ISSN 2710-1142(online)

SIS Conservation

Issue 2, 2020

Special Section

Woolly-necked Stork ecology and conservation

IUCN SSC Stork, Ibis and Spoonbill Specialist Group

Publication of the IUCN-SSC Stork, Ibis and Spoonbill Specialist Group

IUCN

SSC Species Survival Commission

SIS Conservation

Publication of the IUCN SSC Stork, Ibis & Spoonbill Specialist Group

View this journal online at https://storkibisspoonbill.org/sis-conservation-publications/

AIMS AND SCOPE

SIS Conservation (*SISC*) is short for "*Stork, Ibis and Spoonbill Conservation*" and is a peer-reviewed publication of the IUCN SSC Stork, Ibis and Spoonbill Specialist Group (SIS-SG). *SISC* publishes original content on the ecology and conservation of both wild and captive populations of SIS species and Shoebills worldwide, with the aim of disseminating information to assist in the management and conservation of SIS populations and their habitats worldwide.

We invite anyone, including people who are not members of the SIS-SG, to submit manuscripts.

All enquiries, including but not limited to, ideas for special issues, special sections, participation as an Editor, submission of original papers, short notes, essays or letters, should be emailed to sis.conservation@gmail.com.

We welcome sponsorship of individual issues of *SISC*. Please direct queries regarding sponsorship to storkibisspoonbill@gmail.com.

Cover photo: © Pradeep Sukhwal. Woolly-necked Stork *Ciconia episcopus* in a spread-wing posture in Rajasthan, India.

Back cover photo: © Peng Jian-Sheng. Woolly-necked Stork *Ciconia episcopus* at 3,500 m altitude at Napa Lake, China.

Recommended citation of an article:
Rodríguez, J. P. 2019. Welcome to Stork, Ibis and Spoonbill Conservation. *SIS Conservation* 1: 5.

Supporting Institutions:

SIS Conservation, Issue 2, 2020

Table of contents

ISSN 2710-1142(online)
SIS Conservation, 2020, 2, 1-2
EDITORIAL

A new *SIS Conservation* issue amid a pandemic

K. S. Gopi Sundar[1], Luis Santiago CANO ALONSO[2]

[1]Nature Conservation Foundation, 1311, "Amritha" 12th Main, Vijayanagar 1st Stage, Mysuru 570017, Karnataka, India
[1]Department of Biodiversity, Ecology, and Evolution, Univesidad Complutente de Madrid, E-28040 Madrid, Spain
Email for communication: storkibisspoonbill@gmail.org

2020 has been an unforgettable year. As the global pandemic spread across the planet, we have collectively and individually had to endure many changes. Some of these have been somewhat easier to address, such as working from home where possible. Others, like the inability to travel to fieldwork location, have been far more challenging.

Despite these circumstances, we continued working on the Specialist Group looking for support and partners. We received great news from the Species Survival Commission IUCN that the SIS specialist group was selected for the IUCN-SSC internal small grant in 2020. Part of this support will be used towards *SIS Conservation* as a recognised open access publication. This has been an enormous acknowledgment of the value of *SIS Conservation* by the SIS UICN and its partner Global Wildlife Conservation, and we are very grateful for this support.

The SIS world has seen its share of hardships with many conferences cancelled, annual meetings held online, and journal issues delayed. It is therefore with some apology but great excitement that we complete Issue 2 of *SIS Conservation*. The apology is for the delay in completing this issue, and the excitement is for the contents, and what it took to get these completed.

In Issue 2, we have been able to achieve nearly all of the things we envisioned for this new journal. In the first collection of "*Letters to* SIS Conservation", we gratefully compile the messages and letters we received from friends, colleagues and supporters around the world. All of them speak kindly of the inaugural issue that was put together thanks to the epic effort of SIS-SG member Simone Santoro. We introduce the "*Opinion*" section with an important essay on the status of Saddle-bill Storks *Ephippiorhynchus senegalensis* in Africa, and the need to replace early natural history observations with more robust tolls and information (Gula 2020). We should add that Jonah's seminal paper on factors affecting this species across Africa in the prestigious journal *Ostrich* secured him the Best Student Paper published in the journal in 2019 (Lee 2020). This is the first time a paper focusing on a SIS species has secured this accolade.

In the general section of articles, we host important papers from China, Australia and Indonesia covering a range of SIS species found in these areas. The complexity of fluctuations of water levels and how it affects behaviour and habitat use of wintering Eurasian Spoonbills *Platalea leucorodia* is explored in detail in the globally important site Lake Poyang (Sullender *et al*. 2020). This is cutting-edge work that underscores the value of field observations and hydrological measurements. To further highlight the importance of retaining waterlevels to benefit SIS species, Brandis *et al*. (2020) analyze a multi-year data set of colonially nesting waterbirds in one of the most important agricultural landscapes in Australia for SIS species. This paper tells an elegant tale of breeding waterbirds, water levels, and the value that artificial irrigation can provide to SIS species. Finally, field observations from Indonesia confirms the very exciting news of Milky Storks Mycteria cinerea returning to Banten to breed after a gap of 45 years (Noor *et al*. 2020).

We are also excited to introduce the "*Special Section*" where a number of short notes and papers provide the first ever detailed description of natural

Article history

Published online: 11 April 2021

history, ecology and conservation status of the Woolly-necked Stork *Ciconia episcopus* from several locations in south and south-east Asia. Significantly, the information provided for this Special Section was used to evaluate the conservation status of the species, and succeeded in convincing the Red List authorities that the Woolly-necked Stork requires to be downlisted from "Vulnerable" to "Near-threatened" (Sundar 2020).

The papers for Issue 2 were written, reviewed and revised as the world experienced the most recent pandemic in the form of Covid-19. Great uncertainly gripped the globe as we experienced unprecented lockdowns that governments imposed to reduce the chances of transmission. The world endured great human tragedy in many countries as issues of equity and access to resources were laid bare, and we count ourselves as very fortunate to be among those few that could continue working from the comfort of our homes. Our hearts go out to the people who could not, and suffered a great deal.

The world also saw short-term benefits to nature as populations of some birds seemed to proliferate, but some SIS species in some locations experienced increased hunting pressures as humans struggled to find food (e.g. WCS 2020). As the pandemic continues to drive new human behaviours, and challenge scientists and governments, the full import of this novel disease on the natural world and on SIS species will reveal itself in the future. We gratefully acknowledge the reviewers and authors who, through all of this ensuing pandemonium, continued to support SIS species with their work that they provided for publication in *SIS Conservation*.

As we start developing Issue 3, we continue to depend on your interest in SIS species, and ask that you consider SIS Conservation to publish your work. We will continue to strive to improve the publication. Articles are now put on our website as Online First accepted publications that are ready for citation and use. The new artwork of SIS species at the bottom of the pages, the updated formatting (made possible by the time that the lockdown provided to learn a new freeware!), the increased network of colleagues, and the spanking new ISSN number for the publication are all small steps towards our goal of improvement. We will work to ensure the inclusion of SIS Conservation into the directory of open access publications, set up better documentation of each paper by adding doi identities, and are certain that all of these features will help us improve both searchability and the altimetric scores of individual paper. While we are not obsessed by metrics such as impact factors, we are interested in ensuring that the work of our colleagues are indexed widely and be freely available. We will continue also to assist colleagues who wish to submit their information in ways that are possible for us. Language editing, making improved maps, statistical assistance, and providing background literature where possible are on our list of things-to-do.

We wish all of your the best of health and hope that you are putting safety and care before all else as we collectively emerge into what will be a new world. We hope that this new world will continue to have SIS species proliferating, more species being brought out of endangered and vulnerable categories, and certainly many more with their ecology and habits becoming better known to all of us. We certainly cannot imagine any future where SIS species are not being obsessed about, and given what we have experienced so far, it is clear that many of you cannot either.

References

Brandis, K. J., S. Ryall, R. T. Kingsford and D. Ramp. 2020. Colonial waterbird breeding in the Gayini-Nimmie-Caira wetlands, Australia 2010-2011. *SIS Conservation* 2: 19-28.

Gula, J. 2020. Opinion: It's time for the Saddle-billed Stork to be on our radar. *SIS Conservation* 2: 7-9.

Lee, A. T. K. 2020. Best student article published in Ostrich in 2019: hold onto your saddle, Bill, for the story behind a close race. *Ostrich* 91: 1.

Noor, Y. R., Umar, A. Mardiastuti, R. S. Gumilang and M. Iqbal. 2020. Observation of Milky Stork *Mycteria cinerea* breeding on Pulau Dua, Banten, Indonesia after 45 years. *SIS Conservation* 2: 29-32.

Sullender, B. K., J. Barzen and J. Silbernagel. 2020. Effects of seasonal hydrological connectivity on Eurasian Spoonbill *Platalea leucorodia* foraging ecology. *SIS Conservation* 2: 10-18.

Sundar, K. S. G. 2020. Special Section Editorial: Woolly-necked Stork - a species ignored. *SIS Conservation* 2: 33-41.

WCS. 2020. Covid-19 fueling an uptick in poaching: three critically endangered Giant Ibis – Cambodia's National Bird – killed in Protected Area. *The Cambodia Daily, April 16, 2020*.

ISSN 2710-1142(online)
SIS Conservation, 2020, 2, 3-6
LETTERS TO *SISC*

The inaugural issue is a remarkable collection

The initiation of this new journal is very impressive in its goals, constitution - in being completely Open Access – and editorial oversight and guidance. Its inaugural issue is a remarkable collection across many researchers on a single species. This greatly illustrates the potential for the collective contributions towards gaining knowledge on this group of birds; while also encouraging the later publication of research on the many other species within the journal's remit. Personally, I am a researcher on raptors and waders, and there are dedicated journals/publications accordingly, but this *SISC* journal initiative's concept and goals will hopefully also serve as a beacon for other researchers and publications involved with other groups of birds.

I hope but trust that the Aims and Scope of *SISC* will continue to be realised, with continued exemplary efforts as already illustrated and propounded. As I've noted, these birds are not those I study. I would urge, nevertheless, that those researchers involved in this group of birds will support this excellent dedicated publication initiative which clearly has laudable global aspirations with inherent provision of opportunities in spreading knowledge, and importantly, encouraging that prospect of knowledge to be based on a rigorous scientific basis.

Philip WHITFIELD,
Managing Director, Natural Research, UK.

Received 15 December 2019.

SISC *fills a previously empty niche*

I was pleased to receive and review Issue 1 of *SIS Conservation*. I commend Editors-in-Chief Sundar and Alonso, Guest Editor Santoro, and the 75 article authors, for producing a wonderful inaugural issue on Glossy Ibis in numerous countries and geographic settings. *SIS Conservation* fills a needed, previously empty niche in the ornithological literature, for a peer-reviewed forum to promote the science and conservation of storks, ibises, spoonbills, and shoebills. With continued IUCN support and rigorous peer review, I am confident that the publication will excel in providing high-quality scientific information at a global scale.

Dr. Bruce G. MARCOT, Research Wildlife Biologist, United States of America.

Received 22 December 2019.

SIS Conservation *promises to be a rich source of data*

The launch of a new scientific journal dedicated to the conservation and ecology of any group of threatened species is welcome. Storks, Ibises and Spoonbills include a number of highly threatened bird species, so the emergence of a new publication to share the latest knowledge and relevant information about them is timely. For those of us at BirdLife International responsible for applying the IUCN Red List criteria to bird species and evaluating their global extinction risk, *SIS Conservation* promises to be a rich source of data, which will help us to ensure that the information in the 'other' SIS (IUCN's Species Information Service – the global Red List database used by BirdLife and other Red List Authorities) is kept updated. The comprehensive nature of the first issue, reviewing the current status of Glossy Ibis around the world, bodes well. We congratulate all those involved in this endeavour, particularly Gopi and Luis, and look forward to future issues, and especially to more papers on hitherto poorly studied species, which will help to improve knowledge and inform conservation.

Dr. Ian BURFIELD,
Global Science Coordinator (Species),
BirdLife International, UK.

Received 05 Aug. 2020.

SISC *provides one forum for this group of species*

I was delighted to see the new publication, *Storks,* *Ibises and Spoonbills Conservation* (*SISC*), which was launched in 2019. As the last publication from the SIS Specialist Group was 16 years before, *SISC* obviously fills a major gap. It is excellent news that *SISC* is online and available for free download making it widely accessible amongst researchers of these charismatic species.

After reading the first issue, with its many contributions on Glossy Ibis *Plegadis falcinellus*, I was most impressed by the quality and scope of the contributions, which are peer-reviewed.

The SIS Specialist Group covers the large number of 81 species, many of which remain poorly understood and for which conservation plans are lacking, especially those species from Africa and South America. This publication should stimulate further work on poorly known species, as well as more work on species that have been already studied, but for which more information is needed to ensure their long-term conservation. It is also hoped the *SISC* will encourage researchers of storks, ibises and spoonbills to write up work in their notebooks that they have been unable to get published previously. Importantly, *SISC* provides one forum for this group of species where researchers can publish their findings.

I congratulate Gopi Sundar, Luis Cano Alonso and their colleagues on the Editorial Board of *Storks, Ibises and Spoonbills Conservation* on this excellent new publication.

Carol INSKIPP, Patron, Himalayan Nature, UK.

Received 05 August 2020.

Updates to status of Glossy Ibis are welcome

I would like to congratulate the SIS specialist group on producing a terrific inaugural volume of their journal *Stork, Ibis and Spoonbill Conservation*. The group has thus achieved a long-standing goal and does so with a clear vision; the editors identify their objectives to showcase ongoing work, inspire new work, and document all of these in an easily and freely available format. By producing this first volume on Glossy Ibis Ecology and Conservation, they have made an admirable beginning. The geographical scope of the expertise gathered in this volume is impressive in its own right, and the updates to the current status of the Glossy Ibis are extremely welcome. The changing distribution and abundance of the species, manifested in multiple regions of the globe, provides a rallying point for students and managers of waterbirds and wetland resources; we are reminded of the still enormous gaps in our knowledge (in Australia, for example, where the map of known breeding colonies remains almost entirely blank, even in areas where many thousands of Glossy Ibis may sometimes be seen in the wet season, as in the Gulf of Carpentaria), but also the potential for meaningful conservation action when we can access the required knowledge. By presenting the accumulated understanding of worldwide experts, the new journal will spur us on to address deficiencies in our data and refine management practices for the benefit of wetland species and ecosystems. To this end it would be wonderful to see some further input from the Glossy Ibis Network emphasizing the historical context to Glossy Ibis decline and subsequent resurgence, so that conservation priorities can be more sharply delineated.

Many thanks to all involved in coordinating and producing the journal, and especially their commitment to communicating the work and observations of field practitioners.

Dr. John D. GRANT, Independent Ornithologist/ Researcher, Queensland, Australia.

Received 08 Aug. 2020.

Threatened Storks, Ibis and Spoonbills are not yet safe

There are 56 species of storks, spoonbills, and ibises — give or take a few for the inevitable taxonomic disagreements. At 0.5% of all bird species, they are a small sample, but they are disproportionately interesting for those who care are conserving biodiversity. Extinction threatens a quarter of them — twice the fraction for birds as a whole. There's more than that to justify their interest.

First, they are large and conspicuous in the open wetlands and grasslands that most of them frequent. I've seen three-quarters of the species, compared to under half of all bird species. Their being so obvious means we have a good idea of their status and threat even when they are rare. I've watched nesting greater adjutant storks on their nesting trees in Assam with Aparajita Datta. And I've counted oriental storks on their wintering grounds at Poyang Lake in China with Lei Cao. In both cases, I saw significant fractions of the global populations. Accurate counts of the black-faced spoonbill now aid in its management https://storkibisspoonbill.org/general/international-black-faced-spoonbill-platalea-minor-census-2019/.

Second, what threatens them is a good representation of what we do to species and ecosystems globally. We destroy their habitats. We clear forests and overgraze grasslands, but especially drain wetlands that are often very poorly protected worldwide. Species that migrate suffer triple threats — on the breeding grounds, where they winter, and migratory stop-overs — with the loss of any one fatal to the species' chance of survival. A migration from Syria, via Yemen, to winter in Ethiopia surely gives the northern bald ibis one of the riskiest routes of any species. (The story of a different population whose migration is human-led is a fantastic adventure https://storkibisspoonbill.org/news/25-northern-bald-ibis-start-a-new-life/).

Finally, but most importantly, their all-so-obvious presence and simple avian charisma mean they afford many examples of species that conservation practitioners have snatched from the jaws of extinction. Great adjutants may not win a beauty contest, but the pride the villagers have where they nest is inspiring. So, too, is the recovery of the Asian crested ibis. White storks nested in England this year after an absence of centuries, part of a Europe-wide trend in the expansion of waterbirds following increasingly aggressive habitat restoration https://storkibisspoonbill.org/projects/the-white-stork-project-britain/.

The threatened storks, spoonbills, and ibises are not yet safe, but let's celebrate the success of those who have stemmed their declines and prevented their extinction. The new publication on this group https://storkibisspoonbill.org/sis-conservation-publications/ now makes that a message to share and energise conservation beyond this small group of species.

Dr. Stuart PIMM, Doris Duke Chair of Conservation, Duke University and President, Saving Nature, United States of America.
Received 10 Aug. 2020.

The SISC *initiative is very timely*

Storks, Ibises and Spoonbills are magnificent birds and pride of our wetland ecosystems. They are widely distributed often in unprotected areas. Information on their status is scanty. They also are getting affected in India primarily owing to habitat loss and some of them have been enlisted in the threatened categories of IUCN red lists. Therefore, the IUCN species specialist group on Storks, Ibises and Spoonbills has a huge task and responsibility on its shoulders. Owing to the fact that fairly large share of the population of these birds occurs in unprotected areas often in human dominated landscapes, the specialist group must have involvement of people in conserving these species as a high priority in its list of activities. Status surveys of the species and a regular monitoring must also be an activity of priority in which citizen science must play an important contribution. Sharing of information and research findings is also an important step to draw the attention of all stakeholders including policy makers for which the latest initiative by the IUCN SSC Specialist group of the peer reviewed publication of '*SIS Conservation*' is a very timely one. I would like to congratulate the members of the specialist group for this.

Dr. Dhananjay MOHAN, Director, Wildlife Institute of India, India.

Received 10 Aug. 2020.

The first digital issue of SISC *is a meaty one*

I am very pleased to receive the first digital issue on the Glossy Ibis Ecology & Conservation which I believe is the first e-publication solely devoted to storks, Ibises and spoonbills. It is a meaty issue with 25 research articles running into 150 pages.

This is a wonderful concept and I congratulate the editors for understanding the need for creating such a platform to bring together researchers from all over the world who can not only showcase their work but also share their findings with colleagues in different continents.

The editors have rightly pointed out that there is a pressing need to fully understand the ecology of these highly visible birds in an ever-changing landscape especially, in the context of pesticide overloads in wide swathes of our agricultural and semi-agricultural landscapes.

We generally tend to ignore the larger birds in wetlands and agricultural landscapes and plumb for smaller and secretive birds so I was particularly glad to see your article on status of the Glossy Ibis in a couple of districts in Gujarat. Although researchers and birders are documenting these birds in India, very little scientific work has actually been published.

I hope this issue reaches out to researchers in wildlife institutions as well as to students in colleges and universities across India and provides motivation to work on this group of birds in their States as well. Good Luck!

Kiran SRIVASTAVA,
COO, Raptor Research and Conservation Foundation, Mumbai, India.

Received 11 Aug. 2020.

The attempt to bring work on SIS species in one publication is commedable

Thank you for sharing the link to the first issue of Stork, Ibis and Spoonbill (SIS) publication. My heartiest congratulations to the editorial team for envisaging such an interesting publication on SIS. A lot of work is being done on these magnificent birds all over the globe and your attempt to bring them under one publication is commendable. I look forward to reading the monograph on glossy ibis, a widely distributed species, to understand how it is surviving despite increasing challenges. I must also congratulate you on the attractive layout and logo of SIS! Looking forward to reading more from SIS. All the best.

Dr. Prachi MEHTA,
Senior Scientist and Executive Director,
Wildlife Research and Conservation Society, India

Received 18 Aug. 2020.

SISC *is helpful for public awareness in Rajasthan*

Namaskar. Though I am not a regular reader of *SIS Conservation*, however I read it wherever I get the opportunity. *SIS Conservation* is an important scientific document which covers various aspects of natural history of storks, ibises and spoonbills. All these birds are signs of a healthy ecosystem. Their long-term monitoring can help us to judge the health and functioning status of wetlands more precisely. *SIS Conservation* is also very helpful for public awareness en-mass and it is improving the status of citizen science in Rajasthan.

Gradually more and more youth, conservationists, scholars and wildlife photographers are reading, contributing and utilizing the scientific information available in *SIS Conservation*. Really *SIS Conservation* is worth reading. Hope, *SIS Conservation* would help to conserve all the aquatic ecosystems and their inmate birds of Rajasthan as well as Indian union.

Hats off to your dedicated efforts for conserving the aquatic life of our wetlands.

Dr. Satish Kumar SHARMA,
Rajasthan Forest Department (Retired).

Received 25 Aug. 2020.

Storks, Ibis and Spoonbills are beautiful

SIS Conservation is really nice. I was just wondering if articles have a DOI number. I noticed one in the recent issue. But the old one did not have any. For a reader and a contributor it will be good to give the number of issues in year, article turn around time. For each SISC issue, you can have an Editorial podcast that summarises what are the contents of that issue, and also raise some important conservation issues. Storks, Ibises and Spoonbills are beautiful. You can use more of their pictures or paintings to make the website interactive.

Dr. Karthikeyan Vasudevan, Laboratory for the Conservation of Endangered Species, Centre ofr Cellular and Molecular Biology, Hyderabad, India

Received 11 Oct. 2020

ISSN 2710-1142(online)
SIS Conservation, 2020, 2, 7-9
OPINION

It's time for the Saddle-billed Stork to be on our radar

Jonah GULA[1]

[1]Graduate Student, Texas State University.
E-mail: jonah.gula@yahoo.com

I dare say the Saddle-billed Stork *Ephippiorhynchus senegalensis*–or simply, Saddlebill–is Africa's most striking waterbird, a favorite of birders, safari-goers, and photographers alike. We are not the first people to be captivated by the Saddlebill, however. Ancient Egyptians of the Predynastic Period (pre-3150 BC) associated the Saddlebill with the religious concept of *ba*, which is related to divinity or manifestation of the divine (Janák 2014), and depicted them in hieroglyphs and artwork. It is no wonder why it was held in such high regard, for it's stately beauty was unmatched among ancient Egyptian avifauna. Such cultural following has helped provide evidence of the susceptibility of the Saddlebill to a changing environment: following a period of known climate change, it apparently disappeared from northeastern Africa and significance in Egyptian culture (Janák 2014). Now, in the twenty-first century, as the Saddlebill's Africa continues to change in the midst of a myriad of threats, it is more important than ever to understand the dynamics of a species like this, which could potentially act as an early indicator of a degrading environment.

In a somewhat circular situation, the Saddlebill has stayed under the radar of researchers and conservationists thanks to a perpetuated lack of research attention. As early as the 1980s, a lack of scientific information led some authors to make presuppositions about its ecology in some authoritative pieces of literature, leading many to believe there is little to learn. Contrary to information in the literature, we are still missing data on the reproductive cycle, movement patterns, territoriality, and environmental requirements, to name the most basic knowledge gaps. To confound the dilemma, the IUCN status assessment of the Saddlebill is far from empirical–in fact, the data used in it are based on existing and additional unsubstantiated assumptions. This is not uncommon for birds that do not have adequate field data, and status assessments instead take a best-guess approach in which accuracy and authenticity are impossible to verify. This approach is particularly true for poorly-studied species that are assumed to be "common" due to widespread distributions. Such assessments are not useful and lead people to take categorizations such as the IUCN status "Least Concern" literally, diverting research attention and resources to species in higher IUCN categories suggestive of a greater level of threat. The Saddlebill–and many other large African waterbirds, I might add–suffers from this very scenario and has thus fallen by the wayside.

Recently, colleagues and I took a first step in addressing the paucity of information on Saddlebills in the first distribution assessment for the species (Gula *et al.* 2019). As the first empirical basis for assessing range-wide status, our findings merit repetition here. The Saddlebill is not as widespread and contiguous as has been assumed, and small peripheral populations are clearly sensitive to environmental changes. Similar responses to change are unclear in the core of the range, which is from Uganda and southern Kenya to western Zambia, northern Botswana, and northeastern South Africa. Additionally, South Sudan likely still holds a significant population: in

Article history

Received: 08 August 2020,
Accepted: 12 August 2020,
Published online: 05 October 2020

An adult female Saddle-billed Stork in Liuwa Plain National Park, 2019. Photographed by Jonah Gula.

1981, the last survey of the Sudd alone found approximately 4,000 (Howell *et al.* 1988). Occurrence and status in the Congo region remains mysterious, as it is unclear if the lack of recent records in comparison to historic records indicates population declines or a lack of recent ornithological coverage due to civil conflicts.

The apparent lack of stability of peripheral populations such as those in Somalia (although conflict has also prevented good coverage here more recently) and highly fragmented West Africa is a result of environmental degradation in the form of decades-long drought, nest-tree cutting (Somalia in particular), overfishing, and flood-altering dam construction. The Inner Niger Delta in Mali is perhaps the most telling example of the sensitivity to change: depletion of fisheries caused by the introduction of nylon fishing nets in the 1960s and subsequent dam construction in the 1980s resulted in extirpation of the isolated breeding population there (Zwarts *et al.* 2009). Habitat loss has also more recently caused Saddlebills to disappear from Togo. Therefore, the greatest concern is for the West African population–or metapopulations, as connectivity in the region is uncertain.

Currently, my Master's research is addressing the question of why Saddlebills occur where they do, now that we have established as much. I am using the program MaxEnt to model the climatic niches of the six endemic African storks so we can better understand the conditions they require and how this may feed into sensitivities to climate changes. Although my results are still preliminary, the models consistently show annual precipitation as the single most important climatic variable in predicting Saddlebill distribution. It also has the narrowest tolerance for precipitation, which helps explain why a drought, such as the one beginning in the 1970s in the Sahel, can quickly impact a population.

Even with our growing knowledge of Saddlebill distribution, we still do not know how many Saddlebills remain in Africa–although it is clear from the range assessment alone that they are decreasing in many countries. As peripheral populations continue to decline or vanish, it is time to start becoming concerned about this species. Rather than continue to assume a "Least Concern" status based on inadequate data, given what the initial assessment has shown, I believe we should be putting resources and effort into developing a detailed, data-driven assessment of the Saddlebill. To address this need, we are in the beginning stages of establishing a Saddlebill Working Group, which will be a collection of people interested in helping in the development of a long-term research and conservation agenda for the species. In particular, we hope to address the immediate research needs: movement ecology (research in Zambia is ongoing at this time), breeding distribution, reproductive cycle, and population estimates, trends, and connectivity.

The Saddlebill's conservation scenario is by no means unique. Many species have similarly been victims of scientific and conservation neglect despite status assessments that seem otherwise. It is time we reconsider the way in which poorly-studied, widespread species are assessed on the IUCN Red List, and begin a discussion on how the data deficiency of such species relates to the actual Red List status of "Data Deficient." The decline of species long perceived as "common" has been a slow creep up to this point, but globally we are learning how rapidly populations can be extinguished. It is time for species that are truly data deficient to be on our radar lest their declines catch us off guard.

References

Gula, J., F. Weckerly and K. S. G. Sundar. 2019. The first range-wide assessment of Saddle-billed Stork *Ephippiorhynchus senegalensis* distribution. *Ostrich* 90: 347-357.

Howell, P., M. Lock and S. Cobb. 1988. *The Jonglei Canal: impact and opportunity*. Cambridge University Press, Cambridge, United Kingdom.

Janák, J. i. 2014. Extinction of Gods: impact of climatic change on religious concepts. *Berliner Beiträge zum Vorderen Orient* 23: 121-131.

Zwarts, L., R. G. Bijlsma, J. van der Kamp and E. Wymenga. 2009. *Living on the edge: Wetlands and birds in a changing Sahel*. KNNV Publishing, Zeist, The Netherlands.

ISSN 2710-1142(online)
SIS Conservation, 2020, 2, 10-18
RESEARCH ARTICLE

Effects of seasonal hydrological connectivity on Eurasian Spoonbill *Platalea leucorodia* foraging ecology

Benjamin K. SULLENDER[1,2,*], Jeb BARZEN[3,4], Janet SILBERNAGEL[1]

[1]Nelson Institute for Environmental Studies, University of Wisconsin-Madison, 550 North Park Street, Madison, WI, 53706, USA
[2]Audubon Alaska, 431 West 7th Avenue, Suite 101, Anchorage, Alaska, 99501, USA
[3]International Crane Foundation, E-11376 Shady Lane Road, P.O. Box 447, Baraboo, Wisconsin, 53913, USA
[4]Current Address: Private Lands Conservation LLC, S-12213 Round River Trail, Spring Green, Wisconsin, 53588, USA
*Corresponding author; e.mail: bsullender@audubon.org

Abstract Seasonal inundation is a key aspect of flood pulse ecosystems, connecting otherwise isolated river channels and lakes into a panmictic floodplain. This period of hydrological connectivity is strongly linked with biological productivity. Particularly in systems that serve as winter refuge for migratory wildlife, time-lags exist between the increase of habitat productivity at lower trophic levels and increases in foraging at higher trophic levels. These time-lags make it difficult to assess the ecological importance of flooding solely through within-season observations. We examine the effects of hydrological connectivity on waterbird habitat selection to quantify the ecological impact of summer flooding on conditions during the following winter. We calculated the number of days in which summer overbank flow connected Sha Hu and Bang Hu sub-lakes of Poyang Lake (China) and then constructed a series of regression models comparing the area of preferred winter foraging habitat of Eurasian Spoonbill *Platalea leucorodia* with spoonbill use days under three different flooding conditions: years with above-average, average, and below-average duration of hydrological connectivity. In both the average and below-average inundation conditions, spoonbill use days were positively correlated with extent of preferred habitat, suggesting that spoonbills typically rely on these habitats for foraging. However, in years with greater hydrological connectivity, extent of preferred habitat and spoonbill use days were not related. Seasonal flood pulses play an important role in structuring Eurasian Spoonbill foraging behavior and the duration of connectivity in summer alters habitat use in winter.

Keywords Eurasian Spoonbill, *Platalea leucorodia*, flood pulse ecology, foraging habitat, habitat use, Poyang Lake, wintering ecology.

Introduction

Natural flow or pulse regimes are key drivers of productivity in floodplain wetland ecosystems (Bunn and Arthington 2002), and hydrological variability is particularly important for waterbird communities (Kingsford *et al*. 2004). Seasonal floods trigger productivity at a variety of trophic levels: inundation has a major role in nutrient cycling and brings inflows of organic carbon and other nutrients (Sparks 1995; Thoms 2003), leads to an increase in plant and invertebrate biomass (Anderson and Smith 2000; Sheldon *et al*. 2002; Jenkins and Boulton 2003), provides a vector for larger aquatic biota to re-colonize seasonally inhabited areas (Poff and Allan 1995), and, by increasing system-wide productivity, results in a higher abundance of predators that rely on these lower trophic levels (Kingsford *et al*. 2004).

Article history
Received: 11 November 2019,
Received in revised form: 02 August 2020,
Accepted: 06 August 2020,
Published online: 05 October 2020.

Floods such as overbank flows create hydrological connectivity, a key facet of flood pulse systems (Bunn and Arthington 2002) and of vital importance for waterbirds (Guadagnin and Maltchik 2007). In a connected basin, aquatic organisms may freely move throughout the entire floodplain system during the inundation phase. Within Poyang Lake, drawdowns in autumn and winter follow high water periods in summer (Shankman *et al*. 2006). During drawdowns, the receding water concentrates and eventually traps organisms in sub-basins, creating patches of high biomass throughout the wetland matrix (Beerens *et al*. 2011; Lorenz 2014). Migratory waterbirds arrive in winter during or after the drawdown period and utilize these areas of concentrated food items (Li *et al*. 2012).

Anthropogenic disturbance and regulation of natural flow regimes tend to degrade flood pulse ecosystems (Arthington and Pusey 2003; Kingsford and Thomas 2004). For example, upstream dam construction reduces or halts sediment flow, increases the difficulty of migration for aquatic biota, and reduces water minima and maxima (Kingsford and Thomas 2004; Guo *et al*. 2012). In ecosystems worldwide, disrupted natural flow regimes have consistently and dramatically reduced fish abundance (Naiman *et al*. 2002; Bunn and Arthington 2002) and eroded biodiversity (Brinson and Malvarez 2002; Tockner and Stanford 2002). These changes may be even more pronounced for waterbirds: artificial water level stabilization triggered an 80% or greater decline in waterbird abundance across all functional groups in Australia's Murray-Darling flood pulse ecosystem (Kingsford and Thomas 2004) and similar changes have occurred in the Yangtze system at Shengjin Lake (Fox *et al*. 2011).

Poyang Lake is at risk of hydrological disruption from extensive sand dredging (de Leeuw *et al*. 2010; Lai *et al*. 2014a) and potential construction of an outlet dam at Hukou (Wang *et al*. 2013). The Three Gorges Dam, nearly 1,000 km upstream, has been shown to significantly impact the middle-lower Yangtze River (Zhang *et al*. 2015), reducing variability and decreasing the annual mean water level (Lai *et al*. 2014b). Understanding the role of hydrological fluctuations in determining the food abundance and availability is the first step in mitigation of these effects.

This study assesses how summer flooding affects winter waterbird habitat use in Poyang Lake. In particular, we examine whether the duration of summer inundation (the period of connectivity) changes the relationship between Eurasian Spoonbill *Platalea leucorodia* abundance and extent of preferred spoonbill winter habitat. By quantifying the connectivity between a perennially productive sub-lake and the greater Poyang wetland complex, we categorize and compare annual hydrological conditions in relation to Eurasian Spoonbill habitat use. We hypothesize that 1) years with reduced summer connectivity will result in lower winter spoonbill densities and decreased use of suitable foraging habitat, indicating poorer foraging conditions; 2) years with typical connectivity will result in average densities and average use of suitable foraging habitat; and 3) years with greater connectivity will result in greater densities and decreased use of suitable foraging habitat due to increased prey abundance and superior foraging conditions.

Study area

During the summer wet season, Poyang Lake is the largest freshwater lake in China (Shankman *et al*. 2006) and provides critical wintering habitat for migratory waterbirds along the East Asian – Australasian Flyway (Barter *et al*. 2005; Wang *et al*. 2013). Poyang Lake serves both as a floodplain for the Yangtze River to the north and for five tributary rivers to the south. Flood pulses from these rivers seasonally inundate Poyang Lake as widespread overbank flows provide basin-wide hydrological connectivity (Shankman and Liang 2003; Wu *et al*. 2009). During the summer flood months, Poyang's surface area can increase to as large as 3,000 km^2 (Feng *et al*. 2013). During the autumn drawdown period, water is concentrated in smaller sub-basins such as those within the boundaries of Poyang Lake National Nature Reserve (PLNR). Within PLNR, Sha Hu sub-lake (N 29° 10', E 115° 56'; Figure 1) serves as wintering habitat for wading birds including the Eurasian Spoonbill and the endangered Oriental White Stork *Ciconia boyciana* (Zeng *et al*. 2012).

Methods

Four analyses were performed with hydrological and

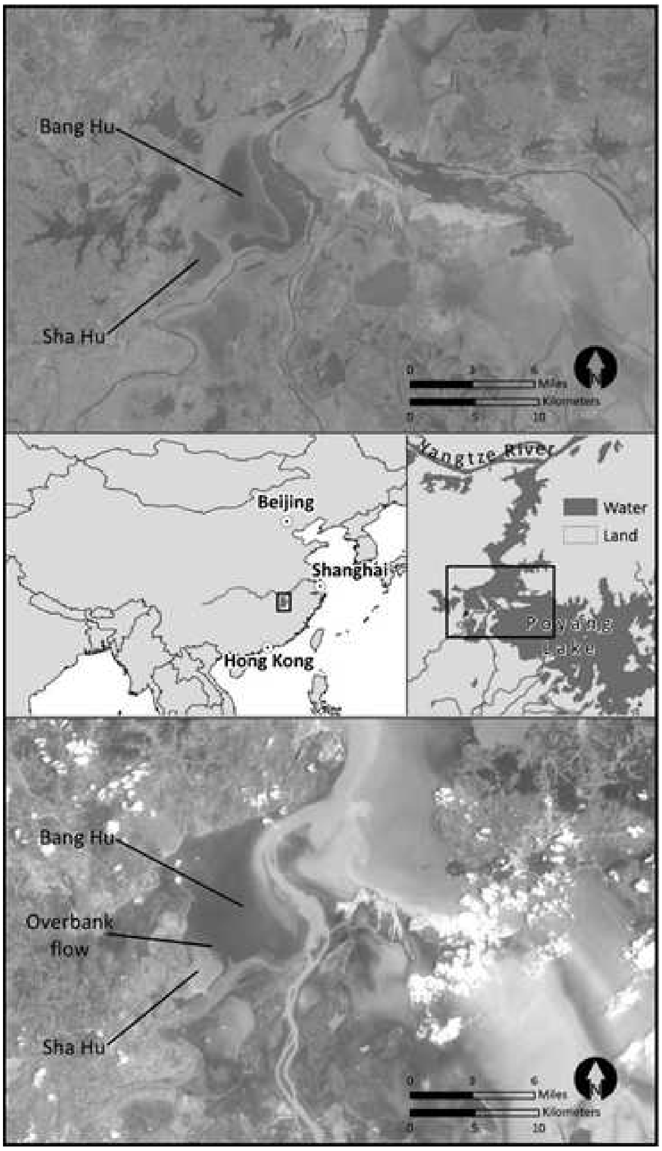


Figure 1. The location of Poyang Lake and examples of water level variation in the northwestern area of the lake between winter lows (top), where each sub-lake becomes separated from the greater Poyang Basin except by shallow channels, and summer highs (bottom), where many sub-lakes like Sha Hu become one connected hydrological system. All images from Landsat 8 (data available from the U.S. Geological Survey).

spoonbill observation data: 1) categorization of each year into an inundation class, 2) across-year comparisons of spoonbill abundance, 3) within-year spoonbill density comparisons by inundation class, and 4) within-year regression models of suitable foraging area and bird use days by inundation class. Both within-year analyses used moving averages.

Hydrological data and inundation classes

Based on Landsat 7 and 8 imagery from 2008-2015, we determined when Sha Hu sub-lake was connected to the main body of Poyang Lake through Bang Hu sub-lake (Figure 1). Satellite imagery on all available, cloud-free days were compared with the same day's water level as measured at a staff gauge at Sha Hu (International Crane Foundation, unpublished data) to determine water levels during flooding. This inundation threshold was estimated as 16.5 m above sea level (Wu Song datum).

Long-term data were collected through a monitoring protocol shared by the International Crane Foundation (ICF) and Poyang Lake National Nature Reserve (PLNR). For hydrology, these data were collected by daily observations of water level at a central staff gauge in the Sha Hu sub-lake. Based on these data, we calculated the number of days when water depth in the Sha Hu basin exceeded the inundation threshold and summed these days for each year. Next, we categorized each year into one of three inundation classes based on how that year's number of flooded days compared to the 12-year average. All years with water levels greater than one standard deviation (SD) below the 12-year average were classified as below-average, all years with water levels within one SD were classified as average, and all years greater than one SD above the average were classified as above-average.

Spoonbill observation data

As with hydrological data, long-term observation data were collected by ICF and PLNR. Specifically, bird surveys across the entire sub-lake were conducted every seven or 10 days during the winter season (October to March). Protocol involved systematic scan sampling from a central observation point.

During these surveys, absences were not recorded and were populated a posteriori. Since bird arrival dates at Poyang varied by year, no absences were generated until after the season's first recorded bird presence. After all wintering periods were populated with absences, we calculated bird counts for each day using linear interpolation from observed counts and generated absences.

Across-year comparisons

We summed interpolated counts for each winter to get a cumulative number of spoonbills at Sha Hu. We plotted the cumulative number of spoonbills against year to investigate whether general trends existed across years, and ran a regression model using hydrologically connected days as the predictor variable to investigate whether summer conditions alone were correlated with bird abundance.

Within-year moving averages

To account for potential time-lags between changes in habitat quality and bird abundance, interpolated bird count data were also used to calculate moving averages. If an area's food supply became unavailable or was exhausted, birds could delay their response to changing conditions and continue to search for food. Eventually, as foraging birds are unable to satisfy nutritional requirements, we expected them to move to a more productive site if one existed. However, the amount of time between habitat condition shift and bird response was unknown.

Sensitivity analysis suggested that a 10-day window provided the best duration for a moving average. For each day (hereafter, an anchor point), we calculated the average interpolated bird count using count data from the 10 days before and after that point.

To compare the amount of foraging habitat available in Sha Hu, we averaged winter water level for each window, using the same window sizes and anchor points. Winter water level was measured only at a central staff gauge located in Sha Hu, from which we extrapolated across a regional digital elevation model (Sullender *et al*. 2016). We then reclassified the resulting raster data and summed the number of cells with preferred foraging water depth, defined as a water level between 28.1 cm and 36.6 cm (Sullender *et al*. 2016). 10-day window averages of suitable foraging area and number of spoonbills were then aggregated by year and labeled by inundation class (below-average, average, and above-average).

Within-year density comparison

We divided the 10-day window average for bird abundance by a measure of average suitable habitat within the 10-day window to calculate the density of spoonbills (individuals/ha). We log-transformed data to satisfy assumptions of normality and ran a one-way ANOVA to investigate significance and a post-hoc Tukey's Honestly Significant Differences (Tukey's HSD) test to compare differences in inundation classes. Because consecutive data points were not temporally independent, we split the dataset into 21 non-overlapping windows and ran the same tests.

Within-year regression models

To satisfy the normality assumption, we square-root transformed bird use days and used these data as the response variable in a series of 21 linear regression models, taking the moving average of suitable foraging habitat area as the predictor variable. We then calculated the percentage of models returning a significant correlation ($p < 0.05$) and calculated the overall values for each coefficient, each inundation class across all models and within only significant models. Program R (R Development Core Team 2015) was used for all analyses.

Results

Inundation classes

We categorized each year's data into three groups based on number of inundated days: below-average, average, and above-average years. 2 years (2006 and 2011) had greater than one SD below the mean number of connected days, 7 years were within one SD of the average, and 3 years (2010, 2012, and 2013) had greater than one SD above the mean number of connected days (Figure 2).

Across-year comparisons

The cumulative number of spoonbills ranged from 12,558 in 2013 to 216,395 in 2011, with an average of 109,481 birds per year (Figure 3). The cumulative number of spoonbills generally declined as connected days increased (Figure 4), although this relationship was not significant (p = 0.26).

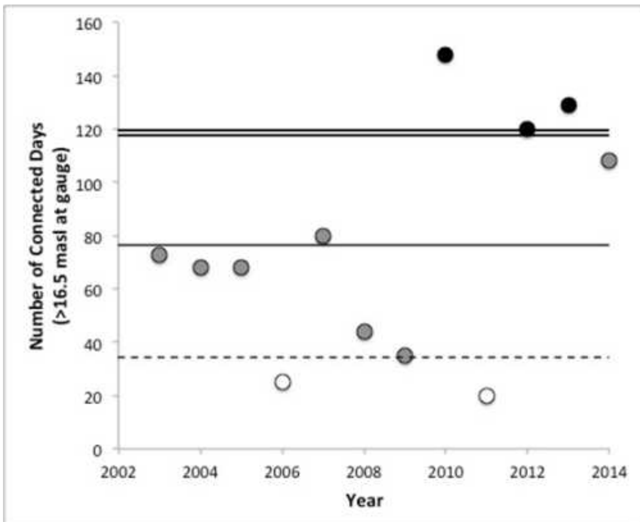


Figure 2. Determining annual inundation class groups. Inundation class measured by the annual number of days when seasonal flooding connected the Bang Hu sub-lake with the Sha Hu sub-lake. The solid black line illustrates the 12-year mean number of connected days, the dotted line shows one SD less than mean, and the double line shows one standard deviation (SD) greater than mean. White points represent below-average years, grey points represent average years, and black points represent above-average years for connectivity.

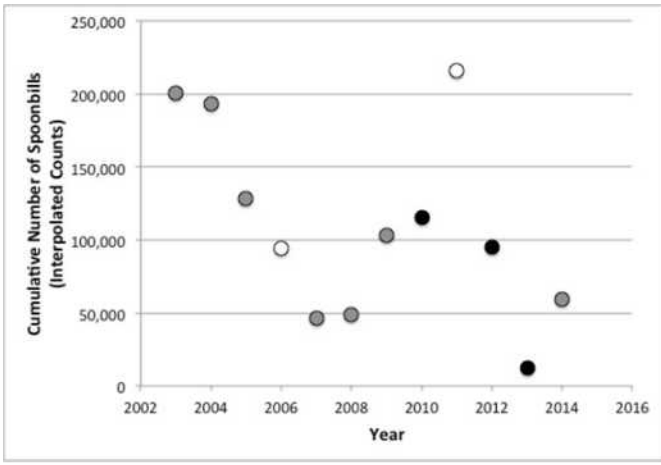


Figure 3. Cumulative number of Eurasian Spoonbills by year. Total cumulative number of Eurasian Spoonbills observed at Sha Hu sub-lake by year (2003-2014). Data points colored according to inundation class: white represents below-average inundation, gray represents average inundation, and black represents above-average inundation (see Figure 2 for inundation class definitions).

Within-year density comparisons

Although there appeared to be differences in Eurasian Spoonbill density across inundation classes (Figure 5), the use of moving windows made data non-independent. When data were aggregated into 21 separate datasets to remove overlap, no difference in spoonbill density was found among all inundation classes (minimum p = 0.46).

Within-year regression models

The relationship between Eurasian Spoonbill usage of Sha Hu and extent of suitable foraging area varied considerably across inundation classes (Table 1). For years with a below-average number of connected days, only two models had a significant relationship, both of which had positive slopes (Figure 6). For years with an average number of connected days, 16 of 21 models had significant positive relationships (slope > 0; $p < 0.05$) between suitable foraging extent and bird usage (Figure 7). In years with above-average inundation there was no relationship between spoonbill bird use days and suitable foraging extent ($p > 0.05$ for each model, $N = 21$ models, Figure 8). To remove consecutive anchor days from the same regression, each year's data was split into 21 sets and a linear regression model was run for each set.

Discussion

Summer conditions appear to play an important role in determining spoonbill habitat usage the following winter, and our results support most of our hypotheses. Because foraging is the most frequent behavior and comprises the highest proportion of Eurasian Spoonbill activity budget at Sha Hu (Sullender *et al*. 2016), we analyzed extent of preferred foraging habitat to test whether foraging conditions are related to summer hydrological connectivity. In years with a typical duration of flooding, spoonbills appear to be reliant on preferred foraging habitat – as more habitat is available, utilization increases. In contrast, years with below-average connectivity demonstrate a weaker but positive relationship between extent of foraging habitat and spoonbill usage. These results are consistent with our hypothesis. Contrary to our hypothesis, years with above-average connected days appear to render extent of suitable habitat an insignificant predictor of bird usage, as indicated by the discrepancy between slopes and the proportion of significant models.

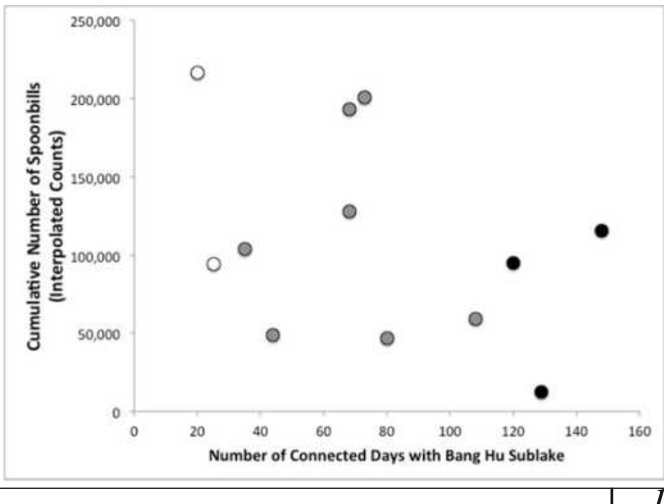


Figure 4. Cumulative number of Eurasian Spoonbills by duration of connectivity. Total cumulative number of Eurasian Spoonbills observed at Sha Hu sub-lake plotted against number of days when Sha Hu sub-lake was hydrologically connected with Bang Hu sub-lake (water level at Sha Hu marker >16.5 masl). Data points colored according to inundation class: white represents below-average inundation, gray represents average inundation, and black represents above-average inundation (see Figure 2 for inundation class definitions).

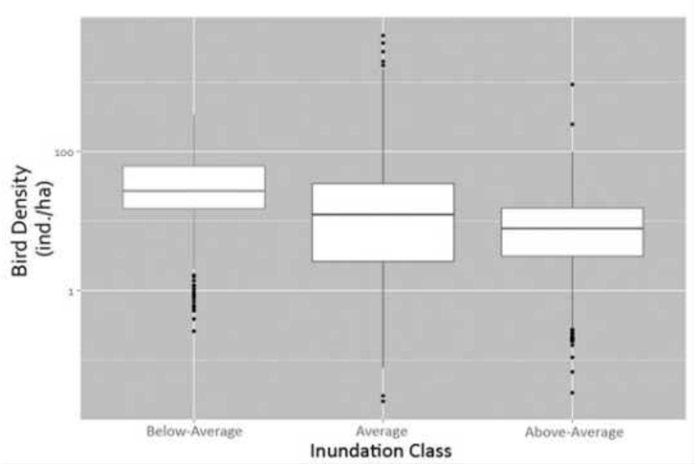


Figure 5. Boxplot of Eurasian Spoonbill density by inundation class. Each data point represents the 21-day moving average bird abundance divided by the 21-day moving average extent of suitable foraging area at Sha Hu sub-lake. Subsequent data points are non-independent and therefore, although the aggregated data as above appear to be significantly different, analysis of non-overlapping densities suggests inundation classes did not differ.

Waterbird occurrence and abundance have been widely correlated with habitat area (David 1994; Tozer *et al*. 2010; Zheng *et al*. 2015), particularly within other seasonally inundated wetland systems (e.g. Ma *et al*. 2009; Lorenz 2014) and within Poyang Lake (Sullender *et al*. 2016). In instances where bird abundance fails to reflect in-season extent of suitable habitat, myriad factors such as off-season conditions, population fluctuations, availability of alternate habitat, predation or disturbance, and changes in food resources may be altering this fundamental relationship (Tellería and Pérez-Tris 2003). Our study identifies duration of summer hydrological connectivity as a significant factor that impacts waterbird winter habitat use.

Table 1. Linear regression results of Eurasian Spoonbill use days by suitable foraging area.

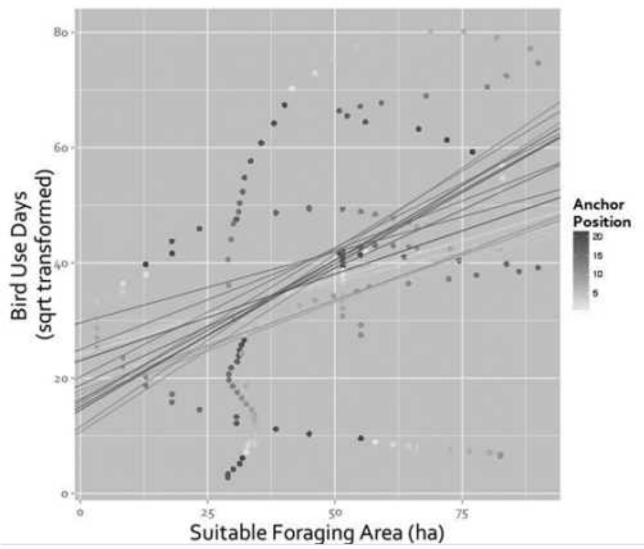
Inundation class	Average intercept	Average slope	Average slope of significant regression models	Number of significant regression models	Percent of total
Below-average	18.61	0.38	0.58	2	10%
Average	9.23	0.31	0.34	16	76%
Above-average	23.42	-0.07	N/A	0	0%

Substantial evidence supports the ecological importance of seasonal flooding. Flooding both supplies the trophic system with nutrients and provides a movement vector for fish and mobile prey items (Goss *et al*. 2014). Results of seasonal flooding include higher productivity, greater fish yields, and a variety of other indicators of prey item abundance (Tockner and Stanford 2002; Ausden 2004). Conversely, disruption of normal flood dynamics – such as imposed hydrological stabilization – has been shown to negatively impact waterbird habitat use (Kingsford 2000), reduce waterbird abundance (Kingsford and Thomas 2004; Fox *et al*. 2011) and even trigger ecosystem-scale changes (Bunn and Arthington 2002). Disruption of normal flood dynamics and ecological responses can also occur with extreme events such as higher than average flooding (Tryjanowski *et al*. 2009).

Our study refines the specific ecological role of flooding in the Poyang ecosystem. We used the duration of the hydrologically connected period as a proxy for the volume of nutrients, organic matter, and aquatic organisms that are transferred between the greater Yangtze River, Poyang Lake, and the Sha Hu sub-lake. With overbank flows to transport mobile prey, food items can accumulate in deeper basins such as Sha Hu. After flooding subsides, the drawdown period concentrates food items so that when wintering migrant birds arrive, there will typically be high densities of food distributed across suitable foraging habitat (Burnham *et al*. 2017). In years with average summer connectivity, spoonbill abundance was positively correlated with suitable foraging extent. Years with less than average connectivity exhibited similar but weaker relationships, and years with greater than average connectivity decoupled this relationship entirely.

There are a number of other factors that characterize flood pulse systems, such as the magnitude of flooding. During the summer of 2010, for example, Poyang Lake was exposed to such severe flooding that submerged aquatic vegetation grew poorly, if at all (Burnham *et al*. 2017), due to high water levels preventing photosynthetically active radiation from reaching lakebeds (Wu *et al*. 2009). Birds that fed on these plants were displaced and forced to adopt novel foraging strategies because typical habitats were rendered unusable (Burnham *et al*. 2017). Although Eurasian Spoonbills do not directly eat vegetation (Aguilera *et al*. 1996; Sullender *et al*. 2016), preferred prey items may depend upon plants. Since abnormally high flood waters in the Poyang ecosystem may disrupt the vegetation

Figure 6. Relationship between suitable foraging area and Eurasian Spoonbill habitat usage in years with below-average summer hydrological connectivity (2006, 2008, and 2011). Only two of the 21 models showed significant relationships. Data were partitioned into 21 non-overlapping groups and a linear regression model was constructed for each group. Groups of data are indicated by the hue of the points and corresponding regression lines.



community and decrease primary productivity (Wu *et al*. 2009), we suggest that spoonbill prey items may exhibit declines corresponding to declines in vegetative food sources under extreme flooding. However, because our study shows that absolute abundance and densities of spoonbills are not related to duration of connectivity, these declines are likely manifested in altered foraging behaviors, rather than altered habitat use and spoonbill distribution.

Additional data would allow these hypotheses to be directly tested. Future studies incorporating measurements of in-system productivity such as repeated surveys of fish biomass at a fine-scale temporal resolution would allow researchers to identify the specific relationships between flooding and food abundance within Poyang Lake. When coupled with our results, emerging statistical methods such as multivariate autoregressive models (Ives *et al*. 2003; Batt *et al*. 2017) may better identify temporally offset phenomena as sufficient long-term datasets become available. Additionally, aside from magnitude and duration, other flood-related variables that drive ecological processes in flood pulse systems include frequency, timing, and rate of change (Poff *et al*. 1997). Although our study did not examine aspects of flooding besides duration, other factors such as magnitude have clearly identified impacts and should be assessed in combination with our findings regarding duration of flood.

Within Poyang Lake, seasonal inundation connects sub-lakes and rivers and, through physical exchanges at multiple trophic levels, creates highly productive patches. Our study indicates that the duration of summer flooding – hydrological connectivity – alters winter foraging conditions of the Eurasian Spoonbill. In particular, Eurasian Spoonbills rely on preferred habitat patches after years with below-average or average connectivity. In years with above-average connectivity, however, this relationship destabilizes, suggesting that the system's productivity and food abundance are affected by the duration of flooding.

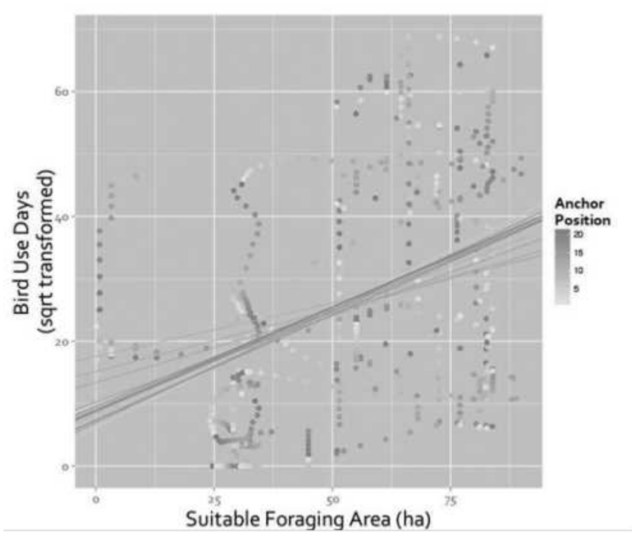


Figure 7. Relationship between suitable foraging area and Eurasian Spoonbill habitat usage in years with average summer hydrological connectivity (2003, 2004, 2005, 2007, 2009, and 2014). Sixteen of the 21 models had significant relationships. Methods and data are as indicated in Figure 6. Groups of data are indicated by the hue of the points and corresponding regression lines.

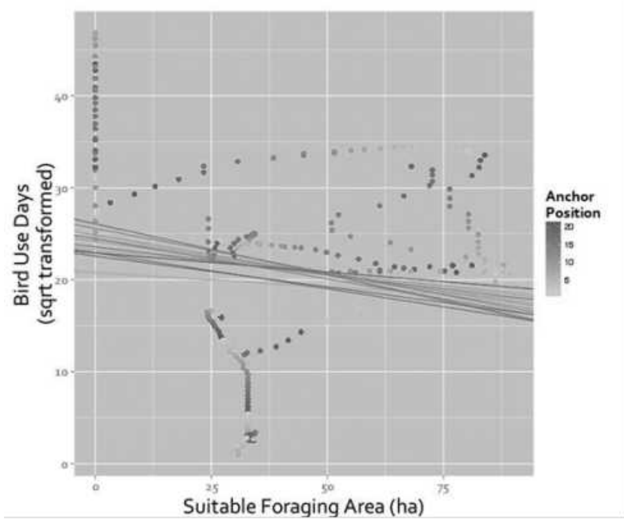


Figure 8. Relationship between suitable foraging area and Eurasian Spoonbill habitat usage in years with above-average summer hydrological connectivity (2010, 2012, and 2013). No models showed significant relationships. Methods and data are as indicated in Figure 6. Groups of data are indicated by the hue of the points and corresponding regression lines.

Acknowledgments

We thank J. Burnham, J. Vander Zanden, and F. Li for guidance and advice. We also thank our collaborators at Nanchang University and Poyang Lake National Nature Reserve, including H. Qin, B. Jin, X. Wu, and G. Liu.

References

Aguilera, E., C. Ramo, and C. de le Court. 1996. Food and feeding sites of the Eurasian Spoonbill (*Platalea leucorodia*) in southwestern Spain. *Colonial Waterbirds* 19: 159-166.

Anderson, J. and L. Smith. 2000. Invertebrate response to moist-soil management of playa wetlands. *Ecological Applications* 10: 550-558.

Arthington, A. H. and B. J. Pusey. 2003. Flow restoration and protection in Australian rivers. *River Research and Applications* 19: 377-395.

Ausden, M. 2004. Habitat management. Pp. 329-362. In: Sutherland, W. J., I. Newton and R. Green (eds.). *Bird ecology and conservation: a handbook of techniques*. Oxford University Press, Oxford, United Kingdom.

Barter, M., L. Cao, L. Chen and G. Lei. 2005. Results of a survey for waterbirds in the lower Yangtze floodplain, China, in January-February 2004. *Forktail* 21: 1-7.

Batt, R. D., S. R. Carpenter and A. R. Ives. 2017. Extreme events in lake ecosystem time series. *Limnology and Oceanography Letters* 2: 63-69.

Beerens, J. M., D. E. Gawlik, G. Herring and M. I. Cook. 2011. Dynamic habitat selection by two wading bird species with divergent foraging strategies in a seasonally fluctuating wetland. *The Auk* 128: 651-662.

Brinson, M. M. and A. I. Malvárez. 2002. Temperate freshwater wetlands: types, status, and threats. *Environmental Conservation* 29: 115-133.

Bunn, S. E. and A. H. Arthington. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental Management* 30: 492-507.

Burnham, J., J. Barzen, A. M. Pidgeon, B. Sun, J. Wu, G. Liu and H. Jiang. 2017. Novel foraging by wintering Siberian Cranes *Leucogeranus leucogeranus* at China's Poyang Lake indicates broader changes in the ecosystem and raises new challenges for a critically endangered species. *Bird Conservation International* 27: 204-223.

David, P. G. 1994. Wading bird use of Lake Okeechobee relative to fluctuating water levels. *The Wilson Bulletin* 106: 719-732.

Feng, L., C. Hu, X. Chen and X. Zhao. 2013. Dramatic inundation changes of China's two largest freshwater lakes linked to the Three Gorges Dam. *Environmental Science and Technology* 47: 9628-9634.

Fox, A. D., L. Cao, Y. Zhang, M. Barter, M. J. Zhao, F. J. Meng and S. L. Wang. 2011. Declines in the tuber-feeding waterbird guild at Shengjin Lake National Nature Reserve, China–a barometer of submerged macrophyte collapse. *Aquatic Conservation: Marine and Freshwater Ecosystems* 21: 82-91.

Goss, C. W., W. F. Loftus and J. C. Trexler. 2014. Seasonal fish dispersal in ephemeral wetlands of the Florida Everglades. *Wetlands* 34: 147-157.

Guadagnin, D. L. and L. Maltchik. 2007. Habitat and landscape factors associated with neotropical waterbird occurrence and richness in wetland fragments. *Biodiversity and Conservation* 16: 1231-1244.

Guo, H., Q. Hu, Q. Zhang and S. Feng. 2012. Effects of the three gorges dam on Yangtze river flow and river interaction with Poyang Lake, China: 2003–2008. *Journal of Hydrology* 416: 19-27.

Ives, A., B. Dennis, K. Cottingham and S. Carpenter. 2003. Estimating community stability and ecological interactions from time-series data. *Ecological Monographs* 73: 301-330.

Jenkins, K. and A. Boulton. 2003. Connectivity in a dryland river: Short-term aquatic microinvertebrate recruitment following floodplain inundation. *Ecology* 84: 2708-2723.

Kingsford, R. T. 2000. Ecological impacts of dams, water diversions and river management on floodplain wetlands in Australia. *Austral Ecology* 25: 109-127.

Kingsford, R. T. and R. Thomas. 2004. Destruction of wetlands and waterbird populations by dams and irrigation on the Murrumbidgee River in arid Australia. *Environmental Management* 34: 383-396.

Kingsford, R. T., K. Jenkins and J. Porter. 2004. Imposed hydrological stability on lakes in arid Australia and effects on waterbirds. *Ecology* 85: 2478-2492.

Lai, X., Q. Liang, J. Jiang and Q. Huang. 2014a. Impoundment effects of the Three-Gorges-Dam on flow regimes in two China's largest freshwater lakes. *Water Resources Management* 28: 5111-5124.

Lai, X., D. Shankman, C. Huber, H. Yesou, Q. Huang and J. Jiang. 2014b. Sand mining and increasing Poyang Lake's discharge ability: A reassessment of causes for lake decline in China. *Journal of Hydrology* 519: 1698-1706.

de Leeuw, J., D. Shankman, G. Wu, W. F. de Boer, J. Burnham, Q. He, H. Yesou and J. Xiao. 2010. Strategic assessment of the magnitude and impacts of sand mining in Poyang Lake, China. *Regional Environmental Change* 10: 95-102.

Li, F., G. Liu, J. Wu, N. Zeng, J. Harris and J. Jin. 2012. *Ecological study of wetlands and waterbirds at Poyang Lake*. Popular Science Press, Beijing, China.

Lorenz, J. J. 2014. The relationship between water level, prey availability and reproductive success in Roseate Spoonbills foraging in a seasonally-flooded wetland while nesting in Florida Bay. *Wetlands* 34: 201-211.

Ma, Z., Y. Wang, X. Gan, B. Li, Y. Cai and J. Chen. 2009. Waterbird population changes in the wetlands at Chongming Dongtan in the Yangtze River estuary, China. *Environmental Management* 43: 1187-1200.

Naiman, R. J., S. E. Bunn, C. Nilsson, G. E. Petts, G. Pinay and L. C. Thompson. 2002. Legitimizing fluvial ecosystems as users of water: an overview. *Environmental Management* 30: 455-467.

Poff, N. L. and J. D. Allan. 1995. Functional organization of stream fish assemblages in relation to hydrological variability. *Ecology* 76: 606-627.

Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. D. Richter, R. E. Sparks and J. C. Stromberg. 1997. The natural flow regime. *BioScience* 47: 769-784.

R Development Core Team. 2015. R: A language and environment for statistical computing, v. 3.2.3. R Foundation for Statistical Computer, Vienna, Austria. https://www.R-project.org/, accessed 27 June 2016.

Shankman, D. and Q. Liang. 2003. Landscape changes and increasing flood frequency in China's Poyang Lake region. *The Professional Geographer* 55: 434-445.

Shankman, D., B. D. Keim and J. Song. 2006. Flood frequency in China's Poyang Lake region: trends and teleconnections. *International Journal of Climatology* 26: 1255-1266.

Sheldon, F., A. J. Boulton and J. T. Puckridge. 2002. Conservation value of variable connectivity: aquatic invertebrate assemblages of channel and floodplain habitats of a central Australian arid-zone river, Cooper Creek. *Biological Conservation* 103: 13-31.

Sparks, R. E. 1995. Need for ecosystem management of large rivers and their floodplains. *BioScience* 45: 168-182.

Sullender, B. K., J. Barzen and J. Silbernagel. 2016. Foraging success and habitat selection of the Eurasian Spoonbill (*Platalea leucorodia*) at Poyang Lake, China. *Waterbirds* 39: 356-364.

Tellería, J. L. and J. Pérez-Tris. 2003. Seasonal distribution of a migratory bird: effects of local and regional resource tracking. *Journal of Biogeography* 30: 1583-1591.

Thoms, M. C. 2003. Floodplain–river ecosystems: lateral connections and the implications of human interference. *Geomorphology* 56: 335-349.

Tockner, K. and J. A. Stanford. 2002. Riverine flood plains: present state and future trends. *Environmental Conservation* 29: 308-330.

Tozer, D. C., E. Nol and K. F. Abraham. 2010. Effects of local and landscape-scale habitat variables on abundance and reproductive success of wetland birds. *Wetlands Ecology and Management* 18: 679-693.

Tryjanowski, P., T. H. Sparks and P. Profus. 2009. Severe flooding causes a crash in production of white stork (*Ciconia ciconia*) chicks across Central and Eastern Europe. *Basic Applied Ecology* 10: 387-392.

Wang, Y., Y. Jia, L. Guan, C. Lu, G. Lei, L. Wen and G. Liu. 2013. Optimising hydrological conditions to sustain wintering waterbird populations in Poyang Lake National Natural Reserve: implications for dam operations. *Freshwater Biology* 58: 2366-2379.

Wu, G., J. de Leeuw, A. K. Skidmore, H. H. Prins, E. P. Best and Y. Liu. 2009. Will the Three Gorges Dam affect the underwater light climate of *Vallisneria spiralis* L. and food habitat of Siberian crane in Poyang Lake? *Hydrobiologia* 623: 213-222.

Zeng, N., G. Liu, X. Wu, H. Xiong and Y. Huang. 2012. Oriental stork and white spoonbill monitoring. Pp. 85-95. In: Li, F., G. Liu, J. Wu, N. Zeng, J. Harris and J. Jin (eds.). *Ecological study of wetlands and waterbirds at Poyang Lake*. Popular Science Press, Beijing, China. 271 pp.

Zhang, Z., X. Chen, C. Y. Xu, Y. Hong, J. Hardy and Z. Sun. 2015. Examining the influence of river–lake interaction on the drought and water resources in the Poyang Lake basin. *Journal of Hydrology* 522: 510-521.

Zheng, M., L. Zhou, N. Zhao and W. Xu. 2015. Effects of variation in food resources on foraging habitat use by wintering Hooded Cranes (*Grus monacha*). *Avian Research* 6: 11.

ISSN 2710-1142(online)
SIS Conservation, 2020, 2, 19-28
RESEARCH ARTICLE

Colonial waterbird breeding in the Gayini-Nimmie-Caira wetlands, Australia, 2010-2011

Kate J. BRANDIS[1,*], Sharon RYALL[1], Richard T. KINGSFORD[1], Daniel RAMP[2]

[1]Centre for Ecosystem Science, School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, NSW 2052, Australia
[2]Centre for Compassionate Conservation, University of Technology Sydney, Broadway 2055, Australia
*Corresponding author; e.mail: Kate.Brandis@unsw.edu.au

Abstract Globally, irrigated agricultural landscapes represent about 20% of all cultivated land. In many areas of the world they can provide significant waterbird habitat. In Australia, the Murray Darling Basin, the stronghold of colonial waterbird breeding wetlands, contains 70% of the nation's irrigation resources. In 2010 two colonial waterbird colonies were established on natural wetlands in an irrigated agricultural landscape on the lower Murrumbidgee floodplain in eastern Australia. An estimated 50,000 ibis, spoonbill and cormorants bred at the two colonies. A total of 1,555 nests were monitored throughout the breeding event. Overall nest success was high (72% to 75%). Water was actively managed for the two colonies to ensure that falling water levels which can cause nest desertion were avoided and the two colonies recorded high reproductive success.

Keywords Ibis, Lowbidgee, Murray-Darling Basin, reproductive success, water management.

Introduction

Irrigation is the largest global water use sector accounting for ~70% of freshwater extraction and covering an area of 301 million ha (Siebert *et al*. 2010). Traditionally there has been a competition for water resources for wildlife conservation and irrigated agriculture (Lemly *et al*. 2000). However, areas of irrigated agriculture can provide critical habitat for many species of waterbirds in areas that have been heavily modified by anthropogenic changes (Czech and Parsons 2002). In the United States, croplands cover one fifth of the country's total area, forming an extremely large part of the ecological landscape (Huner *et al*. 2002). Similarly, in China, irrigated agriculture covers 66.1 million ha (Hu 2016) and can provide key breeding and feeding habitat for a range of waterbird species (Wood *et al*. 2010). In Australia, areas of irrigated agricultural areas are increasing, while natural wetlands are lost or degraded due to river regulation and water development (Kingsford 2000).

In Australia, a small number of key wetlands (less than 4% of all wetlands) are used by colonial waterbirds for breeding (Brandis 2010). The Murray Darling Basin (MDB) is the main region for wetlands used by colonially breeding waterbirds in Australia with 46% (2,596,209 ha; Bino *et al*. 2016) of wetlands in the Basin supporting breeding. The MDB covers 14% of Australia's land area, but accounts for 52% of Australia's total water consumption. In 2018-19, 94% of water consumed in the MDB was consumed by the agriculture industry (ABS 2020). In 2014 - 15, the MDB contained 66% of Australia's irrigated land (ABARES 2020).

Article history
Received: 31 July 2020,
Received in revised form: 20 November 2020,
Accepted: 20 November 2020,
Published online: 08 December 2020.

Impacts from water resource development have been recorded at several key waterbird breeding sites in the MDB. In the Macquarie Marshes, colony sizes, species abundance, species diversity and breeding frequency have all been reduced following reductions in flows (Kingsford and Thomas 1995, Kingsford and Johnson 1998). Similar impacts have also been reported in other major wetlands in the MDB including the Narran Lakes (Brandis *et al*. 2018), the Barmah-Millewa Forest (Leslie 2001) and the lower Murrumbidgee Floodplain (Kingsford and Thomas 2004).

The lower Murrumbidgee River floodplain, hereafter referred to as the Lowbidgee (Figure 1), has a long history of water development with the first flow altering structures established in 1928 (Murrumbidgee Catchment Management Authority 2009). Since then at least 77% of wetlands in the Lowbidgee have been impacted as a result of dams, diversions and floodplain development. Consequently, long-term monitoring found that that waterbird abundance dropped by 90% in the period 1983-1999 (Kingsford and Thomas 2004), however since 2010, post drought and changes to water management at waterbird colonies, abundances have stabilised (Kingsford *et al*. 2020).

The region contains a mosaic of pasture, irrigated agriculture, forestry and floodplain wetlands on private and protected lands (Yanga National Park), which support a range of waterbird habitats when inundated including breeding, roosting and foraging sites. During this study, the region was one of Australia's most intensively farmed with extensive water management infrastructure including large channels, levee banks, pumps and weirs to regulate overland flow movements. More recently (2018) this area has been returned to conservation through the Gayini-Nimmie-Caira project and transferred to indigenous ownership (https://www.natureaustralia.org.au/what-we-do/our-priorities/land-and-freshwater/land-freshwater-stories/gayini/).

This study aimed to monitor and quantify the reproductive success of two colonial waterbird colonies to advise on water requirements for successful ibis and spoonbill breeding in these wetlands and other sites in the Murray-Darling Basin.

Methods

Significant local and upper catchment rainfall during 2010 resulted in localised flooding and large river flows in the Murrumbidgee River catchment in southern New South Wales (NSW), Australia. The Murrumbidgee River is the third largest river in Australia flowing for 1,485 km with a catchment area of 81,641 km^2 (MDBA 2020). The Murrumbidgee

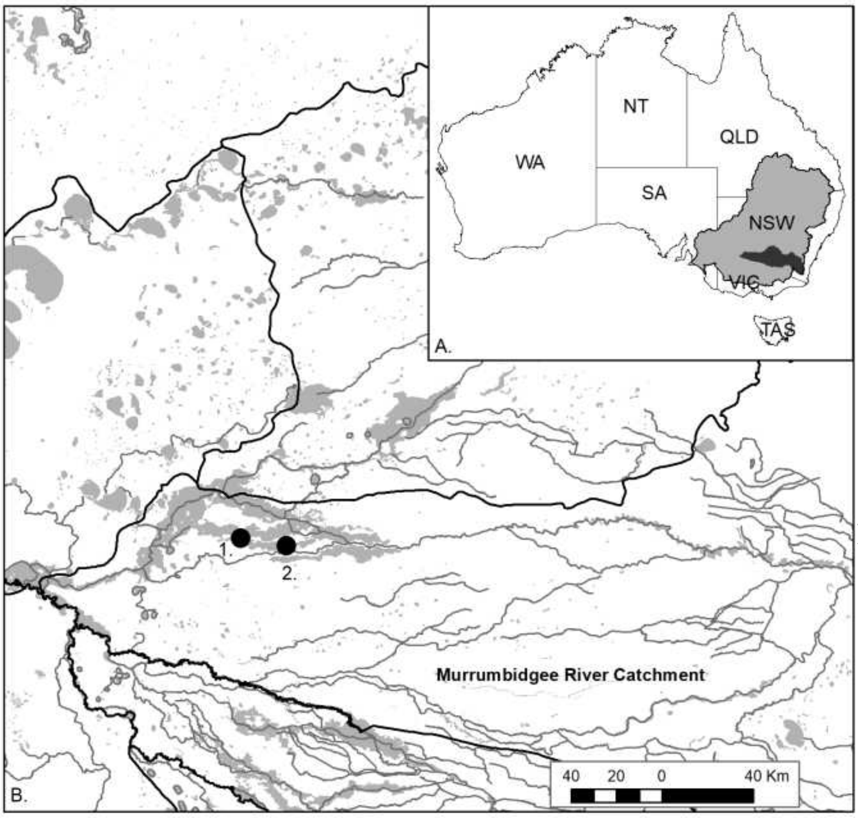


Figure 1. A. Location of the Murrumbidgee Catchment (dark grey) within the Murray Darling Basin (light grey) in south-eastern Australia. B. The location of 1. Telephone Bank Swamp and 2. Eulimbah Swamp waterbird breeding colonies in the lower Murrumbidgee floodplain (Lowbidgee). Catchment boundaries (black lines), river channels (grey lines) and wetland areas (grey shading) also shown.

River is regulated for most of its length with 26 dams and wiers and over 10,000 km of irrigation canals (Page *et al*. 2005).

The Lowbidgee covers an area of 217,000 ha km^2 and contains the largest areas of wetlands (Rogers *et al*. 2013) remaining in the Murrumbidgee River. It is an area of national and international significance providing habitat for fifteen migratory bird species listed on international agreements (JAMBA 1981, CAMBA 1988, ROKAMBA 2006), and endangered and vulnerable flora (6) and fauna species (32; EPBC Act 1999). The Lowbidgee is key breeding area for colonial waterbirds in Australia (Brandis 2010), with breeding recorded at 34 wetlands 2006-2016 (Spencer 2017). In October 2010 two colonial waterbird breeding colonies established on private wetlands in the Gayini-Nimmie-Caira system in the Lowbidgee (Figure 1).

Study site

The 'Torry Plains' property is situated on the floodplain of the Nimmie-Caira Creek in the Lowbidgee, NSW. The Nimmie-Caira is a distributary creek system of the lower Murrumbidgee River. 'Torry Plains' was an agricultural property producing irrigated organic wheat. It employed a system of levee banks, flood gates and pumps to move water across the landscape. This infrastructure was utilised during the 2010/2011 colonial waterbird breeding event to manage water levels and flow rates at colony sites.

Local rainfall (measured at Nap Nap (075049) (Australian Government Bureau of Meterology 2011) during 2010 recorded eight months of higher than the long-term average (1889 - 2011). High local rainfall continued into early 2011 maintaining river flows (Figure 2). During late September 2010 Telephone Bank Swamp and Eulimbah Swamp on the Tori Plains property became inundated. These sites are the largest regularly used ibis colony sites in the Lowbidgee (Kingsford *et al*. 2020).

Eulimbah Swamp lies behind a levee bank created in 1986 that crosses the entire width of the Nimmie-Caira creek floodplain (Murrumbidgee Catchment Management Authority 2009; Figure 1). It is used for water holding and to supply water along channels to other parts of the floodplain. It covers an area of 600 ha and has a maximum capacity of 3,000 ML (DWR 1994), it is confined on all sides by levee banks. It is usually inundated once every two years (Wassens 2008). Eulimbah Swamp is a Lignum shrubland *Duma florulenta* dominated swamp with small areas of Common Reed *Phragmites australis* and cumbungi *Typha latifolia*.

Telephone Bank Swamp is located on Pollen Creek (Figure 1). The Telephone Bank levee was built in 1960. The Telephone Bank Swamp is approximately 1,000 ha when inundated (DWR 1994). The swamp consists of a mixed vegetation community, including

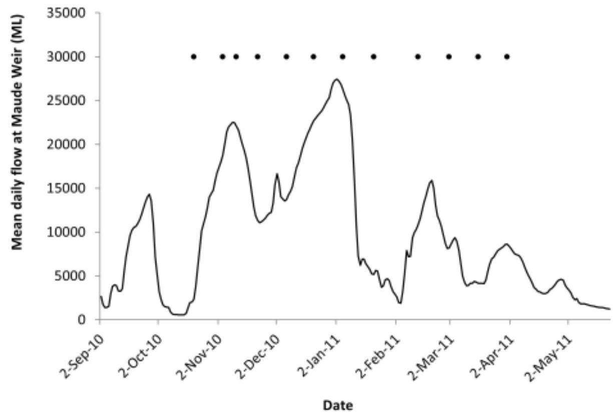


Figure 2. Mean daily river flow in the Murrumbidgee River (at Maude Weir 41010941) from September 2010 to May 2011 with timing of nest surveys indicated (black dots).

River Red Gums *Eucalyptus camaldulensis*, Lignum shrubland and Common Reed. This swamp retains high water levels for longer periods that other wetland storages in the Gayini-Nimmie-Caira system and provides valuable nesting habitat for a diverse range of waterbirds including cormorants and Australasian Darters *Anhinga novaehollandiae* (Murrumbidgee Catchment Management Authority 2009).

Following the establishment of colonial waterbird breeding colonies at Telephone Bank and Eulimbah swamps in October 2010, the first breeding event since 2005, a comprehensive nest monitoring program was undertaken. Straw-necked Ibis *Threskionis spinicollis*, Glossy Ibis *Plegadis falcinellus*, Royal Spoonbill *Platalea regia* and Little Pied Cormorant *Phalacrocorax melanoleucos* nests were monitored.

We undertook nest monitoring between November 2010 - April 2011 with a total of 12 surveys per colony were conducted throughout the breeding and flooding period (Figure 2). At each colony a sample of nest clumps were randomly selected. A nest clump is a grouping of nests (> 2) that are all placed together separated from the next nest clump by a channel of water or non-flattened vegetation (Figure 3). Each nest clump was assigned a unique number and the geographic location recorded using a GPS (5 - 10 m accuracy). At each nest clump, individual nests were labelled with a unique identifier. For each labelled nest, the number of eggs or chicks were recorded. Nests were monitored fortnightly. As new nests were established additional clumps were included in the monitoring program. Nest monitoring continued from November 2010 - April 2011 (Figure 2). Access to and around the colonies were by small motorised boat. Monitoring of individual nests was done by a person standing in the water recording individual nest contents. We also monitored water depth at each nest clump and water quality at three sites (pH, conductivity, dissolved oxygen, turbidity and temperature) at each colony at each survey time.

The colony boundary was mapped using GPS locations recorded at the maximum extent of nests. This

Figure 3. A photograph showing a nest clump of 10 Straw-necked Ibis nests with eggs, Telephone Bank colony. Photograph by Kate Brandis.

made statistical comparisons using t-tests. For Straw-necked Ibis we analysed temporal changes in clutch size as additional laying events occurred. As the most abundant species, and of key interest for water management, we also estimated total Straw-necked Ibis abundance at each colony site.

We calculated the hatching rates for each species in each colony. Data were categorised into three groups: egg, chick and nest. Success was determined for periods between surveys. For example, if at the end of each time period between surveys the nest contained eggs or chicks it was scored 1, if neither then 0 (Hazler 2004). Data for Straw-necked Ibis were further analysed based upon date of first survey. All initial surveys were at egg stage. We used date of first survey as a surrogate for laying period. Analyses were grouped based upon date of first survey of that site.

Generalised additive models (GAM) were developed to understand the relationships variables for breeding of Straw-necked Ibis. In model 1, we examined the relationship between clutch size, lay date and nest site size. In model 2, we examined the relationship between clutch size, nest site size and reproductive success. Laying periods were categorised into: early (< 50 days from first survey), middle (50 - 100 days) and late (> 100 days from first survey), from November 2010.

A total of 680 nests were monitored at Telephone Bank Swamp colony including four species of colonially breeding waterbirds, Straw-necked Ibis, Glossy Ibis, Royal Spoonbill and Little Pied Cormorant (Table 1). At Eulimbah Swamp colony, 795 nests were monitored including two species, Straw-necked Ibis and Royal Spoonbill (Table 1).

Results

Nesting surveys

Nesting at Telephone Bank Swamp was first established in early - mid October 2010 and Eulimbah Swamp late October - early November 2010. Breeding activity at these colonies continued until May 2011. Throughout this period there were several distinct laying events and the extent of the colonies shifted as new nests were built. Telephone Bank Swamp colony area was approximately 19 ha while the Eulimbah Swamp colony area was approximately 31 ha.

We estimated from aerial surveys (Kingsford *et al.* 2020) that there were approximately 15,000 - 20,000 Straw-necked Ibis at Telephone Bank Swamp and 20,000 - 30,000 at Eulimbah Swamp. Glossy Ibis were more numerous at Telephone Bank than Eulimbah Swamp. Both sites recorded breeding by several species, however Eulimbah Swamp colony was dominated by Straw-necked Ibis with few Glossy Ibis or Royal Spoonbill observed breeding and no Little Pied Cormorants were recorded breeding at this site.

At Telephone Bank a total of 1,361 Straw-necked Ibis eggs were monitored at 621 nests at 37 nests clumps. At Eulimbah Swamp colony a total of 1,885 eggs were monitored at 778 nests at 40 nest clumps.

During the breeding event there were four periods of egg laying by Straw-necked Ibis: early November, late November, late January and early March. Our observational data suggests that some Straw-necked Ibis pairs laid second clutches while other nests were established by newly arrived birds. This is illustrated by the changes in composition of eggs and chicks over time (Figure 4).

Glossy Ibis nesting at Telephone Bank had two laying periods, one in early November and a second in late December. Royal Spoonbill were present in both colonies for the entire breeding

Table 1. Reproductive success measures for each colony.

Species	Colony	Mean clutch size, ± SD, *N* (nests)	Egg hatch rate %, *N* (eggs)	Reproductive success % (eggs laid/chicks fledged)
Straw-necked Ibis	Telephone Bank	2.16 ± 0.75, 621	70, 1361	77
	Eulimbah Swamp	2.35 ± 0.69, 778	73, 1885	75
Glossy Ibis	Telephone Bank	3.26 ± 0.84, 45	70, 141	93
Royal spoonbill	Telephone Bank	2.64 ± 0.64, 13	72, 39	82
	Eulimbah Swamp	3.5 ± 1.5, 2	42, 7	33
Little pied cormorant	Telephone Bank	4.43 SD±0.53, 7	100	100

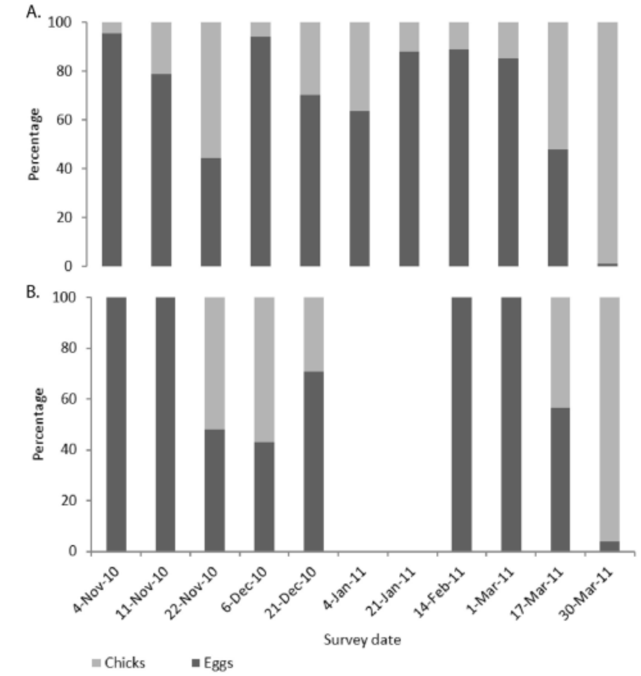


Figure 4. Changes in the relative composition of Straw-necked Ibis eggs and chicks at A. Telephone Bank and B. Eulimbah Swamp colony throughout the 2010-11 breeding period. 4-21 Jan. 2011 recorded no data at Eulimbah Swamp due to flooding and then drying of the colony site.

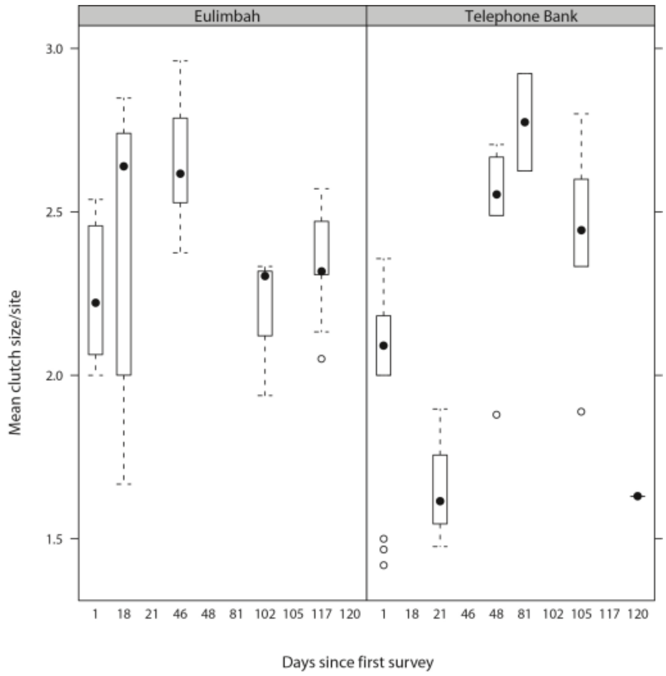


Figure 5. Changes in mean clutch size of Straw-necked Ibis at each colony over time.

period but were more numerous at Telephone Bank. They did not appear to have clearly defined laying events. All 13 nests that were monitored at Telephone Bank were first surveyed in early November (02 November 2010). Three Royal Spoonbill nests were monitored in Eulimbah Swamp, two nests were first surveyed in early November (02 November 2010), one nest was first surveyed in late December (20 December 2010). One site of Little Pied Cormorant nests was monitored at Telephone Bank. There were only two nest sites for this species observed at Telephone Bank. Little Pied Cormorant were not observed nesting at Eulimbah Swamp.

We measured a range of reproductive success measures including clutch sizes, egg hatch rates (% eggs laid that hatched) and overall reproductive success (eggs laid/chicks fledged; Table 1).

There was a significant difference in Straw-necked Ibis clutch sizes between Telephone Bank and Eulimbah swamps ($p < 0.001$), and there were some observed differences based on time of laying, particularly at Telephone Bank with eggs laid during the 'middle' of the breeding period being larger (Figure 5). This was also reflected the model results with clutches laid in the middle of the breeding period being larger (Figure 8). Similarly, clutch size data for Glossy Ibis varied with lay date. Nests established in early November 2010 (surveyed 02 November 2010) had a mean clutch size of 3.47 eggs/nest (N = 30, SD ± 0.77) while nests established in late December 2010 (surveyed 20 December 2010) had a mean clutch size of 4.23 (N = 13, SD ± 0.96). We did not undertake the same analyses for the other species due to low sample sizes.

Overall nest success Straw-necked Ibis for Eulimbah Swamp colony was 75% while Telephone Bank colony was 72%. Mean nest clump success for Eulimbah Swamp across all dates was 71% and 68% for Telephone Bank. Nest and nest clump success varied over time, most notably for Eulimbah Swamp where the wetland was firstly inundated (04 January) then dried (21 January; Figure 6). Removing the loss of nests to flooding in Eulimbah Swamp, the site success rates at Eulimbah Swamp were 60 - 100%. Telephone Bank, did not lose nests to flooding but had a wider range of site success from 0 - 100%. Overall success rates were relatively consistent irrespective of lay date (Figure 6).

Breeding models

Model 1: Clutch size

Nest clumps with a total number of nests between 20 - 40 nests had a higher probability of having clutch sizes greater than two (Figure 7). Nest

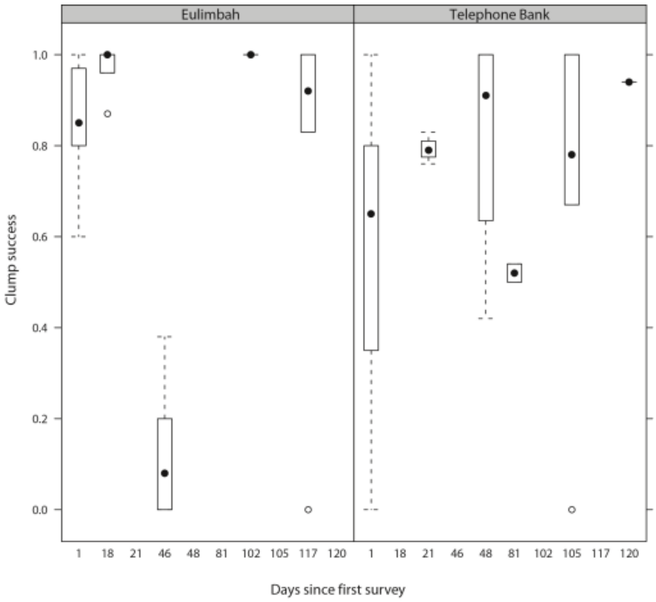


Figure 6. Success for individual clumps of nests over time for nests of Straw-necked Ibis at Eulimbah Swamp and Telephone Bank colonies.

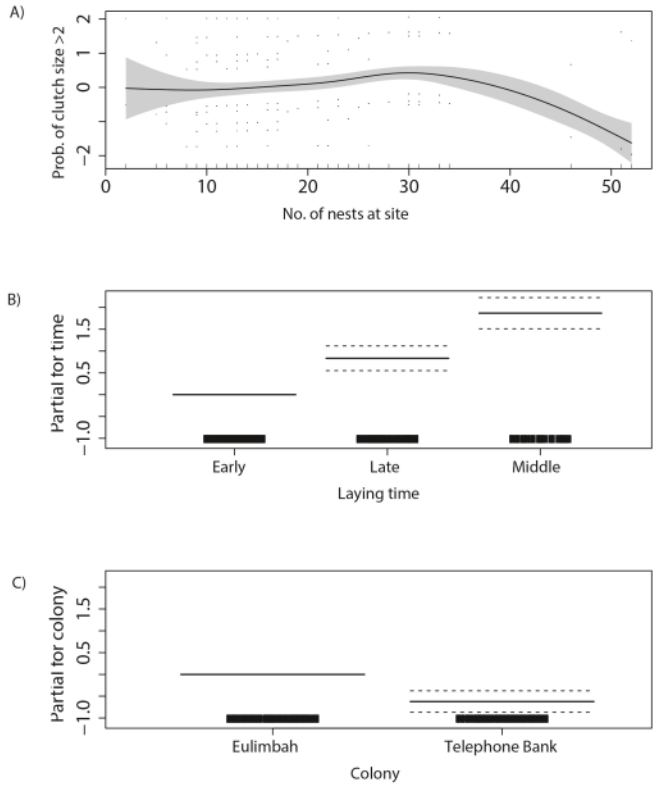


Figure 7. General Additive Models (GAMs) outputs illustrating the relationships between a) the number of nests at a nest clump and the probability of clutch sizes>2, b) the relationship between laying period and clutch sizes and c) clutch sizes at each colony.

clumps with > 40 nests had increasingly lower probabilities of having clutch sizes greater than 2. Early layers had a lower probability of having a large clutch size (more than two eggs) than birds that laid in the middle of the breeding event. Middle layers had the highest probability of having larger clutch sizes, while late layers had a lower probability, although not as low as early layers (Figure 7). There was a high probability of nests at Eulimbah Swamp having larger clutch sizes than nests at Telephone Bank (Figure 7).

Model 2: Reproductive success

The relationship between individual nest success and the size of the nest clump it was located within was variable with a general trend of greater nest success for nests in larger clumps (Figure 8). Middle and late nesters had greater nest success than early nesters (Figure 8). Larger clutch sizes had a greater overall success rate than small clutch sizes (Figure 8).

Colony conditions

Water depth

The two colonies experienced different water depth conditions. Water depths in Eulimbah were maintained at a relatively stable depth until early January 2011 when the third and largest flood pulse inundated the Eulimbah Swamp colony site. To minimise nest inundation and control flooding a hole was cut the levee bank to allow water to flow through the Eulimbah Swamp site. By late January Eulimbah Swamp had dried, the levee bank repaired and Eulimbah Swamp was refilled to approximately the same depth prior to flooding.

Water depth in the Telephone Bank colony was maintained at a relatively stable level (mean = 78 cm, min. 70 cm, max. 86 cm) for the duration of the ibis breeding event.

Water quality

pH is a measure of how acidic/basic water is, ranging from 0 - 14, with 7 being neutral. pH can be affected by chemicals in the water and is an important indicator of water that is changing chemically. Pollution is one source that can change a water's pH, which in turn can impact aquatic flora and fauna. pH was relatively stable at both colony sites for the duration of breeding (Eulimbah Swamp mean = 7.2, Telephone Bank mean = 6.8; Table 2).

Dissolved oxygen (DO) measurements record the amount of water dissolved in water. This is an important measure needed to sustain fish, aquatic invertebrate and macrophyte communities. Rapidly moving water general has a higher level of dissolved oxygen than stagnant water. This may

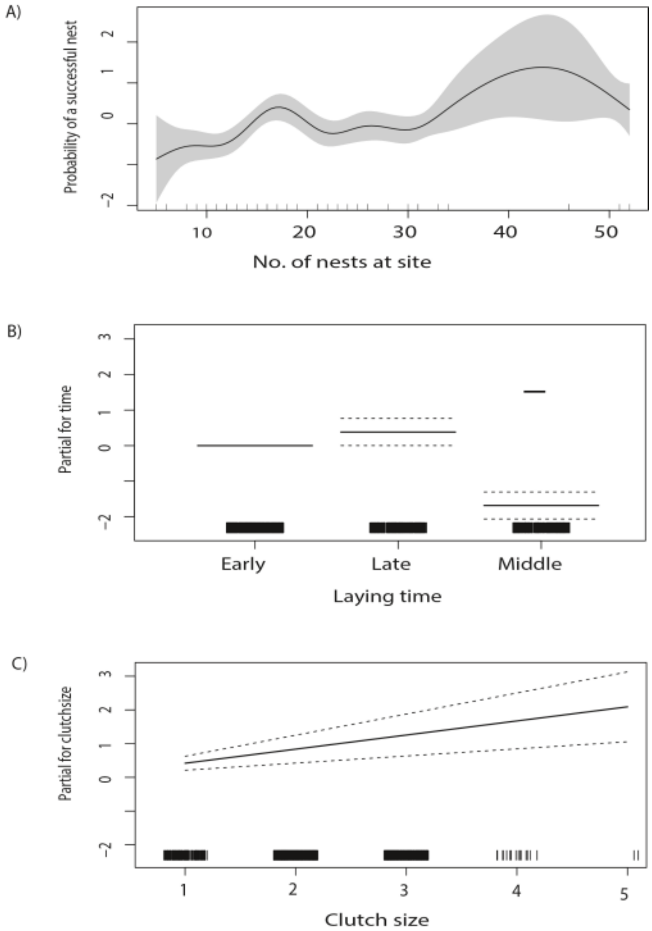


Figure 8. General Additive Models (GAMs) outputs illustrating the relationships between a) the probability of a nest being successful based upon the total number of nests at the nest clump, b) the relationship between laying time and nest success and, c) the relationship between clutch size and the overall success of the nest.

explain the higher reading at Eulimbah Swamp on the 14 February 2011 (Table 2) as the colony site has been recently refilled. Dissolved oxygen levels are also impacted on my water temperature and aquatic vegetation. Under normal atmospheric pressure and a temperature of 20^0 C water will contain about 2% (2 ppm by volume) dissolved oxygen (Gordon 2004).

Conductivity measures the ability of water to conduct an electrical current. It is highly dependent on the amount of dissolved solids, such as salt in the water. As water evaporates, or is used by vegetation the concentration of dissolved solids increases. This may explain the slight increase in conductivity at both sites over time (Table 2).

Turbidity is a measure of the particulate matter in the water. High levels of turbidity result in a higher scattering of light. Factors that can cause turbidity include: clay, silt, organic and inorganic matter, and microscopic organisms. Turbidity can be highly variable and is impacted by short term events such as increased flow velocity or rainfall runoff.

At the colony sites, turbidity levels would have been influenced by bird faecal matter and the inflow of water into the colony sites. The variation seen in the results for Eulimbah Swamp and Telephone Banks (Table 2) may be due to water management practices and the movement of water through colony sites, especially the high turbidity recorded at Eulimbah Swamp following refilling in late January.

Water temperature is an important measure for some aquatic organisms and can affect dissolved oxygen levels. Water temperature measures can be affected by the time of day that sampling was undertaken. Water temperatures at Eulimbah Swamp and Telephone Bank were relatively consistent, ranging from 18^0 C - 30^0 C (Table 2).

Discussion

This study highlighted the importance of the Lowbidgee wetlands as providing key breeding habitat for colonial waterbirds in the Murray Darling Basin and Australia. The diversity of wetland types and the managed delivery of flows to two key colony sites contributed to the breeding success of ~50,000 Straw-necked Ibis and high diversity of waterbird species breeding (N = 28) at these wetlands in 2010 - 11.

The breeding colonies at Telephone Bank and Eulimbah Swamps in 2010/2011 had high rates of reproductive success for all species monitored. Straw-necked Ibis were the most abundant species breeding at both sites with breeding success of 72% and 75% respectively. These colonies were unusual in the number of laying events that occurred throughout the breeding season. Reasons for this may include the management of water at the colony sites and the availability of suitable food resources for the duration of breeding. Water levels at colony sites and the availability of food resources are key factors in determining breeding success in colonially-breeding waterbirds (Tortosa *et al*. 2003; Djerdali *et al*. 2008; Brandis *et al*. 2011).

Water management during the breeding event aimed to maintain water levels without significant fluctuations. This was successfully achieved at Telephone Bank. While despite the unmanageable

Table 2. Mean water quality results per survey per colony.

Colony	Date	Dissolved oxygen (ppm)	Conductivity (µS)	pH	Turbidity (NTU)	Temp. (^{0}C)
Eulimbah Swamp	04 Nov. 2010	3.245	132.5	6.8	72.83	17.8
Telephone Bank		1.88	170.6	6.71	14.6	20.6
Eulimbah Swamp	11 Nov. 2010	2.50	198.5	8.33	6.5	29.4
Telephone Bank		1.10	168.3	6.71	18.4	22.8
Eulimbah Swamp	22 Nov. 2010	3.60	170.0	7.34	6.8	29.0
Telephone Bank		4.30	190.5	7.88	6.7	27.9
Eulimbah Swamp	4 Jan. 2011	3.39	261.0	6.93	8.3	24.2
Telephone Bank		4.11	286.0	7.4	5.3	27.7
Eulimbah Swamp	22 Jan. 2011	Dry				
Telephone Bank		2.34	198.3	5.97	77.8	29.5
Eulimbah Swamp	14 Feb. 2011	10.12	182.2	6.42	32.2	29.2
Telephone Bank		3.10	185.7	6.43	28.9	24.7
Eulimbah Swamp	1 Mar. 2011	3.41	199.3	7.25	24.2	24.3
Telephone Bank		6.93	221.5	6.93	70.1	25.5
Eulimbah Swamp	16 Mar. 2011	4.06	310.0	7.39	19.0	20.1
Telephone Bank		4.35	392.0	7.04	8.2	27.0

flooding of nests, and then drying at Eulimbah Swamp in January 2011, adult and juvenile birds remained in the colony site (pers. obs.) and new nests were built and clutches laid after the site was refilled with water. This observation was also made during a subsequent breeding event in 2016 when similar conditions occurred (Wassens *et al*. 2019).

This study demonstrated that with the support of landholders, beneficial outcomes for waterbirds and waterbird populations were achieved in an irrigated landscape. As floodplain wetlands in Australia continue to be threatened by water resource development and climate change it is critical that these wetland ecosystems are protected and managed effectively to support waterbird populations.

In 2016 - 17 colonial waterbird breeding colonies again established at these two sites with ~15,000 Straw-necked Ibis at Eulimbah Swamp and ~30,000 at Telephone Bank (Wassens *et al*. 2017). Most recently (2018) the Gayini-Nimmie-Caira region of the Lowbidgee has been returned to conservation with joint management by local indigenous groups (Nari Nari) in partnership with The Nature Conservancy, the University of New South Wales, and the Murray Darling Wetlands Working Group to manage the wetlands along with Commonwealth and state agencies who manage environmental water delivery. Results of this study and the 2016 - 17 monitoring will be used to inform the water requirements of colonial waterbird breeding so that flows can be managed to support further successful breeding at these important colony sites and elsewhere in the Murray-Darling Basin.

Acknowledgments

This project was greatly assisted by many people and we would like to thank the Lowbidgee landholders (2010-11): Steve Blore, Michael Spinks, Hamish Cullward and Frank Old; Lynne Wells, and field work assistance by Gilad Bino and Hazel Watson. We also wish to thank the reviewers for suggestions resulting in a much improved manuscript.

References

ABARES. 2020. Water. https://www.agriculture.gov.au/abares/research-topics/water, accessed 15 August 2020.

ABS. 2020. Water Use on Australian Farms, 2018-19. https://www.abs.gov.au/statistics/industry/agriculture/water-use-australian-farms/latest-release, accessed 30 June 2020.

Australian Government Bureau of Meterology. 2011. Nap Nap Rainfall. http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=2010&p_c=-1126660419&p_stn_num=075049, accessed 30 June 2011.

Bino, G., R. T. Kingsford and K. Brandis. 2016. Australia's wetlands - learning from the past to manage for the future. *Pacific Conservation Biology* 22: 116-129.

Brandis, K. J. 2010. Colonial Waterbird Breeding in Australia: wetlands, water requirements and environmental flows. PhD Thesis, University of New South Wales, Australia.

Brandis, K. J., R. T. Kingsford, S. Ren, and D. Ramp. 2011. Crisis water management and ibis breeding at Narran

Lakes in arid Australia. *Environmental Management* 48(3): 489-498.

Brandis, K. J., G. Bino, J. A. Spencer, D. Ramp and R. T. Kingsford. 2018. Decline in colonial waterbird breeding highlights loss of Ramsar wetland function. *Biological Conservation* 225: 22-30.

CAMBA. 1988. Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment. The Government of Australia and the Government of the People's Republic of China, Australian Government Publishing Service, Canberra.

Czech, H.A. and K. C. Parsons. 2002. Agricultural Wetlands and Waterbirds: A Review. *Waterbirds: The International Journal of Waterbird Biology* 25: 56-65.

Department of Water Resources. 1994. Lowbidgee management plan: Stage two: land and water management 1991–96. NSW Department of Water Resources, Sydney, Australia.

Djerdali, S., F. S. Tortosa, L. Hillstrom, and S. Doumandji. 2008. Food supply and external cues limit the clutch size and hatchability in the White Stork *Ciconia ciconia*. *Acta Ornithologica* 43(2): 145-150.

EPBC Act. 1999. Environment Protection and Biodiversity Conservation Act. Department of Agriculture, Water and the Environment, Australian Government.

Gordon, N. D., T. A. McMahon, B. L. Finlayson, C. J. Gippel, and R. J. Nathan. 2004 *Stream Hydrology: An introduction for ecologists*. John Wiley & Sons, Chichester, West Sussex, England.

Hazler, K. R. 2004 Mayfield logistic regression: A practical approach for analysis of nest survival. *The Auk* 121(3): 707-716.

Hu, F. 2016. 8 Reasons to Invest in Irrigation in China. https://www.chinawaterrisk.org/resources/analysis-reviews/8-reasons-to-invest-in-irrigation-in-china/, accessed 20 October 2020.

Huner, J. V., W. J. Clinton and W. Norling. 2002 Managing Agricultural Wetlands for Waterbirds in the Coastal Regions of Louisiana, U.S.A. *Waterbirds: The International Journal of Waterbird Biology* 25: 66-78.

JAMBA. 1981. Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment. The Government of Australia and the Government of Japan, Australian Government Publishing Service, Canberra.

Kingsford, R. T. 2000. Review: Ecological impacts of dams, water diversions and river management on floodplain wetlands in Australia. *Austral Ecology* 25: 109-127.

Kingsford, R. T. and W. Johnson. 1998. Impact of water diversions on colonially-nesting waterbirds in the Macquarie Marshes of Arid Australia. *Colonial Waterbirds* 21(2): 159-170.

Kingsford, R. T., J. L. Porter, K. J. Brandis and S. Ryall. 2020. Aerial surveys of waterbirds in Australia. *Scientific Reports* 7(172): doi:10.6084/m9.figshare.12280112.

Kingsford, R. T. and R. F. Thomas. 1995. The Macquarie Marshes in arid Australia and their waterbirds: a 50-year history of decline. *Environmental Management* 19(6): 867-878.

Kingsford, R. T. and R. F. Thomas. 2004. Destruction of wetlands and waterbird populations by dams and irrigation on the Murrumbidgee River in arid Australia. *Environmental Management* 34(3): 383-396.

Lemly, A. D., R. T. Kingsford, and J. R. Thompson. 2000 Irrigated agriculture and wildlife conservation: conflict on a global scale. *Environmental Management* 25(5): 485-512.

Leslie, D. J. 2001 Effect of river management on colonially-nesting waterbirds in the Barmah-Millewa Forest, South-Eastern Australia. *Regulated Rivers: Research and Management* 17(1): 21-36.

MDBA. 2020. Murray Darling Basin Authority: Murrumbidgee. https://www.mdba.gov.au/discover-basin/catchments/murrumbidgee, accessed 2 February 2020.

Murrumbidgee Catchment Management Authority. 2009. Lower Murrumbidgee floodplain: natural resource management plan, New South Wales Government, Canberra, Australia.

Page, K., A. Read, P. Frazier, and N. Mount. 2005. The effect of altered flow regime on the frequency and duration of bankfull discharge: Murrumbidgee River, Australia. *River Research and Applications* 21: 267-578.

Rogers, K., M. Colloff, N. Saintilan, and L. Wen. 2013. Application of thresholds of potential concern and limits of acceptable change in the condition assessment of a significant wetland. Environmental Monitoring and Assessment 185(10): 8583-8600.

ROKAMBA. 2006. Agreement between the Government of Australia and the Government of the Republic of Korea on the protection of migratory birds and exchange of notes. The Government of Australia and the Government of the Republic of Korea, Department of Foreign Affairs and Trade Canberra, Canberra, Australia.

Siebert, S., J. Burke, J. M. Faures, K. Frenken, J. Hoogeveen, P. Doll and F. T. Portmann. 2010. Groundwater use for irrigation – a global inventory. *Hydrological Earth Systems* 14: 1863-1880.

Spencer, J. 2017. Evaluation of colonial waterbird breeding in NSW Murray-Darling Basin: 2006-16. NSW Office of Environment and Heritage. Sydney, Australia.

Tortosa, F. S., L. Perez, and L. Hiillstrom. 2003 Effect of food abundance on laying date and clutch size in the White Stork *Ciconia ciconia*. *Bird Study* 50: 112-115.

Wassens, S., J. Spencer, B. Wolfenden, J. Thiem, R. Thomas, K. Jenkins, K. J. Brandis, E. Lenon, A. Hall, J. Ocock, T. Kobayashi, G. Bino, J. Heath, and D. Callaghan. 2017. Commonwealth Environmental Water Office Long-Term Internvention Monitoring project Murrumbidgee River system Selected Area evaluation report, 2014-17. Charles Sturt University. Albury, Australia

Wassens, S., J. Spencer, B. Wolfenden, J. Thiem, R. Thomas, K. Jenkins, A. Hall, J. Ocock, T. Kobayashi, G. Bino, T. Davis, J. Heath, W. Kuo, C. Amos and D. Michael. 2019. Commonwealth Environmental Water Office long-term intervention monitoring project Murrumbidgee River system selected area technical report, 2014-18. March 2019. Canberra, Australia

Wassens, S., R. J. Watts, A. Jansen, and D. Roshier. 2008. Movement patterns of southern bell frogs (*Litoria raniformis*) in response to flooding. *Wildlife Research* 35: 50-58.

Wood, C., Y. Qiao, P. Li, P. Ding, B. Lu and Y. Xi. 2010. Implications of rice agriculture for wild birds in China. *Waterbirds* 33: 30-43.

ISSN 2710-1142(online)
SIS Conservation, 2020, 2, 29-32
SHORT COMMUNICATION

Observation of Milky Stork *Mycteria cinerea* breeding on Pulau Dua, Banten, Indonesia, after 45 years

Yus Rusila NOOR[1*], UMAR[2], Ani MARDIASTUTI[3], Ragil Satriyo GUMILANG[4], Muhammad IQBAL[5]

[1]Yayasan Lahan Basah, Jl. Bango 11, Bogor 16151, Indonesia
[2]Kasemen, Desa Sawah Luhur, Serang, Banten, Indonesia
[3]Pangandaran Golf 37 - Mediterania 2, Sentul City, Bogor 16810, Indonesia
[4]Perumahan Bukit Asri Ciomas, Blok B15 No15, RT05/RW13, Kecamatan Ciomas, Bogor 16610, Indonesia
[5]Biology Program, Faculty of Science, University of Sriwijaya, Jl. Padang Selasa 524, Palembang 30139, South Sumatra, Indonesia
*Corresponding author; e.mail: yus.noor@gmail.com

Abstract Observations of Milky Storks *Mycteria cinerea* were made in Pulau Dua Strict Nature Reserve (Cagar Alam Pulau Dua; 30 hectare reserve; 6° 01' S, 106° 21' E), Banten, Northwest Java, Indonesia in 2020. These observations confirmed that the storks returned to breed at a site where breeding was last recorded in 1975.

Keywords Indonesia, Milky Storks, *Mycteria cinerea*, Pulau Dua Nature Reserve

Introduction

The Milky Stork *Mycteria cinerea* is categorized as Endangered on the IUCN Red List, with an estimated global population of 1,500 individual and a decreasing population trend. This stork was up-listed to Endangered in 2013 because recent population estimates from its stronghold population in Sumatra suggested that it is undergoing a very rapid ongoing population decline due to intense hunting pressure at nesting colonies, human disturbance and the rapid loss and conversion of coastal habitat (BirdLife International 2020).

The Milky Stork has been a regular visitor to the Pulau Dua Strict Nature Reserve. Kretschmer de Wilde (1939) reported the presence of "each time a small group", but mentioned explicitly no breeding of the storks in 1936, 1937 and 1938. Hoogerwerf (1947) reported breeding before May 1942, when the whole vegetation of the island was razed immediately after the outbreak in the region of World War II, but he reported a rapid recovery in the years after. Hoogerwerf (1948) also listed Milky Stork as breeding on the island, 11 years after the island was gazetted as protected area in 1937.

Van Beuninger *et al*. (1976) recorded 7 Milky Stork nests in 1975, "when overland access to the island first became possible". Harvey (1975) reported maximum of 11 birds roosted in tall trees and fed on muddy shores. No nests seen although some of the birds appeared to be juveniles and a few pairs may have bred earlier in year. Alternatively breeding may not have begun yet. Milton and Marhadi (1985) counted 32 non-breeding individuals in 1985. During a four-year (1997 - 2001) weekly observation of waterbird species on the island, Noor (2004) observed regular visitation of Milky Storks to the island; the maximum being 32 individuals in June 2000. During June 2000, several storks brought nest materials to one of the tallest Kepuh/Java Olive *Sterculia foetida*, but abandoned the nests (Noor

Article history
Received: 19 June 2020,
Received in revised form: 10 December 2020,
Accepted: 10 December 2020,
Published online: 25 December 2020

2004).

Study area

Observations were conducted in the Pulau Dua Strict Nature reserve, Banten, Indonesia. The origin of the name Pulau Dua is explained by Kretschmer de Wilde (1939) to refers to the original existence of twin islands which were subsequently united and still later connected to the mainland. At that time, the island of Pulau Dua was separated from the main island of Java by a 500 m narrow strait. The island eventually became connected with the main island due to sedimentation resulting from materials transported by several rivers to the Banten Bay (Sulaeman 1995). The accreted land, which was still submerged during the high tides, became naturally vegetated by *Avicennia marina* with a 6-8 m canopy height. These trees were then occupied by a waterbird breeding colony (Milton and Marhadi 1985).

Methods

The Milky Stork nests were irregularly monitored from 18 April to 15 October 2020 following the sighting of two Milky Stork nests on the island by the Ranger of the reserve. Observations were made from a distance by using binoculars to observe the occurrence of breeding and non-breeding Storks, nest condition and breeding success. We also photographed the nest at different intervals to record the growth of the chick.

Results

We made the following observations of the Milky Stork nest. Both behavioural observations as well as dates of observation are provided. We stopped observations after the chick fledged from the nest.

18 April 2020, *ca*. three and a half morning hours: day 1 of observation 25 Milky Storks observed, two pairs sitting on two nests (Figure 1A).

14 May 2020, *ca*. two morning hours: One nest still used by a pair; the other nest was no longer used. Some individuals were still observed in the island, but no additional nest building was seen.

26 May 2020, *ca*. three afternoon hours: One chick observed in the active nest (Figure 1B). Some Milky Storks (< 25 individuals) still returning to the island, but we could not identify the individual that abandoned the nest.

24 June 2020, *ca*. three and a half afternoon hours: one chick was observed being fed by one of the parents (Figure 1C).

15 October 2020, *ca*. one morning hour: chick observed flying from the nest.

Figure 1. Nest of Milky Stork observed in Pulau Dua Strict Nature Reserve, Indonesia. This series of photographs shows the nest being incubated nest on 18 April 2020 (A), with recently hatched single chick on 26 May 2020 (B), and a juvenile bird immediately after the adult fed it on 24 June 2020 (C).

On 18 April 2020, 25 Milky Storks were observed perching on top of the seven-eight-meter canopy of Avicennia marina mangroves, together with Little Egret *Egretta garzetta*, Black-crowned Night Heron *Nycticorax nycticorax*, Cattle Egret *Bubulcus ibis*, Intermediate Egret *Egretta intermedia*, Great Egret *Ardea alba* and Grey Heron *Ardea cinerea*. Two pairs of Milky Storks were observed sitting on nests. As no observations were made prior to 18 April 2020 it is highly possible that the birds arrived at the island much earlier, and the nest was built prior to this first observation.

One of these two nests was no longer in use by 14 May 2020. Although some of the Milky Storks were still returning to the island, we could not identify whether the abandoned individual was still returning to the island. On 26 May 2020 still only one chick was observed on the active nest and no more nests had been built by other individuals/pairs. We do not know the chick's hatch date. One chick was observed being fed by one of the parents on the remaining nest on 24 June 2020. During observation on 15 October 2020, the chick flew away from the nest together with one parent and less than 10 Milky Storks were one observed on the island.

Discussion

The only other known breeding site of this species in Java is in Pulau Rambut Wildlife Sanctuary, some 60 km eastward of Pulau Dua Strict Nature Reserve. A total of 17 nests were recorded in 2001 and 20 nests in 2002 with a breeding success of 46% and 49%, respectively (Imanuddin and Mardiastuti 2003). Observations made every January during the last 4 years (2017 - 2020) recorded populations of 11, 70, 36, 64 individuals, respectively, including breeding and non-breeding individuals (Y. R. Noor pers. obs.)

During the Asian Waterbird Census 2017 (supported by National Geographic Society Explorer), 73 Milky Storks were observed at a colony with about 20 nests in the Liquefied Petroleum Gas/LPG terminal complex of Patrol, Indramayu, West Java (Y. R. Noor and R S. Gumilang pers. obs.). No chicks were reported on any of the nests however.

Most observations of Milky storks are from South Sumatra Province. Iqbal and Hasudungan (2008) indicated a maximum population of 324 individuals in Banyuasin Peninsula (in 2002) and 500 individuals in Timbul Jaya Village (in 2005). Three breeding populations were recorded during 1988, with estimated numbers of 280, 300, and 300-400 nests respectively (Danielsen et al. 1991). On 17 June 2008 after a gap of 20 years (2 September 1988), a Milky Stork breeding colony of 100-115 nest was found on Kumpai lake (Iqbal et al. 2008). Two additional records from South Sumatra are of at least 81 juveniles feeding with adults in Siput on the coast of the Banyuasin Peninsula on 1 November 2008 and a group of six juveniles resting in mangroves on Lumpur river on 30 November 2008 (Iqbal *et al*. 2009).

The Black-headed Ibis *Threskiornis melanocephalus* also ceased breeding in Pulau Dua for some years before breeding was recorded again in 1998 (Noor and Hasudungan 2000).

It is difficult to explain the temporary absence and comeback of both Black-headed Ibis and Milky Stork as breeding species in Pulau Dua, as they still occur regularly on the island. However, disturbance from visitation of local tourists (despite the status of the island as strict nature reserve) may have been an important factor as the last reports of breeding were when overland access to the island became possible (Milton and Marhadi 1985). We suspect that the comeback of Milky Stork to breed again in Pulau Dua related to the placement of the nested tree, which is located some distance from the tourist's foot track. Further observations are still required to confirm whether the Storks will continue breeding in this location, or in other locations in Indonesia.

Acknowledgments

We are very grateful to Mr. Umar for allowing us to use his photographs. We thank Dr. Luis Santiago Cano Alonso for his advice on the publication of this manuscript. We also thank the anonymous reviewers for providing review on this manuscript. The National Geographic Society Explorer supported the census of waterbirds in 2017.

References

BirdLife International. 2020. Species factsheet: Mycteria cinerea. http://www.birdlife.org, accessed 19 June 2020.

Beuninger, C. S., van, I. J. de Boer, N. A. de Joncheere and J. M. A. van de Velde. 1976. Pulau Dua. Report of a four day stay, 6-10 May 1976. Unpublished report.

Danielsen, F., A. Purwoko, M. J. Silvius, H. Skov and W. Verheugt. 1991. Breeding colonies of Milky Stork in South Sumatra. *Kukila* 5 (2): 133-135.

Harvey, W. G. 1976. Field expedition of Indonesian Ornithological Society. *Kukila* 1 (2): 26-28.

Hoogerwerf, A. 1947. Ornithologische ervaringen tijdens een naar het Natuurmonument Poelau Doewa gemaakte dienst-tournee (Ornithological experiences during a service tour to the Natural Monument Poelau Duwa). *Limosa* 20: 193-196.

Hoogerwerf, A. 1948. Contribution to the local knowledge of the distribution of birds on the island of Java, with

remarks on some new species. *Treubia* 19:83-137.
Iqbal, M., F. Takari, H. Mulyono and Rasam. 2009. A note on the breeding success of Milky Stork *Mycteria cinerea* in 2008, South Sumatra Province, Indonesia and more on its diet. *BirdingASIA* 11: 73-74.
Iqbal, M., A. Ridwan, F. Takari and H. Mulyono. 2008. Rediscovery of a Milky Stork *Mycteria cinerea* breeding colony in South Sumatra Province, Indonesia. *BirdingASIA* 10: 62-66.
Iqbal, M. and F. Hasudungan. 2008. Observations of Milky Stork *Mycteria cinerea* during 2001 - 2007 in South Sumatra Province, Indonesia. *BirdingASIA* 9: 97-99.
Imanuddin and A. Mardiastuti. 2003. Ekologi bangau bluwok *Mycteria cinerea* di Suaka Margasatwa Pulau Rambut, Jakarta (Ecology of the Milky Stork *Mycteria cinerea* in Pulau Rambut Wildlife Reserve, Jakarta). Fakultas Kehutanan IPB/Disney Wildlife Conservation/ Wildlife Trust. [In Indonesian].
Kretschmer de Wilde, C. J. M. 1939. Vogelparadijs op Java's Noordkust. Pp. 299-309 in 3 Jaren Indisch Natuurleven (Bird paradise on Java's North coast. Pp. 299-309 in 3 Years of Indian Nature Life). Nederlandsch-Indische Vereeniging tot Natuurbescherming, Batavia, Indonesia. [In Dutch].
Milton, R. G. and A. Marhadi. 1995. The bird life of Nature Reserve Pulau Dua. *Kukila* 2(2): 32-41.
Noor, Y. R. and F. Hasudungan. 2000. Observation of Black-headed Ibis breeding again on Pulau Dua, Banten Bay, West Java. *Kukila* 11: 128-129.
Noor, Y. R. 2004. Paparan nilai penting Cagar Alam Pulau Dua, Teluk Banten sebagai kawasan berbiak burung air. Seri Selamatkan Lingkungan Teluk Banten 4 (Exposure to the important value of Pulau Dua Nature Reserve, Banten Bay as a water bird breeding area. Save the Environment in Banten Bay Series 4). Wetlands International, Indonesia Programme, Bogor, Indonesia. [In Indonesian]
Sulaeman, E. 1995. Studi struktur dan komposisi jenis flora dan keanekaragaman jenis burung di Cagar Alam Pulau Dua (Study of the structure and composition of flora species and bird species diversity in Pulau Dua Nature Reserve), Kabupaten Serang, Jawa Barat. Skripsi Fakultas Kehutanan, Universitas Nusa Bangsa, Bogor, Indonesia. [In Indonesian].

ISSN 2710-1142(online)
SIS Conservation, 2020, 2, 33-41
SPECIAL SECTION EDITORIAL

Woolly-necked Stork - a species ignored

K. S. Gopi Sundar[1]

[1]Nature Conservation Foundation, 1311, "Amritha" 12th Main, Vijayanagar 1st Stage, Mysuru 570017, Karnataka, India.
E-mail: gopi@ncf-india.org

Introduction

Storks, Ibises and Spoonbills (SIS) are most diverse in Africa and Asia, but SIS species in these two continents are also among the least studied. The IUCN SIS Specialist Group is determined to change this situation working with colleagues who are intrigued by these species. This issue of *SIS Conservation* takes another small step towards this goal of improving understanding of poorly studied species. The Special Section focuses on one of the least studied waterbird species in the world, the Woolly-necked Stork. In this Editorial I provide an overview of the species' ecology and conservation status, describe in brief the contributions to the Special Section, and contrast some of the published information with information available online. This editorial and the Special Section is biased towards the population found in south and south-east Asia, though information from Africa is included where pertinent. I also bias the editorial to few aspects of the species' ecology, and a full literature review will be provided elsewhere.

A prologue to this editorial is that the taxonomy of Woolly-necked Storks remains unresolved with authorities either recognising one species with three subspecies (Gill *et al*. 2020), or separating the African and Asian Woolly-necks into two separate species, *Ciconia microscelis* and *C. episcopus* respectively (del Hoyo *et al*. 2019). The split into two species is based on geographical separation alone and requires additional genetic analyses to confirm the proposed split. In this issue of *SIS Conservation*, authors were not asked to follow any one taxonomy and the Special Section reflects the diversity of current opinions.

Article history

Received: 10 November 2020,
Published online: 24 November 2020

Background to the Special Section

In the recent past a few observations on Woolly-necked Storks (WNS) attracted my attention to this species. The first was a field visit in November 2015 to Haryana state in India to observe a WNS nest that a colleague had discovered on a fig *Ficus religiosa* tree amid crop fields. We got exceedingly lucky in reaching the nest just in time to watch the juveniles fledge. To our astonishment, six juveniles fledged from the single nest. The juveniles continued begging on the ground and sported a prominent white forehead (Figure 1). Such a large number of fledgelings from one nest of a single-nesting stork species was unprecedented. This WNS pair in Haryana had fledged two chicks more than the previous record of four chicks in a nest documented in southern Africa (Scott 1975) and India (Vyas and Tomar 2006), and had a larger clutch size than was known for the species (3-5 eggs; Hancock *et al*. 1992). In addition, the white forehead helps to identify newly fledged WNS, and is an unreported colouration.

The second observation was the discovery of WNS above 3,500 m in China and Nepal (Han *et al*. 2011; Ghale and Karmacharya 2018). This too was unprecedented, and the observation in China (Figure 2) also constituted a major range extension of WNS. Both observations coming within a few years of each other were suggestive of a species expanding its altitudinal and geographic range. With several SIS species struggling to survive and

Figure 1. Six newly fledged Woolly-necked Stork juveniles (right) in a farmland area of Haryana, India. Fledgelings are soliciting attention from the adult bird (left) and sported distinct white colouring on the forehead that is not seen in older birds. Photograph by K. S. Gopi Sundar, November 2020.

requiring expensive conservation interventions, news of a species expanding on its own was significant.

Finally, the third detail that attracted my attention was the proposal in 2014 to elevate the conservation status of the Asian WNS from "Near-threatened" to "Vulnerable" following the proposed split of the WNS into two species (BirdLife International 2014). This proposal was made on an online forum where experts from south and south-east Asia provided their thoughts. Several experts from south Asia provided field observations that did not support a change in status. Published literature from south Asia supported these observations. Two experts from south-east Asia made passionate calls to elevate the conservation status suggesting that the species was imperilled by conversion of forests to agriculture and hunting in south-east Asian countries. They suggested that these habitat changes exposed the species to increased hunting and that the species may not be able to survive in agricultural areas. Using the inputs on this forum, BirdLife International elevated the Asian WNS from "Least Concern" to "Vulnerable" (BirdLife International 2014).

These three disparate but somewhat connected aspects converged in my mind towards a couple of realizations. The first was that it was entirely likely that other ornithologists and researchers had field observations on WNS that could help build a more complete picture of the species' ecology and conservation requirements. The second was that conservation status of several SIS species (see also Gula 2020), and most certainly the WNS, may be biased by anecdotal information from a small part of its distribution range.

Species accounts and WNS ecology

As with all poorly studied species, generalized accounts based on anecdotal reporting and ad hoc field observations formed the majority of literature driving understanding of WNS ecology and conservation requirements. Early accounts of the species derived from field observations during surveys of relatively small geographical areas described it as using a variety of habitats including lowland swamps and rice paddies up to elevations of 1,400 m and 3,000 m (Britton 1980; White and Bruce 1986). In a prominent generalized species account that considered the species' full distribution range, WNS began being described as a solitary forest-nesting stork species (Luthin 1987). Subsequent species accounts highlighted anecdotal information from south-east Asia and provided early suggestions that deforestation and hunting were primary threats to the potentially imperilled WNS. These suggestions were repeated in subsequent generalised accounts, including in the seminal SIS book by Hancock *et al*. (1992). Based on their personal observations, the authors described the WNS in India as difficult to observe due to its habit of sharing the same habitat as the tiger (Hancock *et al*. 1992: 83-84). The authors noted the ability of WNS to nest in or near human

Figure 2. Adult Woolly-necked Stork at 3,500 m altitude at Napa Lake, China. Photograph by Peng Jian-sheng.

habitation but did not discuss these observations further beyond a parenthetical mention. Some later species accounts included agricultural areas as habitats used by WNS, but the source of this information was not clear (Elliott 1992). These species accounts continued to state that primary threats to WNS were habitat loss and hunting.

Other literature with analysed field observations, primarily from south Asia and southern Africa, took a different trajectory in describing WNS status and ecology. Multi-year counts along a protected riverine reserve showed WNS populations to be stable in multiple locations (Sharma and Singh 2018). Higher resolution observations showed WNS to habitually use unprotected wetlands situated in agricultural landscapes (Pande *et al*. 2007). Analyses also showed relatively large numbers of WNS to be resident in human-modified landscapes using a variety of man-made features such as gardens, cell-phone towers, residential back yards, irrigation canals, village trees, crop fields and fallow fields in Asia and Africa (Sundar 2006; Choudhary *et al*. 2013; Vaghela *et al*. 2015; Greeshma *et al*. 2018; Thabethe and Downs 2018). In KwaZulu Natal, several observations have been made on WNS at land fills with dozens of storks gathering at sites where livestock offal was dumped (J. Gula pers. comm.; Thabethe and Downs 2018). In south-east Asia, research continued to be focussed largely inside protected reserves, and camera-trapping studies confirmed the value of seasonal shallow water holes inside forest preserves for WNS (Pin *et al*. 2020).

Both generalized accounts and literature published using primary observations provided similar information regarding some aspects of the species' biology. For example, both suggested that WNS in Africa nested singly but often congregated suggestive of seasonal movements. Both sources also described the WNS in Asia as being a solitary nesting stork usually found in small groups of < 4 with larger flocks being rare and seasonal.

Depending on the source of information, descriptions of the ecology and conservation requirements of WNS varied in key aspects. The conservation implications of this variation were not trivial. Generalized accounts continued to stress that the species was imperilled by habitat loss and hunting especially in Asia. This continued repetition alongside the proposed split of WNS into two species likely biased status assessments. However, primary literature from south Asia showed the species using a variety of human-dominated landscapes including agricultural areas in relatively large numbers. This was similar to the habits of the WNS in Africa. Thanks in part to an absence of ecological work on the species, the population estimate for the Asian WNS is a "best guess" at 25,000 (Wetlands International 2020).

Special Section on WNS

I started reaching out to colleagues, researchers and students in 2019 to consider delving into their notebooks looking for unpublished information on WNS. By early 2020, enough people had responded for me to be sure that a Special Section on the species could be developed in *SIS Conservation*. Luis Santiago Cano was enthusiastic as ever about the idea and I started working with potential authors to develop manuscripts. At the time of finalising Issue 2, we have completed reviewing, editing, and proofing nine articles that form the Special Section on WNS. There are additional manuscripts in different stages of completion that could not meet the deadline for Issue 2 but will hopefully be included in subsequent issues.

The papers

The articles for the Special Section are diverse, including a collection of unpublished field sightings (Tiwary 2020), a couple of sightings of nesting in previously unreported locations (Hasan and Ghimire 2020; Mehta 2020), an analysis of secondary data available on the online portal eBird (Roshnath and Greeshma 2020), analyses of a combination of field data and volunteer observations from various sources (Gula *et al*. 2020; Mandal *et al*. 2020), and analyses of information collected from systematic field surveys (Katuwal *et al*. 2020; Kittur and Sundar 2020; Win *et al*. 2020). Such a combination of papers with such disparate sources of information has its challenges in terms of how results should be interpreted and whether findings can be easily compared. Notwithstanding these relatively minor challenges, the papers comprise the largest yet source of ecological information on WNS. This helps to propel the species from being one of the least studied storks to one whose habits are much better understood.

Tiwary (2020) used opportunistic field observations made while on other research to build a small and useful understanding of WNS using agricultural fields and unprotected wetlands in northern India. Tiwary (2020) also describes a potentially novel foraging behaviour that speaks of the behavioural plasticity that WNS appear capable of. Hasan and Ghimire (2020) describe nesting of WNS on cell phone towers in Bangladesh – a country where the species was suspected to be extinct as a breeding species. This behaviour of using human-made structures for nesting by WNS was once thought to be novel but seems to be widespread suggesting that some constructions potentially benefit the species. Mehta (2020) provides observations of failed nests of WNS in Udaipur city in India which suggest that WNS may be starting to nest in cities. This is exciting news since WNS have never been observed nesting inside cities in south Asia. The phenomenon of WNS using artificial structures close to human habitation to nest suggests that the species is not persecuted in these areas while also underscoring the species' ability to use unprotected human-dominated areas.

Secondary data from online portals where volunteers upload observations can often be of great use to develop preliminary understanding of birds such as the poorly studied WNS. Roshnath and Greeshma (2020) pull together thousands of observations from Kerala state to piece together an understanding of WNS ecology. Significantly, they show that frequency of sightings of WNS has remained stable between 2000 and 2019, that breeding records are restricted to few areas in the state, and that numbers of WNS appear to reduce across the state during summer. Similarly, Mandal *et al*. (2020) assemble sightings for the north-eastern state of Assam and combine their own observations to build a picture of the species' ecology. Their analyses show WNS in Assam to be seasonal visitors primarily during the winter, with no confirmed record of breeding. This is unusual for WNS that shows seasonal movements in summer in other locations in south Asia. Both these papers also caution readers about the challenges that freely available data posed, but effectively use available information to set up interesting hypotheses that will require standardised field studies to confirm.

Gula *et al*. (2020) similarly used thousands of records of WNS from across Africa and Asia. They obtained observations on WNS from various published and online sources, and were able to include more recent field records that authors of papers in the Special Section provided. Gula *et al*. (2020) provide a comprehensive predictive modelling of WNS distribution across their entire distribution range. Their results show the storks' distribution is affected by slightly different variables in Africa and Asia pointing to varying environmental conditions and potentially also how storks interact with humans in each location. They suggest that differences could also be due to African researchers usually avoiding agricultural areas where WNS are being increasingly sighted. Modelling also confirmed that the species is very widespread in south Asia and Africa, but with a restricted and declining distribution in south-east Asia.

While papers relying on secondary information have developed substantial understanding of WNS ecology and conservation requirements, it was very exciting to receive manuscripts that analysed primary field data. The three papers with field data are additionally exciting in using systematic repeatable field methods, covering relatively substantial swathes of geographical areas, and undertaking repeated visits to sampling sites across seasons and years. Katuwal *et al.* (2020) use a novel data set from transects laid across lowland Nepal to show that WNS are perhaps uncommon on these floodplains. Kittur and Sundar (2020) use a multi-year multi-location data set to show that WNS are widely distributed across agricultural areas in lowland Nepal and northern India. They also provide preliminary population estimates suggesting that WNS population size has previously been severely underestimated. They also underscore the complexity of monitoring WNS and the ecological plasticity that this species appears to display potentially in response to seasonal landscape-level changes that different agricultural landscapes experience. Finally Win *et al*. (2020) have analysed a unique data set, perhaps the first such data from Myanmar, that allows an assessment of WNS abundance and habitat use inside and outside protected areas. Using data collected systematically from several locations and seasonally over multiple years, they showed that WNS were more abundant outside protected areas in Myanmar, and that WNS liberally used unprotected wetlands and agriculture fields.

Emerging methodological considerations

Transect based monitoring of WNS has been carried out in several locations across south and south-east Asia. Some studies have used transects of varying lengths placed either systematically across entire landscapes (e.g. Sundar and Kittur 2012; Katuwal *et al*. 2020) or in areas having different protection status (Win *et al*. 2020). These studies visited transects multiple times for a relatively large number of transect runs providing a noticeable propensity to variation in WNS sightings. Katuwal *et al*. (2020) used 0.5 km transects across lowland Nepal and recorded WNS in 1.4% of 985 transect runs. Sundar and Kittur (2012) used 1 km transects across the Gangetic floodplains of Uttar Pradesh and recorded WNS in 12% of 360 transect runs. Win *et al*. (2020) used 1.5 km transects inside protected areas and 2 km transects outside protected areas. WNS were seen in 25% of 342 transect runs inside protected areas, and in 61% of 648 transect runs outside protected areas. Each of these studies were carried out on landscapes that varied enormously in land use but were in areas where human attitudes to wildlife was more tolerant relative to places like south-east Asia where hunting appears to be widespread. Many different factors could explain the variation in the proportion of transect runs with WNS sightings. However, it is somewhat compelling to note that the WNS sightings were the least in the study with the smallest transects and vice-versa. Intermediate values were obtained in the study with intermediate transect length. These preliminary observations suggest that studies focusing on WNS across relatively large landscapes will require transects of at least 1.5 km in length to obtain adequate information.

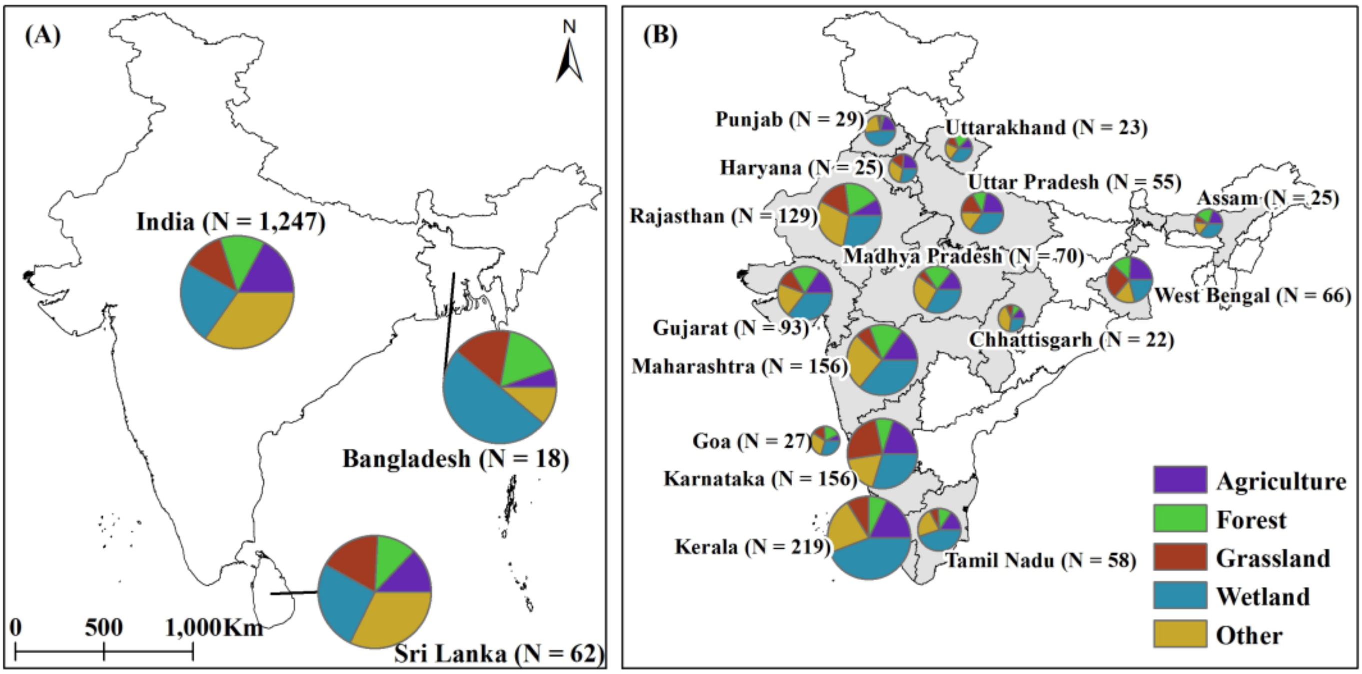
An additional aspect that the new papers bring out is the widespread and significant use of non-wetland habitats by WNS. Past long-term monitoring data on WNS were counts of storks from wetlands as part of the mid-winter waterfowl census that have been useful to develop "guesstimates" of population sizes (Wetlands International 2020). These censuses focus entirely on wetlands and these counts would therefore be inadequate to understand population sizes of the WNS. Other SIS species that have previously been assessed using wetland surveys but are inadequately represented in such counts due to their habit of largely using farmland habitats, include the Black-necked Stork *Ephippiorhynchus asiaticus* (Sundar 2005), the Painted Stork

Mycteria leucocephala and the Black-headed Ibis *Threskiornis melanocephalus* (Sundar 2006). A much more careful assessment of the habits of SIS species is needed to identify which species can be reliably monitored using only wetland surveys and which ones require wider coverage.

WNS natural history and information sources

While some papers in the Special Section were developed using either freely available data online, or combined different sources of data, there is not yet an evaluation of the reliability of the different sources of information. Habitat use emerged as an aspect that was relatively easy to document. Findings from few sites within the WNS distribution varied significantly from information in most generalised accounts. I was curious as to whether a similar understanding would be reached if photographs available on the internet were used as a source of data to measure habitat use of WNS. Thanks to volunteers, 2,254 photographs of WNS in south Asia were curated from the internet (eBird, Facebook, iNaturalist, Wiki photographs, individual blogs, and others). Volunteers listed the broad habitat categories (agriculture, forests, wetlands, other) that WNS were using in photographs. WNS habitat use determined from these photographs showed considerable variation in the three south Asian countries for which we obtained at least 15 photographs each (Figure 3A). In addition, WNS habitat use was similar across some Indian states but differed in others (Figure 3B). WNS habitat use assessed using photographs suggested a low use of agricultural areas and a high use of wetlands (Figure 3C). This was contrary to the data obtained by systematic field work across large landscapes in south Asia (Figure 3C).

This variation likely reflects the habits of photographers and bird watchers visiting some areas like wetlands more than they do others. Data obtained from online photographs may therefore reflect people's biases rather than habits of WNS, similar to the bias in historic observations by researchers and conservationists. Any freely available data therefore requires to be used thoughtfully and will likely not be adequate to



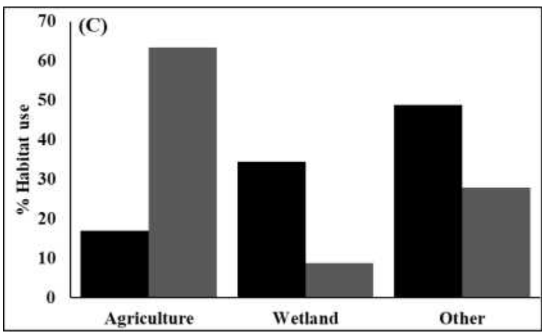


Figure 3. Habitat use by Woolly-necked Storks assessed using freely available photographs online at the level of the country in south Asia (A: only countries that had at least 15 photographs) and states of India (B: only states that had at least 20 photographs). Maps were developed by Swati Kittur using information curated by volunteers listed in the Acknowledgements. Additionally, a comparison of use of two major habitat types by storks as assessed using online photographs (C: black bars) and multi-year field data (from Kittur and Sundar 2020; C: dark-grey bars).

develop an unbiased understanding of the species' natural history and conservation requirements.

WNS as a study species

Papers in the Special Section and other literature point to the suitability of WNS as a model study species, especially to understand how agricultural areas can be retained as multifunctional landscapes for both growing crops and providing SIS species with habitat. Such understanding is critically important to conserve biodiversity in crowded countries such as those in south and south-east Asia where developing new reserves for wildlife is becoming less and less feasible. New papers in this issue of *SIS Conservation* and available literature provide considerable understanding of WNS, but many ecological aspects remain unstudied. Studies to understand its feeding habits, breeding ecology, movements, and seasonal use of habitats in unexplored landscapes. Behaviour of WNS in different conditions are very poorly documented, and recent observations are beginning to showcase how this line of study may yield novel insights into bird behaviour and conservation (Ghimire *et al*. 2020; Ghimire *et al*. in press). Studies are needed across Africa to understand if the species uses areas close to and within human habitation elsewhere in the continent, and whether different pressures such as land use change and hunting regulate where and how many WNS live.

WNS is also a species that can be used to underscore the importance of using evidence to build conservation status assessments. WNS has helped to showcase how generalised species accounts can either add new information or accentuate some aspects of existing information without substantiation. This in turn, when parroted by subsequent generalised accounts, can lead to incomplete and incorrect understanding of the species' habits. Incorrect assumptions regarding a species' habits can lead to unreliable population estimates and eventual assignment to an inappropriate conservation status. This problem appears to be more widespread for SIS species than previously known (see also Gula *et al*. 2019; Gula 2020). While all SIS species have been accorded conservation status, several species like the WNS lacked even basic studies, leading to questionable status assessments. Such species that require basic ecological research need to be explicitly identified so that resources may be acquired to develop studies which in turn can inform evidence-based status assessments.

An additional problem that the WNS is helping highlight is the unequal level of threats that a single species faces in different parts of its distribution range. While the south Asia population of WNS appears to be safe outside inviolate forested reserves, the south-east Asian population, which constitutes a relatively small proportion of the species' distribution range (see Gula *et al*. 2020), appears to require urgent conservation intervention (e.g. Mittermeier *et al*. 2019). The status assessment of the species will, however, be biased by its population and status in the rest of the distribution range. To address this bias - which is certainly not unique to WNS - the IUCN status assessment process needs to develop a mechanism where imperilled populations can be highlighted even for species that are not endangered or threatened.

Epilogue

A discussion to reassess the conservation status of WNS was recently hosted on a new online forum (BirdLife International 2020). New information that was being developed for the Special Section of this issue of *SIS Conservation* was provided on this forum to help build a more complete understanding of WNS. Several papers published in the Special Section were not complete at the time of the discussion and will add to the growing information on the species. The new discussions included observations from Pakistan and Nepal that suggested that the south Asian population was expanding. Experts, however, underscored the serious predicament of the WNS in south-east Asia, as did a recent publication along the Mekong river in Cambodia (Mittermeier *et al*. 2019). One of the concerned experts on the discussion suggested that the WNS numbers being reported across south Asia may be due to roaming individuals that were being recounted in different locations. This suggestion seemed bizarre and experts in south Asia responded on how this was implausible. To me, it brought home the dire situation in south-east Asia where experts appear unable to conceive that the species may number in the tens of thousands anywhere. Using the information provided to the updated discussion, WNS in Asia is now proposed to be classified as "Near-threatened". This revision is certainly a more realistic reflection of the species' state of being, but the new down listing reduces the number of species that conservationists can use in south-east Asia to stem the ongoing deterioration of forests and wetlands. While new work has added tremendously to knowledge of WNS ecology, they also help bring out how much remains unknown. My hope is that the Special Section attracts additional attention to WNS and that we can together find a way to help secure the species, specially the faltering population in south-east Asia. At the very least, I hope that WNS, and other SIS species, no longer remain ignored.

Acknowledgments

I am grateful to Luis Santiago Cano Alonso for his support during the development of the Special Section. I am also grateful to the many authors who responded to my call readily to develop manuscripts, and some kindly invited me to co-author papers with them. In the process, we have collectively improved understanding of WNS substantially, and I have personally learnt a lot. The reviewers of manuscripts submitted to the Special Section were outstanding for ensuring that authors received timely but critical and helpful inputs. Many thanks also to the volunteers who fastidiously curated photographs from the internet, especially Radhika Chaturvedi, Nandini Pathak, Vedang Saikhedkar, Rishwa Shekhar, Nawin Tiwary, and Harsh Trivedi. I am also grateful to Fen-qi for reaching out to us with the excellent photographs of WNS taken at 3,500 m in China. Thanks are also due to Pradeep Sukhwal for donating the excellent photograph of WNS that we selected as the cover photo for this issue. Thanks to Luis Santiago Cano, John Grant, Jonah Gula and Swati Kittur for their thoughts on this Editorial. I am grateful to the Nature Conservation Foundation for providing a home to the SIS Specialist Group.

References

BirdLife International. 2014. Archived 2014 discussion: Woolly-necked Stork (*Ciconia episcopus*) is being split: list *C. episcopus* as Vulnerable? Topics archived. Archived 2014 topics A-H. https://globally-threatened-bird-forums.birdlife.org/topics-archive/, accessed 07 November 2020.

BirdLife International. 2020. Asian Woollyneck (*Ciconia episcopus*): revise global status? BirdLife's Globally Threatened Bird Forums. https://globally-threatened-bird-forums.birdlife.org/2020/06/asian-woollyneck-ciconia-episcopus-revise-global-status/, accessed 07 November 2020.

Britton, P. L. (Ed.). 1980. *Birds of East Africa*. East Africa Natural History Society, Nairobi.

Choudhary, D. N., T. K. Ghosh, J. N. Mandal, R. Rohitashwa and S. K. Mandal. 2013. Observations on the breeding of the Woolly-necked Storks *Ciconia episcopus* in Bhagalpur, Bihar, India. *Indian BIRDS* 8(4): 93-94.

del Hoyo, J., N. Collar and E. F. J. Garcia. 2019. African Woollyneck (*Ciconia miscroscelis*). In: J. del Hoyo, A. Eliott, D. A. Christie and E. de Juana (Eds.) *Handbook of the birds of the world*. Lynx Edicions, Barcelona, Spain.

Elliott, A. 1992. Family Ciconiidae (storks). Pp. 441–442. In: J. del Hoyo, A. Elliott and J. Sargatal (eds.) *Handbook of the birds of the world. Vol 1*. Lynx Edicions, Barcelona, Spain.

Ghale, T. R. and D. K. Karmacharya. 2018. A new altitudinal record for Asian Woollyneck *Ciconia episcopus* in south Asia. *BirdingASIA* 29: 96-97.

Ghimire, P., N. Pandey, B. Belbase, R. Ghimire, C. Khanal, B. S. Bist and K. P. Bhusal. 2020. If you go, I'll stay: nest use interaction between Asian Woollyneck *Ciconia episcopus* and Black Kite *Milvus migrans* in Nepal. *BirdingASIA* 33: 103-105.

Ghimire, P., N. Pandey, Y. P. Timilsina, B. S. Bist and K. S. G. Sundar. In press. Woolly-necked Stork activity budget in lowland Nepal's farmlands: The influence of wetlands, seasonal crops and human proximity. *Waterbirds*.

Gill, F., D. Donsker and P. Rasmussen. 2020. Storks, frigatebirds, boobies, cormorants, darters. *IOC World bird list v. 10.2*. International Ornithologists Union. https://www.worldbirdnames.org/bow/storks/, accessed 07 November 2020.

Greeshma, P., R. P. Nair, E. A. Jayson, K. Manoj, V. Arya and E. G. Shonith. 2018. Breeding of Woolly-necked Stork *Ciconia episcopus* in Bharatapuzha river basin, Kerala, India. *Indian BIRDS* 14(3): 86-87.

Gula, J. 2020. It's time for the Saddle-billed Stork to be on our radar. *SIS Conservation* 2: 7-9.

Gula, J., W. R. J. Dean and K. S. G. Sundar. 2020. Known and potential distributions of African *Ciconia microscelis* and Asian *C. episcopus* Woollyneck Storks. *SIS Conservation* 2: 80-95.

Gula, J., F. Weckerly and K. S. G. Sundar. 2019. The first range-wide assessment of Saddle-billed Stork *Ephippiorhynchus senegalensis* distribution. *Ostrich* 90: 347-357.

Han, L. -X., B. Han, Z. -W. Den, H. -Z. Yu and J. -L. Zhao. 2011. Woolly-necked Stork, a new bird record of China. *Zoological Research* 32: 575-576. (In Chinese with English abstract).

Hancock, J. A., J. A. Kushlan and M. P. Kahl. 1992. *Storks, ibises and spoonbills of the world*. Academic Press, London, United Kingdom.

Hasan, M. T. and P. Ghimire. 2020. Confirmed breeding records of Asian Woollyneck *Ciconia episcopus* from Bangladesh. *SIS Conservation* 2: 47-49.

Katuwal, H. B., H. S. Baral, H. P. Sharma and R.-C. Quan. 2020. Asian Woollynecks are uncommon on the farmlands of lowland Nepal. *SIS Conservation* 2: 50-54.

Kittur, S. and K. S. G. Sundar. 2020. Density, flock size and habitat preference of Woolly-necked Storks *Ciconia episcopus* in south Asian agricultural landscapes. *SIS Conservation* 2: 71-79.

Luthin, C. S. 1987. Status of and conservation priorities for the world's stork species. *Colonial Waterbirds* 10: 181-202.

Mandal, J., L. M. Abraham and R. Bhaduri. 2020. A note on the spatial and temporal distribution of Asian Woollyneck in Assam. *SIS Conservation* 2: 62-67.

Mehta, K. 2020. Observations of Woolly-necked Stork nesting attempts in Udaipur city, Rajasthan. *SIS Conservation* 2: 68-70.

Mittermeier, J. C., E, M. Sandvig and M. Jocque. 2019. Surveys in 2018 along the Mekong river, northern Kratie province, Cambodia, indicate a decade of declines in populations of threatened bird species. *BirdingASIA* 832: 80-89.

Pande, S., N. Sant, R. Bhate, A. Ponkshe, P. Pandit, A. Pawashe and C. Joglekar. 2007. Recent records of wintering White *Ciconia ciconia* and Black *C. nigra* storks and flocking behaviour of White-necked Storks *C. episcopus* in Maharashtra and Karnataka states, India. *Indian Birds* 3(1): 28-32.

Pin, C., D. Ngoprasert, T. N. E. Gray, T. Savini, R. Crouthers and G. A. Gale. 2020. Utilization of waterholes by globally threatened species in deciduous dipterocarp forest of the Eastern Plains landscape of Cambodia. *Oryx* 54: 572-582.

Roshnath, R. and P. Greeshma. 2020. Status of Woolly-necked Storks in Kerala, south-western India. *SIS Conservation* 2: 55-61.

Scott, J. A. 1975. Observations on the breeding of Woollynecked Storks. *Ostrich* 46: 201-207.

Sharma, R. K. and L. A. K. Singh. 2018. Spatial and temporal patterns of stork sightings (Aves: Ciconiidae) in National Chambal Sanctuary of Gangetic river system. *Journal of Threatened Taxa* 10: 11410-11415.

Sundar, K. S. G. 2005. Effectiveness of road transects and wetland visits for surveying Black-necked Storks *Ephippiorhynchus asiaticus* and Sarus Cranes *Grus antigone* in India. *Forktail* 21: 27-32.

Sundar, K. S. G. 2006. Flock size, density and habitat selection of four large waterbirds species in an agricultural landscape in Uttar Pradesh, India: implications for management. *Waterbirds* 29: 365-374.

Sundar, K. S. G. and S. Kittur. 2020. Methodological, spatial and temporal factors affecting modelled occupancy of resident birds in the perennially cultivated landscape of Uttar Pradesh, India. *Landscape Ecology* 27: 59-71.

Thabethe, V. and C. T. Downs. 2018. Citizen science reveals widespread supplementary feeding of African woolly-necked storks in suburban areas of KwaZulu-Natal, South Africa. *Urban Ecosystems* 21: 965-973.

Tiwary, N. K. 2020. Observations on distribution and feeding behaviour of Woolly-necked Storks *Ciconia episcopus* during 2010-20 in north India. *SIS Conservation* 2: 42-46.

Vaghela, U., D. Sawant and V. Bhagwat. 2015. Woolly-necked Storks *Ciconia episcopus* nesting on mobile towers in Pune, Maharashtra. *Indian BIRDS* 10(6): 154-155.

Vyas, R. and R. S. Tomar. 2006. Rare clutch size and nesting site of Woolynecked Stork (*Ciconia episcopus*) in Chambal River Valley. *Newsletter for Birdwatchers* 46(6): 95.

Wetlands International. 2020. *Waterbird population estimates*. http://wpe.wetlands.org/, accessed 09 November 2020.

White, C. M. N. and M. D. Bruce. 1986. *The Birds of Wallacea*. British Ornithologists Union Checklist No. 7.

Win, M. S., T. S. Myint, A. M. Yi, K. Khine, H. S. Po, K. S. Non and K. S. G. Sundar. 2020. Comparing Woolly-necked Stork *Ciconia episcopus* abundance and habitat use inside and outside protected areas in Myanmar. *SIS Conservation* 2: 96-103.

ISSN 2710-1142(online)
SIS Conservation, 2020, 2, 42-46
RESEARCH ARTICLE

Observations on distribution and feeding behavior of Woolly-necked Stork *Ciconia episcopus* during 2012-20 from north India

Nawin Kumar TIWARY[1*]

[1]Department of Environmental Studies, Indraprastha College for Women, University of Delhi, Delhi, India.
*E.mail: tiwarynawin@gmail.com

Abstract Woolly-necked Stork *Ciconia episcopus* is a tropical species which has its distribution range in south Asia and south-east Asia with a stronghold of its population in India, Sri Lanka, Nepal, Myanmar, Thailand, and Indonesia. It inhabits a wide range of habitat from wetlands, rivers, ponds, tanks, mudflats, and agricultural fields. Despite its population having a strong presence in India, little is known about their habitat preferences, nesting, and foraging behavior. This paper reports observations about the habitat use and observation of a previously unknown foraging habit of the species in northern India. Wetlands (58.3 % of sightings) and agricultural fields (37.5 % of sightings) were found to be the most occupied habitats with an average flock size of 1.87 ± 0.25. This study also reports an unusual feeding behavior among Woolly-necked Stork which may be a true scavenging behavior or an opportunistic feeding of insects from an animal carcass. Woolly-necked Storks appear to be relatively plastic in their ability to use both wetlands and agricultural fields and being able to scavenge when the opportunity was available. Detailed studies on habitat use and foraging requirements of the species are missing and are required to assist with developing a better ecological understanding of the species.

Keywords Woolly-necked Stork, flock size, habitat use, north India, scavenging.

Introduction

Woolly-necked Stork *Ciconia episcopus* is a glossy-black stork with a fluffy white neck and white under tail coverts. It is distributed in south Asia and south-east Asia with a large part of its population in India, Sri Lanka, Nepal, Myanmar, Thailand, and Indonesia (BirdLife International 2017). It inhabits a wide range of habitat from wetlands, rivers, ponds, tanks, mudflats, and agricultural fields. Despite its population having a stronghold in India, robust ecological knowledge about their habitat preferences and key vital functions like nesting and foraging is largely missing (Jangtarwan *et al*. 2019; Kularatne and Udagedara 2017). Studies from around the world have mostly focused on the breeding of the species and provide basic information about their nesting period, mating display, nesting substrate, and clutch size. They are solitary nesters (Vaghela *et al*. 2015) and prefer tall trees located in any natural landscape for placing their platform nests. However, there are existing records of their nesting on trees in villages (Choudhary *et al*. 2013; Kularatne and Udagedara 2017) and unique substrate like mobile towers in urban areas (Vaghela *et al*. 2015). Even in the domain of breeding ecology, information on vital rates like nest survival for the species is not available.

Woolly-necked Stork is predominantly carnivorous with a wide range of dietary preferences including frogs, reptiles, molluscs and large insects (Ali and Ripley 1978; del Hoyo *et al*. 1992). They also occasionally forage for fishes in dried up water

Article history
Received: 22 July 2020,
Received in revised form: 04 August 2020,
Accepted: 06 August 2020,
Published online: 05 October 2020

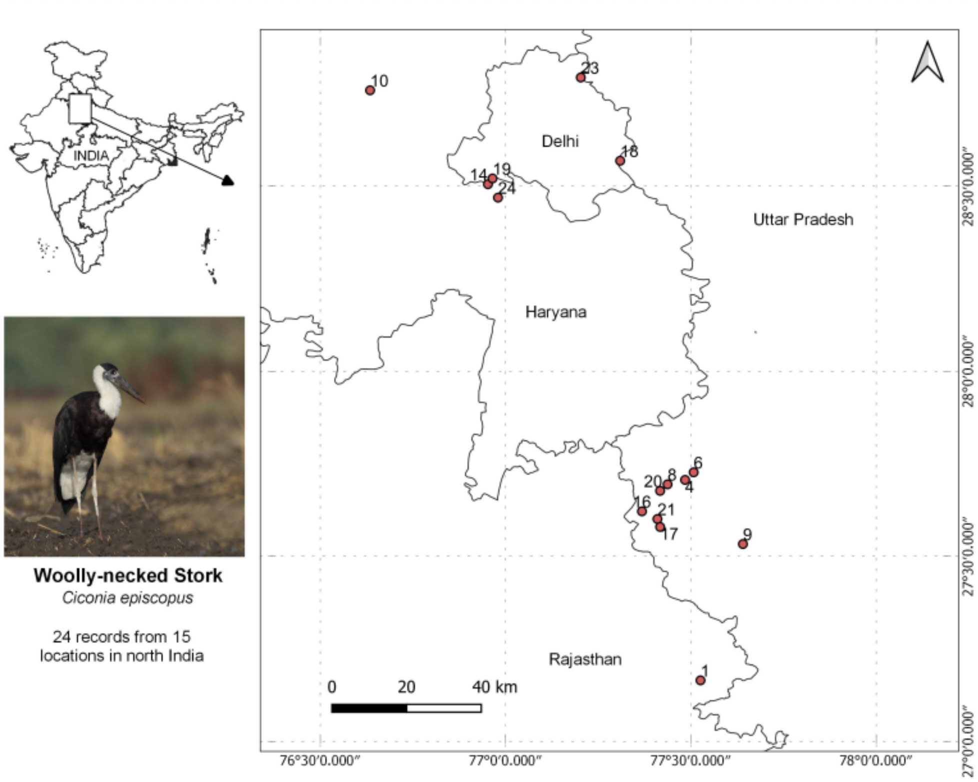


Figure 1. A map showing records of Woolly-necked Stork presence at 15 locations in North India. The description of the location marker is in Table 1. Serial number of a location as per their first appearance in the table is used as labels.

holes and streams. Studies have shown that natural wetlands are their preferred foraging sites (Sundar 2006) but they also use agricultural fields, marshes, and flooded pastures. The species is thought to be threatened by fragmentation and loss of habitat which have negatively impacted its population, mainly in south-east Asia where a marked decline is observed over the past few years (BirdLife International 2017). The absence of baseline data on the distribution and ecology of the species and lack of a better understanding of relative threats is a major challenge in devising effective conservation strategies for this species. This note reports observations about the habitat use and one instance of scavenging by Woolly-necked Storks in northern India.

Methods and study area

The observations on Woolly-necked Stork were made mainly in four states of northern India, *viz*. Delhi, Haryana, Uttar Pradesh, and Rajasthan. From Rajasthan, the Keoladeo National Park, Bharatpur was the only site where data was recorded. During several field visits from 2012 to 2020, we conducted extensive surveys in these four states to record sightings of the focal species (Figure 1). Field surveys were conducted for 10 to 14 days, every year between November to March. Counts were made at focal wetlands and all the road routes traversed to reach these wetlands. Observation on habitat use, flock size, flock composition and foraging behavior were recorded. All observations were made in the early morning (0600 to1000 h) using a pair of binoculars.

Results

Woolly-necked Storks were sighted in different habitats with most of the observations in unprotected agricultural wetlands (N = 8), protected wetlands (N = 6), agricultural fields (N = 9), and riverbeds (N = 1) (Table 1). The average flock size of Woolly-necked Stork observed was 1.87 ± 0.25 (range = 1 to 8). Mean flock size for the species was estimated to be 2.33 ± 0.62 in agricultural fields and 1.57 ± 0.17 in wetlands. The largest recorded group was a flock with eight individuals foraging in an agricultural field near Palson village, Uttar Pradesh along with other waterbird species. They were seen foraging alongside other species (45% of sightings) like Painted Stork *Mycteria leucocephala*, Black-headed Ibis *Threskiornis melanocephalus*, Eurasian Spoonbill *Platalea leucorodia*, Cattle Egret *Bubulcus ibis*, Little Egret *Egretta garzetta* and Grey Heron *Ardea cinerea*.

In June 2018, an unusual feeding behavior was observed. A pair of Woolly-necked Stork was seen feeding on a cattle carcass in Keoladeo National Park, Bharatpur, India (Figure 2). They were seen digging their beak into the flesh of the dead animal. They were either feeding on the flesh or were picking up insects or maggots from the

Figure 2. A pair of Woolly-necked Stork feeding on the cattle carcass at Keoladeo National Park, Bharatpur, Rajasthan, India. Photograph by Nawin K. Tiwary.

rotting carcass. Another interesting observation was made in January 2020, when a pair of Woolly-necked Stork was seen foraging for insects in freshly plowed agricultural fields along with a flock of Cattle Egrets (Figure 3). One foraging individual in this pair had a considerably larger or overgrown lower mandible. Despite this deformity in its beak structure, the bird was able to forage normally alongside its conspecific.

Discussion

Sightings of Woolly-necked Stork in north India during the study reflects that both wetland and agricultural fields were used by Woolly-necked Stork, and they were seen largely in small flocks of 2-3 individuals. Most of the observations were from unprotected agricultural wetlands with very few from a protected reserve. These observations are identical to those from another agricultural landscape in south-western Uttar Pradesh where the storks also used irrigation canals, fallow fields and grasslands (Sundar 2006). Unprotected wetlands, which are mostly outside the protected area network, are fast diminishing due to rapid urban expansion and agricultural intensification.

In our study, the mean flock size for Woolly-necked Stork was estimated to be 1.87 ± 0.25, however, in one case the largest recorded flock was of 8 individuals. Woolly-necked Storks are known to exhibit social foraging behavior during non-breeding seasons (Pande *et al*. 2007) and aggregate in large numbers in foraging patches usually

Figure 3. Woolly-necked Stork feeding with a flock of Cattle Egret in a freshly tilled agricultural field. The unusual growth in the lower mandible can be seen in this individual. Photograph by Nawin K. Tiwary.

Table 1: Woolly-necked Stork *Ciconia episcopus* sightings in north India. Sightings are provided in chronological order.

Sl. No.	Location	Coordinates	Flock size	Habitat	Monospecific/ Mixed flock (species composition*)	Date
1.	Keoladeo National park, Rajasthan	27° 9'54.12"N; 77°31'33.92"E	2	Wetland	Mixed (KBD, ES, BHI)	28 November 2012
2.	Keoladeo National park, Rajasthan	27° 9'54.12"N; 77°31'33.92"E	2	Wetland	Monospecific	12 February 2013
3.	Keoladeo National park, Rajasthan	27° 9'54.12"N; 77°31'33.92"E	1	Wetland	Mixed (LE)	06 December 2013
4.	Khanpur, Uttar Pradesh	27°42'41.77"N; 77°29'26.42"E	2	Agricultural field	Monospecific	17 January 2014
5.	Keoladeo National park, Rajasthan	27° 9'54.12"N; 77°31'33.92"E	2	Wetland	Mixed (BHI, LE)	15 September 2015
6.	Chhata, Uttar Pradesh	27°43'37.57"N; 77°30'27.59"E	1	Wetland	Monospecific	09 November 2015
7.	Chhata, Uttar Pradesh	27°43'37.57"N; 77°30'27.59"E	1	Wetland	Monospecific	13 November 2015
8.	Khaira, Uttar Pradesh	27°41'41.88"N; 77°26'14.17"E	2	Wetland	Mixed (PS)	20 December 2015
9.	Mathura, Uttar Pradesh	27°31'59.78"N; 77°38'26.10"E	1	Agricultural field	Monospecific	25 November 2017
10.	Dighal, Haryana	28°45'33.69"N; 76°38'4.24"E	1	Wetland	Mixed (BHI)	14 February 2018
11.	Dighal, Haryana	28°45'33.69"N; 76°38'4.24"E	1	Agricultural field	Monospecific	08 December 2018
12.	Dighal, Haryana	28°45'33.69"N; 76°38'4.24"E	1	Wetland	Mixed (PS)	08 December 2018
13.	Keoladeo National park, Rajasthan	27° 9'54.12"N; 77°31'33.92"E	1	Wetland	Mixed (GH,PS)	16 December 2018
14.	Najafgarh Jheel, Haryana	28°30'19.98"N; 76°57'9.36"E	2	Wetland	Monospecific	05 January 2019
15.	Najafgarh Jheel, Haryana	28°30'19.98"N; 76°57'9.36"E	1	Agricultural field	Mixed (BHI, CE)	05 January 2019
16.	Barsana, Uttar Pradesh	27°37'19.23"N; 77°22'11.28"E	2	Agricultural field	Monospecific	07 February 2019
17.	Palson, Uttar Pradesh	27°34'46.22"N; 77°25'1.64"E	8	Agricultural field	Mixed (PS)	07 February 2019
18.	Okhla Bird Sanctuary, Uttar Pradesh	28°34'8.28"N; 77°18'33.44"E	1	Wetland	Monospecific	08 February 2019
19.	Jhatikra, Haryana	28°31'16.18"N; 76°57'53.77"E	3	Agricultural field	Monospecific	29 March 2019
20.	Ajanoka, Uttar Pradesh	27°40'37.27"N; 77°25'1.50"E	2	Agricultural field	Monospecific	09 December 2019
21.	Seeh, Uttar Pradesh	27°36'3.39"N; 77°24'35.33"E	2	Agricultural field	Monospecific	09 December 2019
22.	Najafgarh Jheel, Haryana	28°30'19.98"N; 76°57'9.36"E	2	Wetland	Mixed (CE)	10 January 2020
23.	Yamuna River, Ibrahimpur, Delhi	28°47'38.24"N; 77°12'10.89"E	2	Riverbed	Monospecific	12 February 2020
24.	Basai Wetland, Haryana	28°28'9.61"N; 76°58'46.80"E	3	Wetland	Mixed (IE, CE)	04 March 2020

*The abbreviations used are as follows – KBD: Knob-billed Duck *Sarkidiornis melanotos*; PS: Painted Stork *Mycteria leucocephala*; GH: Grey Heron *Ardea cinerea*; IE: Intermediate Egret *Ardea intermedia*; LE: Little Egret *Egretta garzetta*; CE: Cattle Egret *Bubulcus ibis*; BHI: Black-headed Ibis *Threskiornis melanocephalus*; ES: Eurasian Spoonbill *Platalea leucorodia*.

located in the vicinity of water bodies. They mostly feed on large insects, frogs, crabs, lizards, and snakes (Ali and Ripley 1978). However, there are no previous records of scavenging behavior in Woolly-necked Storks. The unusual feeding behavior observed by us may be a true scavenging behavior or an opportunistic feeding of insects from the animal carcass. In either case, this remains a unique photo documentation for this species. Detailed studies on habitat use and foraging pattern can be very useful in filling the gaps in the knowledge about this species. Maintaining agricultural landscape with interspersed wetlands can be a key in developing a congenial habitat for the Woolly-necked Storks.

Acknowledgments

I thank Indraprastha College for Women, University of Delhi for the award of an Undergraduate Research Grant which assisted in some parts of the fieldwork. I thank Dr. K. S. Gopi Sundar for his constructive comments on the initial drafts of this manuscript and suggesting some useful literature. I gratefully acknowledge Dr. Abdul Jamil Urfi for many insightful discussions I had with him on the storks of India. I also thank Dr. Asani Bhaduri, Vijay Singh, Mukesh, Draksha Singh, and Nandini Pathak for their assistance in fieldwork. An early draft of this manuscript immensely benefitted from the constructive comments of an anonymous reviewer.

References

Ali, S. and D. S. Ripley. 1978. *Handbook of the birds of India and Pakistan, Together with those of Bangladesh, Nepal, Sikkim, Bhutan and Sri Lanka*. Oxford University Press, Bombay, India. Vol. 1. https://doi.org/10.2307/4085288.

BirdLife International. 2017. *Ciconia episcopus* (amended version of 2016 assessment). The IUCN Red List of Threatened Species 2017: E.T22727255A110064997. 2017. https://dx.doi.org/10.2305/IUCN.UK.2017-1.RLTS.T22727255A110064997.en.

Choudhary, D. N., T. K. Ghosh, J. N. Mandal, R. Rohitashwa and S. K. Mandal. 2013. Observations on the Breeding of the Woolly-necked Stork *Ciconia episcopus* in Bhagalpur, Bihar, India. *Indian Birds* 8: 93-94.

del Hoyo, J., A. Elliot and J. Sargatal. 1992. *Handbook of the birds of the world, Vol. 1: Ostrich to Ducks*. Lynx. Lynx Edicions, Barcelona, Spain.

Jangtarwan, K., T. Koomgun, T. Prasongmaneerut, R. Thongchum, W. Singchat, P. Tawichasri, T. Fukayama, S. Sillapaprayoon, E. Kraichak, N. Muangmai, S, Baicharoen, C. Punkong, S. Poyacheknagul, P. Duengkae and K. Srikulnath. 2019. Take one step backward to move forward: assessment of genetic diversity and population structure of captive Asian Woolly-necked Storks (*Ciconia episcopus*). *PLoS ONE* 14 (10): e0223726.

Kularatne, H. and S. Udagedara. 2017. First record of the Woolly-Necked Stork *Ciconia episcopus* Boddaert, 1783 (Aves: Ciconiiformes: Ciconiidae) breeding in the lowland wet zone of Sri Lanka. *Journal of Threatened Taxa* 9 (1): 9738-9742.

Pande, S., N. Sant, R. Bhate, A. Ponkshe, P. Pandit, A. Pawashe and C. Joglekar. 2007. Recent records of wintering White *Ciconia ciconia* and Black *C. nigra* Storks and flocking behaviour of White-necked Storks *C. episcopus* in Maharashtra and Karnataka States, India. *Indian Birds* 3 (1): 28-32.

Sundar, K. S. G. 2006. Flock size, density and habitat selection of four large waterbirds species in an agricultural landscape in Uttar Pradesh, India: implications for management. *Waterbirds* 29: 365-74.

Vaghela, U., D. Sawant and V. Bhagwat. 2015. Woolly-necked Storks *Ciconia episcopus* nesting on mobile-towers in Pune, Maharashtra. *Indian Birds* 10 (6): 154-55.

ISSN 2710-1142(online)
SIS Conservation, 2020, 2, 47-49
SHORT COMMUNICATION

Confirmed breeding records of Asian Woollyneck *Ciconia episcopus* from Bangladesh

Mohammad Tarik HASAN[1], Prashant GHIMIRE[2*]

[1]Pixmatic Digital, Dhaka, Bangladesh
[2]Faculty of Science, Health & Technology, Nepal Open University, Lalitpur, Nepal
*Corresponding author; e.mail: prashantghimire66@gmail.com

Abstract Asian Woollyneck is a globally "Vulnerable" stork species found in Asia. Information on its status in Bangladesh is scanty. In this note we provide successful breeding records of Asian Woollyneck from Rajshahi and Chapainawabganj Districts confirming the breeding of the species in Bangladesh.

Keywords Bangladesh, *Ciconia episcopus*, Woolly-necked Stork.

Introduction

Asian Woollyneck *Ciconia episcopus* is a vulnerable stork species patchily distributed across South Asia and South East Asia (BirdLife International 2019). It nests on a stick platform built 10-30 m (and sometimes up to 50 m) above the ground in a tree or on artificial structures such as towers which are sometimes over water (Greeshman *et al*. 2018; BirdLife International 2019).

In Bangladesh, Asian Woollyneck was considered to be a rare winter migrant and is listed as a "Critically Endangered" species considering its small and fluctuating wintering population in the country (IUCN Bangladesh 2015). Khan (1987) mentions that Asian Woollyneck used to breed infrequently in Sunderbans, Mymensingh and Sylhet districts. However, he had no sightings of the species in a decade-long survey except for a dead bird record in Rajshahi district in 1972 (Khan 1987). Only three records of this stork were reported from the Jamuna River, Padma River and the Sundarbans between the 1990s and 2013 (Thompson *et al*. 2014). There are no breeding records for Asian Woollyneck in Bangladesh. This note provides two recent observations of breeding along with details of the nest site and the number of chicks that fledged.

Study area

Ad-hoc observations were conducted in two districts, Rajashahi and Chapai Nawabganj. Rajashahi District lies on the north bank of the Padma River opposite the Bangladesh-India border. Chapai Nawabganj is the western most district of Bangladesh bordered by the Padma River and India to the southwest.

Methods

Nests were monitored from August 2017 (Rajshahi) and September 2018 (Chapai nawabgunj) onwards after an opportunistic sighting of an Asian Woollyneck during regular birding in August 2017. Observations were carried out between August and December of 2017, 2018 and 2019 to observe nest conditions and track breeding success. Nests were observed using binoculars and photographs were taken from afar to minimize disturbance. Distances from nest site to important

Article history
Received: 24 January 2020,
Received in revised form: 22 June 2020,
Accepted: 25 June 2020,
Published online: 05 October 2020

features were estimated by the observer.

Results

Nest 1: On November 2017, we found a single nest on cell phone tower of Rajshahi district (Figure 1). This nest was 45 m above ground and located on a 65 m cell phone tower. According to local people 2017 was the first year of breeding of storks on this tower. The nest site was very close to settlements, 50 m from the Rajshahi-Nawabganj highway, 1 km to Padma River, and the tower was located on agricultural land. Number of chicks that fledged were two (2017), three (2018) and two (2019) in the three years of observation. There were two other cell phone towers within a 200 m radius of the nest within human settlements, but nesting was observed on the same tower that stood on agricultural lands. Some of the tree species that were present around the nest were *Acacia nilotica*, *Dalbergia sisso* and *Mangifera indica*.

Figure 1. A pair of Asian Woollynecks and a chick preening in a cell phone tower at Rajashahi district, Bangladesh in 2019.

Nest 2: In September 2018, the nest was observed 30 km north-west to Nest 1 near Joyandipur in Chapai Nawabganj District. Two adults with four unfledged chicks were observed in a nest on a cell phone tower which is very close to settlements and 300 m distance to Padma River. However, according to local people, this nest was subsequently disturbed during regular maintenance of the tower, and the adults abandoned the nest. None of the juveniles fledged, and this tower and nest site was not used in 2019. The most common tree species around this site were *Bombax ceiba* and *Dalbergia sisso*.

Discussion

Asian Woollyneck nests on *Bombax ceiba* (Ali & Ripley, 1978), *Dalbergia sissoo* (Ishtiaq *et al*. 2004) and *Mangifera indica* (PG, unpublished information), all of which were present around nest sites in Bangladesh. But Asian Woollyneck seemed to prefer artificial towers likely due to the greater height of the towers and the stronger nest substrates that towers provided. Vaghela *et al*. (2015) had also observed this species breeding on towers and suggests that nesting on towers could be an adaptation to rapid development. Cell phone tower of nest 1 was on an agricultural field and may have provided prey to storks during breeding. This suggests that storks could be using towers that provide easy access to food and may have avoided other towers in the vicinity that were located inside human habitation. It is also possible that they were avoiding direct human disturbance. Asian Woollyneck also forages on human dominated landscapes such as rice paddy-fields (Sundar 2006). Asian Woollyneck used to be hunted in Rajshahi (IUCN Bangladesh 2015) but the breeding of the storks so close to human habitation suggests that hunting has reduced in this region.

We have no information on maintenance of tower of Nest 1 and assume that nesting birds were disturbed minimally, or the tower was not visited for maintenance during the breeding period. When not disturbed, cell phone towers appear to be adequate for Asian Woollynecks to nest. Therefore, an awareness program is needed that can help to reduce disturbance to storks that nest on towers. Finally, there is a need to understand why Asian Woollynecks choose cell phone towers instead of nearby trees.

Acknowledgments

MTH is thankful to Enam Al Haque, Onu Tarek, Arif Ul Anam, Dr. Reza Khan, Monirul H. Khan for continuous guidance and support. PG thanks Paul Thompson and Carol Inskipp for their comment on manuscript. We appreciate support of Md. Faruk, local student who helped during nest observation. We thank two anonymous reviewers for comments and suggestions on the manuscript.

References

Ali, S. and S. D. Ripley. 1978. *Handbook of the birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan and Sri Lanka. Divers to hawks*. 2nd Edition. Oxford University Press, Delhi, India.

BirdLife International. 2019. *Ciconia episcopus*. (Amended version published in 2016). The IUCN Red List of Threatened Species 2017, accessed 2 January 2020.

Greeshman, P., P. Riju, P. Nair, E. A. Jayson, K. Manoj, V. Arya and E. G. Shonith. 2018. Breeding of Woolly-necked Stork *Ciconia episcopus* in Bharathapuzha River Basin, Kerala, India. *Indian Birds* 14: 86-87.

IUCN Bangladesh. 2015. *Red List of Bangladesh. Volume 3: Birds*. IUCN, Bangladesh Country Office, Dhaka, Bangladesh.

Ishtiaq, F., A. R. Rahmani, V. Javed, and M. C. Coulter. 2004. Nest-site characteristics of black-necked stork (*Ephippiorhynchus asiaticus*) and white-necked stork (*Ciconia episcopus*) in Keoladeo national park, Bharatpur, India. *Journal of the Bombay Natural History Society* 101: 90-95.

Khan, M. J. R. 1987. Conservation of storks and other waterbirds in Bangladesh. *Colonial Waterbirds* 10: 229-235

Sundar, K. S. G. 2006. Flock size, density and habitat selection of four large waterbirds species in an agricultural landscape in Uttar Pradesh, India: implications for management. *Waterbirds* 29: 365-374.

Thompson, P. M., S. M. Chowdhury, E. U. Haque, M. Monirul and R. Halder. 2014. Notable bird records from Bangladesh from July 2002 to July 2013. *Forktail* 30: 50-65.

Vaghela, U., D. Sawant and V. Bhagwat. 2015. Woolly-necked Storks *Ciconia episcopus* nesting on mobile-towers in Pune, Maharashtra. *Indian Birds* 10 (6): 154-155.

ISSN 2710-1142(online)
SIS Conservation, 2020, 2, 50-54
RESEARCH ARTICLE

Asian Woollynecks are uncommon on the farmlands of lowland Nepal

Hem Bahadur KATUWAL[1,2,*], Hem Sagar BARAL[3,4], Hari Prasad SHARMA[5], Rui-Chang QUAN[1]

[1]Southeast Asia Biodiversity Research Institute, Chinese Academy of Sciences, Yezin, Nay Pyi Taw 05282, Myanmar and Center for Integrative Conservation, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Mengla, Yunnan 666303, China
[2]University of Chinese Academy of Sciences, Beijing 100049, China
[3]Zoological Society of London-Nepal Office, Kathmandu 44600, Nepal
[4]School of Environmental Sciences, Charles Sturt University, Albury-Wodonga, Australia
[5]Central Department of Zoology, Institute of Science and Technology, Tribhuvan University, Kathmandu 44600, Nepal
*Corresponding author; e.mail: hembdrkatuwal@gmail.com

Abstract Asian Woollyneck *Ciconia episcopus* is a globally threatened stork found across south and south-east Asian countries. In Nepal, it is considered as a fairly common resident species although categorized as 'Near-Threatened'. Here, we report on Asian Woollyneck occurrences in 116 transects (farmland-100, forest-8, river-8) each measuring 500 m across four districts of lowland Nepal (Kapilvastu, Chitwan, Sarlahi and Sunsari) and surveyed in multiple seasons from April 2018 to December 2019 for a total of 985 transect counts. Despite our extensive survey, we recorded Asian Woollynecks in only 14 transect counts of which eight were along the buffer zone of Chitwan National Park (CNP). All sightings were of small flocks with 1-2 storks. Majority of the sightings (85%) were in farmlands, remaining in river but not in forest. We observed one nest on a Sal *Shorea robusta* tree along the buffer zone of CNP in 2019 from which one chick fledged in early October. Our study adds to the meager information available on Asian Wollyneck in Nepal and indicates that this species is sparsely distributed in the lowland farmlands.

Keywords Chitwan National Park, farmland bird, nest, Sal tree, threatened species.

Introduction

Asian Woollyneck *Ciconia episcopus* is a globally "Vulnerable" stork species distributed across south and south-east Asian countries including India, Nepal, Pakistan, Bangladesh, Bhutan, Sri Lanka Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Thailand and Vietnam with non-breeding populations in Iran and China (BirdLife International 2017). This species uses both artificial and natural wetlands such as agricultural lands, grassland, marshes, water holes, lagoons, flood plains, dams, flooded pastures, rivers, streams, lakes, and ponds (Sunder 2006; del Hoyo *et al*. 2020). Asian Woollynecks have been observed constructing nests on trees close to forest edges, wetlands, grasslands and agricultural lands (BirdLife International 2017), and more recently also on man-made structures such as cell-phone towers (Vaghela *et al*. 2015; Hasan and Ghimire 2020).

Asian Woollynecks are assumed to be declining in its range due to hunting, felling of nesting trees, habitat loss, fragmentation, wetland degradation, environment pollution and agro-chemicals (Inskipp *et al*. 2016; BirdLife International 2017). In Nepal, the species has been accorded the status of "Near-threatened" and is considered to be a fairly common resident species with a wide distribution across the length of the country and up to an altitude of 3,540 m (Inskipp *et al*. 2016; Ghale and Karmacharya 2018). However, a large distribution

Article history
Received: 30 August 2020,
Received in revised form: 13 September 2020,
Accepted: 20 September 2020,
Published online: 07 October 2020

range and a stable population has been recorded in India (SoIB 2020) with more recent work suggesting that the population of Asian Woollynecks have been greatly underestimated (Kittur and Sundar 2020). Based on emerging new information, the global status of the species was reviewed recently and a tentative decision to categories the species from "Vulnerable" to "Near-threatened" has been announced (https://globally-threatened-bird-forums.birdlife.org/2020/06/asian-woollyneck-ciconia-episcopus-revise-global-status/). Information from Nepal with which to understand the status of Asian Woollyneck remains sparse. In this paper, we analyzed data from the Farmland Bird Survey Program conducted from across four districts in lowland Nepal to understand if Asian Woollynecks are indeed common and widespread on the farmlands of lowland Nepal. The data we are presenting is from a multi-site survey and is one of the very few systematic surveys from Nepal with ecological information available for this species. We therefore believe that our work can help evaluate the status of this species in the country.

Study area

The Farmland Bird Survey Program was conducted in lowland Nepal between 2018 and 2019 across the dominant agricultural areas in this region. The lowlands extend across approximately 885 km in an east-to-west direction and comprises 43% of the country's agricultural lands (Paudel *et al*. 2017). The agricultural landscape of lowland Nepal is a highly populated region and supports half of Nepal's human population (Central Bureau of Statistics 2012). The crops are seasonal with three district growing seasons. People grow rice in the monsoon or rainy season (June-September), and mustard, wheat, sugarcane, lentils during the much drier winter (November-February). Some people keep their land fallow after the rice harvest until the next rice growing season. Other farmers cultivate maize and rice in the summer (March-May) and keep fields fallow until the subsequent rice growing season (HBK, pers. obs.). We chose four districts (Sunsari, Sarlahi, Chitwan and Kapilvastu) across lowland Nepal to conduct the bird surveys (Figure 1). Ornithological work has been previously conducted in three of these four districts, and our work was the first to conduct field work to document birds in the Sarlahi district. There are two protected areas within the study sites namely the Chitwan National Park (CNP) in Chitwan district and the Koshi Tappu Wildlife Reserve in Sunsari district. Each protected area has designated buffer zones where people can stay with the intention of strengthening the linkage between biodiversity conservation and local communities.

Methods

We overlaid 2x2 km grids across the four districts and systematically selected 100 grids located in farmlands, eight in forests and eight along a river. Using Google Earth we established one 500 m transect in each grid ensuring that transects were > 1.2 km from each other (see Figure 1). We walked transects from April 2018 to December 2019 and counted all birds within 150 m on either side of each transect. We stratified the year into

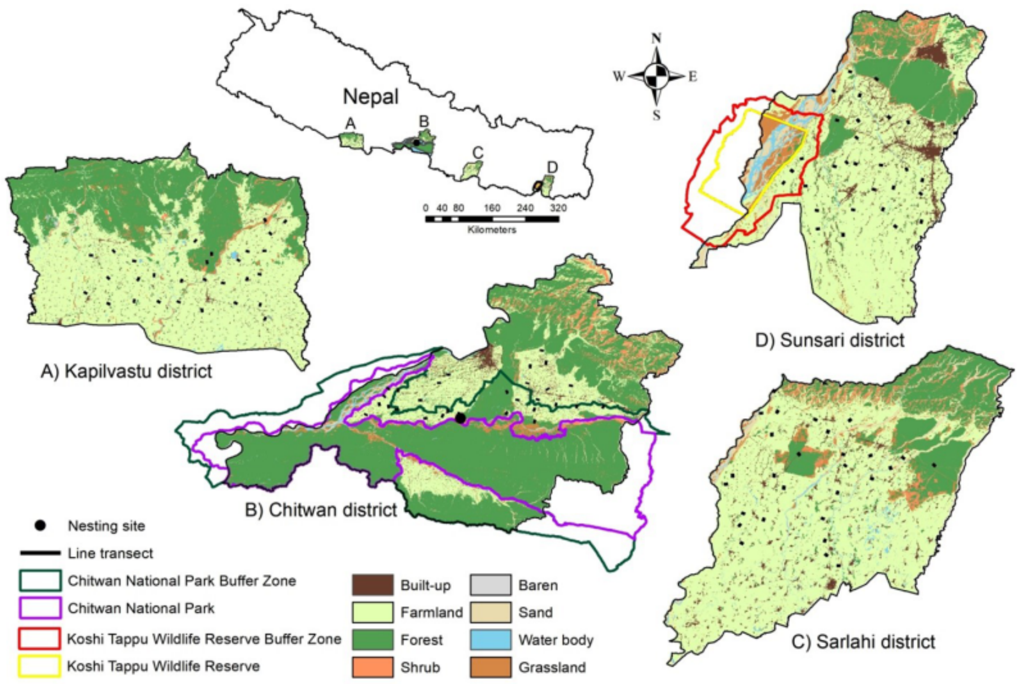


Figure 1: Study area showing locations of four focal districts in lowland Nepal (inset of Nepal map) where 116 transects of 500 m each were located systematically to count Asian Woollynecks between April 2018 and December 2019. Eight land uses derived from satellite imageries are shown for all districts, and the borders of two protected areas with buffer zones around each that were surveyed are shown. The location of a single Asian Woollyneck nest that was monitored during the study is also provided.

three seasons (summer: April-May, monsoon: July-August, and winter: December-January) and monitored each transect three times in each season. In Kapilvastu and Sarlahi districts, we could cover transects only twice during the summer due to the national lockdown imposed in Nepal following the outbreak of Covid-19. In total, we completed 985 transect counts. During transect surveys we located one nest of Asian Woollyneck which we visited multiple times between August-October 2019 to record the chick fledging.

Results

Out of 985 transect counts, we recorded Asian Woollynecks only in 14, and storks were seen in 11 out of the 116 separate transects (Table 1). Majority of the Asian Woollyneck observations (57%) were from Chitwan with the rest of the observations from Kapilvastu (21%), Sarlahi (14%) and Sunsari district (7%). All observations at Chitwan were made on farmlands inside the buffer zone of CNP. Asian Woollynecks were mostly seen on farmlands (86% of all transects on which storks were seen). The rest of the sightings were along the river and none were seen inside forests. There was some seasonal variation in observations with most sightings made during the monsoon (43% of all transects on which storks were seen) with fewer observations in the winter (36%) and summer seasons (21%). In each observation, flock sizes were small with 1-2 birds.

We located one nest with one chick on a Sal *Shorea robusta* tree inside CNP's buffer zone (N 27° 34' 12.24", E 84° 22' 53.64") that was ~ 150 m from farmlands and human settlements (Figure 1). We first observed the nest on 3 August 2019 and the chick was already hatched. We visited the nest repeatedly until 20 September 2019 when the chick showed signs of fledging. The chick and the adult birds had left the nest when we visited the nest on 7 October 2019.

Discussion

We conducted extensive surveys in farmlands of four districts which are potential Asian Woollyneck habitats in lowland Nepal, but storks were not

Table 1. Details of Asian Woollyneck sightings during surveys across four districts of lowland Nepal from April 2018 to December 2019. A total of 116 separate transects were located on agriculture fields, along rivers and in forests, and were covered 985 times during the survey.

District	Protection status	Location	Habitat	Season	No. of individuals
Kapilvastu	Outside protected area	N 27° 34' 19.84" E 83° 4' 48.47"	Farmland	Winter	2
	Outside protected area	N 27° 35' 19.65" E 83° 8' 42.54"	Farmland	Monsoon	1
	Outside protected area	N 27° 34' 45.91" E 82° 55' 54.65"	Farmland	Winter	2
Chitwan	Protected area	N 27° 35' 13.61" E 84° 31' 15.52"	Farmland	Monsoon	2
				Summer	2
	Protected area	N 27° 35' 33.65" E 84° 35' 58.26"	Farmland	Summer	1
				Monsoon	1
				Winter	2
	Protected area	N 27° 34' 41.99" E 84° 22' 38.97"	Farmland	Monsoon	2
	Protected area	N 27° 35' 1.78" E 84° 21' 27.06"	Farmland	Monsoon	1
	Protected area	N 27° 34' 47.62" E 84° 28' 0.88"	River	Summer	1
Sarlahi	Outside protected area	N 26° 53' 55.01" E 85° 33' 10.08"	Farmland	Winter	1
	Outside protected Area	N 27° 2' 29.83" E 85° 34' 39.10"	River	Winter	2
Sunsari	Outside protected area	N 26° 32' 17.28" E 87° 8' 21.27"	Farmland	Monsoon	1

common across sampled sites. This contrasts with the national assessment which suggests that this species has a widespread distribution in entire lowland Nepal including our field sites (Inskipp *et al*. 2016). During our study Asian Woollynecks were sighted more frequently on the farmlands located in the buffer zone of CNP where the species has been previously recorded (Inskipp *et al*. 2016). Urbanization is increasing significantly in Chitwan district making it one of the most urbanized districts in Nepal (Rimal *et al*. 2020). However, farmlands in this district, especially inside the buffer zone of the CNP, appear to support Asian Woollynecks throughout the year. Other studies have also reported Asian Woollynecks using farmlands throughout the year as foraging habitats in India, Myanmar and Nepal (Sundar 2006; Inskipp *et al*. 2016; Ghimire and Pandey 2018; Sundar and Kittur 2020; Tiwary 2020; Win *et al*. 2020).

Our effort was inadequate to estimate the population size of the Asian Woollyneck in the whole of Nepal. There are very few robust estimates of population sizes of this species in Nepal. Kittur and Sundar (2020) estimated 30 ± 22 Asian Woollynecks in a small area covering parts of Rupandehi and Kapilvastu districts using systematic road transects carried out seasonally between 2014 and 2019. Seasonal densities of Asian Woollynecks did not vary much in the two districts (see Kittur and Sundar 2020). In the same districts, in a slightly larger area, Ghimire and Pandey (2018) and Ghimire (2019) recorded < 50 individuals along seven roads transects that varied in length from 15 to 34 km between 2016 and 2018. During our surveys, Asian Woollynecks were observed more during the monsoon and the least in summer months identical to many other locations where multi-season work has been carried out (Kittur and Sundar 2020).

We always observed the species with 1-2 individuals, which is lower than flock sizes reported for lowland Nepal and India (Sundar 2006; Sharma and Singh 2018; Kittur and Sundar 2020). However, an unusually large flock of 28 Asian Woollynecks were seen recently in April 2020 along one of our transect in buffer zone of CNP, and were observed for three weeks (Y. Mahato, B. Bidari and R. Krishna, pers. comm. 2020). Large flocks of Asian Woollynecks have been reported from some locations in India as well but appear to be rare (Pande *et al*. 2007; Kittur and Sundar 2020).

Though the information currently available of Asian Woollynecks outside of Rupandehi and Kapilvastu is still meager, our systematic observations showed seasonal variations in the frequency of observations that suggest possible seasonal movements of this species to the mid-hill region of Nepal. Such movements have been suspected previously (Inskipp *et al*. 2016). Movement patterns of the species and location of breeding areas can be better understood by satellite tagging.

Previously records of Asian Woollyneck nests in Nepal have been from both the lowlands and the mid-hill regions (Inskipp *et al*. 2016). In addition, 12 nests were recorded from Rupandehi between 2016 and 2020 (P. Ghimire, pers. comm. 2020). Our record of one nest adds to this small number of observations of Asian Woollyneck nests in Nepal. A careful study on the breeding biology of Asian Woollynecks in Nepal is required to provide detailed information on nesting sites, nesting habitat requirements and nest survival.

Acknowledgments

This work has been supported by CAS-SEABRI program (Y4ZK111B01). HBK would like to thank CAS-TWAS President's Fellowship for providing the Ph.D. fellowship. The Department of Forests and Soil Conservation and the Department of National Parks and Wildlife Conservation in Nepal provided permissions to carry out this work. We thank Yam Mahato, and Anis Timsina for helping monitor farmland birds, Basu Bidari, Ram Krishna and Prashant Ghimire for sharing information on the recent sighting of the species, Bhagawat Rimal for helping in land cover map preparation and Mingxia Zhang for comments on a previous draft. We also thank K. S. Gopi Sundar for inviting this paper for the special section in SISC on Asian Woollyneck for comments on several previous drafts and for providing background literature. We thank two anonymous reviewers for suggestions that improved an earlier draft.

References

BirdLife International. 2017. *Ciconia episcopus* (amended version of 2016 assessment). The IUCN Red List of Threatened Species 2017. https://dx.doi.org/10.2305/IUCN.UK.2017-1.RLTS.T22727255A110064997.en, accessed 10 August 2020.

Central Bureau of Statistics. 2012. *National population and housing census 2011 (National report)*. Government of Nepal, National Planning Commission Secretariat, Central Bureau of Statistics, Kathmandu, Nepal.

del Hoyo, J., A. Elliott, N. Collar, E. F. J. Garcia, P. F. D. Boesman and G. M. Kirwan. 2020. Woolly-necked Stork

(*Ciconia episcopus*), version 1.0. In: Billerman, S. M., B. K. Keeney, P. G. Rodewald and T. S. Schulenberg (eds.). *Birds of the World*. Cornell Lab of Ornithology, Ithaca, NY, United States of America. https://birdsoftheworld.org/bow/species/wonsto1/cur/introduction?login, accessed on 10 August 2020.

Ghale, T. R. and D. K. Karmacharya. 2018. A new altitudinal record for Asian Woollyneck *Ciconia episcopus* in South Asia. *BirdingASIA* 29: 96-97.

Ghimire, P. 2019. Asian Woollyneck: Research and conservation efforts in Nepal (Original in Nepali). *Munal* 19:1-3.

Ghimire, P. and N. Pandey. 2018. Conserving the Asian Woollyneck in Nepal: efforts, outcomes and lessons learnt. *The Himalayan Naturalist* 2: 44-45.

Hasan, M. T. and P. Ghimire. 2020. Confirmed breeding records of Asian Woollyneck *Ciconia episcopus* from Bangladesh. *SIS Conservation* 2: 47-49.

Inskipp, C., H. S. Baral, S. Phuyal, T. R. Bhatt, M. Khatiwada, T. Inskipp, A. Khatiwada, S. Gurung, P. B. Singh, L. Murray, L. Poudyal and R. Amin. 2016. *The status of Nepal's birds: The national red list series*. Zoological Society of London, United Kingdom.

Kittur, S. and K. S. G. Sundar. 2020. Density, flock size and habitat preference of Woolly-necked Storks *Ciconia episcopus* in south Asian agricultural landscapes. *SIS Conservation* 2: xx-xx.

Pande, S., N. Sant, R. Bhate, A. Ponkshe, P. Pandit, A. Pawashe and C. Joglekar. 2007. Recent records of wintering White *Ciconia ciconia* and Black *C. nigra* storks and flocking behaviour of White-necked Storks *C. episcopus* in Maharashtra and Karnataka states, India. *Indian BIRDS* 3(1): 28-32.

Paudel, B., Y. Zhang, S. Li and X. Wu. 2017. Spatiotemporal reconstruction of agricultural land cover in Nepal from 1970 to 2010. *Regional Environment Change* 17: 2349-2357.

Rimal, B., S. Sloan, H. Keshtkar, R. Sharma, S. Rijal and U. B. Shrestha. 2020. Patterns of historical and future urban expansion in Nepal. *Remote Sensing* 12: 628.

Sharma, R. K. and L. A. K. Singh. 2018. Spatial and temporal pattern of stork sightings (Aves: Ciconiidae) in National Chambal Sanctuary of Gangetic river system. *Journal of Threatened Taxa* 10: 11410-11415.

SoIB. 2020. State of India's Birds factsheet: Woolly-necked Stork *Ciconia episcopus*. https://www.stateofindiasbirds.in/species/wonsto1/, accessed 06 July 2020.

Sundar, K. S. G. 2006. Flock Size, density and habitat selection of four large waterbirds species in an agricultural landscape in Uttar Pradesh, India: Implications for management. *Waterbirds* 29: 365-374.

Tiwary, N. K. 2020. Observations on distribution and feeding behavior of Woolly-necked Stork *Ciconia episcopus* during 2012-20 from north India. *SIS Conservation* 2: 42-46.

Vaghela, U., D. Sawant and V. Bhagwat. 2015. Woolly-necked Storks *Ciconia episcopus* nesting on mobile-towers in Pune, Maharashtra. *Indian BIRDS* 10:154-155.

Win, M. S., A. M. Yi, T. S. Myint, K. Khine, H. S. Po, K. S. Non and K. S. G. Sundar. 2020. Comparing abundance and habitat use of Woolly-necked Storks *Ciconia episcopus* inside and outside protected areas in Myanmar. *SIS Conservation* 2: 96-103.

ISSN 2710-1142(online)
SIS Conservation, 2020, 2, 55-61
RESEARCH ARTICLE

Status of Woolly-necked Storks in Kerala, south-western India

R. ROSHNATH[1*] and P. GREESHMA[2]

[1]Department of Zoology, Central University of Kerala, Periya 671316, Kerala, India
[2]Wildlife Department, Kerala Forest Research Institute, Peechi 680653, Thrissur, Kerala, India
*Corresponding author; e.mail: roshnath.r@gmail.com

Abstract Woolly-necked Stork is a large wading bird found in wetlands and reservoirs in Kerala. Using bird checklists uploaded on eBird, we analysed the distribution, seasonality, flocking propensity, breeding and trend of reporting of Woolly-necked Storks by bird-watchers in Kerala. We found no long-term variation in the annual rates of reporting in checklists between 2000 and 2020. Reports of Woolly-necked Storks were largely of solitary birds, with reports of flocks of more than five individuals being infrequent. Although widespread in the state during winter, Woolly-necked Storks are found concentrated in central Kerala during the summer months. Only 16 nesting sites were identified, most of which were in central Kerala, and included both trees and man-made structures such as cell-phone towers. From our analyses of checklists, we infer that Woolly-necked Storks in Kerala have a small resident population with indications of seasonal movements.

Keywords Breeding, distribution, Kerala, seasonality, Woolly-necked Storks, Kerala.

Introduction

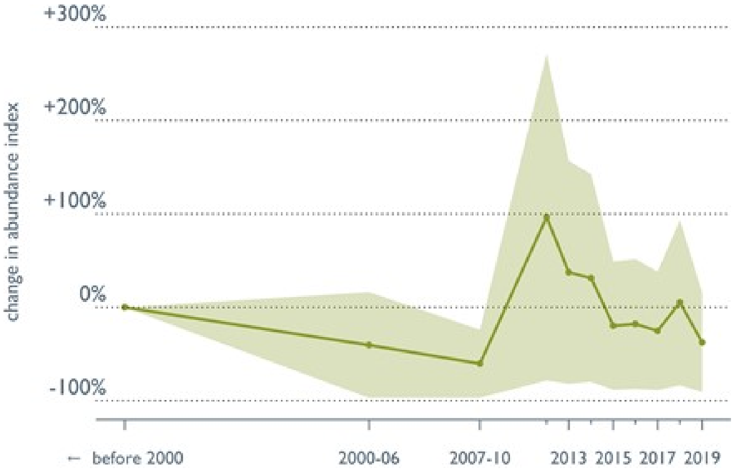
Woolly-necked Stork *Ciconia episcopus* is a large wading bird that inhabits various wetland habitats including natural wetlands, manmade reservoirs, paddy fields, and other cultivated fields in Kerala (Sashikumar *et al*. 2011). Among the three subspecies recognised, *Ciconia episcopus episcopus* (Boddaert 1783) is the subspecies found in Kerala and throughout India (del Hoyo *et al*. 2020; Gill *et al*. 2020). Together with *Ciconia episcopus neglecta* (Java and south Sumatra), the Asian population is accorded species status by BirdLife International as 'Asian Woollyneck' and its threat status is assessed as Vulnerable (BirdLife International 2020).

Historical records of the species in Kerala date back to before the 1920s from the Bharathapuzha river basin in central Kerala which was then a known hotspot for these birds. K K Neelakantan, also known as Induchoodan on his book "Keralathille Pakshikal", mentioned sighting records of these birds during the 1930s by Salim Ali (Sashikumar *et al*. 2011). During 1938-1960, Induchoodan himself sighted up to nine birds (at least one each time) when he was travelling by train via Bharathapuzha. He also mentioned sighting of a flock of 14 birds in Periyar during the summer, which was the highest count then. Thus, the bird was referred as "uncommon" in Kerala (Induchoodan 2004). Later, with more records available from within the state, the bird was referred as winter visitor in Kerala with 180 birds recorded in 1999 at Cheruvallor in Thrissur district (Sashikumar *et al*. 2011).

There is no systematic long-term monitoring of Woolly-necked Storks in Kerala, and we have no information on its general habits, potential seasonal variations in distribution, and nesting ecology. In other locations in India and Nepal, Woolly-necked Stork densities, flock sizes and habitat use varied by location and by season potentially due to

Article history
Received: 08 September 2020,
Received in revised form: 10 September 2020,
Accepted: 10 September 2020,
Published online: 07 October 2020

Figure 1. Long-term trends in frequency of reporting for Woolly-necked stork in Kerala on the online portal eBird.org. In the graph, tick marks on the x-axis are placed at the median year of observation in that particular time-period. Shaded regions represent 95% confidence intervals that include random effect variance estimated from Generalized Linear Mixed Effects models.



changing landscape conditions brought about by cropping patterns and climatic variations (Sundar 2006, Kittur and Sundar 2020). Using citizen data uploaded on the online platform eBird (eBird.org), we undertake the first analyses of distribution, seasonality, flocking propensity, breeding and trends in rates of reporting of Woolly-necked Storks by bird-watchers in Kerala. We specifically hypothesized that: (1) reporting trends of the species over time has increased (2) flock sizes would vary by month in response to changing seasons; and (3) the species' distribution across Kerala would vary by season also in response to changing seasons.

There is very little information on the breeding ecology of the species, though it is known to use both trees and man-made structures such as cell phone towers to nest on (Hasan and Ghimire 2020). Using available reports on the portal eBird, we summarised nest locations of Woolly-necked Storks in Kerala.

Study area

Kerala state lies in the South Western coastal region of India between latitudes 8^0 17' and 12^0 47' North and longitudes 74^0 52' and 77^0 24' East. Kerala harbours a total of 44 rivers and a continuous chain of lagoons or backwaters along the coast that give rise to a number of wetlands. Kerala has 1,60,590 ha of wetlands which include shallow ponds, reservoirs, low lying coastal lands, brackish water creeks, lagoons, estuaries, mangroves, swamps, lakes, marshes, saline-tolerant paddy farming fields and floodplains (Chitra *et al*. 2020). But because many of these wetlands co-exist in a single site, wetlands are simply classified as lagoons, low lying cultivation, estuaries, beaches, inland reservoirs and mid elevation paddy fields (Nameer *et al*. 2015). The total wetland area in Kerala is dominated by natural or manmade inland wetlands (73 %) while 25 % consists of natural coastal wetlands, and a small amount (2 %) are small wetlands not more than 2.25 ha. Kerala wetlands are also important stop over site for migratory birds and come under the Central Asian – Indian Flyway (Chitra *et al*. 2020).

Kerala is one of the most densely populated states in the country (859 persons per km2; Census of India 2011), with 93% growth in urbanisation between the year 2001 and 2011 (Pradhan 2013). Kerala is renowned for land reforms which eases conversion of natural areas to farmland and other human uses (Roy 2016), which in turn threatens existing wetlands.

Methods

eBird is a global platform where bird-watchers upload bird checklists from individual events of bird-watching. This information is potentially useful to understand various aspects of bird ecology and habitats including distribution, habitat use and trends in the reporting rate of a particular species in the checklists. To understand trends in reporting rates, we used the 'rel-Jun2020' version of the eBird Basic Dataset (EBD) for India that contained data submitted up to 31 May 2020 and extracted all checklists from Kerala. We did not use count data to estimate abundance since methods of counting vary between the observers who upload checklists. Instead, we used the frequency of reporting of Woolly-necked Storks in checklists for our analyses. This reporting frequency of a species is a crude representation of its detectability (function of its biology, habitat structure, and observer ability) alongside its actual presence. We do not assume this index of reporting frequency to be proportional with the population size of a species (SoIB 2020). We also do not correct for observer ability, spatial and temporal variation in bird-watching effort of individuals, and group sizes of bird-watchers that were associated with each individual checklist. All of these aspects can affect observability and therefore reporting rates of

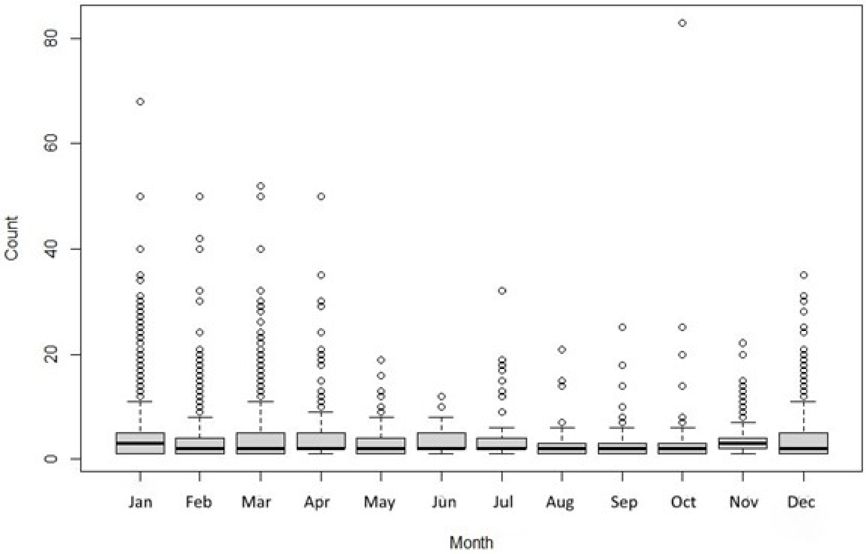


Figure 2. Box-plots showing flock sizes reported by bird-watchers of Woolly-necked Storks in Kerala.

species. After excluding duplicate checklists (when a checklist is shared with multiple eBird users), each unique checklist was treated as an independent sampling unit assumed to have a binomial error distribution. Detection/non detection (whether or not the species was observed in a checklist) information for the species was modelled as a function of list length (a measure of effort), season and year using Generalized Linear Mixed Effects Models (Walker and Taylor 2017). This modelling was used to obtain standardised frequency of reporting annually along with SE estimates. The year 2000 was taken as a cut off since checklists before this period were relatively fewer. The percentage change in standardized frequency of reporting in 2018 when compared to pre-2000 levels constitutes our index of long-term trend in reporting frequency (SoIB 2020).

Additionally, sighting data of Woolly-necked Stork available on eBird (from the year 1973-2020; 6,984 individual observations) for Kerala state was downloaded. We examined the flock sizes reported in each observation assuming that bird-watchers reported storks from a single flock when more than one bird was reported, and also that they always reported full flock sizes. With a monthly average of 582 ± 687 SD checklist, the number of checklists varied considerably across the months (Jan to Dec; 2355, 1209, 748, 422, 224, 81, 69, 90, 105, 179, 383, and 1119). We assessed monthly flock sizes and used the non-parametric Kruskal-Wallis test to ascertain if flock sizes differed by month, but do not control for bird-watching effort in this analysis. We used box-plots to visually assess the monthly flock size information.

We then assessed if Woolly-necked Stork distribution in Kerala varied across two seasons: summer (April to September) and winter (October to March). We used a subset of the sighting data from January 2014 to May 2020 for this because eBird usage increased from 2014 in Kerala providing substantial information for both seasons. We studied the average ratio of checklists in summer and winter months in the state and concluded that the birding effort did not vary between summer (0.43 ± 0.06 SD) and winter (0.57 ± 0.06 SD) months. We obtained 5,711 observations of Woolly-necked Storks in winter and 962 observations in summer from eBird, and used these to map the distribution of the species in each of the two season.

Nesting sites were identified from published literature (Sashikumar *et al*. 2011; Greeshma *et al*. 2018) and from eBird data. Confirmed breeding behaviour such as nest building and occupied nests either with eggs or young ones were considered as nesting sites and each location was mapped separately. We additionally supplemented this information by personally communicating with bird-watchers and other professional colleagues in Kerala. Age of nests were unknown in almost all cases. For sites where multi-year monitoring was available, we provide year of first recording when the nest was observed first. From these sites, where current information was available, we provide information on whether or not nesting was still being observed. The nesting month provided refers to when the observation was made and not to when the nest was initiated. To understand the precise nesting period, we tried to get further information on nesting stage of that respective month from the observer wherever possible.

Results

The long-term trend analysis using rates of reporting on eBird.org showed no significant change in the reporting frequency of Woolly-necked Storks (Figure 1). Most reports were of solitary birds (30% of all observations) or in small groups of not more than 5 individuals (49% observations). Only less than one percentage (0.74%) of all observations reported large flock of more than 30 individuals mostly during December to February months. There was no significant difference (p = 0.07) in their flock sizes sighted during different months across the state (Figure 2). Woolly-necked Storks were much more widespread during winter relative to summer when they were concentrated in central Kerala with very few observations from northern and southern Kerala (Figure 3).

A total of 16 nesting sites were identified (Figure 4). Most of these were from central Kerala except for one site in Periyar Tiger Reserve in Idukki district. Woolly-necked Storks were reported nesting on various nesting trees such as *Ficus religiosa* (N = 3), *Mangifera indica* (N = 3), *Alstonia scholaris* (N = 2), and also on cell-phone towers (N = 4). One nest was observed in March but this was historical data from 1954 (Table 1). Apart from the four nesting locations, all the sites had nests active over multiple years. Nests reported since 2002 were seen between September and December, with storks seen incubating one nest as late as November (Table 1).

Discussion

The trend of reporting of Woolly-necked Storks from 2000 to 2020 was similar year-to-year in Kerala. We were able to use only available checklist data on eBird and therefore are unable to conclusively state anything regarding the abundance or population of Woolly-necked Storks in Kerala. Formal monitoring across Kerala using robust field methods are needed to derive current populations, and long-term monitoring is needed to understand if the species' population fluctuates in the state.

Reports suggest that Woolly-necked Storks were solitary, and mostly remain in small groups throughout the year, but flocks of more than 50 birds were sometimes seen in winter in wetlands of central Kerala including inland reservoirs (Nameer *et al*. 2015). Only 0.74% of the observations reported flocks more than 30 birds. This habit of largely being seen in small flocks with extraordinary large flocks being rare is similar to information available from other locations in Nepal and India (Sundar 2006, Kittur and Sundar 2020).

During summer months, most reports of the species were from central Kerala which hosts the Kole wetlands and the Bharathapuzha River. In winter months, bird-watchers reported this species from many more locations across the state. This suggests that the species displays strong seasonal variation in distribution at the level of the state. Such a large variation in distribution with season has not been observed during seasonal, long-term

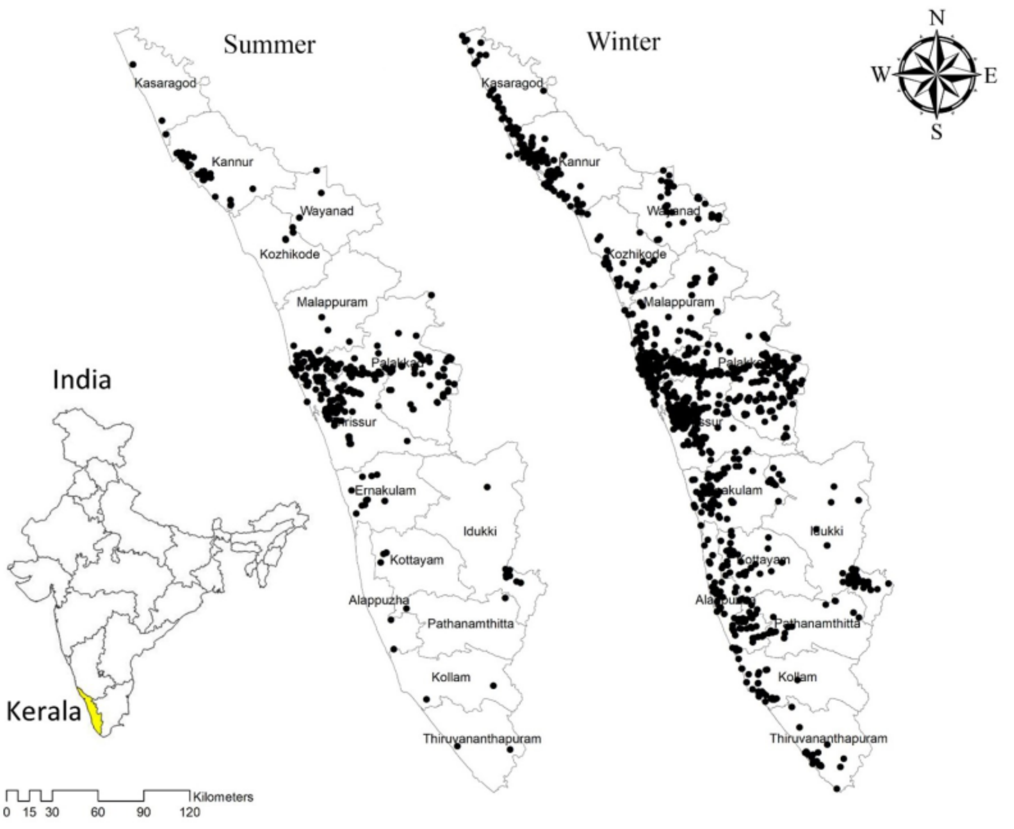


Figure 3. Map of Kerala state showing the Seasonal distribution of Woolly-necked Storks in Kerala using eBird data.

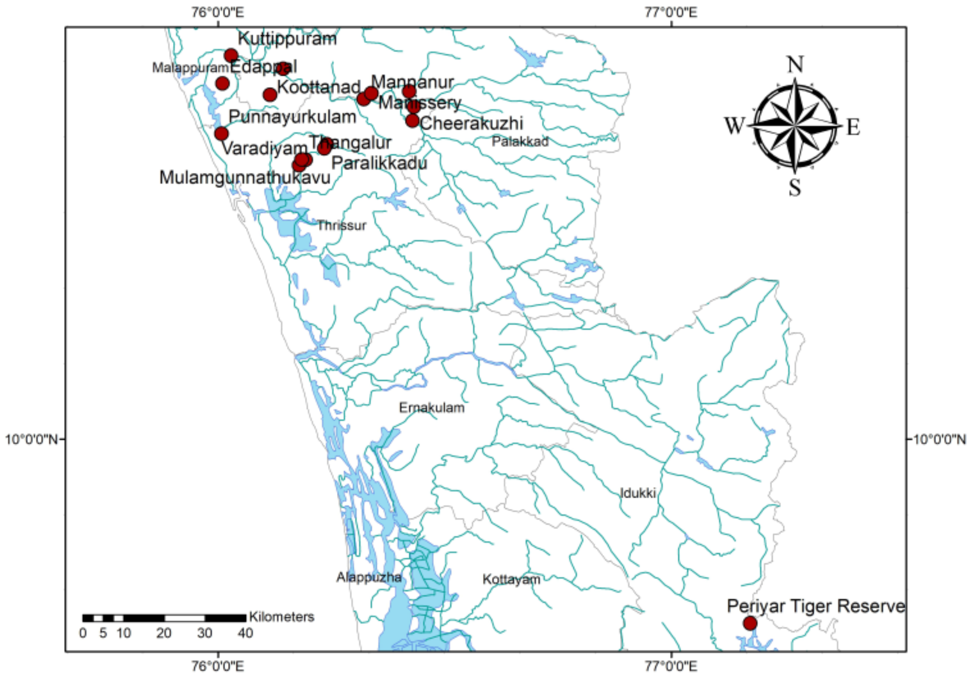


Figure 4. Map of central Kerala showing breeding locations of Woolly-necked Storks reported on eBird.org and in additional reports since 1954.

monitoring efforts in northern India and in lowland Nepal (Sundar 2006, Kittur and Sundar 2020). It is not immediately clear why Woolly-necked Storks show a much smaller distribution in summers, but we suspect that the shrinking of wetlands and other water bodies may force this species to existing sources of water on the landscape. Existing accounts refer to Woolly-necked Storks as an "uncommon" species (Induchoodan 2004) and as a "widespread winter visitor" in Kerala (Sashikumar *et al*. 2011). Our analyses of bird-watcher's reports suggests that while Woolly-necked Storks are a resident species in Kerala, it is possible that the number of birds reduces during the hot summer months. A more careful evaluation of distribution and numbers of Woolly-necked Storks using year-long field data is needed to understand if the species varies in distribution during the breeding season as well. If the distribution during the breeding season is also smaller than the observed distribution in the winter, it can be suggested that Kerala experiences inward movement of Woolly-necked Storks during the winter.

Woolly-necked Storks are solitary breeders nesting singly on trees (Ali and Ripley 1987), cliffs (Rahmani and Singh 1996) and on cell-phone towers (Choudhary *et al*. 2013; Vaghela *et al*. 2015; Greeshma *et al*. 2018; Hasan and Ghimire 2020). In this study, we found Woolly-necked Storks using large trees such as *Ficus religiosa, Mangifera indica*, and *Alstonia scholaris* for nesting in Kerala. In Paralikkadu, Thrissur, a pair was found nesting on a Jackfruit tree (*Artocarpus heterophyllus*). After the tree was cut, the storks nested again on a nearby cell-phone tower (pers. obs.). We also obtained reports of four nests on cell-phone towers. Storks may view man-made structure like cell-phone towers as safer nesting sites compared to trees owing to the reduced accessibility of such nests to certain predators (Tryjanowski *et al*. 2009, Bialas *et al*. 2020).

Breeding season of Woolly-necked Storks in India has been reported during the rainy season in the months July to September in the south, but the species is reported to nest between December and March in the north (Ali and Ripley 1978). But, we found Woolly-necked Storks to breed largely during the post-monsoon season in Kerala. This pattern is similar to observations in Pune, which is slightly to the north of Kerala (Vaghela *et al*. 2015).

Several nesting reports of Woolly-necked Storks were from the Bharathapuzha River Basin in central Kerala (Sashikumar *et al*. 2011, Greeshma *et al*. 2018). However, the first nesting record for the species in the state is from Periyar Tiger Reserve that is not in central Kerala (Figure 4). Since the first report in 1954, a single pair has continued to nest in a large *Ceiba pentandra* tree near the boat landing centre in the Tiger Reserve (Induchoodan 2004). In 2018, three active nests were observed in the same site near to the lake (Patrick David pers. comm. 2020). During our study, we did not get any confirmed nesting reports from Edappal, Thiruvilvamala, and Kuttipuram where nests were recorded earlier

Table 1. Nesting location and present status of Woolly-necked Stork in Kerala.

District	Location	Nest found		Month	Nesting stage	Tree/substrate
		From	To			
Idukki	Periyar Tiger Reserve	1954	2019	Mar	-	*Ceiba pentandra*
Malappuram	Edappal	2002	Unknown	-	-	-
Malappuram	Kuttippuram	2002	Unknown	Sept	-	*Ficus religiosa*
Palakkad	Koottanad	2004	2019	Nov	With chicks	*Mangifera indica*
Palakkad	Mannanur	2004	2018	Nov	-	-
Thrissur	Thiruvilvamala	2004	Unknown	Oct	-	*Alstonia scholaris*
Thrissur	Paralikkadu	2015	2019	Dec	Nest building	Cell-phone tower
Palakkad	Manissery	2016	Unknown	Sept	Nest building	*Mangifera indica*
Thrissur	Punnayurkulam	2017	2017	Nov	Nest building	*Ficus religiosa*
Thrissur	Varadiyam	2017	2017	Oct	With chicks	*Mangifera indica*
Thrissur	Wadakkanchery	2017	2019	Nov	With chicks	Cell-phone tower
Thrissur	Cheerakuzhi	2017	2018	Nov	Incubation	*Ficus religiosa*
Thrissur	Mulamgunnathukavu	2018	2019	Oct	With chicks	Cell-phone tower
Palakkad	Kodumunda	2019	2019	Sept	Nest building	-
Thrissur	Thangalur	2019	2019	Sept	Nest building	Cell-phone tower
Palakkad	Palappuram	2019	2019	Sept	With chicks	*Alstonia scholaris*

(Sashikumar *et al*. 2011). And part the above three nesting sites and Manissery, all the other nesting sites were found active over multiple years suggesting that the species remains faithful to nesting sites. Nest-site fidelity is known behaviour in Ciconiiformes (Cezilly *et al*. 2000). Thus, these nesting trees have to be given priority for conservation. From the evidence that we have collated, and from existing literature, it appears that Woolly-necked Storks do not have a very large breeding population in Kerala. This additional bit of information would also suggest that Woolly-necked Storks are likely primarily local winter migrants to the state.

Our analyses provide some initial understanding of the biology and habits of Woolly-necked Storks. However, a much more focused effort is needed to obtain robust metrics of population sizes, and to understand breeding propensity of the species in the state. We suggest that such studies can provide invaluable additional knowledge to understanding how Woolly-necked Storks – one of the least studied stork species in the world – is faring.

Acknowledgments

We thank K.S. Gopi Sundar for inviting this paper for the Special Section of *SIS Conservation*, for editing and revising multiple previous drafts, and for providing pertinent literature. We thank Ashwin Viswanathan for help with the analysis and writing and Anjana Unni for helping with the data analysis. We thank Arya Vinod, Ashfaq Muhammed, Kavya H Das, Manoj Karingamadathil, Patrick David and all the birders of Kerala for contributing information on Woolly-necked Stork in eBird. We thank Arjun C.P. for providing the maps and Praveen J. for his generous support in structuring the manuscript in present form. We also thank an anonymous reviewer for constructive comments.

References

Ali, S. and S. D. Ripley. 1978. *Handbook of the birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan and Sri Lanka. Volume 1: Divers to hawks*. 2nd edition. Oxford University Press, Delhi.

Bialas, J. T., L. Dylewski and M. Tobolka. 2020. Determination of nest occupation and breeding effect of the white stork by human-mediated landscape in Western Poland. *Environmental Science and Pollution Research* 27: 4148-4158

BirdLife International. 2020. Species factsheet: *Ciconia episcopus*. Downloaded from http://www.birdlife.org, accessed 25 August 2020.

Census of India. 2011. https://censusindia.gov.in/2011-Common/CensusData2011.html, accessed 25 July 2020.

Cezilly, F., F. Dubois and M. Pagel. 2000. Is mate fidelity related to site fidelity? A comparative analysis in Ciconiiforms. *Animal Behaviour* 59: 1143-1152

Chitra, K. P., K. V. Preetha and P. A. Vikas. 2020. Wetland Conservation and Sustainable Development in Kerala, India. In: Filho W. L, A.M. Azul, L. Brandli, A. L. Salvia and T. Wall (eds.) *Life on Land. Encyclopedia of the UN Sustainable Development Goals*. Springer, Cham. https://doi.org/10.1007/978-3-319-71065-5_115-1, accessed 25 July 2020

Choudhary, D. N., T. K. Ghosh, J. N. Mandal, R, Rahul and M. S. Kumar. 2013. Observations on the breeding of the Woolly-necked Stork *Ciconia episcopus* in Bhagalpur, Bihar, India. *Indian Birds* 8 (4): 93-94.

del Hoyo, J., A. Elliott, N. Collar, E. F. J. Garcia, P. F. D. Boesman and G. M. Kirwan. 2020. Woolly-necked Stork (*Ciconia episcopus*), version 1.0. In: Billerman, M., B.

K. Keeney, P. G. Rodewald and T. S. Schulenberg (eds.) *Birds of the World*. Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.wonsto1.01, accessed 25 July 2020.

Greeshma, P., R. P. Nair, E. A. Jayson, K. Manoj, V. Arya and E. G. Shonith. 2018. Breeding of Woolly-necked Stork *Ciconia episcopus* in Bharathapuzha River Basin, Kerala, India. *Indian Birds* 14 (3): 86-87.

Hasan, M. T. and P. Ghimire. 2020. Confirmed breeding records of Asian Woollyneck *Ciconia episcopus* from Bangladesh. *SIS Conservation* 2: 47-49.

Induchoodan. 2004. *Keralathile pakshikal* ("*Birds of Kerala*"). Kerala Sahitya Academy, Thrissur, Kerala, India.

Kittur, S. and K. S. G. Sundar. 2020. Density, flock size and habitat preference of Woolly-necked Storks *Ciconia episcopus* in south Asian agricultural landscapes. *SIS Conservation* 2: 71-79.

Nameer, P. O., J. Praveen, G. Tom, C. Sashikumar and B. Sreekumar. 2015. Long term population trends of waterbirds in Kerala over three decades. Pp 44-69. In Gopi, G. V. and S. A. Hussain (eds.) *Waterbirds of India*, ENVIS Bulletin: Wildlife & Protected Areas. Vol. 16. Wildlife Institute of India, Dehradun, India.

Pradhan, K. C. 2013. Unacknowledged urbanisation. *Economic and Political Weekly* 48 (36): 43-51.

Rahmani, A. R. and B. Singh. 1996. White-necked or Woolly-necked Stork *Ciconia episcopus* (Boddaert) nesting on cliffs. *Journal of the Bombay Natural History Society* 93 (2): 293-294.

Roy, V. P. N. 2016. Land reforms, land markets and urban transformation: identifying some long run impacts of land reforms from Kerala, India. *Journal of Land and Rural Studies* 4 (2): 123-139.

Sashikumar, C., J. Praveen, M. J. Palot and P. O. Nameer. 2011. *Birds of Kerala: status and distribution*. DC Books, Kottayam, Kerala, India.

SoIB 2020. *State of India's Birds, 2020: Range, trends and conservation status*. The SoIB Partnership. 50pp.

Tryjanowski P., J. Kosicki, S. Kuźniak and T. H. Sparks. 2009. Long-term changes and breeding success in relation to nesting structures used by the White Stork, *Ciconia ciconia*. *Annales Zoologici Fennici* 46: 34-38.

Vaghela, U., D. Sawant and V. Bhagwat. 2015. Woolly-necked Storks *Ciconia episcopus* nesting on mobile-towers in Pune, Maharashtra. *Indian Birds* 10 (6): 154-155.

Walker, J. and P. D. Taylor. 2017. Using eBird data to model population change of migratory bird species. *Avian Conservation and Ecology* 12(1).4 https://doi.org/10.5751/ACE-00960-120104

ISSN 2710-1142(online)
SIS Conservation, 2020, 2, 62-67
RESEARCH ARTICLE

A note on the temporal and spatial distribution of Asian Woollyneck in Assam, India

Jaydev MANDAL[1], Leons Mathew ABRAHAM[2], Rupam BHADURI[3,*]

[1]Department of Zoology, Madhab Choudhury College, College Road, Barpeta Town, Barpeta, 781301, Assam, India
[2]College of Veterinary Science, Assam Agricultural University, Khanapara, Kamrup, 781022, Assam, India
[3]Centre for the Environment, Indian Institute of Technology Guwahati, North Guwahati, Kamrup, 781039, Assam, India
*Corresponding author; e.mail: bhadurirupam@gmail.com

Abstract Asian Woollyneck *Ciconia episcopus* is listed as a globally Vulnerable bird species and there is very little detailed information about its ecology, including basic aspects such as distribution and seasonal movements. In this paper, we assembled primary and secondary information on the species focusing on the Indian north-eastern state of Assam and provide a preliminary understanding of its movement, distribution and breeding in Assam. We collated our individual field observations from 2010 to 2020 in five districts, invited responses from experienced bird-watchers using a standard questionnaire, and downloaded available data provided by volunteers on online portals. Asian Woollynecks were seen in Assam largely in the months of November to April with comparatively fewer sightings in other months. Most observations were in Kaziranga National Park which is one of the most visited national parks by tourists and bird-watchers. No confirmed breeding record was available of the species in Assam. Observed flock sizes were mostly 1 – 2 birds, with a much higher average flock size in Sonitpur district. The collated data suggests that the Asian Woollyneck is a seasonal non-breeding migrant to Assam occurring largely during the winter months..

Keywords Asian Woollyneck, Assam, seasonal non-breeding migrant.

Introduction

Assam, a state in northeastern India, is a land of plains and river valleys with three principal physical regions: Brahmaputra Valley in the north, Barak Valley in the south, and the hill systems of the south-central region. The state is one of the hotspots for avian biodiversity in the country with 696 species recorded (Clements *et al*. 2019). Several wading birds are supported by this unique co-occurrence of biomes, including the Asian Woollyneck *Ciconia episcopus* (Chakdar *et al*. 2019; Grimmett *et al*. 1999; Ali and Ripley 1983).

Article history
Received: 01 October 2020,
Received in revised form: 10 October 2020,
Accepted: 13 October 2020,
Published online: 16 October 2020

The species is widely distributed in south Asia with an extensive elevational range from the low plains to 1,800 mamsl in the Himalayas (Sundar 2006; Ghale and Karmacharya 2018; Gula *et al*. 2020). In Assam, there have not been any focused exploration of the Asian Woollynecks' ecology, habits and requirements despite its status as a globally "Vulnerable" species (BirdLife International 2020). In this paper, we evaluate the occurrence of the Asian Woollyneck in Assam using a combination of our personal observations, interviewing bird-watchers, and analysing the information uploaded by volunteer bird-watchers on the online portal eBird.org. Specifically, we seek to understand the status of the species in Assam in terms of its distribution and occurrence throughout the year. We also use our personal

Table 1. Personal observations of Asian Woollynecks by authors between 2010 and 2020 in Assam, India.

Location*	District	Month & Year	Count	Habitat
Kaziranga NP	Golaghat	1 February 2010	1	Wetland
Roumari beel, Kaziranga NP	Golaghat	2 February 2010	1	Wetland
Pobitora WLS	Marigaon	1 February 2016	1	Wetland
Kaziranga outskirts, Western side	Nagaon	6 May 2016	3	Agriculture
Kokilamukh beel	Jorhat	18 February 2017	1	Wetland
Pobitora WLS	Marigaon	22 January 2017	4	Wetland
Bagori range, Kaziranga NP	Nagaon	17 February 2017	1	Wetland
Bagori range, Kaziranga NP	Nagaon	17 February 2017	1	Wetland
Bagori range, Kaziranga NP	Nagaon	19 February 2017	1	Wetland
Nahrubasti, Kaziranga NP	Sonitpur	22 February 2017	1	Wetland
Bagori range, Kaziranga NP	Nagaon	16 January 2018	4	Wetland
Gaikhuti beel, Kaziranga NP	Sonitpur	19 February 2019	13	Wetland
Central range, Kaziranga NP	Sonitpur	18 February 2019	1	River
Western range, Kaziranga NP	Sonitpur	19 February 2019	3	Wetland
Bagori range, Kaziranga NP	Nagaon	12 February 2020	2	Wetland
Bagori range, Kaziranga NP	Nagaon	10 February 2020	1	Wetland
Bagori range, Kaziranga NP	Nagaon	11 February 2020	1	Wetland

observations to document the average flock size of the species, and carefully review all of the available information to understand the breeding status of the species in Assam.

Study area

Our collective field work covered the five districts of Golaghat, Jorhat, Morigaon, Nagaon and Sonitpur. All these districts lie on the flood plain of the river Brahmaputra. Sonitpur shares its boundaries with Arunachal Pradesh in the north, and Golaghat and Jorhat are bordered by Nagaland in the south. The climate of the area is humid with an annual rainfall of approximately 2,135 mm with peak rainfall from June to September (Guhathakurta *et al*. 2020). Based on the trend in rainfall, four seasons are recognized in the northeastern state of Assam namely; pre-monsoon (March-May), monsoon or rainy season (June-September), post-monsoon (October-November) and winter (December-February; Deka *et al*. 2015). The mean temperature recorded in the state during monsoon is 28.8^0 C, with a minimum of 16.9^0 C during the winter (Tamuly *et al*. 2019). Our personal field surveys were relatively higher in protected areas that were dominated by woodlands and wetlands. Additional habitats covered were wetlands, grasslands and forests with equal efforts towards agricultural fields that were located in and around the unprotected areas.

Methods

To assess the presence and distribution of Asian Woollyneck in Assam we used three different sources of information. The first was our personal observations that we maintained during various field work between 2010 and 2020 when we noted all observations of Asian Woollynecks (Table 1). These observations were not systematic in the sense of timing of visits, the kinds of habitats covered, and field effort was essentially *ad-hoc*. During each observation, we noted the location, the habitat used by the birds, and the number of Asian Woollynecks seen.

The second method we employed was a structured questionnaire that was sent to bird-watchers who frequently bird-watched in their respective locations. The main intent of the questionnaire was to record the locations and months when Asian Woollynecks were sighted in Assam. We sent out questionnaires to fifteen people and received six responses, which are collated in Table 2.

Lastly, the third method employed was the analysis of records of Asian Woollynecks uploaded by volunteer bird-watchers on the online portal eBird.org. For this paper we downloaded all records for the species between 2010 and 2020. We computed two metrics from this data. The first was the frequency of sightings, or the proportion of checklists that reported Asian Woollynecks. The second was average abundance, or the average number of birds observed in the checklists

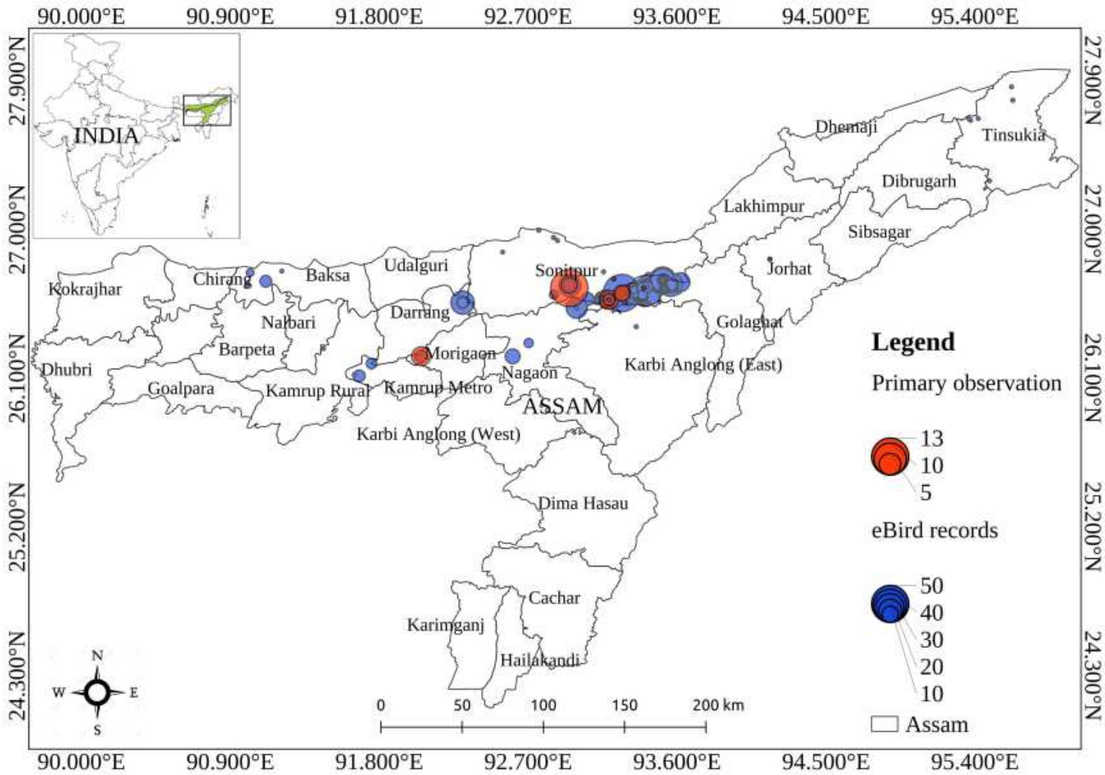


Figure 1. Map showing distribution and size of flocks of Asian Woollyneck in Brahmaputra valley of Assam. Primary observations are personal sightings of the authors, and eBird sightings were uploaded by volunteer birdwatchers to the online portal.

that reported Asian Woollynecks. The total number of checklists from Assam between 2010 and 2020 which were used for analysis varied for each month and season. Winter and pre-monsoon had the highest effort with 9015 and 7569 checklists respectively, followed by 3130 during the post-monsoon season. Monsoon had the least number of checklists with only 2021 total checklists. However, the checklists in which the Asian Woollynecks were recorded in Assam during winter, pre-monsoon, post-monsoon and monsoon of the mentioned period were 321, 319, 152 and 7 respectively.

Results

We personally recorded Asian Woollynecks 17 times (Table 1) and the majority of sightings were in Kaziranga National Park, which lies in Nagaon, Golaghat and Sonitpur districts, followed by Pobitora Wildlife Sanctuary in the Morigaon district of Assam (Figure 1, 2). The response provided by the birdwatchers through structured questionnaires also provided Asian Woollyneck records largely from protected areas including Manas National Park, Orang National Park, Nameri National Park, and Laokhowa-Burachapori Wild Life Sanctuary. Few records were also reported from the unprotected areas of Maguri-Motapung beel, Deobali jalah, Puthimari beel and agricultural fields in Simla, Baksa district (Table 2). Records of Asian Woollynecks on eBird were along the Brahmaputra river basin, starting from Sadia in the Tinsukia district to Manas National Park (Figure 1). Species presence was also recorded at the river island of Majuli, around Bhamaraguri and within many other unprotected areas. However, neither the birdwatchers nor the

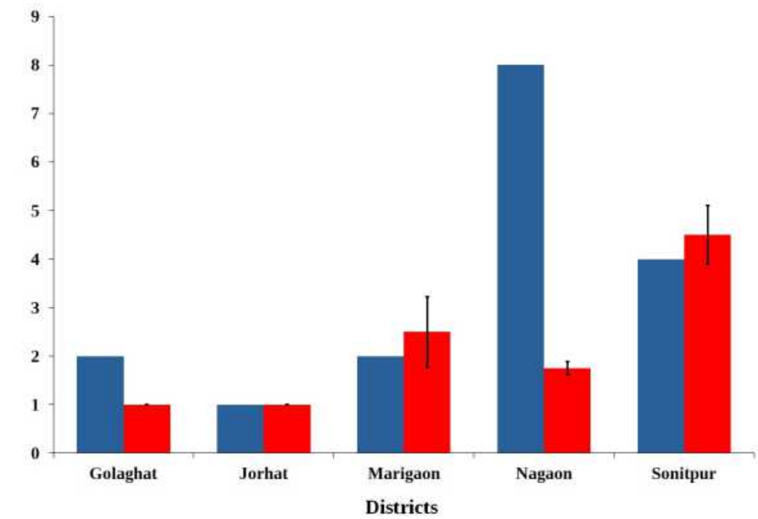


Figure 2. Average flock size of Asian Woollynecks observed in Assam between 2010 and 2020. Seventeen sightings made by the authors are summarized in the bar graph. The blue bars represent the number of observations and the red bars represent the average flock size observed in the respective districts.

Table 2. Questions that were sent to birdwatchers, along with a summary of their responses.

Questions	Cumulative responses
Probable places where you have observed Asian Woollyneck in Assam?	Kaziranga National Park, Pobitora Wildlife sanctuary, Laokhowa Burachapori Wildlife sanctuary, Manas National Park, Orang National Park, Nameri National Park, Maguri Beel, Deobali Jalah, Puthimari, Simla-Baksa district.
Are they found in these locations throughout the year?	No
If not, when are they usually seen? (Answer in range of months)	Very frequent-November to February, Less frequent-March to October
Is hunting/trapping common in these habitats?	No/Not inside the national park or protected areas
Do they nest in any of these locations?	Never observed

data from eBird mentioned the presence of Asian Woollyneck from the Barak Valley which consists of numerous wetlands and water bodies.

Our personal encounters with Asian Woollynecks was mostly in winter between January and February (94% of 17 sightings). Only one observation of a flock of three Asian Woollynecks was observed on 6 May 2015 from the Kaziranga Outskirts-Western side, Nagaon district. Birdwatchers' sightings of Asian Woollyneck were also largely between November to February including the post-monsoon to winter and very few sightings during the monsoon. Similarly, the eBird.org data also suggested the temporal distribution of the species to be minimum during monsoon. However, the frequency of observation of Asian Woollyneck according to the data from eBird.org was relatively higher during the post-monsoon and pre-monsoon compared to winter (Figure 3).

Most of our personal observations of the species were within wetland habitat. A total of 40 individuals were encountered with average count of 2.35 ± 2.96 SE (flock size 1 – 13; Figure 2). We noticed a flock of three birds roosting in an agricultural field, which is also the only evidence of Asian Woollynecks using agricultural areas during our survey. Birdwatchers also observed the species mostly within wetland habitat (90% of sightings) with no confirmed breeding records. An observation made on 22 April 2015 reported on eBird.org recorded the highest flock size of 50 individuals at Kaziranga NP-Western Range, Nagaon district. No additional details of habitat use or behavior was provided for this observation. Our personal surveys recorded higher observation of Asian Wollynecks from the protected areas as compared to unprotected areas with a ratio of 7:1. Similarly, the eBird.org data also suggested the records to be higher from protected areas with a ratio of 12:1.

Discussion

We provide a preliminary overview of Asian Woollyneck distribution, seasonality and some aspects of ecology of the species. All of the records we obtained suggest that this species is not very widely distributed in Assam, and also that it is very strongly seasonal. It is not clear why the species is so sparsely distributed. On seasonality, it is possible that the annual flooding which the region experiences during and immediately after the monsoon, dissuades Asian Woollynecks and potentially other wading resident birds from remaining in Assam. We also failed to locate any breeding records. Typically, the breeding season, in north India, commences in May with most nests built during the rainy season (Ishtiaq *et al*. 2004). The very low number of observations of Asian Woollynecks in Assam during the rainy season suggests that conditions are unsuitable for foraging which in turn would make it difficult for storks to provision chicks. Asian Woollynecks have been observed to be seasonal in other areas of India as well with number of sightings dropping greatly during the summer because of drying up of wetlands and the general landscape (Kittur and Sundar 2020; Roshnath and Greeshma 2020). Assam appears to be the only location where

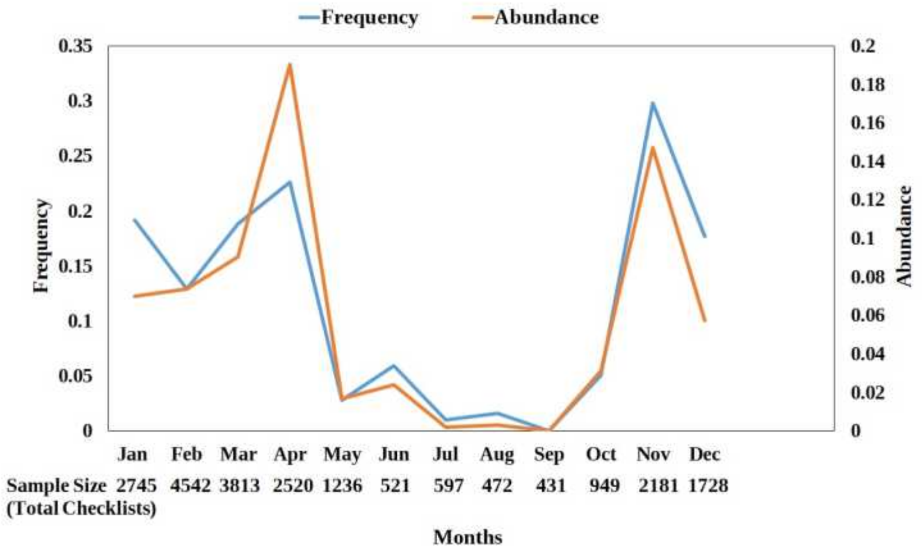


Figure 3. Monthly frequency and abundance of Asian Woollynecks in Assam as reported by volunteer birdwatchers on the online portal eBird.org from 2010 to 2020.

excessive flooding during the rainy season forces Asian Woollynecks to move out of the state.

Unlike in other locations like Myanmar (Win *et al*. 2020), Nepal (Katuwal *et al*. 2020) and other regions of India (Sundar 2006; Kittur and Sundar 2020), we found very little evidence that Asian Woollynecks use agricultural areas regularly for foraging. Partly, this finding could be due to our focus on protected forested and swamps, and partly because much of the information on Assam's birds on online portals is provided by tourists who also focus on protected forests.

As with other studies on Asian Woollynecks, flock sizes were mostly small with flocks of more than 10 birds being very rare (see Table 1). Even on eBird, only one large flock of 50 individual storks was reported. This is identical to observations in other regions of India (Kittur and Sundar 2020) and Nepal (Katuwal *et al*. 2020).

Despite being a small study in its scope, we have attempted to put together information from various sources. Our findings showcase the settings in Assam to be unique for Asian Woollynecks. A large proportion of our data were volunteer records, and our own field records were collected in an *ad-hoc* manner. It would therefore be useful to conduct specific studies on Asian Woollynecks in Assam to understand whether they truly avoid agricultural areas, to confirm their seasonal occurrence in the state, and to decipher the reasons for their not breeding in Assam.

Acknowledgments

We would like to acknowledge Dr. Anukul Nath, Biswajit Chakdar, Manash Jyoti Talukdar, Dr. P. K. Saikia, Rejoice Ghassan and Rustom Basumatary for providing us with the details of Asian Woollyneck which was the basis for secondary assessment. We also extend our thanks to Muzaffar A. Kichloo for his guidance in preparing the map. Finally, we would like to express our gratitude to Dr. K. S. Gopi Sundar, Editor-in-chief, SIS Conservation, for inviting us to articulate our research in the special edition of this journal. His guidance has been utmost important in shaping the research. We thank an anonymous reviewer for comments that improved a previous draft.

References

Ali, S. and S. D. Ripley. 1987. *Handbook of the birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan and Sri Lanka*. Oxford University Press, New Delhi, India.

BirdLife International. 2020. *Ciconia episcopus*. (Amended version published in 2016). The IUCN Red List of Threatened Species 2017, accessed 2 January 2020.

Chakdar, B., H. Singha and M. Ray. 2019. Bird community of Rajiv Gandhi Orang National Park , Assam. *Journal of Asia-Pacific Biodiversity* 12(4): 498–507.

Clements, J. F., T. S. Schulenberg, M. J. Iliff, S. M. Billerman, T. A. Fredericks, B. L. Sullivan, and C. L. Wood. 2019. *The Clements Checklist of Birds of the World: v2019*. Cornell University Press, USA.

Deka, R. L., C. Mahanta, K. K. Nath and M. K. Dutta. 2015. Spatio-temporal variability of rainfall regime in the Brahmaputra valley of North East India. *Theoretical Applied Climatology* 120: 3-4.

eBird Basic Dataset. *Version: EBD_relAug-2020*. Cornell Lab of Ornithology, Ithaca, New York, accessed 24 August 2020.

Ghale, T. R. and D. K. Karmacharya. 2018. A new altitudinal record for Asian Woollyneck Ciconia episcopus in South Asia. *BirdingASIA* 29: 96–97.

Grimmett, R., C. Inskipp and T. Inskipp. 1999. *Pocket guide to the birds of the Indian subcontinent*. Oxford University Press, New Delhi, India. 384 pp.

Guhathakurta, P., A. Bandgar, P. Menon, A. K. Prasad, N.

Sangwan and S. C. Advani. 2020. *Observed Rainfall Variability and Changes Over Assam State*. Met Monograph No.: ESSO/IMD/HS/Rainfall Variability/ 03(2020)/27. India Meterological Department, Pune, India.

Gula, J., W. R. J. Dean and K. S. G. Sundar. 2020. Known and potential distributions of the Woollynecked Storks *Ciconia episcopus* and *C. miscroscelis*. *SIS Conservation* 2: 80-95.

Ishtiaq, F., A. R. Rahmani, S. Javed and M. C. Coulter. 2004. Nest-site characteristics of black-necked stork (*Ephippiorhynchus asiaticus*) and white-necked stork (*Ciconia episcopus*) in Keoladeo national park, Bharatpur, India. *Journal of the Bombay Natural History Society* 101: 90-95.

Katuwal, H. S., H. S. Baral, H. P. Sharma and R.-C. Quan. 2020. Asian Woollynecks are uncommon on the farmlands of lowland Nepal. *SIS Conservation* 2: 50-54.

Kittur, S. and K. S. G. Sundar. 2020. Density, flock size and habitat preference of Woolly-necked Stork *Ciconia episcopus* in agricultural landscapes of south Asia. *SIS Conservation* 2: 71-79.

Roshnath, R. and P. Greeshma. 2020. Status of Woolly-necked Storks in Kerala, south India. *SIS Conservation* 2: 55-61.

Sundar, K. S. G. 2006. Flock size, density and habitat selection of four large waterbirds species in an agricultural landscape in Uttar Pradesh, India: implications for management. *Waterbirds* 29: 365-374.

Tamuly, G., R. L. Deka, B. Goswami and J. Goswami. 2019. Trend of temperature regime in the brahmaputra valley of assam during 1986-2015. *Journal of Agrometeorology* 21(1): 110-116.

Win, M. S., A. M. Yi, T. S. Myint, K. Khine, H. S. Po, K. S. Non and K. S. G. Sundar. 2020. Comparing abundance and habitat use of Woolly-necked Storks *Ciconia episcopus* inside and outside protected areas in Myanmar. *SIS Conservation* 2: 96-103.

ISSN 2710-1142(online)
SIS Conservation, 2020, 2, 68-70
SHORT COMMUNICATION

Observations of Woolly-necked Stork nesting attempts in Udaipur city, Rajasthan, India

Kanishka MEHTA[1*]

[1]Wildlife Research Laboratory, Mohanlal Sukhadia University, Udaipur, 313001, Rajasthan, India
*Corresponding author; e.mail: mehta.k2510@gmail.com

Abstract The Woolly-necked Stork is widely perceived to prefer isolated areas for nesting, but there have been multiple observations of this species nesting successfully near urban areas in south Asia. In this note, I provide additional observations of Woolly-necked Storks attempting to nest in Udaipur city and in an agricultural field and provide some observations about two unsuccessful attempts that were observed. This note adds to growing observations of the Woolly-necked Storks being able to nest in urban areas and farmlands.

Keywords Breeding biology, *Ciconia episcopus*, nest abandonment, urban nesting

Introduction

The Woolly-necked Stork *Ciconia episcopus* is a large tropical wading bird species sparsely distributed throughout the Indian subcontinent and breeds in Africa and in Asia from India to Indonesia (Ali and Ripley 1987). It has been known to be a solitary nester and observed nesting in tall and dense canopy trees and on cliffs along rivers, and was assumed for a long time to require undisturbed areas to breed (Ali and Ripley 1987; Vyas and Tomar 2006). In India, it breeds between July-September during the monsoon season while in Indonesia December–March and in the dry season throughout Africa. However, records of Woolly-necked Storks readily using man-made structures such as cell phone towers are growing, suggesting that the species is more versatile than was previously believed (Vaghela *et al*. 2015; Greeshma *et al*. 2018; Hasan and Ghimire 2020). The number of reports on the storks' ability to breed in or near urban areas is still sparse, and this study adds to existing literature with observations on two nesting attempts in and near Udaipur city in Rajasthan, India.

Article history
Received: 2 October 2020,
Received in revised form: 19 October 2020,
Accepted: 19 October 2020,
Published online: 20 October 2020

Study area and methods

Observations for this note were made in and immediately around Udaipur city, Rajasthan, when I was engaged in field work during June 2019 to September 2019 to enumerate bird diversity in Udaipur. The entire city limits were overlaid with a grid of 2.5×2.5km, and the center of each grid was visited thrice a year in each of three seasons. The city experiences strong seasonality with scorching summer (March-June), monsoon (July-October) and dry winter (November-February).

When Woolly-necked Stork nests were located, I conducted focal observations on nesting birds for one hour during each visit. At first site, I spent a total of four hours and at second site six hours for observing the stork pair's activities. I visited nest sites on alternate days until storks were no longer seen at nests. At each nest site, I briefly interviewed a few locals including a farmer regarding the storks' both nesting and foraging habits.

Results

I observed Woolly-necked Storks attempting to nest on two occasions and provide a description of each attempt below.

The first nest site was discovered on 21 June 2019 in a densely populated area of Kanpur village in Udaipur city adjoining a road with a high level of traffic. I saw a Woolly-necked Stork on a 15m high *Ailanthus excelsa* tree (Figure 1). The stork was arranging sticks into a platform apparently building a nest and was joined by a second stork after a few minutes. One stork stayed at the nest while the second made forays bringing in additional nesting material. I visited the nesting site again on 23 June 2019 and observed similar behavior for another hour. On 1 July 2019, I visited the nesting site again and found both storks missing, and they did not return in the 45 minutes I waited. The storks remained missing during additional subsequent visits despite the platform remaining intact. The cause of nest abandonment could not be determined.

Figure 1. A pair of Woolly-necked Stork organizing nesting material on a forked branch of tree by picking sticks in bill at Kanpur village road in Udaipur. Photographed on 21 June 2019 by Kanishka Mehta.

The second nest was observed on 29 August 2019, also on a 15m high *Ailanthus excelsa* tree. This tree was almost 5 km away from the first nest site and was located a little distance away from the main Udaipur city in a crop field. I observed the pair constructing the nest using thick twigs and branches for nearly an hour. The farmer who owned the fields with the nest tree was aware of the storks and indicated that he had observed them feeding in the crop fields and had also noticed that the storks were active after sunset. I visited the nest every alternate day and observed them feeding in the crop fields, and once observed both of them sitting at the nest. After 14 days, the storks were not visible at nests and the farmers also indicated that the birds had not returned despite the platform remaining intact. The cause of nest abandonment could not be determined.

Discussion

This is the first observation of Woolly-necked Storks nesting in and near Udaipur city despite the species being seen in small numbers in fields and wetlands inside and around the city (pers. obs). In both instances, storks built nests but did not appear to lay eggs, and abandoned both nests. There could be several reasons for this. Both storks could have been driven away by either predators or humans. Alternatively, the stork pair may be very young attempting to nest for the first time making the second nest slightly away from the city after being disturbed at the first nest inside the city. Udaipur city hosts many species of waterbirds that use the lakes as foraging and breeding habitats (pers. obs), and many large waterbirds roost on large trees inside the city (Koli *et al*. 2019). According to Ali and Ripley (1987), the Woolly-necked Stork may use old nesting sites in subsequent years if the birds are left undisturbed. This suggests that storks may revisit the nesting sites in subsequent years for nesting.

Woolly-necked Storks are assumed to prefer isolated areas for nesting but were seen building a nest in a very busy area in Udaipur. Human disturbance could be the major issue dissuading nesting in ciconiiform birds (Bouton et al. 2005). The first site I observed had high human disturbance and likely caused the stork pair to move away, similar to observations that have been made for other stork species nesting near human habitation in India (Tiwary and Urfi 2016). These nest or nest like structures doesn't necessarily receive eggs but are made as decoy or dummy nests to distract predators' focus. Unlike other observations near cities where Woolly-necked Storks used cell phone towers to potentially avoid being disturbed (Vaghela *et al*. 2015; Greeshma *et al*. 2018), in Udaipur the storks used existing trees and were not seen nesting on towers. It is not clear if Woolly-necked Storks in Udaipur will continue their nesting attempts in Udaipur city. It also remains to be seen if they will continue using natural nest platforms such as trees or whether they will start using artificial platforms such as cell phone towers like in other cities in south Asia.

Acknowledgments

I am grateful to Dr. K.S. Gopi Sundar for inviting this note for SIS Conservation, for discussions, for providing the background literature, and for correcting previous drafts of this note. I thank my supervisor Dr. Vijay Kumar Koli for providing the guidance and equipment, and Department of Zoology, Mohanlal Sukhadia University for infrastructure in conducting this study. I also thank local shopkeepers, farmer and his daughter Ms. Pooja for sharing details of Woolly-necked Storks' activities.

References

Ali, S. and S. D. Ripley. 1987. *Compact handbook of the birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan and Sri Lanka. Divers to Hawks.* 2nd ed. Oxford University Press, Delhi.

Bouton, N.S., P. C. Frederick, C. D. Rocha, A. T. B. D. Santos and T. C. Bouton. 2005. Effects of tourist disturbance on Wood Stork nesting success and breeding behavior in the Brazilian Pantanal. *Waterbirds* 28: 487-497.

Greeshma, P., R. P. Nair, E. A. Jayson, K. Manoj, V. Arya and E. G. Shonith. 2018. Breeding of Woolly-necked Stork *Ciconia episcopus* in Bharathapuzha river basin, Kerala, India. *Indian BIRDS* 14: 86-87.

Hasan, M. T. and P. Ghimire. 2020. Confirmed breeding records of Asian Woollyneck (*Ciconia episcopus*) in Bangladesh. *SIS Conservation* 2: 47-49.

Koli, V. K., S. Chaudhary and K. S. G. Sundar. 2019. Roosting ecology of Black-headed Ibis (*Threskiornis melanocephalus*) in urban and rural areas of southern Rajasthan, India. *Waterbirds* 42: 51-60.

Tiwary, N. K. and A. J. Urfi. 2016. Nest survival in Painted Stork (*Mycteria leucocephala*) colonies of north India: the significance of nest age, annual rainfall and winter temperature. *Waterbirds* 39: 146-155.

Vaghela, U., D. Sawant and V. Bhagwat. 2015. Woolly-necked Storks *Ciconia episcopus* nesting on mobile-towers in Pune, Maharashtra. *Indian BIRDS* 10: 154-155.

Vyas, R. and R. S. Tomar. 2006. Rare clutch size and nesting site of Woollynecked Stork (*Ciconia episcopus*) in Chambal river valley. *Newsletter for Birdwatchers* 46: 95.

ISSN 2710-1142(online)
SIS Conservation, 2020, 2, 71-79
RESEARCH ARTICLE

Density, flock size and habitat preference of Woolly-necked Storks *Ciconia episcopus* in agricultural landscapes of south Asia

Swati KITTUR[1,*], K. S. Gopi Sundar[1]

[1]Nature Conservation Foundation, 1311, "Amritha" 12th Main, Vijayanagar 1st Stage, Mysuru 570017, Karnataka, India
*Corresponding author; e.mail: swatikittur@ncf-india.org

Abstract Crowded agricultural landscapes of the tropics and sub-tropics are assumed to be responsible for the decline of many waterbird species. This includes Woolly-necked Storks, one of the least studied large waterbirds, with no long-term multi-scale information on its ecology. In this study we provide densities, population size, flock size and habitat use of the species in agricultural landscapes across seven districts in lowland Nepal and India using the largest available field data set of Woolly-necked Stork observations (N = 8,906 individuals in 3,133 flocks observed seasonally between 2014 and 2019). With this data, we asked whether these metrics showed variation by season and location. Woolly-necked Stork densities fluctuated considerably, both with season in each location and across locations. Estimated population of Woolly-necked Storks in the study area was 1,689 ± 922 (SD) which extrapolated to the known distribution range of the species in south Asia provided a coarse population estimate of 2,38,685 ± 1,24,471 (SD). Woolly-necked Storks were seen mostly in small flocks of 1-4 birds (86% of flocks) with few extraordinarily large flocks. Flocks were significantly larger in Jhajjar and Kheda districts, in winter, and in fallow fields and wetlands. Most Woolly-necked Storks were observed in agriculture fields (64% of 1,874 observations) with much fewer in wetlands (9%). In three locations where seasonal habitat use was measured, Woolly-necked Storks varied habitat use seasonally in all locations. Of six locations where habitat preference was assessed, storks preferred wetlands in five locations. Results of this study suggest that the largest known global population of this species is resident in agricultural landscapes, and coarse population estimates suggests that the population size of this species was previously underestimated. Results also showed considerable variations in flock size and habitat use with location and season suggesting that Woolly-necked Storks show plasticity in response to changing conditions on agricultural landscapes. These findings will be helpful to revise the species' status assessment and understanding its conservation requirements.

Keywords Agricultural landscapes, lowland Nepal, north India, population estimate.

Introduction

Expanding agriculture in south Asia with conversion of natural habitats and is ranked as one of the most important threats to waterbirds (Sundar and Subramanya 2010). One of the species that was recently elevated to the status of "Vulnerable", partly due to assumptions that its forest and undisturbed wetland habitats were being lost to agriculture, is the Woolly-necked Stork *Ciconia episcopus* (BirdLife International 2020). This stork species is one of the least studied large waterbirds globally with a vast majority of information on its ecology constituting anecdotal observations (BirdLife International 2020; Sundar 2020). Until very recently, Woolly-necked Storks

Article history
Received: 31 August 2020,
Received in revised form: 10 October 2020,
Accepted: 24 October 2020,
Published online: 28 October 2020.

were assumed to need undisturbed areas such as forests with wetlands or large protected wetland reserves. The number of studies documenting behaviour and other ecological aspects of Woolly-necked Storks in south Asia is growing and contrary to existing assumptions, points to the species being widespread, common and resident in agricultural landscapes (Sundar 2006; Pande *et al*. 2007; Katuwal *et al*. 2020; Sundar 2020; Tiwary 2020; Ghimire *et al*. in press). Information on the species' habits in agricultural areas is still piecemeal with existing studies covering a miniscule proportion of its distribution range, and field observations made over relatively short periods of time (Sundar 2006; Pande *et al*. 2007; Ghimire *et al*. in press). Detailed information on ecological aspects of Woolly-necked Storks over multiple years or multiple locations is still missing, and it is not yet clear if they are able to use agricultural areas similarly across their distribution range.

The only existing study conducted over a full year on this species is from Etawah district, Uttar Pradesh, India that showed Woolly-necked Storks to have seasonally varying densities and flock sizes, with the highest of both being recorded during winter months (Sundar 2006). Storks in Etawah used several components of the agricultural landscape including fallow fields, fields with standing crops, irrigation canals, and seasonal grasslands. The storks appeared to respond to seasonal changes in conditions by shifting to different habitats. Behavioural observations in lowland Nepal across two seasons showed Woolly-necked Storks changing time spent foraging in crop fields over seasons with less time spent foraging in winter wheat crops relative to monsoonal rice paddies reflecting higher forage quality of wheat fields (Ghimire *et al*. in press). A shorter study conducted over two seasons in Maharashtra and Karnataka also found the highest flock sizes of Woolly-necked Storks in winter months, with flocks of up to 80 storks seen using unprotected wetlands (Pande *et al*. 2007). All of these studies showed storks commonly using agricultural, unprotected wetlands, and storks in Uttar Pradesh using wetlands proportionally more than available (or preferring this habitat; Sundar 2006). It remains unclear if variations exist in other locations and whether these storks use agricultural landscapes and unprotected wetlands similarly throughout their distribution range in south Asia.

In this paper, using the world's largest field data set on Woolly-necked Storks collated between 2014 and 2019 simultaneously from seven different agricultural landscapes in lowland Nepal and India, we detail several aspects of the species' ecology. The agricultural landscapes we covered included the Gangetic floodplains in lowland Nepal and Uttar Pradesh in India where Woolly-necked Storks and other large waterbird species occur in relatively high numbers despite the high human population of the region (Sundar 2006; Sundar *et al*. 2019; Ghimire *et al*. in press). We also include information from additional agricultural landscapes in the Indian states of Haryana and Gujarat from where information on large waterbirds is sparse. All the areas we explored had agriculture as the major land use, but differed in the crops planted seasonally, had differing proportions of major seasonal crops, and varying human densities (Table 1). All the seven landscapes experienced dramatic seasonal variations in conditions due to a combination of cropping patterns and weather conditions. Collectively, therefore, the data offers a unique view of how one species – the Woolly-necked Stork – fares in different locations all of which are dominated by agriculture, but are disparate with respect to important aspects such as crops and human densities that are known to impact large waterbirds at landscape scales (Sundar and Kittur 2012). We focus on three ecological aspects of the stork that have been documented in previous studies namely density, flock size, and habitat preference. Specifically, we ask if these three ecological aspects varied with location, and whether measures of these three aspects showed variations across years and seasons reflecting altering conditions on the landscape.

Despite a near-total absence of robust field studies with which to derive an informed assessment, their population size across south and south-east Asia is estimated to be 25,000 (Wetlands International 2020). It is not clear how this estimate was reached but was likely biased by the growing number of reports of threats to the species in south-east Asia where it is severely threatened by hunting and habitat loss (BirdLife International 2020). In this paper, using seasonal densities, we compute population estimates of Woolly-necked Storks at each location. As a crude exercise, and being aware of the potential to over-estimate the population using simple density estimates (e.g. Blanco *et al*. 2012; 2014) we extrapolate measured density estimates to the species' south Asian distribution range to obtain the first evidence-based population estimate for the species in south Asia.

Study area

Woolly-necked Storks were surveyed in six districts in India and one in lowland Nepal. Five districts in India were covered nearly completely (Anand, Etawah, Jhajjar, Kheda, Rohtak), one was covered in part along with a part of the adjoining district (Unnao-Rae Bareli in Uttar Pradesh), and a part of the neighbouring districts of Rupandehi and Kapilavastu were covered in lowland Nepal (see Figure 1). We refer to the Unnao-Rae Bareli landscape as "Unnao" and the Rupandehi-Kapilavastu landscape as "Rupandehi" in this paper. Several characteristics of the focal districts are presented in Table 1. All districts were predominantly agricultural (72 – 89% of area under agriculture), with three seasonal crops cultivated over the year. Major crops in these districts were rice during the rainy season or the monsoon (July-October), wheat and mustard during the winter (November–February), and varied crops such as vegetables and pulses in few fields during the summer (March–June) with many fields remaining fallow due to the summer heat. These landscapes also supported extremely high human densities of between 520 to 680 people/km^2 (Table 1). Along with agriculture and scattered towns/villages, these landscapes also hosted several types of wetlands including large perennial reservoirs, seasonal marshes, small scattered ponds used for fish farming, village ponds used to graze livestock, and water from all these wetlands were used for irrigation. A number of natural resources such as fish and lotus stems were manually extracted from wetlands by local people. Anand district in Gujarat also had coastal wetlands but we did not survey these since Woolly-necked Storks were never observed using coastal areas. Most of the landscapes also had streams and rivers flowing through them or on the edges and supported patches of scrub forests and grasslands along the river and scattered across the countryside. All of the focal districts experienced very wet monsoons and the countryside experienced flooding during this season. Summer was the driest and hottest period and all of the seasonal wetlands dried out. Patches of the landscapes were, however, still wet during the summer due to leakages from extensive networks of irrigation canals. These canals provided habitats to storks and other birds practically throughout the year and also added to the

Table 1. Characteristics of the seven districts surveyed for Woolly-necked Storks in lowland Nepal and India. Statistics are taken from Government of India and Government of Nepal websites including from departments relating to national census, agriculture and weather (Indian National Census 2011). We used total area under crops to list the primary crops grown in each district. Climate statistics were downloaded in 2018 and relate to the period 1995-2015. Survey effort lists the cumulative total km traversed for surveys from which data have been used in this paper.

District	Size (km^2)	Human population	Primary crops	Climate (min-max temperature in °C; average rainfall)	Survey effort (km)
Anand	3,204	20,90,000	Rice, wheat, tobacco, banana	21-33°C; 882 mm	27,838
Etawah	2,331	13,39,870	Rice, corn, wheat, potato	7-43°C; 930 mm	40,593
Jhajjar	1,834	9,57,000	Rice, cotton, wheat, millet	9-45°C; 290 mm	55,268
Kheda	3,959	22,98,900	Rice, millet, wheat, pulses	20-34°C; 830 mm	22,781
Rohtak	1,668	10,58,700	Rice, millet, wheat, sugarcane	2-45°C; 580 mm	54,213
Rupandehi	1,360	8,80,200	Rice, wheat, mustard, sugarcane	12-44°C; 530 mm	43,211
Unnao	4,589	31,10,590	Rice, corn, wheat, vegetables	8-44°C; 850 mm	18,165

hydrological complexity of the landscape.

Methods

Field surveys

In each district, one observer traversed the road network of the district once in each season ensuring complete coverage by using overlaid grids of 5’x5’ (approximately 10x10 km) and covering similar lengths of road in each grid. Due to a limited road network in all districts, some roads had to be covered more than once to allow access to all of the grids. Observers carried hand-held GPS units that recorded the survey routes providing a measure of effort for all districts in all seasons. All sightings of Woolly-necked Storks were noted with details of location and number of birds. Starting from winter 2016-2017, observers were trained to also collect data on the habitat in which storks were observed. Habitats were categorised broadly into five types: standing crop, fallow fields (fields after crops had been harvested or uncultivated crop fields), wetlands (lakes, ponds, marshes, and for this manuscript, also included sightings in canals and rivers), trees, and other (included sightings in all other habitats including on artificial structures as well as flying birds).

Habitat availability

To obtain a measure of habitat availability in each district, cloud-free Landsat 8 imageries taken between October and November 2016 were procured (U.S. Geological Survey 2016). Imageries were classified into broad classes (wetlands, habitation, agriculture, trees, scrub and open) using unsupervised classification (Iso-data clustering), to assign pixels into the above classes using ERDAS Imagine version 9.1 (Hexagon Geospatial 2006). Area of Interest (AOI) polygons created by onscreen digitization using Google Earth images were used to reclassify incorrectly classified pixels to the correct classes. Additional details of the classification process are given elsewhere (Sundar *et al*. 2019). Imageries were classified at 30 x 30 m resolution. The overall classification accuracy of the districts varied between 92 and 96%. To match with field observations, the ‘wetland’ class included natural and artificial ponds, lakes and other water bodies, rivers and canals. However, we clumped standing crop and fallow fields into one ‘agriculture’ class due to difficulties in assessing their accuracy. For the purpose of this paper habitation, scrub and open classes were merged into the ‘other’ class. The class ‘tree’ included orchards, forests and scattered tree patches.

Data analyses

Throughout this document, we present results as average ± SD. We also present numbers using the south Asian convention of 2,2,3 digit grouping where a million is written as "10,00,000".

A majority of the storks were counted within 150 m on either side of the roads in all the districts, and we use this measure as the transect width. Length of survey (in km) recorded in GPS units multiplied by the transect width provided the area surveyed. Density was computed as storks/ km^2 each season at each location. We used non-parametric ANOVA tests to test if density varied by season and location, and whether density varied by season within each location. Non-parametric tests freed us from the strict requirements of data distributions and heteroscedacity required for the use of parametric tests. For permutation tests, we used function ‘aovp’ in R-package ‘lmPerm’ (Wheeler and Torchiano 2016).

Density computations were conservative as they included all land uses that were traversed using the road network in each district without biasing effort to cover or avoid certain habitats. Additionally, we did not measure and correct for potential variability of detection due to habitat or observer. We estimated populations of Woolly-necked storks for each district using seasonal densities and total area covered. We averaged densities across seasons to arrive at a mean density and the standard deviation (SD) to represent variation in stork numbers in each district. Though we include information over 15 seasons for some locations, densities were computed in all locations for only seven of these seasons due to logistical reasons (see Figure 1). Densities were averaged across all locations only from these seven seasons. We calculated the total area of the distribution range of Woolly-necked Storks in south Asia as 21,62,359 km^2 using the map provided by BirdLife International (2020). Extrapolations were made for seven seasons separately and an average and SD population estimate of Woolly-necked Storks in south Asia was obtained from these. Despite being coarse, we consider this estimate to be conservative for two reasons. First, estimated densities were for entire districts including towns and villages where Woolly-necked Storks are extremely rare (personal observations). Second, while Woolly-necked Storks are well distributed across the entire distribution range drawn by BirdLife International (2020), they also occur beyond this range (see Gula *et al*. 2020) suggesting that the distribution range we used was itself an underestimate. The extrapolated population estimate, however, should be treated as preliminary since such estimates can frequently have a very wide range and can also be over-estimates (Blanco *et al*. 2012; 2014).

Both flock size and habitat use of waterbirds can vary due to time of day. In this study, field surveys in all the seven districts extended across the day and we do not consider time of day in analyses. It will be useful to conduct additional studies of Woolly-necked Storks to assess the importance of time of day on these two metrics. Woolly-necked Storks were considered to be in a single flock when multiple birds foraged together, or when they used a single wetland. We computed average (± SD) flock sizes seasonally for each district. Flock

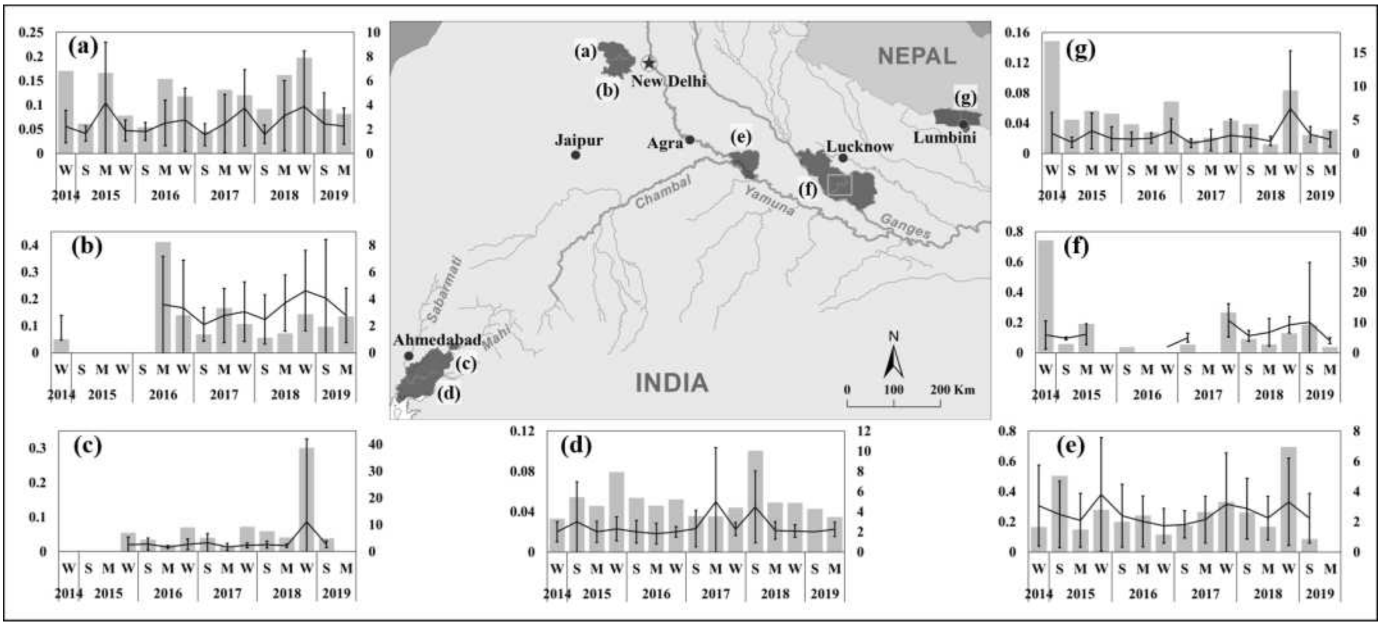


Figure 1. The map shows the locations of the focal districts (dark grey polygons) in lowland Nepal and India. Graphs show measured seasonal densities (bars relate to primary y-axis; M - monsoon, S - summer, W - winter) and flock sizes (average ± SD; lines relate to secondary y-axis) of Woolly-necked Storks in each district. Missing data signifies periods when field work was discontinued. Districts are: (a) Rohtak, (b) Jhajjar, (c) Kheda, (d) Anand, (e) Etawah, (f) Unnao and (g) Rupandehi.

size distributions were skewed towards smaller flocks, so we employed non-parametric permutation ANOVAs with R-package ‘lmPerm’ to test for differences in mean flock sizes. We tested for differences individually between locations, season, and year and for two-way interactions between these three aspects. Using a smaller data set (see Methods above) we also assessed if flock sizes varied between habitat types, and tested for two-way interactions between habitat and season, and habitat and location to understand if flocks varied solely due to habitat or whether additional variables also influenced flock sizes of Woolly-necked Storks in different habitats. For all tests of flock sizes with habitat, two unusually large flocks were removed from the data prior to the analyses.

We computed both seasonal and aggregate habitat use by Woolly-necked Storks using a smaller data set starting from the winter of 2016-2017. Each observation was used as a data point and not each stork since individual birds in a flock are not independent. Seasonal habitat use was constructed for three districts where we obtained over 400 individual records of habitat use. We used Fisher’s exact tests (R Core Team 2019) to test if number of observations of Woolly-necked Storks using individual habitat types varied across seasons.

Using the habitat data from field surveys and land cover data from classified imageries we applied the use-availability framework of Manly *et al*. (2004) to understand if Woolly-necked Storks exercised habitat preference and avoidance. For this analyses, we aggregated all stork sightings in each district and contrasted these against a one-time measure of habitat availability. We used function ‘widesI’ in R-package “adehabitat” (Calenge 2006) which uses measurements of habitat use and availability to estimate preference at the population level without requiring data from marked animals. The method also requires each observation to be independent and therefore we used number of observations and not the number of storks sighted in each habitat. The algorithm computes the Manly selectivity measure allowing tests of habitat use at two scales. The first scale is for the overall data set estimated using log-likelihood χ^2 (or the ‘Khi2L’ statistic of “adehabitat”) to test the hypothesis that all habitats were used randomly. Next, selection ratios (use/ available) were estimated for each habitat and differences between the ratios were tested using pair-wise Bonferroni tests. These allowed a formal assessment of whether each habitat was preferred (used more relative to availability), avoided (used less relative to availability) or used in proportion to availability (Manly *et al*. 2004).

Results

This study includes monitoring across 15 seasons from winter 2014 to monsoon 2019. However due to logistical reasons surveys in some seasons could not be carried out in some of the districts (see seasons with missing values in Figure 1). A total of 8,906 Woolly-necked Storks were observed in 3,133 flocks, with habitat use noted for 1,874 observations.

Density and population estimates

Woolly-necked Stork density varied widely seasonally in each location and across locations (Figure 1, Appendix). The overall average density was 0.12 (± 0.13) storks/km^2. Density was significantly different with location (p < 0.001) and season (p = 0.01). However, at each location, density did not vary significantly with season (p = 0.46). The estimated population of Woolly-necked Storks cumulatively in the seven districts was 1,689 ± 922 (SD). The lowest estimated population was in the relatively small area covered in lowland Nepal with 30 ± 22 Woolly-necked Storks. The largest populations were estimated in Etawah (522 ± 368) and Unnao (303 ± 464) districts, but with considerable seasonal variations in estimated numbers. The districts in Haryana also had fairly high estimated populations of Woolly-necked Storks with Rohtak (192 ± 79) having more estimated storks than Jhajjar (179 ± 194) district. Districts closer to the coast had intermediate estimated populations with Kheda (161 ± 239) having a slightly higher number of storks compared to Anand (150 ± 53) district. Extrapolated to the distribution range in south Asia, the species' population estimate was 2,38,685 ± 1,24,471 (SD) across south Asia.

Flock size

Woolly-necked Storks were usually seen in small flocks of 1 to 4 birds (86%) and only 2.5% of flocks were more than 10 birds. Average flock size pooled across all the areas and all seasons was 2.8 ± 3.5 (SD). Seasonal averages for each location are detailed in the Appendix. Two unusually large flocks were observed during systematic surveys: 66 (Unnao, summer 2019) and 114 (Kheda, winter 2018-19). Another large flock of 120 storks was sighted in Etawah district in December 2014 (winter) during an ad-hoc visit. Flock sizes showed significant differences across years, seasons and landscapes (p < 0.001; Figure 1). Flock sizes were also significantly different across seasons within a year (p < 0.001) and across landscapes each year (p < 0.001). Finally, in each landscape they also showed significant seasonal variation (p < 0.001). Seasonal average and SD for flock sizes are shown as lines in Figure 1. Flock sizes were also significantly different across habitat types with the largest flocks observed in fallow fields and wetlands (p < 0.001).

Habitat use and preference

In all locations, most of the Woolly-necked Stork observations were in agriculture fields (64% of observations were in standing crop and fallow fields; Figure 2), and very few were seen in wetlands at each location (9% of total observations). The aggregated data did not show significant variations in habitat use across different

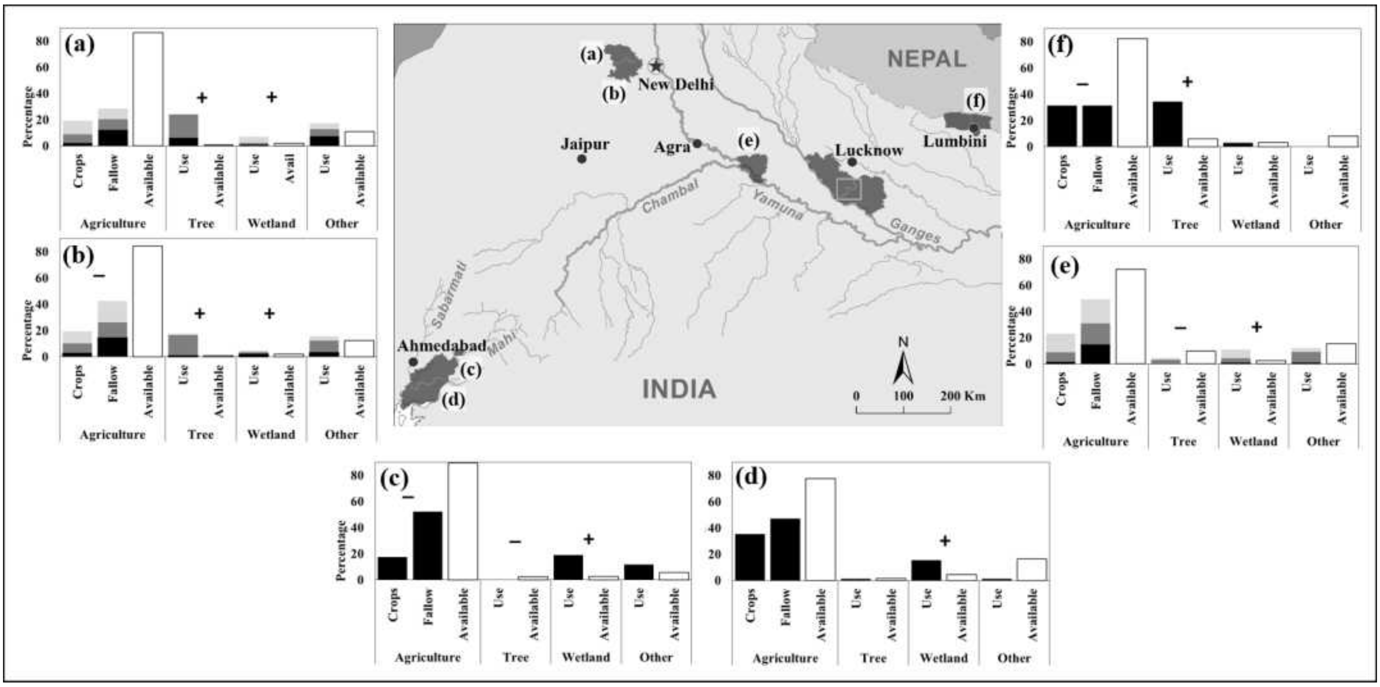


Figure 2. Graphs show habitat use (coloured bars) by Woolly-necked Storks and available habitat (white bars) in districts (dark polygons in map) surveyed over multiple seasons. Symbols indicate whether a particular habitat type was preferred (+) or avoided (-) using a use-availability framework. When habitats were used in proportion to their availability, no sign is provided. For three districts with > 400 observations each of storks using habitats, proportional contribution of habitat use in each of three seasons (black: summer; dark-grey: monsoon; light-grey: winter) are shown as stacked bars. Districts are: (a) Rohtak, (b) Jhajjar, (c) Kheda, (d) Anand, (e) Etawah and (f) Rupandehi.

locations ($p = 0.48$) but showed significant seasonal variations ($p < 0.001$) in habitat use. In the three districts with > 400 observations each of habitat use (Etawah, Jhajjar, Rohtak), Woolly-necked Storks used significantly different habitats seasonally in each of the three districts (Figure 2; $p < 0.001$).

Agricultural fields were the dominant land use in all surveyed districts, with wetlands and trees being relatively rare (see Figure 2). Woolly-necked Storks preferred wetlands in nearly all the locations and avoided agriculture in three districts, using them in proportion to availability in the other districts (Figure 2). Trees were strongly preferred in three districts (mostly used during the monsoon), avoided in two and used in proportion to availability in the remaining district (Figure 2).

Discussion

Measured metrics of Woolly-necked Storks varied greatly with location and season. This suggests that these storks exhibit behavioural plasticity likely in response to changing conditions on agricultural landscapes. Densities varied significantly with location and season, but at each location, seasonal densities were not significantly different despite some variation being apparent (Figure 1, Appendix). This suggests that Woolly-necked Stork population are largely resident with some local or regional movements of birds. These movements do not appear to be consistently in one season since highest measured densities were in winter in some locations (e.g. Etawah; Appendix) and monsoon in others (e.g. Jhajjar). The least number of Woolly-necked Storks were seen in summers and monsoons (see Appendix) suggesting that some local movement may occur in response to water availability. These findings match previous observations in Etawah (Sundar 2006). Overall density in Etawah in this study (average of 0.26 ± 0.16) was lower than the estimated density in 2000-2001 (0.41 ± 0.4; from Sundar 2006). This reduction in densities is likely to be related to the coverage of the district, with a lot more area covered during this study relative to the few roads covered in 2000-2001. Findings suggest that metrics such as density and population size estimated over short periods of time are unlikely to provide a reasonable understanding of the local or regional status of Woolly-necked Storks.

Woolly-necked Storks occurred largely in flocks of < 4 birds suggesting that these birds largely occur as pairs or small family groups. Extraordinary sizes of flocks were rare but exceeded a hundred storks foraging together in wetlands and in crop fields. Flock sizes, however, appear to vary substantially across season, year and location suggesting that this metric may not be a suitable representative of landscape quality. Significantly large flocks occurred in both fields and wetlands additionally suggesting that Woolly-necked Storks are versatile foragers on agricultural landscapes. Unusually large flocks occurred in more than one season with the timing suggesting that these can occur in response to fledged chicks (winter flocks) and in response to drying wetlands (summer flocks). Observations therefore match suggestions in previous studies (Sundar 2006; Pande *et al*. 2007), but indicate that Woolly-necked Storks may respond to both and not any one stimuli across its distribution range. One caveat of our study was the inability to factor in time of day in the analyses of flock sizes. Large waterbirds such as storks often aggregate in the afternoons after foraging in the mornings (pers. obs.). However, it is not known if such aggregations occur similarly across seasons and locations for Woolly-necked Storks.

Woolly-necked Storks were mostly observed using agricultural fields in all the districts which is contrary to existing information (BirdLife International 2020). Tree use during the monsoon increased in a few districts matching breeding seasonality of this species. Differences in districts and in seasons could also be due to observer bias, though field associates were usually very careful and were very highly trained. Another potential reason for observed variability in use of different habitats could be detection bias, and a separate measurement of this bias can help with correcting potential errors. Additionally, large waterbirds could use different habitats with time of day – a variable that we have not included in the analysis for this paper. Multi-season multi-location information on habitat use is absent for most bird species in south Asia. For Woolly-necked Storks, our analyses confirms that this species is capable of considerable plasticity in habitat use on agricultural landscapes. Their habit of being resident alongside their ability to be plastic in using disparate habitats in all of the study locations suggests that this species is likely to adjust to similar suitable agricultural areas. This finding is contradictory to many past treatises that suggest that increase in agriculture is detrimental to Woolly-necked Storks. Our findings offer hope that this is one of the few large waterbird species whose long-term status is likely stable and positive notwithstanding expanding agriculture in south Asia.

Similar multi-year multi-seasonal studies on the Glossy Ibis (*Plegadis falcinellus*) in two of the districts that were included in this study (Anand and Kheda) showed considerable seasonal and annual differences in densities and flock sizes (Sundar and Kittur 2019) suggesting that Woolly-necked storks are not unique in being able to use south Asian agricultural landscapes. Additional studies are needed in south Asian agricultural landscapes and elsewhere to understand if other large waterbirds species are similarly well adjusted to these seasonally changing landscapes.

It is not clear what the past population estimates of 25,000 for Woolly-necked Storks in south and south-east Asia is based on, but this work suggests that it was a severe underestimate. We are aware and acknowledge that our estimate of 2,38,685 ± 1,24,471 Woolly-necked Stork is coarse. However, as we have explained in the Methods, this estimate is unlikely to be an over-estimate. The relatively wide bias in the estimate is a consequence of the seasonal and locational variations of stork densities, but are appropriate in the absence of better designed larger-scale studies. The current distribution range of the Woolly-necked Storks in south Asia needs to be expanded (see Gula *et al*. 2020) and improved methods that can explicitly control for potential biases due to observers and time of day are needed. Our population estimate for the species is therefore to be regarded as a conservative and preliminary estimate.

Our findings collectively suggest that the Woolly-necked Stork cannot continue to be considered a "Vulnerable" species. The new population estimate and the findings that agricultural landscapes are not necessarily detrimental for the species should both be considered for an update of the species' status. Our findings also showcase the value of remnant scattered wetlands on south Asian agricultural landscapes for large waterbirds such as Woolly-necked Storks. Woolly-necked storks seem to have complex and varied flocking and habitat use patterns and appear to be an erstwhile-ignored study model to help understand how human-modified landscapes can be useful as bird habitats.

Acknowledgments

Data were collected as part of a long-term initiative to monitor large waterbirds in south Asian agricultural landscapes. We thank our field associates Rakesh Ahlawat, Sonu Dalal, Sandeep Dubey, Kailash Jaiswal, Amit Makwana, and Saurabh Shukla. We thank the International Crane Foundation, USA and the Nature Conservation Foundation, India for administrative and other support. We thank The Bryan Guinness Charitable Trust, The Eppley Foundation for Research and the National Geographic Society for multi-year support of field work. Additional support were kindly provided by an anonymous donor, Karen & Joseph Branch, Judith Derse, Lata Kittur, Regina Phelps and Sanjay Prasad. We thank an anonymous reviewer for thoughtful and useful advice that improved the manuscript.

References

BirdLife International. 2020. Species factsheet: *Ciconia episcopus*. http://datazone.birdlife.org/species/factsheet/asian-woollyneck-ciconia-episcopus/text, accessed 18 August 2020.

Blanco, G., F. Sergio, J. A. Sánchez-Zapata, J. M. Pérez-García, F. Botella, F. Martínez, I. Zuberogoitia, O. Frías, F. Roviralta, J. E. Martínez and F. Hiraldo. 2012. Safety in numbers? Supplanting data quality with fanciful models in wildlife monitoring and conservation. *Biodiversity and Conservation* 21: 3269-3276.

Blanco, G., O. Frías, J. A. Cuevas, J. L. González and F. Martínez. 2014. Commonness of not-so-common birds: the need for baseline knowledge of actual population size for the validation of population size predictions. *Bird Study* 61: 351-360.

Calenge, C. 2006. The package "adehabitat" for the R software: a tool for the analysis of space and habitat use by animals. *Ecological Modelling* 197: 516-519.

Ghimire, P., N. Pandey, Y. P. Timilsina, B. S. Bist and K. S. G. Sundar. *In press*. Woolly-necked Stork activity budget in lowland Nepal's farmlands: the influence of wetlands, seasonal crops and human proximity. *Waterbirds*.

Gula, J., K. S. G. Sundar and W. R. J. Dean. 2020. Known and potential distributions of the Woollyneck Storks *Ciconia episcopus* and *C. microscelis*. *SIS Conservation* 2: 80-95.

Hexagon Geospatial. 2006. *Erdas Imagine Version 9.1*. Hexagon Geospatial, Stockholm, Sweden.

Indian National Census. 2011. *15th National census survey, Census Organization of India*. https://www.census2011.co.in, accessed 15 August 2020.

Katuwal, H. B., H. S. Baral, H. P. Sharma and R.-C. Quan. 2020. Asian Woollynecks are uncommon on the farmlands of lowland Nepal. *SIS Conservation* 2: 50-54.

Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald and W. P. Erickson. 2004. *Resource selection by animals. Statistical design and analysis for field studies*. Second Edition. Kluwar Academic Publishers, New York, USA.

Pande, S., N. Sant, R. Bhate, A. Ponkshe, P. Pandit, A. Pawashe and C. Joglekar. 2007. Recent records of wintering White *Ciconia ciconia* and Black *C. nigra* storks and flocking behaviour of White-necked Storks *C. episcopus* in Maharashtra and Karnataka states, India. *Indian BIRDS* 3 (1): 28-32.

R Core Team. 2019. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Sundar, K. S. G. 2006. Flock size, density and habitat selection of four large waterbirds species in an agricultural landscape in Uttar Pradesh, India: implications for conservation. *Waterbirds* 29: 365-374.

Sundar, K. S. G. 2020. Special section editorial: Woolly-necked Stork – a species ignored. *SIS Conservation* 2: 33-41.

Sundar, K. S. G. and S. Kittur. 2012. Methodological, temporal and spatial factors affecting modelled occupancy of resident birds in the perennially cultivated landscape of Uttar Pradesh, India. *Landscape Ecology* 27: 59-71.

Sundar, K. S. G. and S. Kittur. 2019. Glossy Ibis distribution and abundance in an Indian agricultural landscape: seasonal and annual variations. *SIS Conservation* 1: 135-138.

Sundar, K. S. G., R. Koju, B. Maharjan, B. G. Marcot, S. Kittur and K. R. Gosai. 2019. First assessment of factors affecting the breeding success of two stork species in lowland Nepal using Bayesian Network models. *Wildfowl* 69: 45-69.

Sundar, K. S. G. and S. Subramanya. 2010. Bird use of rice fields in the Indian subcontinent. *Waterbirds* 33 (sp. issue 1): 44-70

Tiwary, N. K. 2020. Observations on distribution and feeding behaviour of Woolly-necked Stork *Ciconia episcopus* during 2012-20 from north India. *SIS Conservation* 2: 42-46.

U.S. Geological Survey. 2016. *Landsat 8 Data Products*. Geological Survey, U.S. Department of the Interior, Washington D.C., USA. Available at http://glovis.usgs.gov/, accessed November 2016.

Wheeler, B. and M. Torchiano. 2016. lmPerm package for R: Permutation Tests for Linear Models version 2.1.0. https://github.com/mtorchiano/lmPerm, accessed 13 August 2020.

Wetlands International. 2020. *Waterbird Population Estimates*. Retrieved from wpe.wetlands.org on 28 August 2020.

Appendix. Density (birds/ km^2) and flock size (average ± SD and range) of Woolly-necked Storks in six districts in Nepal and India. Values are average ± SD, along with the range (in parenthesis). Estimates were derived for each season after pooling data across all years of field work for that season at each district. Sample sizes for each district are provided for both metrics below district names (total number of storks encountered for density; total number of flocks for flock sizes).

District	Monsoon	Summer	Winter	Total
	Density			
Anand (426)	0.04 ± 0.01 (0.03 to 0.05)	0.06 ± 0.03 (0.04 to 0.1)	0.05 ± 0.02 (0.03 to 0.08)	0.05 ± 0.02 (0.03 to 0.1)
Etawah (3,034)	0.21 ± 0.06 (0.15 to 0.26)	0.25 ± 0.16 (0.09 to 0.5)	0.32 ± 0.23 (0.12 to 0.69)	0.26 ± 0.16 (0.09 to 0.69)
Jhajjar (2,059)	0.2 ± 0.15 (0.07 to 0.41)	0.07 ± 0.02 (0.06 to 0.1)	0.11 ± 0.04 (0.05 to 0.14)	0.13 ± 0.1 (0.05 to 0.41)
Kheda (403)	0.03 ± 0.01 (0.01 to 0.04)	0.04 ± 0.01 (0.03 to 0.06)	0.12 ± 0.12 (0.05 to 0.3)	0.07 ± 0.08 (0.01 to 0.3)
Rohtak (1,843)	0.14 ± 0.03 (0.08 to 0.17)	0.07 ± 0.02 (0.04 to 0.09)	0.14 ± 0.05 (0.08 to 0.2)	0.12 ± 0.05 (0.04 to 0.2)
Rupandehi (540)	0.03 ± 0.02 (0.01 to 0.06)	0.03 ± 0.01 (0.02 to 0.04)	0.08 ± 0.04 (0.04 to 0.15)	0.05 ± 0.03 (0.01 to 0.15)
Unnao (601)	0.1 ± 0.08 (0.04 to 0.19)	0.09 ± 0.06 (0.04 to 0.18)	0.28 ± 0.32 (0 to 0.74)	0.15 ± 0.2 (0 to 0.74)
	Flock size			
Anand (181)	2.2 ± 1.7 (1 to 13)	2.7 ± 2.4 (1 to 12)	2.1 ± 0.8 (1 to 5)	2.4 ± 1.8 (1 to 13)
Etawah (1,208)	2.1 ± 1.6 (1 to 16)	2.4 ± 1.9 (1 to 20)	3 ± 3 (1 to 20)	2.5 ± 2.3 (1 to 20)
Jhajjar (641)	3.1 ± 2.6 (1 to 22)	2.9 ± 3 (1 to 24)	3.6 ± 2.9 (1 to 24)	3.2 ± 2.8 (1 to 24)
Kheda (116)	2 ± 0.8 (1 to 4)	2.8 ± 2 (1 to 11)	4.3 ± 14.3 (1 to 114)	3.5 ± 10.5 (1 to 114)
Rohtak (702)	2.8 ± 2.6 (1 to 20)	1.9 ± 1.5 (1 to 18)	3.2 ± 3.3 (1 to 30)	2.6 ± 2.6 (1 to 30)
Rupandehi (201)	2.4 ± 1.6 (1 to 9)	2 ± 1.1 (1 to 5)	3.5 ± 4.3 (1 to 30)	2.7 ± 2.9 (1 to 30)
Unnao (84)	6 ± 3.4 (1 to 17)	7 ± 12.4 (1 to 66)	7.9 ± 5 (2 to 21)	7.2 ± 7.7 (1 to 66)

ISSN 2710-1142(online)
SIS Conservation, 2020, 2, 80-95
RESEARCH ARTICLE

Known and potential distributions of the African *Ciconia microscelis* and Asian *C. episcopus* Woollyneck Storks

Jonah GULA[1,*], K. S. Gopi Sundar[2], W. Richard J. DEAN[3,4,5]

[1]Texas State University, , 601 University Drive, San Marcos, Texas 78666, USA
[2]Nature Conservation Foundation, 1311, "Amritha" 12th Main, Vijayanagar 1st Stage, Mysuru 570017, Karnataka, India
[3]Wolwekraal Conservation and Research Organisation, P.O. Box 47, Prince Albert 6930, South Africa
[4]Percy FitzPatrick Institute of Ornithology, University of Cape Town, Rondebosch 7700, South Africa
[5]South African Environmental Observation Network, Arid Lands Node, P.O. Box 110040 Hadison Park 8306, Kimberley, South Africa
*Corresponding author; e.mail: jonah.gula@yahoo.com

Abstract Range-wide distribution patterns and environmental requirements of the African *Ciconia microscelis* and Asian *C. episcopus* Woollyneck Storks are poorly understood, which has confounded the ability to develop empirical conservation status assessments for either species. We collated thousands of records for each species to create the first objective distribution maps, and used these data to model environmental suitability at the continental and regional scales in Africa and Asia with the machine-learning program MaxEnt. We found the African Woollyneck to be fairly widespread in southern and East Africa but its distribution in West Africa was fragmented. The Asian Woollyneck had a widespread distribution in south Asia, an isolated population segment in Cambodia and Vietnam, and was sparsely distributed on the southeast Asian islands. Predictions of suitable distributions and responses to climate variables in the MaxEnt models were scale-dependent for both species. Annual and seasonal precipitation were most important in Africa, and the most influential variables differed across Asian models. Field studies testing these findings will bolster the knowledge of ecological requirements, as well as help determine how responses to environmental variation influence population dynamics. While our findings indicate neither species are of immediate conservation concern, there is evidence of population declines and range fragmentation and contractions in some regions. Understanding factors that have caused these changes is especially important in the face of ongoing environmental change on both continents.

Keywords Climate, environmental requirements, land cover, precipitation, temperature.

Introduction

Storks remain a poorly-studied group of waterbirds despite their charismatic appeal. Over thirty years ago Luthin (1987) called this to attention yet still the basic ecology of most species remains unknown. While many African and Asian species have large extents of occurrence, population status and trends and patterns of distribution are often unclear. Inadequate data about these make it difficult to assess species-environment relationships and how individual species are responding to a growing number of threats, thereby presenting a challenge for the development of empirical conservation assessments and strategies (Farashi and Alizadeh-Noughani 2019).

Wetlands are among the most threatened habitats on earth (Junk *et al*. 2013), and as predominantly wetland birds, storks face associated threats,

Article history
Received: 07 October 2020,
Received in revised form: 26 October 2020,
Accepted: 30 October 2020,
Published online: 02 November 2020.

including habitat degradation and loss, prey depletion, and climate change. There is growing evidence in Asia, however, that some storks and other waterbirds do well in agricultural landscapes where natural wetlands are maintained primarily for human use within a mosaic of traditional agriculture (Sundar 2006; Kim *et al*. 2008; Masahiro *et al*. 2010; Wood *et al*. 2010; Sundar 2011b; a; Sundar and Kittur 2013; Kamaruddin *et al*. 2017; Koju *et al*. 2019; Ghimire *et al*. in press), yet comparable research from Africa is lacking. Also lacking is information about the ecological requirements of storks and their responses to climate change on both continents. In the Sahel region of West Africa, there is evidence of local extirpations and population declines of several species due to long-term drought related to climate change and anthropogenic landscape alteration (Zwarts *et al*. 2009; Gula *et al*. 2019). The only study to address the threat of climate change for Asian storks was on the Oriental White Stork *Ciconia boyciana*, in which it was found habitat suitability could decline by as much as 80% without conservation action under future climate projections (Zheng *et al*. 2016).

Until recently, the African *Ciconia microscelis* and Asian *C. episcopus* Woollyneck Storks were treated as a single species despite disjunct geographic ranges with no connectivity (Bannerman 1953; del Hoyo *et al*. 2014). The African species occurs throughout sub-Saharan Africa, excluding the dry southwestern subcontinent. The Asian species is found in south and southeast Asia, including the Philippines and Indonesian islands (except Borneo). Within each species' range, patterns of occurrence are not understood except that distribution is fairly patchy, and there is considerable variation in density and flock size with location and season in south Asia (Kittur and Sundar 2020). Both species are described as inhabiting wet grasslands and wetlands, often near open forest (Hancock *et al*. 1992), and Asian Woollynecks also commonly use agricultural areas (Holmes 1977; Sundar 2006; Ghimire *et al*. in press). To date, the only study to provide insight into landscape patterns of woollynecks was in north India, where Asian Woollynecks exhibited scale-dependent patterns with higher abundance in areas with more and larger wetlands (Sundar and Kittur 2013). Migration in Africa has been inferred from influxes of observations and large gatherings (commonly 100 - 300, max. 500 - 1,000; Bulmahn and Bulmahn 1985 in Herremans *et al*. 1996) during the southern wet season (November - May; Benson *et al*. 1971; Irwin 1981; Aspinwall 1987; Herremans *et al*. 1996). However, any aspects of migration beyond seasonal influxes and aggregations are unknown. In Africa, breeding occurs during the respective regional dry season and ends around the onset of the rains, ranging from November - March north of the equator (Brown and Britton 1980; Nikolaus 1987) and August - December south of the equator (Herremans *et al*. 1996; Berruti 1997; Parker 2005). Conversely, breeding in south Asia occurs during the rains from July - October (Hancock *et al*. 1992; Ishtiaq *et al*. 2004; Sundar 2006; Ghimire *et al*. in press). Evidence of seasonal movements or migration in south Asia is now increasing, with some areas witnessing drastic reductions in stork numbers during the rainy season (Mandal *et al*. 2020), and others having fewer storks during the summer (March - June; Sundar 2006; Kittur and Sundar 2020; Roshnath and Greeshma 2020).

Along with poorly-understood distribution patterns, the contrary seasonality of breeding between sister species raises questions about the environmental requirements of the woollyneck storks, especially how similar their niches are to one another. These questions have important conservation implications in the face of the environmental change their wetland and agricultural habitats have and are experiencing. In particular, such information would greatly contribute to the development of conservation assessments and strategies, as the status of the African Woollyneck is uncertain and in need of assessment. Although the Asian Woollyneck has been recently reassessed with a preliminary decision to be downgraded on the IUCN Red List (Sundar 2020), there is still much to learn about population dynamics, distribution, and the environmental processes that influence them. Therefore, we developed maps of known distribution for both species and compared them to the IUCN maps to assess occurrence more precisely. We also modeled potential distribution and environmental relationships to assess determinants of distribution. Our hypothesis was that environmental variables influencing distribution would differ between the two species given the contrasting breeding seasonality, implicit differences in ecology, and variations in human land use on each of the two continents; and that responses to the variables would vary by species.

Methods

Range-wide locality data from eBird (eBird 2020) and the Global Biodiversity Information Facility (GBIF.org 2020) were collated and vetted for both woollyneck species. A variety of additional sources were used for the African Woollyneck, including the West African Bird Database (WABDaB 2020), the National Geographic Okavango Wilderness Project (M. Mills, unpub. data), the West African Ornithological Society's journal Malimbus, the Southern African Bird Atlas Project (SABAP) 1 (Harrison *et al*. 1997), SABAP2 (ongoing effort), and country-specific bird atlases: Benin and Togo (Dowsett-Lemaire and Dowsett 2019), Botswana (Penry 1994), eSwatini (formerly Swaziland; Parker 1994), Ethiopia and Eritrea (Ash and Atkins 2009), Ghana (Dowsett-Lemaire and Dowsett 2014), Kenya (Lewis and Pomeroy 1989), Malawi (Dowsett-Lemaire and Dowsett 2006), Mozambique (central and southern; Parker 1999; 2005), Somalia (Ash and Miskell 1983; 1998), Sudan (including South Sudan; Nikolaus 1987), Tanzania (N. Baker, unpub. data), Uganda (Carswell *et al*. 2005), and Zambia (Dowsett *et al*. 2008). To a lesser extent, records were located by tracing citations from known literature used by Gula *et al*. (2019). Additional records for the Asian Woollyneck were found in the journal Forktail as well as traced through citations therein. Data used for other papers in this issue of *SIS Conservation* were also used for the analyses, especially the following papers: Katuwal *et al*. (2020), Kittur and Sundar (2020), and Win *et al*. (2020). Photographs available on the internet with locational details were also collated by volunteers and data from nearly 1,000 individual records were included for this analysis (see also Sundar 2020). For both species, in cases where records were manually traced in the literature, locations were geo-referenced as precisely as possible given the available descriptions. A detailed list of sources is available upon request. It should also be noted that we were unable to obtain data from International Waterbird Counts, which could increase the extent of occurrence.

Maps of known distribution were developed in QGIS 3.12 (QGIS 2020) at a 0.5° resolution because most African atlases did not provide a higher resolution. The Sudan atlas used a 1° resolution and most of the data compiled for it were historic, thus it was only used for considering historic distribution. Records were categorized as 'historic' if they occurred prior to 1970 and 'recent' from 1970 - 2020. In cases where years of occupied atlas cells were unclear, they were defaulted to the recent period given their more recent compilations. Therefore, it is possible the recent distributions may be an overestimate of modern occurrence in some African countries.

Environmental distribution models were developed at a spatial resolution of 0.17° (10 arc minutes) to account for imprecision in geo-referenced records and because of the large scale of the models. As most atlases provided distributions at resolutions coarser than 0.17°, only geo-referenced point records were used for African modeling. When atlases provided detailed localities in the text, these records were used, however. One exception was SABAP2, which mapped distribution at 0.08° (5 arc minutes), which is smaller than the distribution model resolution. Nearly all data for the Asian Woollyneck were geo-referenced point records aside from several historic ones that were only mapped at the 0.5° resolution due to less precise locality descriptions. Geo-referenced records for both species were filtered to one per 0.17° cell so as to prevent false cross-validation in the model replicate tests (see below). The geographic extent of geo-referenced locality data was buffered by 450 km to define the model extent. Given the lack of information on woollyneck movement, this buffer size was chosen based on the approximate distance between the most outlying record in central Pakistan and the nearest record at the edge of the range in India. This same exercise was not possible in Africa because the patchiness of occurrence made identifying outlying records difficult; therefore, the same buffer was applied to both species. Theoretically, the size of the buffer is meant to characterize the distance a vagrant or dispersing woollyneck could travel and thus habitat in that area would be available to them. For the Asian Woollyneck model, however, the outlying records in Pakistan and China were not buffered because regular occurrence in Pakistan is unclear and the record in China represents vagrancy, so we did not want to overestimate the area available to storks. Additionally, the model extent was cut off at the northern Nepalese border in the Himalayas (elevation ≥ 5,000 m). The highest altitudes recorded for this species have been 3,540 m in Nepal (Ghale and Karmacharya 2018) and 3,790 m in China (Burnham and Wood 2012), so using the edge of the Tibetan Plateau as a cut off for the model provides a reasonable buffer in light of potential unrecorded occurrences.

Distribution of potentially suitable areas was modeled using variables from the WorldClim 2.1 database (Fick and Hijmans 2017) and land cover from the GlobCover project (ESA and UCL 2010; Bontemps *et al*. 2011). The WorldClim variables represent annual trends and extremes in precipitation and temperature while GlobCover provides vegetation cover at a 1 km spatial resolution. For more detailed descriptions of WorldClim variables see the database webpage (WorldClim 2020). To convert the GlobCover layer to the model resolution, the 1 km raster was resampled by the majority of values in a 0.17° cell; the land cover input used herein represents the dominant classification per cell. For each species' independent range, WorldClim (including elevation) variables with Pearson correlation coefficients > 0.75 were eliminated, and only uncorrelated ones were used in the models (Table 1).

A model of suitable continent-wide distribution for each woollyneck was developed using MaxEnt, a statistical machine-learning tool that outperforms similar methods in predicting species distributions (Elith *et al*. 2006; Phillips *et al*. 2006; Elith *et al*. 2010). While many modeling methods require presence-absence data of varying quality (primarily when it comes to true absences), the utility of MaxEnt is in its use of presence-only data to predict potential distributions and estimate non-linear relationships between presence records and a set of environmental variables (Phillips *et al*. 2006; Elith *et al*. 2010). The environmental conditions at the presence locations are considered samples of the realized niche, so the output of a distribution model represents an approximation of the realized niche (Phillips *et al*. 2006). Along with spatial predictions of distribution, MaxEnt generates model-derived response curves that plot bivariate relationships between probability of occurrence (i.e. suitability) and a given environmental variable, with other variables held constant at their means. The MaxEnt algorithm uses the area under the receiver operating curve, known as AUC, as a metric for assessing predictive capacity of models. Essentially, AUC provides the probability that a known presence observation will be selected over a random background observation (Fielding and Bell 1997; Jorge *et al*. 2013). Thus, models that perform better than random will have an AUC that falls between 0.5 and 1.0, with values closer to 1.0 indicating better predictive capacity of the input variables (Fielding and Bell 1997; Phillips and Dudík 2008). Models using population demographics, such as distribution of nesting locations, can further assist in improving the specific needs of each species. For woollynecks, such high resolution data is absent and we restrict analyses in this study to sightings of the species notwithstanding demography.

Fifty replicate models were run for each species and averaged due to the different learning paths the MaxEnt algorithm takes in each run. Running a high number of replicate models has two advantages: (1) it allows averages of AUC and variable contributions to be estimated due to slight variations in the algorithm of each individual model, and (2) it tests each model's predictions against the others using a cross-validation technique, which is beneficial when sample sizes may be small (Phillips 2017). The influence of each variable on distribution was assessed using a jackknife test of AUC, whereby each model was re-tested with one variable removed to determine the subsequent drop in AUC (Elith *et al*. 2010; Farashi and Alizadeh-Noughani 2019). Fifty replicates of three regional models were subsequently developed for each species after the continental models indicated smaller scale variation in environmental relationships. African data were divided into East, Southern, and West, and Asian data were divided into South, Southeast, and Indonesia based on visual clustering of records. Similar to the continental models, variables correlated at the regional scale were removed, resulting in non-identical input variables for each model. Spatial predictions of potential continental and regional distributions are reported, incorporating the cloglog threshold for

Table 1. Uncorrelated environmental variables used in the species-specific environmental distribution models and jackknife test importance ranks. Cells with (-) indicate those variables were eliminated from the model after a correlation test.

Variable	WorldClim Code	African	East	Southern	West	Asian	South	Southeast	Indonesia
Annual mean temperature	bio1	8	8	7	5	8	6	5	3
Mean diurnal temperature range	bio2	9	7	8	-	5	1	2	5
Temperature seasonality	bio4	6	3	-	-	3	2	1	-
Minimum temperature in the coldest month	bio6	10	9	-	3	-	-	-	-
Annual precipitation	bio12	1	4	1	1	4	5	4	4
Precipitation seasonality	bio15	7	5	6	-	1	3	3	2
Precipitation of driest quarter	bio17	5	2	3	6	6	8	-	-
Precipitation of the warmest quarter	bio18	2	-	2	-	2	7	6	-
Precipitation of the coldest quarter	bio19	4	1	4	4	-	-	-	-
Land cover*	n/a	3	6	5	2	7	4	7	1

*Categories: post-flooding or irrigated croplands, rainfed croplands, mosaic cropland (50–70%)/vegetation (20–50%), mosaic vegetation (50–70%)/cropland (20–50%), closed to open (>15%) broadleaf evergreen or semi-deciduous forest, closed (>40%) broadleaf deciduous forest, open (15–40%) broadleaf deciduous forest, closed (>40%) neede leaf evergreen forest, open (15–40%) needeleaf deciduous or evergreen forest, closed to open (>15%) mixed broadleaf and needeleaf forest, mosaic forest (50 – 70%)/grassland (20–50%), mosaic grassland (50–70%)/forest (20–50%), closed to open (>15%) shrubland, closed to open (>15%) herbaceous vegetation, sparse (<15%) vegetation, closed to open (>15%) broadleaf forest regularly flooded, closed (>40%) broadleaf forest/shrubland permanently flooded, closed to open (>15%) grassland/woody vegetation on regularly flooded soil, artificial areas (>50% urban), bare areas, water bodies, and permanent snow and ice maximum test sensitivity plus specificity generated by MaxEnt (De Barros Ferraz *et al*. 2012; Jorge *et al*. 2013; Kebede *et al*. 2014) as a lower end cutoff, below which conditions are likely unsuitable (Phillips 2017). Sensitivity is the probability that a model correctly predicts an observation of a species, and specificity is the probability it correctly predicts an absence (Liu *et al*. 2011). Finally, response curves from respective models are reported and compared qualitatively.

Results

Known distribution

Qualitatively, the map of known distribution of the African Woollyneck matched the extent of occurrence from the IUCN map very closely (Figure 1). However, distribution was sparse outside several southern and East African countries. Recent distribution in West Africa appeared especially fragmented, and most historic records were from central Africa, namely the Democratic Republic of Congo (DRC). The known Asian Woollyneck distribution did not agree as well with the IUCN map (Figure 2). In particular, there were differences in India, Pakistan, Myanmar, Thailand, Indonesia, and the Philippines. The updated range in India extended further east than the IUCN distribution suggests, and the range on Sumatra extended further north. Only four records exist for Pakistan and it is unclear how many of these were vagrants. Porter and Aspinall (2010) considered the species a vagrant in Iran despite the lack of acceptance of one record from the southeast due to lack of details (Khaleghizadeh *et al*. 2011). We could find no further occurrence in Iran, however. No records were found in eastern and far southern Myanmar either. The majority of records from the Philippines were from the historic period, all dating to before 1910. Of the scant records from Thailand that we located, only one observation of three storks in 1995 was during the recent period. Delacour and Greenway (1940) described encountering woollynecks sparingly along the Mekong in Laos, but a precise area was not provided. Nevertheless, a centralized 0.5° cell was mapped as occupied in the general region for visual purposes only because this record represents the only known occurrence of the species from northern Laos. Additionally, a record from the northern Thailand-Laos border also suggests historic presence in the region.

Species distribution models

The average AUCs were 0.80 for the African model (Figure 3) and 0.76 for the Asian model (Figure 4), indicating good predictive capacity for both species. For the African Woollyneck, the

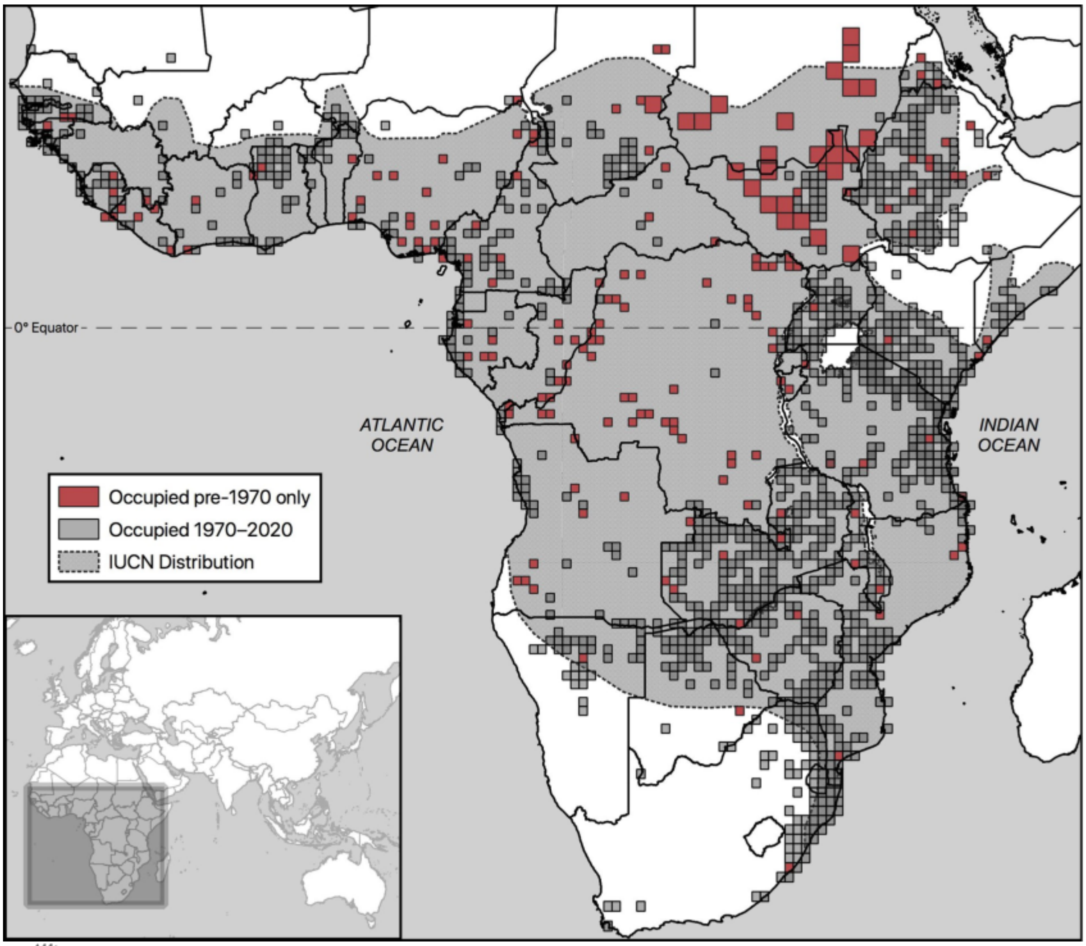


Figure 1. Known records of historic (pre-1970) and recent (1970 – 2020) occurrence of the African Woollyneck with the IUCN distribution map for comparison. The Sudan atlas (Nikolaus 1987) is represented by 1° x 1° cells, which was the highest resolution in which these data were available. Note: country borders (sourced from www.hub.arcgis.com) are purely for display purposes and do not reflect the authors' particular support for or against existing national claims on international borders.

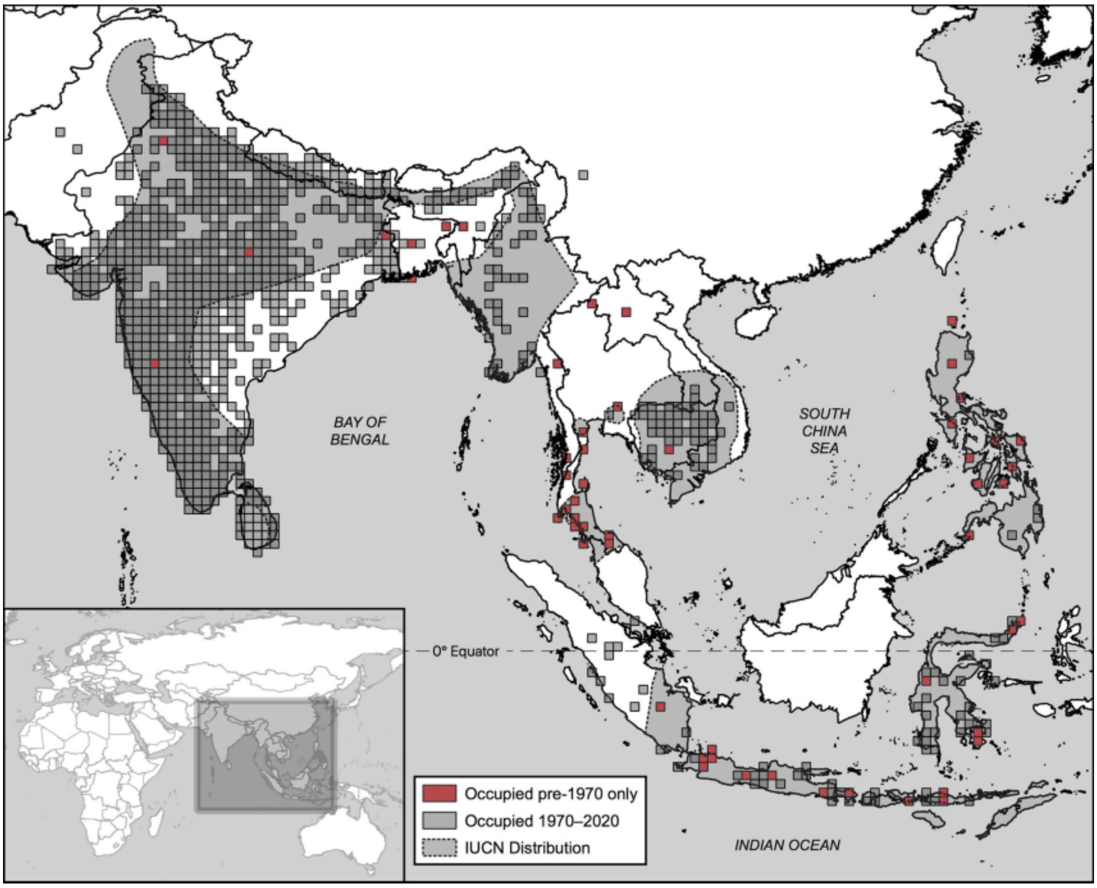


Figure 2. Known records of historic (pre-1970) and recent (1970 – 2020) occurrence of the Asian Woollyneck with the IUCN distribution map for comparison. Note: country borders (sourced from www.hub.arcgis.com) are purely for display purposes and do not reflect the authors' particular support for or against existing national claims on international borders.

jackknife test showed annual precipitation had the greatest influence on distribution followed by precipitation in the warmest quarter and land cover (Table 1). Precipitation seasonality was the most influential variable in Asia, followed by precipitation in the warmest quarter, temperature seasonality, and annual precipitation. Additionally, the Asian model AUC decreased the most when temperature seasonality was omitted, indicating this variable has the most information not present in others. The models showed contrasting responses to high levels of annual precipitation between the species but similar responses below c. 2,000 mm (Figure 5). Similarly, as precipitation in the warmest quarter increased, the responses of each species diverged. The African species showed an optimal range of precipitation seasonality, which contrasted with the near-logistic response to seasonality in Asia. In Asia there was a lower threshold for precipitation in the driest quarter, and the African model showed an optimal range. Both species had similar responses at high annual mean temperatures, with an apparent threshold at c. 28 - 29° C, but the responses were different at low temperatures, likely reflecting different available conditions on the two continents. Responses to temperature seasonality were generally similar, and there was similarity between the species at higher diurnal temperature ranges. Regarding land cover, the African Woollyneck was positively associated with permanently flooded closed forest/shrubland, regularly flooded grassland with woody vegetation, and urban areas (artificial surfaces) while the Asian Woollyneck was positively associated with urban areas (artificial surfaces) and a mosaic of natural vegetation (50 - 70%) and cropland (20 - 50%).

The African Woollyneck's approximately bimodal response to annual precipitation and the finding that the Asian Woollyneck likely occurs in three disjunct distribution segments led us to develop three smaller scale regional models for each species. The West African regional model (AUC = 0.83) predicted more widespread suitable areas than at the continental scale while in East (AUC = 0.90) and Southern Africa (AUC = 0.85) suitable areas were more limited despite slightly lower cloglog thresholds (Figure 3). Annual precipitation was most important in Southern and West Africa but precipitation in the coldest and driest quarters ranked higher than annual precipitation in East Africa (Table 1). In East and Southern Africa, the jackknife tests also showed AUC decreased the most when annual precipitation was removed, indicating it has the most information not present in other variables. In West Africa, AUC decreased the most when land cover was removed. Land cover played a weaker role in East and Southern Africa, but in West Africa woollynecks responded negatively both to agricultural and closed forest categories. Responses to annual precipitation were similar in East and Southern Africa but the West African model showed a positive relationship well above the optimal range for the other regions (Figure 6). West Africa also showed a negative relationship with precipitation in the dry quarter, which was the opposite of the responses in the other regions. East Africa showed the opposite relationship to precipitation in the coldest quarter compared to the other regions.

The Southeast model (AUC = 0.90) had the highest predictive capacity of the Asian regional models, but the South (AUC = 0.76) and Indonesian (AUC = 0.75) models performed fairly well. The Southeast and Indonesian model predictions contrasted with the continental model in that suitable areas were more widespread at the regional scale (Figure 4). Additionally, suitable areas in Thailand were much more limited in the regional model. The jackknife test for the South Asian model showed temperature seasonality and diurnal temperature range to be of equal importance, followed by precipitation seasonality. The model AUC decreased the most when temperature seasonality was removed. The Southeast model showed temperature seasonality to be the most important variable, ranking significantly higher than others. The model AUC also decreased the most when temperature seasonality was removed. In Indonesia precipitation seasonality and land cover ranked equally as the most important variables, but AUC decreased the most when mean annual temperature was removed. Response to increasing temperature seasonality was negative overall in the South model, while the Southeast model showed optimal ranges of temperature and precipitation seasonality (Figure 7). Response to precipitation seasonality varied greatly between the regional models. The response to land cover in the South model was not very different from the continental model, but in Southeast Asia the highest probability of occurrence was in closed evergreen forests and open broadleaf forests, and to a lesser extent in a mosaic of natural vegetation (50 - 70%) and cropland (20 - 50%). The Indonesian model showed the highest probability of occurrence in rainfed croplands and a mosaic of natural vegetation and cropland.

Discussion

This study is the first to empirically map known distributions, model potentially suitable areas, and

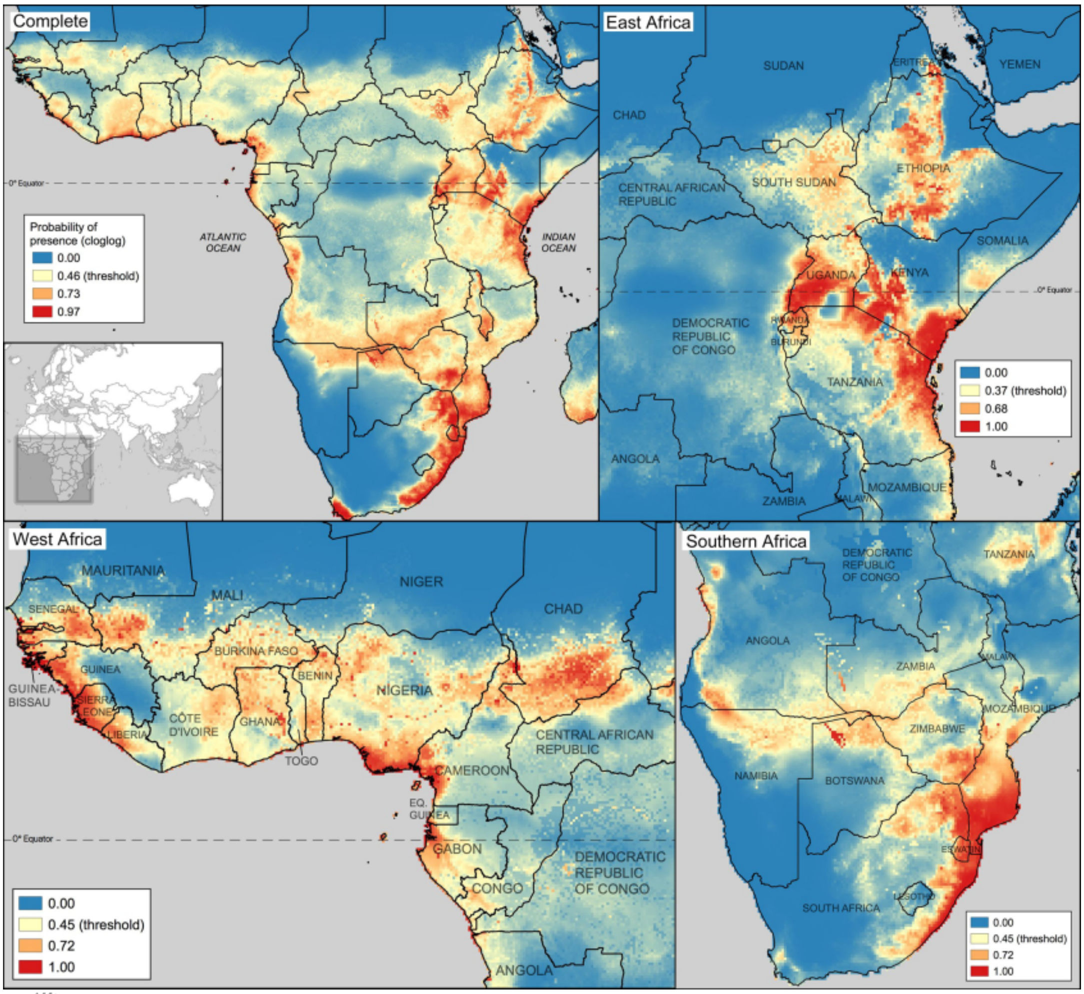


Figure 3. Average suitability predictions from 50 model replicates for the African Woollyneck at the continental and regional scale. Areas with predictions below the cloglog thresholds are likely unsuitable based on the input variables. Note: country borders (sourced from www.hub.arcgis.com) are purely for display purposes and do not reflect the authors' particular support for or against existing national claims on international borders.

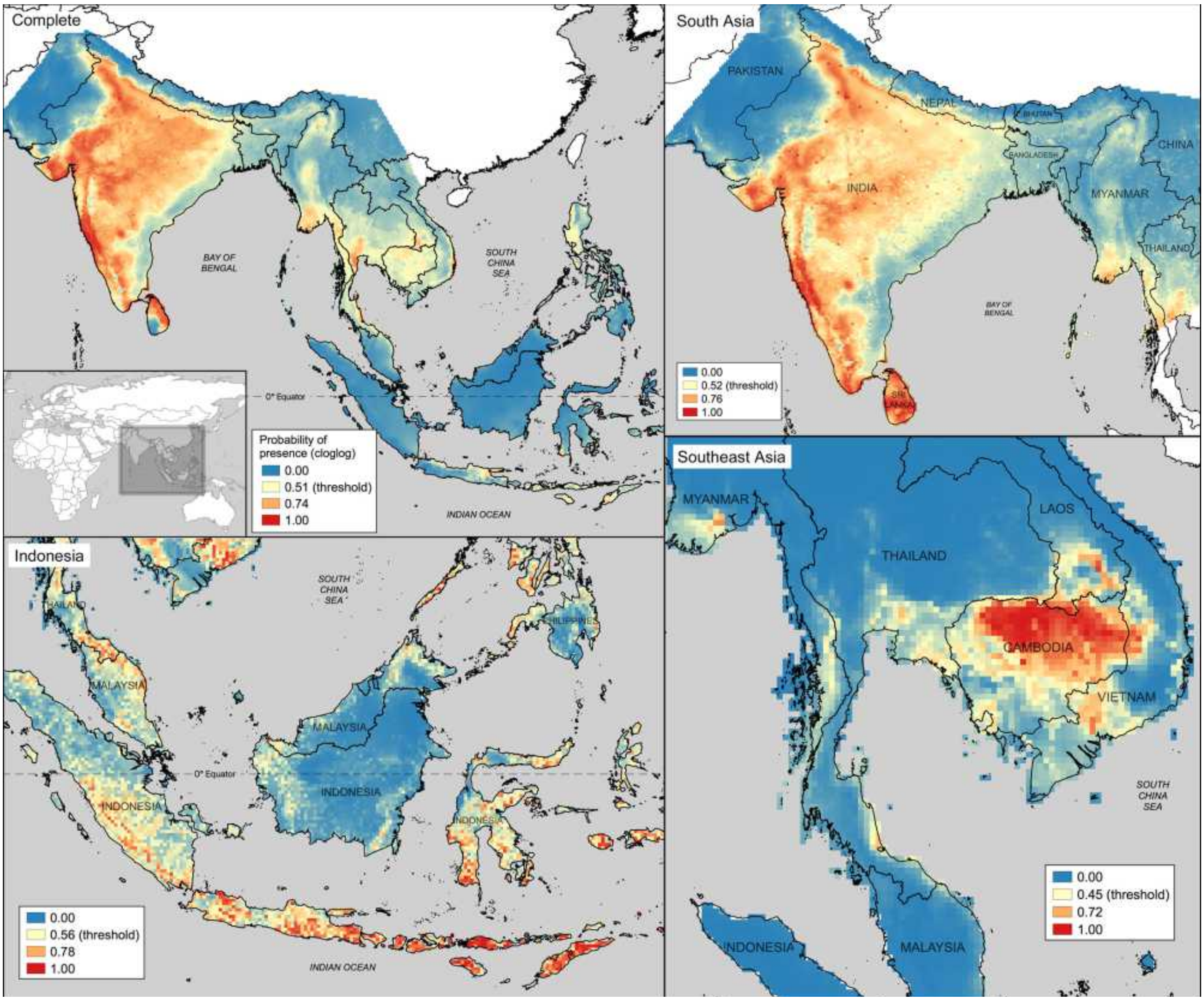


Figure 4. Average suitability predictions from 50 model replicates for the Asian Woollyneck at the continental and regional scale. Areas with predictions below the cloglog thresholds are likely unsuitable based on the input variables. Note: country borders (sourced from www.hub.arcgis.com) are purely for display purposes and do not reflect the authors' particular support for or against existing national claims on international borders.

assess environmental determinants of range-wide distributions of the African and Asian Woollynecks. The development of both continental and regional models has helped characterize what variables are important for each species, which has particularly high value in the face of ongoing and future environmental change. The models also provide for a comparison between sister species on separate continents, although inherent variation in predictor values between the continents is likely responsible for some of the interspecific differences. The predictive capacities of the models indicate there are also other factors that influence distribution not accounted for in the models, and further field studies on woollyneck ecology can help increase this growing area of knowledge. However, one shortcoming is that we did not include any temporal scale to the models, which would be important for both species since they appear to undertake seasonal movements in some regions. Indeed, temporal variation in environmental conditions influences species distributions (Andrew and Fox 2020), and recent research has demonstrated divergence in seasonal climatic niches of some migratory birds, including the White Stork *C. ciconia* (Fandos *et al*. 2020; Ponti *et al*. 2020).

The differences between the continental and regional models highlight that predicting suitable areas for woollynecks is scale dependent. Studies at smaller scales than in this study have found that as model extent increases, model predictive capacity improves (Connor *et al*. 2019; Khosravi *et al*. 2019), which is the opposite of what we found for both stork species. All of the African and one of the Asian regional models were more parsimonious (i.e. higher AUCs and fewer environmental variables) than the respective continental models, suggesting smaller scale environmental variations are important determinants of distribution for woollynecks. However, we did not test varying cell size in conjunction with varying scale, which can influence model accuracy as well (Connor *et al*. 2019). An important caveat of our regional models is that, although they shared some common input variables, the elimination of correlated variables made it so all the models did not have identical combinations of inputs. While this represents an obvious limitation on comparison between models, it was necessary to avoid spurious model outputs using correlated variables. Therefore, this must be kept in mind in light of our interpretations and comparisons of the different models.

Outside its core distribution from Ethiopia to eastern South Africa, the African Woollyneck occurs relatively sparsely despite the extent of suitable conditions predicted elsewhere in the two model scales. There are several possible explanations for the lack of records from such areas: (1) poor ornithological coverage in countries that have experienced civil unrest in recent decades, such as Angola, Côte d'Ivoire, Nigeria, and South Sudan; (2) coverage biased toward protected habitat, especially in West Africa, has prevented woollynecks from being recorded in agricultural areas, which can still provide habitat (W.R.J. Dean, pers. obs.); or (3) there may be biotic factors such as interspecific interactions that exclude them from some areas. Future surveys in such areas will help test the accuracy of the model predictions and these possibilities. The limited number of occupied cells in the DRC exclusively from the historic period is very similar to what was found for the Saddle-billed Stork *Ephippiorhynchus senegalensis* (Gula *et al*. 2019). It is unclear if this reflects decreased coverage in the recent period or real declines in the country, perhaps due to environmental changes in an already-marginal region. The low suitability in each of the regional models for the DRC may indicate conditions have changed since the historic period when occurrence was more widespread. Similar research on the distributions and environmental associations of other sympatric storks may help provided insight about this part of Africa.

The approximately bimodal response of the African Woollyneck to annual precipitation is not intuitive and led us to investigate regional distribution suitability. Most of the continent receives less than 2,000 mm of rain annually except parts of West Africa. And indeed, the division into three regional models demonstrated woollynecks in West Africa are more likely to occur in areas with higher precipitation. This can be attributed to two potentially interacting factors: (1) the greater availability of high rainfall areas in the region, and (2) the inclusion of the much drier southern Sahara Desert along the distribution periphery, where conditions are markedly different from presence records. The response to high rainfall there makes the absence from the DRC all the more curious given the similarity in climatic conditions to West Africa and land cover in other occupied areas. It may be that rapid recent habitat changes, such as the decrease in surface water (Gula *et al*. 2019), reduced more recent occurrence and therefore records available for modeling.

The West African model showed a negative response to increasing precipitation in the driest quarter, which was similar to the warmest quarter at the continental scale. Low seasonal rainfall and

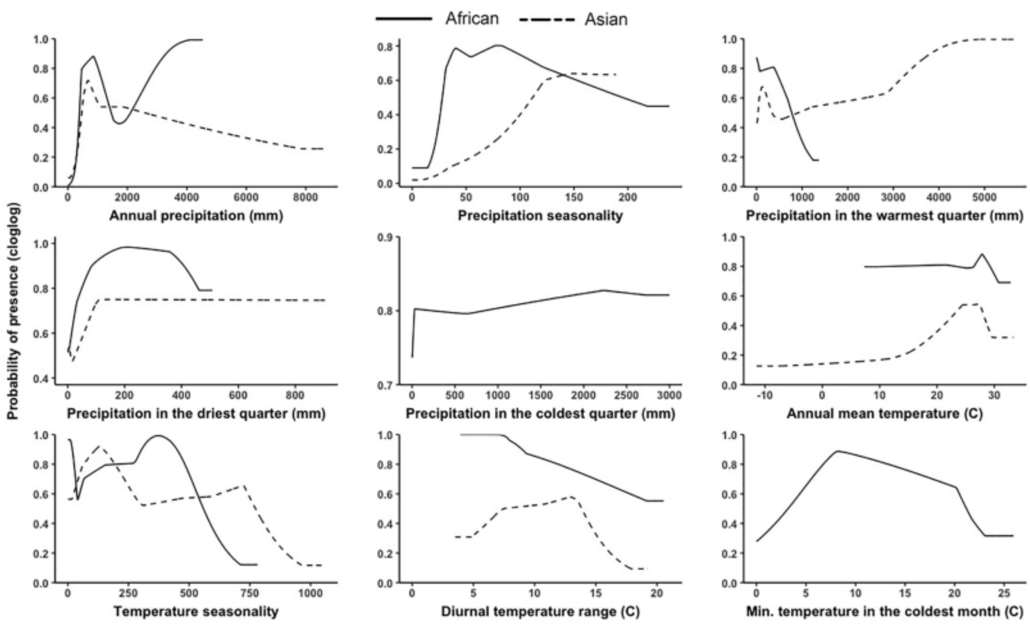


Figure 5. Response curves for both woollyneck species at the continental scale when all other variables are held constant at their means.

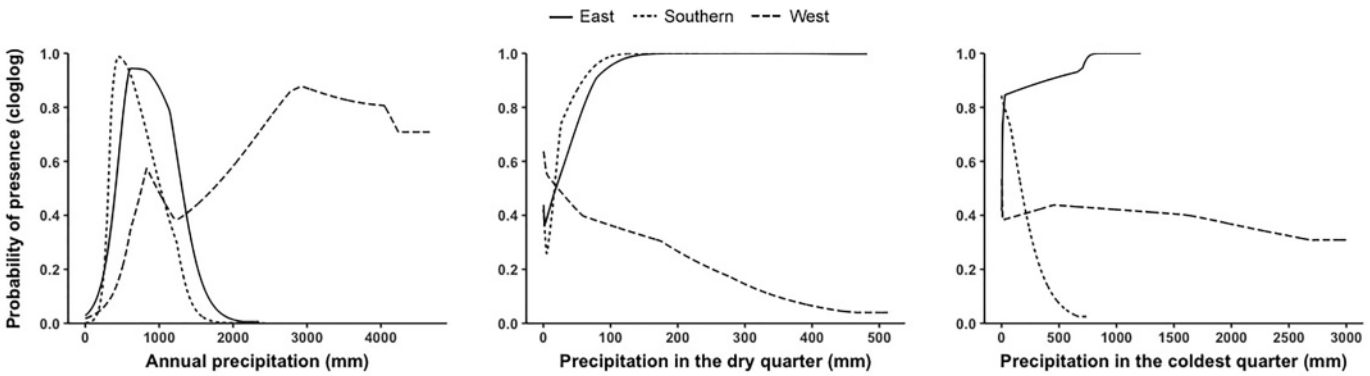


Figure 6. African Woollyneck regional response curves for three important climate variables when all other variables are held constant at their means.

water levels have been shown to be important determinants of reproductive success in the Marabou Stork *Leptoptilos crumeniferus* (Monadjem and Bamford 2009) and the Wood Stork *Mycteria americana* (Kushlan *et al*. 1975; Kushlan 1986), which rely on such conditions for increased and easy access to aquatic prey during the breeding season. Although the dietary habits of woollynecks are poorly known, the observed relationships with seasonal precipitation may be related to foraging in a similar way because breeding occurs during the dry season in most areas (Brown and Britton 1980; Nikolaus 1987; Hancock *et al*. 1992; Parker 2005). The contrast in dry quarter responses of East and Southern with West Africa is probably due to differences in regional precipitation. West Africa naturally experiences higher water levels during the dry season compared to other regions and increased rain would only make foraging more difficult. In East and Southern Africa, on the other hand, water levels are lower during the dry season due to less precipitation in the wet season and higher evaporation during the dry season compared to West Africa. So woollynecks may experience a balance between the need for rain to create foraging habitat yet not too much to make foraging more difficult. If this hypothesis is accurate, these relationships to different quarters of the year may be representative of varying breeding months regionally. Additionally, the optimal range of precipitation seasonality at the continental scale may be responsible for migration, although this needs significantly more study. It may also be that the year-round presence data used in the models do not appropriately incorporate seasonal absences from with certain conditions but testing this requires more precise and a higher quantity of data on migration timing.

The Asian Woollyneck's distribution outside Cambodia, India, Nepal, and Sri Lanka was relatively sparse. It is on the verge of extinction in the Philippines, where it is commonly hunted for food (A. Jensen, pers. comm.). Given the limited suitability in the country, it is possible a combination of environmental change and hunting is responsible for its disappearance in the last century. Curiously, however, models predicted low suitability on the island of Mindanao, where three of the four recent records come from and where a flock of five to six woollynecks have been reported from the Liguasan Marshes (A. Jensen, pers. comm.). Perhaps the species has been pushed to marginal habitat by human persecution, or biotic factors like interspecific interactions may be more important there. Aside from a single occurrence in Thailand during the recent period, the species appears to be functionally extirpated there. In addition, the regional model showed very limited suitable areas where it historically occurred in the country, so it may be that climatic and/or land cover changes and associated human-related activities are responsible for extirpation. The overall historic loss of range in southeast Asia, apparently including interior Laos and Thailand, has likely served to reduce or extinguish population connectivity in the absence of significant long-distance dispersal or movements. What role this lack of connectivity has played in regional adaptations to environmental conditions (Gaston 2003) is beyond the capabilities of the modeling in this study and therefore yet to be described.

In India and Nepal, woollyneck preference for apparently higher quality dry areas in winter and summer (Sundar 2006; Ghimire *et al*. in press), which follows the nesting season (Hancock et al. 1992; Ishtiaq *et al*. 2004; Sundar 2006), may be particularly important for hatch year storks and adults that have spent the monsoons raising chicks.

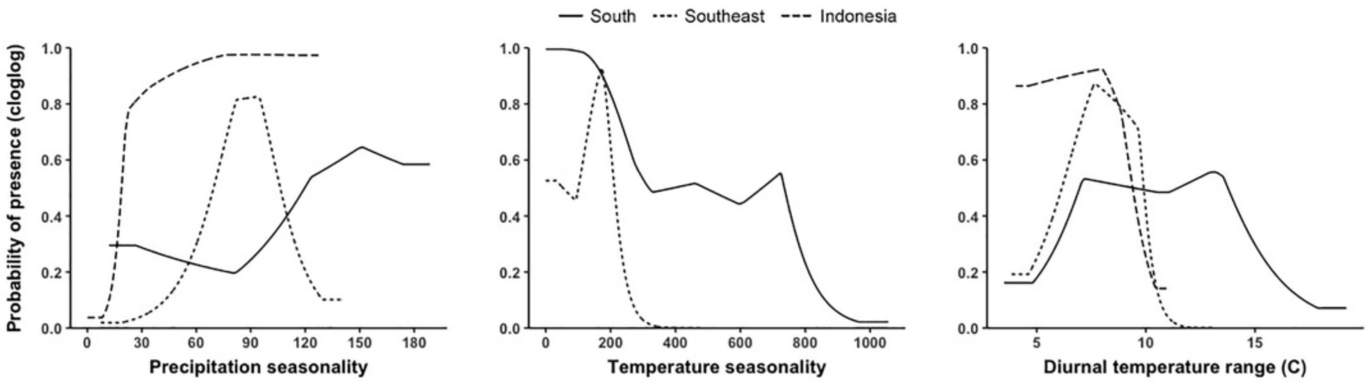


Figure 7. Asian Woollyneck regional response curves for three important climate variables when all other variables are held constant at their means.

They may require periods of reduced precipitation following the monsoons because it helps concentrate prey as water levels drop, thus increasing fitness in a similar way to decreasing seasonal precipitation in parts of Africa. This would explain the importance of precipitation seasonality in the Asian models. This hypothesis is also supported by a camera trap study that found woollyneck use of waterholes in Cambodia during the dry season declined at water depths above 40 cm (Pin *et al*. 2020). Areas with very strong seasonal precipitation would also have reduced tree cover and increased openness, which may be important for woollynecks, especially as irrigation and agriculture-related structures increase in such areas and potentially increase foraging opportunity (Sundar 2006; Katuwal *et al*. 2020; Kittur and Sundar 2020; Win *et al*. 2020). Asian Woollynecks were positively associated with human-altered areas, which agrees with observations in India, Myanmar, and Nepal where many more birds used agricultural areas, and where woollynecks were far more abundant and widespread on agricultural landscapes and outside forested protected areas (Katuwal *et al*. 2020; Kittur and Sundar 2020; Win *et al*. 2020). The positive relationship with precipitation in the warmest quarter could be related to increased stress in late summer as foraging habitat dries leading up to the breeding season. It seems apparent, therefore, that there are seasonal requirements regarding precipitation that have implications for fitness, which also likely explains seasonal variation in group size and habitat use (Sundar 2006; Kittur and Sundar 2020). Yet breeding information for Asian Woollynecks is generally scarce, so the scenario in Nepal and India may not be representative of the whole range. It is less clear why temperature seasonality was so important in the South and Southeast Asian models. While physiological limitations are possible, especially in the Himalayan foothills, it may be that prey such as frogs and insects are dependent on fairly stable temperatures, which would also explain the importance of diurnal temperature range in the same models.

Climate projections for south and southeast Asia predict increased heat stress in the near future, rainfall is predicted to decrease in southeast Asia (mainland and maritime), and there will be increased monsoon variability in south Asia (Tesfaye *et al*. 2017; Amnuaylojaroen and Chanvichit 2019). These changes will have significant consequences for the ecology of woollynecks and have the potential to cause shifts or contractions in distribution in areas that experience extreme climate fluctuations, as has been demonstrated in part of the Oriental White Stork's range (Zheng *et al*. 2016). The already small and sparsely distributed populations in mainland and maritime southeast Asia may be particularly prone to local extirpations in the face of decreased precipitation and changes in seasonality. The response of woollynecks to such changes will also significantly depend on how their prey respond.

Climate models predict decreased rainfall and increased dry spells in southern Africa and some parts of East Africa (Dosio *et al*. 2019; Gaetani *et al*. 2020; Haile *et al*. 2020). In East African countries with predicted increases in rainfall, it is unclear how woollynecks' seasonal reliance on dry conditions may affect distribution. In addition to the environmental changes the Sahel Region of West Africa has already experienced in recent decades (Zwarts *et al*. 2009), an imminent change in the region's climate state is predicted, with marked shifts in precipitation patterns over the next few decades (Gaetani *et al*. 2020). While the current study has shown suitable conditions for woollynecks to be relatively widespread in the region, the fragmented range may contribute to the susceptibility of local extirpations, which has already been found in some other storks in the region due to environmental change (Zwarts *et al*. 2009; Gula *et al*. 2019).

Although some populations of both woollyneck species may experience ecological stress in the near future, there is some evidence from both continents of their plasticity in the wake of environmental changes. In South Africa, African Woollynecks have recently colonized suburban areas, where they have been successful due to man-made wetlands and supplementary feeding at residences (Thabethe and Downs 2018) and landfills (JG, pers. obs.). This ability to use artificial habitats has allowed for an overall 11% range expansion across southern Africa (Okes *et al*. 2008). Asian Woollynecks in India, Myanmar, and Nepal are successful in a mosaic landscape of agriculture and natural wetlands (Sundar 2006; Win *et al*. 2020; Ghimire *et al*. in press). This adaptability appears to be related closely to farmer mindsets that discourage hunting. The Southeast models and data availability pointed to woollyneck occurrence in forested areas that are largely protected reserves. Hunting is far more widespread and intense in southeast Asia, matching with the modeled distributions that suggest agricultural and other human modified areas there are not suitable. However, this study found positive association with a similar mosaic in Indonesia.

Unfortunately, besides data from Kittur and Sundar's (2020) recent study, sufficient data from standardized surveys of woollynecks at scales comparable to our models do not exist for assessing correlations between population metrics (e.g. abundance, density, flock size) and suitability predictions. However, a recent meta-analysis showed a significant positive relationship between abundance and MaxEnt suitability in all cases and that scale of the models did not influence the relationship (Weber *et al*. 2017), which is therefore likely to be the case for woollynecks. Studies on spatial variation in fitness (e.g. across environmental gradients) will answer many questions about smaller scale environmental requirements and the responses of each species to change. These would be especially useful in vulnerable peripheral populations, which may have greater variability in fitness because they experience the limits of environmental tolerances (Sexton *et al*. 2009). Sufficient genetic variation at these edges, however, may also serve to facilitate favorable selection as conditions change outside historic tolerances (Kawecki 2008). In West Africa, this seems unlikely because similar fragmentation occurs with the Saddle-billed Stork (Gula *et al*. 2019) and other African storks (J. Gula, unpub. data), suggesting current and ongoing change may be too rapid for selection to keep up. The region may therefore fit Sexton *et al*.'s (2009) characterization of a range limit where adaptation is prevented by small populations and maladaptive gene flow from core populations with more favorable conditions. Genetics and movement research on woollynecks there would greatly improve the understanding of these dynamics, and a more thorough look into population sizes and trends in southeast Asia may elucidate the scenario there.

Several aspects of the results obtained from MaxEnt modeling appear crucial for conservation planning. In Africa, the strong positive associations with forested areas underscores the importance of current conservation efforts in maintaining populations of Asian Woollynecks. Though as discussed earlier, models indicate suitability in some areas where populations appear to be in decline. In southeast Asia, modeled distributions are also closely related to forested areas overlapping with the protected area network in many countries. This finding matches existing descriptions of the species requiring wetlands inside forested areas with minimal human presence. However, both field observations and outputs of modeled distributions in this study show that large numbers of woollynecks can avail of human-modified landscapes such as agriculture in many locations, but especially Myanmar, Nepal, and India. Woollynecks appear to be an ideal candidate species whose conservation requirements are relatively easy to determine using tools such as MaxEnt but will require field data to explain smaller scale nuances. Our collated data and modeled outputs suggest that neither the African nor the Asian Woollyneck have critical conservation requirements due to being widespread and being able to use areas outside of protected reserves. However, our outputs provide some cause for concern especially in central and West Africa and several southeast Asian countries. Results also signal a strong indication that projected climate change will affect both species, albeit to different extents. We suggest that our work, in combination with emerging new field-based studies, be used to carefully assess the conservation status of woollynecks, and such modeling exercises be urgently considered for similar large waterbirds.

Acknowledgments

Thanks to the contributors of the atlases and databases used in this study, including eBird and the West African Bird Database, managed by Ulf Liedén, Tim Wacher and Joost Brouwer; and to Neil Baker, Stephane Doppagne, Robert Dowsett, Arne Jensen, and Michael Mills, who kindly provided unpublished data or sources. Also thanks to Radhika Chaturvedi, Dorn Moore, Nandini Pathak, Vedang Saikhedkar, Rishwa Shekhar, Nawin Tiwary, Harsh Trivedi, and Myo Sander Win for assisting with data curation. Finally, thanks to Swati Kittur for aiding with preparation of some GIS layers for the models.

References

Amnuaylojaroen, T. and P. Chanvichit. 2019. Projection of near-future climate change and agricultural drought in mainland Southeast Asia under RCP8.5. *Climatic Change* 155: 175-193.

Andrew, M. E. and E. Fox. 2020. Modelling species distributions in dynamic landscapes: The importance of the temporal dimension. *Journal of Biogeography* 47: 1510-1529.

Ash, J. and J. Atkins. 2009. *Birds of Ethiopia and Eritrea: an atlas of distribution*. Christopher Helm, London, United Kingdom.

Ash, J. and J. Miskell. 1983. Birds of Somalia, their habitat, status and distribution. *Scopus Special Supplement* 1: 1-97.

Ash, J. and J. Miskell. 1998. *Birds of Somalia*. Pica Press, Sussex, United Kingdom.

Aspinwall, D. R. 1987. Movement analysis charts (MAC), comments on Woolly-necked Stork. *Zambian Ornithological Society Newsletter* 17: 106-112.

Bannerman, D. A. 1953. *The birds of West and Equatorial Africa, vol. 1*. Oliver and Boyd, Edinburgh, United Kingdom.

Benson, C. W., R. K. Brooke, R. J. Dowsett and M. P. S. Irwin. 1971. *The birds of Zambia*. Collins, London, United Kingdom.

Berruti, A. 1997. Woollynecked Stork. Pp. 89-91. In: Harrison, J., D. Allan, L. Underhill, M. Herremans, A. Tree, B. Parker, and C. Brown (eds.). *The atlas of southern African birds, vol. 1*. BirdLife South Africa, Johannesburg, South Africa.

Bontemps, S., P. Defourny, E. Van Bogaert, O. Arino, V. Kalogirou and J. R. Perez. 2011. *GlobCover 2009: Products description and validation report*. European Space Agency and Université Catholique de Louvain.

Brown, L. H. and P. L. Britton. 1980. *The breeding seasons of East African birds*. East Africa Natural History Society, Nairobi, Kenya.

Burnham, J. W. and E. M. Wood. 2012. Woolly-necked Stork *Ciconia episcopus* at Napahai wetland, Yunnan, China. *Forktail* 28: 158-159.

Carswell, M., D. Pomeroy, J. Reynolds and H. Tushabe. 2005. *The bird atlas of Uganda*. British Ornithologists' Club and British Ornithologists' Union, London, United Kingdom.

Connor, T., A. Viña, J. A. Winkler, V. Hull, Y. Tang, A. Shortridge, H. Yang, Z. Zhao, F. Wang, J. Zhang, Z. Zhang, C. Zhou, W. Bai and J. Liu. 2019. Interactive spatial scale effects on species distribution modeling: The case of the giant panda. *Scientific Reports* 9: 14563.

De Barros Ferraz, K. M. P. M., M. F. De Siqueira, E. R. Alexandrino, D. T. A. Da Luz and H. T. Z. Do Couto. 2012. Environmental suitability of a highly fragmented and heterogeneous landscape for forest bird species in south-eastern Brazil. *Environmental Conservation* 39: 316-324.

del Hoyo, J., N. J. Collar, D. A. Christie, A. Elliott and L. D. C. Fishpool. 2014. *HBW and BirdLife International illustrated checklist of the birds of the world, vol. 1: Non-passerines*. Lynx Edicions, Barcelona, Spain.

Delacour, J. and J. C. Greenway. 1940. Liste des oiseaux receuillis dans la province du Haut-Mekong et le royaume de Luang-Prabang. *L'Oiseau et la Revue Francaise d'Ornithologie* 10: 25-59.

Dosio, A., R. G. Jones, C. Jack, C. Lennard, G. Nikulin and B. Hewitson. 2019. What can we know about future precipitation in Africa? Robustness, significance and added value of projections from a large ensemble of regional climate models. *Climate Dynamics* 53: 5833-5858.

Dowsett, R. J., D. R. Aspinwall and F. Dowsett-Lemaire. 2008. *The birds of Zambia: An atlas and handbook*. Tauraco Press, Liège, Belgium.

Dowsett-Lemaire, F. and R. J. Dowsett. 2006. *The birds of Malawi: An atlas and handbook*. Tauraco Press, Liège, Belgium.

Dowsett-Lemaire, F. and R. J. Dowsett. 2014. *The birds of Ghana: An atlas and handbook*. Tauraco Press, Liège, Belgium.

Dowsett-Lemaire, F. and R. J. Dowsett. 2019. *The birds of Benin and Togo: An atlas and handbook*. Tauraco Press, Liège, Belgium.

eBird. 2020. *Basic dataset, version: EBD_relAug-2020*. Cornell Lab of Ornithology, Ithaca, New York, United States of America.

Elith, J., C. H. Graham, R. P. Anderson, M. Dudík, S. Ferrier, A. Guisan, R. J. Hijmans, F. Huettmann, J. R. Leathwick, A. Lehmann, J. Li, L. G. Lohmann, B. A. Loiselle, G. Manion, C. Moritz, M. Nakamura, Y. Nakazawa, J. McC. M. Overton, A. Townsend Peterson, S. J. Phillips, K. Richardson, R. Scachetti-Pereira, R. E. Schapire, J. Soberón, S. Williams, M. S. Wisz and N. E. Zimmermann. 2006. Novel methods improve prediction of species' distributions from occurrence data.

Ecography 29: 129-151.

Elith, J., S. J. Phillips, T. Hastie, M. Dudík, Y. E. Chee and C. J. Yates. 2010. A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions* 17: 43-57.

ESA and UCL. 2010. *GlobCover. European Space Agency and Université Catholique de Louvain*. http://due.esrin.esa.int/page_globcover.php, accessed 30 March 2020.

Fandos, G., S. Rotics, N. Sapir, W. Fiedler, M. Kaatz, M. Wikelski, R. Nathan and D. Zurell. 2020. Seasonal niche tracking of climate emerges at the population level in a migratory bird. *Proceedings of the Royal Society B: Biological Sciences* 287: 20201799.

Farashi, A. and M. Alizadeh-Noughani. 2019. Niche modelling of the potential distribution of the Egyptian Vulture *Neophron percnopterus* during summer and winter in Iran, to identify gaps in protected area coverage. *Bird Conservation International* 29: 423-436.

Fick, S. E. and R. J. Hijmans. 2017. WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology* 37: 4302-4315.

Fielding, A. H. and J. F. Bell. 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. *Environmental Conservation* 24: 38-49.

Gaetani, M., S. Janicot, M. Vrac, A. M. Famien and B. Sultan. 2020. Robust assessment of the time of emergence of precipitation change in West Africa. *Scientific Reports* 10: 1-10.

Gaston, K. J. 2003. *The structure and dynamics of geographic ranges*. Oxford University Press, Oxford, United Kingdom

GBIF.org. 2020. *GBIF occurrence download*. https://doi.org/10.15468/dl.6scxkb, accessed 4 August 2020.

Ghale, T. R. and D. K. Karmacharya. 2018. A new altitudinal record for Asian Woollyneck *Ciconia episcopus* in South Asia. *BirdingASIA* 29: 96-97.

Ghimire, P., N. Pandey, Y. P. Timilsina, B. S. Bist and K. S. G. Sundar. in press. Woolly-necked Stork activity budget in lowland Nepal's farmlands: The influence of wetlands, seasonal crops and human proximity. *Waterbirds*.

Gula, J., F. Weckerly and K. S. G. Sundar. 2019. The first range-wide assessment of Saddle-billed Stork *Ephippiorhynchus senegalensis* distribution. *Ostrich* 90: 347-357.

Haile, G. G., Q. Tang, S. M. Hosseini-Moghari, X. Liu, T. G. Gebremicael, G. Leng, A. Kebede, X. Xu and X. Yun. 2020. Projected impacts of climate change on drought patterns over East Africa. *Earth's Future* 8: 1-23.

Hancock, J. A., J. A. Kushlan and M. P. Kahl. 1992. *Storks, ibises and spoonbills of the world*. Academic Press, London, United Kingdom.

Harrison, J., D. Allan, L. Underhill, M. Herremans, A. Tree, B. Parker and C. Brown. 1997. *The atlas of southern African birds, vol. 1*. BirdLife South Africa, Johannesburg, South Africa.

Herremans, M., M. Joos-Vandewalle and W. D. Borello. 1996. The status of the Woollynecked Stork *Ciconia episcopus* in Botswana. *Ostrich* 67: 80-83.

Holmes, D. A. 1977. Faunistic notes and further additions to the Sumatran avifauna. *British Ornithologists' Club Bulletin* 97: 68-71.

Ishtiaq, F., A. R. Rahmani, S. Javed and M. C. Coulter. 2004. Nest-site characteristics of Black-necked Stork (*Ephippiorhynchus asiaticus*) and White-necked Stork (*Ciconia episcopus*) in Keoladeo National Park, Bharatpur, India. *Journal of the Bombay Natural History Society* 101: 90-95.

Jorge, M. L. S. P., M. Galetti, M. C. Ribeiro and K. M. P. M. B. Ferraz. 2013. Mammal defaunation as surrogate of trophic cascades in a biodiversity hotspot. *Biological Conservation* 163: 49-57.

Junk, W. J., S. An, C. M. Finlayson, B. Gopal, J. Květ, S. A. Mitchell, W. J. Mitsch and R. D. Robarts. 2013. Current state of knowledge regarding the world's wetlands and their future under global climate change: a synthesis. *Aquatic Sciences* 75: 151-167.

Kamaruddin, Z., M. Farah Shafawati and M. N. Shukor. 2017. Distribution and habitat selection of the Asian Openbill (*Anastomus oscitans*) in Peninsular Malaysia. *Malayan Nature Journal* 69: 169-181.

Katuwal, H. B., H. S. Baral, H. P. Sharma and R.-C. Quan. 2020. Asian Woollynecks are uncommon on the farmlands of lowland Nepal. *SIS Conservation* 2: 50-54.

Kawecki, T. J. 2008. Adaptation to marginal habitats. *Annual Review of Ecology, Evolution, and Systematics* 39: 321-342.

Kebede, F., P. D. Moehlman, A. Bekele and P. H. Evangelista. 2014. Predicting seasonal habitat suitability for the critically endangered African wild ass in the Danakil, Ethiopia. *African Journal of Ecology* 52: 533-542.

Khaleghizadeh, A., D. A. Scott, M. Tohidifar, S. B. Musavi, M. Ghasemi, M. E. Sehhatisabet, A. Ashoori, A. Khani, P. Bakhtiari, H. Amini, C. Roselaar, R. Ayé, M. Ullman, B. Nezami and F. Eskandari. 2011. Rare birds in Iran in 1980–2010. *Podoces* 6: 1-48.

Khosravi, R., M.-R. Hemami and S. A. Cushman. 2019. Multi-scale niche modeling of three sympatric felids of conservation importance in central Iran. *Landscape Ecology* 34: 2451-2467.

Kim, S. K., N. S. Kim, S. Cheong, Y. H. Kim, H. C. Sung and S. R. Park. 2008. A habitat analysis of the historical breeding sites of Oriental White Storks (*Ciconia boyciana*) in Gyeonggi and Chungcheong Provinces, Korea. *Journal of the Korean Geographic Information Society* 11: 125-137.

Kittur, S. and K. S. G. Sundar. 2020. Density, flock size and habitat preference of Woolly-necked Storks *Ciconia episcopus* in agricultural landscapes of south Asia. *SIS Conservation* 2: 71-79.

Koju, R., B. Maharjan, K. R. Gosai, S. Kittur and K. S. G. Sundar. 2019. Ciconiiformes nesting on trees in cereal-dominated farmlands: Importance of scattered trees for heronries in lowland Nepal. *Waterbirds* 42: 355-453.

Kushlan, J. A. 1986. Responses of wading birds to seasonally fluctuating water levels: Strategies and their limits. *Colonial Waterbirds* 9: 155-162.

Kushlan, J. A., J. C. Ogden and A. L. Higer. 1975. *Relation of water level and fish availability to Wood Stork reproduction in the southern Everglades, Florida*. United States Geological Survey. Tallahassee, Florida, United States of America.

Lewis, A. and D. Pomeroy. 1989. *A bird atlas of Kenya*. A.A. Balkema, Rotterdam, The Netherlands.

Liu, C., M. White and G. Newell. 2011. Measuring and comparing the accuracy of species distribution models with presence–absence data. *Ecography* 34: 232-243.

Luthin, C. S. 1987. Status of and conservation priorities for the world's stork species. *Colonial Waterbirds* 10: 181-202.

Mandal, J., L. M. Abraham and R. Bhaduri. 2020. A note on the temporal and spatial distribution of Asian Woollyneck in Assam, India. *SIS Conservation* 2: 62-67.

Masahiro, F., L. Sang Don, K. Masayuki and Y. Hoshiko. 2010. Bird use of rice fields in Korea and Japan. *Waterbirds* 33: 8-29.

Monadjem, A. R. A. and A. J. Bamford. 2009. Influence of rainfall on timing and success of reproduction in Marabou Storks *Leptoptilos crumeniferus*. *Ibis* 151: 344-351.

Nikolaus, G. 1987. Distribution atlas of Sudan's birds with notes on habitat and status. *Bonner Zoologische Monographien* 25: 1-322.

Okes, N. C., P. A. R. Hockey and G. S. Cumming. 2008. Habitat use and life history as predictors of bird responses to habitat change. *Conservation Biology* 22: 151-162.

Parker, V. 1994. *Swaziland bird atlas 1985–1991*. Websters, Mbabane, Swaziland.

Parker, V. 1999. *The atlas of the birds of Sul do Save, Southern Mozambique*. Avian Demography Unit and Endangered Wildlife Trust, Cape Town, South Africa.

Parker, V. 2005. *The atlas of the birds of Central Mozambique*. Avian Demography Unit and Endangered Wildlife Trust, Cape Town, South Africa.

Penry, H. 1994. *Bird atlas of Botswana*. University of Natal Press, Pietermaritzburg, South Africa.

Phillips, S. J. 2017. *A brief tutorial on Maxent*. http://biodiversityinformatics.amnh.org/open_source/maxent/, accessed 15 August 2020.

Phillips, S. J., R. P. Anderson and R. E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190: 231-259.

Phillips, S. J. and M. Dudík. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography* 31: 161-175.

Pin, C., D. Ngoprasert, T. N. E. Gray, T. Savini, R. Crouthers and G. A. Gale. 2020. Utilization of waterholes by globally threatened species in deciduous dipterocarp forest of the Eastern Plains landscape of Cambodia. *Oryx* 54: 572-582.

Ponti, R., A. Arcones, X. Ferrer and D. R. Vieites. 2020. Seasonal climatic niches diverge in migratory birds. *Ibis* 162: 318-330.

Porter, R. and S. Aspinall. 2010. *Birds of the Middle East*. Christopher Helm, London, United Kingdom.

QGIS. 2020. *QGIS Geographic Information System v. 3.12*. Open Source Geospatial Foundation Project. http://qgis.org, accessed 27 April 2020.

Roshnath, R. and P. Greeshma. 2020. Status of Woolly-necked Storks in Kerala, south-western India. *SIS Conservation* 2: 55-61.

Sexton, J. P., P. J. McIntyre, A. L. Angert and K. J. Rice. 2009. Evolution and ecology of species range limits. *Annual Review of Ecology, Evolution, and Systematics* 40: 415-436.

Sundar, K. S. G. 2006. Flock size, density and habitat selection of four large waterbirds species in an agricultural landscape in Uttar Pradesh, India: Implications for management. *Waterbirds* 29: 365-374.

Sundar, K. S. G. 2011a. Agricultural intensification, rainfall patterns, and large waterbird breeding success in the extensively cultivated landscape of Uttar Pradesh, India. *Biological Conservation* 144: 3055-3063.

Sundar, K. S. G. 2011b. Farmland foods: Black-necked Stork *Ephippiorhynchus asiaticus* prey items in an agricultural landscape. *Forktail* 27: 98-100.

Sundar, K. S. G. 2020. Special section editorial: Woolly-necked Stork–a species ignored. *SIS Conservation* 2: 33-41.

Sundar, K. S. G. and S. Kittur. 2013. Can wetlands maintained for human use also help conserve biodiversity? Landscape-scale patterns of bird use of wetlands in an agricultural landscape in north India. *Biological Conservation* 168: 49-56.

Tesfaye, K., P. H. Zaidi, S. Gbegbelegbe, C. Boeber, D. B. Rahut, F. Getaneh, K. Seetharam, O. Erenstein and C. Stirling. 2017. Climate change impacts and potential benefits of heat-tolerant maize in South Asia. *Theoretical and Applied Climatology* 130: 959-970.

Thabethe, V. and C. T. Downs. 2018. Citizen science reveals widespread supplementary feeding of African woolly-necked storks in suburban areas of KwaZulu-Natal, South Africa. *Urban Ecosystems* 21: 965-973.

WABDaB. 2020. Woolly-necked Stork (*Ciconia episcopus*), West African Bird Database (WABDaB). https://www.wabdab.org/db/species?18319=&d-49653-o=1&pid=viewspecies&pid=viewspecies&d-49653-p=1&d-49653-s=1 - url, accessed 25 March 2020.

Weber, M. M., R. D. Stevens, J. A. F. Diniz-Filho and C. E. V. Grelle. 2017. Is there a correlation between abundance and environmental suitability derived from ecological niche modelling? A meta-analysis. *Ecography* 40: 817-828.

Win, M. S., A. M. Yi, T. S. Myint, K. Khine, H. S. Po, K. S. Non and K. S. G. Sundar. 2020. Comparing abundance and habitat use of Woolly-necked Storks *Ciconia episcopus* inside and outside protected areas in Myanmar. *SIS Conservation* 2: 96-103.

Wood, C., Y. Qiao, P. Li, P. Ding, B. Lu and Y. Xi. 2010.

Implications of rice agriculture for wild birds in China. *Waterbirds*: *The International Journal of Waterbird Biology* 33: 30-43.

WorldClim. 2020. *Bioclimatic variables*. https://www.worldclim.org/data/bioclim.html, accessed 5 October 2020.

Zheng, H., G. Shen, L. Shang, X. Lv, Q. Wang, N. McLaughlin and X. He. 2016. Efficacy of conservation strategies for endangered oriental white storks (*Ciconia boyciana*) under climate change in Northeast China. *Biological Conservation* 204: 367-377.

Zwarts, L., R. G. Bijlsma, J. van der Kamp and E. Wymenga. 2009. *Living on the edge: Wetlands and birds in a changing Sahel*. KNNV Publishing, Zeist, The Netherlands.

ISSN 2710-1142(online)
SIS Conservation, 2020, **2**, 96-103
RESEARCH ARTICLE

Comparing abundance and habitat use of Woolly-necked Storks *Ciconia episcopus* inside and outside protected areas in Myanmar

Myo Sandar WIN[1], Ah Mar YI[2], Theingi Soe MYINT[3], Kaythy KHINE[4], Hele Swe PO[5], Kyaik Swe NON[6], K. S. Gopi Sundar[7,*]

[1]Department of Zoology, University of Yangon, Building No. C-11, Room no. 303, Mindama Education Avenue, Hlaing Township, Yangon, Myanmar
[2]Department of Zoology, University of Yangon, Room, No.65, ThayaPhi Hostel, Hlaing Township, Yangon Region, Myanmar
[3]Department of Zoology, University of Yangon, No. 45/4, Mahar Mying Avenue, Sanchaung Township, Yangon Region, Myanmar
[4]Department of Zoology, University of Yangon, Street, 13/4(B), Thiri Mying Street, Hlaing Township, Yangon Region Myanmar
[5]Department of Zoology, University of Yangon, D-1, Room-206 ,Mindama Education Avenue, Hlaing Township, Yangon, Myanmar
[6]Department of Zoology, University of Mawlamyine, Tanintharyi Hostel, Room – 9 Mawlamying Township, Mon State, Myanmar
[7]Nature Conservation Foundation, 1311, "Amritha" 12th Main, Vijayanagar 1st Stage, Mysuru 570017, Karnataka, India
*Corresponding author; e.mail: gopi@ncf-india.org

Abstract Protected areas form the backbone of biodiversity conservation especially in south-east Asia which is both a global biodiversity hotspot and is facing extreme developmental pressures. The ability of large waterbirds to use habitats outside protected areas is poorly understood in most south-east Asian countries despite the potential of human-modified areas such as agricultural fields to provide alternative habitats. We assessed abundance and habitat use inside and outside protected areas of Woolly-necked Storks, a large waterbird species thought to be declining due to deterioration of forested reserves, in five regions of Myanmar. Woolly-necked Stork abundance (birds/km) and use of three habitats (agriculture fields, forests, wetlands) were compared using transects within and outside protected areas, each monitored six times annually for three continuous years (2016 – 2018). Specifically, we assessed if abundance and habitat use varied due to protection status and whether location, season (summer, winter, and rainy season) and time of day (morning and evening) additionally influenced measured metrics. Woolly-necked Storks were seen in 55% of all transects, but in the 990 total transect runs, were seen in only 44% of transects with a higher frequency of sightings on transects outside (61%) compared to inside protected areas (25%). Encounter rates were, on average, 1.5 times higher outside compared to inside protected areas. Encounter rates also varied significantly with season with most storks being encountered in summers and the least in the winters, and seasonal patterns were similar inside and outside protected areas. Encounter rates showed weak declining trends in the majority of transects with measured declines being more than twice inside protected areas than outside. Woolly-necked Storks were mostly observed in wetlands (53%) and in agricultural fields (35%) and used forested areas and wetlands significantly more inside protected areas. Storks displayed plasticity outside protected areas by using agricultural fields. This study provides the first formal comparison of Woolly-necked Stork ecology inside and outside protected areas. In addition to continuing to secure protected areas for biodiversity conservation in Myanmar, expanding the conservation paradigm into agricultural landscapes with unprotected wetlands is essential for the long-term persistence of large waterbird species such as the Woolly-necked Storks.

Keywords Agricultural fields, protected versus unprotected areas, unprotected wetlands, Woolly-necked Stork.

Article history
Received: 23 September 2020,
Received in revised form: 10 November 2020,
Accepted: 11 November 2020,
Published online: 24 November 2020.

Introduction

The biodiversity crisis in south-east Asia is now deemed to be critical as increasing developmental pressures threaten biodiverse habitats including forests and wetlands (Donald *et al*. 2015; Harrison *et al*. 2018). The problem is exacerbated by the sparse amount of scientific research in many south-east Asian countries including Myanmar. The status of taxa such as large waterbirds, that can use human-modified land uses like agriculture are particularly poorly known in south-east Asia since the majority of conservation research and attention are focused largely on species and habitats that are within forested protected areas (Wilcove *et al*. 2013). Several bird species are suspected to be strongly associated with forested protected areas and therefore declining due to expansion of agricultural areas. One large waterbird species that was recently elevated to the conservation status "Vulnerable" due to suspected declines following conversion of its forested habitats to cultivation is the Woolly-necked Stork *Ciconia episcopus* (BirdLife International 2020). In south-east Asia Woolly-necked Storks have most commonly been reported from ephemeral shallow waterbodies inside protected forest areas and there is no published information from outside protected areas with which to evaluate its status (BirdLife International 2020; Sundar 2020).

Though Myanmar is well known to be part of the distribution range of the Woolly-necked Storks, there is exceedingly little understanding of its habits and requirements from this country (BirdLife International 2020; Gula *et al*. 2020; Sundar 2020). However, recent observations of Sarus Crane *Antigone antigone* populations using agricultural areas of Myanmar have provided optimism that other large waterbird species, including Woolly-necked Storks, are likely found outside protected areas in this country (Anon 2017). This situation is similar to other locations in Asia where agricultural landscapes supporting populations of Sarus Cranes also support other large waterbird species (Sundar 2006; Kittur and Sundar 2020).

Emerging information on Woolly-necked Stork ecology suggests that this species uses agricultural areas readily where even artificial structures such as irrigation canals and cell-phone towers are used for foraging and nesting respectively (Sundar 2006; Hasan and Ghimire 2020; Katuwal *et al*. 2020; Roshnath and Greeshma 2020). Systematic surveys using transects (1 - 1.5 km in length) across agricultural landscapes have shown Woolly-necked Storks to be sparse in India and Nepal (Sundar and Kittur 2012; Katuwal *et al*. 2020), though surveys across larger landscapes using road routes have been useful to understand ecological aspects such as seasonal variations in density and habitat use (Sundar 2006; Kittur and Sundar 2020). Woolly-necked Storks have also been observed to commonly use agricultural fields to forage while also using golf courses and gardens in suburban areas and unprotected wetlands in agricultural landscapes (Sundar and Kittur 2013; Thabethe 2018; Tiwary 2020). Empirical estimates of abundance and habitat use of Woolly-necked Storks from inside protected forest areas are not available making it impossible to contrast with metrics available from outside protected areas. Such a comparison is essential to confirm existing assumptions regarding Woolly-necked Stork reliance on protected forested areas.

We set up 55 transects inside and outside protected areas across five regions in Myanmar and evaluated Woolly-necked Stork abundance and habitat use over three years of continuous monitoring. We were primarily interested to understand if abundance metrics and habitat use of this species changed on landscapes with different protection status. However, since Woolly-necked Stork ecology from Myanmar is practically unknown, we also use the information to understand if these metrics varied by location, season, and time of day. Finally, we assessed temporal trends in abundance metrics in each transect to evaluate whether abundance of Woolly-necked Storks was changing over the study's duration and whether these changes varied with protection status.

Study area

Woolly-necked Storks were observed in five locations of Myanmar: Kachin State and in four Regions namely Magway, Mandalay, Sagaing and Yangon (Figure 1). The study area was therefore spread practically across the entire north-south length of Myanmar, and spanned a very wide range of conditions, habitats, and landscapes. In Myanmar, three seasons based on precipitation and temperature were recognized namely summer (February - May), the rainy (June - September) and winter (October - January). These three seasons are also referred to as "hot", "rainy" and "cold" seasons respectively. The primary crop grown during the rainy season was rice *Oryza sativa* and the primary winter crop was peas *Pisum sativum*. Wetlands were scattered across the landscape in all the locations surveyed for this study. We describe each location briefly to primarily highlight the differences in vegetation and weather. Information was derived from the World Database on Protected Areas of the IUCN (https://www.iucn.org/theme/protected-areas/our-work/quality-and-effectiveness/world-database-protected-areas-wdpa) and updated climatic detail were taken from the website climate-data.org.

Kachin State was the northernmost location and is 89,041 km^2 in size. The state has various protected areas, and our study was conducted in two of these: Indawgyi Wildlife Sanctuary and the Hukuang Valley Wildlife Sanctuary. Indawgyi Sanctuary is a biosphere reserve and includes Myanmar's largest lake, the Indawgyi Lake, as well as moist deciduous and semi-evergreen forests on the mountainous regions. The Hukuang Sanctuary is Myanmar's largest protected reserve and extends into Sagaing Region. We refer to the combination of both the original and the extension as a single protected area. The average temperature range was 17.9 - 34° C with an annual rainfall of 2000 mm.

The Magway Region is the second largest of Myanmar's seven Regions with an area of 44,820 km^2. This study included survey locations in the Shwesettaw Wildlife Sanctuary that is dominated by mixed deciduous forests. The average temperature range in the Region was 21.9 - 32.2° C with an average annual rainfall of 849 mm.

The Mandalay Region, located in the center of the country, has an area of 37,946 km^2 with a strongly seasonal climate including very warm summers and cooler winters with an average temperature range of 13.3 - 38.4° C and with an average annual rainfall of 812 mm with most of the rainfall falling in September. This study was restricted to areas outside protected areas in the Mandalay Region.

The Sagaing Region is in the north-western part of the country and has an area of 93,527 km^2. The average annual temperature range was 23 - 32° C with an average annual rainfall of 807 mm. Our surveys included the two protected areas Htamanthi Wildlife Sanctuary and Alaungdaw Kathapa National Park. The latter included elevated mountainous areas extending to 1,335 m above mean sea level and a variety of forest types including mixed deciduous, evergreen and pine.

The Yangon Region was the southern-most area in Myanmar covered during this study and includes extensive coastal habitats. The Region's average temperate range was 17.9 – 37° C with a relatively large annual average rainfall of 2,378 mm owing to heavy coastal rainfall. The surveys included the Hlawga Park which was an open zoo around which a natural buffer zone was maintained.

Methods

Field methods

In the five locations described above, we marked transects of 1.5 km inside protected areas and 2 km outside protected areas. These permanent transects were part of another ongoing project, and observations of Woolly-necked Storks made during the project work have been used in this paper. Distribution of transects in each location ensured coverage of as many different habitat types as possible. For these reasons, the number of transects varied with location and were also unequally distributed within and outside protected areas. Of the 55 transects, 15 each were in Kachin State and Sagaing Regions, 10 each were in Magway and Mandalay Regions, and five in Yangon Region. Transects were only outside protected areas in Mandalay Region and only inside protected areas in Yangon region. A total of 19 transects were located inside and 36 were located outside protected areas. Transects were not distributed systematically and were therefore clumped to different extents in each location (see Figure 1). Protected areas varied in the levels of protection each had and in other important aspects such as size of areas protected and time since protection. In this study it was not possible to evaluate whether Woolly-necked Storks responded to differing aspects of protection and habitat availability in protected areas. Similarly, unprotected areas also varied in cropping patterns, human densities, hydrology and other aspects. Results of this study are therefore to be interpreted as being relevant to the range of variations across protected and unprotected areas we covered. To achieve much more specific understanding of how species such as Woolly-necked Storks respond to individual aspects of protected and unprotected areas, studies will require a different resolution of planning suited to specific questions.

Transect observations were made either in the morning (0700 - 1000h) or evening (1400 - 1700h) with two people walking slowly and counting all observed storks. Observations included number of storks and whether storks were using one of three broad habitats (agriculture, forests, wetlands). Each transect was run twice every season annually between January 2016 to December 2018 for a total of 990 transect runs.

Analyses

Abundance of Woolly-necked Stork was estimated per transect as encounter rate (number of storks seen/ km). Since transects were unequally distributed, and because a large number of transects did not have any storks (see Results), we used non-parametric permutational

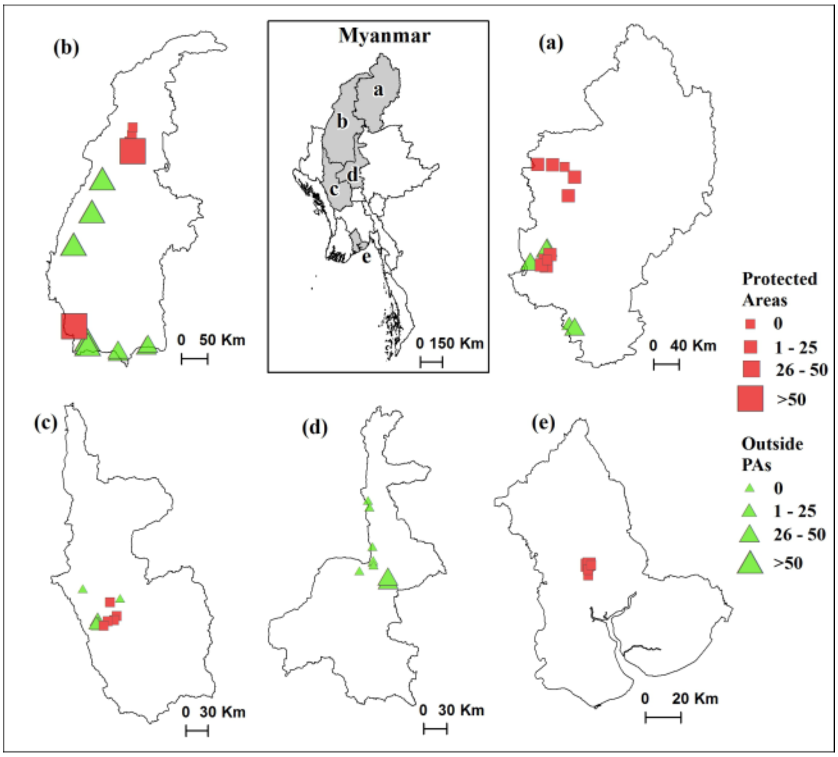


Figure 1. The map shows the five major locations where transects were laid to count Woolly-necked Storks in Myanmar (inset, in box). Along with location of the transects, the map illustrates the distribution of transects inside (pink squares) and outside (green triangles) protected areas. The size of the squares and triangles correspond to the number of sightings of Woolly-necked Storks that were made over 18 runs on each transect between 2016 and 2018. Major locations where transect surveys were carried out (from the northern-most to the southern-most) were Kachin State (a), Sagaing Region (b), Magway Region (c), Mandalay Region (d) and Yangon Region (e).

analysis of variance (PERMANOVA) tests to assess differences, if any, due to protection status and other variables. The non-parametric tests allowed us to work with data that did not conform to strict distribution patterns that are essential for parametric tests. We carried out statistical tests using function 'aovp' in R-package 'lmPerm' (Wheeler and Torchiano 2016). Using the full data, encounter rates were similar across years (p = 0.69) and in different times of day (p = 0.89), and we did not consider these two variables for the rest of the analyses. We tested the hypotheses that Woolly-necked Stork abundance varied due to protection status (transects located in protected/unprotected areas), and that this difference remained in different locations and seasonally.

Using the 18 continuous counts on each transect we estimated the linear trend in encounter rates using linear least-squares and computed slopes for each transect. The slope of the fitted line indicates both the directionality and the rate of change in encounter rate over the 18 counts. We deliberately assumed linear fits to allow direct comparisons across transects notwithstanding varied scales of difference in individual transects.

For each transect we computed the proportion of Woolly-necked Storks seen in each of the three habitats – agriculture, forests, and wetlands. Proportions of use of each habitat type was significantly and negatively correlated with the other two habitat types (Spearman's $r < -0.3$, $p < 0.001$). Wetlands were the only habitat types used by storks in all locations, and we therefore used proportions of wetlands used to assess differences in habitat use with PERMANOVA tests due to protection status, and also whether differences existed across locations and seasonally.

Results

Encounter rate

A total of 1,118 Woolly-necked Storks were counted during the 990 transect runs with storks being sighted in all locations (Figure 1). Storks were seen at least once in 56% of the transects and were seen in all 18 runs in 18% of transects. Woolly-necked Storks were seen at least once in similar proportions of transects inside (53% of 19 transects) and outside (56% of 36 transects) protected areas. However, frequency of sightings differed with protected status. Woolly-necked Storks were seen in 44% of the 990 transect runs, with a much higher frequency of sightings in transects outside (61% of 648 transect runs) relative to those inside (25% of 342 transect runs) protected areas.

Encounter rates varied significantly by location ($p < 0.001$) with the highest rates in Sagaing Region and Kachin State (Figure 2a). The largest count of Woolly-necked Storks in a single transect run was 12 birds and occurred in two different protected areas, both in Sagaing Region. The average number of storks seen in a single transect was 1 bird (± 2 SD). Total stork counts using all 18 runs on a transect varied widely across the 55 transects (average = 20 ± 30 SD; range = 0 - 130; see Figure 1). Encounter rates of Woolly-necked Storks were significantly more outside protected areas ($p < 0.001$). Woolly-necked Storks were seen both

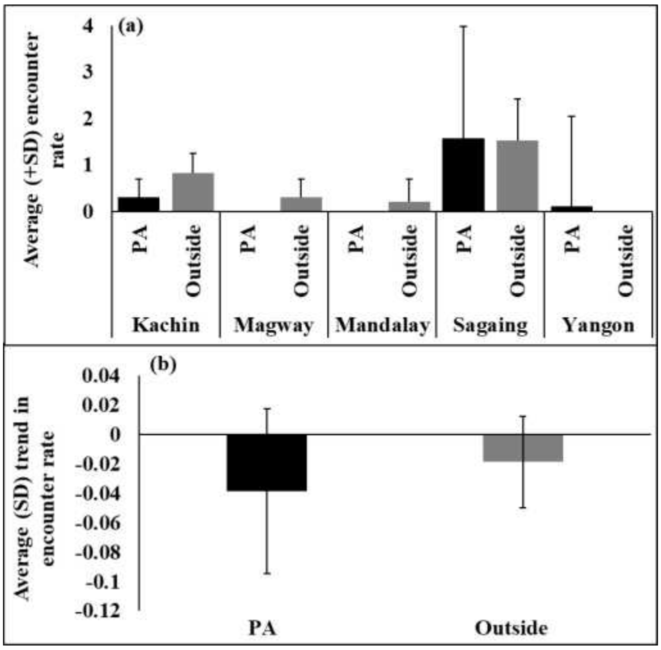


Figure 2. Estimated encounter rates (birds/ km) of Woolly-necked Storks in five locations of Myanmar. (a) Average + SD encounter rates were estimated differently for transects that were located inside ("PA") and outside protected areas ("Outside"). (b) Trends in encounter rates were estimated using 18 consecutive surveys in each transect, and average values of slopes (± SD) are provided for transects that were located inside and outside protected areas.

inside and outside protected areas in two locations and in these locations were significantly more abundant outside protected areas in Kachin State ($p < 0.001$) but did not vary with protection status in Sagaing Region ($p = 0.32$).

On the 31 transects where Woolly-necked Storks were observed, trends in abundance were weakly negative on average (-0.02 ± 0.04 SD) with negative trends in 68% of transects. Decline in abundance inside protected areas (-0.039 ± 0.06 SD) was on average more than twice that observed outside (-0.019 ± 0.03 SD; Figure 2b). Differences in average trends, however, were not significant with standard deviations overlapping zero both inside and outside protected areas.

Habitat use

Combining all observations, most Woolly-necked Storks were seen in wetlands (53%) and agriculture fields (35%) with few seen in forests (12%). Forests were used mostly inside protected areas, while agriculture fields and wetlands were used more outside protected areas ($p < 0.001$; Figure 3a). Use of habitats inside and outside protected areas was similar across seasons ($p = 0.61$) and locations ($p = 0.92$; Figure 3b). Use of different habitats by Woolly-necked Storks were photographed where possible and a small selection is curated in Figure 4.

Discussion

Woolly-necked Storks were observed in all the five locations of Myanmar where transect-based surveys were carried out. Abundance measured as encounter rates were significantly higher outside protected areas, and storks were seen in many more transects outside protected areas. Trends in encounter rates were negative in nearly all transects in Myanmar, though protected areas appeared to be witnessing a much faster decline in Woolly-necked Storks relative to areas outside protected areas (Figure 2b). While negative trends were very weak and not statistically significant, our observations provide additional support to growing observations of habitat deterioration in the protected areas and wetlands of Myanmar (e.g. Su and Jassby 2002; Donald *et al*. 2015). It is not clear what is responsible for these negative trends in abundance, though naturally occurring seasonal and inter-annual variations in numbers cannot be entirely ruled out (as seen in other south Asian populations; Kittur and Sundar 2020).

There was no seasonal variation in estimated encounter rates in Myanmar. In other locations, Woolly-necked Storks were seen much more during winter and the least in summer suggesting local movements potentially brought about by changes in local conditions (Kittur and Sundar 2020; Roshnath and Greeshma 2020). Despite strong seasonality in Myanmar, the apparent absence of local movements of Woolly-necked Storks is suggestive of foraging conditions being suitable throughout the year in many locations. This appears to be an unusual setting for Woolly-necked Storks and is worthy of detailed studies.

Abundance estimates for Woolly-necked Storks are available for very few locations, and encounter rates that we estimated for Myanmar are unfortunately not comparable with estimated densities in lowland Nepal and India (see Kittur and Sundar 2020). On average, nearly two Woolly-necked Storks were seen every km of surveys in Sagaing that suggests a relatively high abundance. All the other locations surveyed had much fewer encounters suggesting that conditions in Sagaing Region, relative to the other areas, were most optimal for Woolly-necked Storks. More careful studies can help with understanding the conditions

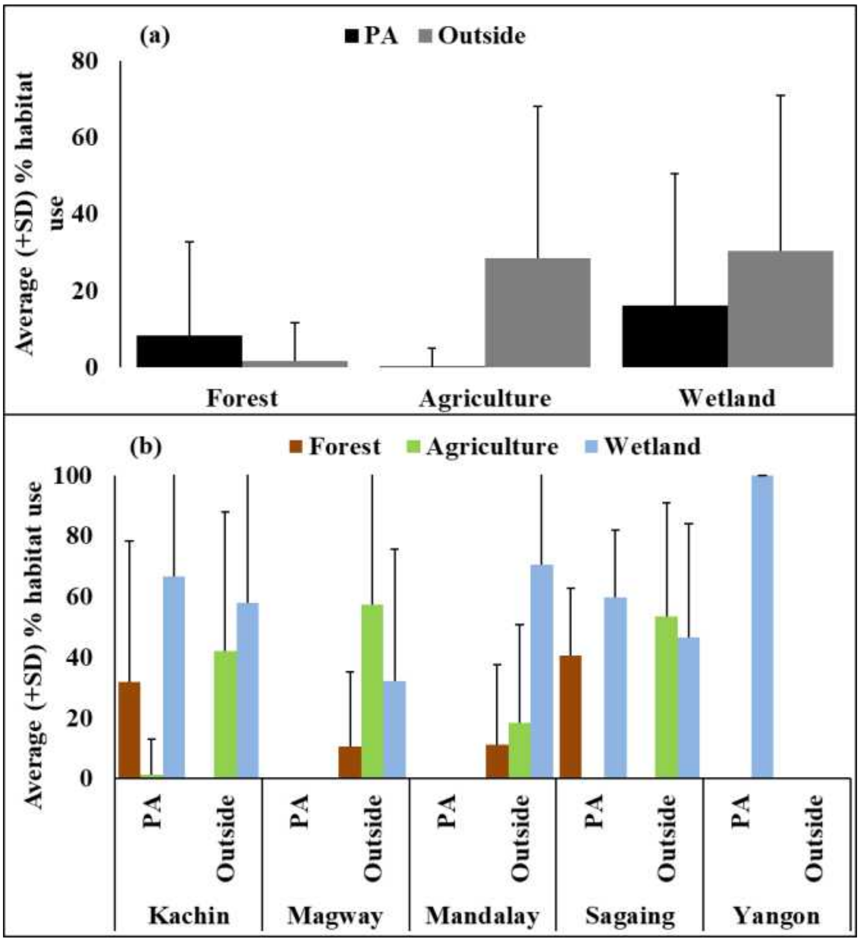


Figure 3. Woolly-necked Stork use of three primary habitats inside and outside protected areas in Myanmar. (a) Average (+ SD) % habitat use combining information from all transects; and (b) average (+ SD) % habitat use in five locations.

in Sagaing Region that were favourable for storks. With our study, we are unable to provide population estimates, though observations on transects that covered a relatively miniscule proportion of the country suggest that Woolly-necked Storks could number in the thousands in Myanmar. It will be useful to undertake robust field studies directed at collecting data with which to estimate population sizes of Woolly-necked Storks in different locations of Myanmar.

Encounter rates of Woolly-necked Storks were much higher outside protected areas raising the possibility that this species favours open areas, and that will likely be resilient to deterioration of forested protected areas in Myanmar. Our findings contrast existing assumptions that Woolly-necked Storks favour protected forested areas, and that agriculture is detrimental for the species (BirdLife International 2020). Instead, our findings in Myanmar support the growing evidence of human-modified open areas such as agriculture fields and unprotected wetlands being primary habitats for Woolly-necked Storks in several locations across Asia and Africa (Thabethe 2018; Katuwal *et al*. 2020; Kittur and Sundar 2020; Tiwary 2020).

Most Woolly-necked Storks observed in Myanmar were in wetlands (53% of 1,118 storks observed) both inside and outside protected areas (Figure 3a), which is different from habitat use observed elsewhere. In lowland Nepal and India, of 1,874 observations of storks, 64% were in agriculture fields with only 9% in wetlands (Kittur and Sundar 2020). Analysis with the use-availability framework showed Woolly-necked Storks in south Asia to be strongly preferring wetlands in nearly all the locations they were studied despite a small proportion of sightings of storks using wetlands (Sundar 2006; Kittur and Sundar 2020). Our observations in Myanmar therefore suggest that Woolly-necked Storks in Myanmar are likely selecting wetlands as foraging habitats even more strongly than in Nepal and India. Though 35% of Woolly-necked Storks were observed in agricultural fields largely outside protected areas in Myanmar, there were considerable location-specific differences in the proportions of storks that used agriculture. In Magway and Sagaing Regions most storks used agriculture, while they mostly used wetlands in Kachin State and Mandalay Region (Figure 3b). These location-specific differences in habitat use are symptomatic of variations in landscape conditions and potentially also of different levels of human activity on the landscape. Variations in habitat use with location could also be due to the unequal distribution of transects inside and outside protected areas and unequal effort in locations. Studies to measure available landscape conditions in different locations to compare against Woolly-necked Stork habitat use can yield nuanced information on the habitat requirements of this species.

We recognize two important aspects of analyses with our data that are important to undertake separately. As we pointed out in the Methods section, the first is the lack of resolution to analyze site-specific differences such as level of protection (for protected areas) and human density (for unprotected areas). This is also part of the reason why we do not provide a nuanced discussion into national policy for conservation. The potential impacts of these variations on species such as Woolly-necked Storks are important but was not possible to incorporate in our study. We also do not include metrics of additional aspects of species biology such as breeding propensity and success. Birds of the year are easily identified using plumage in some large waterbird species such as the Sarus Crane, Painted Storks *Mycteria leucocephala* and Black-necked Storks *Ephippiorhynchus asiaticus* in south Asia (pers. obs.). Locations where immature birds are seen alongside adults can confidently be identified as areas where the species breeds. Such plumage variations also allow for the estimation of metrics important for understanding species population biology. Woolly-necked Stork juveniles, however, are difficult to tell apart from adults except for a short time immediately after fledging (see Sundar 2020). In addition, this species shows local and seasonal movements in response to changing water availability that in turn alters observable metrics such as flock size (Kittur and Sundar 2020; Mandal *et al*. 2020). Using only metrics such as flock size is therefore not a reliable method for Woolly-necked Storks to confirm aspects such as breeding. Careful studies are needed in Myanmar to document and understand critical aspects of Woolly-necked Stork biology such as breeding ecology.

This study is the first from Myanmar to develop a detailed understanding of a large waterbird species capable of using both protected forests and unprotected agricultural areas. Our findings are hopeful in suggesting that the gloom-and-doom that is presented of Myanmar's natural resources is not pertinent to all species, and that at lease some species of birds may be resilient to the dynamism and human presence characteristic of agricultural

Figure 4. Observations of Woolly-necked Storks using different habitats in Myanmar during surveys between 2016 and 2018. Photographs show storks using large waterbodies (a), small shallow ephemeral wetlands alongside other waterbirds (b), pea fields (c), and an agricultural field with harvested crops (d). (Photograph credits: U. Nway Myaing).

landscapes. Findings from this study do not support existing assumptions regarding the conservation requirements and status of Woolly-necked Storks. Our work adds to the sparse amount of research on Woolly-necked Storks globally. It also provides information that suggests that conservation efforts in Myanmar will benefit from including agricultural landscapes to ongoing efforts that seek to preserve forested protected areas critical for the region's biodiversity.

Acknowledgments

Field work was conducted entirely by Myanmar nationals after obtaining requisite permits to access protected areas. KSGS was invited to collaborate on analysing the field data and writing the paper. We thank all the forest officials who aided researchers during field work. We thank S. Kittur for preparing the map of the study area and for suggestions that improved an early draft of the paper. We would like to express our special thanks to U Nway Myaing for sharing invaluable bird photos. Special thanks to U Tin Aung Tun, freelance conservationist, for his invaluable technical support during the survey period. We gratefully acknowledge the suggestions made by two anonymous reviewers that helped improve a previous draft.

References

Anon. 2017. Fifty globally Vulnerable Sarus Crane chicks successfully hatch in northern plains of Cambodia. News Release, October 02, 2017, WCS Newsroom. https://programs.wcs.org/newsroom/News-Releases/articleType/ArticleView/articleId/10559/Fifty-Globally-Vulnerable-Sarus-Crane-Chicks-Successfully-Hatch-in-Northern-Plains-of-Cambodia.aspx, accessed 18 August 2020.

BirdLife International. 2020. Species factsheet: *Ciconia episcopus*. http://datazone.birdlife.org/species/factsheet/22727255, accessed 15 September 2020.

Donald, P. F., P. D. Round, T. D. W. Aung, M. Grindley, R. Steinmetz, N. M. Shwe and G. M. Buchanan. 2015. Social reform and a growing crisis for southern Myanmar's unique forests. *Conservation Biology* 29: 1485-1488.

Gula, J., W. R. J. Dean and K. S. G. Sundar. 2020. Known and potential distribution of the African *Ciconia miscroscelis* and Asian *C. episcopus* Woollyneck Storks. *SIS Conservation* 2: 80-95.

Harrison, I., R. Abell, W. Darwall, M. L. Thieme, D. Tickner and I. Timboe. 2018. The freshwater biodiversity crisis. *Science* 362: 1369.

Hasan, M. T. and P. Ghimire. 2020. Confirmed breeding records of Asian Woollyneck *Ciconia episcopus* from Bangladesh. *SIS Conservation* 2: 47-49.

Katuwal, H. B., H. M. Baral, H. P. Sharma and R.-C. Quan. 2020. Asian Woollynecks are uncommon on the farmlands of lowland Nepal. *SIS Conservation* 2: 50-54.

Kittur, S. and K. S. G. Sundar. 2020. Density, flock size and habitat preference of Woolly-necked Storks *Ciconia episcopus* in agricultural landscapes of south Asia. *SIS Conservation* 2: 71-79.

Mandal, J., L. M. Abraham and R. Bhaduri. 2020. A note on the temporal and spatial distribution of Asian Woollyneck in Assam, India. *SIS Conservation* 2: 62-67.

Roshnath, R. and P. Greeshma. 2020. Status of Woolly-necked Storks in Kerala, south-western India. *SIS Conservation* 2: 55-61.

Su, M. and A. D.Jassby. 2002. Inle: A large Myanmar lake in transition. *Lakes and Reservoirs* 5: 49-54.

Sundar, K. S. G. 2006. Flock size, density and habitat selection of four large waterbird species in an agricultural landscape in Uttar Pradesh, India: implications for management. *Waterbirds* 29: 365-374.

Sundar, K. S. G. 2020. Special section editorial: Woolly-necked Stork – an ignored species. *SIS Conservation* 2: 33-41.

Sundar, K. S. G. and S. Kittur. 2012. Methodological, temporal and spatial factors affecting modelled occupancy of resident birds in the perennially cultivated landscape of Uttar Pradesh, India. *Landscape Ecology* 27: 59-71.

Sundar, K. S. G. and S. Kittur. 2013. Can wetlands maintained for human use also help conserve biodiversity? Landscape-scale patterns of bird use of wetlands in an agricultural landscape in north India. *Biological Conservation* 168: 49-56.

Tiwary, N. K. 2020. Observations on distribution and feeding behaviour of Woolly-necked Storks *Ciconia episcopus* during 2012-20 from north India. *SIS Conservation* 2: 42-46.

Thabethe, V. 2018. Aspects of ecology of African woolly-necked storks (*Ciconia miscroscelis*) in an anthropogenic changing landscape in KwaZulu-Natal, South Africa. Unpublished Ph.D. thesis, School of Life Sciences, College of Agriculture, Science and Engineering, University of KwaZulu-Natal, South Africa. 125 pp.

Wheeler, B. and M. Torchiano. 2016. lmPerm package for R: Permutation Tests for Linear Models version 2.1.0. https://github.com/mtorchiano/lmPerm, accessed 13 August 2020.

Wilcove, D. S., X. Giam, D. P. Edwards, B. Fisher and L. P. Koh. 2013. Navjot's nightmare revisited: logging, agriculture, and biodiversity in Southeast Asia. *Trends in Ecology and Evolution* 28: 531-540.

SIS Conservation articles are peer-reviewed by experts who volunteer their time and experience to help improve the quality and content of manuscripts that are submitted to this publication.

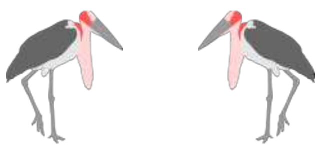
The publication gratefully recognize the reviewers below; names in bold are people who reviewed more than one manuscript.

Issue 1, 2019. *Special Issue: Glossy Ibis ecology and conservation*

Letizia CAMPIONI, **Luis Santiago CANO ALONSO**, Alejandro CENTENO, **Jocelyn CHAMPAGNON**, Marcello D'AMICO, Phillippe DUBOIS, Mauro FASOLA, Frédéric GOES, **Catherine KING**, Ricardo LIMA, Xavier RUFRAY, **Simone SANTORO**, **André STADLER**, **K. S. Gopi Sundar**, **Piotr TRYJANOWSKI**, Amanda WEBBER.

Issue 2, 2020. *With Special Section on Woolly-necked Stork ecology and conservation*

M. O. Anand, Luis M. BAUTISTA, Kate BRANDIS, Luis Santiago CANO ALONSO, Megan DIAMOND, Jonah GULA, Swati KITTUR, Suresh KUMAR, Pablo Alberto Refoyo ROMAN, Jennifer SPENCER, **K. S. Gopi Sundar**, **Nawin Kumar TIWARY**, Robert TIZARD, Abdul J. URFI.



IUCN SSC
Stork, Ibis and Spoonbill Specialist Group

https://storkibisspoonbill.org/sis-conservation-publications/

ISSN 2710-1142(online)