Cranes in East Asia: Proceedings of the Symposium Held in Harbin, People's Republic of China June 9-18, 1998

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Cranes in East Asia: Proceedings of the Symposium Held in Harbin, People's Republic of China June 9–18, 1998

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Introductory Remarks

Rey C. Stendell

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I appreciate the opportunity to be in Harbin and participate in the International Scientific Workshop on Cranes in East Asia. I would like to provide some background information on how this meeting came to be. Almost one year ago, in July 1997, Dr. Kun John of the Seoul National University contacted the U.S. Geological Survey's Midcontinent Ecological Science Center (MESC) requesting that we host a meeting of scientists from the Republic of Korea (ROK) and the Democratic People's Republic of Korea (DPRK) to discuss the biology and ecology of cranes on the Korean peninsula. Dr. John and his colleagues expressed concern about three species of cranes that migrate up and down the Korean peninsula and use the Demilitarized Zone. The species of interest are the Red-crowned Crane, White-naped Crane, and the Hooded Crane. The primary question was the conservation of these species in this part of the world. Another concern involved exploring potential economic values and opportunities associated with these species. Richard Johnson, an economist at MESC, assumed responsibility as the primary MESC contact to help bring about this meeting.

During the fall of 1997 there was much discussion and investigation into the possibility of conducting this meeting in Fort Collins, Colorado. Mr. Johnson and I quickly discovered that it would be difficult, if not impossible, for us to communicate with scientists in the DPRK. We also learned that it would not be possible for DPRK scientists to travel to the United States to participate in this meeting. In November 1997, Dr. Zou Hongfei of the Northeast Forestry University (NFU) arrived at MESC to begin a 6-month post-doctoral appointment. Dr. Zou, Mr. Johnson, and I began discussing other options for conducting this workshop. We quickly realized that the best option was for us to travel to NFU. We contacted my colleague and good friend, Ma Jianzhang, Dean of the College of Wildlife Resources at NFU, and he agreed. We decided that the NFU and MESC would co-host the workshop. After much planning and hard work, we are here today in the beautiful city of Harbin.

Early in the planning stages for this workshop we decided to expand the scope from cranes on the Korean peninsula to include all cranes in Northeast Asia. Invitations to the workshop were sent to scientists in China, Japan, Russia, as well as ROK, and DPRK. It is good to see that we have representatives from most of the countries invited. In addition, we decided to emphasize the use of radio-telemetry for tracking cranes by conducting a training session on telemetry techniques. I contacted two colleagues at the U.S. Geological Survey's Western Ecological Research Center in California, Dr. John Takekawa and Dennis Orthmeyer. Both have extensive knowledge and expertise in radio-tracking large birds. They agreed to participate and are here with us today.

Radio-telemetry is an important technique for studying crane ecology. Exciting new research and technology contribute to our knowledge for management of crane populations. I see at least two very important applications that will contribute to the conservation of cranes in Northeast Asia. The first is knowledge of long distance migration patterns of the various crane species. This information can be used to identify critical stopover areas, such as wetlands, that can be protected. The second is knowledge of local movements that can be used to document areas of crane use, for example to see whether or not they are within protected areas. Radio-tracking cranes in Northeast Asia can provide the needed information. Much exciting work has been done, but there is an urgent need for continuation of this work to insure the protection and preservation of these species.

I would like to thank the following people who were instrumental in organizing this workshop: Dr. Li Jian, President of NFU, for making the facilities of this university available; Ma Jianzhang for his

enthusiasm and efforts in organizing and hosting the workshop and contacting the participants; Dr. Zou Hongfei, Dr. Kun John, and Mr. Richard Johnson for serving as coordinators for the workshop and doing much of the thinking, planning, and organizing; Dr. John Takekawa and Mr. Dennis Orthmeyer for conducting the telemetry training; and Dr. Kun John for developing the idea and being persistent with Mr. Johnson and me to insure that the workshop was conducted.

I thank everyone for their roles in organizing this workshop. Thanks to everyone for coming.

Funding to support this workshop was provided by the Chinese Ministry of Forestry, Heilongjiang Wildlife Conservation Association, U.S. Geological Survey, and U.S. Fish and Wildlife Service.

Special thanks are due to Dora Medellin for final editing of the manuscripts and desktop publishing and Dale Crawford, who did the figures.

The Status and Conservation of Cranes in China

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Cranes are large waterbirds. Of the world's 15 crane species, nine (60%) occur in China. Due to habitat losses, their populations are decreasing. Some species are currently classified as endangered and require protection. In order to save these crane populations from further declines, a great deal of research and protection work has been accomplished in China.

Progress on Crane Research

Crane research in China began in the late 1970's. It expanded quickly with the development of crane conservation worldwide. Following the 1987 International Crane Workshop in Qiqihar, China, crane research was rapidly promoted and developed throughout the country. That year, some 108 papers and research reports on cranes were published, including 80 papers in the *Proceedings of the 1987 International Crane Workshop* (Harris 1991).

After the 1987 workshop, crane research in China continued at a high level. From 1987 through August 1996, a total of 180 papers on cranes were published in China (Table 1), representing an annual average of 18 papers. Fifty-one papers (28%) were on the Red-crowned Crane (*Grus japonensis*) and another 30 on the Black-necked Crane (*Grus nigricollis*). When evaluated by research topic, 56 papers (31%) were on crane ecology and conservation (Table 1). Following the 1986 workshop, (Harris 1991), papers on captive breeding and rearing, disease prevention, and anatomy increased and now comprise 47 (26%) of the total papers.

In the last decade, crane conservation and research have made many achievements, primarily in the following four areas:

- Surveys of the numbers and distribution of Black-necked Cranes were conducted. The Black-necked Crane population is estimated at 5,500 birds.
- Using satellite-tracking techniques, we determined that the main migration route of Hooded Cranes (*Grus monachus*) and Red-crowned Cranes traveling from China to Japan is through the Korean Peninsula. Red-Crowned Cranes also migrate to Yancheng Nature Reserve, Jiangsu Province and Hanjiang Basin in Korea.
- By December 1999, over 50 nature reserves for crane protection were established.
- In 1996, the Ministry of Forestry established The Wetland Monitoring Center of China in Beijing. The center collects, manages, and stores data on China's wetlands and waterbirds.

Table 1. The subject of papers on cranes published in China, 1987–1996.

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Total
General reviews	7	3	1	3	2	3	1	4	1	2	27
Taxonomy and distribution	7	10	5	3	7	3	4	3	2	1	45
Ecology and conservation	11	6	6	1	10	6	2	7	4	3	56
Physiology and biochemistry	-	-	-	-	1	1	1	-	-	2	5
Anatomy	3	1	2	-	1	-	-	-	-	1	8
Captive breeding and rearing	-	2	1	2	1	5	-	8	4	1	25
Disease prevention and treatment	-	1	-	-	2	1	1	6	3	-	14
Total	28	23	15	9	24	19	10	28	14	10	180

The Status and Distribution of Cranes

Within China, seven of the nine species of cranes breed, one winters, and one winters occasionally. Since 1987, we have conducted several successful studies on crane populations and distributions, ecology, and conservation. The number and distribution of nature reserves established to protect cranes in China are shown in Table 2.

Demoiselle Crane (Anthropoides virgo)

Demoiselle Crane is the smallest crane. It breeds primarily in northeast China, Inner Mongolia Autonomous Region, and Gansu Province. They are observed frequently in eastern Inner Mongolia Autonomous Region during the breeding season, but their numbers are declining. During migration, they can be seen in Hebei, Liaoning, Shandong, Shanxi, and Henan Provinces. They winter in Hubei, Hunan, Jiangxi, and Anhui Provinces. Little is known about their wintering areas in China.

Sandhill Crane (Grus canadensis)

Occurrence of the Sandhill Crane in China is accidental. A crane was captured in Muyang, Jiangsu Province (January 1979). Dr. G. Archibald of the International Crane Foundation (Baraboo, Wisconsin) observed a second crane at Poyang Lake Nature Reserve, Jiangxi Province during the winter of 1986.

Hooded Crane (Grus monachus)

The Hooded Crane is medium-sized. Historically, breeding occurred at Three River Plain, Heilongjiang Province and Hulunbeir Lake, Inner Mongolia Autonomous Region. In recent years, no nests or chicks have been found in these areas. In April 1991, one nest was found at Tongbei Forestry Farm, Heilongjiang Province. Subsequent surveys estimated a breeding population of three to five pairs. During migration, Hooded Cranes can be seen in Heilongjiang and Liaoning Provinces. Large numbers have been recorded at Lindian, Heilongjiang Province (423 birds, spring 1992). Two migratory routes have been identified. The first begins in Siberia, continues to Wusuri River on the Korean Peninsula, and then goes on to Japan. The second begins in Far-East Russia, passes over Lindian, Baicheng, Panjin, Beidaihe, and Wudi. Birds using this route winter in the lower reach of Yangtze River, including Caohai Natural Reserve, Guizhou Province, and the Huanghe River Delta, Shandong Province. Wintering birds have also been observed at Shenjin Lake, Anhui Province (370 birds, 1991); Poyang Lake, Jiangxi Province (358 birds, 1990); Longgan Lake, Hubei Province (270 birds, 1990); and Dongting Lake, Hunan Province (38 birds, 1991). The total wintering population in the lower reaches of Yangtze River is about 1,000 individuals.

Siberian Crane (Grus leucogeranus)

The Siberian Crane is one of the largest cranes in the world. Reportedly, they bred at Dalai Lake, Inner Mongolia Autonomous Region and Qiqihar, Heilongjiang Province; however, breeding has never been confirmed. They are observed exclusively during migration and winter. During migration, they can be seen in northeast China and Hebei Province. Birds have been recorded at Momoge Nature Reserve, Jilin Province (422 birds, spring 1985; 133 birds, fall 1985) and at Beidaihe Seashore, Hebei Province (577 birds, October 1990). Siberian Cranes winter primarily in the lower reaches of Yangtze River. The most important wintering ground is Poyang Lake, Jiangxi Province, where about 3,000 individuals wintered in 1994.

Common Crane (Grus grus)

The Common Crane is called the "modern crane." This species is known to change their migration route as a way of adapting to environmental changes. They are widely distributed and are China's most abundant cranes. They breed in northwest Xinjiang Province, east Inner Mongolia Autonomous Region, and southeast Heilongjiang and Jilin Provinces. During migration they can be seen in northeast and northern China, including Wafandian, Liaoning Province (1,500 birds, October 1993). They winter south of the Huanghe River, and in Liaoning, Beijing, Shandong, Xinjiang, Guizhou, and Yunnan Provinces. The most famous wintering ground for the Common Crane is along the Huanghe River at Hejun, Shanxi Province where over 3,000 birds winter. Other important wintering area include Caohai Nature Reserve, Guizhou Province (1,000 birds, 1993); Pangzai, Henan Province (981 birds,

Table 2. The 50 Chinese nature reserves established for crane protection.

No.	Name	Location	Area (ha)	Species	Date established
1	Honghe	Tongjiang, Heilongjiang P.	16,333	Cranes	1984
2	Liansanpao	Fujin, Heilongjiang P.	2,000	Red-crowned Crane	1988
3	Xinglung	Fujin, Heilongjiang P.	8,400	Red-crowned Crane	1986
4	Changlindao	Baoding, Heilongjiang P.	10,000	Red-crowned Crane	1989
5	Qixinghe	Baoding, Heilongjiang P.	20,000	Red-crowned Crane	1992
6	Xingkai Lake	Mishan, Heilongjiang P.	222,482	Red-crowned Crane	1986
7	Yangdali	Tonghe, Heilongjiang P.	3,534	Red-crowned Crane	1988
8	Heiyupao	Daqing, Heilongjiang P.	14,000	Cranes	1988
9	Changjigang	Gannan, Heilongjiang P.	87,500	Red-crowned Crane	1988
10	Fuyu	Heilongjiang P.	86,533	Red-crowned Crane	1984
11	Zhalong	Qiqihar, Heilongjiang P.	210,000	Red-crowned Crane	1984
12	Chaganhu	Qian Gorlos, Jilin P.	62,800	Cranes	1986
13	Monoge	Zhenlai, Jilin P.	144,000	Cranes	1981
14	Xianghai[a]	Tongyu, Jilin P.	105,470	Cranes	1981
15	Kerqin	Keyouzhongqi, Inner Mongolia	136,000	Red-crowned Crane	1985
16	Dalaihu	Xin Barhu, NeiMongolia	400,000	Cranes	1986
17	Dalinor	Keshiketeng, NeiMongolia	92,763	Red-crowned Crane	1987
18	Shuangtaihe	Panjin, Liaoning P.	80,000	Red-crowned Crane	1985
19	Donggou	Donggou, Liaoning P.	77,000	Cranes	1992
20	Lotus Hill	Beidaihe, Hebei P.	150	Cranes	1990
21	Gold Coast	Changli, Hebei P.	130,000	Cranes	1990
22	Hejin	Hejin, Shanxi P.	4,689	Common Crane	1993
23	Tanyang	Wudi, Shandong P.	10,000	Cranes	1985
24	Huanghe Delta	Dongyin, Shangdong P.	153,000	Cranes	1992
25	Nansihu	Weishan, Shangdong P.	126,400	Cranes	1982
26	Huanghe Old Way	Weihui, Henan P.	3,000	Common Crane	1988
27	Xiangyang Reservoir	Sihong, Jiangsu P.	10,000	Cranes	1985
28	Yancheng	Yancheng, Jiangsu P.	453,000	Red-crowned Crane	1983
29	Xinglongsha	Qidong, Jiangsu P.	6,000	Red-crowned Crane	1989
30	Shengjinhu	Dongli, Auhui P.	33,300	Hooded Crane	1986
31	Longgan Lake	Huangmai, Hubei P.	800	Hooded Crane	1988
32	East Dongting Lake[a]	Yueyang, Hunan P.	190,300	Cranes	1982
33	Muping Lake	Hanshou, Hunan P.	26,680	Siberian Crane, Hooded Crane	1991

Table 2. Concluded.

No.	Name	Location	Area (ha)	Species	Date established
34	Poyang Lake[a]	Yongxin, Jiangxi P.	22,400	Siberian Crane White-naped Crane	1983
35	Jiujianghuang	Nanhai, Guangdong P.	3,000	Common Crane	1985
36	Small	Akesai, Gansu P.	850	Black-naped Crane	1982
37	Big Sugansu	Akesai, Gansu P.	3,500	Black-naped Crane	1982
38	Ganhaizi	Yumen, Gansu P.	670	Black-naped Crane	1982
39	Heihe	Gaotai, Gansu P.	4,853	Black-naped Crane	1992
40	Gahai	Luqi, Gansu P.	10,800	Black-naped Crane	1982
41	Bird Isle[a]	Gangca, Qinghai P.	708,000	Black-naped Crane	1986
42	Longbaotan	Yushu, Qinghai P.	10,000	Black-naped Crane	1986
43	Shenzha	Shenzha, Xizang AG.	4,000,000	Black-naped Crane	1993
44	Pengpo	Linzhou, Xizang AG.	9,680	Black-naped Crane	1984
45	Napahai	Zhongdian, Yunnan P.	2,400	Black-naped Crane	1984
46	Bitahai	Zhongdian, Yunnan P.	14,181	Black-naped Crane	1984
47	Lugo Lake	Ninglang, Yunnan P.	8,133	Black-naped Crane	1986
48	Dashanbao	Zhaotong, Yunnan P.	19,200	Black-naped Crane	1990
49	Changhaizi	Huize, Yunnan P.	11,387	Black-naped Crane	1990
50	Caohai	Weining, Guizhou P.	12,000	Black-naped Crane	1985

[a]Wetlands of the Ramsar Convention.

1993); and Huanghe River Delta, Shandong Province (740 birds, 1995).

Red-crowned Crane (Grus japonensis)

The Red-crowned Crane is the most famous crane in China. Historically their breeding grounds were widely distributed across eastern China. Today they breed primarily in Heilongjiang Province, with lesser numbers breeding in Jilin and Liaoning Provinces, and Inner Mongolia Autonomous Region. An estimated number of birds include 64 at Xingkai Lake Nature Reserve, Heilongjiang Province (May 1991); 100 at the Three River Plain, Heilongjiang Province; and approximately 70 at Shuangtai Nature Reserve, Liaoning Province. During migration, Red-crowned Cranes can be seen in Jilin, Liaoning, Hebei and Shandong Provinces. Migrants have been recorded at Beidaihe Seashore, Hebei Province (533 birds, October 1990), the lower reaches of the Tumen River, Jilin Province (87 birds) and Liaoning Province (280 birds, fall 1991). Red-crowned Cranes winter primarily in the lower reaches of the Yangtze River, with some also wintering in Shandong and Henan Provinces. The most important wintering ground for the Red-crowned Crane is Yancheng Natural Reserve, Jiangsu Province (877 birds, January 1995). Wintering birds have also been recorded from Huanghe River Delta (46 birds, 1995) and Hongze Lake, Hunan Province (78 birds, January 1990).

White-naped Crane (Grus vipio)

White-naped Cranes breed in the lower reaches of Wuyuer River and Xingkai Lake, Heilongjiang Province, Xianghai Nature Reserve, Jilin Province, and Dalinor Lake, Inner Mongolia Autonomous Region. China's breeding population is declining. During migration, the White-naped Crane can usually be observed in Liaoning, Shandong, and Hebei Provinces including at Beidaihe Seashore, Hebei (68 birds, October 1990). They winter primarily in the lower reaches of Yangtze River, with lesser numbers found in Tianjin, Shandong, and Henan Provinces. The most important wintering ground is Poyang Lake, Jiangxi Province. Over 3,000 birds were observed in January 1989; however, the Poyang Lake population has declined in more recent years (679 birds, January 1991; 330 birds, January 1992; Dongting Lake, 16 birds, January 1992).

Black-necked Crane (Grus nigricollis)

Black-necked Cranes are found exclusively on plateaus. They breed in grassy marshlands above 4,000 m on the Qinghai-Tibet Plateau. Birds have been observed summering in the Ruoergai marshes, Sichuan Province. They winter in Yunnan and Guizhou Provinces, and in the Tibet Autonomous Region. Wintering populations have been recorded at Caohai Nature Reserve, Guizhou Province (285 birds, January 1993) and along the Lhasa River, Tibet Autonomous Region (661 birds, winter 1992). The total wintering population is estimated at 5,600–6,000 birds (Bishop 1996).

Sarus Crane (Grus antigone)

The Sarus Cranes occur in very small numbers. Historically, they were observed only in east and southeast Yunnan Province. There is one record of 600 birds at 3,300 m at Posnec, Yunnan Province. From 1959 until the mid-1970's, 5–10 birds were observed and/or captured. There are no recent records of this species in China.

Recommendations for Crane Conservation

- Strengthen crane management.
- Establish a nature reserve network that includes crane breeding and wintering grounds.
- Expand management and protection at important breeding and wintering grounds.
- Monitor crane conservation efforts and results annually.
- Establish a database and management system. The Ministry of Forestry has established The Wetland Monitoring Center of China in Beijing.
- Establish an international information system on crane conservation that emphasizes Asian cranes.

- Strengthen public education.
- Heighten people's awareness of crane conservation, especially for those residents living in nature reserves.
- Strengthen law enforcement. Promote the Wildlife Conservation Law and other laws concerning wildlife. Strengthen laws for the conservation of cranes and their habitats.
- Publish a crane newsletter. Increase information exchange between official organizations, non-governmental organizations, and nature reserves.
- Prepare a multi-party agreement on crane conservation in Asia.

References

Bishop, M. A. 1996. Black-necked Crane Species Account. Pages 184–193 *in* C. D. Meine and G. W. Archibald, editors. The cranes: Status survey and conservation action plan. ICUN, Switzerland and Cambridge, UK.

Goroshko, O. 1995. Russian cranes in China. Pages 530–532 *in* H. Prange, editor. Crane research and protection in Europe. European Crane Working Group. Deutsche Lufthansa Ag. Frankfurt.

Harris, J., editor. 1991. Proceedings 1987 International Crane Workshop. International Crane Foundation, Baraboo, Wisconsin.

Higuchi, H. 1991. Cooperative work on crane migration from Japan to the USSR through Korea and China. Pages 189–20I *in* T. Salathe, editor. Conserving migratory birds. International Council for Bird Preservation Technical Publication No. 12. ICBP, Cambridge. UK.

Higuchi, H., K. Ozaki, K. Golovushkin, O. Goroshko, V. Krever, J. Minton, M. Ueta, V. Andronov, V. Ilyashenko, N. Kanmuri, and G. Archibald. 1994. The migration routes and important rest sites of cranes satellite tracked from south-central Russia. Pages 15–25 *in* H. Higuchi and J. Minton, editors. The future of cranes and wetlands. Wild Bird Society of Japan. Tokyo, Japan.

Lu, J. 1990. Wetlands in China. East China Normal University Press. Shanghai, China.

Ma, Y., and X. Li. 1990. Status of Red-crowned Crane resources in China. Territory and Natural Resources Research I:62–65.

Ma, Y., and X. Li. 1992. The numerical distribution of cranes in China. Animal Magazine of Natural History (232):38–42.

Ma, Y., and X. Li. 1994. The conservation of endangered species crane in China. Pages 761–763 *in* B. Li and Z. Chan, editors. Proceedings of the First Conference on National Parks and Protected areas in East Asia (CNPPA/IUCN). Beijing.

Ma, Y., and X. Li. 1994. The population and habitat of cranes in China's nature reserves. Pages 141–145 *in* H. Higuchi and J. Minton, editors. The future of cranes and wetlands. Wild Bird Society of Japan, Tokyo.

Ma, Y., and X. Li. 1995. The status of the Red-crowned Crane in China. Pages 316–324 *in* H. Prange, editor. Crane Research and Protection in Europe. European Crane Working Group, Deutsche Lufthansa AG. Frankfurt.

Ozaki, K., and T. Baba. 1994. Recoveries and resightings of color banded Hooded and White-naped Crane *Grus monachus* and G. *vipio*, in northeast Asia. Pages 32–40 *in* H. Higuchi and J. Minton, editors. The future of cranes and wetlands. Wild Bird Society of Japan. Tokyo, Japan.

Status and Habitat Use of Cranes in the Republic of Korea During Winter

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Of the 15 species of cranes (Howard and Moore 1980), eight occur as migrants or winter residents in the Republic of Korea (ROK). They include: White-naped (*Grus vipio*), Red-crowned (*G. japonensis*), Hooded (*G. monachus*), Common (*G. grus*), Demoiselle (*Anthropoides virgo*), Siberian (*G. leucogeranus*), and Sandhill Crane (*G. canadensis*), as well as Common/Hooded crane hybrids (Won 1981, 1988).

Recent habitat losses and environmental changes threaten cranes that regularly winter in Korea. Cranes are large, wetland birds. Their decline is related to wetland destruction and degradation in Korea. Effective and appropriate protection and management of the wintering grounds are needed (Chan 1999). This study was conducted to clarify the current wintering status and habitat use of cranes in the Republic of Korea.

Study Area

We surveyed the status and distribution of wintering cranes at eight sites (Fig. 1): Cholwon Basin area, Imjin River, Han River Estuary, Panmunjom, Kanghwa Island, Taegu, Naktong River, and Sunchon Bay.

Methods

We conducted surveys from November 1997 to February 1998. Numbers of wintering cranes were counted and recorded simultaneously at all observation points, hourly from 0600–1700 h. Observers recorded number of cranes per species, direction in which cranes flew, and the location of feeding sites. Roost observations were made from 30 minutes before sunrise until all roosts were vacated and in the afternoon until darkness prevented further observations. In the Demilitarized Zone (DMZ), morning observations at roost sites continued for 30 minutes after the last cranes departed.

Fig. 1. Wintering grounds of cranes in the Republic of Korea.

Observers used a telescope (20–30X) and binoculars (8 X 30). Study sites were subdivided for purposes of recording crane locations. At Cholwon Basin, we sampled rice seed availability in crane habitats. Based on crane distribution, we divided the basin area into three areas: ICM, WHM, and 8GP. Within each area we randomly sampled 100, 30 cm^2 quadrats. All soil and vegetation were removed from each quadrat. At the laboratory, we counted the number of rice seeds in each sample.

Status of Wintering Cranes

Cranes wintered at all eight study sites. (Fig 1). Cholwon Basin is the most famous crane wintering ground in Republic of Korea. Peak wintering populations for 1998 were 248 Red-crowned and 305 White-naped Cranes. The Cholwon Basin is located in a valley that links Pyonggyang and Seoul. A wide corridor of grasslands and wetlands marks the path of the DMZ across the basin. Rice paddies occur in the buffer zone stretching south from the DMZ (Forestry Research Institute 1998; Lee and Rhim 1999).

The Imjin River study site was divided into three sub-areas, Changdan, Machongni, and Chopyongdo. These three areas are similar: they include tidal mudflats bordered by rice paddies that are used by wintering cranes. Cranes prefer harvested and uncleared rice paddies in this area; however, mudflats are readily available. Satellite-tracking by the Wild Bird Society of Japan found that the area between Changdan and the mouth of the Sachon River is an important crane stopover site (Chong et al. 1994; Chong and Morishita 1996).

The Taegu and Naktong River wintering grounds have been destroyed by development, including construction of dams and automobile factories. A new airport impacted the Kanghwa Island wintering grounds.

Hooded Cranes were discovered wintering at Sunchon Bay in 1996. Approximately 80 cranes winter here. At Sunchon Bay, foraging and roosting sites are separate areas (Fig. 2). Hooded Cranes forage in farmlands and reed mudflats, and roost at night in the bay waters at the edge of the reed mudflats. This is similar to the habitat-use patterns of Red-crowned and White-naped Cranes in Cholwon Basin, where foraging and roosting sites are also separate (Kaliher 1993).

Fig. 2. Distribution of Hooded Crane (*Grus monachus)* in Sunchon Bay, Republic of Korea (10 January 1998).

Figure 3 shows the distribution of Red-crowned and White-naped Cranes in Cholwon Basin on 16 February 1995. Both species were distributed throughout the basin. The highest numbers occurred between Ice Cream Mountain and Kangsan Reservoir (Lee and Kaliher 1995, 1996; Lee and Rhim 1999). The rice paddies around Ice Cream Mountain were good crane foraging sites (Fig. 3). Close to the road, however, rice paddies had been turned under so cranes could not easily find rice seeds. Difficulties locating food could have affected crane distribution.

Following road construction, crane distribution changed. With increased disturbance from high-speed vehicles, most cranes moved to another area. Numbers declined between Ice Cream Mountain and Kangsan Reservoir (Fig. 4). Habitat losses and environmental changes caused by the new road and agricultural practices may be affecting crane distribution.

Within Cholwon Basin, there were differences in rice density between sites. The density of rice (seeds/30 cm^2) was highest in area 8GP (37 ± 7.25, 0 ± S.E.), and lowest at area WHM (5 ± 3.78). There

Fig. 3. Distribution of Red-crowned Crane (*Grus japonensis*) and White-naped Crane (*G. vipio*) in Cholwon Basin, Republic of Korea (16 February 1995).

Fig. 4. Distribution of Red-crowned Crane (*Grus japonensis*) and White-naped Crane (*G. vipio*) in Cholwon Basin, Republic of Korea (14 February 1998). Bold line indicates newly built road.

was also a positive relationship between rice density and crane numbers (Table 1). The highest Red-crowned and White-naped Crane numbers occurred in area 8GP and the lowest in area WHM.

These results indicate crane distribution is related to rice seed densities, i.e., to the distribution of food resources. Food supplies are critical for management of wintering crane populations. Rice seeds should be left in the rice paddies for cranes wintering in Cholwon Basin.

Red-crowned Cranes spent more time gleaning and less time alert than White-naped Cranes. Juveniles spent more time gleaning and less time alert than adults. In the afternoon, alert behavior increased while gleaning decreased (Table 2). Red-crowned Cranes and adult cranes seem to be more sensitive to disturbance.

References

Chan, S. 1999. Atlas of key sites for cranes in the North East Asian flyway. Wetland International Japan. 67 pp.

Chong, J. R., H. Higuchi, and U. I. Pak. 1994. The migration routes and important rest-sites of cranes on the Korean Peninsula. Pages 41–50 *in* H. Higuchi and J. Minton, editors. The future of cranes and wetlands. Wild Bird Society of Japan. Tokyo, Japan.

Chong, J. R., and T. Morishita. 1996. Report on conservation measures for important areas of cranes in East Asia. Wild Bird Society of Japan. 219 pp.

Forestry Research Institute. 1998. Report of forest ecosystem survey in Demilitarized Zone and around areas. Forestry Research Institute, Forestry Administration. 289 pp.

Howard, R., and A. Moore. 1980. A complete checklist of the birds of the world. Oxford University Press. Oxford, UK. 39 pp.

Kaliher, F. T. 1993. Population and distribution of wintering and migratory cranes in South Korea, winter 1992–1993. Report to the International Crane Foundation, Baraboo, Wisconsin, USA.

Lee, W. S., and F. T. Kaliher. 1995. Population and distribution of wintering cranes, Seoul, Korea. Field Report, 1995. Report to the International Crane Foundation, Baraboo, Wisconsin, USA.

Lee, W. S., and F. T. Kaliher. 1996. The protection of endangered cranes in Korea. Field Report, 1996. Report to the International Crane Foundation, Baraboo, Wisconsin, USA.

Lee, W. S., and S. J. Rhim. 1999. Current status and management of cranes in Korea. Pages 185–195 *in* Proceedings of the IUCN/WCPA-EA-3 Seoul Conference. Seoul, Korea.

Won, P. O. 1981. Status and conservation of cranes wintering in Korea. Pages 61–65 *in* J. C. Lewis, and H. Masatomi, editors. Crane research around the world. International Crane Foundation, Baraboo, Wisconsin, USA.

Won, P. O. 1988. Present status of cranes wintering in Korea, 1986–1987. Pages 17–28 *in* H. Masatomi, editor. International censuses on *Grus japonensis*, the Tancho or Red-crowned Crane in its wintering grounds 1986–1987. Hokkaido College of Senshu University, Bibai, Hokkaido, Japan.

Table 1. Numbers of Red-crowned Cranes (*Grus japonensis*) and White-naped Cranes (*G. vipio*), and density of rice (seeds/30 cm^2) in Cholwon Basin, Republic of Korea.

	Area		
	ICM	WHM	8GP
Rice density (0 ± SE)	28 ± 4.98	5 ± 3.78	37 ± 7.25
Number of Red-crowned Crane	84	21	173
Number of White-naped Crane	197	57	239

Table 2. Percent time in diurnal behavior by species, time of day, and social status of Red-crowned Cranes (RCC; *Grus japonensis*) and White-naped Crane (WNC; *G. vipio*) in Cholwon Basin, Republic of Korea. Ad = adult; juv = juvenile.

		Behavior			
		Glean	Alert	Locomotion	Other
Time of day	RCC am	74	13	11	2
	RCC pm	28	57	13	2
	WNC am	85	14	1	0
	WNC pm	65	30	2	3
Social status	RCC ad	47	45	7	1
	RCC juv	93	2	4	1
	WNC ad	63	32	2	3
	WNC juv	72	13	2	3
Total	RCC	47	39	13	1
	WNC	78	18	2	3

Status and Distribution of the Hooded Crane in China

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The Hooded Crane (*Grus monachus)*, also referred to as the "mystery crane," and "pot crane" belongs to the Order *Gruiformes*, family *Gruidae*. It is a medium-sized crane. Its Latin name means "nun crane," and refers to the crane's white head and neck and gray trunk appearing similar to a nun in a white hat. The *Red Book* of the International Committee for Bird Protection (ICBP) lists the Hooded Crane as a vulnerable species because of its low population status. CITES lists the Hooded Crane in *Appendix 1*, as an endangered species. In China it is a Class 1 protected animal. The total world population is estimated at 9,400–9,600 birds (Meine and Archibald 1996).

The distribution of the Hooded Crane is limited to northeast Asia, including Siberia (Russia), and northeast Heilongjiang Province for breeding, and southern Japan and lower reaches of Yangtze River, China for wintering. In Russia, there are two breeding areas: Weiliuyi River valley and nearby regions (3,000 km^2), and Bijin River zone of Wushuli River valley (6,000 km^2). Tomusk, Minusk, and Lake Baikal are summer areas used by nonbreeders or as stopover areas.

Hooded Crane wintering grounds are limited to Japan, the Korean Peninsula, and China. In southern Japan, the two wintering areas are Kagoshima and Yamaguchi Counties. In these areas, wetland and rice paddy habitats are limited. Because of artificial feeding, Hooded Crane populations have increased sharply. During the 1980's, an estimated 7,000 Hooded Cranes wintered at Izumi, Kagoshima County, whereas now approximately 9,000 birds winter. This change in status sparked the interest of international crane researchers and in 1988, the International Crane Foundation (ICF) designed a 5-year research plan. We were relieved when during the 1989–1990 winter, 200–300 Hooded Cranes were found wintering at Taegu, west of Qingshand Beidao in the Republic of Korea. This new wintering population may be a result of dispersal from the Japanese population.

In China, Hooded Crane research was limited to a few reports on wintering ecology and migration (Wang 1986,1988; Zhao 1990). Since 1945, there had been no reports of breeding Hooded Cranes. Whether or not the Hooded Crane still bred in northeast China was the subject of heated debate and deep concern among Chinese academic circles and the ICF. We needed to conduct systematic research on endangered species such as the Hooded Crane. So in 1989, Heilongjiang Provincial Wildlife Institute applied to the Chinese Ministry of Forestry to conduct a study on the Hooded Crane. In 1990, the investigation was approved and a research program developed. The objectives of our research were to

determine the status and distribution of Hooded Crane, to verify if it was breeding in China, and to summarize its ecology. Our ultimate goal was to save an endangered species – the Hooded Crane.

Study Sites and Methods

From March–August 1991, we surveyed for breeding Hooded Cranes at Fuyan, Hulim, Raohe, Zhaodong, Mingshui, Lindian, and at Zhalong Nature Reserve. During October–November 1991, we monitored their migration at Beidaihe, Hebei Province. We surveyed Lindian, Heilongjiang Province for migrant cranes twice in 1992, first in spring from March to April and again in fall from September to October.

From December 1992–March 1993 we surveyed the number and distribution of wintering Hooded Cranes at Shengjin Lake Waterfowl Nature Reserve, Anhui Province, and at Longgan Lake, in Huangmei County Hubei Province. At Longgan Lake we also conducted research on their wintering ecology. From March–June 1993 in Heilongjiang Province we monitored spring migration at Lindian County, and discovered a Hooded Crane nest and investigated their breeding ecology in the Tongbei Forest region. We surveyed the population and distribution of Hooded Cranes at Daxinganling, Shanjiang Plain, and the eastern mountainous region of Heilongjiang Province from July–September 1993.

From March–June 1994 we surveyed for migrant Hooded Cranes at Hailar, Inner Mongolia Autonomous Region and Shongnen Plain, Heilongjiang Province, and again searched for nesting Hooded Cranes at Tongbei Forest region. At Heilongjiang Province during 1995 and 1996, we determined the status and distribution of Hooded Cranes at Daxinganling and searched for the breeding cranes in the Xing'an Mountains.

Numbers and Distribution of Breeding Hooded Cranes

The Hooded Crane is a waterbird that inhabits large wetlands. Its breeding distribution primarily depends on specific habitat conditions. This crane prefers building its nest in quiet and remote wetlands surrounded by forests, thus restricting its breeding distribution. Through our surveys and research, we found Hooded Crane breeding grounds at the juncture of Tongbei and Zhanhe Forest regions, located on the west side of the Xing'an Mountains. This is a new record on this crane's breeding distribution in China, and is also an important breakthrough. The Xing'an Mountains are located in the middle part of Heilongjiang Province. They border the Shongnen Plain to the west, and approach Shanjiang Plain to the east. The total area is about 77,888 km^2. Their highest peak, Daqing Mountain is 1,203 m high. The weather in this area is cold and moist. Winters are long, cold, and dry, and summers are short, hot, and rainy. Except for Daqing Mountain, this area is largely low, forested mountains and hills. In the forests, small streams and pools have formed large wetlands that are ideal breeding habitat for the Hooded Crane. As a result of logging over several decades, some wetlands were destroyed and/or drained for farmlands. The increase in human activities has reduced the Hooded Crane's breeding habitat.

As part of our research, we conducted surveys during the breeding season in the Xing'an Mountains. During an 87-day period, we surveyed a total of 72 line transects, totaling 913.5 km. Areas surveyed include Yichun County, the cities of Heihe, Xunke and Jiayin, and the forest regions of Tieli, Shuiling, Tongbei, and Zhanhe. In all, we observed a total of five to seven Hooded Cranes in the Tongbei and Zhanhe Forest regions, but only one pair nested.

According to the *Distribution List of Chinese Birds* (Zheng 1976) Hooded Cranes bred in the Wushuli river valley and Heilongjiang valley, and possibly at Hailar, Inner Mongolia Autonomous Region. In the Wushuli area, we conducted surveys in Fuyuan County, Mishan City, Dongfanghong Forest Bureau and the along the banks of Wushuli River. This region borders Russia's Bijin River Valley, a breeding grounds for the Hooded Crane. We conducted 66 line transects, totaling 78.6 km, over 56 days. We found no Hooded Cranes and determined that they do not breed in the Wushuli River valley.

We investigated the possibility of Hooded Cranes breeding in Heilongjiang valley and at Hailar, Inner Mongolia Autonomous Region. We conducted a survey at Mohe, Tahe, Humeng, and Hailar Counties. Our survey included 69 line transects, totaling 1,024.1 km. We found no evidence of Hooded Cranes at either Heilongjiang Valley or Hailar. We found that the Hailar region is predominantly grassland with few forest wetlands necessary for Hooded Crane

breeding. The Heilongjiang Valley has little human disturbance but the habitat in this area consists of only a few large lakes and few small wetlands in forested areas.

Distribution During Migration

During migration, Hooded Cranes are found primarily at Lindian and Yichun Districts, Heilongjiang Province, Momoge Nature Reserve, Jilin Province, and Beidaihe, Hebei Province. At Lindian County, the Army Horse Farm and Xiaoyushu Village are important spring and fall stopover areas. The highest number we observed was 482 birds (spring 1994). During spring 1992, 243 Hooded Cranes stopped at the southwest pasture and southeast wheat field of the Army Horse Farm. Our final 1992 spring survey on 14 May found 28 and 56 cranes at the south and southwest fields of Xiaoyushu Village. In addition, we observed 48 Hooded Cranes, in 2 flocks of 16 and 32, depart from the roost site and spiral up 70–80 m and then fly westward in a single line.

We found that some cranes stopped at Lindian for a few days before continuing north, where they stayed for long periods. In 1992, the first fall migrants arrived on 6 October and were observed in the cornfield (69 birds) and grass pasture (19 birds) of the southeast corner of the Army Horse Farm. The last flock (39 birds) was observed on 16 October at a reed lake northeast of Langdonggang.

At Yichun District, we observed one family (2 adults, 1 young) during September 1991. At Momoge Nature Reserve, we observed only a few cranes (7–11 birds) stopping over in spring. Beidaihe is on the main migration route of the Hooded Crane, with large numbers migrating through every spring and fall. We recorded 309 cranes in spring 1985, and 527 cranes in fall 1986 (Williams et al. 1987). In fall 1991 we recorded 159 cranes migrating through this region during 4–9 November.

Winter Numbers and Distribution

Based on our research and historical records (Liu et al. 1987; Wang 1988; Zhao 1990), the principal wintering areas in China include:

Longgan Lake, Hubei Province. This 106.2 km^2 area includes a relatively large freshwater lake at 116^o 03' N, 29^o 55' E. In January 1988, 379 Hooded Cranes were found and the following winter 407 birds were observed (Zhao 1990). In March 1993, we observed 13 birds. Presently, Longgan Lake hosts China's largest Hooded Crane wintering population. Throughout the area there are many freshwater lakes, rice fields, small rivers, and canals. Hooded cranes forage in rice fields on waste grain, and less often on rhizomes.

Shengjin Lake, Dongzhi and Chizhou Counties, Anhui Province. This area is located on the south bank of the Yangtze River (30^o 16'–26'N, 116^o 58' 117^o -11'E) and covers a 113.3 km^2 area. Recorded populations include 401 birds (12 March 1991), 237 birds (29 November 1991), 354 birds (4 January 1992), and 309 birds (26 February 1993). Earliest fall arrival was 22 October and latest spring departure 8 April. Most cranes arrive the first 10 days in November and depart the last 10 days in March. Cranes remain at the lake for 145–150 days. Principal winter habitats are the lakeshore and wet meadows. Hooded Cranes forage primarily on plant rhizomes.

Poyang Lake, Jiangxi Province is located at 29^o 05'–15'N, 115° 55'–116° 03' E. This area, which covers 224 km, is located at the north end of the province. During winter's low water period, the lake becomes nine separate lakes. Principal crane habitats include the lakeshores and wet meadows, with farmlands used to a lesser extent. In spring 1985 and 1986, 183 and 210 Hooded Cranes were observed respectively (Wang 1988).

East side of Dongting Lake, Hunan Province. This 1,900 km^2 area is located in eastern Hunan province at 28^o 59' – 29^o 38'N, 112^o 43' – 113^o 15' E. In January 1987, 120 Hooded Cranes were recorded in this area. Principal habitats used by Hooded Cranes for feeding include a large lake and river, wetlands, and some of the rice paddies that border the lake. Rice paddies also serve as the primary roosting habitat.

Taking into account these four major wintering areas, total wintering population of Hooded Cranes in China is approximately 1,000–1,100 birds. This number is less than Japan's wintering population. It is heartening that the Chinese wintering population is distributed into four areas, all nature reserves, including two listed as International Important Wetlands.

Causes of Population Declines

Our research determined that the Hooded Crane builds its nest in scattered wetlands of forested areas. It prefers wetlands in mature forests and uses higher grasses and small shrubs for nest cover. This open nesting habitat allows long-distance visibility, and the water protects the cranes from predators. The area around the nest must include abundant food resources. Due to these strict nest site requirements, Hooded Crane distribution is highly restricted. In recent years logging has reduced forestlands and increased the network of paths crisscrossing between villages. Some Forest Bureaus are facing pressures to open up logged-over areas and undeveloped lands for agricultural development. Meanwhile, suitable breeding habitat for the Hooded Crane is being reduced day-by-day in China. These conditions have forced the Hooded Crane to migrate farther north and breed in Russia, leaving only small, remnant populations in China.

We found in our studies that Hooded Cranes select wetlands in thickly forested, remote areas. The nest we found was approximately 17 km from human habitation, 12 km from the road, and 10 km from human activities. Nest site characteristics are very specific, and their availability is limited in this region. Activities such as fishing and hunting are widespread. People penetrate every possible area and disturb the quiet isolation of the breeding cranes, making it impossible for them to build their nests, lay eggs, and rear young. These human disturbances have caused the Hooded Cranes to abandon their traditional breeding grounds and seek more secure breeding areas.

Recommendations for Future Protection

Given these conditions that have limited the Hooded Crane population, the following actions to protect this endangered species are recommended.

1. Establish a nature reserve that includes existing breeding areas. Immediately cease development of remaining suitable crane habitats. Protect existing forest wetlands and suitable crane habitats. Restore habitats previously used by breeding cranes.
2. Limit human activities, reducing as much as possible disturbance to cranes especially during the breeding season. Reduce fishing and hunting access to the mountains, so that Hooded Cranes return to breed in an undisturbed environment.
3. Strengthen public education and information. Strengthen management of existing nature reserves to protect Hooded Cranes. Build cooperation and communication between wintering areas for protection. Achieve the goal to protect and save the Hooded Crane.
4. Promote active and thorough research on the Hooded Crane. Monitor the population at breeding, migration, and wintering areas.

References

Li, L. 1993. The first breeding record of the Hooded Crane in China. Chinese Wildlife 5:16.

Li, L., R. Piao, J. Wang, Y. Liu, and J. Fu. 1995. The migration research of the Hooded Crane in Lindian. Chinese Wildlife 2:14–17.

Liu Z., B. Chen, and Y. Wang. 1987. The habits of the wintering Hooded and Common Cranes. Pages 61–68 *in* Poyang Lake Nature, editor. Report on Rare Bird Winter Ecology Study at Poyang Lake Migratory Bird Reserve. Jiangxi Scientific Technical Press, Nanchang, Jianxi.

Meine, C. D., and G. W Archibald, editors. 1996. The cranes: Status survey and conservation action plan. ICUN, Switzerland and Cambridge, UK.

Wang, Q., and X. Hu. 1986. Wintering observations of the Hooded Crane at Shengjin Lake. Pages 184–187 *in* Chinese Cranes Research. Heilongjiang Education Publishing House.

Wang, Q. 1988. The Hooded Crane. Zoology Magazine 4:30–34.

Williams, M. D., D. N. Bakewell, G. J. Carey, W. Xu, and L. Jin. 1991. Migration of cranes at Beiidaihe

Beach, Hebei Province, China. Pages 139–147 *in* Proceedings of the International Crane Workshop, 1987. Qiqihar, China.

Yang, Z. 1993. The International Crane Status and Research. Chinese Wildlife 1:12–16.

Zhao, X. 1990. The largest wintering place of the Hooded Crane is located at the Longgan Lake of Hubei Province. Chinese Wildlife 2:20.

Zheng, Z. 1976. The Chinese Birds Distribution Name List. Science and Technology Publishing House.

Cranes and Their Conservation in Huanghe Delta National Nature Reserve, Shandong Province

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Huanghe Delta National Nature Reserve (hereafter referred to as the Nature Reserve) is located at the Huanghe River Delta estuary by Dongying City, Shandong Province. To the north is the Bo Sea, and to the east is Laizhou Bay. The area covers 153,000 ha and is situated at 37° 35' to 38° 12' N, 118° 33' to 119° 20' E, between inland northeast Asia and the Jianghuai Plain. The Nature Reserve is the newest, best protected, and most extensive wetland reserve. It includes the Huanghe River estuary, a relatively recent wetland ecosystem that is used by rare and endangered birds. The Nature Reserve is one of the most important stopover and wintering and breeding areas for birds migrating through the inland northeast Asia-West Pacific Ocean Flyway.

Methods

Since 1990, line-transects, roadside surveys, and sample counts have been conducted to determine crane species, their numbers and distribution, and wintering behavior.

Crane Species

Five crane species are found in the Nature Reserve: Common Crane (*Grus grus*), Red-crowned Crane (*G. japonensis*), Hooded Crane (*G. monachus*), White-naped Crane (*G. vipio*), and Demoiselle Crane (*Anthropoides virgo*). Their migratory and ecological habits are described below.

Common Crane

The Common Crane is an important species wintering in the Nature Reserve. It has the largest population and most widespread distribution among the five species. Common cranes arrive annually at the Nature Reserve after mid-October. Peak numbers are approximately 6,000 birds, with the largest flock observed being more than 300 birds. Upon arrival, Common Cranes are found primarily in loose flocks numbering 100–200. Later these flocks separate into family units containing three to four cranes. Some Common Cranes stage at the Nature Reserve in fall then continue south for the winter, returning to the Nature Reserve in late March. The annual wintering population at the Nature Reserve has remained stable at approximately 1,000 birds. Therefore, this area is an important wintering ground for the Common Crane and is also the northernmost boundary of its winter range.

Sometimes Common Cranes are seen in soybean and wheat fields feeding in mixed flocks with geese and other crane species. Common Cranes are found primarily along the old channels of the Huanghe River, in the estuary, at Dawenliu Wetland, and in farmlands. They feed on tender aquatic grasses, soybeans, winter wheat, mollusks, and crustaceans.

Red-crowned Crane

The Red-crowned Crane is a common species in the Nature Reserve. Most Red-crowned Cranes are

migrants, stopping over for a short time in fall to replenish their energy reserves before continuing south. Only a small population winters here. Migrants pass through the Nature Reserve in mid-October and again from February to early March. During fall migration an estimated 1,000 Red-crowned Cranes can be seen in the Nature Reserve. Approximately 800–900 birds leave after a short stopover, and 100–200 birds remain and overwinter.

Red-crowned Cranes concentrate in estuarine lowlands, the estuary, Dawenliu Wetland, and in wheat and soybean fields. Usually flocks number four to eight birds. Occasionally we have observed up to 20 Red-crowned Cranes in mixed flocks with Common Cranes. Red-crowned Cranes feed on tender aquatic grasses, soybeans, winter wheat seedlings, mollusks, small fish, and shrimp. The species prefers remote areas seldom disturbed by human activity. Promoting conservation of these habitats is of great importance for the protection of the Red-crowned Crane.

Hooded Crane

The population of Hooded Cranes in the Nature Reserve is relatively small. Birds begin arriving in mid-October, stopping for a brief time before continuing south. Fall migration is complete by early November. Hooded Cranes stop over during spring migration, from late March to early April. Annually, about 100 Hooded Cranes migrate through the Nature Reserve, with the largest flocks numbering around 20 birds. They are often seen in mixed flocks with Common Cranes. Primary areas used by the Hooded Crane include the Yiqian'er Administrative Station, Dawenliu Wetland, and the Huanghe River Delta estuary. They feed primarily on winter wheat seedlings, soybeans, and small vertebrates.

White-naped Crane

White-naped Cranes migrate through the Nature Reserve, stopping over briefly during early November and again from late March to early April. About 150 White-naped Cranes can be seen during migration. They are scattered in small flocks in the river estuary, streams, and ponds beside Yiqian'er Administrative Station, and occasionally in wheat fields.

Demoiselle Crane

The Demoiselle Crane is a rare visitor to the Nature Reserve. Three were recorded in 1986, with none observed since then. Further research is needed on this species.

Siberian Crane

Based on results of satellite-telemetry studies conducted by the National Bird Banding Center, the Siberian Crane stops briefly at the Nature Reserve. Due to the short time they stay and their tendency to stop at the river mouth and beach, no other observations have been recorded for this crane. Further research is needed on this species.

Importance of the Nature Reserve

Huanghe Delta National Nature Reserve lies in the middle of the flyway for northeast Asian inland birds that encircles the west Pacific Ocean. The reserve serves as a migratory stopover, wintering, and breeding site. Recent studies have identified nearly 270 avian species breeding, wintering, or stopping over at the Nature Reserve. The 153,000 ha Nature Reserve includes a well-protected wetland that supports abundant food resources and cover. Its good habitat and suitable climate make it an excellent migratory stopover and wintering area. Both national and international scientists have highly acclaimed the Nature Reserve. They noted that this large, well-conserved area provides perfect wintering grounds for cranes.

Principal Threats to Cranes

Oil Exploration and Development

Beneath the Nature Reserve are subsurface natural gas and oil deposits. Gas and oil exploration and development not only destroy large areas of crane habitat (especially wetlands), but also increase the level of human activities. Polluted water and noise negatively impact cranes. Prior to its development in 1992, the Feiyantan Oil Field located in nearby Yiqian'er Administrative Station was the principal nighttime roost site for Common Cranes. Oil

exploration and development in this area have destroyed the ecosystem and increased the level of human activities. As a result, the Common Crane is very rarely seen in this area.

Natural Disasters

Natural disasters impacting cranes refer primarily to storm tides. The elevation of the Nature Reserve is low. Storm tides inundate large areas of uplands, resulting in increased soil salinity and the loss of farmlands. As a result, feeding habitat is reduced and the wintering and migrant cranes cannot obtain enough nutrition. The area around Yiqian'er Administrative Station was once the main wintering site for Common and Red-crowned Cranes. Of the 500–800 Common Cranes wintering in the Nature Reserve, 100–200 regularly use this area. In 1997, a very large storm tide flooded nearly all of this area's farmlands, resulting in a sharp decline in the local population of Common Cranes.

Cessation of Flow in Huanghe River

The Huanghe River flow is the dominant factor forming and maintaining the wetland ecosystem in the Nature Reserve. Since 1995, the river has temporarily ceased to flow, with the duration of flow cessation increasing annually. The Lijjn section of the river ceased to flow for 118 days in 1995, 136 days in 1996, and 226 days in 1997. The annual cessation in river flow combined with significant high evaporation (annual evaporation = 1,962 mm; annual mean precipitation = 592 mm) is reducing wetland habitats and causing soybean and winter wheat crop failures. Both habitat and food resources are decreasing. Although this situation has not yet impacted the cranes very much, the reduced river flow is a very serious threat. Countermeasures must be adopted right now to prevent more serious impacts.

Recommendations for Crane Conservation

Cranes are one of nature's most precious assets. However, environmental problems have caused most crane species to be endangered. Based on our research and analyses, the following recommendations are made:

1. Enhance law enforcement within the reserve. In order to prevent further destruction of crane habitat, strictly prohibit by law activities harmful to the reserve's natural resources.
2. Promote the development of the Nature Reserve and support economic and social benefits to residents.
3. Alleviate poverty for residents around the Nature Reserve by supporting economic efforts that enhance conservation and optimize the natural environment. This is an important new way to build responsible community management and to share economic and social benefits.
4. Promote scientific research and sustainable development. Scientific research provides the basis for Nature Reserve development and conservation of cranes and habitat. On one hand, research should be conducted on crane ecology, environmental changes impacting cranes and their habitat, and habitat restoration to form a scientific basis for effective protection. On the other hand, rational utilization of resources to achieve sustainable development should be pursued to provide economic support for the construction and development of the Nature Reserve.
5. Conserve and restore habitat. Based on scientific research, engineering actions should be taken to conserve and restore crane roosting and feeding habitat. Two issues need to be solved immediately. For areas around Yiqian'er Administrative Station destroyed by storm tides, impounding fresh water to alkalize the soil and restoring the original plant life are necessary to reestablish crane-feeding habitat. At restored feeding areas, further engineering projects are needed to prevent or mitigate the effects of future natural disasters.
6. Enhance public education. Large-scale public education using multiple outlets such as newspapers, radio broadcasting, TV, and movies is an effective way to encourage

people to love and protect birds. Cultivating this attitude will result in their conscious actions to protect cranes and their habitat. Continued public education over the past few years has had some good outcomes. Since 1990, local residents have saved 17 cranes, including Red-crowned, Common, and Hooded Cranes.

Status of Crane Protection in Xingkai Lake National Nature Reserve, China

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Xingkai Lake National Nature Reserve was approved and established by the People's Government of Heilongjiang Province on 27 April 1986, and designated a National Nature Reserve by the State Council of China on 5 April 1994. A Sino-Russian governmental agreement for the reserve was signed in Beijing on 22 April 1996. On 7 March 1997, the reserve was ranked first in the network of crane reserves for northeast Asia. Since 1998, Global Environment Facility (GEF) has designated the reserve as a national demonstration area for the protection of biological diversity and sustainable use of wetlands.

Chinese and foreign experts took an interest in Xingkai Lake National Nature Reserve because this wetland is an exemplary area for biological diversity. There are 292 species of vertebrates including 48 fish, 6 amphibians, 7 reptiles, 192 bird, and 39 mammal species. Of these, four species are first-class protected animals: *Grus japonensis*, *Ciconia boyciana*, *Haliaeetus albicilla*, and *Aquila chrysaetos*. Another 34 species are second-class protected animals and include *Grus vipio*, *Cygnus cygnus*, and *Cervus elaphus*. This area is not only important breeding grounds for numerous waterbirds but also a migratory bird stopover during spring and fall.

From 1987–1996 the Red-crowned Crane (*Grus japonensis*) population declined in the reserve (Table 1). The population steadily decreased from 58–62 birds (1987–1990), to 45–51 birds (1991–1992), to about 40 birds (1993), and was <30 birds from 1994–1996. Similarly, the population of White-naped Cranes (*Grus vipio*) declined from 16–18 birds, including 6–7 breeding pairs, to 6–8 birds, including 2–3 breeding pairs.

At the reserve, protection and management stagnated even though the reserve's importance was constantly promoted and the public's consciousness for protection strengthened. Improper management and unsuccessful protection resulted in increased marsh reclamation and the gradual reduction of waterbird habitats. When the reserve was created, it extended along the 90 km shoreline of large Xingkai Lake from Dangbi Town to Longwang Miao. The reserve boundaries were later reduced to the surface waters on the Chinese side of large Xingkai Lake as well as the marshes along the east side of this lake, and the surface waters of small Xingkai Lake, and Dongbeipaozi, located northeast of small Xingkai Lake. Currently, the total area in the reserve is about 220,000 ha.

Originally, reserve management was inconvenient because it included two state farms, one township,

Table 1. Red-crowned Crane population at Xingkai Lake National Nature Reserve, 1987–1996.

Year	Breeding (no.)	Non-breeding (no.)	1-year old (no.)	Total (no.)
1987	26	18	14	58
1988	28	20	12	60
1989	30	18	14	62
1990	30	16	14	60
1991	26	10–12	13	49–51
1992	28	8–10	9	45–48
1993	14	9–12	14	37–40
1994	8–10	13–14	4–5	26–29
1995	14–16	5–6	4	24–26
1996	-	-	-	27–29

and one aquatic products farm. Therefore, four administrative offices were setup in the reserve in May 1995. Since then 5,300 ha of the central zone where cranes and Oriental White Storks (*Ciconia boyciana*) bred has been legally eliminated from the reserve. Some 2,200 ha were leased for 40 years, and in the south end of the central zone, an additional 2,600 ha of marshlands converted to farmlands. So far, this important central zone has been reduced by one-third. Additionally, in the near future, construction will begin on a 13 km road from the Seventh Production Team, Xingkaihu Farm, to Longwang Miao. In 1996, the 6,600 ha experimental area in the east side of the reserve was leased for 40 years to the Jixi and Qi Taihe Mineral Bureaus. Another 2,000 ha of the reserve's east side around Dongbeipaozi will be reclaimed by the aquatic products farm. This area is used as a breeding ground for ducks, geese, and gulls. Now the reserve's central zone has become an isolated island.

The effect of large forest fires on the cranes reflects improper management and unsuccessful protection practices. For example, three serious fires on 16 April 1993, 23 April 1996, and 19 April 1998 almost burned up the central zone where cranes were incubating. A shortage of operating funds has prevented reserve personnel from investigating population changes in rare birds such as cranes, from gathering data on species and number of waterbirds during spring migration, and from conducting public education campaigns. This National Nature Reserve does not deserve its current situation. Improvements are needed.

It was encouraging news in December 1998 when GEF approved a wetlands protection project for China that includes Xingkai Lake National Nature Reserve. Additionally, the People's Government of Heilongjiang Province has resolved to strengthen wetland protection. These efforts will allow for renewed protection for the Xingkai Lake National Nature Reserve and will attract world attention.

References

Li, W., K. Peng, and R. Piao. 1994. Resources and research on wildlife in Xingkai Lake National Nature Reserve. Harbin Northeast Forestry University Press 6–36.

Protection of Cranes and Wetlands in the Democratic People's Republic of Korea

By

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One of the most important tasks confronting the conservation of biodiversity in East Asia is the protection of cranes and wetlands. Seven of the world's 15 species of cranes occur in the Democratic People's Republic of Korea (DPRK) including: Red-crowned (*Grus japonensis*), White-naped (*G. vipio*), Hooded (*G. monachus*), Common (*G. grus*), Sandhill (*G. canadensis*), Siberian (*G. leucogeranus*), and Demoiselle Crane (*Anthropoides virgo*). Four of these species, Red-crowned, White-naped, Hooded, and Common Crane occur regularly in DPRK. In this paper we provide information on the distribution, numbers, and habitats of these four species, and on status of wetland protection.

Winter Crane Distribution and Ecology

Red-Crowned Crane (Grus japonensis)

Red-crowned Cranes arrive in the DPRK from late October through early December. They return to their breeding grounds in late March. The main wintering areas of Red-crowned Crane are: Sungye ri and Kokjong ri, Ryongyon County; Songnam ri and Buyang ri, Taetan County; Kurang ri, Haebang ri, and Sohae ri, Ongjin County; Dongpo ri, Kangryong County; Yongsan ri, Chongdan County in south Hwanghae Province; and, Dongchang ri, and Jogang ri, Panmun County on the west coast of DPRK. On the east coast they occur at: Ryukhwa ri, and Bisan ri, Anbyon County; Kwangwon Province; and Hwasan ri regions of Cholwon County in central DPRK (Fig. 1).

The wintering population of Red-crowned Cranes in these areas declined from 166 birds in 1991 to 52 in 1998 (Table 1). Taking into account families wintering at other sites, the population is probably less than 100 birds. Currently, the principal wintering area is Taedong Bay in Ryongyon County, South Hwanghae Province. This is a wintering and migratory stopover area for many birds because of its protected coastline, large mudflats, and mild winter climate. It was designated a State Migratory Bird (wetland) Reserve in 1995 and comprises 2,000 ha. At Taedong Bay, Red-crowned Cranes inhabit wetlands throughout the day and roost in the intertidal areas. Feeding areas are located within 10–12 km of the roost site. The activities of the Red-crowned Crane are closely related with the tidal cycle. They feed in tidelands during the falling tide, and in rice paddies during the rising tide.

White-naped Crane (Grus vipio)

White-naped Cranes arrive in the DPRK from early to mid-November. The species occurs at Ongjin, Baechen, Panmun of Kaesong City; at Mundok and Onchon, south Pyongan Province; and at Ryongyon, south Hwanghae Province. The main flock migrates to Kyusu lzumi, Japan. A few cranes overwinter in the fields and wetlands at Panmun, Cholwon area.

Fig. 1. Crane distribution in the Democratic People's Republic of Korea.

From 1991–1998, approximately 30 cranes overwintered in the agricultural fields along the Sachon and Rimjin Rivers located in Panmun County of Kaesong City.

Hooded Crane (Grus monachus)

Hooded Cranes migrate through the DPRK during mid- to late November, stopping for one to two days at the Chongchon River estuary before continuing on to their Japanese wintering grounds. Every year, 1–2 birds overwinter with the Red-crowned Crane flock at Ryongyon County, south Hwanghae Province.

Common Crane (Grus grus)

Thirty to 50 flocks stopover during fall and spring migration at the Chongchon River estuary. No wintering areas have been detected in the DPRK although one or two birds sometimes overwinter with Red-crowned Cranes.

Major Stopover Areas for Migratory Cranes

Because it is located on a large peninsula, the DPRK is a major stopover area for migratory birds from northeast Asia. Our study shows that the main stopover areas for cranes on the DPRK's west coast are Chongchon River estuary, Taedong Bay, 9.18 Reservoir Chongdan County, and Panmun County. On the east coast, important sites include Keumya River estuary and the Tuman River. Satellite tracking from 1991–1993 identified the Chongchon River estuary, Panmun area, and Keumya River estuary as principal migratory crane stopover areas.

In order to protect migratory birds and to implement the "Convention on Biodiversity," the Government of DPRK in 1995 designated 12 State Migratory Bird (wetland) Reserves (Table 2), of which the following have state and regional significance as crane habitats.

Mundok Migratory Bird Reserve

This 3,000 ha estuarine reserve is located at the mouth of the Chongchon River on the west coast of the DPRK, in the middle of Pyongan Province by Dongrim ri. A total of 152 bird species occur here, representing 13 orders, 20 families, and 76 genera. This area is a major stopover area for Red-crowned, White-naped, Hooded, and Common Cranes (Table 3). It is also a stopover and wintering area for ducks and geese, and a stopover area for snipe. Excluding cranes, rare species include *Anser cygnoides*, *Otis tarda*, *Tringa gutiffer*, and *Platalea*

Table 1. Wintering populations of Red-crowned Cranes, Democratic People's Republic of Korea, 1991–1998.

Dates	Ryongyon	Taetan	Ongjin	Kangryong	Chongdan	Cholwon	Anbyon
12/91–1/93	68	27	19				52
12/92–1/93	61	5	13	3			19
12/93–1/94	45	41	41	3	21	1	24
12/94–2/95	50	8	8		5	*	8
1–2/96	39				3	*	
1–2/97	29				7	*	
1–2/98	46		6			*	

*Not surveyed.

Table 2. Migratory bird (wetland) reserves in the Democratic People's Republic of Korea.

No.	Name	Location	Size (ha)	Year established
1	Keumya	Keumya County, South Hamgyong Province	2,000	1995
2	Mundok	Mondok County, South Pyongan Province	3,000	1995
3	Ryongyon	Ryongyon County, South Hwanghe Province	2,000	1995
4	Chongdan	Chongdan County, South Hanghae Province	1,000	1995
5	Sindo	Ryongchon County, North Pyongan Province	1,000	1995
6	Ongjin	Ongjin County, South Hwanghae Province	1,000	1995
7	Unryul	Unryul County, South Hwanghae Province	800	1995
8	Chonapo	Tongchon County, Kangwon Province	700	1995
9	Lake Dongjong	Tongchon County, Kangwon Province	800	1995
10	Kwangpo	Jongpyong County, South Hamgyong Province	2,000	1995
11	Orangchon	Orang County, North Hamgyong Province	1,500	1995
12	Sonbong	Rajin-Sonbong City, North Hamgyong Province	3,200	1995

Table 3. Numbers of cranes at Mondok Reserve during March, 1993–1998, as determined from diurnal observations.

Year	Red-crowned Crane	White-naped Crane	Hooded Crane
1993	76	298	2,246
1994	23	49	1,653
1995	38	155	2,325
1996	39	330	540
1997	31	167	1,286
1998	25	161	1,003

minor. The principal crane roosting area is located at Ryodo, a delta formed by sediments from the Chongchon and Taeryong Rivers. Cranes forage over a 1,200 ha area centered at Ryodo that includes the riverbanks and rice paddies of the Chongchon River estuary (Table 4). Tidelands are the primary feeding area. Red-crowned cranes forage over 500 ha, White-naped Cranes over 450 ha, and Hooded Crane over 970 ha of tidelands. Cranes forage for 12.0 to 12.5 hours per day, including 9 to 11.0 h in tidelands, and 1.5 to 3.0 hours in rice paddies.

Keumya Migratory Bird Reserve

This reserve is located on DPRK's east coast, at the edge of Songjon Bay by Hodo peninsula, where the Keumya and Dokji Rivers flow in to Songjon Bay. Estuaries are the principal habitat used by cranes and other migratory birds. Red-crowned and White-naped Cranes occur here during migration (Table 5). The Keumya Reserve includes arable fields, tidelands, and reed fields in the middle of the Keumya and Dokji River Deltas. The area is rich with aquatic grasses. The principal crane roost site is Yudo Island, an isolated island in the Keumya River estuary with foraging areas up to 8 km away. Within the reserve, foraging habitat is unevenly used (Table 6). Foraging areas are often located 0.5 to 1.0 km away from villages. The construction of salt fields in this area has doubled the distance from the roost to areas used for foraging. A total of 126 bird species occur in this reserve, including 70 waterbirds. Estimated numbers for some of the rare species include *Ciconia boyciana* (1–2), *Otis tarda* (3–4), *Cygnus olor* (20–30), *C. cygnus* (300), *C. bewickii* (70–80), *Aythya baeri* (15–20), *Larus saundersi* (3–5). Rare raptors include: *Haliaeetus albicilla*, *H. pelagicus*, *Aquila heliaca*, and *A. chrysaetos*.

Other Significant Wetland Reserves

The above-mentioned Mundok and Keumya Reserves have state and regional significance for protection of cranes. Other significant reserves with cranes include Ryongyon, Chongdan, Ongjin, and Sonbong Migratory (wetland) Bird Reserves. The protection of cranes in the DPRK is closely related

Table 4. Crane foraging habitats at Mondok Reserve.

Area	Total area (ha)	Field (km^2)	Tideland (km^2)	Location
Often used	6.1	0.9	5.2	Dongrim ri, Ryongo ri Ryongo Island, Yodo
Rarely used	5.8	1.6	4.2	Dongrim ri, Ryongo ri, Inhung ri

Table 5. Number of cranes observed at Keumya Reserve, spring 1993–1997.

Species	1993	1994	1995	1996	1997
Red-crowned Crane	54	63	101	95	102
White-naped Crane	401	440	400	450	350

Table 6. Crane foraging habitats at Keumya Reserve.

Usage	Total area (ha)	Habitat type (ha)			Location
		Field	Reed	Tideland	
Often	550	450		100	Haejung ri, Songjae ri
Rarely	580	300	200	80	Haejung ri, Dokkumi ri Andong ri, Songrae ri

to the problem of how to improve wetland protection and management. With respect to this problem, the state is now developing a strategy and action plan for the protection and management of the newly established migratory bird (wetland) reserves. The important challenge is to promote wise use so that the protection of cranes and wetlands is closely related to the local residents' economic and social needs. Both regional and international cooperation will be needed in this area in the future.

References

Chong, J. R., H. Higuchi; and Pak U Il. 1994. The migration routes and important rest-sites of cranes on the Korean peninsula. Pages 41–50 *in* H. Higuchi and J. Minton, editors. The future of cranes and wetlands. Wild Bird Society of Japan. Tokyo, Japan.

Higuchi H., K. Ozaki, M. Soma, N. Kanmuri, and M. Ueta. 1992. Satellite tracking of the migration routes of cranes from southern Japan. Strix 11:1–20.

Shibaev, Y., and S. G. Surmach. 1994. Autumn migration of Red-crowned and White-naped Cranes in the Primorye Region, Far East Russia. Pages 114–120 *in* H. Higuchi and J. Minton, editors. The future of cranes and wetlands. Wild Bird Society of Japan. Tokyo, Japan.

Il, P. U., and R. C. Yon. 1983. On the distribution of Red-crowned Crane in the DPRK of Korea Bulletin Academy of Science 5:54–55(in Korean).

Il, P. U., and R. C. Yon. 1997. Distribution and migration of Red-crowned Crane. Bulletin of Academy Science DPRK 4:40–42 (in Korean).

An Urgent Problem for Preserving Biodiversity in Korea's Demilitarized Zone: A Fragile Ecosystem in Willful Human Hands

By

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The Demilitarized Zone (DMZ) and the Civilian Control Zone (CCZ) along the northern Democratic People's Republic of Korea and the southern Republic of Korea Divide are well-known, biologically diverse reserves (Kim 1997). The DMZ, a 4-km wide and 250-km long corridor crossing the Korean peninsula at around 38° latitude has served as a sanctuary to wildlife and flora since the cessation of the Korean Civil War in 1953. The CCZ is a 5- to 20-km wide strip of farm and forest lands with few inhabited residential or commercial areas. It functions as a buffer zone for the DMZ bioreserve.

The CCZ buffer zone has endured a persistent threat of development. Landowners in the CCZ have actively sought to expedite a development program. The impetus behind this movement is the local landowners' exaggerated hopes of huge monetary profits from converting farms and forests into commercial sites. These private interests wield enough power to pressure legislators to legalize development in the CCZ. In fact, a special CCZ development program was nearly created by these private interests, but the Republic of Korea's current financial crisis has slowed down its progress. The threat of legalized mass extinction, however, still remains.

The economic activities in the CCZ (buffer zone) are not independent of or neutral with respect to the DMZ. That is, once the CCZ ecological buffer zone disappears, the entire ecosystem will eventually be threatened. The Korean Peace Bioreserves System (KPBS) (see Kim 1997 for details) is powerless to alter the fates of the area's bioreserves as evidenced by a previous government defeat. Several years ago, the Republic of Korea's Ministry of Environment attempted to designate the Cholwon area [wintering grounds for endangered species including Red-crowned Crane (*Grus japonensis)* and White-naped Crane (*G. vipio*)] a National Ecological Park by enforcing the Natural Resource Conservation Act. This attempt failed because of strong resistance from landowners. More recently, in early 1997 the Korean National Commission for UNESCO designed a CCZ ecosystem preservation plan that proved useless for neutralizing development interests. The fundamental problem is that there is a conflict between private interests that want resource appropriation and the public's interest that values resource preservation.

Aligning Private and Public Values

The lack of appreciation for biodiversity is the fundamental cause of the conflict. The solution to this conflict can be addressed in a constructive manner if approached from a non-market valuation perspective. Here we need to consider the long-term benefits derived from preserving bioreserves and compare these benefits to individuals' immediate monetary benefits resulting from land conversion. The government, lawmakers, biologists, ecologists, and landowners alike are not cognizant of the value of ecosystem resources in these areas. It is critical, therefore, to clarify the language and concepts we use to express the value of biodiversity and the policies that bring about preservation of biodiversity.

Here the word "value" does not only mean the ethical and/or emotional judgement about duty to future generations and responsibility to the non-human natural world. Value also refers to monetary worth of the non-market value of ecological resources and non-use values perceived by existence, option, and bequest preferences. Existence value is the willingness to pay for the satisfaction of knowing that a natural environment is protected. Option value is defined as the annual premium payment for a kind of

insurance to retain the option of future use. Bequest value is defined as the willingness to pay for the satisfaction derived from endowing future generations with unaltered biological resources (Walsh et al. 1984). A preservation program based on these values can alter the fate of an ecosystem by showing that biodiversity is not in conflict with the local economic well-being but is, instead, essential to it.

It is generally accepted that the general public is becoming more sensitive to environmental and biological resource issues. However, the notion that bioreserves are valuable and therefore worth protecting cannot be legally enforced. The dilemma for ecosystem conservation does not rest on the question of legal measures, but rather on balancing landowners' livelihoods and the preservation of biological resources. The recent failure of the government to institute a preservation program is evidence that a conservation project without economic incentives to landowners will not be successful.

Currently, tourism of the Cholwon area battlefield monuments in the CCZ attracts 360,000 people per year. This provides the regional economy with tangible effects such as related business opportunities (e.g., hotels and restaurants). However, the landowners are not aware of the connection between the regional economy and ecosystem integrity. This is most likely because without a monetary valuation for the preserved ecosystem, there is no way for landowners to see beyond the immediate profit potential that development offers. A preservation program that offers monetary economic incentives while prohibiting development is a new pragmatic vehicle that can ultimately lead to preservation of biodiversity.

Valuation-Based Approach

A valuation study was performed in the Cholwon area in the fall of 1997 (John 1997). The total value of eco-tourism in the Cholwon area was estimated at 1.05 billion won (approximately 1,600 won = $1 US). Of this, the average annual income from tourist entrance fees is 385 million won. Thus, there is a 665 million won surplus from eco-tourism. This estimate represents only a portion of the total value of Cholwon's bioreserves. In addition to the eco-tourism value, the non-use existence, option, and bequest values amount to a few hundred billion won. Eco-tourism may provide the financial impetus for farmers to practice environmentally safe farming, and justify government compensation to landowners for not converting land into commercial sites. Meanwhile, the multiplier effects generated by eco-tourism-related business activities will continue through the regional economy, which will eventually sustain itself in harmony with a healthy regional ecosystem.

The eco-tourism value study performed in the Cholwon area represents a preliminary example of the kind of bioreserve valuation and new decision-making procedure in the Republic of Korea with which policymakers are unfamiliar. The difficulty in changing landowners' behavior is that although the rewards of a bioreserve program are lucrative in the long run, these rewards appear negligible when compared to the profit potential of resource-consuming development projects. This is compounded by the fact that adverse environmental impacts are not included or recognized in feasibility accounting until the adverse effects become a debatable issue among the general public. It is difficult to understand how the United Nations Development Program, UNESCO, the World Bank, and the International Union for the Conservation of Nature can, "greatly enhance the chance of successfully establishing the KPBS (Kim 1997)" to preserve biodiversity when the primary threat comes not from public inaction but from willful actions of private landowners. The most efficient and pragmatic solution is a rational and tangible valuation scheme that can convince landowners and other private interests that their economic interests are best served by activities that conserve resources instead of destroying them. In this way, powerful and willful business interests in the region will naturally, out of their own self-interest, work to preserve the rich and unique ecosystem of the 38th parallel.

References

John, K. H. 1997. An economic evaluation of ecosystem preservation of Cholwon Area. Page 215 *in* The survey of forestry ecology in the DMZ and the adjacent areas (in Korean). The Ministry of Agriculture and Forest, Forest Research Institute.

Kim, K. C. 1997. Preserving biodiversity in Korea's Demilitarized Zone. Science 278(10):242–243.

Walsh, R. G., J. B. Loomis, and R. A. Gillman. 1984. Valuing option, existence, and bequest demands for wilderness. Land Economics 60(1):14–29.

The Impact of Human Activities and Conservation Strategies for Zhalong Wetland

By

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Zhalong National Nature Reserve is part of a huge wetland complex formed over many years by the Wuyuer and Shuangyang Rivers, which flow out of a series of hills above Qiqihar, Heilongjiang Province. The total area of the Reserve comprises 210,000 ha of the 2.65 million ha wetland complex. The Reserve is located on the northwest side of the delta near Qiqihar, at 46° 52'–47° 32' N, 123° 47'–124° 37' E.

The topography of the Zhalong wetland is flat, with elevations ranging from 140–160 m. The annual temperature is 2.0–4.3 °C. Annual rainfall is 402.1 mm that occurs mostly from July to October. The majority of the water loss from the delta is attributed to evaporation and evapo-transpiration. A combination of low rainfall, one-way drainage, and high evaporation rates has resulted in all low-lying areas becoming saline. These salts probably are chlorides and sulfates of magnesium, calcium, potassium, and sodium. In some places, salts occur at levels high enough to inhibit all vegetation growth, and in other areas they restrict growth to short, salt-tolerant grasses most of which are unpalatable to livestock.

Zhalong wetland is rich in wild plant and animal resources. The four major habitats are marshlands, grasslands, wet meadows, and aquatic plants, with reed marshlands comprising the largest area. Many plants occur in staggered zones. There are 468 species of vascular plants belonging to 67 families, most of them herbs. There are 269 bird species distributed across this wetland, representing 17 orders and 48 families. Most birds are migratory. Zhalong wetland provides ideal breeding grounds for many species of waterbirds, and is also an important migratory stopover for more northern-breeding birds. Of the world's 15 crane species, nine species occur in China, and six species occur at Zhalong wetland. The world's wild population of Red-crowned Crane (*Grus japonensis*) is about 1,500 birds. In 1996, 346 Red-crowned Cranes were observed at Zhalong. White Storks (*Ciconia ciconia*), Black Storks (*C. nigra*), swans, herons, and falcons also occur in Zhalong, with 35 species designated as state-protected animals.

Zhalong National Nature Reserve was established in 1979, and was designated a national reserve in 1987. In 1992, the Reserve was listed as an "International important wetland." Reserve headquarters are located in Zhalong, 26 km from the city of Qiqihar, Heilongjiang Province.

Influence of Human Activities

Water Management and Utilization

Agriculture development in the Wuyuer River region has increased, especially since the implementation of the "changing the dry land to paddy" program. Varying sized reservoirs were built in the river's upper reaches and the Wuyuer River was dammed. Donsheng Reservoir intercepts the Wuyuer River inside the Zhalong marsh, and Shuangyang Reservoir intercepts the Shuagyang River. These reclamation projects have changed the water supply and distribution, and impacted the wetland's natural functions. In the spring, reservoir floodgates are opened to irrigate fields but not the marsh. During the rainy season, water levels are increased within the Reserve, whereas during the low water season, reservoirs do

not let water out. This form of water management is contrary to the natural cycle and does not benefit plant growth or nesting birds. Ultimately, it will change the entire wetland ecosystem.

Road Construction and Drainage Projects

Since 1992 when Road #301 was built crossing the Zhalong wetland from east to west, more and more roads have been built inside the Reserve boundaries. Now some seasonal roads are not closed during the off-season. Even in the central zone of Zhalong, roads have been built between villages. The Daqing Longqingpao Diversion Canal built in 1996 crosses north to south along the western portion of the Zhalong wetland. All these large-scale engineering projects have destroyed the integrity and continuity of this wetland ecosystem. The natural wetland has been divided into isolated islands that will eventually result in species' declines and a loss of biodiversity. Wetland areas that previously sustained natural protected conditions for wildlife will lose their waterbirds.

Wetland Reclamation and Cultivation

Most of the higher lands within the Reserve have been converted into agricultural fields. During high-water years, most of these fields are submerged. As a result, soils in these areas have become more saline, and in some higher-lying areas a desert now exists. Large wetland areas were converted to rice fields during low water years. These activities have destroyed the natural vegetation that comprised the wetland for thousands of years. Soil erosion due to cultivation has caused the lake to become filled with silt.

Fishing and Over-harvesting

All lakes and the deeper river channels and tributaries in the Zhalong wetland are leased to individuals. These leaseholders impound the natural lakes for fish breeding. Leaseholders with access to the river channels and tributaries can harvest fish without any limits on catch. The Zhalong wetland, including its river channels, tributaries, and lakes, comprises a huge and distinctive environment for fish reproduction. Because fish breed primarily in shallow marshlands but winter in deeper lakes, river channels are an important migration route for them. Impounding lakes cuts off the natural route of fish and results in harsh over-wintering conditions. Combined with over-harvesting, impoundments have caused a decline in fish resources throughout the shallow marshlands.

Threats to Waterbird Habitat

Increased human activities in wetlands are destroying the natural protection the wetlands provide. As more people use the wetlands, birds are increasingly disturbed. Consequently, the distribution of waterbirds is shrinking rapidly, and both species and bird numbers are declining. With the reduction of fish resources, both food availability and habitat carrying capacity for waterbirds are declining. These conditions are especially difficult for storks and herons because their primary food is fish. In the past two years, heron nestlings were found dying in nests from starvation. In addition, a number of birds suffered from poisoning and, in some cases, died from pesticides applied to agriculture fields.

Conservation Strategies

Compared with other ecosystems, wetlands are more vulnerable and can easily be destroyed. Since the 1980's, the Zhalong wetland environment has continued to be destroyed by human activities. Therefore, conservation strategies should be considered in the future.

Promulgate Laws and Strengthen Conservation Education

Local regulations should be drawn up to protect the Zhalong wetland. Conservation education for the local people should be strengthened so that they realize the value of the wetland and its conservation significance.

Road building and large-scale canals in the central zone of the reserve should be prohibited. For public water works already in existence, remedial measures should be taken. We recommend that several culverts be built under Road #301. High trees should be planted along both sides of this road.

Strengthen Water Management

Water use should be limited in the river's upper-reaches. In order to guarantee adequate water levels within the wetland, the number of rice fields should be reduced and no more reservoirs built. During low-water years, water should be released from the Yinnen Engineering Canal.

Strengthen Habitat Restoration Within the Reserve

Cultivation and conversion of fields around lakes to agriculture should be stopped. Agricultural fields located in the Reserve's central zone and in low-lying marshlands should be restored to grasslands and wetlands.

Stop Fishing and Over-Harvesting

The original river channels should be restored for fish migration. Fisheries law enforcement should be strengthened. A firm and inflexible regulation to prohibit fishing for three years in Zhalong wetland should be considered.

Strengthen Management of Waterbird Breeding Areas to Reduce Human Disturbance

- Limit human activity in breeding areas during the breeding season.
- Establish a research station to monitor the wetland ecosystem and provide scientific data for wetland management and restoration.

The Rescue and Release of White-naped Cranes in Heilongjiang Province

By

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Wild cranes are easily injured or incapacitated because of human-caused or natural factors. These birds will die or be eaten by predators if they are not rescued. It is very important to save sick and injured cranes so they can be rehabilitated and released back to the wild to increase natural populations of these rare birds. We report on the rescue of five White-naped Cranes in Heilongjiang Province, their rehabilitation, and release.

The Rescue of the Cranes

Group 1

Local farmers found two cranes at Jianguo Town, Datong District, Daqing City on 8 November 1996. A snowstorm and drop in temperature had occurred two days before. Five cranes were observed at the Inlet Channel of the Nenjiang River, about 0.5 km from the village. The village was surrounded by cropland, and a large area of wet grassy marshland was located 5 km to the southwest. When the men approached the cranes, three flew off and two remained. The larger bird, later identified as a male, was not able to stand and could not fly. His right tarsus had been frozen and was slightly swollen, and a scab at the tip of the left hind toe was bloody. The smaller bird, a female, was sick but not injured, and was still able to fly and attack her rescuers.

Group 2

Local farmers in Xiangyang Town, Jiayin County, captured these cranes. Wet grassy marshlands that contain mainly liver mosses and cattails predominate in the area. The site is less than 2 km from the Heilongjiang River and is surrounded by cropland. The cranes showed no fear of humans when they were approached and had minor injuries to their wings, legs, or toes. All three birds were juveniles and had been banded with metal and white rings; two had satellite-tracking transmitters attached to their backs. We determined, with help from the Bird Banding Center of China and the International Crane Foundation that these birds were from the Khingganski Nature Reserve of the Amur Region of Russia. They had been hand-reared for release.

Rehabilitation

Group 1

The two cranes were given medical treatment that included pseudo-ginseng, Vitamin C, and penicillin. After one week, the female had recovered and the medication was stopped. By six weeks, both birds could move about easily. At this time the pair often chirped face-to-face and displayed to each other. Food for these birds included corn, chicken pellets, and varieties of fish; however, corn was the main food. They showed little interest in living frogs and loaches that were provided. When given fish, the cranes would hold up the fish, remove the tip of the head, and swallow it from head to tail. When eating hurriedly, they could swallow four to five fish, each about 15 cm long.

Group 2

Because these birds were only slightly injured, they recovered quickly without medical treatment. They fed normally and preferred wheat to corn. We

suspect this was because they were fed wheat in Russia. Consumption of fish was the same as for the birds in Group 1.

Banding and Releasing

Group 1

These two cranes were fed indoors during the entire winter. By April both sought food on their own and were able to fly. In order to acclimate the birds to outside low temperatures, we opened the window of their pen. On April 13, we banded the birds and transported them to the Zhalong National Nature Reserve. This reserve is a major breeding ground for White-naped Cranes and is about 100 km from Daqing. After the pair was released, they landed in nearby reeds, frolicked in the water, and chirped. When we approached, they flew again and settled into a deeper reed marsh. We believe they had regained the ability to survive in the wild and avoid capture. Three days later we returned to the marsh and found no trace of the birds.

Group 2

These birds completely recovered after we fed them indoors for one month. They were transported to the Zhalong National Nature Reserve and released in July 1997. After their release, the three cranes did not avoid humans. They often sought food and remained at a site near people. We are concerned that these birds will be captured again.

With the support of the National Bird Banding Center of China, we banded the five cranes. Information on banding and characteristics of the birds are provided in Table 1.

Acknowledgments

We express our sincere thanks to the Bird Banding Center of China, Heilongjiang Forestry Department, Daqing Forestry Bureau, and Jiayin Forestry Bureau, who provided assistance in rescuing these valuable birds. We give special thanks to Dr. Liu Xiaolong, who provided instruction and care for the recovery of these birds.

Table 1. Banding records and data for the White-naped Cranes.

Length of body	Length of wing	Length of tail	Length of head beak	Length of beak	Length of tarsus	Weight	Metal ring number (left)	Color ring number (right)	Date for release
105	56	20.5	25.5	15	28	5,350	N00-9271	Yellow 076 Orange No number	04/13/97
123	59	22	29	15	29	7,100	N009272	Yellow 077 Orange No number	04/13/97
117	53	20	25	15	24.5	5,100	N00-9276	White A02	07/14/97
110	58	19.5	25.5	14.3	22.5	4,300	N00-9277	White A03	07/14/97
124	55	20	25	15	24.5	5,600	N00-9278	White A20	04/17/97

The Relationship of Black-necked Crane Migration to the Uplift of the Qinghai-Tibetan Plateau

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The Black-necked Crane (*Grus nigricollis*), an endangered species worldwide, is found primarily in China. It breeds on the Qinghai-Tibetan Plateau, northern Sichuan, and southern Gansu, and winters on Yunnan-Guizhou Plateau, in southern Tibet Autonomous Region and the Kingdom of Bhutan. It is the only crane species that inhabits plateaus 3,000–5,000 m high.

Migration is a seasonal movement between breeding and wintering grounds. Some 80% of all bird species migrate. When we use bio-geographic principles to determine crane systematics over time and space, the reasons why the Black-necked Crane migrates and its place of origin need to be determined. In this paper, we use biological data from the Black-necked Crane and geological data of Qinghai-Tibetan Plateau to discuss the reasons for Black-necked Crane migration, and where it originated.

Reasons for Bird Migration

At present, there are three theories to explain bird migration. The first is that migratory birds originated in northern latitudes and were forced to move during the Quaternary Period when glaciers surged southward. They returned to their former habitats in summer when glaciers receded. With periodic surging and receding of glaciers, a tradition perpetuated and became migratory behavior. The second theory is that birds originated in the tropics. Birds needed more food supplies because of rapid population growth. Population pressures forced some bird species to disperse during the summer to areas where glaciers had receded. When glaciers surged again the birds returned south. As time passed, migration behavior evolved. The third theory is that migratory birds originated from their breeding grounds. With the continental plates drifting south to north, many bird species were forced northward. Their attempts to return home to their ancestral homes became the behavior of migration.

Generally, a bird that lives in the same area throughout the year is called a resident bird. Migratory birds leave their breeding areas after nesting and move to outside wintering areas. Bird species that are in-between resident and migrant are called migratory wanderers. Even though this division can reflect the essence of the differences of seasonal migration, it is relative because of many transitional forms existing in nature. Comparing the habits of resident and migratory birds, differences include:

Food habits of resident birds are wide (e.g., sparrow, magpie) or they forage primarily on plants. Most migratory birds are carnivorous (insects or meat) or feed primarily on fish and snails (e.g., waterfowl and wading birds). Food abundance for migrants is impacted by seasonal changes.

Resident birds are mostly terrestrial species, whereas migratory birds live primarily in or beside water. Resident birds' habitats are relatively stable across seasons, but migratory birds' habitats change. These indicate that bird migration is an active

adaptation for the most difficult time of year, and is similar to the hibernation of some animals and metamorphosis in some insect species.

Biological Characteristics of the Black-necked Crane

The Black-necked crane is a special crane species because of its distribution across unusual areas in China. It is also an ideal bird for studying migration theory. Figure 1 shows the geographic distribution of the Black-necked Crane (from Lu 1986). Altitude on breeding grounds ranges from 3,000–4,000 m, and from 2,200–3,500 m on the Chinese wintering grounds. On the breeding grounds the climate is cold and dry but has long days and intense sunshine. The climate on wintering grounds is temperate or temperate-mountain and is milder than the breeding grounds. Characteristics of wintering and breeding grounds are provided in Table 1.

Reproduction is seasonal. The latitude of breeding grounds is 30°–33°N, and 26°–27°N for wintering grounds. Among all kinds of climate factors in nature, illumination changes have their own periodicity. The changes in the light cycle at high-latitude areas are most obvious because of large differences between day length and night. Changes in the light cycle at lower latitude areas are not as obvious because changes in day length and night are small.

Two studies, breeding minks by changing light cycles and breeding deer by changing light cycles, showed the relationship between the light cycle and reproduction. Animal breeding showed that light stimulates reproduction by the following pathway: sunshine length to eye to hypothalamus to pituitary gland to reproduction hormone secretion, to sexual gland development, then to breeding. The Black-necked Crane winters at lower latitudes and breeds at higher latitudes. Its breeding, therefore, is controlled by light-cycle changes.

Fig. 1. Distribution of Black-necked Cranes [from Bishop (1996)].

Table 1. Comparison of wintering and breeding grounds of Black-necked Cranes.

Area	Location (lat long)	Elevation (m)	Mean temperature (C)	Climate
Wintering Grounds				
Caohai, Guizhou	26 48' N 104 10' E	2,172–2,234	10.5	temperate; 79% average relative humidity
Heqing, Yunnan	26 36 N 100 11 E	2,600	-	temperate high mountain climate
Lugu Lake, Yunnan	27 42–27 44 N 100 44–105 50 E	2,685	12.7	temperate high mountain climate
Bitahai, Yunnan	27 49 N 99 59 E	3,540	5.4	temperate high mountain climate
Yuepahai, Sichuan	27 49–27 55 N 99 37–99 40 E	3,260	5.4	temperate high mountain climate
Breeding Grounds				
Ruoergai Plateau, Sichuan, and Gansu	33 10–33 57 N 102 52 E	3,275	0.6	plateau climate, strong sunshine
Naihai, Gansu	102 20 E	3,320	1.0	plateau climate, strong sunshine, windy
Zhaling Lake, Qinghai	43 55 N 97 15 E	4,287	0.4	plateau continental climate, strong sunshine, long days
Longbaotan, Qinghai	33 09–33 17 N 96 24–96 37 E	4,100–4,200	0.4	plateau continental climate, strong sunshine, long days
Qiangtang, TAR*	30 03–36 30 N 79 00–95 E	4,500	-	plateau climate, cold and dry, strong sunshine
Lhasa River, TAR*	29 38 N 91 05 E	3,680	-	plateau climate, cold and dry, strong sunshine
Bangong Lake, TAR*	33 30 N	4,212	-	plateau climate, cold and dry, strong sunshine

*TAR = Tibet Autonomous Region

Qinghai-Tibetan Plateau Uplift and Glaciation During the Quaternary Period

Patterns of animal distribution are due to ecological and geological factors. The uplift of the Qinghai-Tibetan Plateau caused the allopatric speciation of Black-necked Cranes and glaciation during the Quaternary Period caused its migration. The uplift of the Qinghai-Tibetan Plateau was earth's most important geological event during the Cenozoic Era. Many studies have shown that since the late Eocene Epoch, the Qinghai-Tibetan Plateau started to uplift and experienced a succession of uplifts. When its height was 3,000–5,000 m in the Quaternary Period, glaciers started to surge. At that time, the main mountains of Qinghai-Tibetan Plateau had been formed so glaciers surged through river valleys (Li 1979). With the onset of glaciation, the climate changed rapidly and all lands were covered by ice and snow. Shi and Zheng (1995) showed that the whole Plateau became a frost zone, and more than 500,000 km^2 were covered by glaciers. Most parts of the Plateau had snow for most of the year. The climate was cold and wet. This inhospitable climate resulted in the Black-necked Crane migrating in order to survive.

Using leg bands, Wu and Li (1987) studied the migration of the Black-necked Crane and found three migration routes. The first, an eastern route, begins at the Ruoergai breeding area in Sichuan and Gansu Provinces. Cranes migrate along Qionglai Mountains and Min Jiang (River) through Ya'an and Yibin arriving at Weining, Guizhou Province and Huize Yunnan Province in the Wumeng Shan (mountain) region. The second route begins at the breeding grounds at Longbaotan, Qinghai Province. Cranes migrate to Caidamu Basin, along the Tongtian River, and Jinsha Jiang River (both the Yellow River), passing through Shiqu County, Garze, and Litang in Sichuan Province arriving at the Hengduan Mountain region, including Zhongdian. Lijiang, and Ninglang in Yunnan Province. Cranes breeding in southeast Xinjiang and western Qinghai Provinces use the third route. These birds migrate to the river valleys in the middle reaches of the Yarlung Zangbo River. The majority of cranes breeding in the northern and western Tibet Autonomous Region also migrate to the river valleys in the middle reaches of Yarlung Zangbo River. A few others fly over the Himalayas and winter in Bhutan. These three routes showed that Black-necked Cranes migrate along river valleys. These routes are identical to the routes where glaciers surged on the Qinghai-Tibetan Plateau.

It is estimated that glaciers currently cover 10% of the earth's surface, with the majority located in Antarctica, Greenland, Iceland, and high mountain areas. Historically, glaciers covered three times more area than now. Because of different impacts by glaciers, resident and migratory bird species are different worldwide. Most migratory bird movements are from south to north, with birds flying from their wintering to breeding grounds. Migratory species have their distinct routes. Species living in the same area often migrate via different routes, while some birds do not fly the shortest route. For example, the Yellow-breasted Bunting breeds in Western Europe and winters in India and the Indochina Peninsula. This species does not migrate directly from Western Europe to India. Instead, it flies to India through Eastern Europe, Siberia, and southern China. Presumably, in spring its return route to Western Europe is the same as in fall. Perhaps this migration route coincides with where glaciers occurred. Migratory routes repeat historic adaptations and can be inherited. Therefore, every bird species has a different migratory route.

Conclusions

According to the above analyses, our conclusions are as follows. First, Black-necked Crane migration from breeding to wintering grounds is caused by the unfavorable environmental conditions created by glaciers in the Quaternary Period. Migration from wintering to breeding grounds is driven by reproductive physiology. It can be inferred that birds migrate to wintering grounds because of their need for food and habitat, and this is a passive adaptation. Migration to the breeding grounds is an active breeding behavior, just like fish reproductive migration. Both internal (endocrine system) and external (environment) factors cause migration. The origin of a migratory species can be deduced as their breeding grounds.

Second, the migratory routes of Black-necked Cranes are determined by the pattern of glaciers on the Qinghai-Tibetan Plateau. This is a historical, geological cause, but migration is also influenced by

the modern natural landscape. Therefore, when we explain behavior and geographic distribution patterns, not only historic geological factors, but also ecological factors, must be considered together.

References

Bishop, M. A. 1996. Black-necked Crane species account. Pages 184–193 *in* C. D. Meine and G. W. Archibald, editors. The cranes: Status survey and conservation action plan. IUCN, Gland, Switzerland, and Cambridge, UK.

Li, J. 1979. The time, range, and form of the uplift of the Qinghai-Tibetan Plateau. China Science (6):608–616.

Lu, Z. 1986. Ecology of Black-necked Crane. Animal World 3(1):37–51.

Shi, Y., and B. Zheng. 1995. The time, height, and impact on around areas while Qinghai-Tibetan Plateau in frost zone. Form, evolution, and environmental change of Qinghai-Tibetan Plateau and ecosystem. Science Press. pp. 136–146.

Wu, Z., and R. Li. 1985. Wintering ecology of Black-necked Crane. Journal of Ecology 5(1):71–75.

Behavior of Captive Red-crowned Cranes (*Grus japonensis*) During the Breeding Season

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The Red-crowned Crane (*Grus japonensis*) belongs to the order Gruiformes, family Gruidae. It is listed as a Class I protected animal in China and is usually found in marshes or wet meadows. The Red-Crowned Crane's range is northeast and eastern China, northeast Russia, Japan, and the central Democratic People's Republic of Korea. The breeding population of Red-crowned Cranes in China has declined. In 1980, the estimated population was 1,300 birds. Results of ground and air surveys indicate a current breeding population in China of approximately 700 birds distributed across three northeast provinces (Feng and Li 1985).

In recent years, habitat destruction has led to a decline in Red-crowned Crane numbers. This decline has been a source of concern for experts and scholars worldwide. Many nature reserves have been established to protect these cranes. Presently, there are many studies on crane ecology, population status, captive-rearing, physiology and biochemistry. Until now, however, Red-crowned Crane behavior during the breeding season has not been studied. This study reports time-budgets of captive, Red-crowned Cranes during the breeding season. Copulation, egg laying, and vocalizations are also described. This study is an important scientific contribution to the theory of behavior, breeding and rearing, and for crane conservation.

Study Site and Methods

We studied captive Red-crowned Cranes from early April–mid June 1997 and 1998 at the Harbin Zoo, Harbin City, Heilongjiang Province. Harbin City (45°21'–46 °21'N, 126°17'–127°30'E) is located within the breeding range of the Red-crowned Crane. Two pairs of adult cranes were observed during this study. Cranes were held in 13 m x 5 m x 3.5 m(h) pens that were isolated from public viewing. Pen sides were padded to prevent cranes from hurting themselves.

Observations occurred between 4:30–17:30h. We were careful not to disturb cranes during observations. We recorded a pair's behavior every 5 min using the instantaneous scan method (Li and Ma 1992; Yang and Wen 1995). Once an hour we recorded air temperature and wind speed. We analyzed behavior by hour, day, across the season (early, middle and late breeding season) and climatological conditions. Besides the date and time, we recorded in detail all observed mating and egg laying behavior, including the behavior immediately before, during, and after mating or egg laying.

We used the following categories to describe crane behavior:

- *Walk*: walk, run, fly.

- *Preen*: nibble, bathe, head-neck dip, oil, scratch, bill wipe, ruffle-shake, leg flick.
- *Forage*: search, peck, probe, swallow, drink.
- *Rest*: head-droop sleep, standing still. Does not include incubation or standing still while foraging.
- *Breed*: courtship, mount and dismount, egg laying and incubation. Courtship behavior included dancing (bowing, jumping, stick-tossing) and pre-copulatory and unison calls.
- *Vocalizations*: fear, alarm, egg-laying, pre-copulation and unison call.

Results

Walking and resting were the principal behaviors observed, making up 60% of the daily activities. The next most common behaviors were preening (14.9%), foraging (22.2%), and breeding (2.5%). We divided the breeding period into three parts: early, middle, and late ranging in length from 3–6 weeks each. Our analyses showed that cranes rested significantly less (P <0.05) during the middle of the breeding season. During this time foraging and breeding behavior increased, while walking and preening remained about the same (Table 1).

Time budgets (daily activity patterns) for Red-crowned Cranes show that foraging is a major activity at 0500, 1200, and 1600h (Table 2). Peak resting occurs in the morning between 0600 and 1100h, and peak walking between 1100 and 1600h. Resting and walking typically occur after foraging. Breeding occurs primarily from 0430–0600h (related to courtship behavior that occurs primarily from 0430–0900h), and again from 1500–1800h.

We analyzed activity patterns of the two breeding pairs throughout the breeding season (early, middle, late; Table 3). We found no significant differences (P <0.01) in the time budgets of the two pairs. When we analyzed time-budgets by sex, we found differences (Table 4). Male cranes spent more time walking, resting, and breeding and less time foraging than females. Variance analysis found that time spent foraging by males was significantly lower than females (P >0.01), and their time spent resting significantly higher than females (P >0.01)

We found that climate significantly impacted crane behavior ($P \leq 0.05$; Table 5). On cool, rainy days cranes spent more time foraging, most likely due to higher energy needs. During warmer temperatures, cranes spent more time breeding and preening. This indicates that captive-cranes are more active in warmer than in cooler temperatures.

Breeding, Egg Laying, and Vocalizations

Courtship and breeding behavior occurred daily beginning 15 days before the first egg was laid. Breeding occurred mainly between 0400–0900 and 1500–1800h, and occasionally around 1200h. We removed the first egg from each pair in order to stimulate further egg laying (Table 6). As soon as the last egg was laid, all courtship and breeding behaviors ceased.

Breeding behavior of cranes has been studied and described by many scholars. During our research, we found the mating behaviors included the following behaviors:

1. *Head lift*. The male stands or walks, stretching neck and lifting the head. This is the first behavior before copulation. Usually the female shows the same behavior.
2. *Chasing*. The female walks ahead and the male chases her.
3. *Jumping*: The male rotates his body while he walks. Sometimes, he pecks at grass or something small and tosses it upward. The pair dance face to face, stretching their wings. This occurs before or after copulation.
4. *Head and tail sway up and down*. Both male and female show this action before and after copulation. The crane uses its leg as fulcrum and pumps its head quickly, and sways its tail up and down.
5. *Breeding vocalizations*. Both male and females vocalize before and after copulation. The call is brief, the tone is not high, and the rhythm is gege-guge. When the frequency of the call becomes fast, mating behavior will occur.
6. *Female spreads wings*. When the female is ready to mate, it always shows these series of actions: slightly squatting, lifts head, slowly spreads wings.
7. *Coupling*: The male jumps on the back of female, swaying its wings to keep balance. He drops his head and presses his tail. The female sticks up her tail and raises her head. Copulation occurs for 10–20 seconds. The pair may call. Male jumps off from the front side and the female lifts her head immediately (Tian et al 1992).

Table 1. Daily activity pattern by hour and breeding seaon (early, middle, and late) for Red-crowned Crames.

		Time of day												
Activity	Season	4:30	5:30	6:30	7:30	8:30	9:30	10:30	11:30	12:30	13:30	14:30	15:30	16:30	17:30
Walking	Early	14.6	4.17	16.7	41.7	20.8	16.7			70.8	91.7	91.7	58.3	29.2	8.31
	Middle	47.9	54.2	62.5	66.7	52.1	72.9	85.8	70.8	16.7	41.7	8.3	8.3		16.7
	Late		18.8	12.5	22.9	18.8	33.3	54.3	68.8	54.2	62.5	60.4	43.8	18.8	39.6
91.6															
Preening	Early	12.5	4.2	25.0	12.5	4.2		8.3	41.7				12.5	29.2	75.0
	Middle	18.8	14.6	8.3	4.2	6.3				8.3	12.6		12.5	29.2	25.0
	Late		20.8	40.0	20.8	16.6	39.6	10.4	2.1	2.3		4.2	35.4	43.8	2.1
Foraging	Early	25.0	70.8	25.0		16.7	8.3	25.0	16.7	8.3			8.3	29.2	4.2
	Middle	6.3	29.2	20.8	29.2	22.9	10.4	14.6	25.5	45.8	25.2	29.2	45.8	58.3	16.7
	Late		23.0	8.3	10.4	8.3	20.8	27.1	12.5	25.0	29.2	20.8	16.7	27.8	22.9
8.4															
Resting	Early	33.3	8.3	33.3	37.5	58.3	75.0	58.3	41.7	20.8	4.2	8.3	12.5	12.5	4.2
	Middle	22.9	8.3	2.1		16.7	10.4		4.2	25.0	12.5	54.2	33.3	4.2	41.7
	Late		29.2	35.4	47.9	54.2	10.4	8.3	18.8	12.5	8.3	14.6	4.2	10.4	20.8
Breeding	Early	14.6			4.2						4.2		12.5		8.3
	Middle	2.1		4.2						4.2	4.2			8.3	
	Late		8.3	4.2			4.2								12.8

Table 2. Daily time budget for captive Red-crowned Cranes, spring 1997 and 1998.

	Time of day													
Activity	4:30	5:30	6:30	7:30	8:30	9:30	10:30	11:30	12:30	13:30	14:30	15:30	16:30	17:30
Walking	27.1	23.6	34.0	42.2	35.4	47.9	51.4	41.67	50.0	64.5	47.9	30.9	22.9	38.9
Preening	17.4	20.3	18.0	11.1	16.7	4.9	3.5	16.7	2.8	5.6	11.8	22.9	20.2	33.3
Foraging	18.1	37.0	18.3	12.5	20.1	15.3	17.4	22.2	37.5	15.3	15.3	27.3	36.8	9.8
Resting	28.5	17.3	27.8	30.6	28.5	31.2	25.7	19.5	18.0	10.4	22.2	18.7	12.5	15.3
Breeding	8.3	8.3	1.4						1.4	2.8		4.2	7.0	2.8

Table 3. Comparison of time budgets by captive Red-crowned Cranes, spring 1997 and 1998.

		Activity				
Breeding period	Crane	Walking	Preening	Foraging	Resting	Breeding pair
Early	No. 1	32.6	16.0	18.4	29.3	3.6
	No. 2	27.0	17.8	28.1	24.8	2.0
Middle	No. 1	35.2	14.1	29.4	16.6	4.23
	No. 2	28.4	14.8	25.8	26.2	4.9
Late	No. 1	30.1	14.7	19.0	33.2	2.2
	No. 2	20.2	19.5	23.1	34.2	3.0

Table 4. Red-crowned Crane percent time by behavior, sex, and time period during the breeding season.

Period	Sex	Walking	Preening	Foraging	Resting	Breeding
Early	Female	33.17	15.66	22.29	26.51	2.41
	Male	32.12	16.51	14.55	32.12	4.85
Middle	Female	30.72	12.05	42.17	10.65	4.41
	Male	39.75	16.15	16.15	23.71	4.24
Late	Female	36.77	18.21	22.34	20.27	2.41
	Male	44.98	10.78	15.24	26.02	1.86
Average	Female	33.53	15.31	28.97	19.81	3.08
	Male	38.28	14.50	15.32	28.28	3.65
F		1.718	0.094	4.17	4.60	0.26
P		>0.10	>0.10	<0.10	<0.10	>0.10

Table 5. Red-crowned Crane percent time by behavior and climate during the breeding season.

Climate	Walk	Preen	Forage	Rest	Breed
Rain, temperature ≤15°C	7.5	16.0	58.0	17.3	0
No rain, temperature 16–31°C	9.8	38.0	40.0	13.9	5.0
F test	8.50 > F (1, 4) = 7.71; *P* = 0.05				

Table 6. Red-crowned Crane breeding season 1993–1998.

Year	Pair	Laying date first egg	Laying date last egg	Total eggs	Egg-laying period (days)	Mating period (days)
1993	1	May 23	May 23	1	1	15
1994	1	May 27	May 27	1	1	15
1995	1	April 29	May 29	6	30	45
1996	1	March 31	May 25	11	55	70
	2	April 30	June 1	6	32	47
1997	1	March 31	June 1	11	60	75
	2		May 26	5		
1998	1	April 6	May 26	8	50	65
	2	April 25	May 19	6	24	39

8. *Unison Calling*
9. *Preening*: The female preens after copulation.

These behaviors occurred during each breeding attempt except chasing, jumping, and head and tail swaying up and down occurred occasionally.

Breeding behavior can be inhibited if the female is not interested in breeding or if there is a disturbance. A pair will also terminate copulation attempt if any of the breeding behaviors are disturbed. If the disturbance takes place as the male approaches a female with spread wings, the male will walk away and the female will fold her wings. If the disturbance takes place while the male is mounted on the female, he will jump off quickly and vocalize a high-pitched alarm call.

Egg laying behavior is divided into three periods: early, middle, and late. During the early period, behavior includes nest building and soft, low-pitched vocalizations. Nest building occurs two days before eggs are laid. The nest sites are located in the same place every time. Nests are large and made of many kinds of materials including large quantities of dry hay and little branches.

When the female lays the egg, she squats so that her tarsometatarsus and tail feathers touch the ground and she elevates the chest off the ground at a 60–70° angle, and calls loudly. The head is stretched out and then drawn back as she lays the egg. After laying, the female stands up and moves the egg with her beak and then sits on the egg. Several seconds later, she stands up again and moves the egg, and then sits again. Both male and female incubate the egg.

According to their different meanings, we observed the following vocalizations: fear, alarm, pre-copulation, and unison calls (Table 7). The unison call occurs after breeding. We found that the sexes differed in posture and vocalization during fear, pre-copulation, and unison calls (Table 7).

Discussion

Alarm behavior was not listed as a behavioral category because the two pairs of Red-crowned Cranes were kept isolated from human contact. We found that under the same captive-conditions, Red-crowned Cranes have a lower sensitivity to disturbance than White-naped Crane (*G. vipio*) and Demoiselle Crane (*Anthropoides virgo*).

During the breeding season, little time was spent in incubation and chick-rearing because eggs were

Table 7. Vocalizations of the Red-crowned Crane.

Vocalization	Sex	Call	Characteristic	Behavior
Alarm	M, F	Gaou-gaou	Sonorous, loud, intermittent	Stretched neck and gazing at source of danger
Egg-laying	F	Bululu	Low and deep, short interval	Beak pointed to ground
Fear	F	Gaga	Double syllable, sudden call, then stops	Beak pointed at sky, no wing spread
	M	Ga	Single syllable, sonorous, deep, brief	Beak pointed at sky, wings spread in certain rhythm
Pre-copulation	F	Guge-guge	Double syllable, low, deep, brief	Male follows female
	M	Gu-gu	Single syllable, low, deep, brief	Walk and call
Unison call	F	Gaga-gaga	Double syllable, sonorous loud	Beak points to sky obliquely
	M	Ga-ga	Single syllable, sonorous, loud	Beak points to sky directly

removed from the captive pairs, and none raised chicks. This is different from wild cranes that spend most of their time hatching and raising young cranes. During the middle breeding period, foraging and breeding occurred more and resting less than during the early and late periods. This is probably due to differences in the breeding conditions, energy needs, and body conditions. Energy demands are probably higher during the middle period, when breeding and foraging are at their peak.

The two pairs observed showed different time-budgets, but no significant differences were detected. This is probably because the two pairs experienced the same food abundance, living, and climate conditions. When compared by sex, however, there were differences. Males spent less time foraging and more time resting than females. This may relate to the division of labor between the two sexes during the breeding period.

The captive cranes showed significant differences in behavior, depending on the weather. Our study showed that weather condition is the main factor influencing breeding behavior. During rainy and cool temperatures, foraging and resting occurred more often than during warmer temperatures. This is because cranes need more energy during lower temperatures. Because captive cranes are more active during cooler temperatures, they spend more time breeding and preening than during warmer temperatures. In addition to weather conditions, disturbance can impact breeding behavior. Disturbances will often cause mating behavior to cease either before or after copulation.

References

Feng, K., and J. Li. 1985. Aerial surveys on Red-crowned Cranes and other rare water birds. Pages 17–36 *in* H. Masatomi, editor. International spring censuses of *Grus japonensis* (Red-crowned Crane) in 1984. Wild Bird Society of Japan, Tokyo.

Li, F., and J. Ma. 1992. Timing, family, and group benefits of wintering Black-necked Cranes. Chinese Wildlife 3:36–41.

Tian, X., X. Bai, and S. Li. 1992. A study in captive breeding of the White-naped Crane. Chinese Wildlife 3:51–53.

Yang, X., and X. Wen. 1995. Time-budget of captive Lady Amherst's pheasant in breeding season. Zoological Research 16(2):178–184.

Plumage Growth and Molt Sequence in Red-crowned Crane (*Grus japonensis*) Chicks

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The Red-crowned Crane (*Grus japonensis*) is a rare Chinese bird. It is listed as a Class I protected animal by China, and as an endangered species by CITES. In the past, no research had been conducted on the feather growth and molt of young, captive-reared Red-crowned Cranes. Understanding plumage growth and molt in cranes has important significance for avian systematics, avian ecology, and crane growth and development.

Feather Growth and Molt

Beginning in 1989, we investigated feather growth and molt in young, captive-reared Red-crowned Cranes. Our methods included daily inspection during the first month and weekly inspection thereafter. We focused on the growth and molting sequence of flight feathers. We examined the feather sequence of alula (A), primaries (P), secondaries (S), tertiaries (T), and rectrices (R). Feather sequence was recorded in accordance with China's traditional taxonomic method of counting successively outside to inside for wings, and outward from the central rectrices. Additionally, we made supplemental observations on plumage growth on the head, neck, and trunk. For this paper we provide age information by week (wk), where, 1 week old = 7 days, 2 weeks old = 14 days, etc. We determined that Red-crowned Crane flight feathers include 4 A, 10 P, 18 S, 6 T, and 12 R (Figs. 1 and 2). Below we summarize plumage growth and molt patterns in 20 young cranes hatched and raised in captivity from 1995–1996.

Alula

Growth Sequence

- Hatch –1 week: A are natal down
- 2 weeks: A2, A3, A4 sprout as very small feathers
- 3 weeks: A1 sprouts, A2, A3, A4 feather ends open
- 4 weeks: A2, A3, A4 complete growth. A1 is still a feather sprout
- 5 weeks: A1–4 are full-grown contour feathers

Molting Sequence

- 7–8 weeks: A4 molts
- 9–10 weeks: A3 molts
- 11–12 weeks: A2 molts
- 13–14 weeks: A1 molts
- 15 weeks: bases of A1–A4 without feather sheathes

Summary

The growth sequence of alula is A4, A3, A2, and A1. The molting sequence of alula is A4, A3, A2, and A1.

Fig. 1. Molt sequence for flight feathers in Red-crowned Cranes.

Primaries

Growth Sequence

- Hatch –1 week: P is natal down
- 2 weeks: feathers sprout
- 3 weeks: tips of feathers appear slightly brush-like
- 4 weeks: feather sprout ends, feather tips are brush-like
- 5 weeks: P2–P10 emerge, later followed by P1, P1–10 complete growth

Molting Sequence

- 6–7 weeks: P7–P2 molt
- 8–9 weeks: P8 molts
- 10–11 weeks: P9 molts
- 13 weeks: P10 molts
- 14 weeks: P1 molts
- 17 weeks: bases of P1–P10 without feather sheathes

Summary

The growth sequence of primaries is P2–P10, followed by P1. The molt sequence is P7–P2, P8, P9, P10, and P1 (Fig. 3).

Secondaries

Growth Sequence

- Hatch –1 week: S is natal down
- 2 weeks: S2–S15 sprout
- 3 weeks: feather sprout ends
- 4 weeks: S16–S18 sprout
- 5 weeks: S1 sprouts, S1–S18 fully grown

Molting Sequence

- 6–8 weeks: S2–S15 molt
- 9–12 weeks: S16, S17, S18 molt
- 14 weeks: S1 molts
- 17 weeks: bases of S1–S18 without feather sheathes

Summary

The growth sequence of secondaries is S2–S15, S16–S18, and S1. The molt sequence of secondaries is S15–S2, S16–S18, S1 (Fig. 3).

Tertiaries

Growth Sequence

- 4–5 weeks: T1 and T2 sprout

Fig. 2. Sequence of growth and molt by week, feather, and type of flight feather in captive Red-crowned Crane chicks.

Fig. 3. Molt sequence for rectrices in Red-crowned Cranes.

- 6–7 weeks: T3 and T4 sprout
- 8–9 weeks: T5 and T6 sprout, T1–T6 fully grown

Molting Sequence

- 10–11weeks: TI, T2 molt
- 11–12 weeks: T3 molts
- 13–14 weeks: T4 molts
- 14–15 weeks: T5 molts
- 15–16 weeks: T6 molts
- 18 weeks: bases of T1–6 without feather sheathes

Summary

The growth sequence of tertiaries is TI–T2, T3–T4, and T5–T6. The molting sequence is T1–T6 (Fig. 3).

Rectrices

Growth Sequence

- 1–2 weeks: natal down
- 3 weeks: small feather sprouts
- 4 weeks: feather sprouts develop fuzzy barbs at base
- 5 weeks: 10 feathers (sheathed at base) emerge, feather tips are brush-like
- 6 weeks: all 12 R are full-grown

Molting Sequence

Feathers equal number left and right of center molt as pairs.

- 8–10 weeks: R1–R5 molt
- 11–12 weeks: R6 molts
- 16 weeks: base of R1–6 without feather sheathes

Summary

Rectrices grow at the same time and molt simultaneously. The growth and molt sequence is to molt from the center (R1) to outside (R6; Fig. 3).

Summary of Plumage

Apart from the wing and tail flight feathers, plumage growth and molt is as follows. Yellow natal down covers the head, neck, and trunk from hatch to 2 weeks. Except for the head, neck, and breast, very small feathers sprout at 3–4 weeks. By 5 weeks, feathers sprout on the head, neck, and breast. By 6 weeks, the bare area around the eye is obvious. By 7 weeks, the body is covered by juvenile plumage and wing coverts emerge. Upper and lower tail coverts emerge at 8 weeks.

Both male and female cranes have the same plumage color, light yellow mingled with a little white. Secondaries and tertiaries are black, and because tertiaries are elongated they cover the rectrices. In contrast, the alula, primaries, and rectrices are white. The contour feathers of young cranes are light yellow at the tips and turn pure white after the first molt. Juvenile cranes are basically similar to the mature cranes in all aspects except for the Red-crown Crane, which is not as red as in adults.

Conclusion and Discussion

Growth and molt in flight feathers. According to our observations and measurements from 20 young Red-crowned Cranes during their first 2 years, the growth and molt processes for flight feathers are as

follows. Growth process of alula is 5 weeks and molt is 7 weeks. Growth process of primaries is 6 weeks and molt is 8 weeks. Growth process of secondaries is 5 weeks and molt is 12 weeks. Growth process of tertiaries is 6 weeks and molt is 5 weeks. Growth process in rectrices is 6 weeks and molt is 5 weeks.

Sequence of Growth and Molt in Flight Feathers

Both the growth and molting sequences of alula, primaries, secondaries, tertiaries, and rectrices are from inside to outside. That is, the earlier a feather grows, the earlier it molts. Whereas rectrices almost all grow at the same time, their molt occurs from the center outwards on both sides. Only a few individuals molt in irregular sequences.

In summary, we determined that the Red-crowned Crane's postnatal molt is a complete molt, with all flight remiges and rectrices completely shed and replaced by new feathers. We have also observed that the postnatal molt paused for 6–7 weeks from the end of September to 10–20 November. This is possibly an adaptation to migration. We also found that small differences exist between cranes in the timing of growth and molt, and that these are due to such reasons as their different state of health.

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References

Li, F., and B. Liu. 1995. Research on captive breeding and rearing in the Red Osprey. Thesis Collection of China Zoological 3:1–5.

Zheng, G. 1979. *Lanius collurio isabellinus* and its autumn molting of close relatives. Learned Journal of Beijing Teachers University and Natural Science Press 3:100–110.

Zheng, Z. 1995. Annals of the Chinese Economic Animals (birds). Beijing Scientific Press 694–695:230–233.

Chick Growth in the White-naped Crane (*Grus vipio*)

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The White-naped Crane (*Grus vipio)* belongs to the order *Gruiformes*, family *Gruidae*. It is also known as the "Red-faced Crane." It is a large wading bird that frequents marshlands. It has grayish white feathers, a white occiput, red cheeks, beautiful posture, and a brisk and elegant manner. It is a popular bird for its ornamental value and is of great value for scientific research. Because of its low numbers the White-naped Crane is listed as a Class II protected animal in China. It is important to study its foraging, breeding, and development. Because reports on the development of *Grus vipio* chicks are limited, we systematically collected data on its growth.

Materials and Methods

Because of breeding pairs' protective and aggressive behaviors, some eggs were removed and hatched in incubators. Other eggs were incubated by their parents and hatched at the nest. Every other week we weighed, measured, and regularly made notes on the external appearance of chicks, including feather color.

Results

Weight

At hatching, chicks weigh an average of 123.8 g. This average weight is slightly lower than 135 g hatch weight previously reported by Tian et al. (1992), and higher than 108 g hatch weight reported by Wang (1979). Chicks lose approximately 30 g during their first 4 days because they are unable to feed themselves and are absorbing their yolk sac. From then on chicks gain weight. Weight gain is 39 g/day from days 7–21, increasing to 92.4 g/day from days 21–49, and then 64 g/day from days 49–63, and 28 g/day from days 63–105 (Table 1). Peak weight gain occurs between days 14 and 63. During this time, weight gain is 77.5 g/day, higher than the 62.1 g/day reported by Tian et al. (1992) for the same time period. We conclude that the diet provided to chicks at the Harbin Zoo is more suitable. The chicks weigh 4,125 g at day 63, or approximately 54% of an average adult's weight of 7,600 g.

Growth of Body Parts

At hatching, body length is 24.6 $\pm$ 0.6 cm. Peak growth occurs from days 7–63, when body length increases at a rate of 1.24 cm/day. Body length reaches 101 cm by day 63, equal to 70% of an adult's body length (Table 1). Wing length is 2.8 cm at hatching. Peak growth occurs from days 14–70, as wing length increases 0.74 cm/day, reaching 46.65 cm by day 70. Mandible width averages 3.25 $\pm$ 0.25 cm at hatching. Peak growth of 0.11 cm/day occurs between days 7–77, with the mandible width reaching 11.75 cm by day 77. Tail feathers emerge 10–12 days after hatching, and grow 0.42 cm/day from days 28–63. At hatching, length of tarsometatarsus is 4.6 $\pm$

Table 1. Growth of White-naped Crane chicks from hatching to 105 days.

Age (days)	Weight (g)	Measurement (cm)							
		Body	Tail	Culmen	Mandible	Head	Tarsus	Wing	Mid-toe
1	12.8 ± 15	24.6 ± 0.6		2.5 ± 0.2	3.3 ± 0.3	2.6 ± 0.2	4.6 ± 0.5	2.8 ± 0.2	3.4 ± 0.1
7	142.0 ± 35	31.5 ± 1.5		3.3 ± 0.3	4.2 ± 0.2	2.9 ± 0.4	6.2 ± 0.2	3.7 ± 0.5	4.8 ± 0.3
14	325.8 ± 70	44.5 ± 1.0	2.4 ± 0.4	4.4 ± 0.4	4.9 ± 0.1	3.2 ± 0.3	9.8 ± 0.3	4.9 ± 0.5	6.5 ± 0.5
21	64.3 ± 134	49.0 ± 1.5	3.5 ± 0.5	5.1 ± 0.2	5.3 ± 0.5	3.6 ± 0.5	13.0 ± 0.5	6.0 ± 0.5	7.6 ± 0.8
28	1,270 ± 247	58.5 ± 1.5	4.8 ± 0.2	5.9 ± 0.5	6.1 ± 0.5	3.9 ± 0.1	16.3 ± 1.8	10.5 ± 1.5	9.3 ± 0.3
35	2,150 ± 350	68.0 ± 2.0	7.0 ± 1.8	6.7 ± 0.7	7.5 ± 0.5	4.4 ± 0.2	20.8 ± 0.3	18.8 ± 2.3	10.7 ± .2
42	2,750 ± 250	78.0 ± 4.0	10.0 ± 2.0	7.8 ± 0.4	8.3 ± 0.3	4.5 ± 0.2	22.5 ± 0.1	25.5 ± 5.5	11.0 ± 0.5
49	3,230 ± 230	87.0 ± 2.0	15.8 ± 1.2	8.7 ± 0.3	9.2 ± 0.2	4.7 ± 0.1	24.7 ± 0.3	32.4 ± 2.4	11.5 ± 0.5
56	3,560 ± 240	92.5 ± 2.5	17.5 ± 0.5	9.7 ± 0.3	9.5 ± 0.1	4.9 ± 0.1	25.5 ± 1.5	35.8 ± 0.8	11.7 ± 0.3
63	4,125 ± 325	101.0 ± 2.5	19.5 ± 0.5	10.2 ± 0.2	10.5 ± 0.1	5.0 ± 0.1	25.8 ± 0.3	42.5 ± 1.5	11.9 ± 0.4
70	4,250 ± 250	103.5 ± 2.0	20.5 ± 1.0	10.5 ± 0.5	11.1 ± 0.2	5.2 ± 0.1	26.0 ± 0.5	46.7 ± 0.3	12.3 ± 0.4
77	4,400 ± 300	105.0 ± 2.5	21.2 ± 1.5	11.4 ± 0.4	11.8 ± 0.3	5.2 ± 0.1	26.1 ± 0.1	50.2 ± 0.3	12.4 ± 0.4
84	4,650 ± 275	107.0 ± 3.2	21.9 ± 1.5	11.7 ± 0.4	11.9 ± 0.2	5.3 ± 0.1	26.5 ± 0.5	53.0 ± 1.0	12.4 ± 0.2
91	4,850 ± 270	108.8 ± 2.3	22.0 ± 1.5	12.0 ± 0.1	12.2 ± 0.2	5.4 ± 0.2	26.5 ± 0.5	55.5 ± 0.5	12.4
98	5,050 ± 250	110.5 ± 2.0	22.0 ± 1.2	12.1 ± 0.2	12.4 ± 0.2	5.4 ± 0.1	26.8 ± 0.5	56.0 ± 0.5	12.4
105	5,300 ± 230	112.0 ± 1.2	22.5 ± 1.5	12.2 ± 0.2	12.4 ± 0.2	5.4 ± 0.2	27.2 ± 0.5	56.5 ± 1.5	12.4

0.5 cm. Peak growth (0.39 cm/day) occurs between days 7–56, and the tarsometatarsus reaches 25.5 cm by day 56. The midtoe, including the nail, averages 0.165 cm at hatching, and reaches 11.5 cm by day 49 (Table 1; Figs. 1 and 2).

Changes in External Appearance

Grus vipio is a precocial bird. Within 15 hours after hatching it can walk, and within 24 hours it is drinking and eating. At hatching, its natal down is light brown, with the back darker than the breast. On the back, two white, hairline stripes appear like an "X" between the wings. The tip of the bill is apricot-yellow and the mandibles are purplish-gray with an egg tooth on the upper mandible. The tarsometatarsus is bright yellow. Its front is covered with shield-shaped scales and the back with web-shaped scales. The knee joints are inflated, and the claws are purplish-gray. As days pass, the feathers turn from brownish-yellow to gray-brown and then to gray. Feathers begin to differentiate about the time when the remiges emerge.

The tail feathers emerge when the chick is 10–12 days old. The feather shaft can be seen in the right and left tail feathers at day 20 and in the back feathers and primary feathers starting at days 16–18. About the same time, feather color becomes a little darker, claws turn blackish brown, and the shield-shaped scales on the front of the tarsometatarsus turn brown. At days 20–25, the egg tooth falls off and the culmen changes color to pinkish-white. By day 30, the base of the bill is pink, the back is brownish-yellow, the abdomen is grayish-white, tarsometatarsus are pinkish-purple and their front shield-shaped scales are darker. When the chick is 60 days old, its occiput is yellowish-brown, the feathers behind its ears begin to fall off, primary and secondary feathers become blacker, and the wing feathers are white and cover grayish-brown, scale-shaped coverts.

When the chick is 3 months old, its ears turn a dark, yellowish-brown, and the exposed area around its eye turns pink. The white feathers can now be seen in its occiput. The back is grayish with some brown scale-shaped feathers. The abdomen is covered with grayish-white, scale-shaped feathers. The tarsometatarsus is grayish-black.

Logistic Equations for Weight and External Body Parts

Logistic equations for weight and external body parts were calculated for chicks 1–105 days old (Table 2). The K value, which is as much as four times the growth ratio, indicates the state of growth.

Fig. 1. The growth curve of *Grus vipio* nestlings.

Fig. 2. The growth curve of *Grus vipio* chick external body parts.

The K value for tail length is the largest, indicating that the tail grows very fast. In contrast, the K values for mandible and culmen are the smallest, indicating a slower growth.

The value T10-90 represents the growth time needed from 10–90% of the value of the asymptote. The T10-90 value for tail length is lower than other indices. That means the growth time for the tail is shorter than for other body parts. In the case of the White-naped Crane, tail feathers do not appear until the chick is 10–12 days old.

The inflection point values for head width, midtoe length, and tarsometatarsus length are low, but those of wing length, tail length, and weight are comparatively higher. A lower inflection value indicates that it grew earlier in the chick's development, compared with a higher inflection value. All the values of *Grus vipio* chicks are lower than Bustard (*Otis* spp.) chicks. This means that the peak growth for cranes is much earlier than Bustards. The G value for mandible width, culmen length, and weight are small, indicating that these body parts grow rapidly after the chick is 90 days old. The G value for tarsometatarsus length is the largest, indicating that the tarsometatarsus hardly grows after 90 days.

Recommendations for Captive-Rearing

The White-naped Crane chick is very weak when it hatches. In order to guarantee that the chick will grow up healthy, a lamp is used to warm the brooder box and supplement the indoor light. The brooder box should be cleaned daily. The temperature inside the brooder box should be kept at the chick's normal

Table 2. The logistic equations for weight and external body parts of Black-naped Crane chicks.

Item	Asymptote	K	T (10–90)	Inflection boint	G	Logistic equation
Weight	5,000	0.057	77.1	39.1	1.32	$5{,}000/(1 + e^{2.229-0.067t})$
Body length	120	0.077	57.1	30.5	2.09	$120/(1 + e^{2.349-0.077t})$
Wing length	56	0.065	67.3	45.2	1.33	$56/(1 + e^{2.938-0.065t})$
Tail length	22.5	0.095	46.0	43.8	2.01	$22.5/(1 + e^{4.101-0.090t})$
tarsometatarsus length	28	0.078	56.5	22.8	2.38	$28/(1 + e^{1.778-0.078t})$
Culmen	13	0.041	106.0	33.5	1.07	$13/(1 + e^{1.574-0.041t})$
Mandible	13.5	0.043	102.8	29.1	1.18	$13.5/(1 + e^{1.260-0.043t})$
Mid-toe	12.5	0.080	54.9	12.9	2.81	$12.5/(1 + e^{1.032-0.080t})$
Head width	5.5	0.056	78.2	5.6	2.16	$5.5/(1 + e^{0.314-0.058t})$

body temperature. At 1 week old, the chick can be moved outdoors for sunshine, and should be walked in order to improve its condition and build its resistance. Care should be taken that the chick does not get too much sun and suffer from sunstroke.

Chick metabolism is high, so they should be fed frequently. The quantity should be controlled, however, because too much food can lead to indigestion and can also affect growth. Food rations should be decreased if there are signs that the chick's legs cannot support the body's trunk because of excess weight gain. In order to keep the chick active and healthy, calcium, a variety of trace elements, and vitamin D should be included in the diet.

Early in a chick's development, tarsometatarsus length, mandible width, and midtoe length increase, whereas weight and wing length increase between 1–2 months of age. Proper diet and good management should be practiced according to a chick's development.

References

Ricklefs, R. E. 1967. A graphical method of fitting equation to growth curves. Ecology 48:978–987.

Tian, X., X. Bai, and S. Li. 1992. A study in captive breeding of the White-naped Crane. Chinese Wildlife 3:51–53.

Tian X., X. Bai, and S. Li. 1990. Hand-reared chicks of the White-naped Crane and their development. Pages 78–89 *in* Heilongjiang Forestry Bureau, editors. Proceedings of the 1987 International Crane Workshop. Forest Press, Beijing.

Wang, T. 1979. The altricial chick growth in the White-naped Crane. Pages 81–82 *in* Thesis collection of China Zoos.

Speciation of the Black-necked Crane

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The last crane species to be described was the Black-necked Crane (*Grus nigricollis*) of the Qinghai-Tibetan Plateau. It was first described in 1876 at Qinghai Lake, China. Since 1979, Chinese scientists have conducted extensive research on this species, especially on its population status and distribution (Yao and Liao 1984), population structure (Li and Zhou 1987), wintering ecology (Lu 1983; Wu 1985), and breeding ecology (Lu and Yao 1980; Yao and Liao 1984). However, no studies have been published on Black-necked Crane speciation.

The Concepts of Species and Speciation

Species are natural components in the biosphere. The concept and definition of the species has been controversial for a long time. At present, the concept occupying a dominant position in taxonomy is Mayr's biological species concept (Mayr 1963, 1970), whereby a biological species is "a group of interbreeding natural population that is reproductively isolated from other such groups."

Comparing this concept of species with others, three aspects should be considered. First, this species was not considered as a type, but as a group or population that occupies a special niche (Mayr 1988). Second, the species are based on their reproductive isolation, but not on the extent of their differences. Third, a species is defined by its relationship with other species that coexist with it, not by its inherent characteristics. The relationship between species is not only expressed by way of their behavior (non-reproductive hybridization) but also ecologically (no eradicating competition). This concept of species can predict some features that a new species has (e.g., special niche, stable genotype) and also can determine if a similar population is the same species. This concept is widely accepted and applied by most zoologists, geneticists, and ecologists.

Reproductive isolation is the core of the biological species concept. The isolation pattern includes pre-zygotic reproductive isolation and post-zygotic reproductive isolation. Pre-zygotic reproductive isolation includes: (1) ecological or habitat; (2) breeding time or seasonal; (3) reproductive behavior ; and (4) gamete. Post-zygotic reproductive isolation primarily is hybrid sterility including embryo death, miscarriage, and sterile offspring. It is caused by genetic incompatibility. These reproductive isolation patterns cut the gene flow between populations and maintain the independence and integrity of a species.

The process of species formation is called speciation. Speciation has puzzled biologists for many years. Mayr (1963), Grant (1971), White (1978), and Bush (1975) all discussed speciation but did not share identical viewpoints. Recently, speciation has been defined as follows:

1. Allopatric speciation is also called geographic speciation. The basic idea is that when a species is divided into two or more geographically isolated groups, it will have hereditary and adaptive changes. If different

geographic conditions and adaptations result in reproductive isolation, a population will differentiate into a new species. This occurs commonly in nature. Bush (1975) recognized two types of allopatric speciation: one that occurs after geographic separation across a large range (Fig. 1a) and another caused by several individuals separating from the population and forming a new species (Fig. 1b).

2. Sympatric speciation is the process of a new species evolving within the original distribution area of the ancestral species because of ecological differences or other causes (Fig. 2). It is thought that parasitic animals and polyploid plants are formed by sympatric speciation. Bush (1975) also recognized parapatric speciation, a concept that is disputed by others. Some scientists thought parapatric speciation could not be distinguished from the second process of allopatric speciation (Mayr 1970; Wiley 1981). Still other scientists thought parapatric speciation was sympatric speciation (Murray 1972).

The Relationship of Black-necked Crane to Other Crane Species

At present, few papers have reported on crane systematics (Krajewski 1984, 1989; Zheng 1986; Dessauer et al. 1992). Based on feather morphology and anatomy, Zheng (1986) believed that the Red-crowned Crane had the closest relationship to the Black-necked Crane. Dessauer et al. (1992) and Krajewski obtained different results using iso-enzyme analysis, DNA sequencing, and cyto-B gene sequencing techniques.

Bai (1997) conducted studies on systematics of cranes occurring in China. He used cells, proteins, and DNA, and combined these to produce a numerical value classification analysis. He concluded that the Red-crowned Crane is closer to the Black-necked Crane (Fig. 3).

Examining reproductive behavior, the courtship and mating behaviors of Red-crowned Cranes described by Feng and Li (1989) is the same as that of the Black-necked Crane as described by Lu (1991). Liao (1983) reported that captive Black-necked and Red-crowned Cranes can successfully breed, and the offspring develop normally. These all indicate that the Red-crowned Crane is not reproductively isolated from the Black-necked Crane and that they have a close relationship. Gan and Jin (1987) conducted an

Fig. 1. Process of allopatric speciation [from Bush (1975)].

Fig. 2. Process of sympatric speciation [from Bush (1975)].

Fig. 3. Phelogenetic tree of cranes in China.

experiment whereby they inseminated a Black-necked Crane with White-naped Crane (*Grus vipio*) semen. The offspring was very weak, unable to stand, and died 36 hours after hatching. Perhaps this was caused by post-zygotic reproductive isolation.

Qinghai-Tibetan Plateau Uplift and Climate Changes

Ancient Geographic Environment Before the Qinghai-Tibet Plateau Uplift

The Qinghai-Tibet Plateau uplift began in the late Eocene Epoch, Cenozoic Era. At that time, the Plateau separated from the sea and became a land characterized by low elevation. Across the latitudes, climates were distinct. The south was hot and wet and included ancient plant communities; the north was hot and dry. Monsoon circulation did not exist.

Ancient Geographic Environment of the Qinghai-Tibetan Plateau in the Pliocene Epoch

The movement of the Himalayas occurred during the Miocene Epoch. The Himalayas started to uplift and formed new basins and hills. Up until the late Pliocene Epoch, the Qinghai-Tibetan area remained relatively flat with elevations below 1,000 m. The climate was warm and humid. The predominating plant communities were aquatic plants and grasses and dominant animal communities were herbivores, such as antelopes.

The Qinghai-Tibet Plateau rose violently at the end of the Pliocene Epoch and the early Quaternary Period, about 3.4 million years before the present (MaBp). Studies of basin succession in the Qinghai-Tibetan Plateau and the development of the Yellow River indicated that the Plateau experienced at least nine successive uplifts during 2.5, 1.7, 1.3, 1.1, 0.8, 0.6, 0.14, 0.05, and 0.01 MaBp. The average elevation of the Plateau reached 1,500 –2,000 m after 2.5 MaBp, >3,000 m after 0.6 MaBp, and >4,000 m after 0.14 MaBp an elevation close to what presently occurs. The climate and environment also changed with these uplifts. According to Pan (1995), the eastern Asia monsoon was a summer monsoon during 2.5–1.7 MaBp of the Quaternary Period. The period 1.7–1.1 MaBp marked the beginning of winter-summer monsoons with very strong winter-summer monsoons from 1.6–1.1 MaBp. A period of great abundance of winter-summer monsoons occurred from 0.6–0.1 MaBp. The period of winter monsoon began recently, 0.1 MaBp. Because of the sequence of these five monsoon periods and glaciers surging, the biological communities of Qinghai-Tibetan Plateau comprised not only ancient species from the Tertiary Period but also new, specialized species.

Inferences on Speciation of the Black-necked Crane

The principal question of speciation is how discontinuities between populations originated. Biogeographic principles require that speciation should have two basic conditions, hereditary variations, and environmental changes. The hereditary variation provides the materials for natural selection and eventually results in reproductive isolation. The increase in new mutation frequencies and replacement of non-mutation genes are caused by environmental changes. For allopatric speciation, the geographic environment changes first, which results in hereditary differentiation. For sympatric speciation, hereditary variation occurs first, and then environmental changes play the role of selection.

The Black-necked Crane is a unique species of the Qinghai-Tibetan Plateau. From the Plateau's uplift it can be concluded that the Black-necked Crane became geographically disjunct from its ancestral Red-crowned Crane. This disjunction obstructed the gene flow between the two populations. The obstructed gene pool was selected for in different geographic environments. Gradually the gene pool differentiated and resulted in reproductive isolation. Therefore, it can be determined that the Black-necked Crane's speciation was allopatric. Because the process was allopatric speciation, the reproductive isolation of these two crane species was not complete. With allopatric speciation the two species have a close relationship and do not have a problem recognizing courtship signals. Therefore, breeding behavior (courtship, mating) that could cause reproductive isolation did not differentiate completely, the gene pool has no significant differences, and hybrid gametes can develop normally.

Based on crane fossils (Qian 1994) it is believed that Black-necked Crane differentiation occurred during the Quaternary Period, before the Qinghai-Tibetan Plateau uplift. At that time the ancestral species to the Red-crowned Crane lived on the Qinghai-Tibetan Plateau. The Plateau's elevation was not high, and the climate was temperate. With the Plateau's uplift and climate changes, a part of the population remained and adapted to these changes, eventually evolving into the Black-necked Crane. The other population of the ancestral species of Red-crowned Crane evolved into the Red-crowned Crane. The question of whether or not the ancestral species is extinct, that is, if the speciation of the Black-necked Crane is additive speciation or reductive speciation should be further investigated.

References

Bai, X. 1997. Study on the systematic evolution of Chinese cranes. Ph.D. thesis, Northeast Forestry University, Harbin.

Bush, G. L. 1975. Modes of animal speciation. Annual Review of Ecology and Systematics 6:339–363.

Dessauer, G. C., G. F. Gee, and J. S. Rogers. 1992. Allozyme evidence for crane systematics and polymorphisms within populations of Sandhill, Sarus, Siberian, and Whooping cranes. Molecular and Phylogenetics Evolution 1:279–288.

Feng, K., and J. Li. 1989. The breeding ecology of Red-crowned Crane. Pages 1–6 *in* Proceedings of Heilongjiang Institute of Wildlife.

Gan, S., and J. Jin. 1983. Experiment on artificial insemination black-necked crane. Journal of Zoology 3:32–35.

Grant, V. 1971. Plant speciation. Columbia University Press, New York.

Krajewski, C. A., A. C. Driskell, P. R. Baverstock, and M. J. Braun. 1992. Phylogenetic relationships of the thylacine (Marsupialia: Thylacinidae) among dasyuroid marsupials: evidence from cytochrome-b DNA sequences. Proceedings of the Royal Society of London. Series B. Biological Sciences 250:19–27.

Li, D., and Z. Zhou. 1987. The structure and behavior of breeding populations of Black-necked cranes. Abstract, International Crane Symposium, 1987.

Liao, Y. 1983. Breeding behavior of crossing Black-necked Cranes with Red-crowned Cranes. Journal of Zoology 3:28–32.

Lu, Z. 1983. Wintering habits of the Black-necked Crane. Chinese Wildlife 3(2):35–36.

Lu, Z., and J. Yao. 1980. The observation on breeding ecology of Black-necked Cranes. Journal of Zoology 9:27–30.

Mayr, E. 1963. Animal species and evolution. Harvard University Press, Cambridge, Mass.

Mayr, E. 1970. Population, species, and evolution. Belknap Press, Harvard University, Cambridge, Mass.

Mayr, E. 1988. Toward a new philosophy of biology: Observations of an evolutionist. Belknap Press of Harvard University Press, Cambridge, Mass.

Murray, J. J. 1972. Genetic diversity and natural selection. Hafner, New York.

Qian, Y. 1994. Cranes studies. Journal of Zoology 27 (2):41–47.

White, M. J. D. 1987. Modes of speciation. W. H. Freeman, San Francisco.

Wiley, E. O. 1981. Phylogenetics: The theory and practices of phylogenetic systematics, John Wiley, New York.

Wu, Z. 1985. Wintering ecology of the Black-necked crane. Journal of Ecology 5(1):71–75.

Yao, J., and Y. Liao. 1984. Breeding behavior of the Black-necked Crane. Thesis Collections of Plateau Biology 3:141–147.

Zheng, Z. 1986. Systematic index of world cranes. Journal of Zoology 32(2):179–181.

Hematological Indices of the White-Naped Crane (*Grus vipio*)

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The White-naped Crane (*Grus vipio*) belongs to the order Gruiformes, family Gruidae. It is listed as a vulnerable species by the IUCN, and in Appendix I of CITES (1995) (Zheng and Wang 1998). White-naped cranes domesticate easily and have high ornamental value. With the establishment and development of nature preserves and zoos in China, research on crane breeding ecology, both in captivity and in the wild, has gradually increased. Great progress has been made in the field of crane ecology and anatomy. However, there is a lack of data for hematological indices in cranes (Fang et al. 1987; Heilongjiang Forest Bureau 1990; Zhang 1993). Hematological indices are important indicators of physiological condition (Veterinarian College 1979; Fang et al. 1987; Zhang 1993). For this study we analyzed blood profiles for the White-naped Crane and tested it for differences by sex and age.

Materials and Methods

Our study population of White-naped Cranes consisted of three adult males and three adult females, all 8–10 years old. Five, captive-reared young were also sampled. All cranes were healthy and housed at the Harbin Zoo, Harbin, Heilongjiang Province. Cranes were housed in pens that included a brick, indoor pen (5 m x 2 m x 2.5 m) with a southern exposure, and an outdoor pen (13 m x 5 m x 6.5 m). Fences were lined with a layer of soft nylon net to prevent cranes from harming themselves when they flew. The ground was paved with bricks and covered with sand. Pens included trees.

Cranes were fed twice daily, in the morning and afternoon. Drinking water was changed twice daily and cages cleaned every morning. The White-naped Cranes were fed corn and fish mixed with flour, steamed corn bread, seasonal vegetables, and trace nutrients. Every adult crane's daily ration included 500 g fish, 50 g egg, 25 g vegetable, 25 g meat stuffing, and 400 g pellet for a total of 1,000 g.

Blood was drawn on sunny days between 0600–0800h. We drew 1 ml of blood from the brachial vein, and used ethylenediaminetetraacetic acid (EDTA) K2 to prevent coagulation. We used the Coulter Company JT-IL blood cell analytical apparatus. The hemolytic agent was LYSE Sdiff, the diluent ISOTON III, and the cleaning solution CLEANZ. All were Coulter Company products. After the blood sample was taken, it was mixed for 15–30 minutes at an indoor temperature ranging from 20–30 °C. The instrument was utilized according to all rules of operation including the reagent blank determination. Samples were counted by instrument. Smears were stained using a Wright-Romanovsky stain. White blood cells were counted under a microscope using the 4-corner count method. Mean ($\pm$ SD) hematological values were determined for adult and young White-naped Cranes. We tested for differences by age and sex using *t*-tests.

Results and Analyses

We found no statistical differences by sex for White-naped Crane adults in the 12 hematological indices (Table 1). Compared with adult cranes, young cranes had significantly higher mean corpuscular volume (MCV) and platelet volume (PCT) and significantly lower mean corpuscular hemoglobin concentration (MCHC). For adult cranes, average body temperature was 40.00 $\pm$ 0.35°C, average pulse rate 156 $\pm$ 6.50/min, and average respiratory rate 16 $\pm$ 0.50/min.

Discussion

Blood is the most important component of an animal's internal environment, and plays a significant role in maintaining normal biological activity. Blood parameters can reflect the body's metabolism. In clinical practice blood parameters are used to diagnose diseases and evaluate treatments (Veterinarian College 1979). Research on hematological characteristics of White-naped Cranes and determining normal values are important for understanding crane nutrition, metabolism, condition, and reproductive ability.

During our study we found that White-naped Crane blood composition has general characteristics common in birds, such as the red blood cells are long and elliptical and have nuclei (Fig. 1). Compared with other kinds of white blood cells, heterophils and lymphocytes occur in the highest proportions. However, White-naped Crane blood has certain features. In red blood cells, cytoplasm is tinged yellow and the nucleus appears indigo. The nucleus of lymphocytes is magenta and the cytoplasm is deep blue. Heterophils are nearly round and have multi-lobed nuclei. The link belt among the lobes is obvious and the cytoplasm contains granules.

We found no statistical difference between adult male and female White-naped Cranes in any of the hematological indices. Three indices showed statistically significant differences between young and adults. These results indicate that differences exist in metabolism during the course of development in the White-naped Crane. The MCV of young cranes was significantly higher than for adults, but their MCHC was lower. Even though there were no statistical differences, red blood cell, white blood cell, and hemoglobin concentration (HGB) were all lower and PCT higher in young cranes when compared to adults.

The blood cells of birds have cytoplasm. When the average red blood cell hemoglobin concentration is calculated, the measured value should be adjusted to the measured value 0.91–14.9(g/L) (Yang 1992). Hemoglobin is synthesized mainly in the bone marrow's red blood cells containing nuclei. Whether differences in hemoglobin between adults and young have something to do with it, remains to be confirmed.

A previous study on Black-necked Cranes (*Grus nigricollis*) (Zhang 1993) found that their hematological values are: white blood cell (WBC) count 16.3 $\pm$ 4.2 (10^9/L), red blood cell (RBC) count 1.85 $\pm$ 0.44 (10^{12}/L), percent heterophils (He/WBC) 0.39 $\pm$ 0.08 (100%), percent lymphocyte (Ly)/WBC 0.54 $\pm$ 0.11(100%), body temperature 41.35 $\pm$ 0.21°C, pulse rate 122.5 $\pm$ 2.12/min, and average respiration rate 11.0 $\pm$ 0.071/min. Except for RBC and body temperature, other indices such as percent heterophils, pulse and respiration rates are all higher in the White-naped Crane than the Black-necked Crane. These differences may be related to its ecology.

Other studies have found that hematological values can vary, depending on age, condition, food intake, and weight of the crane, as well as environmental elements such as weather and altitude (Veterinarian College 1979; Fang et al. 1987; Zhang 1993). This paper provides a systematic evaluation of hematological indicators of White-naped Cranes. The data illustrate that the White-naped Crane has the ability to adapt to all kinds of environmental conditions.

References

Fang, Z., C. Zhang, J. Su, and Y. Liao. 1987. Some hematological reference values of the Black-necked Crane. Highland Biology Publishing 7:171–174.

Heilongjiang Forest Bureau. 1990. International Crane Protection and Research. China Forestry Press, Beijing. 285 pp.

Veterinarian College of the Chinese People's Liberation Army, editors. 1979. Veterinarian examine. Chinese Agriculture Press.

Yang, Lan. 1992. The Chinese Phasianids Lady Amherst's pheasant. China Forestry Publishing House.

Zhang, W. 1993. Physiological parameter index of Black-necked Cranes and Common Cranes in Coahai. Chinese Journal of Zoology 28(4):38–40.

Table 1. Hematological values for captive White-naped Cranes (M +/- SD).

Index[a]	Female (n = 3)	Male (n = 3)		All adults	Young	
WBC(10^9/L)	14.67 ± 4.64	14.57 ± 3.81	0.029	14.62 ± 3.79	10.28 ± 5.39	1.568
H_e/WBC(100%)	0.56 ± 0.10	0.53 ± 0.15	0.235	0.48 ± 0.18	0.54 ± 0.11	0.582
N_e/WBC(100%)	0	0		0	0	
Eo/WBC(100%)	0	0.02		0.02	0.10	
Ba/WBC(100%)	0	0		0	0	
L_y/WBC(100%)	0.44 ± 0.10	0.47 ± 0.13	0.259	0.47 ± 0.13	0.45 ± 0.13	0.243
Mo/WBC(100%)	0	0		0	0.03	
RBC(10^{12}/L)	1.95 ± 0.11	2.04 ± 0.09	1.097	2.00 ± 0.10	1.85 ± 0.13	2.108
HGB(G/L)	159.33 ± 19.86	166.67 ± 19.50	0.457	163.00 ± 18.06	144.45 ± 12.86	1.925
HCT(L/L)	0.37 ± 0.02	0.39 ± 0.01	1.549	0.38 ± 0.02	0.37 ± 0.02	0.626
MCV(FL)	189.03 ± 2.86	190.27 ± 5.85	0.330	189.65 ± 4.18	198.60 ± 8.02	2.390[b]
MCH(PG/L)	81.67 ± 5.43	81.43 ± 6.49	0.049	81.55 ± 5.35	77.90 ± 2.27	1.413
MCHC(g/L)	432.33 ± 35.23	428.67 ± 41.30	0.117	430.50 ± 34.39	392.80 ± 14.11	2.908[b]
PLT(10^9/L)	43.00 ± 15.56	57.50 ± 6.36	1.230	50.25 ± 12.82	46.00 ± 8.34	0.327
PCT(L/L)	0.003 ± 0.003	0.002 ± 0.001	0.548	0.003 ± 0.002	0.007 ± 0.003	2.813[b]
MPV(FL)	4.27 ± 0.81	3.77 ± 0.31	1.200	4.02 ± 0.61	4.64 ± 0.64	1.633
PDW(%)	16.07 ± 2.50	14.53 ± 1.11	0.975	15.30 ± 1.92	17.04 ± 1.46	1.657

[a]Abbreviations used:

WBC	white blood cell
H_e/WBC	heterophil/white blood cell
N_e/WBC	neutrophil/white blood cell
Eo/WBC	eosinophil/white blood cell
Ba/WBC	basophil/white blood cell
Ly/WBC	lymphocyte/white blood cell
Mo/WBC	monocyte/white blood cell
RBC	red blood cell
HGB	hemoglobin concentration
HCT	hematocrit
MCV	mean corpuscular volume
MCH	mean corpuscular hemoglobin
MCHC	mean corpuscular hemoglobin concentration
PLT	platelet count
PCT	platelet volume
MPV	mean platelet volume
PDW	platelet distribution width

[b]$t(0.05)4 = 2.776$; $t(0.01)4 = 4.604$
$t(0.05)9 = 2.262$; $t(0.01)9 = 3.250$; $t(0.05)<t<t(0.01)$.

Fig. 1. Photographs (10 x 100) of blood cells of the White-naped Crane: a. red blood cell; b. lymphocyte; and c. heterophil.

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The White-naped Crane (*Grus vipio)* is listed as a Class I protected animal in China. This species belongs to the order Gruiformes, family Gruidae. White-naped Cranes are easily tamed and have high ornamental value. However, both the population and distribution of the White-naped Crane in the wild have been decreasing. Studies on captive-breeding and rearing cranes, as well as other aspects of crane ecology have expanded concurrent with the increase in the establishment of nature reserves. Much progress has been made in studies on crane ecology and anatomy, but we still lack information on blood serum chemistry indices for cranes (Ma 1986; Fang et al. 1987; Heilongjiang Forest Bureau 1990).

Because blood serum reflects animal condition and provides a base for further experiments (Yang 1990; Yang 1992; Wei 1995), we determined serum chemistry values for captive White-naped Cranes. We compared these with values obtained from captive Black-necked Crane *(Grus nigricollis)* held at the Beijing zoo. Our results provide information for captive crane management and for the study of cranes worldwide.

Materials and Methods

Our study population of White-naped Cranes consisted of three adult males and three adult females, all 8–10 years old. Five, captive-reared young were also sampled. All cranes were healthy and housed at the Harbin Zoo, Harbin, Heilongjiang Province. Cranes were housed in pens that included a brick, indoor pen (5 m x 2 m x 2.5 m) with a southern exposure, and an outdoor pen (13 m x 5 m x 6.5 m). Fences were lined with a layer of soft nylon net to prevent cranes from harming themselves when they flew. The ground was paved with bricks and covered with sand. Pens included trees.

Cranes were fed twice daily, in the morning and afternoon. Drinking water was changed twice daily and cages cleaned every morning. The White-naped Cranes were fed corn and fish mixed with flour, steamed corn bread, seasonal vegetables, and trace nutrients. Every adult crane's daily ration included 500 g fish, 50 g egg, 25 g vegetable, 25 g meat stuffing, and 400 g pellet for a total of 1,000 g.

Blood was drawn in the morning on sunny days before cranes had eaten. Blood was stored in a buffer solution of exalic acid. A Japanese-manufactured fully automatic 7020 Biochemistry Instrument and American Medical Instrument were used to determine blood serum values. All biochemical reagents used in this study are products of the Shanghai Long March Medical Scientific, Ltd.

Mean ($\pm$ SD) serum chemistry values were determined for adult and young White-naped Cranes. Black-necked Crane serum chemistry values were provided by Beijing Zoo (Yang Minghai, personal communication). We tested for differences by age, sex, and species using *t*-tests.

Results

We found no statistical differences by sex for adult White-naped Cranes in the 28 indices (Table 1). Compared with adult cranes, young cranes had eight indices that were significantly different. In young cranes, glucose was higher than in adults, and lactic dehydrogenase (LDH), total cholesterol (CHO), HBD reagent (HBD), alkaline phosphatase (ALP), creatinine kinase (CK), phosphorus, and creatinine kinase isoenzyme (CKMB) were significantly lower than in adults. When we compared serum chemistry values between species, glucose in the White-naped Crane was higher and uric acid, phosphorus, and CHO were lower than for Black-necked Crane (Table 2). For the adult White-naped Crane, body temperature was 40.00 ± 0.35^{o}C, pulse rate 156 ± 6 .50/min, and respiratory rate 16 ± 0.50/min.

Discussion

Blood is the most important component of an animal's internal environment. Substances in blood serum reflect body condition. In clinical practice, serum chemistry values are used to diagnose diseases and evaluate treatments (Yang 1990; Wei 1995). Determining blood serum chemistry values for White-naped Cranes is an important contribution to the study of cranes worldwide. These values are important for understanding body condition, nutrition, metabolism, reproductive abilities, and development.

Our results show that there are differences between young and adult White-naped Cranes. The ratio of calcium to phosphorus is approximately 2.38 (2.33:0.98) for adult and 1.25 (2.42:l.94) for young White-naped Cranes. For Black-necked Cranes, the ratio of calcium to phosphorus is 2.21 (2.28:1.03) for adults and 0.70 (2.09:2.98) for young. That is to say, the phosphorus content in the blood of young cranes is significantly lower than for adults for both White-naped and Black-necked Cranes.

For both crane species, ALP, CK, and CKMB were significantly higher ($P < 0.01$) in young cranes than adult cranes. Young cranes also had significantly higher ($0.05 > P > 0.01$) levels of LDH, and HBD and significantly lower ($0.05 > P > 0.01$) levels of CHO than adult cranes.

In White-naped Cranes, glucose levels are markedly lower in young than adults. Glucose levels of White-naped Cranes are markedly higher than for the Black-necked Crane. White-naped and Black-necked Crane differences in blood serum chemistry may be a result of their different habitats and diet. The White-naped Crane occurs primarily in low-elevation wetlands, whereas the Black-necked Crane occurs primarily on high-altitude plateaus. Both species, however, reflected similar differences in blood serum chemistry values between young and adults.

In summary, age, habitat, nutrition, and condition influence blood serum chemistry. We determined that for White-naped Cranes, blood serum chemistry values differ by age, but not by sex. Our study results provide basic information for the systematic study of cranes worldwide.

References

Fang, Z., C. Zhang, J. Su, and Y. Liao. 1987. Some hematological reference values of Black-necked Cranes. Highland Biology Publisher 7:171–174.

Heilongjiang Forest Bureau. 1990. International crane protection and research. China Forestry Press, Beijing, China. 285 pp.

Ma, Y, editor. 1986. Crane research and conservation in China. Heilongjiang Education Press, Harbin, China. 253 pp.

Wei, Y. 1995. Medicine biochemistry. World Books Publishing Company.

Yang, J. editor. 1990. Cytochemical and cytobiological techniques. The University Press of Beijing Medical University and China Xie-he Medical University.

Yang, L. 1992. The Chinese Phasianids Lady Amherst's Pheasant. Pages 68–73 *in* China Forestry Publishing House.

Abbreviations used in Tables 1 and 2. These are in alphabetical order, not the same order as the tables.

ALB	albumin
ALB/GLB	albumin/globular proteins
ALP	alkaline phosphatase
AMY	amylase
AST	aspartate aminotransferase (glutamic-oxaloacetic transaminase)
Bile acids	
BUN	blood urea nitrogen
Ca	calcium
CHO	total cholesterol
Cl	chloride
CK	creatinine kinase
CKMB	creatinine kinase isoenzyme
CRE	creatinine
DBIL	direct bilirubin
GGT	glutamyltranspeptidase
GLB	globular proteins
GLU	glucose
GOT	aspartate aminotransferase
GPT	alanine aminotransferase
HBD	HBD reagent
K	potassium
LDH	lactic dehydrogenase
Mg	magnesium
Na	sodium
P	phosphorus
TBIL	total bilirubin
TG	triglycerides
TP	total protein
UA	uric acid

Alanine aminotransferase (glutamic-pyruvic transaminase)

Table 1. Blood serum values for captive White-naped Cranes (M +/-SD).

Index	Adult			Young		
	Female (n = 3)	Male (n = 3)	*t*-test	All adult (n = 6)	Young (n = 5)	*t*-test
GPT(U/L)	28.67 ± 10.40	21.33 ± 8.33	0.954	25.00 ± 9.34	16.60 ± 3.51	1.889
GOT(U/L)	208.33 ± 33.71	202.67 ± 51.05	0.160	205.50 ± 38.82	225.80 ± 37.34	0.239
GOT/GPT)	7.79 ± 2.27	10.00 ± 1.95	1.279	8.90 ± 2.24	14.04 ± 3.17	1.932
LDH(U/L)	265.00 ± 86.63	246.33 ± 103.01	0.240	255.67 ± 85.75	334.40 ± 121.37	2.441*
ALP(U/L)	132.67 ± 47.92	98.00 ± 8.69	0.975	115.33 ± 43.33	293.40 ± 0.23	5.450**
CK(U/L)	149.33 ± 106.24	195.33 ± 71.47	0.622	172.33 ± 84.81	480.40 ± 157.77	4.159**
UA(umol/L)	225.73 ± 102.5	243.53 ± 106.53	0.231	234.63 ± 94.20	319.62 ± 185.52	0.986
BUN(mmol/L)	0.52 ± 0.17	0.46 ± 0.13	0.486	0.49 ± 0.14	0.50 ± 0.13	0.124
CHO(mmol/L)	3.53 ± 0.25	3.57 ± 0.50	0.124	3.55 ± 0.36	4.44 ± 0.77	2.543*
TG(mmol/L)	1.10 ± 0.10	1.27 ± 0.64	0.455	1.18 ± 0.24	1.22 ± 0.26	0.184
GLU(mmol/L)	14.80 ± 0.60	14.77 ± 2.49	0.020	14.78 ± 1.61	12.78 ± 0.61	2.865*
TP(g/L)	37.23 ± 1.36	38.63 ± 3.50	0.646	37.93 ± 2.49	37.40 ± 4.80	0.237
ALB(g/L)	17.70 ± 1.55	18.10 ± 1.47	0.324	17.90 ± 1.37	18.52 ± 1.46	0.725
Ca(mmol/L)	2.30 ± 0.10	2.37 ± 0.06	1.040	2.33 ± 0.08	2.42 ± 0.18	1.110
GLB(g/L)	19.53 ± 0.80	20.55 ± 3.15	0.544	20.03 ± 2.13	18.88 ± 3.40	0.320
ALB/GLB	0.91 ± 0.10	0.90 ± 0.15	0.096	0.91 ± 0.11	1.00 ± 0.11	1.356
P(mmol/L)	1.03 ± 0.45	0.93 ± 0.23	0.343	0.98 ± 0.33	1.94 ± 0.50	3.857**
Mg(mmol/L)	0.53 ± 0.32	0.57 ± 0.38	0.139	0.55 ± 0.31	0.52 ± 0.32	0.155
Na(mmol/L)	137.77 ± 8.78	135.33 ± 6.43	0.388	136.50 ± 6.98	140.60 ± 2.30	0.375
K(mmol/L)	4.06 ± 0.82	3.20 ± 1.23	1.008	3.63 ± 1.05	5.05 ± 1.55	1.942
Cl(mmol/L)	102.77 ± 5.60	102.17 ± 6.33	0.123	102.47 ± 5.38	98.72 ± 6.34	1.065
AMY(mmol/L)	945	1,428			982	
HBD(IU/L)	146.50 ± 36.06	132.00 ± 72.12	0.254	139.25 ± 47.30	199.50 ± 64.63	2.303*
CKMB(U/L)	66.00 ± 45.25	61.00 ± 25.46	0.136	63.50 ± 30.12	185.00 ± 56.17	5.450**
GGT(IU/L)	3.00 ± 0	4.00 ± 0		3.50 ± 0.58	3.00 ± 1.63	0.86
CRE(umol/L)	26.80 ± 6.08	24.40 ± 3.11	0.497	25.60 ± 4.18	22.65 ± 4.73	1.336
TBIL(umol/L)	4.40 ± 3.25	3.05 ± 2.05	0.497	3.73 ± 2.35	9.43 ± 8.18	1.915
DBIL(umol/L)	2.00 ± 0.85	1.55 ± 0.64	0.598	1.78 ± 0.67	2.85 ± 2.04	1.426

Note: t (0.05) 9 = 2.262; t (0.01) 9 = 3.258; t (0.05) 4 = 2.776; t (0.01) 4 = 4.604.
*t(0.05) <t<t (0.01)
**t >t (0.01)

Table 2. Blood serum values for captive White-naped Cranes and Black-necked Cranes (M +/-SD).

Index	Adult			Young		
	Female (n = 3)	Male (n = 3)	*t*-test	All adult (n = 6)	Young (n = 5)	*t*-test
LDH(U/L)	2.55 ± 85.75	318.50 ± 114.26	1.180	334.40 ± 121.37	469.67 ± 149.59	1.503
ALP(U/L)	115.33 ± 43.33	52.50 ± 11.02	4.854**	293.40 ± 50.23	373.25 ± 77.86	1.873
UA(umol/L)	234.63 ± 94.20	379.97 ± 136.09	2.573*	319.62 ± 185.52	806.55 ± 216.34	3.642**
BUN(mmol/L)	0.49 ± 0.14	0.77 ± 0.16	1.840	0.50 ± 0.13	1.65 ± 0.14	12.758**
CHO(mmol/L)	3.55 ± 0.36	4.73 ± 0.12	10.512**	4.44 ± 0.77	4.90 ± 0.00	1.178
TG(mmol/L)	1.18 ± 0.24	0.47 ± 0.35	4.441**	1.22 ± 0.26	2.76 ± 0.21	9.571**
GLU(mmol/L)	14.78 ± 1.61	11.15 ± 0.71	6.751**	12.78 ± 0.61	10.27 ± 0.67	5.879**
TP(g/L)	37.93 ± 2.49	28.78 ± 4.28	4.801**	37.40 ± 4.80	33.80 ± 2.39	1.358
ALB(g/L)	17.90 ± 1.37	13.32 ± 1.46	6.394**	18.52 ± 1.46	14.45 ± 0.57	2.521*
Ca(mmol/L)	2.33 ± 0.08	2.28 ± 0.30	0.396	2.42 ± 0.18	2.09 ± 0.14	2.998*
GLB(g/L)	20.03 ± 2.13	15.36 ± 3.23	3.187**	18.88 ± 3.40	19.35 ± 1.88	0.246
ALB/GLB	0.91 ± 0.11	0.88 ± 0.09	0.621	1.00 ± 0.11	0.75 ± 0.04	4.275**
P(mmol/L)	0.98 ± 0.33	1.03 ± 0.18	0.421	1.94 ± 0.50	2.98 ± 0.53	3.022*
Mg(mmol/L)	0.55 ± 0.31	0.68 ± 0.08	1.401	0.52 ± 0.32	0.67 ± 0.17	0.840
Na(mmol/L)	136.50 ± 6.98	141.98 ± 3.68	2.213*	140.60 ± 2.30	140.15 ± 1.26	0.349
K(mmol/L)	3.63 ± 1.05	2.26 ± 0.30	4.298**	5.05 ± 1.55	6.10 ± 0.69	1.246
Cl(mmol/L)	102.47 ± 5.38	105.25 ± 2.45	1.532	98.72 ± 6.34	114.08 ± 3.15	4.389**

Note: $t(0.05)\ 16 = 2.121$; $t(0.05)\ 16 = 2.921$; $t(0.05)\ 7 = 2.365$; $t(0.01)\ 7 = 3.499$.
*$t(0.05) < t < t\ (0.01)$
**$t > t\ (0.01)$

Data of Black-necked Crane from Yang Minghai's, Bejing Zoo (personal communication).

Application of Radio Telemetry in Studies of Cranes

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Radio telemetry is a widely used tool in wildlife conservation which allows researchers to mark and study avian species from a distance. Researchers who use radio telemetry must weigh the relatively high costs for obtaining transmitters and tracking data compared with the benefits of repeatedly locating a few individuals, especially for fast-moving or wide-ranging migratory species. A larger sample of a population may be examined with surveys, or individuals species marked with less expensive techniques, such as leg bands or colored markers, but radio telemetry provides more detailed information on the individuals that are being studied.

So why are radio telemetry studies conducted? Many are undertaken when the information is otherwise unavailable. For example, recent studies with satellite telemetry have tracked migration of cranes across vast Arctic areas to reveal new breeding or wintering areas where other markers are rarely observed or recovered. In addition, much of the cost of band recovery or re-sighting studies of visual markers is in the costs of capture or field personnel. The fewer the number of birds that can be captured, the more important it is to maximize the information obtained from each. Researchers can obtain more detections from radio-marked individual species than from direct observations. Telemetry can improve on visual studies where birds may only be observed in limited portions of their range.

Studies of standard very-high-frequency (VHF) radio transmitters have been conducted since the 1960s. In the early 1970s, the development of satellite telemetry created a major technological advance in conservation studies by enabling researchers to track remote and trans-border species. The first platform transmitter terminal (PTT) used to track wildlife by satellite was deployed on a large mammal (Craighead et al. 1972). In the early 1980s, Strikwerda et al. (1986) developed the first bird-borne PTT. In the late 1980s, early generation PTTs for birds weighed more than 100 g and were deployed on large species such as cranes, swans, and eagles (Nagendran 1992; Higuchi et al. 1994a; Fuller et al. 1995; Higuchi et al. 1996). As the weight of PTTs decreased in the 1990s, studies were initiated on smaller species in groups such as waterfowl and seabirds. The first shorebird, the far eastern curlew (*Numenius madagascariensis*), was marked with a PTT (L. Bowden and P. Driscoll, unpublished data).

Radio Telemetry Studies on Cranes

VHF and PTT transmitters have made it possible to increase our knowledge of long-distance migratory birds such as cranes (Table 1). Cranes have been marked with VHF transmitters as early as 1975 (Nesbitt 1976) to examine local and regional migrations. Melvin and Temple (1983) reviewed early

Table 1. Common and scientific names, radio type (VHF = very high frequency, PTT = satellite or platform transmitter terminal), sample size, study description, year, location, and references for radio telemetry studies of cranes.

Common name	Scientific name	Radio type	n	Study description	Year	Location	Reference
Sandhill	*G. canadensis*	VHF	3	wintering	1973	Florida	Nesbitt (1976)
Sandhill	*G. canadensis*	VHF	14	migration	1977	Minnesota, Wisconsin	Crete and Toepfer (1978)
Sandhill	*G. canadensis*	VHF	14	regional migration	1977	Minnesota, Wisconsin	Toepfer and Crete (1979)
Sandhill	*G. canadensis*	VHF	?	fall and spring migration	1978	East Coast	Anderson et al. (1980)
Whooping	*G. americana*	VHF	5	movement of juveniles	1978	Idaho	Drewien and Bizeau 1981)
Sandhill	*G. canadensis*	VHF	5	Captive release, local movements	1982	Idaho	Drewien et al. (1982)
Sandhill	*G. canadensis*	VHF	28	local movements, migration	1978	North Dakota	Melvin and Temple (1983)
Sandhill	*G. canadensis*		43	leg, backpack attachment	1978	Midwest USA	Melvin et al.
Whooping	*G. americana*	VHF	11	tests			(1983)
Sandhill	*G. canadensis*	VHF	20	habitat use of migrating cranes	1979	Nebraska	Krapu et al. (1984)
Sandhill	*G. canadensis*	VHF	22	habitat use if wintering	1979	Texas	Iverson et al. (1985)
Sandhill	*G. canadensis*	VHF	18	movement and home range	1985	Florida, Georgia	Bennett (1989)
Whooping	*G. americana*	VHF	9	migration, habitat use, survival	1981	Texas, Saskatchewan	Howe (1989)
Sandhill	*G. canadensis*	VHF	31	home range, habitat use	1981	Florida	Nesbitt and Williams (1990)
Sandhill	*G. canadensis*	VHF	4	implant transmitter test	1985	Florida	Klugman and Fuller (1990)
Sandhill	*G. canadensis*	VHF	6	habitat use	1985	Florida	Bishop (1991)
Siberian	*G. leucogeranus*	PTT	3	long distance migration	1989	Russia, China	Ellis and Markin (1991)
Eurasian	*G. grus*	PTT	3	breeding to wintering	1990	Siberia	Ellis et al. (1991)
Sandhill	*G. canadensis*	PTT	4	behavior of attachment	1989	Maryland	Olsen et al. (1992)

Table 1. Continued.

Common name	Scientific name	Radio type	n	Study description	Year	Location	Reference
Sandhill	*G. canadensis*	VHF	10	distribution and movement	1983	California	Pogson and Lindstedt (1991)
White-naped Hooded	*G. vipio* *G. monacha*	PTT	26	migration routes, rest sites	1989	Korea	Chong et al. (1992)
Eurasian	*G. grus*	PTT	3	long distance migration	1990	Siberia	Ellis et al. (1992)
White-naped Hooded	*G. vipio* *G. monacha*	PTT	15	long distance migration	1991	East Asia	Higuchi et al. (1992)
Sandhill	*G. canadensis*	VHF	15	migration and wintering	1981	Central Canada, USA	Kuyt (1992)
Sandhill	*G. canadensis*	PTT	1	first satellite marked crane	1988	Texas	Nagendran (1992)
Sandhill	*G. canadensis*	VHF	7	reintroduction, regional movements	1988	Texas	Nagendran (1992)
Sandhill	*G. canadensis*	VHF	38	reintroduction, regional Movements	1988	Wisconsin, Michigan	Urbanek and Bookhout (1992)
Sandhill	*G. canadensis*	VHF	27	survival and movements	1982	Florida	Nesbitt and Carpenter (1993)
White-naped Hooded	*G. vipio* *G. monacha*	PTT	?	regional movements	1991	Korea	Chong et al. (1994)
Eurasian	*G. grus*	PTT	3	long distance migration	1994	India	Higuchi et al. (1994)
Eurasian	*G. grus*	VHF	14	foraging behavior, habitat use	1995	?	Alonso et al. (1995)
White-naped	*G. vipio*	PTT	15	long distance migration	1991	Korea	Higuchi et al. (1996)
Sandhill	*G. canadensis*	VHF	7	regional migration	1995	Idaho, New Mexico	Clegg et al. (1997)
Sandhill	*G. canadensis*	VHF	27	survival, habitat use of colts	1990	California	Desroberts (1997)
Sandhill	*G. canadensis*	VHF	38	home range, habitat use	1992	Michigan	Duan et al. (1997)
Sandhill	*G. canadensis*	VHF	14, 2	colt and local movements	1991	Oregon	Ivey and Scheuring (1997)

Table 1. Concluded.

Common name	Scientific name	Radio type	n	Study description	Year	Location	Reference
Whooping	*G. americana*	VHF	52	migration and release techniques	1993	Florida	Nesbitt et al. (1997)
Red-crowned	*G. japonensis*	PTT	12	long distance migration	1998–1999	Russia, China	Higuchi et al. (1999)
Sandhill	*G. canadensis*	VHF	134	Post release and survival	1989	Mississippi	Ellis et al. (1999)
Sandhill	*G. canadensis*	VHF	9	Seasonal movement	1984	Idaho	Drewien et al. (1999)
Eurasian	*G. grus*	PTT	8	migration and breeding areas	1998–2000	India	Higuchi et al. (2000)
Demoiselle	*A. virgo*		3				
White-naped	*G. vipio*	PTT	18	migratory stopover and wintering	2000	East China	Harris et al. (2000)
Hooded	*G. monacha*						

VHF telemetry methods and provided information on tracking procedures. Melvin et al. (1983) discussed VHF transmitters and attachment techniques on large birds such as cranes. Olsen et al. (1992) studied the effects of harnesses on the behavior of cranes, and Klugman and Fuller (1990) provided information on implant transmitters. Ellis et al. (1991) provided an update on progress on the development of satellite telemetry for cranes including transmitter design, tests, and trials.

VHF transmitters have been used to determine habitat use (Iverson et al. 1985; Bishop 1991; Krapu et al. 1994; Desroberts 1997; Duan et al. 1997), regional movement (Anderson 1980; Drewien and Bizeau 1981; Bennett 1989; Nesbitt and Carpenter 1993; Drewien et al. 1999); wintering distribution (Pogson and Lindstedt 1991); home range (Nesbitt and Williams 1990); and survival (Desroberts 1997; Ivey and Scheuring 1997; Ellis et al. 2000). Studies with VHF transmitters generally require a large amount of logistical support including truck-mounted telemetry systems, a network of roads, and aerial telemetry surveys (Gilmer et al. 1981; Kuyt 1992; Clegg et al. 1997).

Increased miniaturization of VHF and PTT transmitters and improved attachment techniques (Olsen et al. 1992; Nagendran et al 1994; Higuchi et al. 1994b) have allowed expansion of studies to include colt survival (Desroberts 1997; Ivey and Scheuring 1997) and reintroduction of pen- and hand-reared cranes to the wild (Nagendran 1992; Urbanek and Bookhout 1992; Nesbitt et al. 1997). Palearctic research on cranes has generally been limited to satellite telemetry because of the logistical difficulties in accessing remote areas in many of these countries. PTT transmitters have been successful for studying long distance migration (Chong et al. 1992; Ellis et al. 1992; Higuchi et al. 1992, 1996); locating resting areas (Chong et al. 1993; Higuchi et al. 1994); and wintering and breeding area (Higuchi et al 1996; Harris et al. 2000).

Designing Radio Telemetry Studies

Radio telemetry studies provide detailed location data for a species over a limited time period, generally several days to a few years. Radio telemetry has been used in studies of nesting and breeding, migration ecology, wintering ecology, habitat interactions, population dynamics, physiology, and behavior. The most common use of radio telemetry has been in migratory species. Several factors require consideration in designing telemetry studies.

Costs

In studies of marked individuals, different techniques had varying costs and benefits. The costs of capturing and marking individuals are incurred in all marking studies, but field personnel are needed for both observation of visual markers and location of standard radio transmitters. Personnel costs are typically much lower for satellite telemetry studies where the data are obtained remotely. Studies with visual markers typically require larger samples and produce fewer returns than telemetry projects. Leg bands or visual markers typically cost less than $5 USD per individual, and equipment for resighting animals usually require binoculars or a spotting scope ($100–$1,500 USD). A standard radio transmitter may be purchased for $100–$250 USD, and a single receiving system of a receiver ($1,000–2,500), handheld antenna ($100 USD), and accessories often cost over $2,000 USD. Satellite telemetry transmitters may cost $2,500 USD each, with data acquisition costs of $1,000 USD. Thus, the cost for supplies and equipment to conduct a study of 10 animals may be less than $1,000 USD for a marker study, $3,000 USD for a radio telemetry study, and $35,000 USD for a satellite telemetry study.

Capture

The difficulty in capturing live animals for research is often one of the most challenging aspects of the project. Researchers may benefit greatly by consulting biologists who have experience in capture and handling of similar species. Capture techniques for migratory birds include bait trapping, mist netting, rocket netting, drive trapping, and net gunning. Proper capture and handling techniques are essential to minimize stress and capture myopathy.

Cranes molt their flight feathers each summer during post-incubation, which provides an opportunity to capture flightless species. In the second half of the 19th century, molting cranes were captured by horseman throwing a whip with a lead weight at the end (Gunda 1968, 1969). More recently, airboats and helicopters have been used to locate cranes or crane colts for capture by hand or with a long-handled nets.

Corral traps have also been used to drive species into nets.

Rocket netting is a common technique for capturing cranes in other times of the year. Rockets consist of a blunt nose cone, a hollow tube body, a stabilizing fin (usually a long steel rod counterweight), and exhaust ports in the base. The rockets are propelled with an electrically-fired Class 1.3C explosive charge and are connected to a net with shock cords and ropes. Cranes are commonly captured in 10 x 20 m nets with three rockets per net or 13 x 20 m nets with four rockets per net. Only one to two nets are used per site, which results in the capturing of a few individuals, because cranes are very susceptible to capture stress and myopathy.

Alpha-chloralose is a sedative that can be mixed with bait at dosages ranging from 0.40 to 0.48 g per 284 cc (cup) of corn (Williams and Phillips 1973) and has been used to successfully capture sandhill cranes in Florida (Nesbitt 1975) and Eurasian cranes in India (M. Nagendran, personal communication). The bait site should not be placed near water because drinking water increases absorption and may cause overdose. Sedated birds may lose motor function and drown or die of exposure when confined (Nesbitt 1975).

Attachment

Perhaps the most overlooked issue in radio telemetry projects is the attachment of the transmitter. The best attachment for a species minimizes stress while providing the most data. Several factors need to be considered including: (1) the smallest possible transmitter (<3% of bird's body weight); (2) as streamlined and inconspicuous a package as possible; (3) preliminary trials on captive individuals; and (4) an acclimatization period of a few days to weeks for newly marked individuals.

The most common attachment method used on birds is a harness made of plastic-coated wire or Teflon ribbon. One of the oldest attachment methods for ducks is the Dwyer harness (Dwyer 1972), a continuous loop design with neck and body loops. A modification of this harness has been used for cranes (Nagendran et al. 1994). Incorporating transmitters on collars is commonly used on geese and swans. Soft collar necklaces have been used on grouse, pheasants, quail, and waterfowl. Gluing (Warnock and Warnock 1993), taping, suturing and subcutaneous anchors (Newman et al. 1999) have been used to attach transmitters to smaller birds (<1 kg). Transmitters may also be surgically implanted with internal or external antennas to eliminate problems from external harnesses.

Transmitters

Three types of radio transmitters are available for migratory bird studies: short-range VHF and long-range PTT and global positioning system (GPS) transmitters. Short-range VHF transmitters produce a unique frequency for each transmitter. Transmitters may be either one- or two-stage designs with an increase in range and size in the latter. Reception is typically limited to a few kilometers from the ground but up to 20 km from the air. The long-range transmitters use satellite technology and include PTT and global positioning system (GPS) transmitters. We provide a table of comparison of general features (Table 2) of the three types of transmitters (VHF, PTT, GPS).

The first PTTs were tracked from polar-orbiting satellites launched by the U.S. National Oceanographic and Atmospheric Administration to track currents in the ocean from buoys. The system works by examining the Doppler shift, or change in PTT frequency (401.65 MHz), detected by a passing satellite to produce a location varying in accuracy from 300 m to >10 km. Our experience is that almost all locations from small transmitters are not extremely accurate, usually within 10 km, but rarely less than that (Takekawa et al. 2000). Thus, satellite transmitters are excellent for determining migration routes, general distribution over large areas, or extensive movements, but they are not useful in examining local habitat use. More locations are

Table 2. Features and relative value of three types of radio transmitters (VHF = very high frequency, PTT = platform transmitter terminal, and GPS = global positioning system) from lower (*) to higher (***) value.

Category	VHF	PTT	GPS
Accuracy	**	*	***
Cost	*	**	***
Size	***	**	*
Logistics	***	*	**
Vendors	***	**	*

obtained in the upper latitudes because the satellites orbit the North Pole. The location data is downloaded to a radio receiving system developed by the French space agency subsidiary, Argos, Inc. PTTs were first used to track wildlife in a bear study in 1970, but since that time, transmitter size has decreased to 15–20 g, small enough for many waterbirds over 500 g. Now, more than 1,100 PTTs are used each year to track wildlife.

Recently developed GPS transmitters receive position data from a constellation of geosynchronous satellites and produce very accurate (<10 m) locations through triangulation. GPS transmitters are primarily data loggers. Obtaining the data from GPS transmitters often requires recovering the transmitter after the data is collected. A recent prototype was developed (Microwave Telemetry) that transmits the data through a satellite data link. We provide a general comparison of the utility of these three transmitters for different ecological study objectives (Table 3).

Sensors are available on many types of transmitters that record additional data besides location. These include temperature, pressure (depth or altitude), and heart rate.

Tracking Equipment, Methods, and Data Compilation

Equipment

A VHF receiver, headset, and antenna are the main pieces of equipment needed with short-range transmitter studies. A study with >10 transmitters will be easier to do with a scanning receiver that stores several frequencies. VHF receivers have a frequency selector, power source, signal-strength control (gain), a jack for headphones, and a jack for the antenna. Data loggers or combined receiver and data-logger systems may be used to automatically record information from a fixed location. Typically used in tower systems, data loggers are not as sensitive at separating signals from noise, but can provide good information on localized areas such as breeding sites.

Table 3. The relative value of different types of three types of radio transmitters (VHF = very high frequency; PTT = satellite or platform transmitter terminal; and GPS = global positioning system) for different ecological study objectives, rated from lowest (*) to highest (***) value on the basis of the transmitter accuracy.

Ecological topics	VHF	PTT	GPS
Nesting and breeding	**	*	***
Migration	*	**	***
Wintering	***	**	***
Habitat interactions	***	*	**
Population dynamics	***	**	*
Physiology and behavior	***	*	***

Several types of radio antennas are available for use in telemetry studies. Dipole (two-pole) antennas are the standard comparison for other antennas, suitable for presence and absence. Loop antennas are configured in a circle or diamond with a smaller size but less gain than directional antennas and are often used in fossorial or aquatic studies. Omni-directional (whip) antennas receive in all directions and are usually used to determine presence or absence. Yagi antennas are directional antennas with higher gain in front of the antenna, providing excellent directionality. Spacing of the 3 to 12 cross-elements depends on the frequency, but with decreasing portability. Adcock ("H") or 2-element antennas are more portable than Yagis but have lower gain than the 3-element Yagi. Many of these antennas are mounted on vehicles or aircraft for searching wide areas.

Methods

Many studies simply use a transmitter to follow and approach marked individuals. Widespread availability of handheld GPS units makes it possible to more readily estimate locations of marked individuals once they are detected. This method is labor intensive and may cause disturbance to the marked individuals, if they are sensitive to human intrusion. Use of aircraft tracking is an effective and efficient method for locating large numbers of transmitters, searching rugged and remote areas, and for locating transmitters that can no longer be found with ground searches (Gilmer et al. 1981). Aerial tracking may be used to determine presence or absence in an area, or individuals may be located more accurately by flying in narrowing circles around the strongest signal. Accuracy of locations depends on altitude, air speed, visibility, and landmarks. The best altitude for a telemetry flight is usually 300–1,500 m.

More accurate locations are obtained with triangulation, where two or more directional bearings are obtained from known locations. Using a fixed tower or a roof-mounted directional antenna array (both affixed with compass rosettes and pointers), a bearing is obtained in the direction of the transmitter. Simultaneously, a bearing from true north is obtained for the observer's position. These bearing and azimuths are converted to angles (in radians), where the converging radians determine the location of the transmitter. There are several computer software programs available to calculate these locations once the bearing, azimuths, and Universal Transverse Mercator (UTM) or latitude and longitude of the two telemetry points are known. There is an error associated with each bearing to the transmitters (referred to as error polygon). The error is compounded by several factors: (1) accuracy of the antenna system, (2) accuracy of the observer, and (3) distance to transmitter. You have some control on all of these and care should be taken to minimize the error associated with each.

Data Compilation

Radio telemetry produces a large amount of information, both raw and processed. The easiest way to enter data is to use programs that provide triangulation calculations. Programs such as XYLOG (Dodge et al. 1986) written in BASIC provide users with a base to write individual code for programs. However, data compilation may be as simple as drawing points or the intersection of lines on a map and recording the final coordinates.

In satellite telemetry, location data is downloaded to a radio receiving system developed by the French space agency subsidiary, Argos, Inc. with offices in Toulouse, France and Landover, Maryland, USA. The easiest way to obtain the satellite data is by daily e-mail messages. However, the data is also available on CD or disk. Almost all waterbird transmitters are small, and the extra service known as animal processing will provide more locations, although their location class is generally less accurate. PTTs require a great deal of power to send their signal at a pulse rate of each 50–90 s during a period of 3–12 h set by the researcher. Different projects require different combinations of pulse rate and duty cycle. For example, a longer-term project might receive detections only every 3–5 days with a transmitter on for 6 hours so the PTT will last for a year. For birds where we are tracking migration, we usually use an on cycle of 4–8 hours, every second or third day.

The estimated location of the device is calculated and any other digital data from the transmitter is recorded. The 1998 cost is $14.93 USD per PTT per day of transmission. The animal location processing service includes the location calculated from fewer messages and is useful for animal transmitters with a cost of $2.88 per PTT per day. Finally, the multi-satellite service provides 50% more chances for locations than from the 2-satellite system and costs are $1.51 per PTT per day. Charges start from testing by the manufacturer until the study period ends. Data may be obtained from online services, telex, or e-mail, and costs for downloads are $0.08 per Kb transmitted. Costs for CD-ROMs are $271.19 each, while 1.44 MB disks are $128.81. A program is available from Argos to handle radio-tracking data to display it on the screen. Program ELSA is available with a world map for $2,542.37. However, many researchers either enter the data by hand or use geographic information systems such as ArcInfo or ArcView to display the data.

Analyzing Radio Telemetry Data

The analysis of radio telemetry and other marked animal data is rapidly advancing and many papers are written about different procedures each year. In this section, we present a general overview of major topics and refer the readers to general overviews, including Austin et al. (1997), Fancy et al. (1988), Harris et al. (1990), Kenward (1987), Samuel and Fuller (1994), and White and Garrott (1990).

Movements

Migratory birds are noted for their large-scale movements (i.e., migration and dispersal). Radio telemetry provides detailed information on these movements at finer levels of detail limited by the time and costs required to follow several individuals. Movement data must be collected at regular intervals for consistent results. For example, locations can be obtained daily or weekly, but waterbirds often move to different areas hourly. In our wintering studies, we usually estimate that 25 marked birds may be followed by an observer in a truck if the objective is daily or weekly observations. Analyses typically

examine shifts in seasonal periods, weeks, or by time-of-day (Ely and Takekawa 1996; Warnock and Takekawa 1996). Analyses have also been produced to examine proximity or flocking (see Turchin 1998).

Home Range

Home range models depict the areas where animals spend most of their time. Radio telemetry is an excellent means of collecting these data because the animal may be located repeatedly during a study period. Convex polygons are a simple methods of mapping the distribution of telemetry data by drawing an outline around the use area. More complex polygons have also been developed to remove empty areas within the polygons (Kenward 2000). More data points (>25) are required to examine harmonic mean or elliptical home ranges (Samuel and Garton 1985; Warnock and Takekawa 1995). Probabilities are calculated from grid systems super-imposed on an animal's use area, and indicate major concentration areas. Even more data intensive, kernel-methods (Worton 1989; Seaman et al. 1999) use non-parametric approaches to estimate home range from 50–100 locations for an individual. Although these home ranges are considered the best from a statistical model standpoint, the sample sizes are rarely obtainable for a large sample of individuals.

Habitat Use

Habitat provides the food, cover, and other factors necessary for the survival of a wildlife population. Knowledge of the habitat requirements for a wildlife species is a critical component in its management. Analysis of wildlife habitat use patterns, including availability, use, preference, and criticalness, has been one of the principal applications of radio telemetry. Typically the observed frequency of locations (see Otis and White 1999) within a given habitat type are compared to an expected frequency (Neu et al. 1974). Thus, the analyses are based on proportions, where the proportion of area of each habitat is considered its availability or expected value, and the proportion of locations in each habitat is considered the use. When use of a particular habitat exceeds its availability, the animal is thought to have a preference for that habitat. If availability exceeds use, then the area may have been avoided.

Determining habitat availability may be a subjective process. One way to reduce researcher influence is to use home ranges to determine availability (Johnson 1980) where the proportion of habitats within the home range are used to estimate the available habitats. Second-order selection compares habitat use in individual home ranges with habitat availability in the overall study area. In contrast, third-order selection compares habitat use determined from radio locations with habitat availability in home ranges. Generally, these reflect a difference in the scale of the problem of interest at a local or regional level (Johnson 1980; Thomas and Taylor 1990; Warnock and Takekawa 1995).

A basic analysis (Neu et al. 1974) compares the differences in proportions among availability and use. More recent methods (Aebischer 1993) have used statistical methods for determining compositions to examine preference while accounting for dependency among habitats (i.e., proportions sum to 1.0). Composition analysis is based on the logarithm of the proportions, rather than on the proportions directly. In addition, it standardizes the proportions to one habitat type, usually the most abundant. Composition analysis accounts allows for testing of habitat differences by classes such as age, sex, or season (Warnock and Takekawa 1995).

Population Size

Population estimation is central to many wildlife management decisions. For example, harvest limits, pest management, recovery population levels, and determination of threatened or endangered species status, are all based on population size. Population size is the currency by which the success of many management programs is judged. Radio telemetry can be used to assist in the estimation of population size and can be useful in validating the assumptions or developing correction factors for other population estimation procedures.

One of the most critical assumptions in capture-recapture population estimates is that the number of marked animals in the population is known (i.e., no loss of marks or death of marked animals). With radio-marked animals, the number of marked animals in the population can be verified prior to a recapture period. Similarly, radio-marked individuals may help

verify the proportion of animals not counted in aerial surveys or observer avoidance by animals in line transect estimates (Buckland et al. 1993). Analyses are available for population estimation specific to radio telemetry data. White (1996) and Lancia et al. (1994) provide an extensive review of general population estimation methods.

Survival

Radio telemetry studies can be very important in identifying mortality factors, survival rates, and factors that influence survival. Transmitters may be used to locate animals soon after death to identify the cause of death and also allow estimation of period-specific survival rates for populations. In its simplest form, survival data is recorded by producing a matrix of 1 and 0 for alive and dead animals for each study interval (days, weeks). Radio telemetry data can also include fate of the individual and covariate analyses such as body weight or age. Simple comparisons of the number of animals that die during an interval may be estimated from telemetry data. More sophisticated methods are available for comparing actual survival curves or to test for the effects of time-specific covariates on survival. It is important to recognize the assumptions for survival estimation regardless of which method is chosen for the analysis (see Bunck 1987).

There are basically two general types of statistical methods to estimate survival rates. The first method involves estimating the rate for a specific time interval and assumes that mortalities occur at a constant rate during the study period; the exact times of mortality are not the primary concern. The second method estimates a continuous survival curve and can be applied when animals are radio-tagged over an extended time period, when censoring occurs, when mortality rates are not constant, or when factors influencing survival are evaluated (Pollock et al. 1989). For example, we can estimate the survival of a population of cranes during the winter if they are located regularly (daily, weekly). Rather than simply using the proportion of radio-marked individuals that die during the period as the rate of mortality, these estimates depend on the number of days of exposure when the animal is detectable by the researcher. This provides a more conservative estimate of survival. It may also be possible to examine covariates such as weight at capture to determine if relationships exist between survival and body mass. In addition, cause-specific mortality estimates are possible if the cause can be determined before the animal is scavenged. Many of the statistical analyses for these types of estimates with marked populations have been included in generalized models (Lebreton et al. 1992; White et al. 1999).

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References

Aebischer, N. J., P. A. Robertson, and R. E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74:1313–1325.

Alonso, J. C., J. A. Alonso, L. M. Bautista, and R. Munoz-Pulido. 1995. Patch use in cranes: A field test of optimal foraging predictions. Animal Behavior 49:1367–1379.

Anderson, R. K., J. P. Velga, and T. Cogger 1980. Fall and spring migration route and behavior of eastern Greater Sandhill Cranes: 1978–1979. Unpublished report. U.S. Fish and Wildlife Service, St. Paul, Minn. 21 pp.

Austin, J. E., P. J. Pietz, J. L. Godbey, D. W. Howerter, K. P. Kenow, and W. Norling. 1997. Forum on wildlife telemetry: Innovations, evaluations, and research needs. Unpublished program and abstracts. Snowmass, Colo. 40 pp.

Bennett, A. J. 1989. Movements and home ranges of Florida sandhill cranes. Journal of Wildlife Management 53:830–836.

Bishop, M. A. 1991. Habitat use by Florida Sandhill Cranes on the Kissimmee Prairie in central Florida. Proceedings of the North American Crane Workshop 6:175.

Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 1993. Distance sampling: Estimating abundance of biological populations. Chapman and Hall, London. 446 pp.

Chong, J. R., H. Higuchi, and U. Pak. 1992. The migration routes and important rest areas of cranes in the Korean Peninsula from the results of satellite tracking. Strix 11:21–34.

Chong, J. R., H. Higuchi, and U. Pak. 1993. The migration routes and important rest-sites of cranes on the Korean Peninsula. Pages 41–50 *in* H. Higuchi, J. Minton, and R. Kurosawa, editors. Proceedings of the International Symposium. The Future of Cranes and Wetlands. Tokyo.

Clegg, K. R., J. C. Lewis, and D. H. Ellis. 1997. Use of ultralight aircraft for introducing migratory populations. Proceedings of the North American Crane Workshop 7:105–113.

Craighead, F. C., Jr., J. J. Craighead, C. E. Cote, and H. K. Buechner. 1972. Satellite and ground radio tracking of elk. *In* S. R. Galler, K. Schmidt-Koenig, G. J. Jacobs, and R. E. Belleville, editors. Animal Orientation and Navigation, NASA SP-262, Washington D.C.

Crete, R. A., and J. E. Toepfer. 1978. Migration of radio-tagged eastern greater sandhill cranes. Unpublished report, U.S. Fish and Wildlife Service, St. Paul, Minn. 42 pp.

Desroberts, K. J. 1997. Survival and habitat use of greater sandhill crane colts on Modoc National Wildlife Refuge, California. Proceedings of the North American Crane Workshop 7:18–23.

Dodge, W. E., D. S. Wilke, and A. J. Steiner. 1986. XYLOG: A computer program for the field processing locations of radio-tagged wildlife. Technical Report No. 4. U.S. Fish and Wildlife Service, Washington, DC.

Drewien, R. C., S. C. Derrickson, and E. G. Bizeau. 1981. Experimental release of captive parent-reared Greater Sandhill Cranes at Grays Lake Refuge, Idaho. Pages 99–111 *in* J. C. Lewis, editor. Proceedings of the 1981 Crane Workshop, Grand Teton National Park, Wyoming. National Audubon Society, Tavernier, Fla.

Drewien, R. C., and E. L. Bizeau. 1981. Use of radio telemetry to study movements of juvenile Whooping Cranes. Pages 130–134 *in* J. C. Lewis and H. Masatomi, editors. Crane research around the world. Proceedings of the International Crane Symposium, Sapporo, Japan. International Crane Foundation, Baraboo, Wisc.

Drewien, R. C., W. M. Brown, J. D. Varley, and D. C. Lockman. 1999. Seasonal movements of sandhill cranes radio-marked in Yellowstone National Park and Jackson Hole, Wyoming. Journal of Wildlife Management 63:126–136.

Duan, W., T. A. Bookhout, and R. Urbanek. 1997. Home range and habitat use by isolation-reared Sandhill cranes. Proceedings of the North American Crane Workshop 7:72–78.

Dwyer, T. J. 1972. An adjustable radio package for ducks. Bird Banding 43:282–284.

Ellis, D. H., and Y. Markin. 1991. Satellite monitors cranes migrating from Siberia. International Crane Foundation Bugle 17:1–5.

Ellis, D. H., Y. M. Markin, C. H. Vermillion, C. M. Hoisington, A. G. Sorokin, and G. W. Pendleton. 1991. Satellite telemetry reveals winter home of Eurasian crane from northwestern Siberia. Proceedings of the North American Crane Workshop 6:172.

Ellis, D. H., D. G. Smith, G. H. Olsen, M. R. Fuller, S. E. Landfried, H. Higuchi, and C. H. Vermillion. 1992. Progress in satellite tracking cranes. Proceedings of the North American Crane Workshop 6:57–61.

Ellis, D. H., G. F. Gee, S. G. Hereford, G. H. Olsen, T. D. Chisolm, J. N. Nicolich, K. A. Sullivan, N. J. Thomas, M. Nagendran, and J. S. Hatfield. 2000. Post-release survival of hand-reared and parent-reared Mississippi sandhill cranes. Condor 102:104–112.

Ely, C. R., and J. Y. Takekawa. 1996. Geographic variation in migratory behavior of greater white-fronted geese (*Anser albifrons*). Auk 113:889–901.

Fancy, S. G., L. F. Pank, D. C. Douglas, C. H. Curby, G. W. Garner, S. C. Amstrup, and W. L. Regelin. 1988. Satellite telemetry: a new tool for wildlife research and management. U.S. Department of the Interior, Fish and Wildlife Service, Resource Publication 172. Washington, D.C.

Fuller, M., W. S. Seegar, and P. W. Howey. 1995. The use of satellite systems for the study of bird migration. Israel Journal of Zoology 41:243–252.

Gilmer, D. S., L. M. Cowardin, R. L. Duval, L. M. Mechlin, C. W. Shaiffer, and V. B. Kuechle. 1981. Procedures for the use of aircraft in wildlife biotelemetry studies. Resource Report No. 140. U.S. Fish and Wildlife Service, Jamestown, ND. 19 pp.

Gunda, B. 1968/69. Die Jagd und Domestikation des Kranichs bei den Ungarn. Anthropos 63/64:473–496.

Harris, R. B., S. G. Fancy, D. C. Douglas, G. W. Garner, S. C. Amstrup, T. R. McCabe, and L. F. Pank. 1990. Tracking wildlife by satellite: Current systems and performance. U.S. Fish and Wildlife Service, Fish and Wildlife Technical Report 30. Washington, D.C.

Harris, J., L. Su, H. Higuchi, M. Ueta, Z. Zhang, Y. Zhang, and X. Ni. 2000. Migratory stopover and wintering locations in eastern China used by White-naped Cranes, *Grus vipio*, and Hooded Cranes, *G. monacha*, as determined by satellite tracking. Forktail 16:93–99.

Higuchi, H. K., S. Javed, and M. Nagendran. 1999. Satellite tracking of large wetland birds in Kutch, Gujarat. Unpublished Progress Report. Tokyo University and Aligarh Muslim University, Tokyo and Aligarh, India.

Higuchi, H. K., M. Nagendran, A. G. Sorokin, and M. Ueta. 1994a. Satellite Tracking of common cranes, *Grus grus*, migrating north from Keoladeo National Park, India. Pages 26–31 *in* H. Higuchi and J. Minton, editors. Proceedings of the International Symposium "The Future of Cranes and Wetlands." Tokyo, Japan.

Higuchi, H., G. Ozaki, J. Fujita, M. Minton, M. Ueta, M. Soma, and N. Mita. 1996. Satellite tracking of white-naped crane migration and importance of Korean Demilitarized Zone. Conservation Biology 10:806–812.

Higuchi, H., K. Ozaki, G. Fujita, M. Soma, N. Kanmuri, and M. Ueta. 1992. Satellite tracking of the migration routes of cranes from Southern Japan. Strix 11:1–20.

Higuchi, H., K. Ozaki, K. Golovuskin, O. Goroshko, V. Krever, J. Minton, M. Ueta, V. Andronov, S. Smirenski, V. Ilyashenko, N. Kanmuri, and G. Archibald. 1994b. The migration routes and important rest-sites of cranes satellite tracked from south-central Russia. Pages 15–25 *in* H. Higuchi and J. Minton, editors. Proceedings of the International Symposium "The Future of Cranes and Wetlands." Tokyo.

Howe, M. A. 1989. Migration of radio-marked whooping cranes from the Aransas-Wood Buffalo population: Pattern of habitat use, behavior, and survival. U.S. Fish and Wildlife Service Technical Report No. 21, 33 pp.

Iverson, G. C., P. A. Vohs, and T. C. Tacha. 1985. Habitat use by sandhill cranes wintering in western Texas. Journal of Wildlife Management 49:1074–1083.

Ivey, D. L., and E. J. Scheuring. 1997. Mortality of radio-equipped sandhill crane colts at Malheur National Wildlife Refuge. Proceedings of the North American Crane Workshop 7:14–17.

Kenward, R. 1987. Wildlife radio tagging. Academic Press, London. 222 pp.

Krapu, G. L., D. E. Facey, E. K. Fritzell, and D. H. Johnson. 1984. Habitat use by migrant sandhill cranes in Nebraska. Journal of Wildlife Management 48: 407–417.

Kuyt, E. 1992. Aerial radio-tracking of Whooping cranes migrating between Wood Buffalo National Park and Aransas National Wildlife Refuge, 1981–84. Canadian Wildlife Service Occasional Papers No. 74. 50 pp.

Klugman, S. S., and M. R. Fuller. 1990. Effects of implanted transmitters in captive Florida sandhill cranes. Wildlife Society Bulletin 18:394–399.

Lancia, R. A., J. D. Nichols, and K. H. Pollock. 1996. Estimating the number of animals in wildlife populations. Pages 215–253 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. Fifth edition. The Wildlife Society, Bethesda, Md.

Lebreton, J. D., K. P. Burnham, J. Clobert, and D. R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: A unified approach with case studies. Ecological Monographs 62:67–118.

Melvin, S. M., and S. A. Temple. 1983. Fall migration and mortality of Interlake, Manitoba Sandhill Cranes in North Dakota. Journal of Wildlife Management 47:805–817.

Melvin, S. M., R. C. Drewien, S. A. Temple, and E. G. Bizeau. 1983. Leg-band attachment for radio transmitters for large birds. Wildlife Society Bulletin 11:282–285.

Melvin, S. M., and S. A. Temple. 1987. Radio telemetry techniques for international crane

studies. Pages 481–492 *in* G. W. Archibald, and R. F. Pasquier, editors. Proceedings of the 1983 International Crane Workshop. Bharatpur, India. International Crane Foundation, Baraboo, Wisc.

Nagendran, M. 1992. Satellite tracking of a greater sandhill crane. Proceedings of the North American Crane Workshop 6:173.

Nagendran, M. 1992. Winter release of isolation-reared Greater Sandhill Cranes in south Texas. Proceedings of the North American Crane Workshop 6:131–136.

Nagendran, M., H. Higuchi, and A. G. Sorokin. 1994. A harnessing technique to deploy transmitter on Cranes. Pages 57–60 *in* H. Higuchi, and J. Minton, editors. The future of cranes and wetlands. Proceedings of the International Symposium. Tokyo.

Nesbitt, S. A. 1975. Capturing sandhill cranes with oral tranquilizers. Pages 296–298, *in* J. C. Lewis, editor. Proceedings of the International Crane Workshop. Oklahoma State University Publisher, Stillwater.

Nesbitt, S. A. 1976. Use of radio telemetry techniques on Florida sandhill cranes. Pages 299–303 *in* J. C. Lewis, editor. Proceedings of the International Crane Workshop, Oklahoma State University Publisher, Stillwater.

Nesbitt, S. A., and J. W. Carpenter. 1993. Survival and movements of Greater Sandhill Cranes experimentally released in Florida. Journal of Wildlife Management 57:673–679.

Nesbitt, S. A., and K. S. Williams. 1990. Home range and habitat use of Florida sandhill cranes. Journal of Wildlife Management 54:92–96.

Nesbitt, S. A., M. J. Folk, M. G. Spalding, J. A. Schmidt, S. T. Schwikert, J. M. Nicolich, M. Wellington, J. C. Lewis, and T. H. Logan. 1997. An experimental release of Whooping Cranes in Florida – the first three years. Proceedings of the North American Crane Workshop 7:79–85.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. Journal of Wildlife Management 38:541–545.

Newman, S. H., J. Y. Takekawa, D. L. Whitworth, and E. E. Burkett. 1999. Subcutaneous anchor attachment increases retention of radio transmitters on Xantus' and Marbled murrelets. Journal of Field Ornithology 70:520–534.

Olsen, G. H., D. H. Ellis, S. E. Landfried, L. J. Miller, S. S. Klugman, M. R. Fuller, and C. H. Vermillion. 1992. Behavior of Sandhill Cranes harnessed with different satellite transmitters. Proceedings of the North American Crane Workshop 6:50–56.

Otis, D. L., and G. C. White. 1999. Autocorrelation of location estimates and the analysis of radio tracking data. Journal of Wildlife Management 63:1039–1044.

Pogson, T. H., and S. M. Lindstedt. 1991. Distribution and abundance of large Sandhill Cranes, *Grus canadensis*, wintering in California's Central Valley. Condor 93: 266–278.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53:7–15.

Samuel, M. D., and M. R. Fuller. 1994. Wildlife radiotelemetry. Pages 370–418 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. Fifth edition. The Wildlife Society. Bethesda, Md.

Samuel, M. D., and E. O. Garton. 1985. Home range: A weighted normal estimate and tests of underlying assumptions. Journal of Wildlife Management 49:513–519.

Seaman, D. E., J. J. Millspaugh, B. J. Kernohan, G. C. Brundige, K. J. Raedeke, and R. A. Gitzen. 1999. Effects of sample size on kernel home range estimates. Journal of Wildlife Management 63:739–747.

Strikwerda, T. E., M. R. Fuller, W. S. Seegar, P. W. Howey, and H. D. Black. 1986. Bird-borne satellite transmitter and location program. Johns Hopkins APL Technical Digest 7:203–208.

Takekawa, J. Y., R. I. Leyva-Espinosa, and E. E. Klaas. 2000. Comparing radio and satellite telemetry to assess movements and habitat use of Arctic nesting geese in northern Mexico. Pages 109–122 *in* F. A. Comin, J. A. Herrera, and J. Ramirez, editors. Limnology and aquatic birds. Monitoring, modeling, and management. Universidad Autonoma de Yucatan, Merida, Mexico.

Thomas, D. L., and E. J. Taylor. 1990. Study designs and tests for comparing resource use and availability. Journal of Wildlife Management 54:322–330.

Toepfer, J. E., and R. A. Crete. 1979. Migration of radio-tagged Greater Sandhill Cranes from Minnesota and Wisconsin. Pages 159–174 *in* J. C. Lewis, editor. Proceedings of the 1978 Crane

Workshop. State University Print Service, Fort Collins, Colo. 595 pp.

Turchin, P. 1998. Quantitative analysis of movement: Measuring and modeling population redistribution in animals and plants. Sinauer Associates, New York. 360 pp.

Urbanek, R. P., and T. A. Bookhout. 1992. Development of an isolation-rearing/gentle release procedure for reintroducing migratory cranes. Proceedings of the North American Crane Workshop 6:120–130.

Warnock, S. E., and J. Y. Takekawa. 1995. Habitat preferences of wintering shorebirds in a temporally changing environment: Western Sandpipers in the San Francisco Bay estuary. Auk 112:920–930.

Warnock, S. E., and J. Y. Takekawa. 1996. Wintering site fidelity and movement patterns of western sandpipers *Calidris mauri* in the San Francisco Bay estuary. Ibis 138:160–167.

Warnock, N., and S. Warnock. 1993. Attachment of radio-transmitters to sandpipers: review and methods. Wader Study Group Bulletin 70:28–30.

White, G. C. 1996. NOREMARK: Population estimation from mark-resighting surveys. Wildlife Society Bulletin 24:50–52.

White, G. C., and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46(Supplement):120–138.

White, G. C., and R. A. Garrott. 1990. Analysis of radio-tracking data. Academic Press, San Diego. 383 pp.

Williams, L. E., Jr., and R. W. Phillips. 1973. Capturing Sandhill Crane with alpha-chloralose. Journal of Wildlife Management 37:94–97.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164–168.

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This publication provides the proceedings of the symposium on cranes of Northeast Asia held at the Northeast Forestry University in Harbin, People's Republic of China during June 1998. Biologists studying cranes in the People's Republic of China, the Republic of Korea, People's Democratic Republic of Korea, and the United States contributed to the proceedings. Various aspects of crane biology are discussed including distribution, status, ecology, behavior, and physiology. Several papers provide recommendations for future conservation of crane species in Asia. An in-depth review of the use of biotelemetry also is provided.

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