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Population trends of the Black-faced Spoonbill *Platalea minor*: analysis of data from international synchronised censuses

YIK-HEI SUNG, IVAN WAI-LUN TSE and YAT-TUNG YU

Summary

Long-term population monitoring is crucial to evaluate the effectiveness of conservation efforts. Systematic surveys of the endangered Black-faced Spoonbill *Platalea minor*, the rarest spoonbill species globally, are not possible during the breeding season as the largest breeding grounds are inaccessible to surveyors. Instead, we have examined population trend in this species during the winter by utilising a dataset of synchronised surveys conducted annually across 42 sites between 1997 and 2014. We found that the global population has increased from 535 individuals in 1997 to 2,726 in 2014, an annual increase of 8.0%. Population increases were more pronounced in protected sites and sites with low levels of human disturbance, indicating that control of human disturbance is crucial for conservation in this species. It is of concern that the wintering populations are highly clumped and the two largest populations have ceased to increase since 2012; research to investigate the underlying causes is urgently needed. Synchronised surveys in all known wintering sites should be continued to provide up-to-date data on the global population of this endangered species.

Introduction

Black-faced Spoonbill *Platalea minor* is the rarest of the six spoonbill species in the world (Matheu and Del Hoyo 1992). This species breeds in the northern Yellow Sea (Hancock *et al.* 2010, IUCN 2014) and winters along the East Asian coast, from Jeju in South Korea to the Red River in Vietnam (Ueta *et al.* 2002). It was described as 'common' in south-east China in the 1930s (La Touche 1931–1934), however, the global population was reduced to less than 300 birds in the 1980s, possibly due to the Korean War, habitat loss and pollution (Kennerley 1990, Yeung *et al.* 2006). Hence, Black-faced Spoonbills were listed as 'Critically Endangered' in 1994 by IUCN (Collar *et al.* 1994). Since then, conservationists have been carrying out conservation actions for Black-faced Spoonbills, including the establishment of protected areas, prohibition of hunting and scientific research on population status and ecology (e.g. Swennen and Yu 2005, Ueng *et al.* 2007, Chan *et al.* 2010, Wood *et al.* 2013). However, many of the major threats to this species, including habitat loss due to industrial development and land reclamation, pollution, and disturbance from human activities such as fisheries and tourism are ongoing and pervasive in both breeding and wintering sites (Chan *et al.* 2010, IUCN 2014).

In addition, long-term population monitoring is essential to evaluate the effectiveness of conservation actions (Marsh and Trenham 2008) and to provide insights into the factors likely to affect long-term survival of the species. Accurate population monitoring of birds can be logistically challenging especially for migratory species and species with ranges that encompass multiple countries or continents. Surveys of some migratory birds are conducted during the breeding season when most birds in the population congregate in their respective breeding grounds (Robbins *et al.* 1986), whereas surveys may be conducted during the non-breeding season for species whose breeding range covers a large area (Sutherland *et al.* 2004). Comprehensive breeding surveys of the Black-faced Spoonbill are not feasible as the main breeding site for this species is located in the demilitarized zone separating the Democratic People's Republic of Korea from the Republic of Korea, which is not readily accessible to surveyors (Dahmer *et al.* 2007).

In this study, we analysed the data from 18 years of international surveys that were carried out at 42 sites throughout the wintering range of the Black-faced Spoonbill. We used these data to 1) estimate the global population trend between 1997 and 2014; 2) identify key wintering sites; and 3) evaluate the effectiveness of conservation efforts for this species by incorporating individual site attributes in the population trend analysis. We predicted that the more significant increases in Black-faced Spoonbill populations would occur in sites within protected areas, with low degree of habitat loss / degradation, and with low levels of human disturbance.

Methods

Synchronised surveys and study area

We analysed data from 18 years of synchronised surveys of Black-faced Spoonbills conducted across wintering sites. Surveys took place between 1997 and 2014 at 42 wintering sites of Black-faced Spoonbills in mainland China, Hong Kong, Japan, Macau, the Philippines, South Korea, Taiwan and Thailand (Figure 1). Survey sites were selected based on previously reported sightings of Black-faced Spoonbills. Surveys were conducted in mid-January as resightings of marked individuals with colour rings ($n = 41$) showed that all individuals arrived at wintering sites by December and no individuals made movements to other study sites between January and February (Y. T. Yu unpubl. data). Surveys were conducted at all sites within a period of three consecutive days. Each site was surveyed once within this period. Voluntary surveyors counted the number of birds with the aid of binoculars or telescopes. The total number of surveyors ranged from 30 in

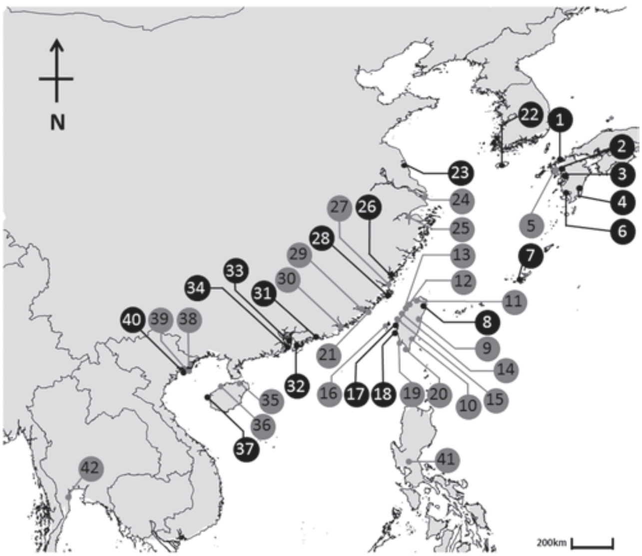

Figure 1. Map of East Asia showing 42 sites where annual synchronised censuses for wintering Black-faced Spoonbills were conducted between 1997 and 2014. Data from sites in black was analysed in this study. The numbers correspond to the sites in Table 1.

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1997 to 350 in 2014 (Figure S1 in the online supplementary materials). For certain sites in some years, censuses were not conducted owing to lack of manpower, inaccessibility of sites or unstable weather (Table S1). The surveys were coordinated by Tom Dahmer and Mary L. Felley from 1997 to 2003 and by the Hong Kong Bird Watching Society since 2004.

Statistical analysis

We excluded sites with over 50% (i.e. more than nine years) of missing data and those with maximum counts of less than 10 individuals from our analysis to reduce the number of missing values. Of the 42 sites where data were available, 23 sites were excluded, hence only 19 were included in the analysis (Table 1 and Figure 1). We regarded these 19 sites as representative of the global wintering population of Black-faced Spoonbills as at least 85% of the total number counted every year were covered by these sites.

We identified key wintering sites by selecting those that held an average > 1% of the total number of wintering Black-faced Spoonbills between 2010 and 2014 (i.e. 23.3 individuals). We analysed the trends in the number of Black-faced Spoonbills using the software TRIM v3.54 (Pannekoek and van Strien 2005). TRIM is developed to examine population trends by analysing counts with missing observations across time. We applied a generalised estimating equation approach using Poisson regression. A population index was calculated as the total count of a given year divided by the count of the base year (i.e. the first year when survey was conducted at a given site). An index larger than one indicates a population increase whereas an index smaller than one indicates a population decrease. We fitted the numbers of the spoonbills to the models using standard methods including no time effects and linear trends with change points, then selected the best model based on Akaike's Information Criterion (Burnham and Anderson 2002). TRIM corrected the possible violation of Poisson distributions owing to overdispersion and serial correlation. The global population trends were established using the classification proposed in Gregory *et al.* (2007).

To investigate the impacts of site attributes on the population trends, we incorporated three categorical site attributes in our models: 1) protection status – protected (sites partly or entirely within protected area) or unprotected (sites outside a protected area); 2) degree of habitat loss and degradation – high (sites partly destroyed or degraded by wetland encroachment, reclamation, urbanisation or pollution) or low (sites not partly destroyed or degraded); 3) degree of human disturbance - high (sites with high levels of human activity that disturbed Black-faced Spoonbills, e.g. hunting, commercial collection, recreational activities) or low (sites with low level of human activity). A category was assigned if it applied to a site for over half of the study period, i.e. 9 years. For degree of habitat loss and degradation and degree of human disturbance, the classification of site attributes was primarily based on the information in Chan *et al.* (2010), and verified after subsequent search of scientific papers or reports, and personal communication with local researchers; details are presented in Table S2.

Results

The global wintering population of Black-faced Spoonbill increased from 535 in 1997 to 2,726 in 2014. The best model (as indicated by the lowest AIC score) showed an average annual increase of 8.0% ($P < 0.01$; Table 2). The global wintering population increased from 1997 to 2010 and experienced a sudden drop in 2011. The population increased subsequently in 2012 then showed a slight drop from 2012 to 2014 (Figure 2). The global wintering population exhibited significant changes in slope in 2010 (Wald = 21.52, df = 4, $P < 0.001$), 2011 (Wald = 27.82, df = 4, $P < 0.001$) and 2012 (Wald = 31.46, df = 4, $P < 0.001$).

Moreover, the best model included all site attributes including protection status, degree of habitat loss and degradation, and degree of human disturbance. The global population trend was significantly affected by protection status (Wald = 16.85, df = 6, $P = 0.010$) and degree of human disturbance

Table 1. Mean (range) number of Black-faced Spoonbill in the survey sites between 1997 and 2014, and 2010 and 2014. Sites in bold indicate that the sites on average hold more than 1% of total population between 2010 and 2014. *Survey was not conducted in Thai Binh Estuary between 2010 and 2014.

Site no.	Location	Mean (Range) number of individuals (1997–2014)	Mean (Range) number of individuals (2010–2014)	Mean (Range) proportion of total population (2010–2014)
1	**Fukuoka Prefecture, Japan**	**40.7 (15–66)**	**56.2 (42–63)**	**0.023 (0.018–0.034)**
2	Saga Prefecture, Japan	5.5 (0–18)	9.8 (5–18)	0.004 (0.002–0.070)
3	**Kumamoto Prefecture, Japan**	**53.8 (5–106)**	**88.2 (72–106)**	**0.036 (0.027–0.045)**
4	Miyazaki Prefecture, Japan	11 (2–25)	19.8 (10–25)	0.008 (0.004–0.011)
5	Isahaya Bay, Nagasaki Prefecture, Japan	1.9 (0–11)	0.0 (0–0)	0 (0-0)
6	**Kagoshima Prefecture, Japan**	**27.2 (8–47)**	**36.6 (29–47)**	**0.015 (0.011–0.020)**
7	Okinawa Prefecture, Japan	16.1 (2–35)	20.6 (11–35)	0.008 (0.005–0.013)
8	Ilan, Taiwan	9.1 (0–28)	19.2 (12–28)	0.008 (0.005–0.010)
9	Hualien, Taiwan	0.8 (0–3)	0.8 (0–3)	0.000 (0–0.001)
10	Taitung, Taiwan	0.5 (0–2)	0.0 (0–0)	0 (0–0)
11	Taipei, Taiwan	0.2 (0–1)	0.0 (0–0)	0 (0–0)
12	Hsinchu, Taiwan	0.8 (0–2)	0.8 (0–2)	0.000 (0.000–0.001)
13	Miaoli, Taiwan	0.2 (0–1)	0.2 (0–1)	0.000 (0.000–0.001)
14	Changhua, Taiwan	1.5 (0–4)	0.5 (0–2)	0.000 (0.000–0.001)
15	Yunli, Taiwan	1.5 (0–4)	1.0 (0–3)	0.000 (0.000–0.001)
16	Penghu, Taiwan	1 (0–3)	0.0 (0–0)	0 (0–0)
17	**Chiayi, Taiwan**	**77.0 (0–266)**	**162.6 (36–266)**	**0.062 (0.020–0.098)**
18	**Tainan, Taiwan**	**765.5 (298–1312)**	**1163.4 (767–1312)**	**0.469 (0.417–0.505)**
19	**Kaohsiung, Taiwan**	**28.3 (0–157)**	**38.2 (0–157)**	**0.014 (0–0.058)**
20	Pingtung, Taiwan	2.0 (0–10)	0.8 (0–3)	0.000 (0–0.001)
21	Kinmen, Taiwan	3.8 (0–6)	4.2 (0–6)	0.002 (0–0.003)
22	Jeju, South Korea	22.2 (14–30)	23.0 (16–30)	0.009 (0.006–0.014)
23	Yancheng Nature Reserve, Jiangsu, mainland China	14.7 (0–72)	0.3 (0–1)	0.000 (0–0.000)
24	Chongming, Shanghai, mainland China	3.5 (0–9)	2.0 (0–4)	0.001 (0–0.001)
25	Nanhui, Shanghai, mainland China	2 (0–6)	2.4 (0–6)	0.001 (0–0.002)
26	Xiapu, Fujian, mainland China	8.8 (0–23)	6.4 (0–12)	0.003 (0–0.006)
27	Fuzhou, Fujian, mainland China	9.1 (0–21)	8.8 (0–21)	0.003 (0–0.008)
28	**Putian, Fujian, mainland China**	**63.7 (3–113)**	**59.0 (3–113)**	**0.024 (0.001–0.042)**
29	Xiamen, Fujian, mainland China	0.9 (0–4)	0.0 (0–0)	0 (0–0)
30	Shantou, Guangdong, mainland China	3.4 (0–15)	4.2 (0–15)	0.002 (0–0.006)
31	**Haifeng, Guangdong, mainland China**	**76.3 (39–128)**	**85.4 (72–128)**	**0.035 (0.026–0.047)**
32	**Deep Bay, Shenzhen and Hong Kong, mainland China**	**263.8 (90–462)**	**373.8 (252–462)**	**0.158 (0.092–0.223)**
33	Nansha wetland, Guangdong, mainland China	3.5 (0–13)	7.2 (2–13)	0.002 (0.001–0.005)
34	**Taipa-Coloane, Macau, mainland China**	**38.7 (6–60)**	**49.4 (39–60)**	**0.020 (0.017–0.027)**
35	Dongzhaigang National Nature Reserve, Hainan, mainland China	0.8 (0–4)	0.0 (0–0)	0 (0–0)
36	Lingao, Hainan, mainland China	8.3 (5–11)	1.4 (0–7)	0.001 (0–0.003)
37	**Sigeng, Hainan, mainland China**	**46 (0–82)**	**40.4 (31–57)**	**0.017 (0.012–0.031)**
38	Ha Nam Island, Quang Ninh Province, Vietnam	0.6 (0–3)	0.0 (0–0)	0 (0–0)
39	Thai Binh Estuary, Red River Delta, Vietnam	0.6 (0–4)	NA*	NA*
40	**Xuan Thuy National Park, Red River Delta, Vietnam**	**43.9 (0–74)**	**41.8 (35–49)**	**0.018 (0.013–0.027)**
41	Candaba, Panpanga, the Philippines	0.2 (0–1)	0.0 (0–0)	0 (0–0)
42	Pak Thale, Phetchaburi, Thailand	1.7 (0–3)	1.0 (0–2)	0.000 (0–0.001)

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Table 2. Summary of TRIM model selection results for the abundance of wintering Black-faced Spoonbills between 1997 and 2014. Asterisks indicate *P*-value: ** = $P < 0.01$. **p** = protection status; **hl** = habitat loss and degradation, and **hd** = human disturbance. **AIC**, Akaike Information Criterion. **OMSI**, Overall Multiplicative Slope imputed. **SE**, Standard Error.

Model	AIC	ΔAIC	weight	OMSI	SE	Trend
p + hl + hd	1967.7	0	1.0	1.080	0.014	Strong increase**
hl + hd	2122.6	154.9	0.0	1.089	0.007	Strong increase**
p + hd	2135.5	167.7	0.0	1.087	0.007	Strong increase**
hd	2201.2	233.5	0.0	1.087	0.007	Strong increase**
p + hl	2231.0	263.2	0.0	1.083	0.009	Strong increase**

(Wald = 21.17, df = 6, $P = 0.002$) but not by degree of habitat loss and degradation (Wald = 10.41, df = 6, $P = 0.108$; Table 2). The populations in protected sites exhibited a marked increasing trend while the populations in unprotected sites were in decline (Table 3; Figure 3). The populations in sites with low levels of disturbance underwent more substantial increases than those in sites with high levels of disturbance.

We identified 12 key wintering sites that held 89% of wintering Black-faced Spoonbills in the last five years (i.e. 2009–2014; Table 1). Highest abundances of wintering birds were recorded in Tainan, Deep Bay and Chiayi, which together accounted for 67% of the global wintering population of Black-faced Spoonbills.

Discussion

The increasing number of wintering Black-faced Spoonbills, which is an 'Endangered' species, surveyed in this study may reflect a genuine increase of the global population. The upward trend in the populations surveyed may partly be attributed to the increase in the number of survey sites and coverage of surveyed area over time (Figure S1). However, a genuine increase of the global population is supported by two observations. First, over half of the sites where we conducted the surveys throughout the study period, including the most important wintering sites at Chiayi, Deep Bay, Ilan, and Tainan, showed considerable population increases over the survey period. Second, a high return rate (86.6 ± 9.3 %) of ringed individuals in Taiwan (Ueng *et al.* 2007) and high proportions of juveniles (32–53%) in Hong Kong (Anon 2015) were observed in the study period, which may indicate continued successful breeding efforts in this long-lived migratory species. It is also possible that birds displaced from other unknown wintering sites moved onto the study sites, leading to increases

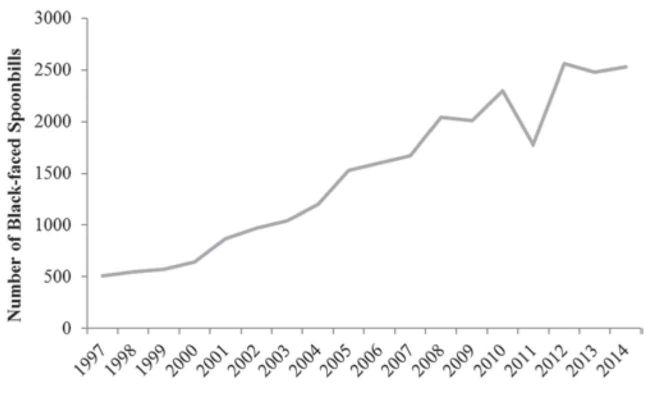

Figure 2. Number of wintering Black-faced Spoonbills counted in this study between 1997 and 2014.

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Table 3. Effects of the significant site attributes on the population trend of wintering Black-faced Spoonbills in the best model between 1997 and 2014

Site attributes	Protection status		Human disturbance	
	Protected	Unprotected	Low	High
1997–2010	1.12 (0.01)	1.01 (0.05)	1.12 (0.01)	0.94 (0.03)
2010–2011	0.74 (0.06)	0.63 (0.28)	0.74 (0.06)	1.39 (0.41)
2011–2012	1.51 (0.13)	2.41 (1.10)	1.51 (0.13)	0.34 (0.13)
2012–2014	0.97 (0.04)	0.34 (0.12)	0.97 (0.04)	1.25 (0.28)

in local population sizes. However, even with the increased popularity of birdwatching in the region (Ma *et al.* 2013), there have been fewer new wintering sites discovered recently, and the populations in those newly identified sites are small relative to the known sites (Wood *et al.* 2013).

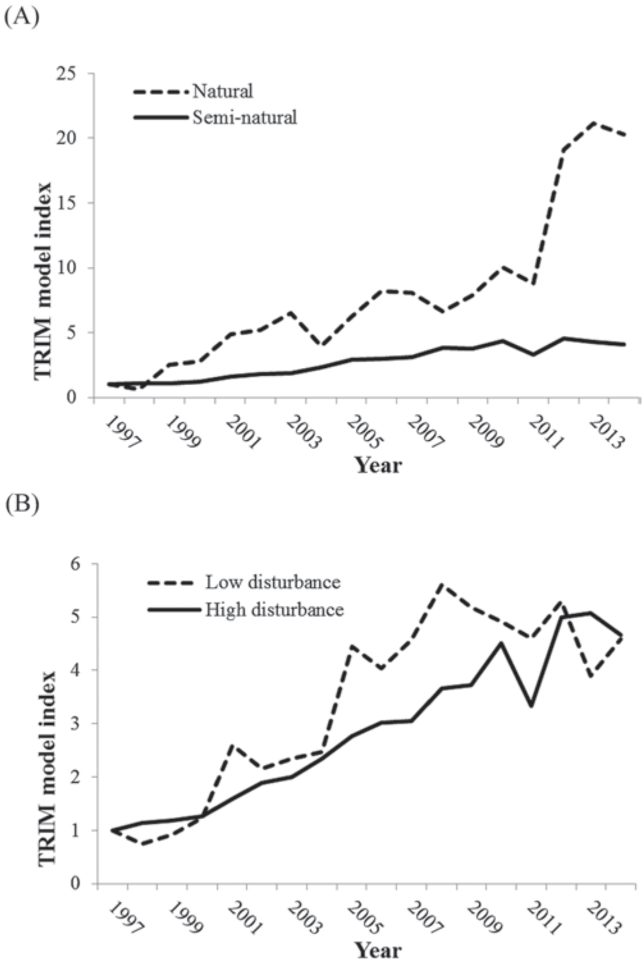

Figure 3. TRIM model-predicted population indexes of Black-faced Spoonbills for different level of the significant site covariates, (A) protected status and (B) degree of human disturbance, at 19 sites between 1997 and 2014.

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Protected sites exhibited apparent upward trends, which indicates high efficacy of some protected areas in provision of suitable habitats to wintering Black-faced Spoonbills. Among all 42 study sites, Tainan in Taiwan, where Chiku Black-faced Spoonbill Reserve was established in 2002, exhibited the most significant increase in its population, rising from 298 to 1,246 individuals over the study period. Human disturbance can trigger strong behavioural responses by Black-faced Spoonbills and the associated increase in energetic cost incurred in turn may affect their survival or fecundity (Choi *et al.* 2015). Effective enforcement against human disturbance is likely to have a positive impact on populations of the wintering Black-faced Spoonbills, supported by our results showing that sites with low levels of human disturbance experienced more significant increases in population sizes than sites with high levels of human disturbance. Illegal activities, such as harvesting of wildlife, are strictly prohibited within protected areas in Tainan and Deep Bay where the two largest wintering populations are located. However, protected areas may not guarantee favourable habitats if effective enforcement cannot be implemented (Bruner *et al.* 2001, Zheng *et al.* 2012). Our data revealed marked decreasing trends in some protected sites, for example Yancheng Nature Reserve and Dongzhaigang National Nature Reserve. Historically, as many as 72 individuals were recorded in Yancheng Nature Reserve in Jiangsu, mainland China, however only one bird was found in the 2009–2014 period. Rapid expansion of *Spartina alterniflora* may be responsible for this decline as it reduces roosting and feeding habitats for Black-faced Spoonbills (Jiang *et al.* 2010). In Yancheng, despite its designation as a nature reserve, encroachment of wetland for aquaculture and poisoning of waterbirds still occurred (Chan *et al.* 2010, Ke *et al.* 2011, Zuo *et al.* 2012). The enforcement efforts against illegal activities in nature reserves (i.e. hunting, poisoning of wildlife, and wetland encroachment), should be critically evaluated and strengthened accordingly in protected areas where apparent declines of Black-faced Spoonbills have been observed.

It was surprising that the number of Black-faced Spoonbills was not affected by the degree of habitat loss and degradation. In Hong Kong, the drain-down practice for harvesting commercial fish in fishponds provides access to a high density of food and suitable water levels and thus suitable feeding habitat for Black-faced Spoonbills (Y. T. Yu unpubl. data). Unlike obligate natural wetland specialists, Black-faced Spoonbills can feed and roost in degraded or artificial habitats if appropriate management is implemented (Yu and Swennen 2004, Tsai 2009, Chan *et al.* 2010). Having said that, human disturbance is usually more intense in artificial habitats, and natural and intact habitats, e.g. intertidal mudflats in estuaries, may still play a significant role in provision of suitable habitats. We suggest that protection of natural and intact habitats and appropriate management of artificial habitats, including minimising human disturbance and provision of suitable feeding environment, are both crucial to accommodate the increasing global population.

From 2010 to 2011, the number of Black-faced Spoonbills in Tainan, Taiwan dropped significantly from 1,185 to 767 individuals, which contributed to an overall decline. It is unlikely that the global population actually declined so significantly in this time period however as (1) no dead spoonbills were discovered as in the massive disease outbreaks in Tainan in 2002 (Yeung *et al.* 2006); (2) the number bounced back to 1,307 immediately in 2012; and (3) the ratio of juveniles in Hong Kong remained similar, which may indicate consistent reproductive success (Anon 2015). South China experienced an exceptionally cold winter in 2011, the coldest since 1977 (Hong Kong Observatory 2016). In response to the extreme weather, Black-faced Spoonbills possibly undertook abnormal movements to places not covered by the survey (Senner *et al.* 2015). Satellite tracking would be a useful tool to provide more insights into the relationship between weather conditions and movements of wintering Black-faced Spoonbills.

The two largest wintering populations in Deep Bay and Tainan appeared to be declining and levelling off respectively, which causes considerable concern. The number of wintering Black-faced Spoonbills in Deep Bay reached 462 in 2010 but only 252 were recorded in 2014. This decline may in part have been caused by a decline in the food availability and feeding habitats due to the high levels of water pollutants (Cheung *et al.* 2003, Niu *et al.* 2009, Zhao *et al.* 2012), expansion of exotic mangrove species (*Sonneratia caseolaris* and *S. apetala*), and siltation and loss of fishponds (Ren *et al.* 2011, WWF-HK 2013). In Tainan, despite the sharp increase in population size from

1997 to 2012, the number of wintering spoonbills remained around 1,300, which might be an indicator that local carrying capacity has been reached at that site. Avian disease may also be playing a role in regulating population size at this site. Two bouts of avian botulism (in 2002 and 2015) killed a total of 74 individuals (Yeung *et al.* 2006, Yin *et al.* 2016), which highlights the risk of disease affecting highly concentrated wintering populations of birds. Continued monitoring of the populations and comprehensive environmental monitoring, for example assessment of pollutant concentration and food availability, are needed to unravel the underlying causes of the emerging trends in population sizes in the key wintering populations.

Historical declines of the Black-faced Spoonbill have been suggested to be associated with habitat loss and disturbance caused by the Korean War, habitat loss and pollution (Yeung *et al.* 2006). The population did not recovery immediately after the Korean War which ended in 1953. The latter two factors remain important threats to the spoonbills at present. Along the coasts of East Asia, the level of pollutants including PCBs and DDTs remains high (Monirith *et al.* 2003, Ogata *et al.* 2009) and the rate of habitat loss and degradation has accelerated in the last twenty years (Yang *et al.* 2011, Murray *et al.* 2014). We speculate that the detrimental impacts associated with the Korean War, for example harvesting of spoonbills or their eggs for food during famine, may be more pronounced than previously thought. Nevertheless, the decline was likely a cumulative outcome of a combination of factors (Yeung *et al.* 2006).

In summary, given the apparent continued increase observed in the global population, the conservation outlook for the endangered Black-faced Spoonbills is deemed to be optimistic. Establishment of protected areas with effective implementation of controls on activities causing disturbance has contributed to the increasing trend. However, the global population is still considerably below the minimum viable population of 7,000 individuals suggested by Yeung *et al.* (2006). Moreover, the populations in the two largest wintering populations have not increased since 2012, and the wintering populations are highly concentrated in a few sites which render them susceptible to disease. Conservation measures in wintering sites, including enhanced enforcement efforts against illegal activities, habitat management and further research efforts, including satellite tracking and environmental monitoring, are needed. Provided that some important breeding grounds remain inaccessible and breeding surveys cannot be carried out there, synchronised surveys across the wintering range should be carried out to monitor the global population, allowing timely responses to any emerging threats to this endangered species.

Supplementary Material

To view supplementary material for this article, please visit https://doi.org/10.1017/S0959270917000016

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YIK-HEI SUNG
Department of Biology, Hong Kong Baptist University, Kowloon Tong, Hong Kong SAR, China.

IVAN WAI-LUN TSE, YAT-TUNG YU*
The Hong Kong Bird Watching Society, 7C, V Ga Building, 532 Castle Peak Road, Lai Chi Kok, Hong Kong SAR, China.

**Author for correspondence; e-mail: bfspoonbill@hkbws.org.hk*

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