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Source: Waterbirds, 40(3) : 282-288

Published By: The Waterbird Society

URL: https://doi.org/10.1675/063.040.0309

Increased Populations of Endangered Cranes After Amur River Flood

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Abstract.—Dam construction on the Zeya River, which is an important tributary of the Amur River in Far East Russia, has caused significant declines in water levels and frequency of floods in the adjacent floodplains since 1980. However, an extreme flood event occurred in 2013. Populations of six crane species were monitored before and after these drastic water level changes at Muraviovka Park in Far East Russia, an important breeding and stop-over site. Individuals were counted by territory mapping during the breeding season (2000-2015) and by roosting site counts during autumn migration (2006-2015). The objective of this study was to evaluate whether changes in water levels had a significant impact on local and migratory crane populations. We found a positive effect of flooding on numbers of breeding Red-crowned Cranes (*Grus japonensis*) and White-naped Cranes (*Antigone vipio*), as well as on numbers of roosting Hooded Cranes (*Grus monacha*) in autumn. Siberian Cranes (*Leucogeranus leucogeranus*) were only observed after the wetlands were flooded. The results of this study highlight the importance of elevated Amur River water levels for crane populations of global importance. *Received 20 November 2016, accepted 2 April 2017.*

Key words.—*Antigone vipio*, cranes, dam construction, East Asian flyway, floodplain, *Grus japonensis*, *Grus monacha*, *Leucogeranus leucogeranus*, population trend, water level.

Waterbirds 40(3): 282-288, 2017

The wetlands along the Amur River in Far East Russia have been regularly flooded in the past, but due to dam construction water levels are shrinking and the former floodplains are drying out (Smirenski and Smirenski 2007; Sokolova 2015). This effect is enhanced by increasing annual average air temperatures (climate change), causing droughts and wildfires (Smirenski and Smirenski 2009). Wetland species, like cranes, are likely affected by such landscape-scale changes. Significant populations of Red-crowned Cranes (*Grus japonensis*) and White-naped Cranes (*Antigone vipio*) breed on the Zeya-Bureya plain, while Eurasian Cranes (*G. grus*), Hooded Cranes (*G. monacha*) and Siberian Cranes (*Leucogeranus leucogeranus*) use the area as a stop-over during migration (Heim 2016). Demoiselle Cranes (*Anthropoides virgo*) are vagrants in the study area.

The quality of a stop-over site can have a substantial impact on the development of bird populations, and safe sites are crucial for the protection of migratory species (Newton 2004; Sheehy *et al.* 2011). Migratory birds often take detours to reach necessary stop-over habitats; this has been documented for White-naped Cranes on their way from Russia to China (Fujita *et al.* 2004). Especially during autumn, cranes stay for many weeks to refuel in the floodplain area, where several roosting sites have been described and monitored (Nosatchenko and Smirenski 2007).

In 2013, the largest flood since the construction of the Zeya dam in 1980 covered large parts of the Amur region (Sokolova 2015). The wetlands, as well as adjacent crop lands and villages, became inundated. As a result, water levels at the crane roosting sites were much higher than in previous years and were still elevated during 2014. The aim of this study was to evaluate whether these changes in water levels had a significant impact on the number of breeding and roosting cranes.

METHODS

Study Area

The study took place at Muraviovka Park (49° 55′ 08.3″ N, 127° 40′ 19.9″ E), a wetland reserve situated on the Zeya-Bureya floodplain along the middle reaches of the Amur River in Far East Russia (Heim 2016). The degree of flooding can be assessed according to the highest annual level of the water hydrological station in Khabarovsk (48° 26′ 48.1″ N, 134° 59′ 15.5″ E). Complete flooding of the upper floodplain (where our study site is situated) requires water levels of more than 500 cm. Lower parts of the floodplains already may be covered with water at levels above 300 or 400 cm. The mean water level of the Amur River has decreased significantly since 1980 (Fig. 1). Furthermore, the maximum height of the floods has decreased, with the exception of the extreme flood event in 2013 (Sokolova 2015).

Data Collection and Statistical Analysis

The number of breeding cranes at Muraviovka Park has been monitored since 2000 by territory mapping during the breeding season (Smirenski and Smirenski 2007, 2009; Kitagawa 2014), and roosting site counts during autumn migration have been conducted since 2006 (Nosatchenko and Smirenski 2007; Stein and Nosachenko 2012). Since 2011, cranes have been counted annually by the Amur Bird Project (Heim and Smirenski 2013). Weekly roosting site counts were conducted during September 2011-2015 from the balcony of Muraviovka Park's nature center, offering a 180° view of the wetlands. The cranes usually feed on the surrounding fields and fly to their roosting sites around sunset. The percentage of juveniles was recorded during daily counts in 2014 and 2015 (double counting of the same individuals during different days cannot be excluded).

The correlation between year and number of breeding pairs (population trend) was tested using a Spearman rank-order correlation. Linear models were used to analyze the impact of water levels on crane populations during both breeding season and migration. We used the following models to explain the dependent variable for crane abundance:

$$\text{Abundance (crane species / season)} \sim \text{year} + (\text{year})^2 + \text{years after flood} + (\text{years after flood})^2 + \text{maximum annual water level} + \text{September average water level}$$

Years after flood were counted starting with zero in the flood year (water level > 500 cm). Significant variables were selected with the help of "backward stepwise model selection" (Crawley 2013) using the Likelihood-ratio test ($P < 0.05$) and AIC-values. Normal distribution and variance homogeneity of residuals was graphically tested with help of a normal probability plot (Crawley 2013). The analysis was carried out using the statistical program R (R Development Core Team 2016).

RESULTS

Breeding Populations

The breeding population of the White-naped Crane showed a significant increase (Spearman rank-order correlation: *rho* = 0.86, $P < 0.01$; Fig. 2), whereas no significant

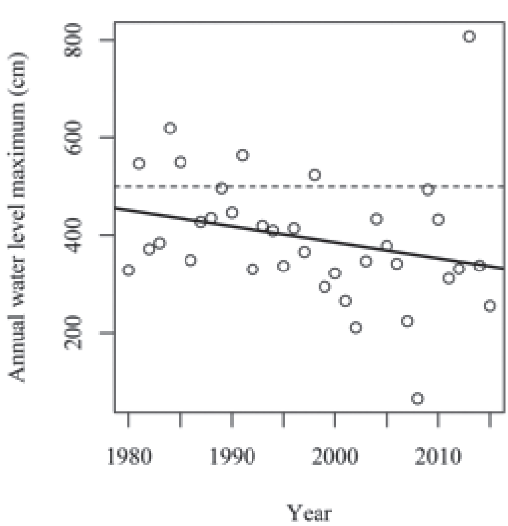

Figure 1. Decreasing annual maximum water level of the Amur River at Khabarovsk, 1980-2015 (Spearman rank-order correlation: *rho* = 0.38, *P* = 0.02). Dashed line indicates water level necessary for flooding the upper part of the floodplain.

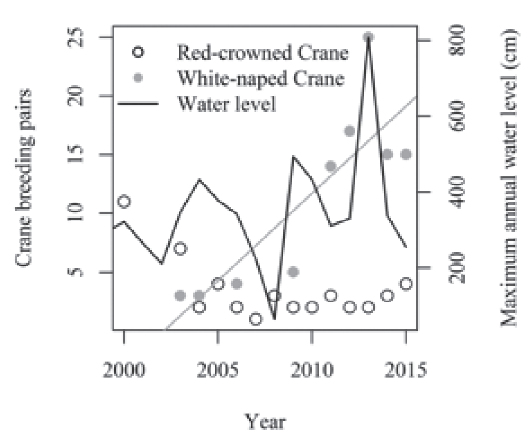

Figure 2. Numbers of White-naped Crane and Red-crowned Crane breeding pairs at Muraviovka Park and maximum annual water levels of the Amur River, 2000-2015. There was a significant increase in numbers of White-naped Crane (Spearman rank-order correlation: *rho* = 0.86, *P* < 0.01). Most breeding pairs were observed in the flood year.

trend was found for the population of the Red-crowned Crane (Spearman rank-order correlation: *rho* = -0.22, $P = 0.44$; Fig. 2). The greatest number of crane breeding pairs was recorded in the flood year 2013 (Fig 2).

Autumn Populations on Roosting Sites

Maximum daily numbers of roosting cranes at Muraviovka Park between 2006 and 2015 are shown in Table 1. No roosting Red-crowned Cranes, except for the local breeding birds, were observed between 2011 and 2015. The number of White-naped Cranes decreased from 2009 until 2013 and increased after the flood year, with a daily maximum count of 475 individuals in 2015. The data for Hooded Crane show the same pattern, with maximum counts of 1,095 individuals in 2009 and 1,031 individuals in 2015 (Fig. 3). Siberian Cranes were recorded for the very first time during autumn migration in the flood year 2013. Since that time, between one and 33 birds were recorded annually. Eurasian Cranes were recorded almost annually in low numbers (one to 10 birds per season), with a daily maximum of 13 individuals in 2015. Possible hybrids between Hooded and Eurasian cranes were observed in 2009 and on 22 September 2015. No Demoiselle Cranes were recorded in autumn within the study period (2000-2015).

Proportion of Juveniles

The percentage of juveniles was first determined in autumn 2009, with 40% of the White-naped Cranes and 25% of the Hooded Cranes being juveniles. In 2014, 28% of the White-naped Cranes ($n = 909$) and 18% of the Hooded Cranes ($n = 266$) were juveniles. In 2015, 14% of the White-naped Cranes ($n = 1{,}025$) and 21% of the Hooded Cranes ($n = 424$) were juveniles.

Drivers of Crane Numbers

Sample sizes were sufficient to evaluate the effects of flooding for three crane species. The final models are shown in Table 2. The number of breeding Red-crowned Cranes and the maximum number of roosting Hooded Cranes during autumn migration depended on the number of years after a flood event and on the year of observation (Fig. 4). The number of breeding White-naped Cranes depended on the number of years after a flood event. None of the variables significantly explained the number of roosting White-naped Cranes during autumn.

DISCUSSION

Flooding had a significant positive effect on the number of breeding pairs of Red-crowned and White-naped cranes. The numbers of roosting Hooded, White-naped and Siberian cranes during autumn increased after the flood event in 2013. Our models show that the quadratic function of the number of years after the last high flood is the most important factor for describing the breeding population dynamics of Red-crowned and White-naped cranes as well as for the number of roosting Hooded Cranes during autumn migration at Muraviovka Park. Crane populations increased during the 3 years following a flood but decreased

Table 1. Daily maximum counts of cranes during autumn migration at Muraviovka Park and IUCN Red List status of the study species (LC = least concern, VU = vulnerable, EN = endangered, CR = critically endangered). The flood year (2013) is shaded in gray.

Species	IUCN Status	2006	2009	2011	2012	2013	2014	2015
Eurasian Crane	LC	> 1	3	3	4	0	3	13
Hooded Crane	VU	> 1,000	1,095	604	380	40	404	1,031
Hooded Crane x Eurasian Crane hybrid	—	0	2	0	0	0	0	1
Red-crowned Crane	EN	13	< 15	4	6	4	6	8
Siberian Crane	CR	0	0	0	0	22	1	33
White-naped Crane	VU	> 327	255	179	85	70	128	475

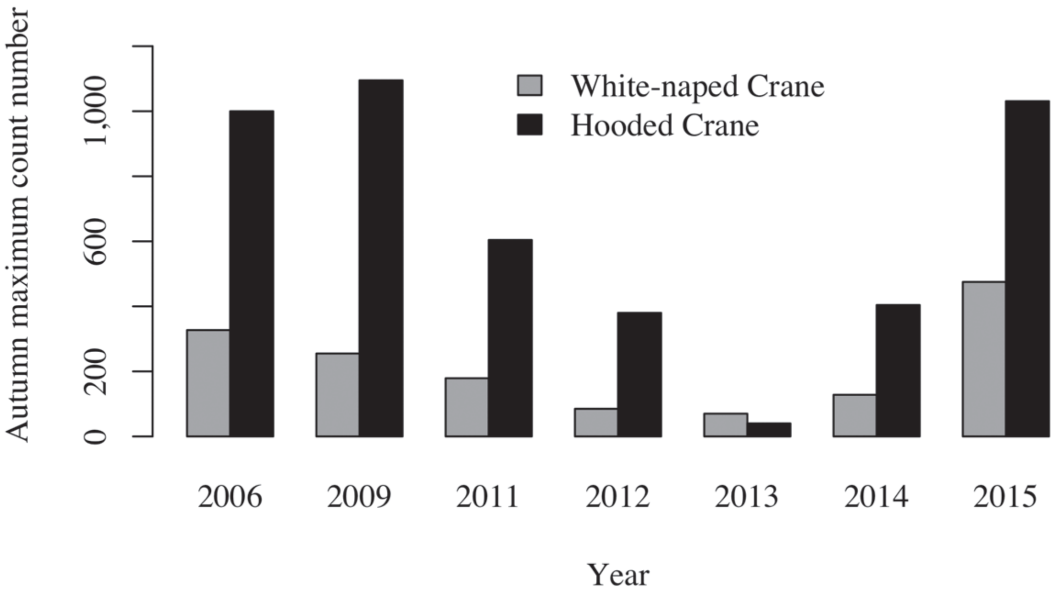

Figure 3. Maximum daily counts of White-naped Cranes and Hooded Cranes at the autumn roosting sites at Muraviovka Park, 2006-2015.

again if the last flood event occurred more than 6 years previously. Studies at Zhalong Nature Reserve in China also revealed that numbers of cranes during spring were highest in years with high water levels (Zou *et al.* 2012). An increase in the maximum daily number of roosting cranes in autumn at Muraviovka Park could mean either that regional conditions during the preceding breeding season were better, resulting in a higher survival rate of adults and chicks, or that the current local conditions at the roosting site were better. If local conditions were better, then either the site was attracting more cranes from a wider geographic range or it was causing individual cranes to stay longer. We lack detailed information about where the cranes originated as well as information on duration of stay since we could not recognize individual cranes. Therefore, we were unable to determine which, if either, of the latter two theories related to local conditions were responsible for the increase in the daily number of roosting cranes. If the conditions during the preceding breeding season were responsible for the observed changes in numbers, we would expect to find differences in the annual percentage of juveniles. However, if only the local conditions at the roosting site were responsible for those

Table 2. Best linear models explaining changes in numbers of cranes (YAF = years after flood, Year = year of observation).

Dependent Variable	Season	Independent Variables (^{2} = values squared)	*P*	R^2
Red-crowned Crane	breeding	Year	0.03	0.83
		$Year^2$	0.03	
		YAF	< 0.01	
		YAF^2	< 0.01	
White-naped Crane	breeding	YAF	< 0.001	0.96
		YAF^2	< 0.001	
Hooded Crane	autumn	$Year^2$	0.03	0.78
		YAF	0.02	
		YAF^2	0.02	

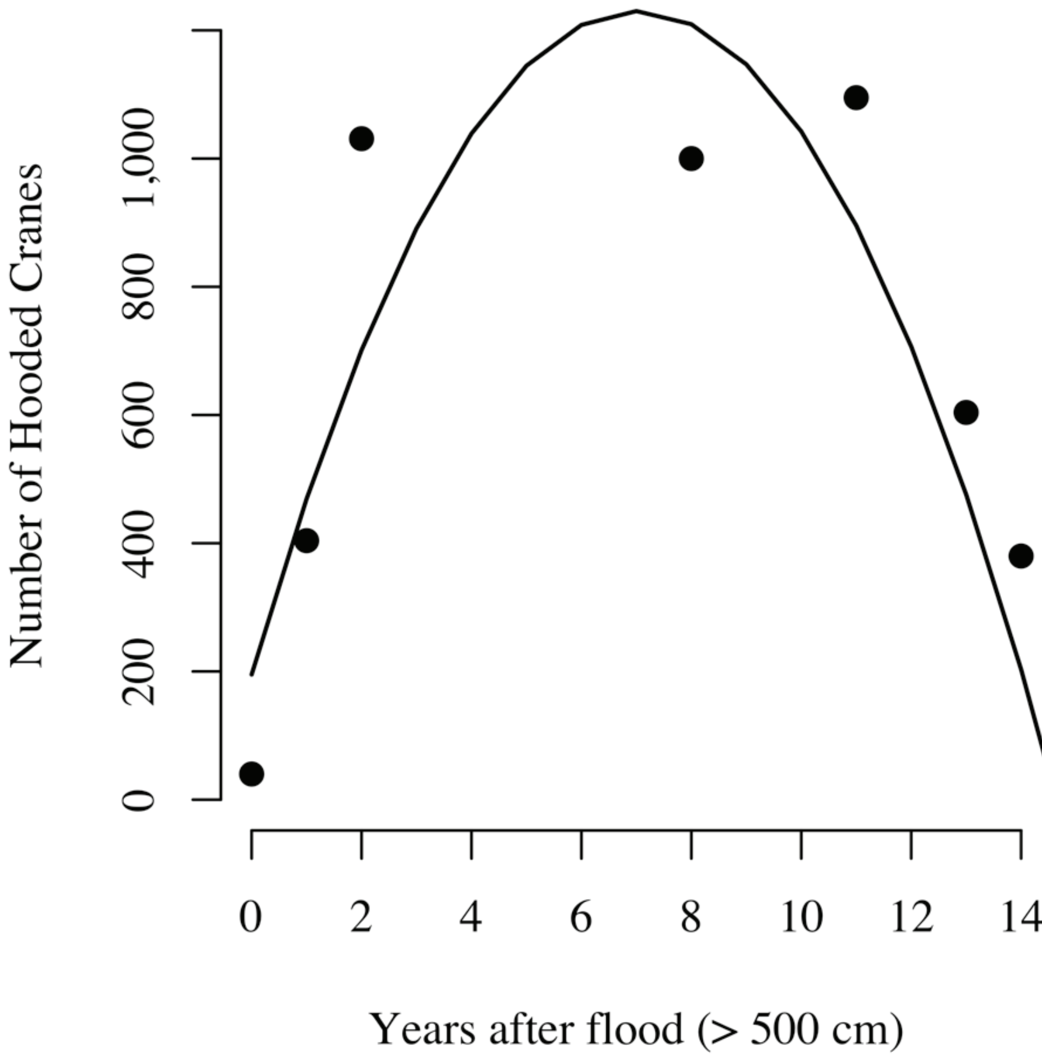

Figure 4. Autumn maxima of Hooded Cranes after flood events follow a quadratic function. High floods (> 500 cm) occurred in 1998 and 2013.

changes, we could not consider the increase of roosting cranes at Muraviovka Park to be an increase in the total (sub-) population.

The increase in numbers of roosting White-naped Cranes from 2014 to 2015 was not caused by an increase in the percentage of juveniles, so the current breeding success was most likely not the driver. A larger number of adults together with a lower percentage of juveniles could mean that there was a higher proportion of non-breeders. Red-crowned, White-naped and Hooded cranes breed for the first time at 3 or 4 years of age (Potapov and Flint 1989), so the increase in numbers could have been caused by increased breeding success 2 years earlier – for example, in the flood year 2013.

In the autumn of the flood year 2013, numbers of roosting cranes were lowest for both Hooded and White-naped cranes. Most likely, the traditional roosting sites were completely under water and not suitable for those species (Zhang *et al.* 2015). These conditions, however, were favorable for the Siberian Crane, which feeds exclusively on aquatic plants (Wu *et al.* 2009) or fish (Degtyaryev *et al.* 2013). Therefore, the increase in sightings starting in the year 2013 might be explained by higher water levels (Suanjak and Heim 2016).

For Red-crowned Cranes, the year of observation was also found to be a significant factor for explaining the number of breeding pairs. This relationship is most likely connected with the change in its population trend during recent decades. The Red-crowned Crane declined in the study area from the late 1990s until at least 2007 (Smirenski and Smirenski 2009), but the population is now stable at a very low level (two to three pairs) or even slightly increasing since 2013 (four pairs in 2015). This trend fits well with the findings of Su and Zou (2012), who described a stable or slightly increasing trend for the eastern population of the continental Red-crowned Cranes, to which the Muraviovka Park birds belong. The number of White-naped Crane breeding pairs has increased in the study area. Both positive and negative population trends have been found at its wintering sites in South Korea (Kim *et al.* 2012; Lee *et al.* 2012), depending on local conditions like snow cover and temperature (Yu *et al.* 2011), availability of waste rice grain (Lee *et al.* 2001) or human disturbance (Lee *et al.* 2012). However, the global population of the White-naped Crane is decreasing (International Union for Conservation of Nature 2016). During autumn 2015, Muraviovka Park hosted up to 7% of the global population of White-naped Cranes and 9% of the global population of Hooded Cranes (International Union for Conservation of Nature 2016).

Further dam constructions on tributaries of the Amur River and regulation of floods could cause drastic declines in crane populations, which will affect protected areas as well. Maintenance of relatively high water levels and/or regular floods appear to have promoted population increases of four species of crane as documented for the Amur River floodplains in this study. The future of the East Asian crane populations and many other wetland species will strongly depend on conservation efforts, which can only be successful if local stakeholders and business representatives participate.

Acknowledgments

This study was enabled by grants of the Förderkreis Allgemeine Naturkunde (Biologie) e.V., the Deutsche Ornithologen-Gesellschaft e.V. and the Oriental Bird Club. Carl Zeiss Sports Optics supported the Amur Bird Project with optical equipment. Water level data were collected with *financial support of the International Science and Technology Center (ISTC), project number 4010.* Many thanks to Sergei M. Smirenski and Svetlana Yakovenko, as well as everybody from the staff of Muraviovka Park. We want to thank all volunteers who took part in the crane counts between 2011 and 2015: Friedrich Eidam, Pia Fetting, Arend Heim, Susanne Jähnig, Bert Jahnke, Steve Klasan, Martha Maria Sander, Nadja Schäfer, Ulrich Schuster, Andreas Siegmund, Martin Suanjak, Christoph Weinrich and Silas Wolf. For additional help, the authors would like to thank Jason Loghry, Juliana Nefjodowa and Yury Shpak. Comments on an earlier draft by Kerryn Morrison, James Harris, Ramona Fitz and one anonymous referee greatly improved this article.

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