livestock grazing. In early 1990s these factors contributed to a positive trend in the Demoiselle Crane numbers, as once cultivated fields became fallow lands where grass cover was more suitable for crane breeding; the level of human disturbances in both pastures and fallow lands also declined. In the late 1990s–early 2000s, continued decline of livestock grazing and arable agriculture resulted in vegetative overgrowth in pastures and abandoned fields in the west and north of the species range (Ukraine, south of Russia); neglect of artesian wells and deterioration of irrigation systems, in combination with regional drought in the south of the species' range (south and south-east of Kazakhstan), reduced water availability for cranes. These changes had substantial effects on the breeding populations of Demoiselle Cranes, reversing their earlier trends of growth and expansion by reducing the quality and availability of breeding habitats and food. The species, which had adapted to breed in agricultural fields in the middle of 20th century, again lost their breeding habitats. For the Demoiselle Crane, it was period of destabilization, redistribution, and declining numbers, especially in Caspian area (Kalmykia and Volgorad provinces) (Bukreeva 2003, Chernobai 2011, Belik et al. 2011), in the southern, southeastern and eastern regions of Kazakhstan (Berezovikov and Kovshar 2006), and in Transbaikalia (Goroshko 2012), where its numbers continue to decline due to continued agricultural crisis.

In the second half of the 2000s, severe, long-term drought that encompassed the breeding range of cranes in Central Eurasia, and an especially abnormally hot summer of 2010, exacerbated the impact of agriculture crisis (Goroshko 2011, Malovichko 2011). Degradation and overgrowth of neglected pastures accompanied by the long-term drought contributed to huge steppe fires that destroyed crane nests and decreased the quality of breeding habitats (Goroshko 2012, Bukreeva 2003, Bragin 2006, Badmayev 2006, Chernobai 2011). Severe fires, particularly in drought conditions, can lead to development of weedy vegetation until the perennials recover, and often such areas became unsuitable for Demoiselle Crane breeding during the first few years after burning (Belik et al. 2011).

Affected by agriculture crisis and long-term drought, estimated crane numbers in the population of the south of European Russia (excluding Orenburg and Kurgan provinces of Russia, and Western Kazakhstan) have declined from an estimated 40,000–50,000 to 30,000–40,000 individuals (Belik 2005, Belik et al. 2011), mainly in Caspian area (Fig. 3). In the Kazakhstan and Central Asia population, the estimated number of Demoiselle Cranes declined from nearly 100,000 in 1980s (Kovshar et al. 1995) to 50,000–60,000 by the end of 2000s (Kovshar 2010). In the Transbaikalia Region of Russia (part of eastern population), numbers declined from an estimated 22,000–27,000 to 12,000–15,000 (Goroshko 2012). However, the total estimated number of the species declined only slightly from 240,000 to 200,000 due to recovery in the most part of the species range (Ilyashenko 2016).

In early 2000s, arable agriculture and livestock farming had recovered in Southern and North Caucasus federal regions (Fig. 1; Fedosov and Malovichko 2008). In Kazakhstan since around 2000, many of the post-Soviet downward trends were reversed; arable agriculture expanded and intensified, livestock numbers increased (Kamp et al. 2011), and Demoiselle Crane numbers started to recover, especially in the north and west of the country.

In north Kazakhstan and Ukraine, fields that had been plowed in regions with extreme agriculture and where the harvest was very low in the 1950s–1960s, were the first to be withdrawn from cultivation due to the crisis in mid-1990s. Abandoned lands become suitable for breeding Demoiselle Cranes 2–3 years after cultivation, when grass is still sparse. Abandoned lands first become overgrown with tall weeds and are unsuitable for crane breeding for several years. After lying abandoned for 8–10 years, however, natural succession allows native steppe plants to become dominant, and steppe conditions are restored. Such restored lands, especially when they are moderately grazed, become suitable again for the Demoiselle Crane breeding (see also Andryuschenko 2018). Crane numbers have remained stable in Ukraine (Andryuschenko 2011) and have even increased in the north part of Kazakhstan (Bragin 2011).

Conclusions

Agriculture in Russia went from a long period of relative stability during the Soviet time through a crisis after the collapse of the Soviet Union in 1991, to a phase of slow recovery in several regions of Russia, Kazakhstan and Ukraine. Three main processes affected agricultural changes in the EPR during the transition period, which had substantial impacts to the number and distribution of the Eurasian Cranes and their staging areas: 1) geographical (north/south) and 2) administrative (periphery/center) polarizations of agricultural development and 3) the dispersion and fragmentation of once large, contiguous areas of crop fields. In Northwestern and some provinces of Central Federal Regions of the EPR, many staging areas were abandoned as cropland area crashed and the number of staging areas and crane numbers decreased substantially. In some provinces of Central and Volga Federal Regions, the number of staging areas increased due to dispersion of previously large flocks among a mosaic of cultivated fields. In the South and Volga Federal Regions, both crane numbers at staging areas and their duration of staging at migratory stopovers increased. Cranes started to concentrate at the few agricultural fields consolidated around large cities and administrative center and sometimes cause the conflict with farmers.

The agricultural crisis in the former Soviet countries (Ukraine, Kazakhstan and in the south of Russia) led to destabilization, redistribution, and declining numbers of Demoiselle Cranes in some parts of their breeding range, especially the south of European Russian and in the south, south-east, and east of Kazakhstan. The impact of the agricultural crisis to the Demoiselle Crane can be compared with the effects of intensive plowing of steppe zone in Central Eurasia in the middle of 20th century, when crane numbers cranes rapidly declined (Kovshar 2010). These patterns demonstrate the strong linkages between agriculture and the distribution and abundance of Eurasian and Demoiselle Cranes in the modern landscape.

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CASE STUDY

South African Crane Conservation Case Studies: Experiences and Observations

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Abstract: South Africa has limited agricultural productivity. This translates into great pressure on natural habitat for cranes in areas where agricultural potential is high. Additional pressures in these areas are mining, other developments, and growth of the human population. This case study explores the Biodiversity Stewardship programme – a legislative mechanism under the National Environmental Management – Protected Areas Act (57 of 2003) and Biodiversity Act (10 of 2004) – as a tool to secure key crane habitat in agricultural areas. It further considers the challenges experienced in two different areas of implementation – Chrissiesmeer and the Southern Drakensberg in South Africa. The former aims to implement conservation strategies on a landscape scale while the latter focuses on individual properties, each approach having its own challenges and opportunities. Key themes include the motivation and willingness of landowners and how these attitudes are influenced by agricultural considerations and other external factors such as mining. Where threats are high landowners generally seem more willing and where threats are low landowners seem more reluctant to participate. While the Biodiversity Stewardship programme is the most advanced tool available for securing habitat in South Africa, its use in tandem with other tools and strategies must be explored to reduce the reliance on emotions such as fear as primary motivations to join the programme. The large scale success of the tool has also opened questions about how the programme will be sustained and what resources will be required to do so. Partnerships between government agencies and NGOs seem to be of key importance in this process.

Keywords: Blue Crane, grasslands, Grey Crowned Crane, habitat protection, private landowners, stewardship, Wattled Crane, wetlands

Biodiversity Stewardship

South Africa has developed a unique and progressive tool to secure habitat on private and communal land. The Biodiversity Stewardship Programme is enabled by the National Environmental Management: Protected Areas Act 57 of 2003 and Biodiversity Act 10 of 2004, which allow for legally binding contracts between landowners and the state to secure land for conservation. In essence, through dedicated negotiation willing landowners enter into agreements with provincial authorities to conserve their land in accordance with mutually agreed management practices, in exchange for formal recognition as part of the protected area network, and to qualify for certain incentives.

The Biodiversity Stewardship Programme is structured around four categories of protection. Support and incentives (or benefits) from government agencies and partners increase correspondingly with each higher level of protection, as represented in Figure 1 below.

Not-for-Profit Organisations (NPOs) have entered the Biodiversity Stewardship Programme to promote the initiative and provide assistance to governmental agencies in its implementation.

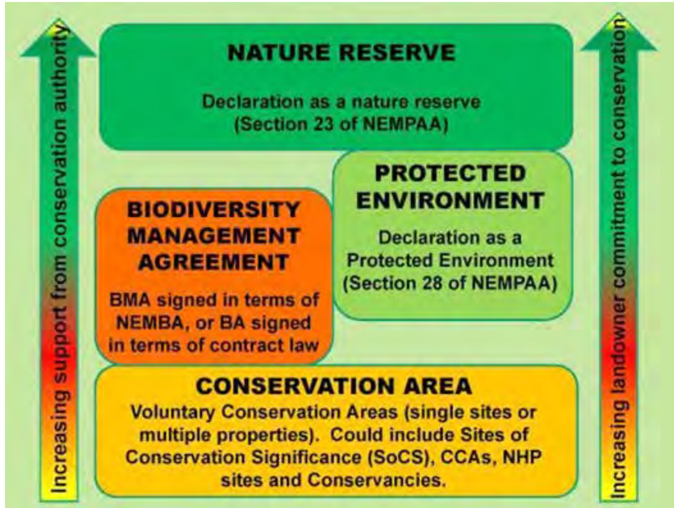

Fig. 1: Different Biodiversity Stewardship categories available to landowners

The African Crane Conservation Programme of the Endangered Wildlife Trust has promoted this programme amongst landowners in two critical crane areas in South Africa in order to secure key habitat for these threatened crane species. These areas are: Chrissiesmeer, located within the Highveld region of the Mpumalanga Province, South Africa (latitude 26º17'50", longitude 30º16'53.1") and the Southern Drakensberg project area located in and around the border of the Eastern Cape and the KwaZulu-Natal province (latitude 29º46'24.6" longitude 29º25'22.3"). Both of these areas are home to Grey Crowned Cranes (*Balearica regulorum)*, Blue Cranes (*Anthropoides paradiseus*), and Wattled Cranes (*Bugeranus carunculatus)*.

Cranes and Agriculture

Transformation of natural habitat and the loss of wetlands are the most significant impacts of commercial farming on cranes in both project areas. With transformation comes increased human activity and disturbance to cranes. In both areas the majority of land is privately owned and farming operations are intensive and profit driven. This case study does not deal with the experiences on communal areas although communal areas probably shares similarities with other private lands as far as impacts on cranes are concerned.

Due to the competitive nature of agriculture in South Africa there is a continuous drive to increase yields and expand farming operations. This trend has put increasing pressure on all cranes, especially Wattled Cranes as wetlands and grasslands are changed to monocultures. In addition, due to the fact that both the project areas fall within a summer rainfall area, most crops are planted in the breeding time of Blue Cranes and Grey Crowned Cranes, which accentuates the habitat loss effect.

This situation does not mean that conserving crane habitat and commercial agriculture are incompatible but rather that conservationists need to constantly evaluate the effectiveness and applicability of their approaches. Cranes are cherished by many landowners who are proud to have them on their land. There are, however, also those landowners who see cranes and conservation as a competing land use to agriculture.

Challenges and Opportunities in the Two Project Areas

Chrissiesmeer

Chrissiesmeer is located within the Highveld region of the Mpumalanga Province, South Africa, and covers an area of 85,065 ha, which consists of Eastern Highveld Grasslands and Eastern Temperate Freshwater Wetlands. The area derives its name from Lake Chrissie, the largest natural freshwater lake in South Africa (covering an area of approximately 1,150 ha when full). The area has the highest concentration of freshwater lakes and pans in the country. It also forms the watershed of four river systems, including the internationally significant Komati and Usutu systems, and water quality is very high. Due to the inability of the lakes and pans to 'flush', the system is extremely susceptible to pollution and other anthropogenic impacts. Although Blue and Wattled Cranes also occur in the area, Chrissiesmeer is of particular importance to Grey Crowned Cranes as a breeding and flocking site.

Due to the unique freshwater characteristics and high biodiversity value, as well as a mining threat, the area was identified as a priority under the Biodiversity Stewardship Programme in 2011. Following a detailed biodiversity assessment, the Protected Environment level was chosen because of the high agricultural production value of the area that needs to coincide with biodiversity conservation while still affording formal protection for the area. Although historic interactions between landowners and conservationists were somewhat strained, the relationship has improved significantly since 2011 and the area was proclaimed as a Protected Environment in January 2014.

One of the major challenges for Chrissiesmeer is the number of landowners involved – about 80 in total – and the sheer scale of the area – it will be the largest declared Protected Environment in South Africa. Mining applications are another challenge to the conservation of the area, although the Protected Environment status should afford a level of protection against such developments in the future. Although this added incentive for protection may increase initial interest, landowners realize that the main aim of the programme is the conservation and management of their natural areas to maintain or improve them for the benefit of biodiversity. To reach this goal the management plan will speak to the collective management of systems rather than the individual management of properties. For instance, the coordinated fire management of all landowners whose properties span a particular wetland system will be needed to achieve optimum conservation impact and provide a secondary economic benefit to the landowners through the efficiency of the firebreak system.

The Chrissiesmeer case study demonstrates the effective ability of Biodiversity Stewardship to secure crane habitat on a landscape scale, amongst agricultural activities and with the support from a multitude of landowners. The maintenance of such a large scale buy-in and the implementation of a management plan across such a large area will, however, require increased commitment of time and resources from conservation agencies. In this respect increased cooperation among non-governmental organizations, government agencies, and even corporate partners will be required for the long term sustainability of the Protected Environment.

Southern Drakensberg

The Drakensberg (meaning the "Mountain of the Dragon) is the biggest mountain range in Southern Africa. The project area is located in the catchments of the three biggest undammed rivers in South Africa – the Umzimvubu, Umzimkhulu, and Umkomaas Rivers.

The main aim of the Southern Drakensberg Stewardship Project (initiated in 2012) is to secure habitat for Blue, Grey Crowned, and in particular Wattled Cranes and their nesting sites. Almost the entire extent of crane habitat in the region is situated on private land.

In an attempt to secure as much of this habitat as possible, more than 50 landowners have been approached to join the Biodiversity Stewardship Programme. The results thus far have been largely disappointing. In contrast to the Chrissiesmeer example it seems that a lack of a threat such as mining combined with a history of conflict between landowners and conservationists is proving to be a major obstacle in the promotion of conservation on private land. As a result only those landowners with a conservation ethic or desire to leave a legacy have embraced the programme. The rest of the landowners have either shunned the notion of concluding contracts with government conservation agencies or have indicated that incentives are not sufficiently compelling to change their minds.

Many farmers also see conservation as imposing an opportunity cost on them. This cost is a lost opportunity that results from taking conservation action. For example, conservation practices may require no further transformation of natural grasslands, a requirement that many farmers view as a limitation on expansion of their croplands and therefore limiting future income potential.

The situation at hand requires us to reconsider our options when it comes to interacting with owners of agricultural holdings which are also important to cranes but where willingness is low or absent. How do we secure habitat under these circumstances?

While the Biodiversity Stewardship Programme is well developed and entrenched in South African Environmental Law, it needs to be considered that in certain instances it may not be the most applicable method to secure habitat. In such cases conservationists need to be flexible and innovative and have access to a suite of options for securing habitat on private land. These options could include less binding agreements, which may lead to later graduation to the Biodiversity Stewardship Programme or could be variants of other existing legal tools such as servitudes adapted to serve conservation needs. Ultimately the development of approaches that are more transaction based, in recognition of the opportunity costs faced by landowners in respect of conservation, could be useful.

Conclusions

Commercial agriculture and crane conservation are irrevocably connected in the case studies discussed above. On the one hand, large scale buy-in, as is the case in Chrissiesmeer, is encouraging, but brings about questions on the long-term capacity of conservation agencies to assist the landowners with the implementation of a systems-driven management plan, provide incentives, and ultimately ensure the sustainability of the programme into the future. On the other hand, relying on willingness only and accepting the fact that large tracts of crane habitat are unsecured on farms where reluctance is encountered, is unsustainable from a species perspective. Without influence in the commercial agricultural sector, conservationists are facing a losing battle. Credibility and the demonstration of value to the landowner/farmer are of critical importance and perhaps may be a better strategy to ensure sustainability and build relationships.

While the Biodiversity Stewardship Programme is a valuable and successful tool in some areas, we need to augment it with strategies which move attempts to secure habitat beyond the ambit of willingness or external threats. Such strategies will also aim to create shared value for farmers and conservationists. This objective may for instance be achieved by offsetting land lost to crane conservation with the promotion of agricultural best practice and increased productivity, or reduction of cost, or by recognition of the opportunity costs brought about by setting land aside for conservation. For this outcome, a leap of faith is required not only from landowners but also from conservationists. The development of alternative models, which complement or can be used in tandem with the Biodiversity Stewardship Programme, combined with the flexibility to assess each landholding as a unique conservation prospect within the larger landscape, is an imperative.

CASE STUDY

Opportunities for Crane Conservation Through US Department of Agriculture Conservation Programs

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Abstract: Private lands are critically important for cranes in the U,S. Conservation programs, authorized through the federal Farm Bill and managed by the U.S. Department of Agriculture (USDA), offer unequalled potential for ecological restoration and conservation of targeted wildlife in North America. Here we describe three case studies to illustrate how USDA conservation programs are being implemented to benefit resident and migratory cranes using private lands in the U.S: 1) provision of critical Whooping Crane (*Grus americana*) habitat in Wisconsin through the Farm Bill's *Wetland Reserve Program*; 2) enhancement of migratory habitats for Sandhill Cranes (*Grus canadensis*) in Nebraska using the Farm Bill's *Wildlife Habitat Incentives Program* and *Environmental Quality Incentives Program;* and 3) enhancement of agricultural working lands for cranes and other waterbirds through the *Migratory Bird Habitat Initiative* in southern Louisiana and Texas.

Keywords: conservation, Farm Bill, private lands, Sandhill Crane, waterbirds, Whooping Crane

With about 70% of the United States (U.S.) excluding Alaska and Hawaii held in private ownership, the future of cranes and other wildlife in the country is inseparably tied to the management of private lands. Agriculture is by far the dominant user of these lands with approximately 52% or 365 million hectares managed as cropland, pastureland, or rangeland. Thus, decisions made by agricultural producers directly affect the availability and suitability of habitat for cranes in the U.S.

Government agricultural programs and policies greatly influence the choices available to farmers and ranchers in the management of their lands. Innumerable agricultural, environmental, social, political, and economic considerations led to the passage of the 1985 Food Security Act (hereafter, Farm Bill), that included for the first time a chapter devoted to conservation (Berg 1994). Subsequent amendments to the Farm Bill in 1990, 1996, 2002, and 2008 retained and expanded conservation provisions (Heard et al. 2000). There are now about 20 agricultural conservation programs affecting vast acreages of agricultural land with a combined funding level of $24.1 billion in 2008–2012 (http://

www.ers.usda.gov/farm-bill-resources.aspx). Farm Bill conservation programs implemented since 1985 have resulted in the application of conservation practices to tens-of-millions of hectares of agricultural working lands, retirement of up to 14.6 million ha of marginal cropland, and restoration of >930,000 ha of wetlands.

The importance of enhancing wildlife habitat in the delivery of these conservation programs was elevated in the 1996 Farm Bill. Wildlife conservation is currently an explicit goal for the Conservation Reserve Program (CRP), Environmental Quality Incentives Program (EQIP), Wildlife Habitat Incentive Program (WHIP), and Wetland Reserve Program (WRP). Recognizing the interrelationships among natural resources (e.g., soils, water, air, plants. and wildlife) and the importance of natural-ecological versus man-made boundaries when planning and implementing conservation, the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA NRCS) has begun addressing conservation priorities on a landscape scale. Several NRCS Landscape Conservation Initiatives focus specifically on birds, e.g., Lesser Prairie-chicken (*Tympanuchus pallidicinctus*), migratory bird habitat, and sage-grouse (*Centrocercus* spp.) initiatives. Working Lands for Wildlife (WLFW) is a new partnership between USDA NRCS and the U.S. Fish and Wildlife Service (USFWS) which takes advantage of the latter agency's technical expertise, combined with financial assistance from the WHIP, to combat the decline of two reptile, four bird, and one mammal species. The WLFW is a model for targeting species whose decline can be reversed and will benefit other species with similar habitat needs.

The potential for ecological restoration and conservation of targeted wildlife through Farm Bill programs is unequalled in North America (Ciuzio et al. 2013). Here we describe three case studies where conservation programs have been implemented to benefit cranes.

Case Studies

1. Provision of Critical Whooping Crane (*Grus americana*) Habitat in Wisconsin through the Farm Bill's Wetland Reserve Program (WRP)

The Whooping Crane (*Grus americana*) is a national and international symbol of efforts to recover endangered species in North America (Lewis 1995). Reestablishment of Whooping Cranes in the eastern U.S. began in part with the reintroduction of an experimental flock at Necedah National Wildlife Refuge (NWR) in central Wisconsin in 2001. The Whooping Crane Recovery Team made up of American and Canadian authorities selected this site because of the protection and habitat provided by the refuge and surrounding landscape (Canadian Wildlife Service and USFWS 2005). The release site is located in the prairie-forest transition zone of Wisconsin, characterized by sandy soils and, at the time of European settlement in the mid-1800s, emergent wetlands interspersed in open oak- and pine-dominated savannas (Wisconsin Department of Natural Resources [WDNR] 2008). Current land uses consist of public land and private and publicly controlled wetlands embedded in a matrix of row-crop agriculture and impoundments managed for cranberry production.

The Whooping Crane chicks released at Necedah NWR from 2001 through 2010 were reared by humans in "crane" costumes and taught their migration route with the assistance of an ultralight airplane. The returning, maturing birds have paired, nested, and hatched young successfully since 2006. However, few have fledged and therefore the population is not yet sustainable. This lack of reproductive success and recruitment was initially attributed in part to biting black flies (Diptera: Simuliidae). The reintroduction effort was modified starting in 2011 when captive-reared birds were released at Horicon NWR and White River Marsh State Wildlife Area in east central Wisconsin. This reintroduced, experimental flock of Whooping Cranes currently fluctuates around 100 individuals and release efforts continue to be modified and evaluated.

The 1990 Farm Bill authorized the NRCS to establish long-term agreements with owners of private lands for the conservation or restoration of wetlands or grasslands on their land (hereafter, conservation easements). The largest of the conservation easement programs is the WRP, which since 1992 has enlisted over 11,000 landowners in the protection and restoration of over 930,000 ha of wetlands and associated habitats. Other easement programs are the Grassland Reserve Program (80,000 ha, 450 landowners) and the Emergency Watershed Protection Program (74,000 ha, 1,300 landowners). All of these private lands are protected for at least 30 years or in perpetuity through deeds that restrict the manipulation of the wetland and grassland habitats. Projects range from 1 ha to >8,000 ha in size.

The WRP is a voluntary program targeting marginal productive farmland that frequently floods. An overwhelming majority of WRP easements are permanent, but some participants opt for 30-year easements or contracts and a restoration-only option. Depending on the enrollment option, NRCS may pay 75 to 100% of the assessed land value and restoration costs.

WRP easement contracts are awarded on a competitive basis with applications ranked on the basis of criteria (e.g., size and location of tract, ability to restore hydrology and native vegetation) established by the state's technical committee composed of representatives from the NRCS and partner conservation organizations. Providing habitat for migratory birds is a priority for WRP, so state priorities commonly reflect regional and national migratory bird priorities. Other goals include providing habitat for other fish-wildlife, improving water quality and groundwater recharge, providing flood protection and educational opportunities, sequestering carbon and reducing greenhouse gas, assisting with the recovery of rare and declining species, protecting cultural resources, promoting rural landscapes and scenic vistas and helping local economies.

WRP easements require an approved restoration and management plan. Long-term management is often accomplished by government and non-government cooperators and the landowner. Deviations from the management plan must be approved by the NRCS as compatible with the program goals.

The WRP is contributing to the re-establishment of Whooping Cranes in the eastern U.S. Although the WRP does not specifically target Whooping Cranes, use of easements by migrating, summering, or wintering cranes has been documented throughout the region. In Wisconsin, active use of 20 WRP easements has been noted with an additional 350+ WRP easements located within 10 km of known Whooping Crane use areas. Along the migration route, cranes have been observed in >50 WRP easements; >1,100 WRP easements are located within 10 km of known Whooping Crane use areas with over 380 of those in Indiana alone (Whooping Crane Eastern Partnership unpublished data).

In south-central Wisconsin, <100 km from Necedah NWR, breeding and nonbreeding Greater Sandhill Cranes (*Grus canadensis tabida*) extensively use agricultural fields (Su 2003). Whereas cranes foraging on invertebrate pests and waste grain generally are considered beneficial to farmers, the uprooting of newly sprouted corn plants and ingestion of the attached kernel can cause significant damage to newly planted crop fields. The International Crane Foundation, a private company (Arkion LLC), and the USDA have collaborated to develop seed treatments that effectively deter depredation on corn seedlings by Sandhill Cranes (Lacy et al. 2013, Lacy 2018). The extent of crop damage caused by Whooping Cranes in Wisconsin is unknown but damage likely is minimal because they are less gregarious than Sandhill Cranes and seed treatments deter crop depredation by both species (Jeb Barzen personal comm.; WDNR 2006). Managers therefore are hopeful that Whooping Cranes will continue to expand their current range throughout the agriculture dominated landscape of the eastern U.S. without conflicts. Further, because the flock is considered experimental (i.e., does not require designation of critical habitat under the Endangered Species Act), the presence of Whooping Cranes on private lands should be of minimal concern to landowners.

After a decade of slow recovery, the future of the reintroduced flock of Whooping Cranes looks promising. Protective easements, such as the WRP, will continue to play a complementary role in providing crane habitat throughout their range by bridging the boundary between public and private land ownership. The success of the WRP hinges on the enthusiastic support of private landowners and other conservation partners. The effectiveness of this partnership is critical to sustaining healthy populations of cranes and a wide array of other fish-wildlife populations.

2. Enhancement of Migratory Bird Habitats in Nebraska Using the Farm Bill's Wildlife Habitat Incentives Program(WHIP) and Environmental Quality Incentives Program (EQIP)

A wetland complex in central Nebraska commonly called the Rainwater Basin is closely associated with the nearby Platte River and provides important habitat for migrating Sandhill and Whooping Cranes each spring and fall. Nearly a half-million Sandhill Cranes and the entire population of Whooping Cranes in the Central Flyway of the United States use these two important wetland complexes located at the mid-point of their migration route. The Rainwater Basin wetlands consist of a combination of seasonal to semi-permanent windblown depressions with a dense clay soil layer causing surface run-off to perch above ground. Braided channels of the Platte River are broad and shallow in many areas. The surrounding landscape is composed of intensive irrigated row-crop agriculture, primarily corn (maize; *Zea mays*) and soybeans (G*lycine max*). These wetlands and braided river channel provide important roosting habitat for migrating cranes (Fig. 1), and the adjacent crop fields allow them to forage on waste grain that is high in carbohydrates. Remnant wet meadows and undisturbed wetlands also contribute to the crane diet by supplying necessary invertebrates.

Fig. 1. Sandhill Cranes roosting on Platte River sandbars near Kearney, Nebraska (Photographer: Jeff Drahota)

The extent and suitability of Rainwater Basin wetlands for cranes and other waterbirds differ dramatically from the historic condition. Approximately 90% of the individual wetlands have been drained or filled and remaining wetlands are highly altered by colonization of invasive plants such as reed canary grass (*Phalaris arundinacea*) or hybrid cattail (*Typha x glauca*) (LaGrange 2005). This condition is exacerbated by hydrologic alterations and man-induced sedimentation that is filling the wetlands. Several of the larger wetlands have been protected through land acquisition by either federal or state wildlife agencies as well as some recent activity by non-profit organizations such as Ducks Unlimited and The Nature Conservancy. Over 15,000 ha of wetlands and associated uplands have been purchased in this area. The USDA NRCS has enrolled over 4,000 ha into WRP across the 22-county region; however, the vast majority of wetlands remain under private control.

The Rainwater Basin Joint Venture was formed in the early 1990s to bring together conservation agencies, organizations and private landowners to conserve the remaining wetlands in the area. This partnership is critical to the ongoing efforts to protect, restore and manage the wetland resource. Emphasis is placed on all aspects of the wetland resource including full restoration of wetlands and proper management of these and other existing wetlands, irrespective of ownership. Furthermore, habitat assessment models are being used to target these efforts toward wetlands which will provide the greatest value for priority species such as the federally endangered Whooping Crane.

Much on-site wetland restoration is readily accomplished on lands brought into public ownership or under easement. However, many alterations remain in the immediate watersheds surrounding these wetlands. Recently, USDA NRCS's WHIP and EQIP have been used as the foundation to help restore watersheds of these protected and restored wetlands. Additional financial assistance to defray restoration costs was obtained by the Rainwater Basin Joint Venture through USFWS's Partners for Fish and Wildlife Program and grant funds, and 'piggy-backed' onto the federal programs to make each project financially acceptable to private landowners in the area. The goal of this work is to remove irrigation re-use pits in uplands, which serve to "short-stop" the run-offs from reaching the larger wetland at the bottom of the watershed. Many of these pits are no longer needed by private landowners who have converted from gravity to center pivot irrigation systems. Efforts to work with these private landowners in order to maximize the benefits provided by the protected and restored wetlands is essential to the long-term value supplied by this system to crane populations.

Like the Rainwater Basin region, the Platte River, described by early settlers as a "mile wide and inch deep," is highly altered. Reductions in flood flows, withdrawal of water for irrigation, and tree encroachment have led to the narrowing and deepening of many channels. Since European settlement of the region, the Platte River has had approximately 70% of its flows diverted for alternative uses resulting in a loss of over 70% of the channel area and adjacent wet meadow habitat (LaGrange 2005). Colonization of these historic channel and wet meadow habitats by woody species and invasive plants, such as purple loosestrife (*Lythrum salicaria*) and common reed (*Phragmites australis*), continues to degrade remaining areas.

Both private landowners and conservation organizations that own land along the Central Platte have participated in EQIP and WHIP to clear historic channels and islands of woody cover and use herbicides to suppress invasive herbaceous vegetation. In 2009, a consortium of interests, including irrigation districts, county weed authorities, private organizations such as The Nature Conservancy and private landowners, banded together to conduct an extensive eradication effort on these invasive plants throughout the majority of the Platte River system in Nebraska. Whereas this one-time effort was successful obtaining some measure of control of targeted invasives, continuous monitoring and treatment will be necessary to maintain control.

In both the Rainwater Basin wetlands and the restored floodplain of the Central Platte, program offerings through NRCS and a wide array of other conservation partners provide assistance to private landowners who desire to use livestock to manage the resulting herbaceous plant community. The Rainwater Basin Joint Venture has worked closely with the Nebraska Cattlemen association and local livestock producers to foster greater use of livestock in a region dominated by row-crop agriculture. Infrastructure to support grazing is often needed on these recently restored areas and financial assistance is available for fencing, watering facilities, and similar appurtenances. Use of these types of "working lands" efforts to manage existing vegetation and maintain reasonable habitat quality on sites with invasive plants provides a win-win benefit to agricultural producers and wildlife.

Lastly, the Rainwater Basin Joint Venture and the associated partners have developed a GIS-based habitat model to predict the wetlands and river segments of greatest value to the endangered

Whooping Crane. Recently, this model was used to identify 25 priority wetlands within the Rainwater Basin where additional conservation work could be accomplished. The model uses past records of roosting and feeding areas along with habitat characteristics (size, distribution, and isolation from disturbance) from known sightings to determine areas of greatest interest. This process allows partners to justify offering additional incentives to private landowners in those areas to implement habitat improvements specifically targeted toward Whooping Crane conservation.

2. Enhancement of Agricultural Working Lands for Cranes and other Waterbirds through the USDA NRCS's Migratory Bird Habitat Initiative

Wetlands along the Gulf Coast historically provided habitat for untold millions of resident and migratory waterbirds. Specifically with respect to cranes, Texas-Louisiana coastal marshes and wet prairies provided essential habitat for migratory Sandhill Cranes, as well as resident and migratory Whooping Cranes before their extirpation from Louisiana in 1939 (Lewis 1995). Extensive conversion of wet coastal prairie to agricultural uses began in the early 20th century with rice (*Oryza sativa*), and crops-livestock produced in rotation with rice are becoming a major component of the contemporary landscape of the region. Other major rice-growing areas are California's Central Valley and the Lower Mississippi Alluvial Valley.

The 1–1.5 million hectares of farmland in coastal Louisiana and Texas operated in crop rotational schemes (rice-crawfish (Cambaridae)-fallow, rice-fallow, rice-pasture, or rice-dryland) simulate wet, early successional habitats that are highly attractive to wetland-associated wildlife (W.L. Hohman, W. Norling, and R.M. Pace unpublished). The close proximity of fields to coastal marshes, their location at the terminus of two major migratory bird flyways, bird-friendly cultivation practices, high annual rainfall, and abundant plant and animal foods further enhance their potential value for waterbirds. Recent shifts in the distributions of waterbirds from coastal wetlands to inland agricultural wetlands (e.g., Fleury and Sherry 1995) coincide with the expansion of crawfish aquaculture and ongoing loss and degradation of coastal wetlands.

Following the 2010 Deepwater Horizon Gulf Oil Spill, the NRCS established the Migratory Bird Habitat Initiative (MBHI) to provide inland waterbird habitats that could compensate for potential oil impacts on coastal wetlands. Through EQIP, WHIP, and WRP, the MBHI private landowners in eight states (Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Missouri, and Texas) received incentives to enhance and increase availability of shallow-water habitats for migrating and wintering waterfowl, shorebirds, and other waterbirds along the Gulf Coast and within the Lower Mississippi Alluvial Valley. The provision of financial assistance and compatibility of management activities with normal agronomic practices and recreational use of sites contributed to the enthusiastic response by landowners who offered more than 400,000 ha for possible enrollment in EQIP or WHIP. To qualify for enrollment the proposed management activity must represent a change from normal agronomic practices (i.e., "enhancement"). Approximately half of the offers were accepted into the program with most of the contracts awarded in the rice growing region of southwestern Louisiana. In coastal Louisiana and Texas, the primary management practices implemented through the MBHI entailed manipulations of rice stubble and shallow flooding of rice fields in early fall or late winter. Stubble manipulations and early flooding were implemented to benefit fall-migrating shorebirds which pass through the region in August and September; late flooding targeted spring-migrating waterfowl. The net result was that shallow-water habitats were available in the coastal region for an extended duration. Activities undertaken through EQIP and WHIP on agricultural working lands were similar, but eligibility differences between the programs enabled the NRCS to serve a broader clientele.

In Louisiana, technical planning and financial assistance were provided through WRP to reestablish early successional habitat (i.e., moist soil and shallow water habitats) on sites that had become overgrown with aggressive native vegetation such as cattail (*Typha* sp.) and black willow (*Salix nigra*) and were no longer attractive to priority waterbird species.

Fig. 2. Reintroduced Whooping Cranes in Louisiana rice field (Photographer: John K. Saichuk)

Agricultural working lands on the coastal plain of Texas and Louisiana, managed under normal agronomic practices, receive high use by waterfowl, shorebirds, and wading birds including Sandhill Cranes (W.L. Hohman, W. Norling, and R.M. Pace unpublished). An evaluation of waterbird responses to MBHI by researchers at Mississippi State University further substantiated the importance of agricultural working lands in coastal Texas-Louisiana (Marty 2017). Regarding cranes, Pickens et al. (2017) documented that habitat selection by Whooping Cranes that were reintroduced to Louisiana in 2009 (Zimorski et al. 2013; Fig, 2), shifted in the fall/winter towards rice and crawfish (*Procambus* spp.) aquaculture fields like those targeted by the MBHI.

Louisiana continues to fund MBHI through EQIP. MBHI was expanded in Louisiana to include activities designed to provide nesting and brood-rearing habitat for resident waterbirds such as the Mottled Duck (*Anas fulvigula*). Although this species is adapted to survive on the wet agricultural/coastal marsh interface, it is vulnerable to urban encroachment, coastal land loss, and conversion from "wet" agriculture (such as rice and crawfish production) to dry land crops (such as soybean, sugarcane [*Saccharum officinarum*], and cultivated sorghum, or milo [*Sorghum bicolor*]). Initial interest in this component of MBHI was constrained by confusion about the level of compensation that was to be provided for various management scenarios. Program restrictions are also limiting expansion of MBHI. Specifically, the EQIP requirement, which only allows for provision of financial and technical assistance for the application of a new practice or activity, prevents producers from re-enrolling fields in MBHI. Consequently, the size of MBHI has declined because producers are unwilling to bear the increased costs of management without compensation.

Summary

USDA conservation programs authorized through the Farm Bill have evolved since initial passage in 1985 to more fully consider fish-wildlife in their application. Adequate levels of funding, increased awareness of the importance of private lands, expanded partnerships, provision of funding for monitoring, improved understanding of habitat relationships at multiple scales, and adoption of a strategic conservation approach, that links objective setting, planning, implementation, and monitoring in an adaptive management framework, have contributed to advancements in wildlife conservation on private lands.

Whereas wildlife groups generally have focused their attention on programs that retire land from agricultural production (e.g., CRP, WRP), expansion of land retirement programs is unlikely and will likely decrease in future Farm Bill legislation. For example, the cap on CRP acreage was reduced from 16 million hectares in 2002 to 13 million hectares in 2008 and will likely be further reduced in future Farm Bills because of federal budget constraints and increased demand for agricultural commodities. The acreage cap on WRP, the other major land retirement program in the Farm Bill, was increased from 0.85 to 1.2 million hectares through 2012, but this program is small in extent compared to CRP.

Consequently, opportunities to implement "bird-friendly" practices through agricultural working lands programs such as EQIP, Grassland Reserve Program, Farm and Ranch Lands Protection Program, Conservation Stewardship Program, WLFW, or WHIP, merit greater attention from bird conservationists. For example, continued loss of coastal wetlands and reductions in rice acreage in coastal Texas–Louisiana have important implications for waterbird conservation in North America. Enhanced management of agricultural wetlands along the Gulf Coast may represent the best opportunity to accommodate waterbirds displaced by wetland loss associated with sea-level rise and other factors.

Economic considerations are the primary drivers of land-use decisions on private lands. Consequently, the implementation of "crane friendly" management actions on private lands requires an awareness of the logistical and financial costs associated with various management options and the necessity of providing adequate financial assistance to offset additional management costs and foregone income (Zedler et al. 2008).

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CASE STUDY

Developing Anthraquinone (AQ) as a Crane Deterrent

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Abstract: Crop damage to newly planted corn by Sandhill Cranes (*Grus canadensis*) has become a problem for farmers in the upper Midwestern states – an economic burden that may only increase as the crane population increases. The International Crane Foundation (ICF) conducted field studies to identify and test the effectiveness of non-toxic compounds as deterrent to depredation on corn seeds and seedlings. One compound proved to be effective in protecting planted corn seed from herbivory, while allowing cranes access to cultivated fields. Building on a strong collaboration of partners who would have a stake in the issue, the International Crane Foundation has helped create a lasting solution to this problem that benefits both farmers and cranes. Successful collaborations like this are key to extrapolating solutions to human-wildlife conflict worldwide, but require considerations of stakeholders – including cranes – at multiple levels.

Keywords: collaborative research, crop deterrent, Sandhill Crane, seed treatment

Wisconsin is home to a core of the breeding population of the eastern Greater Sandhill Cranes (*Grus canadensis tabida*). In addition to a dense population of breeding birds, many non-breeders move about the landscape in search of food sources throughout the spring and summer when they are resident here. The agricultural landscape and wetland basins are attractive to cranes. In 1988, the International Crane Foundation (ICF) began an intensive study of cranes near the city of Briggsville, Wisconsin (43˚ 39' 30" N, -89˚ 35' 00" W) to better understand their natural history. The combination of rich agricultural land and large crane population at times has led to heavy damage to germinating corn fields (Fig. 1).

Fig. 1. Corn seedlings removed from the ground by Sandhill Cranes. In some areas, damage can be severe (Photographer: Liying Su)

One practical application of our long term research in this area was to help alleviate crane damage of corn seedlings. ICF biologists reasoned that as the Sandhill Crane population grew and expanded to other areas in the Midwest, farmers would experience increasingly severe and widespread damage to planted corn elsewhere. Farmers in Briggsville reported that the insecticide Lindane, when applied to their planted corn seed, caused cranes to avoid foraging on germinating corn. Based on these preliminary reports, ICF began to track the use of Lindane by farmers and verified the avoidance behavior. Lindane, however, is a persistent, highly toxic, bioaccumulative chemical. ICF initiated field studies to identify and test the effectiveness of other, less toxic compounds as deterrents in our long term study area. In field trials of several potential deterrents, only –9,10 anthraquinone (AQ) achieved avoidance behavior. AQ is a compound naturally produced by plants to protect fruit from being eaten before ripening. It has low toxicity (category 4, "practically nontoxic" according to the US Environmental Protection Agency), is biodegradable, and has low soil mobility. Preliminary trials in 2000 and 2001 showed AQ worked

Austin JE, Morrison K, Harris JT, editors. 2018. *Cranes and Agriculture: A Global Guide for Sharing the Landscape.* Baraboo, Wisconsin, USA: International Crane Foundation. 303 p.

Fig. 2. Experimental plot in Briggsville, Wisconsin, USA. The area at right and top was treated with Avipel® seed treatment; the area to left was untreated. There was equal crane use throughout the field but no damage to corn seedlings in the treated field (Photographer: Anne Lacy)

as effectively to prevent crane crop damage as Lindane. In field trials of AQ efficacy, crane damage to corn seedlings was estimated in fields treated with AQ and nearby control (untreated) fields. Although the rate of crane use between the treated and non-treated field did not differ, corn seedling densities did differ; the untreated field lost 80% of the seedlings planted while the treated field was unaffected (Fig. 2).

Building collaboration for approval and application

With the efficacy of AQ established, ICF focused on building a consortium of people and organizations at local, state, and federal levels to get federal regulatory approval for use of AQ. Approval by the U.S. Environmental Protection Agency was a lengthy process and during this time, the supply of Lindane products, on which farmers could rely to deter crane damage, was in short supply. Finally, in March 2006 the EPA allowed AQ to be used for the first time by corn growers in Michigan, Minnesota, and Wisconsin under the trade name Avipel®. Coincidently, Lindane was ultimately banned for use in agricultural settings by November 2006.

ICF worked with growers in our long-term study area to determine efficacy of Avipel® within the agricultural setting. In cooperation with the manufacturer, we conducted field trials for five years to study the effectiveness of the chemical to deter cranes. In addition, we continually gathered information on corn growers' opinions about crane crop damage, and if they were aware that a deterrent was available. We found that regardless of the efficacy of this product or process, it was of little value if growers were not aware of its availability. We have found that even after the seed treatment has been available for many years, many growers are unaware that there is a solution available to them to prevent damage. To better inform growers about more effective means of getting Avipel® onto the corn seed, we continue to be in constant communication with the University of Wisconsin-Extension, professional agricultural organizations, U.S. Department of Agriculture, and individual growers about this process (Lacy et al. 2013). This broad spectrum of groups has proven necessary and successful in helping to raise awareness throughout the corn growing areas.

The use of AQ is mutually beneficial to cranes and farmers. The use of AQ allows planted corn seed to be protected from herbivory, while allowing cranes access to cultivated fields. This latter characteristic is critical for the cranes, as these agricultural areas are important both for forage and as safe, open loafing areas. By foraging on food items other than the treated seed, cranes may remove agricultural pests or waste grains, conferring a benefit to the farmer. Additionally, farmers will not experience economic losses due to crop damage, or have to handle toxic seed treatments.

Successful solutions to human-wildlife conflicts such as this case study are critical for advancing wildlife conservation on private lands, which composes over two-thirds of North America's land base. Much of the fertile farmland in high-density crane areas is privately owned in North America, greatly increasing the potential for conflict. Helped in part by the field tests facilitated by ICF, Avipel® is now used in 12 states on corn, in five of those states for cranes specifically; other avian crop depredators are now listed on Avipel® labels as a result of this work. Using the lessons learned from cranes and corn, Avipel® is also used to repel Ring-necked Pheasants (*Phasianus colchicus*), blackbirds (Icteridae), and crows (Corvidae) on varied crops such as sunflowers (*Helianthus annuus*) and rice (*Oryza sativa*).

A Model for Resolving Other Similar Depredation Issues

Generalizing this solution to other areas of the world will require consideration at multiple levels. While crop damage most often occurs on breeding grounds in North America, damage by both wintering and staging birds is significant with Eurasian Cranes (*Grus grus*). Non-migratory birds can do damage at any time of year in many African countries. Crop damage in Africa is further complicated by different farming practices ranging from subsistence farming to conventional commercial farming. For crane conservationists worldwide, the challenge is translating the success of this case study into solutions that match diverse situations, such as staging and wintering birds inflicting damage on various crops at various stages of growth. It is further complicated by cases where crop damage plagues subsistence farmers, who may not have the means to purchase the chemical treatment. With this start, however, we hope by working directly with farmers, their livelihood will be protected as harm to cranes is minimized.

Recently much of the research upon which this case study was developed has been published. Avipel, containing 9-10 anthraquinone, has been tested in comparison with other deterrents (Lacy et al. 2018), it has been tested at landscape scales (Barzen et al. 2018) and it's efficacy has been examined at landscape levels (Barzen and Ballinger 2018).

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CASE STUDY

Agriculture Program of Muraviovka Park: Integrating Wetland Conservation with Farming

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Abstract: Muraviovka Park (the Park), in the rich agricultural lands of Zeya-Bureya Plain in the Amur Region of far eastern Russia, protects wetlands important for breeding Red-crowned (*Grus japonensis*) and White-naped Cranes (*G. vipio*) and Oriental Storks (*Ciconia boyciana*), and as stopovers for five crane species as well as Greater White-fronted (*Anser albifrons*), Bean (*A. fabalis*) and Lesser White-fronted Geese (*A. erythropus*), and many ducks during migration. The Park was established in 1994 on working lands as the first territory for sustainable land use managed by a non-governmental organization in Russia. It contrasts with the magnificent system of *zapovedniks* (State Nature Reserves), or strictly protected areas, where the impacts of people have been minimal and human access minimized. The wetlands and wildlife at Muraviovka occur in close proximity to people; in fact, the great density of nesting cranes and storks as well as gathering migratory birds result from the benefits that the agricultural landscape provides to wildlife using adjacent wetlands. The Park has essentially been an experiment in how to devise conservation programs that preserve and enhance this positive relationship between cranes and people. A demonstration farm, now incorporating over 1,100 ha of prime farmland, has enabled the Park to practice farming compatible with wetland protection. Crop fields were managed until 2015 without pesticides and with minimal use of chemical fertilizers, serving as buffers protecting the wetland from more traditional croplands nearby. Mulching of crop wastes served to enrich soils while eliminating a significant source of fires that can sweep the wetlands in spring or fall, destroying nests, young birds and vegetation. The Park has successfully used diversionary crops to keep migratory cranes and geese on protected lands, where they are not at risk from hunting and do not damage crops of neighboring farmers. Challenges for the Park and its farming and fire control programs arise from the lack of an institutional and legal framework for private conservation initiatives, difficulty in finding good farm workers, an unstable economy, and the growing demands for intensive conventional farming and conversion of wetlands into croplands. The farm had become self-sufficient, and helped support core operations of the Park but in 2015, due to economic difficulties, the Park was forced to sublease croplands for three years.

Key words: demonstration farm, diversionary crop, prescribed burns, Red-crowned Crane, sustainable agriculture, education, White-naped Crane

Background

Muraviovka Park (49º52'23.61"; 127º42'12.87") is the first non-governmentally managed nature territory in Russia. In 1994, the Park leased 5,147 ha of wetlands and 60 ha of croplands for 50 years. Located in Tambovka District of the Amur Region (Province) in the Russian Far East, this area is famous for the best soils and climate conditions favorable for crop production, primarily soybeans (*Glycine ma*x) and small grains. Due to political issues and fast economic changes in the early 1990s, such as the lack experience and skills relative to a market economy, use of obsolete technologies and machines, and sudden openness of domestic markets to imported goods, agricultural production in the Amur Region diminished by 3–4 times. Over 50% of poultry, pig, and beef farmers shut down, and skilled agronomists, veterinarians, mechanics, and farmers left their villages for cities. During this period, Russia's State Nature Reserves were under severe pressure due to diminishing support from the government. Muraviovka Park (Harris 1993, Smirenski 1998) became the first specially used nature territory that, through sustainable land use, could benefit both wildlife and people by protecting wetlands and endangered birds and at the same time developing alternative agriculture methods, wildlife tourism, and other environmentally friendly practices. The Park's wetlands had greater concentrations of White-naped Cranes (*Grus vipio*) and Oriental Storks (*Ciconia boyciana*) than anywhere else in Russia because the waterbirds benefited from the mosaic of wetlands they use for breeding and roosting and nearby farming landscapes which served as their primary feeding habitats (Nosatchenko and Smirenski 2007). Over 300 species of birds and 680 species of vascular plants have been documented for the Park.

The Park was established during a period of immense and rapid change. For the first time in many decades, it was possible for private individuals to own and farm their land. The government eliminated subsidies to the agricultural cooperatives. As a result, enormous areas of crop fields were abandoned and became heavily infested with weeds. Agricultural classes were dropped from high school curricula, and very few teenagers wanted to stay in their villages. To be a farm worker had become a symbol of primitive labor and life. This situation offered the need and the opportunity for different conservation approaches.

From its beginning, farming has been integral to the overall mission of Muraviovka Park, which is to introduce practices that integrate wildlife conservation, sustainable land use, and public education. The issues are many, varied and complicated. Unrestricted and badly managed use of herbicides in the 1960s, 1970s, and 1980s resulted in enormous soil and water pollution. This contamination caused health problems for farm workers and their families (9 of 10 infants in rural areas were born with health problems). Wetland reclamation was subsidized by the federal government for many years – during the Soviet era and again during the most recent decade. These activities resulted in the loss of crane habitats because marginal lands (wetlands) with low soil fertility appeared to have no economic benefit in their natural condition.

In the late 2000s, the situation for agriculture in the Amur Region began improving; increased crop income provided access to modern machinery and equipment, new kinds of fertilizers and pesticides, and better seeds. During 2005–2015 most of the crop fields, which stayed abandoned in the 1990s and early 2000s, have been developed. The federal government resumed financial investments in agriculture and incentives for agricultural producers; financial support from the government further increased since 2014 after initiation of economic sanctions against Russia by the Western countries following the annexation of Crimea. All this resulted in rapid restoration – within just several years – of hundreds of thousands of hectares of arable land abandoned in the 1990s. Soon after wetland reclamation projects resumed, and the Park found itself under growing pressure from the neighboring agricultural producers and district administration, who began demanding the entire Park's territory be used for agriculture. Due to considerable increase in total acreage under grain crops, the planting period has become longer, and, large recently planted fields are now available to birds for nearly one month. These changes have created more favorable foraging conditions for cranes and geese and reduced bird damage to crops in spring. Unlike the geese, cranes do not normally pull out sprouting crops. Geese, however, make only short stopovers in the south of the Amur Region in the autumn, because at that time the hunting season opens on waterfowl. Only small flocks of several dozen birds stay for longer time in the Park. Numbers of ducks are low; they feed in the wetlands and harvested fields and do not cause damage to the crops. Consequently, leaders and staff of agriculture companies do not complain about the presence of cranes and other waterbirds in their fields, but they do complain about hunters who often drive their vehicles across crop fields or dig holes in the fields as hideouts to hunt geese. Unfortunately, the district administration does not understand or just ignores the fact that the Park's wetlands represent a critical habitat for endangered and threatened waterbirds listed in the Russian Federation Red Data List and for migratory species protected by bilateral conventions, as well as the status of the Park and adjacent areas as Wetlands of International Importance under the Ramsar Convention.

At Muraviovka Park, up to 1,000-1,500 predominantly Hooded (*Grus monacha*) and White-naped Cranes, with some Eurasian (*G. grus*) and Red-crowned Cranes (*G. japonensis*), and up to 3,000 White-fronted (*Anser albifrons*) and Bean Geese (*A. fabalis*) arrive in mid-late March and most of them leave the Park in mid-late April. During the first weeks of their stay their main feeding habitats are the harvested fields of corn or maize (*Zea mays*), barley (*Hordeum vulgare*), and wheat (*Triticum*) not yet prepared for the next growing season (Nosatchenko and Smirenski 2007, Smirenski and Smirenski 2010). The fields become the main feeding habitats for migratory birds during or soon after planting. Waterbirds picked up seeds spilled on the ground with no noticeable impact to seeded crops. By mid-April the number of migrating cranes and other migratory birds is already declining. In early May, due to extended time of crop planting and some new, additional food sources of fishes, invertebrates and plants in the Amur floodplain wetlands, cranes here have plenty of food.

Numbers of nesting cranes in the Park have varied since 1994, initially increasing due to protection from disturbances, fires, and other human activities. By the late 1990s, about 10 pairs each of Red-Crowned and White-naped Cranes nested at the Park, almost double the number present before the Park was established. However, dry conditions after 2003 not only reduced suitable crane habitat at the Park, but led to poor reproduction and falling numbers for both populations, and especially for the Red-crowned Crane, throughout the middle and upper Amur River Basin. In the Park, after a 10-year period of gradual growth (from 5 to 12 pairs), a decline was noticed in 2004 and, since 2010, only up to three pairs continue to breed in the park.

Wetland habitat conditions also have been degraded over the long term as dam construction altered river flows. A dam constructed in 1975 on Zeya River in Russia, and a dam built on the Hailar River in China upriver from the Park, prevented major floods that formerly scoured sediments from the channels and pools and opened up the wetland. In addition, small tributaries of the Amur and Zeya Rivers were also dammed that had negative impact on breeding habitats, especially for the more aquatic and endangered Red-crowned Crane. The years 2010–2011 brought better water conditions due to abundant snowfall in winter and spring and unusually heavy and frequent rains in late spring and summer. The number of pairs of White-naped Cranes nesting at the Park rose to 14 in 2011, although only three pairs of Red-crowned Cranes nested here in that year. The low number of Red-crowned Cranes reflects the worsening situation for this species in the western part of its breeding range, as well as mortality of this species from poisons (Su and Zou 2012).

Fig. 1. Hooded Cranes gathering during fall migration on harvested grain fields at Muraviovka Park (Photographer: Vasiliy Dugintsov)

Breeding Red-crowned Cranes visit the crop fields before the nesting begins, but non-breeders may be sometimes seen in the fields in summer and regularly in September and October. White-naped Cranes (predominantly males) use farmlands more for foraging through their entire breeding season, including incubation. Families with chicks begin visiting crop fields when their young are just 3–4 weeks old. In 2012, in spite of the dry spring and lack of residual vegetation (eliminated over most of the Park's territory by a devastating wild fire in October 2011), 19 pairs of White-naped Cranes built nests in the Park. Most likely this increase can be explained by an even worse situation in other parts of the species' breeding range. We also documented two unsuccessful nesting attempts by Eurasian Cranes in the Park. In addition, 15–50 non-breeding White-naped, Hooded, and Eurasian Cranes spend the summer in the Park. They also produce no noticeable impact on crops.

During autumn migration, from early August – late October, a large concentration of cranes forms in the Park and in a number of wetlands outside of the Park, which at any given time may include from 300–400 to 2,000 birds (Fig. 1). Throughout this period new flocks continue to arrive and the first departing flocks have been sighted as early as in the last 10 days of August; the total number of cranes that make stopover or stage at the Park in the fall may constitute 3,000-3500 birds. Hooded, White-naped, and Eurasian Cranes mostly feed in the fall on harvested fields and less so in the Amur floodplain wetlands, while Red-crowned Cranes feed mostly in wetlands.

Harvested fields of barley and wheat, located close to the roosting sites and not yet prepared for the next growing season, are especially attractive for cranes. Grain left in the fields after harvest may exceed 5%, so up to 400 cranes may feed on a 50-ha field for a whole month. Fields that were disked or cultivated after the harvest, however, are much less attractive for cranes, because after such procedures most leftover grain becomes unavailable. In such fields cranes stay no longer than 10–15 days, unless there are other good foraging habitats nearby. In the fall of 2017 local farmers, now well equipped with modern machinery, took advantage of dry weather and by early September have already cultivated the harvested fields twice, leaving practically no grain for birds. A crane concentration of slightly over 500 birds that gathered in the Park area by that time began to scatter. Numbers of White-naped Cranes dropped sharply but Hooded Cranes stayed for two more weeks foraging in the remote fields that were not yet cultivated for the second time. New flocks (up to 150 cranes each) continued arriving to the Park but instead of staying for 2 – 3 week they made a 2 – 3-day stopover and resumed their migration south, so the usual large concentration of cranes had never formed at Muraviovka Park that fall.

Corn is especially attractive for cranes. In the 1990s, acreage under corn was just several hundred hectares in the entire Tambovski District and harvested in August for silage. Accordingly little corn was available to cranes when the majority of migratory birds arrived. Because of very poor growing technique, poor seed quality, and abundant weeds, the corn plants were too spaced out, with large gaps between plants. At that time, we observed cases of damage to corn ears caused by cranes. During the recent years, several thousand hectares in Tambovski District are annually planted with corn and most of the crop is in good condition, with plants forming a dense stand. Cranes do not walk deeply into the densely planted crop and even approach the crop cautiously because of possible presence of hunters.

The situation changes drastically with the start of harvest. Unlike small grains, even those corn fields that were disked or cultivated after the harvest become the most attractive feeding sites for cranes. At any given time 2,000–2,500 cranes may gather in a 250–300 ha corn field. Cranes may forage in a harvested corn field for 1.5–2 months.

In the fall of 2017, only two-three pairs of White-naped and three Red-crowned Cranes visited the diversion small grain crop field (with wheat and barley) that we planted, harvested, but did not cultivate, and an adjacent field with corn that we left unharvested until December. Most of the cranes did not dare to forage in these fields because of the closeness of the road. In spring 2018, over 2000 White-fronted and Bean Geese foraged in the small grain field until a poacher's shots scared them away. White-naped Cranes (~30 birds) began visiting this fields only since mid June. In early March, we spread over 60 tons of corn ears over three feeding sites in the Amur floddland, where up to 300 cranes of five species – Hooded, White-naped, Red-crowned, Siberian, and Eurasian – foraged until early June (the geese did not visit these sites).

Crane behavior and use of harvested fields differ during spring and autumn. In spring, we first spot the cranes on the last year's corn fields, even near villages. At this time, the birds allow people to approach them as close as at 100 m or even less, and vehicles as close as 15–25 m. In the autumn in Konstantinovski District, large flocks of up to 2,500 cranes feed on harvested fields for several weeks but keep longer distance from the roads and people (200–300 m from the roads with regular traffic). In Tambovski District, flocks of 300–500 cranes feed on corn fields but at considerable distance from places frequently visited by people. We believe that this difference can be explained by the fact that in Konstantinovski District the majority of farmers began growing corn in the 1990s while in Tambovski District corn has been grown only since 2009, so the birds there are still very shy of people.

Farmers do not complain about presence of cranes in the autumn fields. Many local people even take pride in the fact that the cranes picked their fields. Unfortunately, there were several recently documented cases of intentional killing of cranes with rifles in spring (White-naped Cranes in Primorski Region) and in autumn (a Hooded Crane in Tambovski District of the Amur Region; Amur Hunting Management Office 2016, Kruchinin 2016), which have made the cranes extremely shy of people in the Park area in autumn of 2016. Cranes stop feeding and even fly away – not only if a vehicle stops on the road at 300–400 m distance, but even when a car is moving under 60 kph. Crane families that breed in the Park are much calmer and do not react so nervously to people and vehicles. In early mornings from 05:00–06:30, when there is still no traffic, foraging cranes can approach the road as close as 200 m or even less.

Weather conditions and flooding greatly influence crane use of the Park and agricultural lands. In April 2013, due to the late snow melting and early pouring rains, significant areas of wet meadows in the Park were already covered with water 10–20 cm deep. This water created favorable conditions for breeding of many waterbirds. Twenty-five pairs of White-naped Cranes began nesting in the Park. Continued heavy rains, however, kept water levels rising, and although cranes kept building up their nests, nests were flooded during the first 15 days of May. During the following flooding in July-August that year, the water rose so fast that seven out of ten pairs that had successfully hatched eggs lost their chicks. Vast flooded areas created favorable conditions for breeding of fish, amphibians, and aquatic invertebrates. Hundreds of hectares of cropland, even on river terraces, were flooded and left unharvested. This situation, in its turn, created abundant food supply for birds. Fifteen pairs of Oriental Storks successfully bred in the Park in 2013, with average number of 3.6 fledged chicks per pair. In August and September, we observed a family of White-naped Cranes in the Park with three chicks of the same age who were already flying (Ishchenko 2014). A number of temporary water bodies still remained in 2014 but by September they became isolated from lakes and rivers and turned into a smorgasbords for waders, herons, cormorants and other waterbirds. In October of 2014, at just one flooded depression with 20–40 cm deep water, 326 Oriental White Storks were feeding together with two Large Egrets (*Egretta alba*) and over 400 Grey Herons (Vasiliy Dugintsov, personal comm.). Numbers of breeding Red-crowned Cranes, however, remained low in spite of favorable conditions (Smirenski and Smirenski 2010). In 2013 and 2014, only three pairs bred in the Park; in 2014 another pair bred successfully in a game refuge on the left bank of the Giltchin River right across from the Park.

When the autumn weather conditions are dry, the harvesting period is shorter and the fields are prepared for the next growing season immediately after the harvest. In such years the importance of crop fields as feeding grounds for birds may sharply decrease within several days. In wet autumns, when the post-harvest works in the fields are delayed by weeks, cranes enjoy more favorable feeding opportunities. When the food is abundant in the harvested but not yet plowed fields, White-naped Cranes stay to feed in these fields later into the fall than Hooded Cranes.

Major flooding in 2013 caused significant changes in behavior and ecology of migrating Siberian Cranes. In the autumn 2013, when vast areas in the Amur floodplain and even on the river terrace were flooded after several months of heavy rains, Siberian Cranes began stopping in the Park and in some other areas in the south of the Amur Region. Prior to that Siberian Cranes occasionally made short stopovers in the Park but mostly during their spring migration. In autumn 2013, however, we noticed that they fed on corn, pecking on ears dropped on the ground during harvest. In the following autumns of 2014 and 2015, growing numbers of Siberian Cranes made stopovers at the Park and in the Amur Game Refuge 60 km south from the park. These cranes spent a significant part of their foraging time in harvested corn fields (Fig. 2).

Objectives and activities of the Park

Protect Critically Important Wetland Areas for Cranes and Other Endangered Species and Upgrade Breeding and Feeding Habitats

Mitigating Illegal Hunting and Fishing

The Park's staff do not have authority to detain poachers. But the very presence of the Park's employees, participants of summer camps and workshops, visiting researchers, journalists, and birdwatchers from Russia and other countries, who would witness poachers' activities, represents a serious obstacle to poaching. In the past illegal fishermen were seen at Kapustikha Lake near the Park's headquarters throughout the year, but construction of the Education Center and a boardwalk blocked the easiest access to the lake used by fishermen and practically stopped this activity. Now the lake is free from fishermen and numbers of breeding and migrating waterbirds are increasing. Local villagers are well informed that the Park's staff does not catch fish for personal needs. We allow the Park's visitors limited fishing with rod only at one designated place, and on condition that their entire catch will be donated as food for our captive cranes.

Fig. 2. Siberian and Hooded Cranes feed in harvested and disked corn field during fall migration at Muraviovka Park (Photographer: Vasiliy Dugintsov)

Wildlife and Habitat Management

Muraviovka Park and Amurski Wildlife Refuge, as well as small wetlands adjacent to the Park and the refuge in Tambovski and Konstantinovski Districts, represent a distinctive migration "bottleneck" similar to the one on the Platte River in Nebraska (USA), where thousands of migrating cranes and geese stop to rest and replenish their fat deposits. Up to 7,000 Hooded Cranes (~50% of the world population), after breeding in Yakutia, Amur Region, Jewish Autonomous Region, and Khabarovsk Region, spend here 2–3 weeks, before continuing to their wintering grounds in Kyushu Island in Japan, south of the Republic of Korea, and lower reaches of Yangtze River in China.

In certain years birds find themselves in dire straits due to inclement weather. In April 2013 cranes could not forage for two weeks because of deep snow and freezing temperatures. The Park developed several feeding sites and provided over 15 tons of small grain from the Park crop production. But it was not enough. Through social and mass media we made appeals to the public and received a tremendous response. With funds that we received from the Amur Region (Fund Sofia and local citizens), the Park supporters from Moscow, other regions of Russia, and also from Armenia and Ukraine we were able to purchase enough frozen fish to feed the birds during these two weeks. Several farming co-ops in Tambovski and Ivanovski Districts of the Amur Region delivered tons of corn, wheat, and barley. The food attracted dozens of cranes and storks (Fig. 3).

Fig. 3. Red-crowned Cranes feed on corn at Muraviovka Park artificial feeding sit. (Photographer: Vasiliy Dugintsov)

Nest site development and improvement

One objective of the Park management is to create more trees suitable for stork nesting. The Park has good feeding habitats for Oriental Storks but there are few trees in the area, while trees big enough to hold nests are even fewer. In addition, canopies of bigger trees are usually too dense. So we began in 1998 the trimming of selected top branches of suitable trees, which resulted in increased numbers of Oriental Stork nests in the Park (from one in 1992 to 13–15 annually in 2010–2016).

In spring 2013, due to continued pouring rains, during the first decade of May the fast rising water flooded 15 of 25 White-naped Crane nests located in the Park. We managed to save one nest by lifting it up with bundles of dry old grass and several days later two chicks hatched in it.

Conducting watershed research program

The district capital town of Tambovka and a large village of Kozmodemyanovka, ignoring federal public water use legislation, are continuing direct dumping of untreated industrial and municipal wastes into the Giltchin River, which flows along the southern border of the Park. Due to the lack of a buffer zone along a significant stretch of the river, runoff from crop fields carries fertilizers, pesticides, and soil particles directly into the river. Seven artificial water reservoirs on the Giltchin River represent huge waste depositories and water evaporators, turning the river into a succession of stagnant canals and ponds. The district court released several decrees prohibiting dumping of untreated sewage into rivers but nothing was done to enforce these decrees. In 2015 warning signs were installed banning swimming in the reservoirs but since the reasons for this ban were not communicated to the villagers, people have continued swimming and fishing (Fig. 4) in highly polluted water, endangering their health.

Since wetland reclamation and pollution represent serious threats to crane habitats, the Park, with support from the International Crane Foundation (ICF), organized in 2010 an international workshop "Cranes, Agriculture, and Climate Change" (Harris 2012) and launched a comprehensive program of watershed research in the Giltchin River basin.

Data from our hydro-biology and hydro- chemistry studies (Krasnova et al. 2013) revealed that the waters in the upper and middle stream of the Giltchin River are highly polluted; only in its lower

Fig 4. Villagers fishing near a warning sign and dead fish near this highly polluted village reservoir (Photographer: Sergei Smirenski)

reaches, thanks to the influx of clean water filtered by the Park's wetlands, does water quality becomes significantly better (Tables 1 and 2). Water from the Park, however, does not flow into Arguzikha River that borders the Park from the west. Water in this river is highly polluted in its upper stream and becomes even worse downstream, but there are no warning signage on its shores.

The first book of the series "Cranes and People, Wetlands and Water" based on the results of this research program will be published in winter 2016. Currently our staff and visiting researchers are continuing complex scientific studies of the Park's wetlands. These studies create a foundation for the long term monitoring of the status of this Ramsar site, produce solid data that allow quantitative assessment of environmental services that wetlands provide, and prove that wetlands are the most efficient natural filters and no less important for people than for wildlife. We believe that these data, being disseminated among all stakeholders in the area, will help raise public awareness, change current people's attitude to wetlands as wastelands, and consequently stop further reclamation of wetlands in the Giltchin River watershed.

Table 1. Condition of Giltchin River water in June 2011 (Krasnova et al. 2016).

Location	Saprobity* index, periphyton	Saprobity index, plankton	Saprobity index, zoo-plankton	Water purity class	Woodiwiss Index	Saprobity Pankle Bukka Index, zoobenthos
					(in brackets - water purity class)	
Upper stream, Nikolo Alexandrovskoye artificial reservoir	1,40	1,87	1,58	II–III	2 (-)	2 (III)
Middle stream, below Tambovka village	1,69	2,07	1,63	III	2 (-)	3,8 (V)
Low stream, below Muraviovka Park	-	1,92	1,69	III	6 (III)	1,2 (II)

* Saprobity is the state of an aquatic ecosystem resulting from the input, decomposition and removal of organic matter and its catabolites.

Table 2. Concentrations of major cations in Giltchin River in April 2014 (Pakusina et al. 2016).

Location	Cations							
	Na^+		K^+		Ca^{2+}		Mg^{2+}	
	Mg/dm^3	mEq/dm^3	Mg/dm^3	mEq/dm^3	mg/dm^3	mEq/dm^3	mg/dm^3	mEq/dm^3
Upper stream, Nikolo-Alexandrovskoye artificial reservoir	5,035	0,219	5,528	0,141	13,46	0,672	3,145	0,258
Middle stream, below Tambovka artificial reservoir	17,84	0,776	5,636	0,144	46,60	2,325	11,29	0,928
Spring coming from Muraviovka Park to the lower stream of Giltchin River	16,47	0,716	3,589	0,092	29,09	1,452	6,344	0,521

Diminish Impact of Wild Fires on Cranes and People

Raging wild fires destroy nests, chicks, and even molting birds. The indirect impact of these fires has been equally significant as they eliminate the dry grass that hides incubating birds from the eyes of predators. Cranes were thus prevented from successful nesting even in otherwise suitable wetlands with sufficient water levels. Burning of dry grass also results in large-scale air pollution and removes natural barriers for soil particles and chemical run-offs from the crop fields, thus leading to water pollution and silting of wetlands. In agriculture areas in the south of Zeya-Bureya Plain, including Muraviovka Park, fires are exclusively human-made and in most cases are set intentionally. Until the mid-1990s straw was used by collective farms as litter and was also added to feed mixes for cows, so their combines were equipped with bail-making attachments. With the decline in dairy and beef production there was no demand for straw and since the farmers did not have straw mulching equipment they began burning the straw (Fig. 5) to clean the fields for the next growing season. This activity became the main contributor to the number and scale of wildfires. Fires that spreads to Muraviovka Park wetlands from our neighbors' fields destroy everything in their wake.

Fig. 5. Until 2014, giant cooperatives in the Amur Region used obsolete harvester stackers on their combines and burned piles of straw left in the fields. (Photographer: Sergei Smirenski)

Among other causes are carelessness of local villagers, hunters, and fishermen, who leave their campfires unattended even when the wind is high, or do not put fires down prior to leaving the campsite. Almost 90 years ago, Alexander Formozov (1929) wrote that many locals start the fires simply for enjoyment of staring at the flames. Trees and shrubs sustain damages but slow down the spreading of fire and break up its front into smaller and manageable sections. In the 19th century, woodlands covered 30% of the of the Tambovski District territory; currently, woodlands now represent less than 0.5% of the landscape due to clear cutting and development. (Shchukin 2016) This change led to more frequent fires, greater susceptibility of the landscape to fires, and much greater damages to natural communities.

Fig. 6. The Park's Demonstration Farm used straw chopper attachments on our combines to mulch straw since the very beginning. (Photographer: Sergei Smirenski)

We have introduced an array of wildfire fighting strategies. The Park conducts an ongoing reforestation program with participation of hundreds of volunteers, including leaders of the region. We were the first in the area to use straw-mulching equipment (Fig. 6) on all our combines, and the mulching of straw converted our crop fields from sources of wildfires into firebreaks. Plowing the mulched plant material into our heavy clay soils has improved the soil structure and fertility, which allows less use of mineral fertilizers. Advantages of approaches used by the Park became obvious to our neighbors, and in 2014–2016 major crop producers in the Amur Region purchased new combine models equipped with straw mulchers, so their fields also stopped being the sources of wildfires.

Prescribed burning has been successfully tested, and the results and experiences have been shared with firefighters, foresters, nature reserve managers, and agricultural cooperatives. Twice the Park invited experts from the USA to share their expertise in controlled burns. Especially successful was a training workshop in April of 2011 led by Jeb Barzen, then Director of Field Ecology at ICF. Among the workshop participants were officials from regional and district administrations, staff from the Ministry of Emergencies, wardens, and firefighters. Hands-on classes clearly demonstrated the high efficiency of mosaic controlled burns in protection of crane breeding sites from devastating wild fires. Over the years the Park has purchased and donated firefighting equipment from the USA to the local forestry service and firefighters – backpack pumps, drip torches, flappers, and portable meteorological equipment which are of much better quality than similar equipment manufactured in Russia. At that time, however, even the regional leaders could not give the Park a permit to conduct prescribed burns, so wildfires continued to engulf the Park lands every year.

In the fall of 2011, only thanks to the vigilance of the Park's staff, who spotted the flames approaching the nearest village in the middle of the night and called the firefighters, the fire was suppressed efficiently and the village was saved, as well as much of the Park's yet unharvested soybean crop. Nevertheless, the wildfire problem remains acute in the Amur Region today. Annually wildfires engulf hundreds of thousands of hectares, destroying buildings and killing people and wildlife.

Yet the situation may be improving. In 2016, at our request, the Amur Ministry of Forestry and Fire Safety conducted controlled burns in the Park, creating a firebreak 8 km long and 70–100 m wide. Because of this help, for the first time in the Park's history over 50% of its territory was not touched by fire. In mid-October the regional government again gave positive response to the Park request and a team of 26 firefighters during three days conducted prescribed burning in the Park over 30 km long and 50 m wide.

Thanks to the fire prevention program developed by the Amur Ministry of Forestry and the Amur Ministry of Emergencies, in the spring of 2017 fires also had very limited impact on the Park. In spite of unfavorable dry conditions of 2017, at least 19 families of White-naped Cranes raised their chicks – a record breeding success for this crane in the Park.

Accumulation of dry vegetation creates conditions for a devastating fire, which happened at the Park in spring 2018. In mid-March on a day with high winds almost entire Park's land suffered from a fire started inside the Park by an arsonist, which resulted in very unfavorable conditions for cranes who returned to their breeding grounds in April. Only regular mosaic burns and creation of firebreaks may prevent such catastrophic results.

We use any opportunity to educate the public – the Park's visitors, attendees of our workshops, summer camps, festivals, and presentations at schools and universities – about negative, often devastating impacts of wildfires. We have organized creative contests and arranged production of an informational video film about causes and consequences of fires, which was broadcast on regional television for several years. At our request, the renowned Russian wildlife artist Vadim Gorbatov created a powerful painting "The Exodus" depicting an adult Red-crowned Crane with two small chicks fleeing from a raging fire.

Participation of the local public in these activities is very important because it educates people about harmful consequences of wildfires and creates an atmosphere of public condemnation towards arsonists.

Diminish Crop Damage by Wildlife and Reduce the Loss and Disturbance of Birds by Farmers and Poachers

Attractiveness of the Park for visitors has to do with the close proximity of relatively safe resting and roosting wetland sites and crop fields with abundant supply of food for waterbirds. Impact of cranes and other waterbirds on crops is minimal and does not evoke negative attitudes towards cranes in local people. Due to resumed reclamation of wetlands and heavy presence of hunters during the migration seasons outside of the Park, however, negative impact of these disturbances is growing from year to year. Frequent disturbances in these unprotected areas have forced the birds to fly from one feeding site to another too often so the birds stay in the area longer, spending precious energy needed for their long migration. As a result, in the spring the birds arrive at their northern breeding ground later (Smirenski et al. 2018).

Spring and autumn hunting is allowed in the fields adjacent to the Park and coincides with the time when large numbers of migrating geese and cranes gather in this area. To mitigate the disturbances from hunters, the Park began planting diversionary (lure) crop fields (mostly of corn, or maize), to attract grazing birds away from neighboring crop fields during early spring when birds suffer from a shortage of food sources. We purchased used John Deere machinery (a corn picker and a combine) in Wisconsin and shipped them to the Amur Region and used them to plant 30–35 ha to corn. In 2016, we planted ~35 ha to corn for cranes in the middle of the Park. In the autumn, we harvest the corn, leaving a considerable number of ears on the ground, which during winter serve as excellent food for pheasants (*Phasianus colchicus*) and roe deer (*Capreolus capreolus*). Still, lots of corn ears would remain on the ground until spring, to be picked over by the first flocks of birds returning from wintering grounds. Then we spread in the fields the corn ears stored in the barn over winter.

Diversionary crops minimize loss and disturbance of wildlife by hunters, while attracting growing numbers of bird watchers to the Park. Furthermore, presence of visitors in the Park significantly reduces the presence and activities of poachers.

During foraging the cranes roosting at the Park and feeding in adjacent fields must cross over powerlines. The birds are aware of the danger and begin gaining height several hundred meters before reaching the obstacle. Still, cases of trauma and mortality of cranes, storks and other birds have been documented along the 13-km stretch between the villages of Muraviovka and Dukhovskoye annually. Such casualties happen mostly in August and September when the morning dense fog can cause visibility as low as 50 m between 07:00 and 10:00. In spring and summer, on days with high winds, we observed crane and stork collisions with powerlines. Diversionary fields allow birds to feed in the safety of the Park, thus diminishing their risk of collisions with powerlines. We have also planned to equip the powerline on the border of our land with markers that warn the birds about the danger of collision.

Teach Rural Youth the Basics of Sustainable Agriculture and Inoculate Society With a Respect for the Farmer's Work

We have conducted annual classes, presentations, and art contests in rural schools and summer camps with instructors comprised of Park staff, Russian, American, Chinese, Japanese, and German teachers, volunteers, and others. The curricula have involved sustainable land use, agriculture, endangered species, wildfires, wetlands, and the economy. Over 3,000 students and educators have participated in these camps since 1994; they studied soil structure, fertility, erosion, pollution, and the role of wetlands as natural filters and habitats for wildlife (Fig. 7; Smirenski and Smirenski 2013a).

Fig. 7. Russian students take water and soil samples at summer camp in Muraviovka Park (Photographer: Elena Smirenski)

Develop Economically Sustainable Agricultural Practices/Strategies That Create Better Environment for Wildlife (Flora and Fauna) and Human Populations

While the past 23 years have been challenging because the Park does not fit the traditional institutional and legal framework for land use and farming, the farm has met considerable success toward achieving its objectives. The Park's farm operation has gradually expanded, with significant assistance from the local and regional governments that approved the Park's application to lease additional farmland. In 2009, the government awarded 500 ha of lowland farmland within the middle of the Park's wetlands to the Park. This acquisition is highly important for the Park in controlling human disturbance and access to waterbird habitats especially during the breeding season.

Currently, the Park has 1,100 ha (over 2,718 ac) of cropland and its land lease has been extended until 2058. With support from ICF, the Park was able to purchase necessary machinery and equipment, build two grain storage sheds and a garage, and develop over 500 ha of arable land. Agriculture became the major source of income to the Park (Smirenski and Smirenski 2013b). We also constructed a woodshop and solar kiln for making lumber for internal Park use and for sale to local people. Until 2015, the Park had four tractors, including a 350-hp tractor to work the lowland fields, and two combines and employed four farm workers. (In 2015, two tractors were sold, one is now kept for parts, and one is still in use by the Park staff on site.)

Our farming team also participated in fire suppression activities and in preparation of the headquarters site for summer camps and other events.

We have implemented agricultural practices seldom used before in the district, including crop rotation and mulching of straw, which eliminated all herbicide use, and limited the use of commercial fertilizers (used by the Park only two times in 13 years). As a result, soil fertility and soil condition have improved, earthworm and arthropod populations increased, weeds have been suppressed, water/soil pollution diminished, and expenses for crop production reduced in comparison with neighboring farms. Higher prices on agricultural chemicals and use of new kinds of fast-decomposing herbicides that do not poison the soil and water also have led to reduced levels of pollution by our neighbors.

By late 2014, however, farming activities became a heavy burden for our small staff and limited budget, and in 2015 the Park signed a three-year agreement on cooperation with a local soybean producer, Amur Ltd. By this agreement, Amur Ltd. received the right to farm 1,000 ha of the Park's arable lands, using their own machinery, fuel, and labor, and contributing in exchange to the Park an annual amount equal to the market price (in the fall of each year) of 100 kg for each farmed hectare, or a total of 100 tons of soybeans. In 2016, an additional one-year agreement was signed on the same conditions, for use of another 65 ha of the Park's land. The only farming activities the Park's staff is still conducting are planting and growing a diversionary crop field of corn (35 ha) for cranes; we also leave ~150 ha under wild grasses for haymaking, which produces a little income for the Park. These agreements freed our staff's hands to conduct other important tasks and provided a steady cash flow to the Park.

Conclusions

The Park has developed its farm operation beyond what we had envisioned in 1994. In 2012, our farming operations had become economically self-sufficient (except for some capital purchases), with the farm providing excess income for core operations of the Park. We effectively demonstrated methods for integrating agriculture and waterbird and wetland conservation. We have been less successful in documenting and disseminating results of our farming approaches. We are challenged by the heavy work demands of maintaining a small-scale farm operation and the retention of effective farm workers. The Park also needs to diversify its income derived from Russian sources as the vagaries of weather make crop harvests less than reliable. Government agencies responsible for fire management, that initially had been reluctant to support prescribed burning methods as a means of fire control, in recent years began providing equipped fire fighters to conduct prescribed burns and develop fire breaks along the Park's borders. Growing numbers of scientists, journalists, and the public have become involved with Park programs, with a strong sense of pride in this local institution and gaining new perspectives on how human activities can be integrated with protection of rare species and habitats. The Park's education activities have generated considerable interest among teachers, students, and families across

Amur Region. One of the Park's significant contributions has been the opportunity for Russians to work with educators and scientists from the international community to explore strategies for adapting conservation approaches to agricultural landscapes important for wildlife.

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CASE STUDY

Stopover Site Management for the Eurasian Crane in Hortobágy National Park, Eastern Hungary

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Abstract: Eurasian Cranes (*Grus grus*) find an optimal combination of a large selection of roost sites inside the Hortobágy National Park (HNP) and extensive cornfields around the area. As these factors have been coexisting since the early 1980s, cranes could set up a stable migratory strategy during autumn migration so that HNP became the largest stopover site in Europe. Agriculture has changed over the past 65 years from small-scale extensive farming and large-scale grazing to a more intensified crop production and decreased grazing densities. However, the level of agricultural intensity showed larger fluctuations with the technological level rapidly growing in the past two decades, which might lead to decreasing food availability and potential for future conflicts with cranes.

Keywords: Eurasian Crane, *Grus grus*, Hortobágy National Park, roosting, staging

Case Description

Hortobágy National Park (HNP), the largest unbroken alkaline steppe in Europe, is located in East Hungary. HNP encompasses 800 km^2 of alkaline grasslands, 30% of which are classified as wetlands including 60 km^2 of fishponds and 2% of lands suitable for agriculture. The areas used by cranes are located in the northern and southeastern part of the HNP (Végvári 2002, Quinnert 2009). It is the primary staging area for at least an estimated 80% of the Finnish and Baltic population of Eurasian Cranes (*Grus grus,* Végvári and Tar 2002, Végvári et al. 2011). During spring and fall migration, the area also supports large numbers of geese (*Anser* spp.), dabbling ducks (*Anas* spp.), and waders (Charadriiformes) from mid-September to late November.

The HNP Directorate manages natural wetlands and 50 ha of cornfields during autumn migration to evaluate whether providing food for cranes, geese, and ducks would distract them from agricultural areas with conflict potential. Based on results obtained so far, this magnitude of distraction feeding or lure crops does not seem to have any effect on the spatial distribution of cranes. This outcome might be related to the fact that fall counts in the HNP have revealed an increase from 3,000 cranes in the early 1980s to a peak of 100,500 cranes; up to 112,000 individuals in 2012 may have used the area during fall migration.

Agriculture has changed over the past 65 years since the Second World War, from small-scale, extensive farming and large-scale grazing to a more intensified crop production and decreased grazing densities. Following the termination of the socialist political system in 1989, agricultural intensity and technological levels have rapidly increased. At the same time, cranes roost primarily on drained fish ponds and shallow marshes and feed in irrigated crops (corn [*Zea mays*], alfalfa [Lucerne, *Medicago sativa*] and native grasslands), up to 30 km from the roosts.

Land-use changes since the 1950s, however, have substantially increased food availability for cranes, particularly through the intensification of corn production. During this period 75 fishponds, covering 6,000 ha in total, became protected as part of the HNP in 1973. Waterfowl hunting has been prohibited in the majority of the ponds since the establishment of the HNP. Some ponds were drained for fishing during autumn migration. From 1999 on, waterfowl hunting was prohibited in all fishponds and one of the largest fishponds was drained each autumn solely to attract cranes for roosting. As a result, cranes find a combination of increasing food and roost site availability.

Crop damage complaints were reported only in three years. In one case, cranes fed on an unharvested field of a shorter corn type. This type of feeding strategy has a simple behavioural explanation: if the corn is shorter than cranes, the birds can feed on unharvested seeds and still be able to spot possibly approaching predators. Accordingly, the HNP Directorate discourages the production of this corn type to avoid further conflicts between cranes and farmers. As a result, no such case was reported since that conflict. The other two cases were reported on spring cereal fields where cranes were attracted by large amounts of corn seeds left behind by harvesting machines. Therefore, no crane damage is to be expected when the right crop types are produced and the right technology applied.

So far no serious conflict between agriculture and conservation has emerged as a result of cranes feeding on corn fields, but the increasing migratory population and decreasing food availability might force cranes to modify their migration strategy and adapt to new types of nutrient resources such as unharvested corn.

HNP has become an important area for wildlife tourism, including several hundreds of crane tourists during fall migration. To promote crane tourism and regional development, the HNP Directorate has organized Crane Days since 2009 when visitors can listen to a talk on cranes and can take part in a tour to watch the roost flight of cranes.

Solutions to the Predicted Negative Changes in Agricultural Technology

The effects of the agri-environmental policy of the European Union (EU) are twofold. On one side, the existing financial tools promote technological intensification and the improvement of harvest efficiency, which are in contrast to the needs of cranes. On the other side, EU agri-environmental schemes facilitate habitat restoration in less productive areas. The network of Environmentally Sensitive Areas provides plausible tools for wildlife conservation, including a specific package of subsidies called "Creating crane and geese habitats" introduced in 2010 in Hungary. At this time, this package has attracted little attention, with only a few tens of hectares applied for as crane-geese friendly fields. However, if conflicts between cranes and farmers arise in the future this specific form of subsidized farming may help preventing problems already experienced elsewhere throughout the continent.

Summarizing, conflicts between conservation and agriculture as a result of crop damage by cranes have still not reached sensitive levels in the HNP. This situation, however, might rapidly change during the next decades as a result of the combination of agricultural modernization, land use change, and predicted climatic variability.

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CASE STUDY

Development of Stop-Over Area for Eurasian Cranes and the Influence of Agriculture in the Rügen-Bock region in Northeast Germany

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Abstract: The number of Eurasian Cranes (*Grus grus*) resting in the Rügen-Bock region during autumn migration has continued to rise steadily since the first crane census in 1965. With up to 70,000 individuals present at the October peak, the region belongs to one of the most important resting sites for cranes in Europe. The increase in numbers mirrors the positive trend of population development in Sweden and Norway. To a lesser extent, cranes from Finland, the Baltic States and Poland are flying through the region. Due to higher efficiency of modern harvesting machinery, harvest residuals are now rare on stubble fields of barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), and maize (*Zea mays)* – important foods for migrant cranes. Moreover, the acreage for maize decreased from 1983 to 2009 by well over 50%, while that for rapeseed (*Brassica napus*), which has no nutritive relevance for cranes and many other wildlife species, doubled. If suitable stubble fields no longer serve as feeding grounds, cranes are more likely to move to newly sown fields where they may cause damage to seedlings. The use of artificial feeding sites has been effective at preventing damage to newly sown fields (although there are concerns about the long-term sustainability of funding for this food supply) and has attracted more tourists to the area. Nowadays in autumn, thousands of tourists visit the resting cranes to enjoy this wonder of nature.

Keywords: agricultural practices, Eurasian Cranes, Germany, migration, tourism, winter

Growing Crane Population

The Eurasian Crane (*Grus grus*) population in Europe has been increasing for more than 30 years. In 2010 about 240,000 cranes migrated on the western flyway through Europe. The Rügen-Bock region in northeast Germany (54°23'24"N, 12°56'59"E) has become increasingly important as a stop-over site due to its numerous roost sites in the shallow lagoon landscape of the Baltic Sea and good food availability on agricultural fields. Accordingly, the number of cranes resting in the region in northeast Germany during autumn migration has risen steadily since the first crane census in 1965, when about 10,000 cranes were present during the second half of October. By the end of the 1990s, up to 40,000 cranes were counted in mid-October. Today as many as 70,000 cranes rest in the area during the first half of October. During the entire stop-over period (late August – early November), a total of over 100,000 birds use the region.

Changes in Food Availability Due to Agricultural Advances

Favored food sources of cranes during autumn migration are maize (corn; *Zea mays*), wheat (*Triticum aestivum*), and barley (*Hordeum vulgare*). In the 1970s and 1980s, cranes found an abundance of leftover grain on stubble fields (3–5% of cereal harvest and 5–10% of maize harvest). But in recent years the birds are finding fewer harvest leftovers on cereal and maize stubble fields (1–2% of cereal

Fig. 1. Cranes feeding in a meadow at Guenz (Photographer: Günter Nowald)

and 0–1% of maize) due to technological advances in harvesting machinery. In sampled areas (25 cm x 25 cm) on cereal stubble fields, we found an average of 10 grains in the year 2000, 20 grains in 2001, and no grain in 2002.

Crop leftovers on cereal stubble fields were low and not uniformly distributed. On maize stubble fields, the leftovers were much more evenly distributed, but in more than 50% of the samples no maize seeds were found in an area of 100 x 100 cm. Moreover, the length of time that crop leftovers are available to cranes is limited because stubble fields are plowed immediately after harvesting, so cranes could forage on an agricultural stubble field for just a few days (median of 4 days on grain and 2.5 days on maize stubble fields). That prompted cranes to switch from harvested areas to newly sown fields, but they were chased out by farmers because of anticipated crop damage. Conflicts between cranes and farmers in autumn have intensified over the past 15 years due to the increasing number of cranes and decreasing availability of maize harvest leftovers. Conflicts in spring have decreased because of the reduction in spring-planting of summer cereals. Cranes are now foraging in smaller flocks on different habitats like meadows (Fig.1).

Compensation for Crop Damages Versus Artificial Feeding Sites

To reduce conflicts with farmers and to protect the cranes, the administration of Mecklenburg-Western Pomerania enacted different directives, guidelines, ministerial acts, or laws. Mostly, farmers were to receive compensation for crop damage. In 1996, the administration remitted a new guideline to prevent or compensate crop damages (*Directive for the loss of income on the grant of loans to reducing economic burdens subsequent to damage inflicted by protected or migrating species*). Food supply for cranes is achieved by spreading grain or providing other suitable arable crops. As a first priority, this guideline lays down measures which aim to prevent crop damage by using artificial feeding sites. Landowners were invited to submit an application form to receive compensation for setting up artificial feeding sites on their land, outlining expected crop damage inflicted by protected species with regular and high local abundance tendencies. Hunting was prohibited within a 500-m radius of the artificial feeding site. Cranes should be diverted from vulnerable fields by the establishment of artificial feeding sites. Plowing and sowing of these sites were not allowed during migration stopover. Farmers, who set up feeding sites but suffered crop losses caused by cranes between winter and summer cultivation, received small compensations after the claimed damages were confirmed by authorities. This guideline was considered very helpful and successful; farmers have since established up to 20 feeding sites in the Rügen-Bock region.

In 2000, the administration established a guideline to prevent crop damages (*Directive for the grant of loans to support extensive farming at the centre of resting areas of migrating bird species*). This guideline involves a 5-year commitment and prohibits use of fertilizers and pesticides from the beginning of the sowing season (depending on weather conditions) until 31 March of the following year. Since its introduction, farmers have boycotted this guideline due to the long commitment time and the ban on use of fertilizers and pesticides. Machines for the mechanical removal of weeds were generally not available.

In Mecklenburg-Western Pomerania, artificial feeding appears to be the most successful management strategy to reduce conflicts, for both farmers and tourists. The feeding sites are financed by the provincial government and non-governmental organizations (NGOs) like "Kranichschutz Deutschland" (Crane Conservation Germany), which was founded as a working group of the German Society for Nature Conservation (NABU), the World Wide Fund for Nature Germany (WWF), and Lufthansa.

As there is very little natural habitat remaining within agricultural landscapes in Germany, cranes do not distinguish between feeding on artificial feeding sites or on newly sown fields or other crops. However, by financial comparison, artificial feeding is much cheaper than paying for crop damage.

Farming Trends: Progress and New Threats

In several recent years, we have had fewer conflicts during spring migration in the Rügen-Bock region because of changes in the agricultural practices. Farmers have switched from growing summer cereals, which were planted in spring when cranes were migrating through the area, to winter cereals. These winter crops are mainly planted in early September and from late October to November or early December, when relatively few cranes are present. Hence, farmers are not sowing winter cereals during the main autumn stop-over period of cranes, which helps to decrease crop damage. In October most of the cranes fed on maize stubble fields.

Beside changes in the time period when crops are most vulnerable to cranes, the type of crops has also changed. The area planted with maize, the favoured food of cranes, has declined from about 15% to 5% of the region. The area planted under winter rapeseed (*Brassica napus*) increased from 10% to more than 20% due to European Union legislation; this is unfavourable to cranes because of the low nutritive quality of rapeseeds and its dense growth, which restricts its use by cranes. The European Union supports rapeseeds as a sustainable vegetable product for oil production (energy).

For the future, there are concerns about the sustainability of funding for the artificial food supply. Due to the limited financial resources of the provincial government, NGOs like Crane Conservation Germany have to invest increasing amounts of money in the feeding project.

Growth of Crane Tourism

Nowadays in autumn, thousands of tourists visit the resting staging cranes in the shallow lagoon landscape of "Vorpommersche Boddenlandschaft" (northeastern Germany) to marvel at this wonder of nature (Fig. 2). Tourism organizations are talking about having a "fifth season" because the cranes bring back special “crane tourists” into the region after the summer tourists have left the beaches. Due to the large number of visitors in recent years, the frequency of disturbances to cranes is increasing. Special Crane Rangers of the Crane Information Centre try to reduce the disturbances by directing visitors to places with fenced-off observation facilities. However, cranes provide a good opportunity for the developing tourism! Highlights for the visitors are special events like the “Week of the Cranes” with slide shows and excursions as well as boat trips towards the shallow night roosting areas of the lagoons of the National Park “Vorpommersche Boddenlandschaft.” Boating is only allowed on the federal waterways. Fortunately no disturbances, or only minor disturbances, caused by boat trips have been documented. Tourists love to watch the cranes. For NGOs the crane tourism is a good opportunity to communicate the goals and needs of nature conservation.

Fig. 2. Large groups of tourists gather to watch cranes at the feeding site at Guenz (Photographer: Günter Nowald)

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CASE STUDY

Integrating Conservation with Rural Development at Cao Hai, China

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Abstract: Livelihoods of local communities often become more difficult after the lands currently being used by people are set aside as protected areas by governments, which enforce conservation laws protecting wildlife. The reserve authorities also regard local communities as ones harming natural resources. Therefore, they reduce access to the natural resources, which creates tension over land use between the local communities and wildlife. Cao Hai is located in southwestern China, in one of the poorest counties and is a highly important wetland for waterbirds. The area supports over 1,000 Vulnerable Black-necked Cranes (*Grus nigricollis*) and has experienced turbulences and challenges in both conservation and development. In 1993, the International Crane Foundation (ICF), working with the Cao Hai Nature Reserve and other Chinese and foreign organizations, started a pilot Cao Hai Community-based Conservation and Development Project. This project is one of the first in China addressing resource conservation and management by engaging local communities. The project has made significant achievements, highlighted by: (1) establishment of Community Trust Funds; (2) provision of small grants for family-based enterprises through the Trickle Up Program; (3) land-use planning by villagers including both conservation and community development activities; and (4) establishment of a grass-root NGO, the Cao Hai Farmer Conservation and Development Association. This project has employed participatory approaches intensively and extensively, stressed farmers' involvement, and placed farmers in the center of Cao Hai conservation and community development. The Cao Hai project, regarded as a model of rural development and conservation in China, has built trust between the reserve and local communities, built the capacity of farmers and the community as a whole, increased the farmers' incomes, and improved the natural environment at Cao Hai.

Keywords: community development, Community Trust Funds, micro-lending, village planning

Study Area

Cao Hai is a karst fresh water lake (2,170 m above sea level) located in Guizhou Province of southwestern China (26º51'N, 104º15'E). It is the most important wintering and stopover ground for waterbirds in southwest China, with over 70,000 wintering waterbirds, of which approximately 1,000 Vulnerable Black-necked Cranes (*Grus nigricollis*) winter each year. Cao Hai is located in a landscape dominated by agriculture with crops of potatoes (*Solanum tuberosum*) and maize (corn; *Zea mays*). There are 14 administrative villages, with a total of over 29,000 farmers from 6,500 households, within the reserve. Economically, Cao Hai lies in one of the poorest areas in China, with an annual income of 1,300–2,300 RMB (~US$300), arable land of 1.0 mu (1/15 ha) and 120 kg of crop per capita (Zhou 2007). Lowland farmland, lake water, and surrounding marshes are used intensively by farmers, as well as by cranes and other waterbirds for foraging and roosting (Fig. 1).

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Fig. 1. Black-necked Cranes in the field with local farmers (Photographer: Zhou Qiuliang)

Conflicts in Conservation and Development

Cao Hai has experienced turbulence and challenges in both conservation and development. In the recent past, the lake was drained twice to create and expand farmland for food production. In 1958, the lake was partially drained amidst the Great Leap Forward movement, and then drained entirely in 1972. The official account for Cao Hai is that drainage was an economic and ecological disaster (Li and Li 1991).

By the late 1970s, the wetlands had almost vanished and only about 35 Black-necked Cranes wintered at Cao Hai. In 1982, the province built a dam across the outlet to Cao Hai and restored the lake. Large numbers of Black-necked Cranes, Eurasian Cranes (*G. grus*), and other birds returned. The Cao Hai Nature Reserve (CNR) was established three years after the lake was restored.

Land privatization was implemented just before the restoration process at Cao Hai, so local communities quickly lost access to agricultural land that had just been given to them by the government, which set people back to the original situation of insufficient land for agriculture and food shortages during some months. The no-use policy of the CNR, introduced to control traditional human uses of the wetland, threatened to sever people from the only remaining source to meet their basic needs. This policy exacerbated the resentment that had already been created by the loss of agricultural land when the wetland was restored. Actions taken by both sides intensified this antagonism and related conflicts, such as hunting of waterbirds, farmers encroaching into the wetland, and the closing of the gate of the outlet dam to raise the water level enough to flood the encroached land. Our project at Cao Hai was initiated at this very critical time to help solve these problems.

Project Approaches and Activities

Conflicts in land use to benefit wildlife or the local community at Cao Hai pushed the resource managers to recognize the ultimate need to have the community participate in the area's conservation.

In 1993, the International Crane Foundation (ICF), CNR, the Trickle Up Program (TUP), and Guizhou Environmental Protection Bureau, also partnering with Yunnan Rural Development Research Center, agreed to cooperate by starting a pilot project with the following strategies: 1) The local community must be placed at the center of conservation efforts; only when local communities are given the central place and work actively for conserving Cao Hai will its conservation be sustainable; 2) The reserve management has to change its working philosophy from "limiting community activities and standardizing community behaviors" to "serving the local communities." Under these strategies, the project from its very start has extensively employed participatory approaches. The following are highlights of the project activities.

Trickle Up Program

The Trickle Up Program (TUP) is a New York-based nongovernmental organization (NGO), which aims to reduce poverty by helping the poorest of the poor start their own micro-enterprises, or small businesses. The program offers two resources: seed capital in the form of US $100 conditional grants and business training material to build skills. One feature that distinguishes TUP from other poverty alleviation programs is its focus on the capabilities of the poorest and their potential to develop sustainable micro-enterprises. TUP is one of the earliest activities that integrated poverty alleviation with community development at Cao Hai. From 1993 to 2003, a total of 572 small business groups were initiated, covering 30 natural villages within eight administrative villages and more than 600 participating households (Li and Song 2007). Their businesses ranged from stove making, electric and bicycle repairing, and retailing to pig raising. Most activities were off-farm, greatly alleviating pressure on nature resources.

Community Trust Funds

Community Trust Funds (CTF) provide microcredit loans that are administered by an elected management committee which reviews and approves project proposals (Fig. 2). The CTFs provide a way for farmers to access more capital to expand their businesses while at the same time becoming more involved in the long-term development of their communities. At the start of the CTF program, each member of the group donated 200 RMB, plus matching funds from ICF and Chinese government donations. Members collectively decide on fund use and management, including delivery methods, loan terms, loan sizes, and interest rates. There are currently 15 CTF groups in the area, most with 10–15 families per group, comprising a total of 500 families. The largest fund has 80 participating families and five women's groups.

Fig. 2. Farmers in Kanghai Village preparing Community Trust Fund management regulations at Cao Hai (Photographer: Li Fengshan)

Village Land Use Planning

The village planning is a participatory land use planning process linking village development and nature conservation at Cao Hai. Through this process, land use plans were both developed and implemented by farmers. Three villages close to the wetland participated in this project, and activities included the establishment of enclosures in the wetland for waterbird breeding, tree/shrub planting on the hillsides to stop erosion and in the villages, renovating roads and drinking wells, and paving home front yards and pig pens. The village planning project has not only helped local development, but also improved the environment of the villages.

Farmer Guards and Farmer Conservation and Development Association

The Farmers' Conservation and Development Association (FA) was formed in 2008. The main tasks of the FA are to facilitate communication between the CNR and local communities, to assist with management and organization of the Community Trust Funds, to organize and facilitate community development projects such as biogas generator and drinking well construction, to participate in the farmer guard program protecting and monitoring the lake, and to assist with the One Helps One education program (helping rural girls to attend school). Over the past several years, the FA has worked with Initiative Development (a French NGO) for biogas and village drinking wells. In addition, FA is currently working with local women organizing a handicraft-making cooperative to generate income for local people and promote local eco-tourism products.

Outputs and Impact

The resolution of the conflict between the reserve and local people through a compromise arrangement is a win-win scenario as the people regain access to the wetland in a managed form, while the reserve benefits from community adherence to the restrictions against over-exploitation. The Cao Hai project is now considered a model for other reserves in China dealing with similar issues, as well as reserves in other developing countries.

- Our project involves local farmers in creating economic alternatives that protect the resource base on which human and avian communities depend and increase livelihoods for local communities. However, neither the Trickle Up Program nor community trust funds are purely economically oriented. The participants in both TUPs and CTFs were required to sign contracts with the reserve authorities for compliance with conservation requirements, such as planting trees and shrubs, no fishing during the fishing ban season, and no hunting of wildlife. An outstanding example was that this project helped to stop quarrying that threatened the lake. During the course of the project, farmers living nearby were blasting limestone at the outlet dam and carting away rock for house building. This activity could open cracks in the bedrock, and lead to the creation of a new outlet and consequent major lowering of water levels in the reserve. By involving the farmers in problem-solving discussions, the villagers chose to participate in our small TUP businesses and CTF development loans at the outlet, and voluntarily gave up the quarrying (Harris 2001);
- The capacity of farmers and cooperation among them have strengthened greatly. By working together on Trickle Up programs, Community Trust Funds, village planning and such, the farmers have developed their skills and vision. As most of the activities were planned, operated and managed by farmers themselves, citizen services and responsibilities have improved greatly. With interest generated from the CTFs and other project funds, they have created new infrastructure and remodeled old infrastructure, such as building village schools, road remodeling, connecting power lines to the villages, and establishing scholarships for school children who were accepted to colleges;
- The Community Trust Fund itself has been recognized as a successful micro-lending program. The Micro-Financing Research Center of the Chinese Academy of Social Sciences concluded: 1) the CTFs at Cao Hai are the first micro-lending project in China and have sustained the longest; 2) it is very important that some inactive CTFs have been reactivated through cooperation with the reserve and re-organization between and among the CTFs, and that some inactive CTFs become active without any intervention by the reserve; and 3) women have become increasingly important in managing the CTFs, indicating that women are very good at managing the small funds (Zhang

2007);

- Since the project started, the waterbird population at Cao Hai has been stable, with 70,000 waterbirds, while Black-necked Cranes numbers have tripled. In addition, the water levels are now managed by the reserve. Although the enclosed wetland area for breeding waterbirds is a very small portion of the total marsh area, almost all nests were recorded within the enclosure, due to better vegetation cover and less human disturbance (Li and Ren 2007). During the project period, the farmland area has not changed at Cao Hai (Lu et al. 2007) while numbers of waterbirds, such as cranes and geese that use farmland for foraging, have increased, indicating that cranes and other waterbirds at Cao Hai have adapted to the agricultural landscape with intensive human activities; and

- The relationships between the local communities and the reserve have improved. The reserve and the communities have become partners in both conservation and development activities.

Thoughts for the Future

- The Farmers' Association should be strengthened and empowered. Its current project on handicraft-making could be an opportunity to achieve that goal;

- It is important and necessary to consider developing official financial channels for community development activities, given that many farmers reside within the reserve. Cao Hai, like many nature reserves in China, has a department for implementing community activities, but like all other nature reserves, receives no governmental funding for this task;

- Civil service organizations for community activities at Cao Hai could be improved dramatically if outside assistance, both financial and political, was provided. For example, with funding and staff in place, the community division of Cao Hai Reserve would be fully functional and could work with local communities directly and provide assistance to the Farmers' Association or to the women's handicraft-making cooperative, by getting grants or providing skill- or capacity-building training. Such support would ensure the long-term survival of community organizations like the FA; and

- Cao Hai is facing serious issues and threats that are too big for the reserve, community-based activities, and foreign NGOs to take on, such as urban expansion, water pollution, and human population growth, all of which directly impact the wetlands, lake and uplands. In this sense, government may need to play a bigger role in Cao Hai's conservation, which could determine the future direction of Cao Hai's conservation and management.

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CASE STUDY

A Review of the Crane-Agriculture Conflict at Gallocanta Lake, Spain

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Abstract: Eurasian Cranes (*Grus grus*) started staging at Gallocanta, NE Spain, in 1973, just after waterfowl hunting was prohibited in the lake. Since then, crane numbers increased in the area each year, due to the abundant food resources provided by intensive cereal farming. During the mid-1980s, farmers started claiming compensations for the damages caused by cranes in their fields. A study revealed that the overall damage was negligible but found that in a few fields close to roosting or drinking sites cranes consumed up to 30% of the planted cereal grain. The regional authorities were not able to manage the social alarm appropriately, and farmers started chasing the cranes from fields and roosting sites. These disturbances contributed to a reverse in the increasing crane population trend of the previous decade, and many cranes shifted northwards to winter at new staging areas in France, where they found abundant food in maize (corn [*Zea mays*]) stubble. Today, a delicate equilibrium has been reached with the provision of compensations through agri-environmental measures within a Rural Development Program funded by the European Union. However, the amount of compensations still continues under strong debate, and the conflict is far from being solved. Compensatory payments do not represent a sustainable solution to the problem because they lead to further social conflicts. To definitely solve them, additional management measures should be evaluated and implemented.

Keywords: agri-environmental measures, compensations, crop damage evaluation, Eurasian Crane, migration, staging area

Eurasian Cranes In Gallocanta: A Four-Decade History

Laguna de Gallocanta is a 1,800 ha shallow saline lake located in north-eastern Spain (40º 58’ N, 1º 30’ W, 990 m a.s.l.). The lake lies in a 54,000-ha endorreic hydrographic basin that is intensively cultivated with wheat (*Triticum spp*.) and barley (*Hordeum vulgare*). Approximately 12,000 ha are in cereal grain production around the six municipalities comprising the lagoon and its immediate surroundings, including Santed, Gallocanta, Berrueco, Tornos, Bello, and Las Cuerlas.

After some attempts to drain the whole lagoon and cultivate it in the 18th, 19th, and early 20th centuries, its value as a wetland area for birds was acknowledged in the 1970s. Gallocanta Lake was declared a Zone of Restricted Hunting in 1972, a Special Protection Area for Birds in 1987, a Ramsar wetland of international importance in July of 1994, a National Wildlife Refuge in 1998, and a Nature Reserve in November 2006. Gallocanta is also a Site of Community Importance as defined by the European Commission Habitats Directive.

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Eurasian Cranes started staging at Gallocanta during spring migration in 1973. Prior to that year, cranes had been regularly observed in small numbers during both migrations, but the birds used this area only as a stopover site for a few days. Cranes never stayed long, probably due to the disturbances caused by hunters shooting waterfowl at the lake throughout the winter. Since 1973 cranes have increasingly used Gallocanta as a staging and wintering area (Alonso et al. 1987b, 1994; Alonso and Alonso 1987; Bautista et al. 1992; Figs. 1 and 2). Amongst several potential causes of that increase, the most important factor that allowed cranes to stage in the area appear to be the restrictions on duck hunting at Gallocanta Lake in 1973 and its total prohibition in 1981 (Bautista et al. 1992). Continuous increase in crane numbers over the following years was supported by the high food availability provided by agricultural resources in the area. A noticeable increase in agriculture machinery had taken place in this and other Spanish regions in the 1950s–1960s, resulting in surplus of leftover grain that exceeded quantities required by staging cranes and was already available in the area of Gallocanta two decades before cranes started using it as a regular staging area (Alonso et al. 1984, 1987a, 1987b 1994; Bautista et al. 1992). As cranes are omnivorous and opportunistic, they have the necessary pre-adaptations to respond quickly to new food resources offered by agriculture.

Today, Gallocanta is the main staging area in the Iberian Peninsula and the lake with the highest average numbers of roosting cranes along the western flyway of the species. It has an average daily occupation of ca. 15,000 cranes from October through March, and recent peak numbers of one third of the total estimated crane population migrating through the western European flyway (114,105 birds in February 2011, Figs. 1 and 2). Historical peak crane numbers at Gallocanta have been 54,114 cranes on 23 November 1989, 60,000 on 28 October 1997, and 114,105 on 24 February 2011 (Fig. 2).

Gallocanta Lake is used as an evening roost from which cranes disperse daily for up to 30+ km to forage in the surrounding fields. Cranes forage on waste grain in stubble and recently planted wheat and barley, but seeds in sunflower (*Helianthus annuus*) and maize (corn, *Zea mays*) stubble are also used (Alonso et al. 1984, 1987a; Alonso and Alonso 1992). When cranes arrive at Gallocanta in autumn, they start feeding on the waste cereal grain and sunflower seeds. At Gallocanta, cranes find the perfect conditions to replenish energy reserves spent on the long migration from northern Europe. Between October and December, the depletion of seeds in stubble and tillage of fields in preparation of planting cause a progressive decrease in food availability, forcing many cranes to leave the area and continue to south-western Spain (Alonso et al. 1984). A study showed that crane numbers at Gallocanta in winter were correlated with the amount of waste cereal grain available (Alonso et al. 1994). A second peak in food availability occurs when winter cereals are planted in late January and early February, offering new feeding opportunities to cranes passing through Gallocanta at the start of their prenuptial (spring) migration. Cranes coming from wintering sites in southwestern Spain, Portugal, or Morocco use these resources at Gallocanta for a short spring staging period before departing to northern Europe.

Although the increase of crane numbers over the last 40 years has been fairly constant, there was a slight decrease between 1995 and 2005 (Figs.1 and 2). The main reason for that slowdown was the use of new autumn staging and wintering areas in France (Fig. 3), where maize fields had markedly increased with respect to preceding decades (Alonso et al. 2003, Salvi 2013). However, in the early 1990s the local farmers around Gallocanta started to scare away the birds from the sown fields as well as from the roost sites, which might have been an additional cause for lower crane numbers at Gallocanta in these years. A comparison of crane numbers at Spanish and French wintering areas during the 1970s–1990s (Figs. 1 and 3) shows that increases in numbers of cranes wintering in France and more recently Germany is the result of a northward shift of the wintering range of the species. It is interesting to note that during the 1980s, before cranes started to use staging areas in France, peak

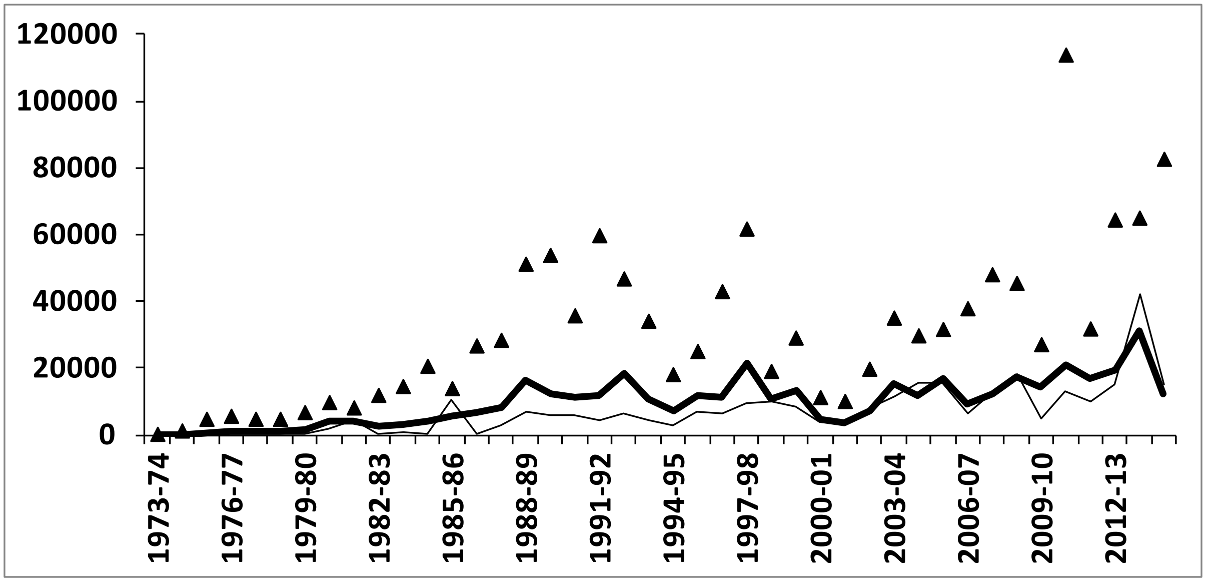

Fig. 1. Numbers of cranes wintering at Gallocanta, Spain from 1973–74 to 2014–15. Triangles: maximum counts in each winter season; thin line: mid-winter (January) counts; thick line: means of weekly counts in each winter. Sources: Bautista et al. (1992), Gobierno de Aragón (2015), Javier Sampietro (personal comm.), and author's unpublished data. A non-official estimate of 135,000 cranes on 27 February 2013 (Anonymous 2013) is not included

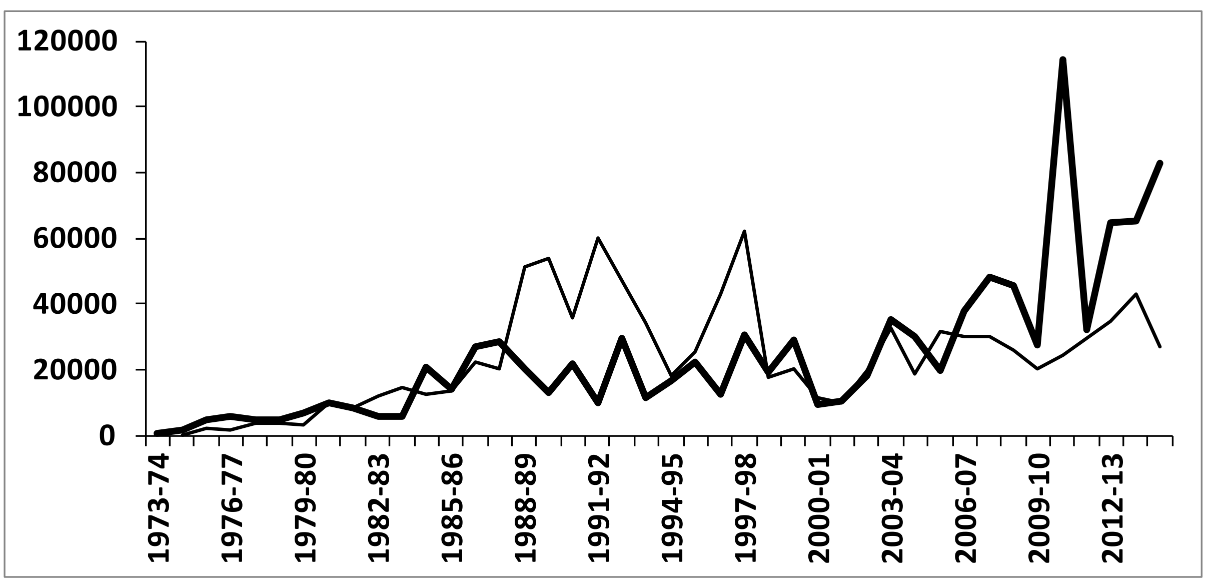

Fig. 2. Comparison of autumn (October-December, thin line) and spring (February-March, thick line) maximum weekly counts of cranes at Gallocanta, Spain, 1973–74 to 2014–15. Sources: Bautista et al. (1992), Gobierno de Aragón (2015), Javier Sampietro (personal comm.), and author's unpublished data. A non-official estimate of 135,000 cranes on 27 February 2013 (Anonymous 2013) is not included

numbers at Gallocanta were usually higher in autumn than in spring, reflecting the importance of this area as a refuelling area after crossing central Europe (Fig. 2). In later decades (1990s–2000s), however, cranes started to use French staging sites in autumn and the importance of Gallocanta as an autumn staging area decreased, with peak numbers occurring now in spring, when migration is concentrated in a couple of weeks in late February (Fig. 2).

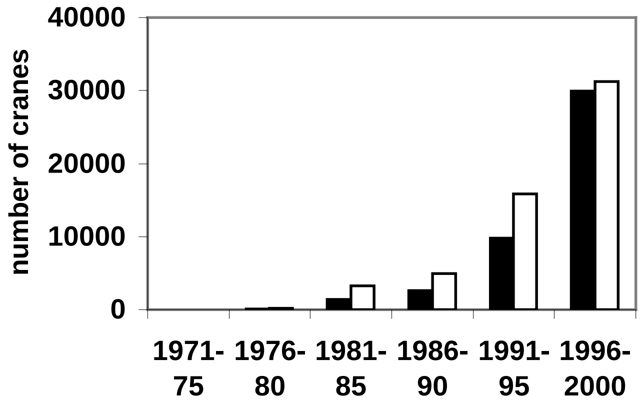

Fig. 3. Start of the Eurasian Crane regular wintering in France, and rapid increase in numbers of wintering cranes in this country in the decades 1980s to 2000s. White bars indicate maximum winter counts, black bars the mean annual maxima, during each 5-year period (from Alonso et al. 2003)

Radio-tagging studies confirmed a clear tendency of several juvenile cranes marked in Germany to remain in France in their second and subsequent winters, after having spent their first winter with their parents in Spain. In contrast, none of these young cranes marked in Germany shifted southwards between consecutive years (Alonso et al. 2008). These data suggest that the northward wintering shift observed during the last decades could start with the more mobile immature and non-breeding birds, which tend to aggregate at areas with higher crane populations and abundant food resources. In contrast, paired adults would likely remain faithful to their traditional wintering areas in south-western Iberia and Morocco (Alonso et al. 2003, 2008). The increase in numbers wintering at more northern areas has continued up to present, and today many cranes spend the winter in France, Germany, Belgium, and Luxemburg (LPO Champagne Ardenne 2015).

In summary, the conditions favouring the use of Gallocanta by cranes have been: (a) the strategic location of this area within the East Atlantic Flyway in the Iberian Peninsula; (b) local hunting restrictions since 1973, and a subsequent hunting prohibition in the main part of the area; (c) the presence of a large, shallow lake that can be used as an appropriate roosting site, and nearby fields where cranes can feed, with few human disturbances; (d) the high food availability provided by the abundant waste grain and seeds after harvest and by the increase in the cultivated surface, thanks to the mechanization starting in the 1950s; and (e) the coincidence between the seasonal pattern of food availability and the migration phenology of the cranes through this area, both with maxima in autumn and late winter.

The Crane-Agriculture Conflict

When cranes arrive at Gallocanta in October-November, approximately half of the region is cereal grain stubble (mostly wheat and barley), with some sunflower fields in certain years, and maize regularly grown in the nearby Jiloca valley. Cranes prefer to feed in stubble fields, where waste grain and seeds from summer harvest are easy to find. This preference obviously causes no damage to farmers, but eventually the waste grain becomes depleted or is lost to pre-planting tillage, and cranes shift to newly planted grain fields as their main source of foraging (Alonso et al. 1984). Planting winter wheat starts in early October, and short-cycle barley planting is done in February. Between late December and March most cranes have switched to recently planted grain fields, where they dig up a variable amount of seeds and sprouts, potentially causing damage to crops. However, since cranes follow the rules of "ideal free distribution" and foraging intensity is proportionate to the food availability (Bautista et al. 1995), the damage tends to be evenly distributed over the region.

In order to quantify the damage caused by cranes to cereal crops, research on crane foraging ecology was initiated in Gallocanta in the early 1980s, with financial support from the Directorate General for Environment, the Spanish Institute for Nature Conservation, and the Directorate General for Scientific Research. Field observations found that the daily food intake of an adult crane decreased from 350 g of waste cereal grain in November to 96 g of planted cereal grain in March (299 g to 104 g for juvenile birds). Detailed maps of crane foraging intensity were developed using field observations of foraging effort, field usage, habitat selection, and seed density measurements to estimate cereal grain consumption each month in the Gallocanta region over two consecutive farming cycles (1981–82, and 1982–83, Alonso et al. 1983). As a result, it was estimated that in 83% of the 1x1-km test squares into which the area was divided for the study, the consumption of cereal seeds did not reach 5% of the weight of the cereal grain planted, and that the total cereal consumed by the crane population in the area of Gallocanta represented, respectively for 1981–82 and 1982–83, 0.75% and 1.47% of the total weight of the seeds planted. Considering that 28.9% of the planted cereal seeds were regularly lost anyway due to various natural causes and never germinated, the estimated grain consumption by cranes represented a negligible fraction of total natural losses. Moreover, the number of germinated cereal plants did not differ between samples of planted fields used and not used by the cranes (respectively, 57.80 ± 5.29 plants, $n = 110$; 58.88 ± 4.84 plants, $n = 90$; $t = 0.30$, $p > 0.05$; Alonso et al. 1983). This suggested that the damage was negligible, considering the region as a whole.

When evaluating the effect of wildlife damage, however, two facts must be taken into account. First, our study has shown that the maximum crop damage figures in the most affected fields are much more relevant than the average damage figures estimated over the entire region. Only in 7.6% of the test squares in 1981–82 and 6.5% in 1982–83 did the consumption of grain surpass 10% of the amount sown but, at one spot located beside a frequented drinking site, consumption figures reached 30% of the grain planted (Alonso et al. 1983). Fields located close to sites used daily by large numbers of cranes, such as roosts or waterholes, frequently suffer considerable losses. Secondly, and most importantly, just the sight of crane flocks foraging on recently planted fields raised great social alarm. The farming community did not accept the situation and started asking for lost crop compensation for what just a few farmers claimed to be significant loss.

As conflict between local farmers and the increasing numbers of cranes escalated, the regional government did not immediately take action to deal with the situation. Only after several years of inactivity did the regional government finally pay compensations to farmers amounting to 3 million Pesetas in 1985 (ca. US$25,000 at the exchange rate Spanish Pesetas-USD of that time, when the Euro didn't exist yet) and 5.5 million Pesetas in 1987 (ca. US$45,500 at the exchange rate of that time). There was no compensation paid to any farmers in 1986 and 1988. However, local and political pressures forced the government to change this initial decision and later pay 47 million Pesetas (ca. US$390,000) for the 1988 damages. Throughout the conflict, the regional administration showed a lack of clear compensation payment criteria for depredation claims and consistently gave in to political pressures, further illustrating the lack of clear criteria and authority with respect to handling crop depredation issues. Combined, these issues provoked immediate negative reactions from local farmers and broke the delicate equilibrium between farming and cranes of previous years.

Compensation paid to farmers in the first years did not stop them from scaring the birds away from fields and roosting sites. Farmers set fire by night to car tires they had previously located close to the lake, and also the vegetation along the lake margins was burnt when all cranes were already at the roosts. During the day, farmers fired rockets directly into foraging flocks of cranes, set up acetylene exploders, and drove cars into flocks forcing them to take flight and move to new locations, all without any control from the reserve guards or police. The reactions of the farmers were reported in the local press and eventually generated national and foreign media coverage. In March of 1989, J.C. Alonso, J.A. Alonso, R. Muñoz-Pulido and L.M. Bautista (researchers from the CSIC and Complutense University who had been studying the behaviour and ecology of cranes in the area for several years) asked the Spanish World Wildlife Fund, the Spanish Ornithological Society, and 80 selected scientific and conservation organizations worldwide to send letters to the regional, Spanish, and European authorities, urging them to take action and find a solution to the crane-agriculture conflict at Gallocanta.

In 1989, the regional government commissioned two teams of experts to evaluate crop depredation by cranes in the region, one representing the administration and the other representing the farmers. The two teams generated extremely different results (damage valued at 3 million Pesetas or US$25,000, vs 16 million Pesetas or US$133,333) which deepened the problem, and farmers resumed their actions against cranes. Several foreign conservation associations led by the German Society for the Protection of Birds (Deutscher Bund für Vogelschutz, DBV) offered funds to cover the amount claimed by the farmers. The offer was not accepted by the regional government, arguing that this was only a temporary solution. Finally, the government decided to pay the 16 million Pesetas in two separate installments, but the second payment was never delivered. Finally, in 1990 farmers and government agreed to commission an evaluation of crop depredation from a private insurance company.

In November 1990, an international meeting for cranes and conservation was held in Daroca, Spain. Thirty-three experts from seven European countries were in attendance to discuss the situation and find solutions to the crane-agriculture conflict at Gallocanta. Recommendations from that meeting included paying off the debts claimed by the farmers in previous years, establishing an appropriate damage evaluation scheme for future years, increasing the protection status of Gallocanta (by changing it from National Wildlife Refuge to Nature Reserve), designing and implementing an education campaign among the local population, and promoting an international agreement for the conservation of the Eurasian Crane within the framework of the Bonn Convention (CMS).

In the meantime, however, farmers continued chasing cranes from foraging and roosting sites. We believe that this was one of the primary reasons for the early departure from Gallocanta by most of the ca. 40,000 cranes staging there in early November 1990, as well as for the extremely fast migration and short staging period during February and March 1991. As stated above, we believe the continuous disturbances caused by farmers during the late 1980s and early 1990s were critical in creating the reversal of the increasing population trend observed over the previous decade (Fig. 2). These disturbances, together with the provision of food from waste corn and appropriate protection at new staging areas in France, fostered the rapid development of a new staging tradition in France, notably at Lac du Der Chantecoq and Arjuzanx.

After almost two decades of a yet unsolved conflict between crane conservation and agriculture, Gallocanta was declared a Nature Reserve in November 2006. It is a Special Protected Area for Birds and a Site of Community Importance defined in the European Commission Habitats Directive, as well as a Ramsar wetland of international importance. After many years of uncertainty and hesitation, the protection status of the area has enabled the regional government to develop a process for farmers to receive compensation for the crop damage caused by the cranes. Between 2007 and 2013, the farmers owning the 12,000 ha of cereal grain in the six municipalities comprising the lagoon and its immediate surroundings (Santed, Gallocanta, Berrueco, Tornos, Bello, and Las Cuerlas) received 927,000 € as part of the agri-environmental measures from the European Community. For the period 2014–2020, an 8% increase has been proposed to the European Community, with a total sum of 1,050,000 € each year to cover the damages caused by cranes. Compensation is to be covered by funds for the Rural Development Plan of the area. Additional compensations are provided to municipalities farther away from the lake, the total amounting to ca. 4 million €, at a maximum rate of 95 €/ha for the six prioritized towns. A recently announced reduction of ca. 30% prompted farmers' associations to ask for a decommissioning of Gallocanta as a protected area (Diario de Teruel 2015). Instead, they asked for 120–150 €/ha, which they consider to be the minimum to warrant profitable results (Aragondigital 2015). Many experts believe these compensation amounts are exaggerated and not justified by the real current amount of crane damages, though these measures appear to be working for all parties.

In conclusion, difficulties in establishing a cost-effective, objective, and technically accurate damage evaluation system will continue to fuel the current debate. Once a compensatory payment rate has been fixed, authorities will have difficulties in reducing or suppressing it without once again incurring negative reactions from farmers. Thus, a compensation system will probably stay necessary forever, but should be complemented with education campaigns that provide farmers information on the benefits of the crane presence in their fields – e.g., income from ecotourism – which should be actively promoted to help mitigate the hostility of the current or at least the next generation of farmers.

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CASE STUDY

A Review of the Crane-Agriculture Conflict in the Hula Valley, Israel

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Abstract: The c. 6000-ha Hula Valley is located at the crossroads of Eurasia and Africa in northeast Israel within the Great Rift Valley. It supports a diverse ecosystem including wetland marshes and papyrus beds, now contained within the Hula Nature Reserve, the newly created Agamon Lake in a portion of the original Hula Lake, and a matrix of agricultural lands comprising both open fields and fruit orchards and many fish farms. The intensification and diversification of land uses in the valley over the last 60 years drastically changed the relationships among agriculture, tourism, nature, and resident communities. Since the 1990s, the distribution of wintering Eurasian Cranes (*Grus grus*) in Israel underwent significant increases of staging and wintering birds at the Hula Valley – from few hundreds in the 1980s to 35,000 wintering cranes in 2010. The peak dates of migration have shifted from 20 November – 10 December during the 1990s to 1–30 November with a longer crane use period. Increasing numbers of crane are an example of how land-use changes have significantly affected birds and impacted various resources both negatively and positively. Cranes became a "flagship species" for the Hula-Agamon complex. Intensive management and tourism infrastructure produced a positive result of reducing agricultural damage and increasing public awareness and tourism with an estimated income of US$25 million a year. The large increase in wintering cranes at the Hula is not only a result of growth of the Eurasian Crane population but probably also reflects northerly shifts in their wintering grounds. Understanding the relationship between crane behaviour and land use within the region is a critical issue for optimal management.

Keywords: avian conflicts, crane management, *Grus grus,* Hula Valley, Israel, migration, staging, tourism

Background

The c. 6,000-ha Hula Valley is located at the crossroads of Eurasia and Africa in northeast Israel within the Great Rift Valley (35°43'E, 33°03'N). It supports a diverse ecosystem including wetland marshes and papyrus (*Cyperus papyrus*) beds, a matrix of agricultural lands comprising both open fields and fruit orchards, and many fish farms. The valley once contained one of the largest freshwater wetlands in the Middle East. In 1953, the wetlands were drained for agricultural purposes and a small southern part of the region was designated as the Hula Nature Reserve.

The Peat-Soils Reclamation Project was aimed at improving water quality and restoring the health of the peat soils for agricultural use (Dimentman et al. 1992). As part of that project, in 1994 a relatively large area of poor agricultural land (peat bog) just north of the existing Hula Reserve was re-flooded to create a shallow-water wetland. This newly created wetland, currently managed by the Keren Kayemet L'Israel, attracted large numbers of waterbirds, raptors, waders, and other birds (Ashkenazi and Dimentman 1998). As a result the valley is now in the process of being nominated as a World

Austin JE, Morrison K, Harris JT, editors. 2018. *Cranes and Agriculture: A Global Guide for Sharing the Landscape.* Baraboo, Wisconsin, USA: International Crane Foundation. 303 p.

Heritage Site by the International Union for Conservation of Nature (IUCN). The intensification and diversification of land uses in the valley has drastically changed the relationships among agriculture, tourism, nature, and resident communities.

Crane Population Dynamics

Since the 1990s, the distribution of Eurasian Cranes (*Grus grus*) in Israel has changed, with significant increases of stop-over, staging, and wintering birds at the Hula Valley. Numbers have risen from the mid-1980s to 35,000 wintering cranes in 2010. During autumn, the peak period of migration has shifted from 20 November–10 December during the 1990s to 1–30 November, and overall the crane season was prolonged. This great increase in crane numbers in the valley parallels changes in agricultural management, especially the intensively grown crop of peanuts (*Arachis hypogaea*), which was not common in the valley before the early 1990s. The increasing wintering population size, together with more efficient agro-technology, has led to a very tense conflict with farmers. On the other hand, successful artificial feeding (Fig. 1) and crane tourism (Fig. 2) programs have been established, and the latter is a growing market for domestic and international tourism, with an estimated income of US$25 million a year.

Fig. 1. Cranes are fed to reduce pressure on sensitive agricultural fields (Photographer: Thomas Krumenacker)

Fig. 2. Tourists enjoy a "mobile hide" at the Hula Lake-Agamon (Photographer: Itai Shanni)

Monitoring and Research

Understanding the relationship between crane behaviour and land use within the region is a critical issue for optimal management. Since the late 1990s, the crane population at the Hula Valley has been monitored through dawn counts of birds leaving their roost sites (Lake Agamon and the Hula Reserve) over 10-day intervals during migration and over winter (1 October – 31 March). Time budget and habitat use data were collected during three separate studies (Alon 2001, Davidson 2004, Shanni et al. 2011). A total of 220 cranes have been marked using color rings and of these, 25 birds were also fitted with different GPS and satellite-transmitter devices during the three research projects.

Crane Management Scheme

Increasing crane numbers (Fig. 3) are an example of how land-use changes have significantly affected birds and impacted various resources both negatively and positively.

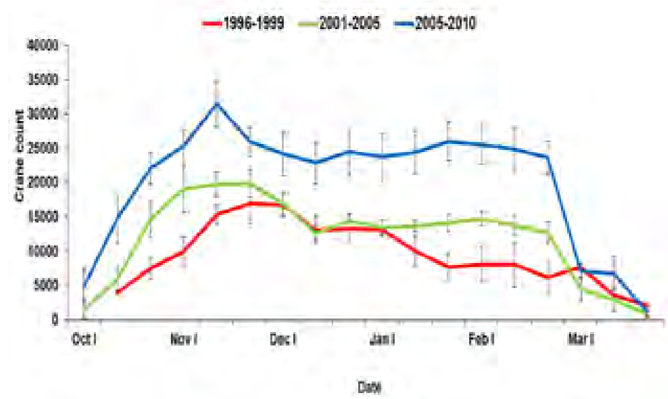

Fig. 3. Seasonal trends in crane numbers in the Hula Valley over three periods

Cranes have become a "Flagship Species" for the entire Hula-Agamon complex. Intensive management involving all the relevant stakeholders has produced a positive result of reducing agricultural damage and increasing public awareness and tourism. Current crane management involves the following activities: (a) During the autumn stopover period (September through December), cranes are allowed to land, forage, and move freely between fields where there is no potential damage. An abundance of left-over peanuts (*Arachis hypogaea*) and corn (maize, *Zea mays*) is available in many fields. Cranes are kept off of sensitive crop fields by means of harassment techniques, such as noise, fireworks, and lights. (b) During the early winter period (November through December), cranes are allowed to forage only in specifically designated areas and kept away from seeded fields by harassment techniques. In addition, a feeding station located within the Hula-Agamon area provides food on a limited scale. (c) For the rest of the winter and spring (late December through March), a period of insufficient food, low ground temperature, and sensitive, newly planted crops, a massive, daily feeding is carried out at the feeding station to prevent crop damage by luring cranes away from sensitive fields.

Rich and developing farmlands, coupled with supplemental feeding, has undoubtedly attracted more cranes, but increased crane numbers also may be due to increasing winter survival rates. Recent work (I. Shanni unpublished) revealed the importance of the Hula Valley as a stop-over and staging site during autumn migration as well as the importance of the feeding station in holding birds in the Hula during winter. Fifteen tagged cranes showed behaviour patterns in accordance to central-place foraging theory. During autumn, when the feeding station is not operating, cranes move between fields surrounding the Agamon, but once the feeding station starts its operation in the winter, most of the crane movement is restricted to between the roost site and the feeding station. During late spring (March-May), when the feeding station substantially reduces its operation, cranes show again a distinct pattern of movement between fields surrounding the Agamon, with a growing distance from the roost as the season proceeds.

Concerns for the future

The large increase in wintering cranes at the Hula is not only a result of growth of the Eurasian Crane population but probably also reflects northerly shifts in their wintering grounds. Recent habitat changes on traditional wintering grounds in northeastern Africa (Ethiopia) from wetlands to greenhouses and farmlands also may have contributed to this northerly shift, but at this time we have no clear evidence to support this. The majority of the projected climate scenarios for the next decades indicate that conditions in Hula Valley will become much drier, thus an increasing wintering population and declining water availability for both wetlands and agriculture could create an unbearable situation at the Hula, in which the current crane management system will no longer be able to protect crops. Another potential scenario is that local agriculture will undergo significant changes as a result of limited water supplies, and this process may negatively impact the staging and wintering cranes. This transition may also have a significant negative impact on the growing nature tourism in the valley.

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CASE STUDY

Relationship Between Eurasian Cranes and Farmers at Wintering Ground in Upper Amu Darya River Valley, Surkhandaria Province, Uzbekistan

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Abstract: Creation of reliable wintering grounds for Eurasian Cranes (*Grus grus)* in the Upper Amu Darya River Valley in south Uzbekistan along the border with Afghanistan was caused by changes in agriculture since early 1990s, mild climate, and a strict protection regime in the national border area. Replacement of cotton fields with winter wheat and rice provided cranes with greater availability of food and relatively safe open areas. As a result, more and more migrating cranes began spending winter in Amu Darya River Valley. Between 2001 and 2011, their numbers increased from 6,000 to 32,000, creating a new relationship between Eurasian Cranes and farmers. So far this change has happened without a major conflict. Different factors, including local agricultural practices, prevalence of harvested rice fields, abundance of *Cyperus rotundus* as an additional food, and farmers' use of simple techniques to scare cranes, now keep the cranes away from newly sown winter wheat fields and reduce crop damage. At the same time, the number of cranes continues to grow. Regular monitoring and maintenance of current agricultural practices will help avoid sharpening of the conflict between cranes and farmer in the future.

Keywords: agricultural practices, crop damage, *Cyperus rotundus,* Eurasian Crane, *Grus grus*, rice, Surkhandarya Province, Upper Amu Darya River Valley, Uzbekistan, winter wheat

Geographical location

The Upper Amu Darya River Valley is located in the arid zone in southern Uzbekistan where the state border with Afghanistan follows the Amu Darya River. The Afghan desert serves as a natural border of the valley. The valley is delimited on the west by the Pamir-Alai Mountains (Gissar Range) and on the east by the Pamirs. Mountains shield the valley from penetration of cold winds from the north. Therefore, the winter climate is relatively mild, with the average temperature in January about 4°C.

Fig. 1. Location of the Eurasian Crane wintering ground in Amu Darya River Valley in Uzbekistan. The green line indicates the floodplain area used by cranes

The wintering grounds of the Eurasian Crane (*Grus grus*) extend along the Amu Darya River Valley in the junction of four countries – Tajikistan, Uzbekistan, Afghanistan, and Turkmenistan – with the core area in Surkhandarya Province in Uzbekistan (37˚19'N, 67˚06'E). The area is located on the north bank of Amu Darya River 23 km northwest from the town of Termez, on the first inundate (flood) terrace (Fig. 1). The area is nearly 8,400 ha, ranges from 1.5 to 6 km in width, and is about 30 km in length (Lanovenko 2008). Natural borders are

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the Amu Darya River in the south and southwest, and the loess breakages differentiating the first and second historically inundated terraces in the east and northeast, as well as bogs and reed brushwood in other parts of the floodplain. The Amu Darya River ranges from 400 to 700 m wide. The river near the northern bank is ~3 m deep and is sometimes shallower near the southern bank; the navigation passage is 5–10 m deep. Spring flooding is minor. The first terrace in the headwaters of the Amu Darya River supports agricultural fields with a network of branching canals and covering 85% of the total terrace area. Outside the zone of agricultural development, continuous thickets of reed brushwood in bogs and small lakes persist (15% of the area), which provides relatively poor habitat for numerous wintering and migrant waterbirds.

Changes in Agriculture

Since ancient times in Central Asia, arable farming was confined to river valleys with limited lands suitable for agriculture. During the time under the Soviet Union, agricultural activity was based on natural economic zones and regions, and there was an emphasis on those types of agricultural production for which the conditions were most favorable and the expenditures were lowest. All Central Asian republics of the USSR were located in the arid zone. Agriculture policies in Uzbekistan and Turkmenistan were focused on increasing cotton production. Therefore, all suitable and not quite suitable lands were used for cotton growing, which led to deterioration and salinization of soils from irrigation. Cereal crop production was limited to drylands without irrigation. After the collapse of the Soviet Union in 1991, the newly independent countries changed the structure of their agriculture significantly. In Uzbekistan, the main agricultural policy was to continue cotton growing along with reaching "wheat independence." By the end of the 20th century, the area in cotton in the republic had been reduced significantly, as well as across the entire Upper Amu Darya River Valley shared by several countries.

Today, the main cultivated crops in the crane wintering area are rice (*Oryza sativa,* 34%) and winter wheat (*Triticum aestivum*, 19.6%) (Fig. 2); 31.4% formerly developed fields are not cultivated annually, and the residual 15% of winter crane habitat is natural reed bed. Uncultivated fields are overgrown with *Karelinia caspia*, Estragon or Wormwood (*Artemisia dracunculus*), Common Reed (*Phragmites australis*), and other reeds (*Phragmites* spp.). In winter, cultivated fields are flushed to reduce salinization. Nearly 10% of cultivated fields are flooded simultaneously. As a result of these agricultural changes, there are now more open areas without cotton plants as well as more suitable food to attract cranes and other waterbirds to this area. Rotation of crops is not conducted regularly. Some fields may stay uncultivated during one or more years, which can also affect foods available to cranes and the way they use these fields.

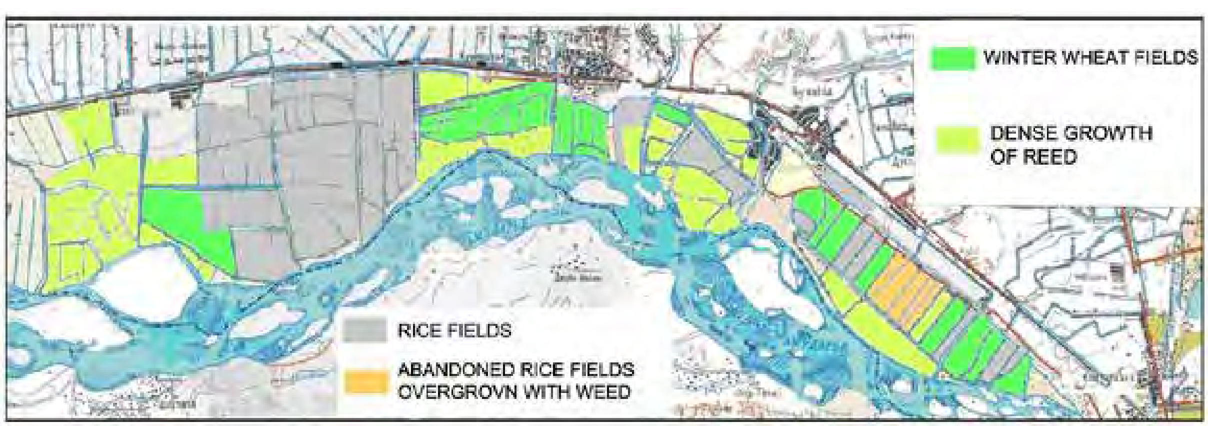

Fig. 2. Agriculture structure at the Eurasian Crane wintering ground

Wintering cranes

Before the end of the 20th century, Eurasian Cranes were considered migrants in Uzbekistan on the way to wintering grounds in India. It is possible that in the late 1980s – early 1990s a few cranes occasionally spent winter in Amu Darya River Valley, feeding in rice fields, which were not common there at the time. Since the mid-1990s, food became abundant on the wheat and rice crop fields that have replaced cotton fields, and more open area created more reliable and attractive wintering habitat in Amu Darya River Valley. Food resources were an addition to other favorable conditions, such as mild winters and lack of disturbance and killing of cranes due to the strict access rules (local people and border guards only) in this frontier zone. Some of the migrating cranes began wintering here by the early 1990s. Numbers of wintering cranes have increased from nearly 6,000 in 2001 to 32,000 in 2011 (Sorokin et al. 2011) and continue to grow. With support from the International Crane Foundation in 2004 and 2005, research studies were conducted on the ecological conditions (habitats, climate, threats, and forage resources), phenology, and population dynamics of Eurasian Cranes during winter and spring migration, as well as their distribution among different types of fields (Fig. 3) (Lanovenko et al. 2008).

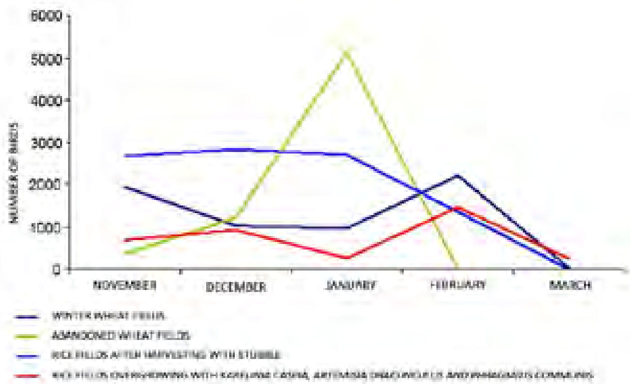

Fig. 3. Distribution of Eurasian Crane flocks among the different field types during the winter of 2004–05

Usually Eurasian Cranes arrive on this wintering ground in October, when rice fields are already harvested and winter wheat fields are sown. Cranes disperse among rice and winter wheat fields quite evenly. Local agricultural practices use small size fields divided by rice paddies, low rolling barrages (dams or levees), and ramified (branching) canals. These practices make watering of crops and winter flushing to reduce salinization more efficient. The mosaic of wheat fields among rice and uncultivated fields ensures crane dispersion and reduces risks of crop damage by large flocks. From November to January, cranes prefer to forage in harvested rice fields that have an abundance of leftover grain. They also feed on tubers of *Cyperus rotundus,* the main weed in rice fields. In January, cranes increasingly use uncultivated wheat fields, where they also feed mostly on *C. rotundus* (Fig. 4). Holes made by cranes feeding on *C. rotundus* tubers were found in all type of fields. By February, rice grain and *C. rotundus* tubers become depleted in the rice fields. Besides, those fields are no longer attractive to cranes because they have been flushed and re-flooded to prepare for sowing of the new rice crop. Consequently, during this period the cranes move into green winter wheat crop where they can damage plants by trampling. At this time winter wheat is at a 3–5 leaves growth stage, with sprouts about 20–25 cm tall. Because the cranes feed only along the edges of wheat fields and on the sites where plants are sparse or short (due to machinery malfunctioning or some other reasons), plant damage by crane trampling is not significant.

Relationship Between Cranes and Farmers

Newly sown winter wheat fields located in the river valley are very attractive to wintering cranes and can be damaged by them. In Amu Darya River Valley, however, the prevalence of rice fields with leftover grain lures the cranes away from the sown wheat fields, and rice provides a good alternative food source, along with *C. rotundus,* which is more abundant in rice fields than in wheat fields. Therefore, damage by cranes in wheat fields is insignificant, and farmers do not consider cranes as

Fig. 4. Tubers of C. rotundus in the fallow rice field after rain (Photographer: Eugenia Lanovenko)

Fig. 5. Plastic bags attached to reed stalks to scare birds away from winter wheat field sown in October (Photographer: Eugenia Lanovenko)

a major pest animal. To protect wheat crops from cranes and rooks (*Corvus frugilegus*), farmers use simple and cheap techniques – scarecrows and flags made from thin, light plastic bags, which oscillate even in light wind (Fig. 5). Farmers also chase cranes from wheat fields to reduce damage to crops.

Conclusions

The relationship between Eurasian Cranes and farmers emerged in the Upper Amu Darya River Valley 15–20 years ago due to changes in agriculture, which contributed to the creation of reliable and attractive crane wintering habitats. After their arrival in October, cranes damage some newly sown winter wheat crops located in the floodplain of Amu Darya River near their roosting sites on the river islands and shoals; some cranes fly to Afghanistan territory for roosting. Losses to crane damage are insignificant and at this time conflict between cranes and farmers is minimal. Reasons for the minimal damage and conflict include:

- prevalence of harvested rice fields with large amounts of leftover grain, which distract cranes from newly sown wheat fields;
- abundant *Cyperus rotundus*, especially in rice fields, which also attract cranes to harvested and fallow rice fields;
- the mosaic of small winter wheat fields among rice and uncultivated fields, which provides for crane dispersion and helps to avoid concentration of large flocks, further limiting potential for crop damage; and
- chasing cranes from wheat fields by farmers and their effective use of simple scare techniques.

The number of cranes wintering in the area continues to grow, however, which may lead to sharpening of the conflict between cranes and farmers in the future. During the last decade, crane numbers have increased from 6,000 to 32,000. To prevent or mitigate conflict between cranes and farmers in the future, the following conditions should be maintained:

- current or increased acreage of rice fields in the area;
- encourage farmers to practice regular crop rotation leaving some fields uncultivated, to sustain the mosaic of field types and avoid crane concentrations; and
- plant winter wheat at the same time of year within a short time frame, to provide an equal stage of winter wheat growth in all cultivated fields.

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Eugenia Lanovenko
1950-2017

Eugenia Lanovenko was the leading ornithologist of Uzbekistan. She was born in 1950 in Siberia, but moved with her parents to Uzbekistan, where she graduated from the Tashkent National University and for the most part of her life worked at the Ornithological Laboratory of the Institute of Zoology, Uzbekistan Academy of Science.

Eugenia was involved in preparation of the *National Strategy on Biodiversity Conservation in Uzbekistan* and participated in numerous international projects supported by GEF, BirdLife International, Wetlands International, and many others. She was a Technical Expert for Uzbekistan under the Convention on Migratory Species Memorandum of Understanding Regarding Conservation Measures of the Siberian Cranes and Their Habitats (CMS MoU) since its signing by Uzbekistan. Eugenia attended all CMS MoU meetings and greatly contributed to the Siberian Crane Conservation Plans. She also organized a Crane Working Group of Uzbekistan.

Eugenia's interests in biodiversity research were very diverse, with crane conservation being one of her priorities. She studied migrations of Demoiselle and Eurasian Cranes and adaptations of Eurasian Cranes to changes in agriculture during wintering. The latter was especially important due to Eugenia involvement in "Flight of Hope" – an international project on the Siberian Crane reintroduction conducted jointly by Russian, Kazakhstan, and Uzbekistan experts.

Eugenia was the author of more than 150 scientific papers, including articles on crane research and conservation published both in review journals as well as in proceedings "Cranes of Eurasia" and the Information Newsletter of the Crane Working Group of Eurasia.

On 6 November 2017, Eugenia tragically died under the wheels of a car. With her departure, ornithology in Uzbekistan lost an active field researcher with a wealth of knowledge on biodiversity conservation in Uzbekistan.

CASE STUDY

Resolving Conflicts Between Sandhill Cranes and Agriculture in the Middle Rio Grande Valley, New Mexico, USA

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Abstract: Conflicts between Greater Sandhill Cranes (*Grus canadensis tabida*) and farmers in the Middle Rio Grande region of New Mexico, USA, intensified as the numbers of cranes wintering in the area increased from <5,000 to >20,000 cranes during the last 50 years. Most crop damage by staging and wintering cranes occurs in young alfalfa fields (lucerne *Medicago sativa*), cereal grains, chilies (*Capsicum annuum*), and silage corn (maize *Zea mays*). Damage is related to proximity of crop fields to roost sites and timing of crane concentrations relative to crop maturity or vulnerability. Conflicts with the growing crane populations have been aggravated by proximity of crops to roosts and wetland feeding areas, losses of wetlands and cropland, changing crop types and practices, and increasing urbanization. Solutions have been developed through cooperative efforts among federal and state agencies, who manage wetlands and croplands to increase food availability and carrying capacity on public lands, provide bird hazing programs for private landowners, and strategically target crane hunting to problem areas. The program has been successful in reducing crop damage complaints but is dependent in part on success of crop production on public lands. Sustaining the success of these programs in the face of changing socioeconomics of agriculture and agencies, increasing water demands, and a warming climate will be challenging.

Keywords: agricultural practices, crop depredation, Sandhill Crane, Rio Grande River, staging, wintering

The Middle Rio Grande Valley (MRGV), located in south-central New Mexico, encompasses 55 km of river, about 2,020 ha of managed wetlands, and limited lands suitable for agriculture. Crane use is centered on Bosque del Apache NWR (33˚50’00”N, 106˚52’00”W) and the state’s Bernardo Wildlife Area, 65 km to the north. The area is the primary wintering area for about 80% of Rocky Mountain Population of Greater Sandhill Cranes (*Grus canadensis tabida*). The area also supports some Lesser Sandhill Cranes (*G. c. canadensis*) of the Midcontinental Population primarily, and large numbers of geese (*Anser*) during winter and even larger numbers – during spring migration (Mitchusson 2003, SRMGSC 2007). Cranes roost primarily on state and federal wetlands and feed in irrigated crops (alfalfa or lucerne [*Medicago sativa*], chili [*Capsicum annuum*], and corn or maize [*Zea mays*]), shallow wetlands, and pastures up to 23 km from roosts. Cranes forage largely on natural foods in wetlands, pastures, and alfalfa during mild weather but seek out high-energy grains during colder periods. Federal and state agencies manage impounded wetlands and corn fields to provide food for cranes, geese, and ducks. Mid-winter counts in the MRGV have increased from about 5,000 cranes in 1967 to an average of 23,510 cranes (1987–2001; Mitchusson 2003); up to 75,000 cranes may use the area during spring migration.

Agriculture has changed over the past 100 years from traditional crops of chilies, onions (*Allium cepa*), corn, and grazing to irrigation-dependent grains in the early to mid-1900s. Land-use changes since the 1970s have substantially reduced habitat and foods available for cranes, particularly through losses of wetlands, field corn, and sorghum (*Sorghum bicolor*). Drainage of riparian wetlands and urban development along the river also reduced suitable foraging and roosting habitat, both in the region as well as in other traditional wintering areas in New Mexico and Mexico. Corn area on private lands in the MRGV declined to <600 ha by 1997 as farmers converted to alfalfa and silage grains for an expanding dairy industry or to chili and cotton (*Gossypium)* crops (Mitchusson 2003). Crop damage complaints before 1993 were valued at more than US$100,000 annually. Most reported damage by cranes was to alfalfa fields in late fall when newly planted fields were irrigated and arriving cranes probed for invertebrates and chufa (*Cyperus esculentus*) tubers in the fields (Taylor 1999). Cranes ate some alfalfa shoots, but most damage to plants was due to up-rooting young plants and trampling. Chilies and silage corn (in feedlots) were the other primary crop-damage complaints from farmers in the MRGV. Damage was related to proximity of crop fields to roost sites and timing of crane concentrations relative to crop maturity or vulnerability.

To address the increasing conflicts, a cooperative agreement was developed in 2003 among the US Fish and Wildlife Service, New Mexico Department of Game and Fish, and the US Department of Agriculture's Wildlife Services (Mitchusson 2003). The goal is to maintain a mean monthly population of 17,000–22,000 Sandhill Cranes during November-February on 6,900 ha of public lands while minimizing crop damage complaints on private lands. The strategy integrates three approaches. The main strategy is timed manipulations of corn on refuge and state lands to encourage cranes to remain on those areas and reduce damage on private fields (Taylor 1999). Standing corn is mown or pushed down as needed to attract cranes, based on weekly ground surveys (Fig. 1). Second, Wildlife Services' personnel haze cranes using disturbance techniques such as propane cannons and visual scaring devices to disperse flocks from private fields experiencing chronic damage. Third, regulated hunting reinforces hazing efforts while also providing recreational opportunities. Hunters with permits to shoot a limited number of cranes are selectively assigned to private lands with depredation complaints. Average annual confirmed depredation loss due to cranes varies annually, depending in part on success of crop production on public lands. During 2005–2007, Wildlife Services responded to an average of 394 incidents of crane and goose damage for alfalfa, pasture, silage, chili, and winter wheat (*Triticum aestivum*) fields with reported average damage of US$31,000 (USDA 2009).

The MRGV has become an important area for wildlife tourism, with much of it focused around Bosque del Apache NWR and its fall "Festival of the Cranes." Local economic effects associated with recreational visits (nearly all non-consumptive wildlife tourism) in 2004 were estimated at over US$4 million (Caudill and Henderson 2005). Strong societal interest in Sandhill Cranes and other wildlife may help provide political support for conservation of crane habitat in the MRGV. Balancing the needs of depredation control with wildlife viewing can be a delicate task, and likely will become more challenging as urbanization increases.

Solutions to Agriculture-Crane Conflicts Must Continually Evolve

The current solutions to minimize conflicts between cranes and farmers rely on a strategic balance of public land management, lure crops, hazing, and carefully controlled hunting. These strategies have largely been successful in reducing local conflicts while sustaining crane populations and providing opportunities for wildlife viewing. However, the balance, scale, and nature of these strategies must adapt to continued changes in the landscape just as the cranes adapt to them. Specific concerns include continued urbanization along the river, increasing water conflicts among urban, agricultural, and

Fig. 1. Sandhill Cranes and Snow Geese feed in corn field at Bosque del Apache National Wildlife Refuge, New Mexico, that has been mown to improve accessibility and use by cranes (Photographer: Matt Boggie)

wildlife interests, and uncertain implications of changing climate that may further reduce hydrological flows on the Middle Rio Grande River. Future efforts to conserve crane habitat and minimize future crane-agriculture conflicts could focus on improving both the distribution and the diversity of food resources and roost sites locally and regionally. Diversification will provide greater security of foods and roost sites in the face of changing climate and agricultural environments. Dispersal of cranes to more areas will reduce concentrations and potential for agricultural conflicts and risks of disease. Water resources will be a critical element in conservation of natural crane habitats and foods as well as agriculture.

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CASE STUDY

Wetland Bird Conservation in California Rice Fields

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Abstract: With much of the Earth's land under agriculture and a growing human population, pressure to expand and intensify farming will only increase. Two broad approaches have been proposed to reconcile society's need to balance food production with conservation. Land sharing focuses on improving wildlife conditions within agricultural landscapes, often by setting aside a subset of the land and farming less intensively. The result is often reduced productivity, and thus farming income. An alternative, land sparing, would involve intensifying agriculture to maximize production, so that more land can be set aside exclusively for conservation. Which approach is likely to produce the greatest net benefits for wildlife remains unclear as few empirical studies have compared the two tactics. A third option is to seek a mixed strategy, whereby conservation value is increased alongside intensive farming. Achieving this goal is clearly not easy and realistic solutions are unlikely without close cooperation between the farming and conservation communities. We describe a recent collaboration between rice farmers and conservation professionals to seek such a solution in the intensively-farmed ricelands of California. Through a series of workshops and other interactions we identified a set of plausible management actions that are expected to benefit wetland birds while being compatible with standard farming operations. These methods have since been implemented experimentally at large spatial scales to allow researchers to test whether they provide the anticipated benefits for birds. Farmer engagement at the earliest stages of this process was crucial in collaboratively designing conservation solutions that farmers would be willing to adopt, and in building the relationships needed to design landscape-scale experiments to ensure that the methods work. This collaborative strategy has great promise for improving the value of farmland for cranes and other wildlife throughout the world.

Key words: California, *Grus canadensis*, land sharing, land sparing, rice paddy, wildlife-friendly agriculture

The Problem

Conservation in agricultural settings has increasingly focused on two alternatives (Green et al. 2005). First are so-called "land sharing" or "wildlife-friendly farming" methods, which involve identifying ways to enhance wildlife habitat within agricultural landscapes. These methods usually involve implementing practices that enhance the habitat value of farmland, for example by setting aside a subset of each field (e.g., field borders), or engaging in less intensive farming (e.g., reduced chemical applications). A downside to these approaches is that they can reduce field area or productivity, which affects individual farmers economically and can influence regional food production. A second option is to farm land that is well suited to agriculture as intensively as possible in order to maximize production, thereby allowing the possibility for more land to be set aside for conservation ("land sparing"). Separating farming from conservation lands allows practitioners to manage each as effectively as possible for its given purpose. The trade-offs between land sharing and land sparing remain uncertain, however, as few studies have been conducted to determine which alternative provides the greatest conservation gains, which conservation targets can benefit from which approach, or how local circumstances affect the costs and benefits of each strategy. These approaches, however, need not be mutually exclusive. Whenever possible, we should seek solutions that achieve conservation benefits across the landscape without compromising agricultural production, thereby gaining the best of both strategies.

In California's Central Valley, a coalition of conservation organizations, federal agencies, the California Rice Commission, and individual farmers have been working towards this ideal in order to enhance intensively farmed rice (*Oryza sativa*) fields for a wide range of wetland-dependent species. Although the program was designed to benefit waterbirds generally, recent pilot work has also targeted focal species such as Sandhill Cranes (*Grus canadensis*). Overall the program provides a model for how to find solutions that increase the conservation value of farmland without hampering economic or food production goals.

The Background

Historically, California's Central Valley (39°0'N,121°30'W) contained extensive seasonally-flooded wetlands. Since European development, much of that land has been drained and converted to farmland. Nonetheless, the region continues to support millions of wetland birds, primarily during winter when few crops are being grown (Eadie et al. 2008). These birds use what is now a mosaic of wetlands and some of the world's most intensively farmed and productive land (Fig. 1). Following legislation introduced in 1991 to phase down the traditional practice of burning straw and stubble after harvest, many rice farmers began to flood their fields during winter to aid straw decomposition and provide some control over fungal diseases that were formerly managed by burning. Flooding also produces suitable conditions for many wetland birds, suggesting that, with over 200,000 ha of rice grown in the region, there is enormous potential to increase habitat during nonbreeding periods (Elphick and Oring 1998). How best to tap this potential, however, has been the challenge.

Initial research in the 1990s, not surprisingly, suggested that water depth greatly affects species use, but that the details of how straw was manipulated in conjunction with flooding (e.g., whether and how it was incorporated into the soil) were less important (Elphick and Oring 1998). That research led to proposed management changes that might enhance the value of flooded fields for a wide diversity of species. For example, it was suggested that asking farmers to close water control structures and trap rainwater on their fields might create sufficient shallow flooding – at least in wet winters – to provide extensive shorebird habitat at very little cost. Whether these methods would really provide the anticipated benefits, however, was unknown. Despite publication of these ideas in the scientific literature since the late 1990s, implementation and further experimental tests were not immediately

Fig.1. Sandhill cranes and other birds using flooded rice field (Photographer: Khara Strum)

forthcoming. As is often the case, turning scientific knowledge into on-the-ground conservation actions proved a stumbling block and two key questions remained: (1) how could one build on the initial research and comprehensively test alternative management practices at scale to increase conservation gains? (2) how could one increase farmer engagement in order to implement practices that benefit birds more widely?

The Approach

With these concerns in mind, conservation groups (Audubon California, Point Blue Conservation Science, and The Nature Conservancy) worked with the California Rice Commission and organized a series of workshops to discuss opportunities to implement farming practices that would benefit wetland birds. The first workshop, held in 2009, was primarily informational. Importantly, this workshop focused on the two-way exchange of information, both to put forth ideas about actions that might provide conservation benefits and to seek input from farmers about the plausibility of these approaches and their likely impacts on rice production and farm economics. This kind of information exchange and trust building is a critical step in designing programs that are seen by stakeholders as legitimate and salient regarding the opportunities that exist (Cook et al. 2013).

A second workshop followed a year later, in which specific management practices were proposed for detailed consideration. Scientists, conservation practitioners, government agency staff, and farmers all engaged in an exercise to identify the pros and cons of each approach, and farmers were encouraged to rule out any that they considered to be inviable. This process provided much clearer insights into the conditions that farmers face, both in terms of the economics of running a farming business and the many logistical and regulatory constraints that limit their field management options. Having stakeholders with very different perspectives in the same room also resulted in more informed discussions about the practicalities of implementation than would otherwise have been possible. Providing growers with better information on the needs of wetland birds prompted additional discussion about potential practices that had not been previously considered and left the farmers better able to contribute their expertise to finding conservation solutions. The meeting ended with a clear prioritization of proposed practices, with those most likely to be widely adopted high on the list. Moreover, the workshops resulted in commitments from several farmers to begin experimental implementation to test whether hypothesized benefits could be achieved. With this framework in place, a subsequent workshop brought together rice producers and program managers from the US Department of Agriculture's Natural Resources Conservation Service (NRCS) to focus more narrowly on the feasibility and costs associated with implementing the alternative practices.

The Results (so far)

Overall, this approach and its ongoing refinement exceeded expectations in terms of the speed and scale of implementation of alternative management practices in California's ricelands. Following the second workshop, replicated experiments were initiated on eight farms to examine bird responses to one of the simplest practices identified: closing water control structures to trap winter rainwater and create shallow flooding on otherwise dry fields (Strum et al. 2013). Subsequently, experiments have been launched to quantify bird responses to six other management practices (e.g., Sesser et al. 2016), engaging over 50 farmers and further establishing the relationship between the farming community and conservation organizations. Most of these experiments are now conducted in concert with government-supported incentive programs run by the NRCS, which provided cost-share and technical support for 226 farmers in 2011–2013 alone. A collaborative working group including NRCS, conservation groups, and the California Rice Commission now oversee the refinement of the program based on new research and lessons learned from implementing the practices. This work also has laid the foundation for a parallel program run by The Nature Conservancy, which uses private funding and a habitat "market" to engage farmers in implementing these practices. Crucially, the overall program has made possible large-scale experiments that allow adaptive management and improvement of the incentive scheme to ensure that it achieves its conservation goals. To date, over 50,000 ha of rice have been enrolled in the different programs.

Important challenges, however, remain. First, the incentive payments may only last for a limited period and it remains unclear whether adoption of all of the alternative practices will continue without a cost-share program to support their implementation. Second, practices have not been in place long enough to determine whether they will result in population-level conservation gains for birds. Despite the challenges, there appears to be great opportunity to apply this model to other crops in the Central Valley and beyond (Elphick et al. 2010).

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GLOSSARY

We recognize that our global audience may view words differently, or not be familiar with the usage in this publication. Hence, we provide a brief glossary to clarify usage in this publication.

Term	Definition and usage
Beak	Horny projecting jaw of birds (upper and lower mandibles); also commonly referred to as a bill
Biome	The world's major communities, classified according to the predominant vegetation and characterized by adaptations of organisms to that particular environment. Biomes recognized here follow those delineated in Olson et al. 2001
Cash crop	A crop produced for direct sale in a market; does not include crops used for feeding livestock, subsistence (see below), or bartering.
Commodity	An article of trade or commerce, especially a product, as distinguished from a service
Depredation	Destruction or plunder; here, destruction of crops by animals
Fledge	To bring up a young bird from hatch until it is ready to fly
Hazing	Intentional disturbance or harassment of birds, usually to cause them to move
Herbivorous	An animal that feeds largely on plant foods
Hydrological regime	Pattern of changes in water conditions (depth, flow) of a wetland, lake or river over time
Life strategy	Suite of reproductive development and behaviors, life span, and post-reproductive behavior of a species, shaped by natural selection
Loafing areas	Areas used by birds to rest, as opposed to areas where birds stop overnight
Migration areas	Used in general reference to areas used during migration; see *staging* and *stop-over* for more specific use of areas during migration
Omnivorous	An animal that feeds on both plant and animal foods
Resting	Resting used here only for the behavior of resting (inactive); for migratory behavior, see *stop-over* or *staging*.
Reclamation	Conversion of natural habitats or other land into land suitable for cultivation
Silage	Fodder prepared by compressing and fermenting green forage crops under anaerobic conditions
Smallholder	Farmer who works an area usually <20 ha (50 ac); in less developed countries of Africa and Southeast Asia, more often <2 ha
Staging	Location or behavior where migrating birds stay for more than 2–3 nights, often where flocks congregate
Stop-over	Location or behavior where migrating birds stop for short period (1 or a few nights)
Subsistence	The action or fact of maintaining or supporting oneself at a minimum level. In agriculture, refers to individuals that grow food only for their use, lacking sufficient production to sell or trade
Sustainable agriculture	The efficient production of safe, high quality agricultural products, in a way that protects and improves the natural environment, the social and economic conditions of farmers, their employees and local communities, and safeguards the health and welfare of all farmed species (see also http://www.saiplatform.org)
Xeric	Characterized by, relating to, or requiring only a small amount of moisture

ABBREVIATIONS

AEWA	African-Eurasian Migratory Waterbirds Agreement
AI	Avian influenza
APLIC	Avian Power Line Interaction Committee (United States)
AQ	Anthroquinone
CBD	Convention on Biological Diversity
CCZ	South Korean Civilian Controlled Zone
CMS	Convention on Migratory Species
CNR	Cao Hai Nature Reserve (China)
CRP	Conservation Reserve Program (United States)
CTF	Community Trust Fund
CUD	Crane use day
DDT	dichlorodiphenyltrichloroethane
DEE	Daily energy expenditure
DEI	Daily energy intake
DMZ	Demilitarized Zone (North and South Korea)
EPR	European Part of Russia
EQUIP	Environmental Quality Incentives Program (United States)
FA	Farmers' Conservation and Development Association (Cao Hai, China)
FA	Food and Agriculture Organization (United Nations)
GEPB	Guizhou Environmental Protection Bureau
GIS	Geographic information system
HNP	Hortobágy National Park (Hungary)
ICF	International Crane Foundation
IUCN	International Union for Conservation of Nature
MBHI	Migratory Bird Habitat Initiative (United States)
MRGV	Middle Rio Grande Valley (New Mexico, USA)
NABU	German Society for Nature Conservation
NASS	National Agriculture Statistics Service (United States)

Austin JE, Morrison K, Harris JT, editors. 2018. *Cranes and Agriculture: A Global Guide for Sharing the Landscape.* Baraboo, Wisconsin, USA: International Crane Foundation. 303 p.

NAWMP	North American Waterfowl Management Plan
NGO	Non-government organization
NPO	Not-for-profit organization
NRCS	Natural Resources Conservation Service (United States)
NWR	National Wildlife Refuge (United States)
OECD	Organization for Economic Development
TUP	Trickle Up Program
UNEP	United Nations Environment Programme
US	United States
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USSR	Union of Soviet Socialist Republics
WDNR	Wisconsin Department of Natural Resources
WHIP	Wildlife Habitat Incentive Program (United States)
WLFW	Working Lands for Wildlife (United States)
WRP	Wetland Reserve Program (United States)
WWF	World Wide Fund

Appendix 1.
SCIENTIFIC NAMES

Taxonomy for cranes follows Livezey (1998. Philosophical Transactions of the Royal Society of London, Series B 353:2077-2151). Other bird names follow the current taxonomy of the BirdLife International (2017. The BirdLife checklist of the birds of the world: Version 9.1. Available at http://www.birdlife.org/datazone/userfiles/file/Species/Taxonomy/BirdLife_Checklist_Version_91.zip).

Other taxa names follow Integrated Taxonomic Information System (www.itis.gov, September 2017).

Crane Species

Common name	Scientific name
Black Crowned Crane	*Balearica pavonina*
Black-necked Crane	*Grus nigricollis*
Blue Crane	*Anthropoides paradiseus*
Brolga	*Grus rubicunda*
Eurasian Crane	*Grus grus*
Demoiselle Crane	*Anthropoides virgo*
Grey Crowned Crane	*Balearica regulorum*
Hooded Crane	*Grus monacha*
Red-crowned Crane	*Grus japonensis*
Sandhill Crane	*Grus canadensis*
Sarus Crane	*Grus antigone*
Siberian Crane	*Leucogeranus leucogeranus*
Wattled Crane	*Bugeranus carunculatus*
White-naped Crane	*Grus vipio*
Whooping Crane	*Grus americana*

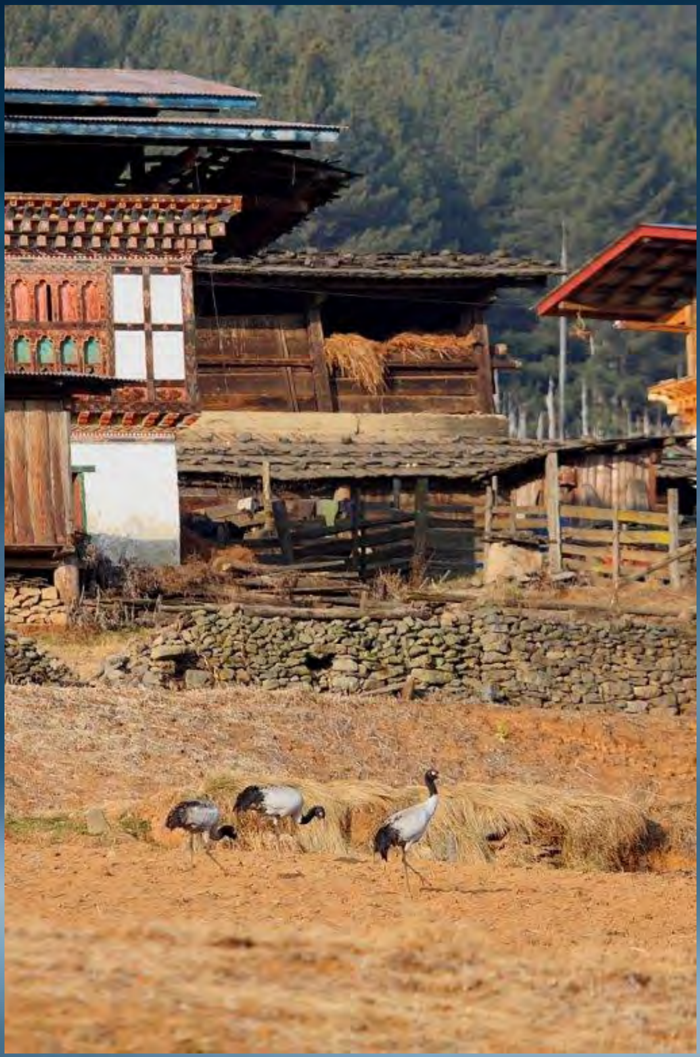
Plant and Animal Species

Common name	Order	Family	Scientific name
PLANTS			
African rice	Poales	Poaceae	*Oryza glaberrima (West Africa)*
Alfalfa (lucerne)	Fabales	Fabaceae	*Medicago sativa*
Asparagus	Asperagales	Asparagaceae	*Asparagus officinalis*
Barley	Poales	Poaceae	*Hordeum vulgare*
Beets	Caryophyllales	Amaranthaceae	*Beta vulgaris*
Black willow	Malpighiales	Salicaceae	*Salix nigra*
Buckwheat	Caryophyllates	Polygonaceae	*Fagopyrum esculentum*
Bulkuru sedge	Poales	Cyperaceae	*Eleocharis dulchis*
Carolina wolfberry	Solanales	Solanaceae	*Lycium carolinianum*

Common name	Order	Family	Scientific name
Cattail	Poales	Typhaceae	*Typha*
Chick pea	Fabales	Fabaceae	*Cicer arietinum*
Chili peppers	Solanales	Solanaceae	*Capsicum*
Chufa	Poales	Cyperaceae	*Cyperus esculentus*
Common reed	Poales	Cyperaceae	*Phragmites*
Common reed	Poales	Poaceae	*Phragmites australis*
Cork oak	Fagales	Fagaceae	*Quercus suber*
Corn (maize)	Poales	Poaceae	*Zea mays*
Cotton	Malvales	Malvaceae	*Gossypium*
Eelgrass	Alismatales	Hydrocharitaceae	*Vallisneria*
Finger millet	Poales	Poaceae	*Eleusine coracana*
Grape (vines)	Vitales	Vitaceae	*Vitis*
Green peas	Fabales	Fabaceae	*Pisum sativum*
Ground nuts	Fabales	Fabaceae	*Arachis*
Gum	Myrtales	Myrtaceae	*Eucalyptus*
Holm oak	Fagales	Fagaceae	*Quercus ilex*
Hybrid cattail	Poales	Typhaceae	*Typha x glauca*
Job's tears	Poales	Poaceae	*Coix lacryma-jobi L.*
Karelinia	Asterales	Asteraceae	*Karelinia caspia*
Lily	Liliales	Liliaceae	*Lilium*
Lucerne (alfalfa)	Fabales	Fabaceae	*Medicago sativa*
Maize (corn)	Poales	Poaceae	*Zea mays*
Millet	Poales	Poaceae	*Panicum miliaceum*
Mustard	Brassicales	Brassicaceae	*Brassica* spp, *Sinapis* spp.
Nutgrass	Cyperales	Cyperaceae	*Cyperus rotundus*
Oats	Poales	Poaceae	*Avena sativa*
Olive	Lamiales	Oleaceae	*Olea europaea*
Olney's bulrush	Poales	Cyperaceae	*Schoenoplectus americanus*
Onions	Asperagales	Amaryllidaceae	*Allium cepa*
Papyrus	Poales	Cyperaceae	*Cyperus papyrus*
Peanuts	Fabales	Fabaceae	*Arachis hypogaea*
Pearl millet	Poales	Poaceae	*Pennisetum glaucum*
Pine	Pinales	Pinaceae	*Pinus*
Potatoes	Solanales	Solanaceae	*Solanum tuberosum*
Purple loosestrife	Myrtales	Lythraceae	*Lythrum salicaria*
Rape/rapeseed/canola	Brassicales	Brassicaceae	*Brassica napus*
Reed canary grass	Poales	Poaceae	*Phalaris arundinacea*
Rice	Poales	Poaceae	*Oryza sativa*
Rye	Poales	Poaceae	*Secale cereale*
Smooth cordgrass	Poales	Poaceae	*Spartina alterniflora*

Common name	Order	Family	Scientific name
Sorghum	Poales	Poaceae	*Sorghum bicolor*
Soybeans	Fabales	Fabaceae	*Glycine max*
Spikerush	Poales	Cyperaceae	*Eleocharis*
Squash	Cucurbitales	Cucurbitaceae	*Cucurbita*
Sugar cane	Cyperales	Poaceae	*Saccharum officinarum*
Sunflower	Asterales	Asteraceae	*Helianthus annuus*
Teff	Poales	Poaceae	*Eragrostis tef*
Tobacco	Solanales	Solanaceae	*Nicotiana*
Tomato	Solanales	Solanaceae	*Solanum lycopersicum*
Walnuts	Fagales	Junglandaeceae	*Juglans*
Water chestnuts	Myrtales	Lythraceae	*Trapa natans*
Wheat	Poales	Poaceae	*Triticum aestivum*
Wormwood	Asterales	Asteraceae	*Artemisia dracunculus*
ANIMALS - VERTEBRATES			
Mammals			
African buffalo	Artiodactyla	Bovidae	*Syncerus caffer*
Bison	Artiodactyla	Bovidae	*Bison bonasus*
Camel	Artiodactyla	Camildae	*Camelus dromedarius and C. bactrianus*
Domestic cattle	Artiodactyla	Bovidae	*Bos taurus*
Domestic dog	Carnivora	Canidae	*Canis lupus familiaris*
Domestic goat	Artiodactyla	Bovidae	*Capra hircus*
Domestic horse	Perissodactyla	Equidae	*Equus caballus*
Domestic pigs	Artiodactyla	Suidae	*Sus scrofa*
Domestic reindeer	Artiodactyla	Cervidae	*Rangifer tarandus*
Domestic sheep	Artiodactyla	Bovidae	*Ovis aries*
Donkey	Perissodactyla	Equidae	*Equus asinus*
Saiga	Artiodactyla	Bovidae	*Saiga tatarica*
South African spring hare	Rodentia	Pedetidae	*Pedetes capensis*
Water buffalo	Artiodactyla	Bovidae	*Bubalus bubalis*
Birds			
African Long-eared Owl	Strigiformes	Strigidae	*Asio abyssinicus*
Banded Barbet	Piciformes	Ramphastidae	*Lybius undatus*
Dabbling ducks	Anseriformes	Anatidae	*Anas*
Domestic chicken	Galliformies	Gallidae	*Gallus gallus*
Mallard	Anseriformes	Anatidae	*Anas platyrhynchos*
Muscovy Duck	Anseriformes	Anatidae	*Cairina moschata*
Geese	Anseriformes	Anatidae	*Anser*

Common name	Order	Family	Scientific name
Greater Spotted Eagle	Accipitriformes	Accipitridae	*Clanga clanga*
Lesser Flamingo	Phoenicopteri-formes	Phoenicopteridae	*Phoeniconaias minor*
Lesser Prairie Chicken	Galliformies	Phasianidae	*Tympanuchus pallidicinctus*
Mottled Duck	Anseriformes	Anatidae	*Anas fulvigula*
Oriental Stork	Ciconiiformes	Ciconiidae	*Ciconia boyciana*
Ostrich	Struthioniformes	Struthionidae	*Struthio camelus*
Pallid Harrier	Accipitriformes	Accipitridae	*Circus macrourus*
Red-winged Blackbird	Passeriformes	Icteridae	*Agelaius phoeniceus*
Ring-necked Pheasant	Galliformies	Phasianidae	*Phasianus colchicus*
Rouget's Rail	Gruiformes	Rallidae	*Rougetius rougetii*
Sage Grouse	Galliformies	Phasianidae	*Centrocercus urophasianus*
Snow Goose	Anseriformes	Anatidae	*Anser caerulescens*
Spur-winged Goose	Anseriformes	Anatidae	*Plectropterus gambensis*
White-backed Tit	Passeriformes	Paridae	*Melaniparus leuconotus*
White-throated Seedeater	Passeriformes	Emberizdae	*Sporophila albogularis*
ANIMALS - INVERTEBRATES			
Black maize beetle	Coleoptera	Scarabaeoidae	*Heteronychus arator*
Blue crab	Decapoda	Portunidae	*Callinectes sapidus*
Clams	Mollusca	Bivalvia	*Ensia*
Dragonfly	Odonata	Aeshnidae	*Aeshna*
Dragonfly	Odonata	Libellulidae	*Libellula*
False wire worm	Coleoptera	Tenebrionidae	
Fiddler crab	Decapoda	Ocypodidae	*Uca*
Ground weevil	Coleoptera	Curculionidae	*Protostrophus*
Leafhopper	Hemiptera	Cicidellidae	*Cicadulina mbila*
Maize rootworm	Coleoptera	Chrysomelidae	
Spotted maize beetle	Coleoptera	Melyridae	*Astylus atromaculatus*



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