SPECIES REVIEW:

SARUS CRANE (*Grus antigone*)

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(with input from Rupak De, John Grant, Kandarp Kathju, Timothy Nevard, Simon Mahood, Elinor Scambler, Rajendra Suwal, Triet Tran, Myo Sander Winn, and Robert van Zalinge)

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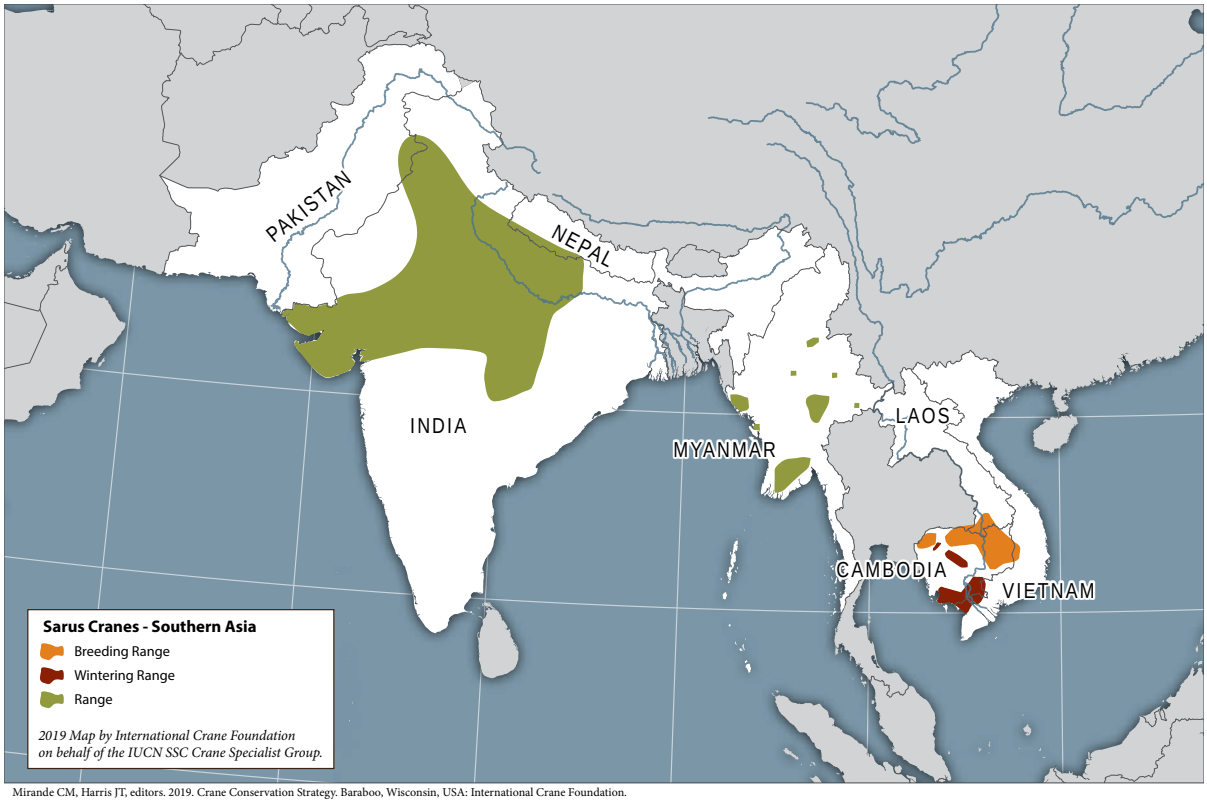
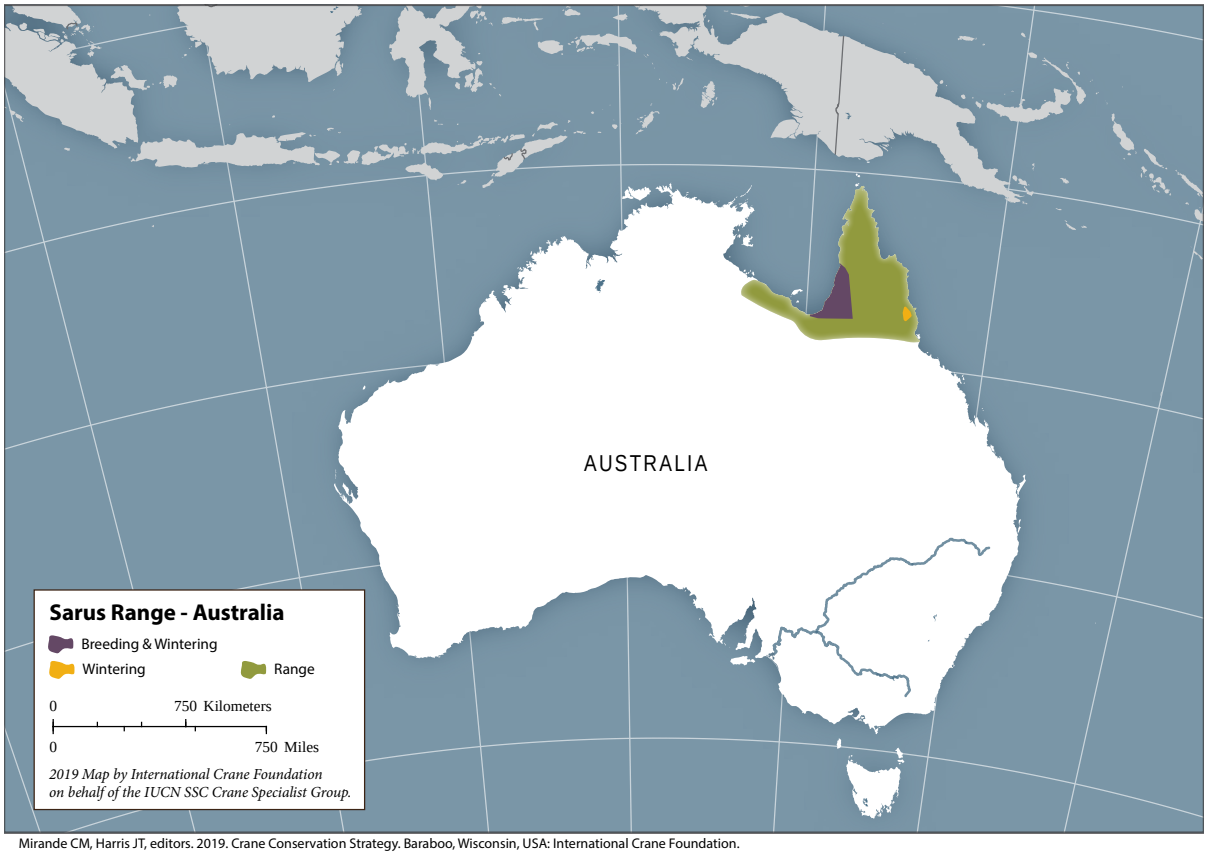
Sarus cranes unison call in rice fields in India (Photographer: K S Gopi Sundar, International Crane Foundation)

Red List Category: Vulnerable
Population Size: 15,000–20,000
Population Trend: Stable or decreasing
Distribution: India, southern Asia, Australia



Mirande CM, Harris JT, editors. 2019. Crane Conservation Strategy. Baraboo, Wisconsin, USA: International Crane Foundation.



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DISTRIBUTION AND STATUS OF KEY SITES

Populations

The Sarus Crane is a monotypic species with populations spread out across tropical and sub-tropical parts of South Asia, Southeast Asia, and Australia. Three subspecies have been identified using morphological and plumage characteristics: Indian (*Grus antigone antigone*), Eastern (*G. a. sharpii*), and Australian (*G. a. gillae*); a fourth, the Phillipine subspecies (*G. a. luzonica*), is presumed extinct. The genetic study by Jones et al. (2005) indicated the three extant subspecies probably represent a fragmented cline with limited, but evolutionarily important, gene flow between all populations. Current reproductive isolation of populations and potential genetic introgression with the Brolga (Archibald 1981) led to the recommendation of managing the subspecies separately (Jones et al. 2005). The four populations are located in South Asia, China-Myanmar, Lower Mekong, and Australia. The species is suspected to be extinct or occurring in very small numbers in Bangladesh, China, Lao People's Democratic Republic, Papua New Guinea, and the Philippines (Archibald et al. 2003) and is being reintroduced into Thailand (N. Purchkoon and N. Tiertisup, personal comm. 2017). Genetic studies suggest that the Australian population was separated from the Southeast Asian population about 30,000 years ago (Jones et al. 2005). There is no evidence that the South and Southeast Asian populations inter-breed, but it is possible that such interactions occur in Myanmar (Archibald et al. 2003).

South Asia

Sarus Cranes are primarily concentrated along the Gangetic floodplains in Uttar Pradesh state in India (~6,000). Significant populations also occur in Gujarat and Rajasthan states in western India (~3,000), and small, scattered populations are known from Madhya Pradesh, Maharasthtra, and Bihar states (~500) in central India. A small but contiguous population (~800) occurs in Nepal, primarily in the districts of Rupandehi and Kapilvastu where land use is dominated by cultivation and floodplain marshes and lakes (K S Gopi Sundar and S. Kittur, unpublished information). Occasional pairs are sighted in Pakistan but the species has not been recorded breeding here for three decades (Sundar and Choudhury 2003).

The largest breeding population and highest number of flocking sites have been recorded in the Indian population. The majority of breeding Sarus Cranes in South Asia use irrigated rice (*Oryza sativa*) fields. Breeding areas are therefore spread out across a large area, especially where non-mechanized cultivation and favorable farmer attitudes persist (Sundar 2009, 2011).

Flocks mostly occur seasonally in response to wetlands drying in the summer, but in some areas flocks comprise young birds and birds without breeding territories and are perennial. Several flocking sites are recorded, but documentation in a large part of the populations' distribution range is absent. Important flocking sites include key reservoirs in Gujarat (Mukherjee et al. 1999, Singh and Tatu 2000), reservoirs as well as perennial wetlands supported by irrigation canals in Rajasthan (Kaur 2007), and a relatively large number of medium-sized shallow wetlands that are maintained as community lands for human use in Uttar Pradesh (Sundar and Choudhury 2003, 2008; Sundar 2005). In Nepal, the most important flocking site is along the banks of the rivers Tinau, Danob, and Banganga in Rupandehi and Kapilvastu districts (Rajendra Suwal, personal comm. 2017).

China-Myanmar

This population is the most poorly studied and understood of all Sarus Cranes. In Myanmar, Sarus Cranes were sighted in five out of seven states (Kachin, Shan, Kayah, Rakhine, and Mon) and in five out of seven regions (Ayeyarwady, Sagaing, Mandalay, Bago, and Yangon; Tin New Latt, personal comm. 2017). Breeding has been confirmed in the states of Kachin, Shan, and Rakhine in Myanmar

(Barzen et al. 1996). A resident population of over 150 cranes, including 23 nests, was discovered during surveys by the Myanmar Crane Team of the Yangon University during 2016–2017 from the Ayeyarwady delta (Myo Sander Winn, personal comm.). Another small, apparently isolated, population is known from the Rakhine state of southwestern Myanmar using both freshwater and brackish coastal marshes for nesting (Tin New Latt, personal comm. 2017). A small, probably breeding population is known from the western Yunnan province and Yunxiang County in China contiguous with the population in Kachin and Shan states of Myanmar (Barzen and Seal 2001).

Lower Mekong Basin

Sarus Cranes in the Lower Mekong Basin (LMB) occur primarily in northern Cambodia, the Tonle Sap lake basin, the Mekong Basin, and parts of Vietnam (Archibald et al. 2003, Barzen 2004, van Zalinge and Tran 2016). Barzen and Seal (2001) referred to this population the Southeast Asia Population. A small number of Sarus Cranes are seen in southern Laos. Similar to populations in South Asia, Sarus populations here are both sedentary (Cambodia, Vietnam) and migratory. Sarus Cranes of the LMB migrate between breeding sites, mainly in Northern Cambodia, to non-breeding flocking sites in the Tonle Sap Lake basin and the Mekong Delta (Robert van Zalinge, personal comm. 2017).

Known breeding sites are located in temporarily inundated grassland patches within open Dipterocarp forests in the low-lying plains of north and north-east Cambodia especially Preah Vihear, but also Stung Treng, Rattanakiri, and Mondulkiri provinces (Barzen 2004).

Nesting in northern Cambodia has been documented to occur between July and September (Clements et al. 2009a). The most important known breeding area is located in the Northern Plains, an area comprising Preah Vihear Protected Forest and Kulen Promthep Wildlife Sanctuary, with more than 50 nests counted annually (Clements et al. 2013). A 2001 aerial survey of northern Cambodia conducted in September (end of breeding season) found clusters of Sarus Cranes present in the above-mentioned Northern Plains area and east of the Mekong around Lomphat Wildlife Sanctuary (Barzen 2004). Results from a recent tracking study conducted in 2015–2017 suggest that cranes that are present in the northern Tonle Sap floodplains (including Ang Trapeang Thmor) in the dry season breed in the Northern Plains, particularly Kulen Promtep Wildlife Sanctuary and south towards Boeung Per Wildlife Sanctuary (Robert van Zalinge, personal comm. 2017), while the breeding area of cranes that use the Mekong delta in the dry season seems divided between east of the Mekong (particularly Lomphat WS) and the eastern section of the Northern Plains, i.e. Preah Vihear Protected Forest (Robert van Zalinge, personal comm. 2017).

After breeding, around half the population moves towards the Tonle Sap floodplain and the other half towards the Mekong delta, aggregating at several wetland sites in Cambodia and Vietnam (Barzen and Seal 2001, Watson et al. 2007, van Zalinge et al. 2011). A few individuals, pairs, or family units will stay in the northern forests the whole year, but permanent wetlands are scarce here in the dry season. Ang Trapeang Thmor, Boeung Prek Lapouv, and Anlung Pring are sites that often have peaks of more than 200–300 cranes from January to March, even as late as April in Ang Trapeang Thmor, while earlier in the dry season the majority of cranes will forage in the floodplains of the Tonle Sap lake floodplain and at Boeung Prek Lapouv in the floodplain of the Bassac River (van Zalinge et al. 2011). There are also several other sites in the Vietnamese Mekong Delta that are used by cranes but usually in lower numbers or less regularly than the above-mentioned sites. These include Phu My, Kien Luong Protected Forest, Tram Chim, Hon Chong, Lang Sen, and Hon Dat Protected Forest. Rapidly changing and intensified land use has reduced Sarus Crane use of many sites in the Vietnamese part of the delta. At the beginning of the century more than 300 cranes were still flocking to Hon Chong in Kien Luong

province, but this has declined to only a few individuals in recent years due to habitat loss. Tram Chim itself also has seen a sharp decline from being the premier site in the non-breeding season with more than 1,000 cranes recorded in 1988 (BirdLife International 2001) to around 100 or less in the last decade.

Australia

Sarus Cranes occur in far north-eastern Australia, largely concentrated in Queensland. The few studies on Sarus Cranes in Australia have focused on the main breeding areas along the southern and eastern shores of the Gulf of Carpentaria, and flocking areas in the Atherton highlands (Archibald and Swengel 1987, Grant 2005; John Grant and Elinor Scambler, personal comm. 2017). Breeding records are primarily from the coastal regions in the Gulf of Carpentaria and Cape York Peninsula (Archibald and Swengel 1987, Marchant and Higgins 1993, Barrett et al. 2003, Franklin 2008; J. Grant, S. Kittur, E. Scambler, K S Gopi Sundar, Michael A. McCarthy, and Inka Veltheim, personal comm. 2017). Most breeding records from the lowlands of the Gulf of Carpentaria are in the Gilbert and Norman River basins where cranes use natural wetlands, flooded open and forested grasslands, artificial wetlands that provide drinking water to cattle, and seasonally flooded borrow pits that were created during road construction (Barrett et al. 2003; J. Grant, S. Kittur, Elinor Scambler, K S Gopi Sundar, Michael A. McCarthy, and Inka Veltheim, personal comm. 2017). Family groups with juveniles have been observed in several other areas, such as Arnhem Land floodplain areas, but breeding at those sites has not been confirmed by observation of nests (John Grant and Tim Nevard, personal comm. 2017). Part of the Sarus population remains in the Gulf area outside the breeding season, where flocks of varied sizes with adults, sub-adults, and juveniles form (John Grant and Tim Nevard, personal comm. 2017). The only other known major flocking site is the Atherton Tablelands where flocks include young of the year allowing a crude estimate of recruitment rates (Marchant and Higgins 1993, Grant 2005). The source of cranes to this wintering site is unknown. Expanded surveys to ascertain the full extent of distribution of breeding and flocking sites in Australia are needed.

ECOLOGY

Studies on Sarus Cranes have been disproportionately from the Indian subcontinent while the populations in China-Myanmar and Australia remain the least studied. Long-term restoration studies on Sarus' habitat are restricted to the Lower Mekong Basin. Surveys and studies on breeding ecology constitute the majority of scientific attention on Sarus Cranes (Archibald et al. 2003, Sundar and Choudhury 2003).

Breeding pairs maintain perennial territories not exceeding 50 ha in southwestern Uttar Pradesh in India, where flocks consist of non-breeding birds, constitute roughly 50% of the total regional population, and can be seen throughout the year (Sundar 2005, 2009, 2011). Everywhere else in their distribution range, Sarus pairs form seasonal flocks with non-breeding cranes in response to wetland drying (Ramachandran and Vijayan 1994, Mukherjee 1999, Kaur 2007) and during seasonal migration like those seen in the Lower Mekong Basin and Australia (Archibald et al. 2003). Sarus Crane flock sizes increase in the Lower Mekong Basin as the advancing dry season reduces wetland habitat (Jeb Barzen and Triet Tran, personal comm. 2017).

Extensive studies on breeding ecology have been carried out in India (Mukherjee 1999; Mukherjee et al. 2000; Kaur 2007; Sundar and Choudhury 2003, 2008; Sundar 2009, 2011). Sarus Cranes nest during the rainy season or the monsoon, with a minor nesting season in early summer usually involving a small proportion of pairs that failed to raise chicks in the regular nesting season. Breeding pairs repeatedly use the same nest site that might be small patches of wetlands amid rice (*Oryza sativa*) fields, wetlands formed by leaking irrigation canals, on dikes used to separate wetlands from

agricultural fields, or on dikes separating agricultural fields. Nest sites are preferentially wetlands that may be either remnant flooded natural marshlands or small unused areas within agricultural fields, though rice fields and dikes within rice fields are also used.

In the Lower Mekong Basin, Sarus were initially thought to nest only in the vast undisturbed wetland complexes or in inaccessible large wetlands, but it is now known that they breed in very small wetlands (0.5–2 ha) that are largely seasonal in nature and are scattered within a landscape of open Dipterocarp forests, such as found in the low-lying plains of northern and northeastern Cambodia (Archibald et al. 2003, Barzen 2004, Clements et al. 2009a).

In Australia, shallow wetlands on cattle (*Bos taurus*) stations and seasonally-inundated grasslands among trees are used, with nests often placed beside *Eucalyptus* tree trunks, sometimes in close proximity to Brolga nests (Archibald and Swengel 1987, Beruldsen 1997; John Grant, personal comm. 2017). Nests in India can be located as close as 3 m to major roads and 20 m to villages. Nests further away from roads have a higher probability of hatching, underscoring the strong role of humans in egg mortality. Preference for wetland nest sites occurs at both the landscape scale as well as within individual crane territories (Sundar 2009).

In India, nest initiation and nesting success are closely matched with farming practices particularly timing of flooding of fields using irrigation canals. Rainfall intensity also has a significant effect, with pairs improving breeding success in years of normal or high rainfall (Sundar 2011). Nest success in Rajasthan and Gujarat is higher when nests are located in wetlands, but evidence for nesting habitat affecting nest success is equivocal in Uttar Pradesh. Average nest success (proportion of nests with at least one egg hatching) varies between 54 and 71% with significant annual variations at each site. Human disturbance and removal of eggs either to reduce crop damage or for food are the principal reasons for egg mortality, and a small amount of egg predation by crows (*Corvus*) occurs. Fledgling success has been calculated using different metrics in three separate studies and varies between 32 and 41% with substantial annual variation. Reasons for chick mortality are largely unknown, though predation by a growing population of feral dogs (*Canis lupus familiaris*) is suspected to be the most important reason. Breeding success declines with low rainfall, conversion of wetlands in crane territories to agriculture fields, and most seriously due to conversion of agricultural land to other forms of more urbanized development. Areas with smaller nesting densities like the semi-arid Rajasthan state experience much larger inter-annual variations relative to wetter areas with high number of nesting pairs as in Gujarat and Uttar Pradesh.

Pairs occurring in landscapes with flooded rice cultivation are more successful in raising chicks relative to pairs in landscapes with drier crops such as soybean (*Glycine max*) and sugarcane (*Saccharum*; Sundar et al. 2000, Sundar and Choudhury 2006). Favorable attitudes towards cranes by farmers results in improved breeding success. In areas with high egg mortality due to humans, complete egg mortality can be prevented only by active nest guarding (Kaur et al. 2008).

In Southeast Asia, Sarus Crane nests are most successful when in inaccessible wetland complexes, and experience near-total egg mortality when they nest in crop fields or near human habitation (Barzen 2004, Handschuh et al. 2010). Even in the remote forest areas of northern Cambodia, the Wildlife Conservation Society has for several years started employing local nest guards for as many nests as possible, due to the high risk of predation by people.

Monitoring of yearlings in non-breeding, flocking sites in the Atherton Tablelands in Australia showed annual recruitment to fluctuate between 5–8% (average of 6.6%, Grant 2005). Similar assessments in the Indian subcontinent from various locations provided a much larger variation annually and

between sites with a range of 4–19% (average of 9.22; Sundar and Choudhury 2003). Regional and annual variations are therefore important to understand before using these metrics.

Sarus Cranes are omnivorous with their diet including a long list of individual items ranging from grass shoots, wild tubers from sedges (*Carex*), potatoes (*Solanum tuberosum*), and grains, to bird and turtle eggs, snakes, and amphibians (Sundar and Choudhury 2003). Seasonal movements of Sarus are most visible during the summer in the semi-arid areas of Gujarat and Rajasthan (Mukherjee et al. 1999, Singh and Tatu 2000) and during the post-breeding season starting as early as October in Southeast Asia (Watson et al. 2007, van Zalinge and Tran 2016).

Movements in winter, likely in response to winter temperatures as well as drying conditions, occur in Australia (Grant 2005) and in northern India (Bal and Dua 2010). The most regular seasonal migrations have been observed in the Lower Mekong Basin where Sarus Crane use few large wetlands after the breeding season (Watson et al. 2007, van Zalinge and Tran 2016) and at the Atherton Tablelands in Australia (Marchant and Higgins 1993, Grant 2005; Elinor Scambler, personal comm. 2017). Regulating flooding regimes and active vegetation management using fire in protected wetland areas are crucial to maintain wintering habitat for Sarus Cranes in Southeast Asia (Meynell et al. 2012).

NUMBERS AND TRENDS

Sarus Cranes are considered to be declining due to expanding agriculture and declining wetland areas (Meine and Archibald 1996, BirdLife International 2001). A total global population of 15,000–20,000 is estimated (Archibald et al. 2003). Robust population estimation, however, is absent for the Sarus, precluding a sound understanding of trends. Long-term monitoring is biased towards flocking sites and provides a snapshot of the complexities inherent in estimating population sizes and trends of this species.

South Asia

An estimate of 8,000–10,000 was provided for the Sarus Crane population in India, Pakistan, and Nepal (Archibald et al. 2003). Though presumed to have declined precipitously in South Asia due to expansion of agriculture (BirdLife International 2001), historical literature points to increases in the network of irrigation canals and flooded rice cultivation (Mann 1999), suggesting that Sarus Cranes witnessed a huge expansion of their distribution on the subcontinent during the 1700s and 1800s. This range expansion is continuing today with irrigation canals spreading from new large dams to erstwhile dry areas in Gujarat and Rajasthan (Kaur 2007; K S Gopi Sundar and S. Kittur, unpublished information). However, rice fields, combined with unfavorable farmer attitudes and landscapes with reducing wetland areas, have the potential to become ecological traps (Sundar 2009, Sundar and Kittur 2012). The greatest population declines of Sarus Cranes are therefore likely from this time forward.

Several national, state-wide, and more local surveys using multiple methodologies and metrics have been conducted in South Asia. Two national surveys for India based largely on roadside observations were conducted in 1987–88 and 1998–99 (Gole 1989, Sundar et al. 2000) but had differing objectives and metrics, making a direct comparison in estimates impossible. Gole (1989) provided an estimate of ~13,000 Sarus Cranes in India based on crude roadside densities. Sundar et al. (2000) do not provide an estimate of the entire population based on the surveys but include relative abundances of each surveyed area. Both surveys, however, confirmed that most of the Sarus population occurred in Uttar Pradesh, Gujarat, and Rajasthan, with small populations in Maharashtra and Madhya Pradesh and no cranes seen east of Uttar Pradesh. Both surveys also identified southwestern Uttar Pradesh as having the highest concentration of Sarus Cranes in the region.

The most comprehensive state-wide surveys have been conducted in Gujarat using volunteer visits to rural areas with reservoirs and wetlands (Singh and Tatu 2000). An estimate of ~2,000 cranes has been provided from this survey with the majority of crane located in the districts of Kheda and Ahmedabad, with smaller populations scattered in the districts of Bharuch, Junagadh, Panchmahal, Surat, and Valsad. A previous estimate of 12,000 cranes in Gujarat is thought to be inflated; surmises of significant declines of Sarus populations in the state are suggested to be incorrect (Singh and Tatu 2000). Currently, however, Gujarat is experiencing the most rapid industrial development of any state in India, and this process is likely occurring at the cost of wetlands and other habitats important for Sarus Cranes (Kandarp Kathju, personal comm. 2017).

An estimate of 6,000–8,000 cranes was provided for Uttar Pradesh (Sundar and Choudhury 2003). However, more detailed studies including a landscape-scale occupancy modelling exercise and an annual state-wide Sarus census conducted by the Uttar Pradesh Forest Department indicates that this is an underestimate (Sundar 2005, Sundar and Kittur 2012; Rupak De, personal comm. 2017). Rainfall in the state is experiencing rapid variations with a higher frequency of extreme events (Sundar 2011). If this forces changes in the major crops from rice to drier crops like corn (maize; *Zea mays*), Sarus Cranes will be very severely affected. Land-use change in the state, especially urbanization of agricultural lands and attrition of wetlands, are the most serious threats and can cause rapid declines in breeding populations of cranes (Sundar 2011). These rapid, large-scale changes are currently heavily localized suggesting that Sarus declines will be limited in the near-term in Uttar Pradesh.

Annual counts in Rajasthan's Keoladeo-Ghana Bird Sanctuary show a decline of Sarus numbers from 238 in 1983 to <40 cranes in recent years (Krishna Kumar, personal comm. 2017). However, Sarus Cranes outside the sanctuary show stable to increasing numbers, suggesting that the reduced numbers are related to altering hydrological regimes in the sanctuary, and it is not possible to relate counts inside the sanctuary to a population decline of the species in the region (K. R. Anoop and Krishna Kumar, personal comm. 2017). Similar detailed surveys are lacking in most of the other parts of the Sarus distribution in South Asia and are needed.

Comprehensive multi-year surveys in the entire potential distribution range in lowland Nepal have not been conducted. Surveys and studies have been restricted largely to Rupandehi district, which is suspected to have the highest Sarus Crane population in the country (Rajendra Suwal, personal comm. 2017). The crane population in Rupandehi and the adjacent Kapilvastu district is around 800 birds (K S Gopi Sundar and S. Kittur, unpublished data). To accommodate increased visitation to the birthplace of the Buddha, southern Rupandehi has experienced increased development. Industrialization accompanied by substantial increase in water pollution to rivers is a serious new threat capable of reducing the quality of existing Sarus Crane breeding habitats (Bhante Vivekananda and Rajendra Suwal, personal comm. 2017).

China-Myanmar

Sarus Cranes are most seen in the Ayeyarwady Delta. Surveys conducted here by the International Crane Foundation and Myanmar Forest Department recorded 122 and 61 Sarus cranes in 1996 and 1998, respectively (Barzen et al. 1996; Curt Meine, personal comm. 1998). Thet Zaw Naing (personal comm.) recorded 88 Sarus Cranes in April 2004 and 128 Sarus Cranes in May 2005 at Tawntay Township, Ayeyarwady Delta. Recently, a research team from Zoology Department of Yangon University conducted a survey at three townships in the Ayeyarwady Delta during August–September 2015 and found 60 Sarus cranes (Myo Sander Winn, personal comm. 2017). The same team conducted more extensive surveys at 74 villages in nine townships across four districts of the Ayeyarwady Region

during June 2016–March 2017 and recorded 158 Sarus Cranes and 23 nests (Myo Sander Winn, personal comm. 2017).

In northern Myanmar, Sarus Cranes were recorded in small numbers around Indawgyi Lake, Kachin State, with as many as 28 counted in February 1999 (Eleanor Briggs and Tin New Latt, personal comm. 2003; T. Z. Naing and Joost van der Ven, personal comm. 2017; A. Si, personal comm. 2017). In western Myanmar, T. N. Latt (personal comm. 2017) reported 38 Sarus Cranes, including four juveniles at several locations in the Rakhine State. In central Myanmar, Sarus Cranes have inhabited the Mandalay Region (Eleanor Briggs and Tin New Latt, personal comm. 2017). Sarus Cranes were also frequently observed in small numbers, including breeding pairs, around Inle Lake, Shan State, and Moneyingyi Bird Sanctuary, a Ramsar Site in the Bago Region (Barzen et al. 1996; Curt Meine, personal comm. 2017; Tin New Latt, personal comm. 2017). Additional sightings of Sarus Cranes have been recorded recently at various locations in Sagaing Region (Eleanor Briggs and Tin New Latt, personal comm. 2017), and there are old unconfirmed records from Mon State (Tin New Latt, personal comm. 2017).

Previous field observations suggest that Sarus Cranes in the Ayeyarwady Delta are non-migratory, often use paddy fields as breeding habitat, and are tolerant of the presence of humans (Barzen et al. 1996, Meine 1999). These sedentary behaviors and nesting habitats are similar to those displayed by the Sarus Cranes in south Asia. Outside of the Ayeyarwady Delta and perhaps in the Rakhine area, Sarus Cranes in Myanmar may have seasonal movements between breeding and non-breeding seasons (Barzen et al. 1996, Barzen and Seal 2001).

Results from recent surveys in the Ayeyarwady Delta (Myo Sander Winn, personal comm. 2017), combined with previous records from other regions, suggest an estimate of 300–400 Sarus Cranes in Myanmar.

Lower Mekong Basin

Vast areas of the Mekong delta and large wetlands areas like the Plain of Reeds have been affected by war and in more recent times have been drained and reclaimed for agriculture (Archibald et al. 2003, Tran et al. 2004a). A population estimate of 800–1,000 cranes was been provided for the Sarus in Southeast Asia (Archibald et al. 2003, van Zalinge et al. 2011), although results from recent years of crane counts suggest a rapid decline now occurring (van Zalinge and Tran 2016, Triet et al. 2018). Annual counts are believed to have the potential to capture a good majority of the crane population but lack precision due to annual climatic and hydrological variations, the complexity and size of the landscape being considered, and the lack of information on crane ecology, movements and distribution (Watson et al. 2007, van Zalinge et al. 2011). New breeding and flocking sites are being discovered regularly in the region, although some of the flocking sites are not used annually, indicating that cranes shift to new sites depending on food availability; this makes annual monitoring of the population very difficult (Watson et al. 2007, van Zalinge et al. 2011; Triet Tran, personal comm. 2017). Highest records since the annual counts began in 2001 have been 878 in 2002 and more recently, 869 in 2011 (van Zalinge et al. 2011). However, counts have recently shown a dramatic decline from 671 in 2014 to 572 in 2015, 433 in 2016, and 253 in 2018 (Triet et al. 2018). Simultaneous tracking of individuals showed that birds tagged or ringed in 2015 stayed at the catch sites for most of the dry season and returned again in 2016. In 2017 some juveniles shifted from Stoung (a site within the Tonle Sap floodplain) to Ang Trapeang Thmor, but adults returned to the same sites as in other years (Robert van Zalinge, personal comm.). Therefore, a high degree of site fidelity is shown and, if counts are maintained at the same sites each year (as is done), a sharp population decline is currently occurring.

Australia
Estimates of 5,000–10,000 Sarus Cranes are provided for Australia, but these are thought to be unreliable (John Grant and Elinor Scambler, personal comm. 2017). The only reliable counts are 1,200–3,000 individuals flocking on the Atherton Tableland from 1997–2016, but it is not known what proportion of the total population these birds represent (Elinor Scambler, personal comm. 2017). Population trends in Australia are currently unavailable.

THREATS
A large number of threats have been documented for all the Sarus populations. These include: increasing urbanization and industrialization; deforestation (mainly affecting breeding habitats of the population found in the Lower Mekong Basin); intensive farming practices on rice paddies; variations in rainfall due to global climate change; increased predation of eggs by humans and pre-fledged chicks by dogs; excessive harvest or poaching of young birds; mortality due to electrical wires and barbed-wire fences; unintended poisoning in agricultural landscapes by chemicals applied to crops; poisonous baits used in waterbird hunting; deterioration of quality of important wetland sites due to invasive species, changes in flooding regimes, and inadequate vegetation management; potentially low recruitment rates (due to unknown reasons); conversion of common-use wetlands for aquaculture; and permanent displacement of breeding and flocking cranes due to urbanization (Muralidharan 1993; Mukherjee 1999; Mukherjee et al. 2000; Pain et al. 2004; Tran et al. 2004b,c; Grant 2005; Sundar and Choudhury 2005; Kaur 2007; Sundar 2009, 2011; Barzen and Tran 2010; Meynell et al. 2012; Sundar et al. 2015; Jeb Barzen, Elinor Scambler, Kandarp Kathju, and Rajendra Suwal, personal comm. 2017).

A number of potential threats that may occur at very large scales, given uncertainties related to climate change and acceleration of development, might cause rapid declines of Sarus populations. These threats are emerging particularly in South Asia and Southeast Asia and include shifts in primary crops from flooded rice to drier crops like corn, soybean and sugarcane; extreme fluctuations in precipitation levels, especially increased frequencies of dry years and years with decrease in rainy days due to global climate change; changes in national land-use policy to favor transformation of agricultural land to industrial and urban requirements; potential displacement and mortality from increasing wind farms; increased invasiveness of exotic, invasive species in wetland sites of importance; and increased pesticide use on crops. Outside of Australia, documentation and studies of wetlands in the rest of the distribution range of Sarus Cranes have been very sparse, indicating that the large-scale threats will have unknown effects on the habitat.

The Southeast Asian population is experiencing the most precipitous decline and threats of any Sarus population. Vast areas of the Mekong Delta such as the former Plain of Reeds have been drained and reclaimed for agriculture (Archibald et al. 2003, Tran et al. 2004a), and changing hydrology and other factors have altered most of the remaining wetlands, causing reductions in numbers of cranes using the Mekong Delta in the non-breeding season. The last five years in Cambodia have seen the highest acceleration of deforestation worldwide. Particularly the more open deciduous forests in which cranes breed are targeted for conversion to large agricultural plantations; if the current trend is followed it looks like the protected area system in Cambodia will also increasingly be compromised and altered. The collection of eggs and chicks for consumption and trade is common and widespread, although nest protection occurs in at least two important breeding areas (Handschuh et al. 2010, Clements et al. 2013), but on top of this hunting and wildlife trade are at unprecedented levels as Cambodia's human population grows, previously undisturbed areas are opened up, and trade networks become more efficient and far-reaching (Robert van Zalinge, personal comm. 2017).

An emerging potential threat in Australia is the development of irrigated agriculture in northern Australian river systems. Impoundment of water for irrigation and 'pest control' issues may possibly impact cranes, which are already under illegal pressure in some agricultural areas near the Atherton Tablelands (Tim Nevard, personal comm. 2017). The Gilbert River basin, one of the key sites for breeding Sarus, has been identified as one of the first northern catchments for agricultural expansion (John Grant, personal comm. 2017). Land-use changes to favor sugarcane and declining rainfall at Atherton Tablelands, the most important non-breeding flocking site for Sarus in Australia, are additional threats in Australia (John Grant, Elinor Scambler, and K S Gopi Sundar, unpublished information).

A significant threat to conservation efforts especially in South Asia is dilution of local belief systems via payment-based conservation projects that tend to be implemented over very small scales and are usually short-lived (Sundar and Choudhury 2003). In Cambodia, nest protection via payments to individuals was useful to increase breeding success, but the program benefited very few people, causing jealousies and inciting deliberate disturbance of nesting birds (Clements et al. 2013). These experiences suggest that payment-based conservation interventions require very careful implementation, but also that it may be useful to seek alternative interventions that strengthen existing positive attitudes where present as in south Asia. Social upheavals due to perceived and real changes in allocation of water and other ecological services due to protectionist conservation efforts can lead to significant declines in quality of wetlands that support important Sarus Crane populations (Lewis 2003). Continuing with the protectionist paradigm to convert community wetlands into protected wetland sites can result in the increase of such social upheavals in some areas like South Asia.

CONSERVATION AND RESEARCH EFFORTS UNDERWAY

Sarus Cranes are protected via national legislation in most of the countries in their distribution range. But the vast majority of cranes occur in private crop and grazing lands and in community lands, rendering typical conservation strategies requiring designation of individual sites as reserves ineffective. Research and conservation efforts have therefore focused on understanding how to reconcile land use vis-á-vis ecological requirements of Sarus Cranes, developing regional and local initiatives to reduce pressures on wetlands and other sites used by cranes, and improving prospects for continued long-term efforts via collaborative training involving universities, non-profits, international conservation initiatives, and the government. Although in Cambodia cranes breed mostly in state-owned protected forests and in three key wetlands that have been officially designated as Sarus Crane reserves (these three sites regularly hold 20–30% of the regional population), human use and influence within these areas is large and will only increase. In Southeast Asia there is also a real need to work with farmers, communities, and civil society in general to improve crane and wetland conservation in the region.

South Asia

The greatest understanding of Sarus Crane ecology comes from research conducted by universities, governmental agencies, and non-profits in India and Nepal. Long-term research and use of robust field and analytical methods are improving greatly. Some of the major developments in research are listed below.

- Development of survey techniques, specifically methods that focus beyond ongoing long-term monitoring efforts at wetlands (Sundar 2005), and implementation of landscape-scale surveys away from roads (Sundar and Kittur 2012). Occupancy modelling has helped identify erstwhile unknown landscapes with good crane populations and helped clarify the importance of retaining community wetlands at the landscape scale;

- Strong understanding of breeding ecology, particularly nesting site preference, hatching and fledgling success, and impacts of rainfall variations and land-use change on breeding success (Mukherjee 1999; Mukherjee et al. 2000; Sundar and Choudhury 2003; Kaur 2007; Sundar 2009, 2011). Research has been carried out at multiple sites at varying spatial scales, providing a strong understanding of how differing land uses and local attitudes and cultures affect Sarus breeding success. Research over longer periods, providing very high resolution understanding of Sarus population trends, behavior, and factors affecting key population metrics, have begun in multiple locations;

- Improved understanding of the impacts of major threats such as farmer removal of eggs, egg removal for food, impacts of mortality of pre-fledged chicks on population structure and growth, and population-level impacts due to mortality by collision with electrical wires (Mukherjee 1999, Mukherjee et al. 2000; Sundar and Choudhury 2005; Kaur 2007; Sundar 2009, 2011). Repeated occurrence of poisoning events due to pesticide application is documented at one site (Muralidharan 1993, Pain et al. 2004);

- Importance of small-holder farmer practices with minimal mechanization for Sarus Crane persistence and relatively high bird diversity, and the critical need to encourage positive farmer attitudes to enable Sarus breeding in private lands has been highlighted in multiple locations (Mukherjee 1999; Sundar 2009, 2011; Sundar and Kittur 2012);

- Development of key population metrics and landscape-scale monitoring protocols for use in volunteer, citizen-science efforts, and mass awareness are underway in India and Nepal;

- State-sponsored, state-wide Sarus Crane censuses to help bring wildlife outside of protected areas into focus, and to understand annual trends in Sarus numbers have begun in Gujarat and Uttar Pradesh (Singh and Tatu 2000; Rupak De, personal comm. 2017);

- State-sponsored education efforts have been carried out by the Forest Departments of Gujarat and Uttar Pradesh in India, and similar efforts by non-profit organizations in association with local and national governments have been undertaken in Nepal. These efforts have enabled completion of films documenting Sarus ecology, radio programs to highlight the importance of Sarus Cranes, and printed material (posters and pamphlets) to showcase the importance of Sarus in ecology and culture. These programs and education materials are being improved on, and plans to undertake wider-scale education are currently underway in India and Nepal; and

- Efforts are underway among the Lumbini Crane Conservation Center, Nature Conservation Foundation, International Crane Foundation, and other national and international institutions to develop collaborative projects to understand institutional frameworks that assist in retaining community wetland areas in important Sarus Crane areas. Projects will focus also on determining wetland values, institutional mechanisms important in retaining wetlands, and the role of caste and economics in maximizing the retention of community wetlands important for Sarus Cranes.

Conservation and restoration efforts have been sparse since the vast majority of the Sarus Crane population occurs in working landscapes, particularly private cropland and community lands. These efforts are therefore largely focused on wetland sites of national importance, and in areas on the periphery of the Sarus' distribution where declines and impacts of threats are readily visible on the already-sparse population.

- Nest guarding using payments to local communities to improve breeding success in areas with very high egg mortality (Kaur et al. 2008);

- Community participation and focused administrative efforts at the district level to locate and conserve important wetland sites are taking place in a few locations and are increasing. Two significant examples are worthy of mention. One is the effort by the District Magistrate in Sitapur district, Uttar Pradesh, to survey wetland sites for Sarus, and implement formal conservation policy (S. Kumar, personal comm. 2017). The second is the active protection and purchase of key crane nesting sites at Chandrapur and Gondia districts, Mahasrashtra, by local non-profits to prevent loss of wetland sites to development, and to improve Sarus Crane persistence and breeding success (B. Katdare, A. K. Bharos, S. Bahekar, and Rajkamal Job, personal comm. 2017);
- Using the strength of cultural and religious values to protect important wetlands and bring about wider awareness and support for the importance of wetlands and Sarus Cranes. This approach has been ongoing in the Lumbini region of Nepal for over two decades, resulting in the conservation of an invaluable wetland area close to the birthplace of Lord Buddha (Suwal 1999); and
- Organising new water sources for Keoladeo-Ghana National Park, which is also a recognized UNESCO site, in Rajasthan has been ongoing. Regular water supply was affected due to local conflicts with farmers and grazers (Lewis 2003), and water supply using an alternative source has been established (K. R. Anoop, personal comm.). This effort has revived the breeding populations of Sarus Cranes in the Park (K. R Anoop and Bijo Joy, personal comm. 2017).

China-Myanmar

The greatest advancements in research efforts have been carried out in this region. Political changes in Myanmar have facilitated collaborations that are yielding new information on the populations and requirements of Sarus Cranes. A collaboration forged between the International Crane Foundation and the Yangon University has led to increases in field surveys since 2015, primarily in the Ayeyarwady Delta region. As part of this collaboration, it is anticipated that surveys will be expanded to additional areas, and ecological research with a focus on conservation requirements of Sarus Cranes will be increased in the region (Triet Tran and Myo Sander, Winn, personal comm. 2017).

Lower Mekong Basin

Conservation efforts have been the most sustained in Southeast Asia, although as pointed out above the population is also the most at risk. Very little research on Sarus Crane ecology has been done due to decades of wars in the region and the slow rebuilding of institutional capacity. Most of the crane related research in the region has been carried out in Vietnam. The focus has been more on population monitoring and developing innovative solutions with local communities to link livelihoods with wetland conservation. Crane breeding sites are very difficult to access, hampering research on this vital aspect of crane ecology, although the nest protection program in Preah Vihear has offered some opportunities to collect important data (e.g., Handschuh et al. 2010), and recently a study has been conducted on nest-site selection in the Northern Plains (Robert van Zalinge, personal comm. 2017). Achievements to date have been:

- Documenting key sites for conservation of Sarus Cranes and other birds, designating three key wetlands in Cambodia as Sarus Crane reserves, and the ongoing evolution of their management (van Zalinge et al. 2011);
- Aerial surveys over inaccessible forested wetland complexes to locate Sarus Crane breeding sites, and to understand importance of these sites to other species of global conservation importance (Barzen 2004);
- Annual monitoring of non-breeding Sarus Cranes at key sites in Cambodia and Vietnam (Watson et

al. 2007; van Zalinge et al. 2010, 2011; van Zalinge and Tran 2016). Efforts have increased from one or two sites by single non-profit organizations, to covering a network of sites with new areas being discovered regularly as part of a sustained collaborative partnership among various local, national, and international institutions;

- Improving water regimes and initiating management of vegetation and select faunal taxa using fire and control of invasive species at key wetland sites (Tran et al. 2004a,b,c; Meynell et al. 2012; van Zalinge and Tran 2016);

- Protecting the extensive deciduous Dipterocarp forest with its network of small wetlands across the entire breeding range of Sarus Crane in Cambodia, with a particular emphasis on Preah Vihear Province (which satellite telemetry and field data indicate is the most important breeding area) is ongoing. However, efforts to prevent loss of forest and in particular grassy wetlands that are a target for small-holder rice cultivation need to be scaled up (Simon Mahood, personal comm. 2017);

- Initiating a region-wide University Network and evolving a wetland training course conducted annually in a different country (Tran et al. 2003, Barzen 2009). This effort, alongside other international efforts to help sustain the unique Lower Mekong River Basin, is helping enhance training to local students and university faculty in a range of aspects of wetland ecology. The network is providing strong and sustained impetus to larger-scale region-wide collaborations to understand wetland dynamics, level of chemical pollution in wetlands, other key threats, ecology of focal species like Sarus Cranes, and highlight the importance of wetlands potentially leading to meaningful interventions in national and regional developmental policies to achieve wetland conservation;

- Hiring local guardians to protect nests located within protected areas of northern Cambodia (Clements et al. 2013) and other community participative and livelihood generation initiatives using locally relevant and innovative approaches at key sites to promote conservation interest and change attitudes, such as handicraft production using natural resources, community-based ecotourism, and wildlife-friendly rice marketing (Tran et al. 2003, Clements et al. 2009b); and

- An instance of captive breeding to reintroduce Sarus Cranes in Thailand—where the species is presently extirpated in the wild—is being undertaken as a national enterprise with support from the Royal Family and several local zoos (N. Purchkoon and B. Sariaroonnat, personal comm.). Eighty-five post-fledged juveniles have been released at wetlands near flooded rice paddies; in 2015, 42 birds survived. There are 151 captive Sarus Cranes in various Thailand zoos and private collections; a few are from the Australian population (received via a donation from the International Crane Foundation), while most are from the eastern population (obtained from poachers who had illegally procured the birds from unknown locations, but most likely from Cambodia). Protocols are currently being developed for captive rearing to maximize breeding success (including a detailed investigation into their pedigree), habitat management and protection at release sites, and appropriate training for all personnel, in part through international collaborations with agencies undertaking crane releases. The first chick from released cranes that paired and nested in the wild fledged in 2016, and another two chicks fledged in 2017 (N. Purchkoon and B. Sariaroonnat, personal comm. 2017).

Australia

Until recently, remarkably little research has been conducted in Australia on Sarus Cranes. Most of the recent effort to connect crane enthusiasts, increase research, and initiate collaborative efforts on the continent has been due to volunteer efforts (Elinor Scambler, personal comm. 2017).

- Long-term monitoring of crane numbers, recruitment rates, and foraging ecology studies at the Atherton Highlands, the primary flocking site known for Sarus Cranes in the region, with standardized counts since 1997 (Grant 2005; Elinor Scambler, personal comm. 2017). These efforts have resulted in the declaration of the Atherton Tablelands as an Important Bird Area;

- Development and maintenance of a website (www.ozcranes.net) to help connect crane enthusiasts; provide updates of ongoing and completed crane research; improve efforts for long-term monitoring via collaborations with national and international institutions, universities and the government; improve understanding of critical conservation issues that may require focussed research attention,;and provide a platform for discussions with Sarus Crane researchers internationally (Elinor Scambler, personal comm. 2017);

- Initiating robust landscape-scale monitoring protocols to understand potential impacts of land use and intervention by landowners such as burning regimes and control of vertebrate pests including pigs (*Sus scrofa*) on Sarus Crane breeding success, distribution, and populations; and

- Evolving partnerships with Sarus Crane researchers and conservationists between Australia and South Asia to provide comparative and collaborative frameworks within which to understand Sarus Crane ecology and develop an understanding of local conservation requirements. This effort is led by the International Crane Foundation and the Nature Conservation Foundation, along with the University of Melbourne and is expected to involve several additional organizations and agencies in both Australia and South Asia.

CHANGES SINCE 1996

Since the writing of the 1996 Crane Action Plan, considerable new research, restoration effort, collaborations, and coverage of areas with varied land use as well as social and cultural norms have provided a much fuller understanding of Sarus Crane ecology and conservation requirements. The on-going conservation and research efforts are outlined in the previous section. Thorough reviews of literature to help interested researchers and governmental agencies have been compiled on the species (Archibald et al. 2003, Sundar and Choudhury 2003). Information provided to BirdLife International on sites important for Sarus Cranes has been critical for recognition of several sites as Important Bird Areas. Improvements in knowledge and field action have been less active in China, Myanmar, and Australia. However, recent efforts to undertake collaborative research and action along with several international and national institutions in Australia promise to change that situation soon (Elinor Scambler and John Grant, personal comm. 2017).

South Asia

Scientifically robust surveys to determine distribution as well as factors affecting distribution and breeding success have been initiated (Sundar and Kittur 2012). Detailed research was restricted largely to one site in Rajasthan (Ramachandran and Vijayan 1994) but has since substantially developed also in Gujarat and Uttar Pradesh. Long-term monitoring at one wetland site continues, and new long-term research in agricultural landscapes has been initiated providing novel findings of global significance (Mukherjee 1999, Kaur 2007, Sundar 2011; Krishna Kumar, personal comm. 2017). Several new populations have been discovered and multiple census efforts at the state level have been initiated (Singh and Tatu 2000; Rupak De, personal comm. 2017). Advances have been most significant in the detailed understanding of the formerly unknown degree of use of farmland landscapes by breeding and flocking Sarus Cranes (Mukherjee et al. 1999; Kaur 2007; Sundar 2009, 2011). A strong understanding of the population-level impacts of mortality due to electrical wires has been developed, and several key areas for focused intervention have been identified (Sundar and Choudhury 2005).

The previous plan recommended enacting strong laws to secure key wetlands and crane populations, but considerable research and restoration efforts show that creative and locally relevant strategies need to be evolved; maintaining community lands with local support can aid in long-term persistence of significant Sarus Crane populations in many areas within the cranes' distribution range. A large set of general recommendations to improve research, collaborations, and conservation legislation was provided in 1996, and a major proportion of these remain to be carried out.

China-Myanmar
A long-term initiative to learn more about the conservation needs of Sarus Cranes has been initiated in Myanmar, which is yielding necessary information regarding the distribution, population, breeding ecology, and relationship with habitats such as natural wetlands and flooded rice fields (Myo Sander Winn and Triet Tran, personal comm. 2017).

The Lower Mekong Basin
Wetland conservation and restoration using active interventions and systematic monitoring to understand critical needs of key wetland sites have been developed at various sites in Southeast Asia. The most important development has been the protection of habitat in the breeding and non-breeding grounds, and in particular the direct protection of nests, without which the decline of Sarus Cranes here would have been much more pronounced (Simon Mahood, personal comm. 2017). A significant progress has been the development of the region-wide collaboration via the University Network, as well as the growing efforts to monitor large wetland sites with flocking non-breeding Sarus Cranes. Progress with these collaborative, regional efforts at the time of writing of the 1996 plan was greatly limited. A collaborative research between the International Crane Foundation and several universities in Cambodia and Vietnam was conducted during 2014–2016 to describe and map wetlands in Kulen Promtep Wildlife Sanctuary Cambodia and Yok Don National Park Vietnam (Triet Tran, personal comm.). A captive breeding and release experiment is ongoing in Thailand.

Australia
Ongoing research collaboration between Charles Darwin University, the International Crane Foundation, and the University of Greifswald has recently seen three papers published (Nevard et al. 2018, 2019a, 2019b). Using genetic analyses of shed feathers and other samples, findings include definitive genetic evidence of past and ongoing introgression between Sarus Cranes and Brolgas and the first confirmation of movement of cranes between breeding and flocking areas. The research also investigated habitat partitioning of Sarus Cranes and Brolgas; distribution, foraging behaviour and food selection in their non-breeding wintering sites on the Atherton Tablelands; and investigation of agriculture-crane interactions and farmer attitudes, including threats and opportunities for crane conservation. Genetic analysis of shed feathers based on the Lincoln-Peterson Index was undertaken to estimate population size (Nevard et al. 2019b). The research team collaborated with colleagues from Myanmar, Cambodia, Thailand, and Germany to re-visit genetic relationships between Sarus Crane populations including the extinct Philippine population (Nevard et al. in preparation). Further work in New Guinea will commence in late 2019.

In addition, a long-term collaborative program focusing on the ecology and conservation requirements of Sarus Cranes in both breeding and wintering areas has been initiated by the International Crane Foundation, the Nature Conservation Foundation, and the University of Melbourne, in association with independent crane researchers and other experts. This collaboration has provided the first empirical information on landscape scale habitat preferences, robust estimates of breeding success derived from tracking individual breeding pairs, relationship of timing of nesting with rainfall, variation in diet derived from isotopic analyses of shed feathers, and behavior (Sundar et

al. 2019). Surveys have since expanded to include all known areas in Queensland with breeding Sarus Cranes and is expected to provide a comprehensive picture of the relationship of crane demography with rainfall, land use, and climate change to build an effective conservation plan.

PRIORITY RESEARCH AND CONSERVATION ACTIONS

Research

- Initiate Sarus Crane population monitoring using robust methods in areas that are poorly covered in past surveys, particularly in the Gulf Plains of Australia; in Nepal especially in Nawal Parasi, Banke, Bardia, Kailali, and Kanchanpur districts; in India especially in Madhya Pradesh and Rajasthan states and also in several districts of Uttar Pradesh not covered by Sundar and Kittur (2012); and in Myanmar especially across the entire Ayeyarwadi Delta; and the Lower Mekong Basin. Surveys and monitoring should be continued and improved for the rest of the distribution range where previous information exists. Surveys should include identification and counts of juveniles to monitor annual reproductive output of the populations;
- Assess impacts of agricultural and industrial chemicals on Sarus Cranes and their food throughout their distribution range;
- Initiate studies on the link between crane mortality and poisoning and the prevalence of poisoning in Cambodia and Vietnam;
- Undertake carefully designed movement studies of (1) dispersal of young birds from natal territories in areas with perennially territorial birds and (2) seasonal movements of cranes in other areas;
- Document areas important for flocking Sarus and understand impacts of surrounding land use on these sites; prepare management plans that explicitly include local stakeholders such as district development committees in Nepal, village councils in India, and landholders in grazing and agricultural areas of tropical Australia;
- Collect more data on distribution of Sarus Cranes breeding sites in the northern and northeastern forests of Cambodia; study the ecology of these sites and requirements of cranes in this landscape;
- Undertake studies to understand factors causing mortality of eggs, chicks, and older birds to enable implementing preventive strategies across the entire distribution range. Improve and enlarge studies on mortality due to electrical wires and barbed-wire fencing in South Asia and Australia, and initiate interventions to minimise these incidents in collaboration with land owners, state, and central agencies;
- Improve understanding of the utility of Sarus landscapes for other wildlife and for human livelihoods to facilitate improvements in policy and prevent myopic development of such areas;
- Increase studies on population genetics, especially to understand the impacts of population sizes on genetic structure and, in Australia, determine the impacts of potential interbreeding with Brolgas; and
- Initiate studies on health of wild Sarus populations and develop indicators of landscape health and chemical use, and develop an understanding of variations due to invasive versus non-invasive techniques.

Habitat Management and Protection

- Continue and expand wetland restoration activities in Southeast Asia and enable information exchanges on these experiences to other areas in the Sarus Crane's distribution range to help initiate locally relevant restoration projects where necessary;
- Expand initiatives to protect breeding and non-breeding wetland sites and Sarus Crane nests in the Lower Mekong Basin;
- Initiate multi-disciplinary studies in South Asia and Australia to understand levels of reliance of farmers and other people on wetlands and rivers; understand socio-political and institutional mechanisms that help retain important breeding and flocking sites; and increase research on wetland ecology, especially sociological perspectives that are currently severely under-explored. These explorations will be particularly important to understand formal and informal mechanisms available to protect and restore important Sarus sites and landscapes;
- Continue to provide information on Sarus flocking sites to key international organizations such as the Important Bird Areas program of BirdLife International and the Key Biodiversity Areas coordinated through IUCN to help highlight these sites and landscapes;
- Initiate detailed exploration of the potential impacts of sea-level rise on the salinity of coastal and inland wetlands in the Lower Mekong Basin and western Queensland to understand upcoming impacts of global climate change, and to prepare for potential changes in habitat conditions for breeding Sarus Cranes;
- Improve and expand research to understand more completely the impacts of climate change in South and Southeast Asia, especially variations in rainfall patterns on probable changes in cropping patterns that in turn can drastically deteriorate habitats and conditions for Sarus persistence;
- Increase focus on large-scale land use change currently being planned in Southeast Asia and Australia focusing on areas important for Sarus Crane breeding and flocking, as well as the implications of changing hydrology at the scale of entire river basins;
- Develop community-based programs and activities to help protect wetlands that cranes use during breeding and non-breeding seasons in Cambodia, Laos, and Vietnam;
- Work with local governmental authorities to integrate crane habitat management with economic development planning; and
- Continue to work with governments to enhance protection at key state owned reserves, particularly in the Lower Mekong Basin.

Education and Awareness

- Improve and expand the demonstration wetland site in Lumbini garden to help showcase importance of small wetlands to Sarus Cranes and other biodiversity. Use the site to enhance awareness among the hundreds of thousands of visitors each year regarding relationships between cranes and religion, and importance of retaining wetlands to help human livelihoods;
- Initiate mass awareness programs in Sarus Crane range countries to increase sensitivity of policy makers towards the importance of wetlands that are otherwise considered as wastelands in some countries, and the multi-functionality of agricultural areas in producing foods and retaining significant populations of globally-threatened species;

- Understand needs of land owners, especially those with breeding Sarus Cranes, and help communicate their important role in conserving cranes to a wider audience including policy makers and local government;
- Initiate and support regular interactions and knowledge exchanges internationally among researchers and managers in Sarus Crane range countries to facilitate improvements in research, restoration, and conservation;
- Improve exchange of information from research findings to policy makers in all the Sarus range countries with intent to help stem large-scale decisions based on usually single dimensions like agricultural production or rural land-use planning;
- Document and highlight local efforts to preserve and restore Sarus populations and habitat to help initiate additional efforts especially at the boundaries of the Sarus distribution range (e.g., Chandrapur in Maharasthtra State, Sitapur District in Uttar Pradesh State in India);
- Work in partnership with civil and religious organizations in developing and implementing educational programs to promote crane conservation (Cambodia, Laos, Myanmar, and Vietnam);
- Support ongoing (e.g., the annual Atherton Tablelands' Crane Week in Australia) and start new local initiatives to celebrate cranes and their habitats in key locations across their distribution range; and
- Explore the potential of developing sustainable ecotourism, and associated manufacture of crane-friendly products (e.g., as in Tram Chim) in key locations across the Sarus' distribution range by engaging the tourism, farming, and local government sectors in each locality.

REFERENCES

Archibald GW. 1981. Introducing the Sarolga. In: Lewis JC, Masatomi H, editors. Crane research around the world. Baraboo, Wisconsin, USA: International Crane Foundation. p. 213–215.

Archibald GW, Sundar KSG, Barzen J. 2003. A review of the three subspecies of Sarus Cranes *Grus antigone*. Journal of the Ecological Society (India) 16:5–15.

Archibald GW, Swengel S. 1987. Comparative ecology and behavior of Eastern Sarus Crane and Brolgas in Australia. In: Lewis JC, editor. Proceedings of 1985 Crane Workshop, 26–28 March 1985, Grand Island, Nebraska. Grand Island, Nebraska, USA: Platte River Whooping Crane Maintenance Trust and U.S. Fish and Wildlife Service. p 107–116.

Bal R, Dua A. 2010. Cranes in unlisted wetlands of north-west Punjab. Birding Asia 14 (Dec.):103–106.

Barrett G, Silcocks A, Barry S, Poulter R. 2003. The new atlas of Australian birds. Victoria, Australia: Royal Australasian Ornithologists Union. 198 p.

Barzen J. 2004. An aerial survey of wetlands in northern Cambodia, 2001. Baraboo, Wisconsin, USA: International Crane Foundation, Cambodia Program. Unpublished report. 65 p.

Barzen JA. 2009. ICF trains a growing community of wetland scientists in Southeast Asia. ICF Bugle 35(3):6.

Barzen J, Briggs E, Latt TN, Thaung UTN. 1996. A preliminary report on the status of Eastern Sarus Crane and other large waterbird species in selected wetlands on Myanmar. Baraboo, Wisconsin, USA: International Crane Foundation. Unpublished report. 19 p.

Barzen JA, Seal US. 2001. Eastern sarus crane PHVA final report. Apple Valley, Minnesota, USA: IUCN/SSC Conservation Breeding Specialist Group. 204 p.

Barzen J, Tran T. 2010. Supporting sustainable development in the Mekong. ICF Bugle 36(4):5.

Beruldsen GR. 1997. Is the Sarus Crane under threat in Australia? Sunbird 27(3):72–78.

BirdLife International 2001. Threatened birds of Asia: The BirdLife International Red Data Book. Cambridge, UK: BirdLife International. p 1118–1150.

Clements T, Garrett L, John A, Keo O, Kong K, Pech B, Rours V, Tan S, Thong S, Rainey H. 2009a. TransLinks case study: bird nest protection in the Northern Plains of Cambodia. Report prepared for WCS TransLinks Program, USAID.

Clements T, John A, Nielsen K, An D, Tan S, Milner-Gulland EJ. 2009b. Payments for biodiversity conservation in the context of weak institutions: Comparison of three programs from Cambodia. Ecological Economics 69:1283–1291.

Clements T, Rainey H, An D, Rours V, Tan S, Thong S, Sutherland WJ, Milner-Gulland EJ. 2013. An evaluation of the effectiveness of a direct payment for biodiversity conservation: The Bird Nest Protection Program in the northern plains of Cambodia. Biological Conservation 157:50–59.

Franklin DC. 2008. Report 9: The waterbirds of Australian tropical rivers and wetlands. In: Lukacs GP, Finlayson CM, editors. A compendium of ecological information on Australia's northern tropical rivers. Sub-project 1 of Australia's Tropical Rivers – an Integrated Data Assessment and Analyses (DET18). A report to Land & Water Australia. Townsville, Queensland, Australia: National Centre for Tropical Wetland Research. 21 p.

Gole P. 1989. The status and ecological requirements of Sarus Cranes. Phase I. Report submitted to Ministry of Environment and Forests, Government of India. 51 p.

Grant JDA. 2005. Recruitment rate of Sarus Cranes (*Grus antigone*) in north Queensland. Emu 105:311–315.

Handschuh M, Rours V, Rainey H. 2010. Clutch size of Sarus Crane *Grus antigone* in the Northern Plain of Cambodia and incidence of clutches with three eggs. Cambodian Journal of Natural History 2:103–105.

Jones KL, Barzen JA, Ashley MV. 2005. Geographical partitioning of microsatellite variation in the Sarus Crane. Animal Conservation 8:1–8.

Kaur J. 2007. Impact of land use changes on the habitat, behaviour and breeding biology of the Indian Sarus Crane (*Grus antigone antigone*) in the semi-arid tract of Rajasthan, India. Dissertation. Uttarakhand, India: Forest Research Institute University.

Kaur J, Nair A, Choudhury BC. 2008. Conservation of the vulnerable Sarus Crane (*Grus antigone antigone*) in Kota, Rajasthan, India: a case study of community involvement. Oryx 42:452–455.

Lewis M. 2003. Cattle and conservation at Bharatpur: a case study in science and advocacy. Conservation and Society 1:1–21.

Mann M. 1999. British rule on Indian soil. North India in the first half of the nineteenth century. New Delhi, India: Manohar Publishers & Distributer.

Marchant S, Higgins PJ, editors. 1993. Handbook of Australian, New Zealand and Antarctic birds. Vol. 2. Raptors to lapwings. Melbourne, Australia: Oxford University Press. 984 p.

Meine CD. 1999. Summary report on a survey of breeding Sarus crane (*Grus antigone*) distribution in Myanmar. Baraboo, Wisconsin, USA: International Crane Foundation in cooperation with the Myanmar Forestry Department and the Wildlife Conservation Society-Myanmar. 27 p.

Meine CD, Archibald GW, compilers. 1996. The cranes: Status survey and conservation action plan. Gland, Switzerland: International Union for the Conservation of Nature and Natural Resources. 282 p.

Meynell PJ, Nguyen TH, Ni DV, Tran T, van der Schans M, Shulman D, Thompson J, Barzen J, Shepherd G. 2012. An integrated fire and water management strategy using the ecosystem approach: Tram Chim National Park, Vietnam. In: Gunawardena ERN, Gopal B, Kotagama H, editors. Ecosystems and Integrated Water Resources Management in South Asia. New Dehli, India: Routledge. p 199–228.

Mukherjee A. 1999. Ecological study on the Indian Sarus Crane *Grus antigone* in the central Gujarat Dissertation. Rajkot, Gujarat, India: Saurashtra University. 281 p.

Mukherjee A, Soni VC, Borad CK, Parasharya BM. 2000. Nest and eggs of Sarus Crane (*Grus antigone antigone* Linn.). Zoos' Print Journal 15(12):375–385.

Mukherjee A, Soni VC, Parasharya BM. 1999. Diurnal use of reservoirs by the Indian Sarus Crane (*Grus antigone*) during summer months. Zoos' Print Journal 14(7):72–74.

Muralidharan S. 1993. Aldrin poisoning of Sarus Cranes (*Grus antigone*) and a few granivorous birds in Keoladeo National Park, Bharatpur, India. Ecotoxicology 2:196–202.

Nevard TD, Leiper I, Archibald G, Garnett ST. 2018. Farming and cranes on the Atherton Tablelands, Australia. Pacific Conservation Biology 25(2):184–192. Available at https://doi.org/10.1071/PC18055 (last accessed on 20 May 2019).

Nevard TD, Franklin DC, Leiper I, Archibald G, Garnett ST. 2019a. Agriculture, brolgas and Australian sarus cranes on the Atherton Tablelands, Australia. Pacific Conservation Biology. Available at https://doi.org/10.1071/PC18081 (last accessed on 20 May 2019).

Nevard TD, Haase M, Archibald G, Leiper I. The sarolga: conservation implications of genetic and visual evidence for hybridization between the brolga *Antigone rubicunda* and the Australian sarus crane *Antigone antigone gillae*. Oryx. Available at https://doi.org/10.1017/S003060531800073X (last accessed on 20 May 2019).

Pain DJ, Gargi R, Cunningham AA, Jones A, Prakash V. 2004. Mortality of globally threatened Sarus Crane *Grus antigone* from monocrotophos poisoning in India. Science of the Total Environment 326:55–61.

Ramachandran NK, Vijayan VS. 1994. Distribution and general ecology of the Sarus Crane (*Grus antigone*) in Keoladeo National Park, Bharatpur, Rajasthan. Journal of the Bombay Natural History Society 91:211–223.

Singh HS, Tatu K. 2000. A study on Indian Sarus Crane (*Grus antigone antigone*) in Gujarat State. With emphasis on its status in Kheda & Ahmedabad districts. The report of a study conducted from 1997 to 1999. Gandhinagar, India: Gujarat Ecological Education & Research (GEER) Foundation.

Sundar KSG. 2005. Effectiveness of road transects and wetland visits for surveying Black-necked Storks *Ephippiorhynchus asiaticus* and Sarus Crane *Grus antigone* in India. Forktail 21:27–32.

Sundar KSG. 2009. Are rice paddies suboptimal breeding habitat for Sarus Cranes in Uttar Pradesh, India? Condor 111:611–623.

Sundar KSG. 2011. Agricultural intensification, rainfall patterns, and large waterbird breeding success in the extensively cultivated landscape of Uttar Pradesh, India. Biological Conservation 144:3055–3063.

Sundar KSG, Chauhan AS, Kittur S, Babu S. 2015. Wetland loss and waterbird use of wetlands in Palwal district, Haryana, India: the role of agriculture, urbanization and conversion to fish ponds. Wetlands 35:115–125.

Sundar KSG, Choudhury BC. 2003. The Indian Sarus Crane *Grus a. antigone*: a literature review. Journal of the Ecological Society (India) 16:16–41.

Sundar KSG, Choudhury BC. 2005. Mortality of Sarus Cranes *Grus antigone* due to electricity wires in Uttar Pradesh, India. Environmental Conservation 32:260–269.

Sundar KSG, Choudhury BC. 2006. Conservation of the Sarus Crane *Grus antigone* in Uttar Pradesh, India. Journal of the Bombay Natural History Society 103(2–3):182–190.

Sundar KSG, Choudhury BC. 2008. Impact of land use changes on the ecology and habitat of the Sarus Crane (*Grus antigone*) in the Indo-Gangetic flood plains. Part II: Uttar Pradesh. Final Report. Dehradun, India: Wildlife Institute of India. 95 p.

Sundar KSG, Grant JDA, Veltheim I, Kittur S, Brandis K, McCarthy MA, Scambler EC. 2019. Sympatric cranes in northern Australia: abundance, breeding success, habitat preference and diet. Emu 119(1):79–89.

Sundar KSG, Kaur J, Choudhury BC. 2000. Distribution, demography and conservation status of the Indian Sarus Crane (*Grus a. antigone*) in India. Journal of the Bombay Natural History Society 97:319–339.

Sundar KSG, Kittur S. 2012. Methodological, temporal, and spatial factors affecting modeled occupancy of resident birds in the perennially cultivated landscape of Uttar Pradesh, India. Landscape Ecology 27:59–71.

Suwal R. 1999. Lumbini Crane Sanctuary: A model of local conservation initiative. Available at http://sajilo.com/lcc/index.htm. (accessed 20 December 2016).

Tran T, Barzen J, Kiet LC, Moore D. 2004a. Wartime herbicidies in the Mekong Delta and their implications for post-war wetland conservation. In: Furukawa H, Nishibuchi M, Kono Y, Kaida Y, editors. Ecological destruction, health, and development: advancing Asian paradigms. Kyoto, Japan and Melbourne, Australia: Kyoto University Press and Trans Pacific Press. p 199–211.

Tran T, Choowaew S, Ni DV. 2003. University Network for Wetland Training in the Mekong Region. ASEAN Biodiversity 3(3–4):25–26.

Tran T, Hong C, Bou V. 2018. Census of non-breeding Sarus Cranes in Cambodia and Vietnam – 2018 Summary report. Baraboo, Wisconsin, USA: International Crane Foundation. 8 p.

Tran T, Kiet LC, Thi NTL, Dan PQ. 2004b. The invasion of *Mimosa pigra* in wetlands of the Mekong Delta, Vietnam. In: Julien M, Flanagan G, Heard T, Hennecke B, Paynter Q, Wilson C, editors. Research and management of *Mimosa pigra*. Canberra, Australia: CSIRO Entomology. p 45–51.

Tran T, Man L, Nga NP. 2004c. Impacts of *Mimosa pigra* on native plants and on soil insect communities in Tram Chim National Park, Vietnam. In: Julien M, Flanagan G, Heard T, Hennecke B, Paynter Q, Wilson C, editors. Research and Management of *Mimosa pigra*. Canberra, Australia: CSIRO Entomology. p 22–27.

Van Zalinge R, Tran T. 2016. Census of non-breeding Sarus Cranes in Vietnam and Cambodia – 2016. Summary report. Unpublished Report. Casuarina, Australia and Baraboo, Wisconsin, USA: Charles Darwin University, Australia: International Crane Foundation, USA. 7 p.

Van Zalinge RV, Tran T. 2016. Census of non-breeding Sarus Cranes in Cambodia and Vietnam, 2016: Summary report. Unpublished Report. Baraboo, Wisconsin, USA: International Crane Foundation, 7 p.

Van Zalinge R, Tran T, Evans T, Hong C, Seng KH, Barzen J. 2010. Census of non-breeding Sarus Cranes in Cambodia and Vietnam. Technical output of the UNDP/ GEF-funded Tonle Sap Conservation Project.

Van Zalinge R, Tran T, Evans T, Hong C, Seng KH, Barzen J. 2011. Census of non-breeding Sarus Cranes in Cambodia and Vietnam, 2011. Phnom Penh, Cambodia: Wildfowl & Wetlands Trust, Cambodian Lower Mekong Wetlands Project.

Watson H, Evans T, Chamnan H, Hout SK. 2007. Records of non-breeding Sarus Cranes in Cambodia in the 2006/7 dry season, including results of the annual census. Phnom Penh, Cambodia: Wildlife Conservation Society Cambodia Program, BirdLife International Cambodia Program and the Forestry Administration.