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Breeding population dynamics and habitat transition of Saunders's Gull *Larus saundersi* in Yancheng National Nature Reserve, China

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Summary

Saunders's Gull *Larus saundersi* is a breeding endemic of Common Seepweed *Suaeda glauca* habitats on the east coast of China and south-west coast of South Korea. Much of this habitat has been lost and degraded due to human land use and expansion of the introduced Smooth Cordgrass *Spartina alterniflora*. Yancheng National Nature Reserve (NNR) is one of three breeding and wintering areas in China. We used satellite images from 1992 to 2007 and visual interpretation combined with ground truthing to classify the land cover and quantify changes in land use and land cover (LULC) in areas of Yancheng NNR used by Saunders's Gull. The Common Seepweed habitat, in which this species nests, decreased in area by 79.1% (27,358 ha) over 15 years, predominantly as a result of conversion to aquaculture ponds (18,929 ha), and is now centred in the south-east of Yancheng NNR. The total population size of Saunders's Gull was maintained at over 900 individuals from 1999 to 2006 in Yancheng NNR, but was only 575 in 2007, and the number of breeding sites decreased from eight in 1992 and 1994 to a single site in 2000–2006 and two sites in 2007. From 1999 to 2007, the breeding population in the core area of Yancheng NNR accounted for 94.93% of the total population, and its nest-site spatial turnover rate was 0.84 ± 0.08 (n = 7 years), but it tended to decrease by about 40% in 2007 because of degradation of the Common Seepweed community. The conversion of Common Seepweed habitats to other habitat types and expansion of introduced Smooth Cordgrass were the major and direct reasons for the loss and degradation of breeding habitats of Saunders's Gull. Smooth Cordgrass habitats increased in area by 321.9% (11,057 ha) during this period and centred on the east, gradually occupying the mudflats, except the beach from Liangduo River to the south of Yancheng NNR, where potential breeding sites for the Saunders's Gull could be located. We discuss the implications of our results for the conservation this species and management of its habitats.

Introduction

Saunders's Gull *Larus saundersi* is recognized as 'Vulnerable' by IUCN (2008) and Birdlife International (2008), and is also listed as vulnerable in China, but it is not nationally protected due to a lack of available information (Zheng and Wang 1998). Its status and distribution have been a mystery for more than a century since its initial description (Swinhoe 1871). Following the proposal by Melville (1987), studies on Saunders's Gull were given more attention by ornithologists around the world. The current world population estimate is a minimum of 14,400 birds, which is more than 70% higher than the mid-point of the estimated range (7,100–9,600) by Wetlands International (2006). However the apparent population increase is almost certainly due to increased survey effort. It is likely that the population is continuing to decline, given the

significant threats to habitats and high human disturbance levels occurring across the species's range (Cao *et al.* 2008).

Saunders's Gull is restricted to Common Seepweed *Suaeda glauca* habitats for breeding on the east coast of China and South Korea, many of which have been lost and degraded due to human land use (Shi *et al.* 1988, Huang 1994, Moores 2002). Yancheng National Nature Reserve (Yancheng NNR) is one of three major breeding and wintering areas in China (Hou *et al.* 2000). It consists of coastal wetlands across five counties in Jiangsu Province. In recent years, some tidal marshes have been converted to aquaculture ponds, salt pans, agriculture, industrial development and other land use types. Meanwhile, since the introduction of the alien Smooth Cordgrass *Spartina alterniflora* into Yancheng coastal wetland in 1982 (Zhong *et al.* 1985), the plant has expanded into the open mudflats and occupied the periphery of the Common Seepweed community from Sheyang River to Liangduo River (Liu *et al.* 2009a). This has seriously affected conditions for breeding, wintering and migratory waterbirds including Red-crowned Cranes *Grus japonensis*, Black-faced Spoonbill *Platalea minor*, ducks and waders (Nanjing Environment Sciences Institute *et al.* 2005).

In this paper, we measure changes in habitats of Yancheng coastal wetlands, especially habitats suitable for breeding Saunders's Gulls, through interpretation of satellite images from six different years, from the establishment of the National Nature Reserve in 1992 to 2007. Combined with ground survey data on the size and distribution of the population and nests, we analysed the actual and potential impact of changes in breeding habitat on the breeding population size and distribution, as well as that of nest-sites. Finally, we also put forward some measures for species conservation and habitat management.

Study area

Yancheng NNR (Figure 1) is located in the centre of the east coast of China, between 32°38′03′ and 34°30′08′N, 119°51′25′ and 121°05′47′E (the former reserve ranged between 32°34 and 34°31́N, 119°48́ and 121°15E). The major objective of the reserve is to protect the Red-crowned Crane and other bird species as well as their habitats. It was approved as a National Nature Reserve by the China State Council and internationally recognised as a Biosphere Reserve by UNESCO in 1992 (Han and Gretchen 1995). Due to the accretion of mudflats and anthropogenic impacts, the functional zones were adjusted and approved by China's State Council in early 2007. The current reserve area is 284,179 ha, a decrease of 169,321 ha in comparison with the former reserve (Nanjing Environment Sciences Institute *et al.* 2005).

The boundaries of the study area followed the former reserve boundaries except that the eastern boundary is in accordance with that of the current reserve. The area of the study area is 579,136 ha (Figure 1).

Methods

Field methods

Saunders's Gulls spend the summer from March to September in Yancheng NNR. In our study, the number and distribution of Saunders's Gulls in Yancheng NNR was surveyed in early June of each year when they are in the stable part of the breeding cycle. The gulls were counted by one person standing on a high point while the other survey members went into nesting areas. As this is a colonial nesting species (Du 1994), we searched thoroughly for nests in each Common Seepweed habitat between April and July 1999–2007. Due to the occurrence of avian influenza, field work was not conducted in 2004. All nests were recorded using a GPS and marked 1 m to the south with a surveyor's flag rolled up and pushed into the ground leaving 4–5 cm of flag exposed to monitor productivity and also to avoid duplicate recording of nest sites.

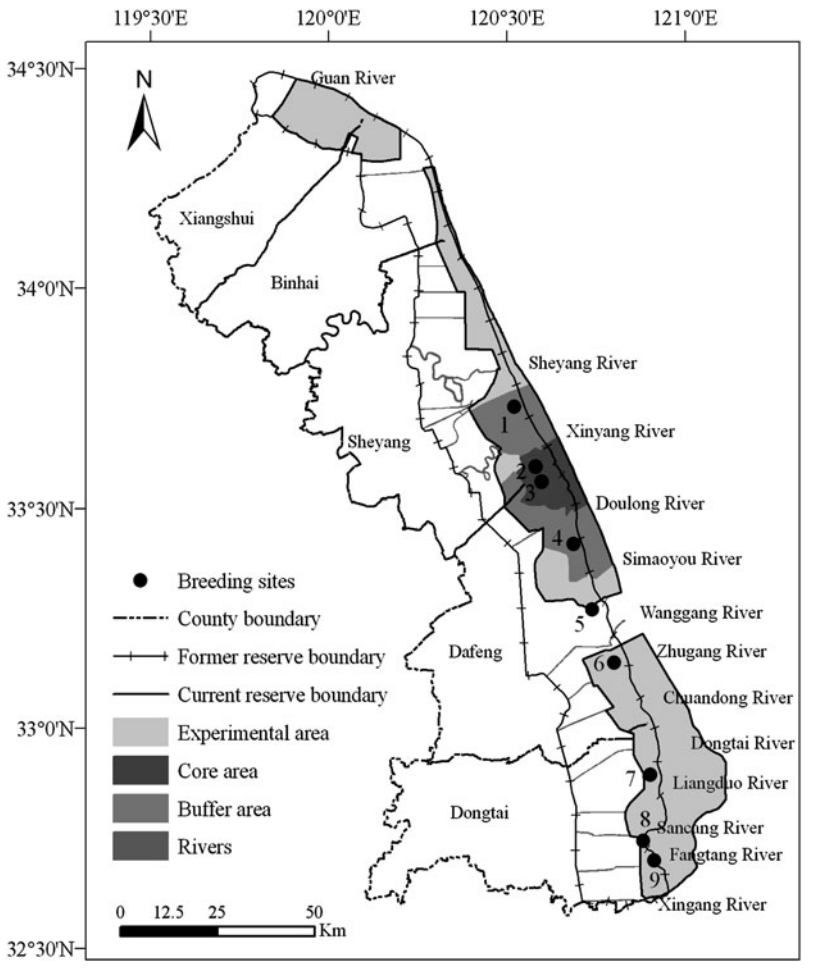

Figure 1. Nesting area distribution and revised functional areas of Yancheng NNR, Jiangsu Province. 1: Dongshagang, 2: North of core Area, 3: South of core area, 4: North of Simaoyou, 5: North of Wanggang, 6: North of Zhugang, 7: North of Liangduo River, 8: South of Sancang River, 9: South of Fangtang River.

Processing of satellite imagery

Cloud-free Landsat TM images for 1992, 1995, 1999, 2002, 2005 and 2007 were used for habitat classification (image orbits for each year include 120/36 and 119/37), which were acquired from February to March since this is the dry season in the study area. Ancillary GIS data used in this research included a digital topographic map of Yancheng NNR from 1986 at the scale of 1:50,000.

All images were registered in a Gauss projection (identical to that of the topographic map) using ERDAS software. Between 50 and 60 ground control points (GCPs) were used for each image, which were evenly distributed throughout the whole study area. The registration procedure achieved an accuracy of less than 0.5 pixel rms error (RMSE) for images in 1992, 1995, 1999, 2002, 2005 and 2007.

Our study area runs across two TM images, so a mosaic was made in the pre-processing stage. We performed histogram matching between the adjacent images for the same year using ERDAS

Imagine 8.7 software to conduct image-to-image radiometric normalisation, as suggested by Tang *et al.* (2005).

To establish visual interpretation marks, ground-truth surveys were conducted over the study area in order to collect real time ground-truth data between February and March in 2005 and 2007 with the help of a global positioning system (GPS). Reference data were collected extensively within the study area and vegetation cover was identified in the field. The accuracy of the resulting landscape maps was assessed using field survey reference data from the study area in 2005 and 2007. Their error matrix indicates that the overall accuracy exceeded 90%.

Classification of habitat types

The sequence of the natural vegetation succession from the sea in a landward direction is: mudflats, Smooth Cordgrass, Common Seepweed, grassland and Common Reed *Phragmites communis* (Ma *et al.* 1999). We classified the coastal wetlands into 14 habitat types: residential area (RA), industrial land (IL), farmland (FL), forests (FR), reed (RD), grassland (GL), aquaculture ponds (AP), reservoirs (RE), salt pans (SP), rivers (RV), Common Seepweed (CS), Smooth Cordgrass (SC), mudflats (MF) and lower mudflats (LM). Meanwhile, we defined RD, GL, CS, SC, MF and LM as natural wetlands, and AP, RE, SP and FL as anthropogenic wetlands.

Data processing

All vector data were converted to raster data on a 100 m × 100 m grid scale. All spatial data were managed using ArcGIS 9.1. We used the Spatial Analyst tool to generate the habitat transition matrix between different years. The centroid coordinates of Common Seepweed and Smooth Cordgrass habitats were acquired using Mean Centre Function of Measuring Geographic Distributions in Spatial Statistics Tools, and the transition angle and distance were acquired by the Near Function analysis tools.

Using the point density function in Spatial Analyst, the annual nest density figure was generated and the number of nests in each cell was also obtained. We defined a minimum rectangle of 37,807 ha (the coordinates of the centroid are N33.56329° and E120.58250°) to cover all nest-sites in the south of core area (site code 3 in Figure 1) during 1999-2007. The overall nest density figure was generated by adding the values of all rasters on a cell by cell basis. Proportions of abandoned nest-sites and available sites occupied between consecutive years (rates of nest-site turnover) were calculated for each nest area from nest-site turnover rate = $[0.5(S_1 \div N_1)+(S_2 \div N_2)]$, where S_1 = number of sites occupied only the first year, N_1 = total number of sites occupied the first year, S_2 = number of sites occupied only the second year, and N_2 = total number of sites occupied the second year (Eileen 1996).

All statistics were preformed using SPSS 11.5 software. All means are presented ± Standard Error (SE) with the range from minimum to maximum presented in brackets.

Results

Population size and distribution of Saunders's Gull

Annual mean population size and breeding population size were 994.09 ± 170.17 individuals (n = 11,575–1,300 individuals) and 874.09 ± 189.49 (n = 11, 575–1,300) separately across the eleven-year period (Table 1). Except in 2007, the total population size was > 900 individuals. The mean breeding population size in the core area of the reserve was 685.18 ± 55.69 individuals (n = 11,377–902), which accounted for 81.82% ± 7.62% (36.82%–100%) of the total breeding population in 1992–2007. The number of breeding sites decreased from eight in 1992 and 1994 (Huang 1994, Wang and San 1994) to four in 1998 and a single site in 2000–2006 (Figure 2). Furthermore, in 2007, one new breeding site was observed. However, the total population size was only 575 gulls, which represented a decrease of about 45% in comparison with the earlier years.

Table 1. Numbers and distribution of Saunders's Gull in coastal marshes of Yancheng NNR, 1992–2007.

Site code	1	2	3	4	5	6	7	8	9	Total
1992	200	100	500	60	200	70	40	130		1,300 (1,300)
1994	340	80	377	34	55	54	16	68		1,024 (1,024)
1998	191	91	600		38	30	28			979 (920)
1999	168	86	592		36	20	21			923 (852)
2000	46	77	748		71	24	24		3	993 (748)
2001	122	52	812		54	20	8		5	1,073 (812)
2002	42	64	839		32		8		6	991 (839)
2003	30	59	862		26		4		12	993 (862)
2005	69	74	902		22				16	1,083 (902)
2006	63	60	842		12				24	1,001 (842)
2007	39	12	463				10		51	575 (514)

Notes:Data from 1992, 1994 and 1998 were sourced from Huang (1994), Wang and San (1994) and Chu *et al.* (2000) respectively. The remaining data were collected during the field survey by the authors. The breeding population size is shown in parentheses. Site codes are as in Figure 1.

Changes in land use and land cover

The land cover classification clearly indicated that large areas of Common Seepweed have been lost along the beach from Sheyang River to Liangduo River except in the core of Yancheng NNR in the study area and that fragmentation of Common Seepweed habitats has occurred elsewhere. Calculations by each LULC class for 1992 and 2007 (Figure 3) showed that 79.1% (27,358 ha) of Common Seepweed has been lost within this 15-year period, while the area occupied mainly by aquaculture ponds more than doubled (122.4% increase) during the same period. However, the introduced Smooth Cordgrass habitat increased in area by 321.9% (11,057 ha) from Sheyang River to Liangduo River from 1992 to 2007 (Figure 3). This mainly occupied the mudflats and constrained the natural transition of tidal vegetation, particularly the Common Seepweed community. The results also showed that land reclamation mostly occurred in Common Seepweed habitats in 1992–2002 and shifted to reclaim the Smooth Cordgrass habitats afterwards (Figure 3). The area of reed and mudflats decreased by 76.1% (30,686 ha) and 16.5% (15,810 ha) respectively, and that of farmlands increased by 12.0% (28,213 ha) within this 15-year period.

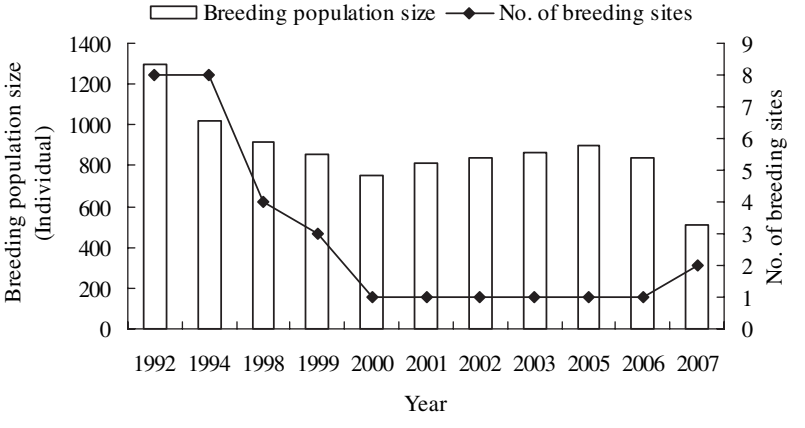

Figure 2. Changes in breeding population size and number of breeding sites of Saunders's Gull at Yancheng NNR 1992-2007.

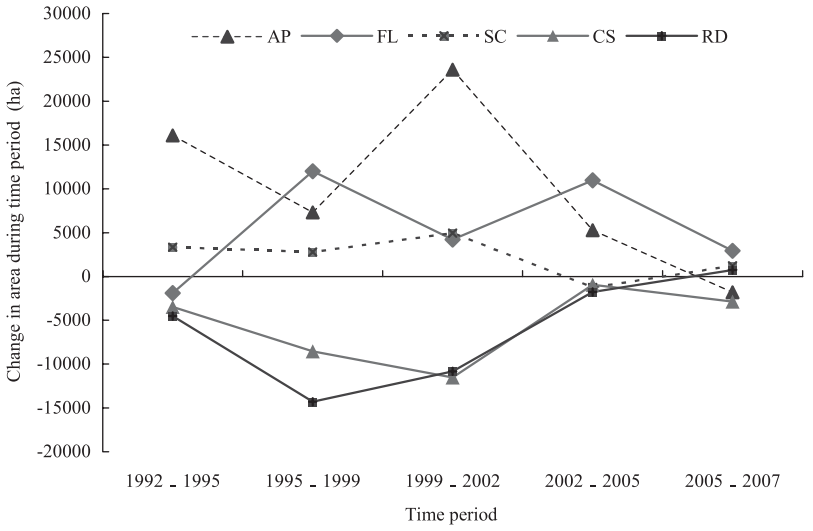

Figure 3. Changes between 1992 and 2007 in the area of five main types of land use or land cover in Yancheng coastal wetlands, Jiangsu (AP: Aquaculture ponds, FL: Farmland, SC: Smooth Cordgrass, CS: Common Seepweed, RD: Reed).

Land reclamation is the major cause of the loss of breeding habitats of Saunders's Gull. Seven breeding sites observed in 1992 and 1994 were lost due to land reclamation and were converted to aquaculture ponds, farmland and industrial use (Table 2).

Changes in Common Seepweed and Smooth Cordgrass communities

The number of patches (NP) and total area of the Common Seepweed community decreased continuously from 1992 to 2007 (Figure 4). However, the mean patch area did not change significantly ($P > 0.05$). This represented a decrease of 88.31%, and conversion to aquaculture ponds was the main cause of Common Seepweed loss (Table 3). There was a significant difference in the area of this plant converted between 1992 and 2007 ($t_4 = 3.491$, $P < 0.005$), and its centroids shifted towards the south-east of the study area (Figure 5).

The NP of Smooth Cordgrass increased between 1992 and 1995, declined to 2002 and then increased in 2002–2007 (Figure 4). However, the area of Smooth Cordgrass increased significantly ($P < 0.05$). This represented an increase of 391.56%, and 92.83% of the increased area was converted from the mudflats in this period (Table 3). The centroids of the Smooth Cordgrass community shifted towards the east (Figure 5).

Table 2. Date and causes of the loss of breeding sites of Saunders's Gull at Yancheng NNR (Site codes as in Fig. 1).

Site code	Time	Area (ha)	Purpose of reclamation
1	1997–1999	2,600	Aquaculture ponds in Dongshagang
2	1997–1999	1,400	Convsersion to *Phragmites* in the north of core area
4	1994–1995	1,442	Aquaculture ponds in the north of Simaoyou
5	1996–1998	1,685	Storage base of Dafeng Port in the north of Wanggang
6	1998–2000	3,033	Aquaculture ponds between Wanggang and Zhugang.
7	1996	2,751	Farmland in the north of Liangduo River.
8	1996	5,858	Farmland between Liangduo River and Sancang River

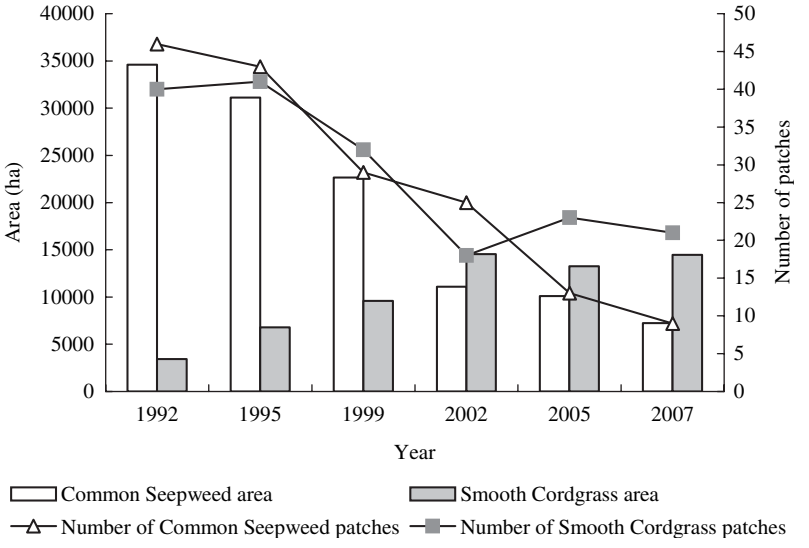

Figure 4. Area and number of patches of Common Seepweed and Smooth Cordgrass habitats in the study area 1992–2007.

Number of nests and density of Saunder's Gull

The number of nests in Zhonglugang tended to decrease and that of Sanlizha to increase (Table 4), with significant differences across years at Zhonglugang: ($t_7 = 6.29$, $P < 0.01$) and Sanlizha ($t_7 = 3.04$, $P < 0.02$), and differences within a year but between two sites ($t_7 = 3.537$, $P < 0.01$). The overall nest density map (Figure 6) indicated that 398 cells contained 1–2 nests, 200 cells contained 3–8 nests and 20 cells contained 9–16 nests.

The overall mean turnover rate was 0.84 ± 0.08 ($n = 7$), whereas in Zhonglugang it was 0.85 ± 0.09 ($n = 7$) and in Sanlizha 0.79 ± 0.18 ($n = 5$) (Table 5). The turnover rates of nest sites differed between years for Sanlizha ($t_6 = 24.936$, $P < 0.01$) and Zhonglugang ($t_6 = 3.612$, $P < 0.02$). However, the overall turnover rate did not differ between years ($t_6 = 1.695$, $P > 0.1$).

Discussion

Breeding habitat changes in Yancheng coastal wetlands

Satellite images generally present the sole source of habitat data for many regions of the world important to wildlife (Gottschalk *et al.* 2005). The remote-sensing approach employed here to quantify changes in breeding habitats of Saunders's Gull indicates rapid and extensive declines in Common Seepweed with an annual loss in area of 5.27%. The majority of these changes can be attributed to the widespread expansion of aquaculture within the area. The number of patches of Common Seepweed has declined significantly in the past 15 years and the expansion of Smooth Cordgrass is likely to further fragment the remaining habitat. These changes seriously threaten the distribution of breeding sites of the 'Vulnerable' Saunders's Gull.

The alien Smooth Cordgrass was introduced into Yancheng coastal wetland in 1982 (Zhong *et al.* 1985). This plant developed from scattered patches in estuarine regions into a continuous belt mainly distributed on the periphery of coastal wetlands from Sheyang River to Liangduo River from 1992 to 2007 (Liu *et al.* 2009a). Its spread has caused high levels of sediment accumulation, which constrains the natural transition of saline plants, especially Common Seepweed (Wang *et al.* 2006). Considering that Saunders's Gull prefers to nest in areas with

Table 3. (a,b) The change in the area of (a) Common Seepweed and (b) Smooth Cordgrass habitats in Yancheng costal wetlands over five periods of varying length between 1992 and 2007. The extent of habitat loss or gain is expressed as the percentage change of the area at the beginning of each period.

	Period				
	1992–1995	1995–1999	1999–2002	2002–2005	2005–2007
(a) Common Seepweed habitats					
Initial area (ha)	33,724	30,747	21,957	11,092	10,114
Loss to aquaculture (%)	9.3	23.4	48.6	8.9	22.3
Loss to other sources (%)	10.7	22.3	13.6	20.4	13.1
Total Loss (%)	20.0	45.6	62.2	29.3	35.5
Gain from mudflats (%)	6.1	6.6	9.5	16.2	6.2
Gain from other sources (%)	5.1	10.4	3.3	4.2	1.0
Total Gain (%)	11.1	17.0	12.8	20.5	7.2
Net change over period (%)	−8.8	−28.6	−49.5	−8.8	−28.3
(b) Smooth Cordgrass habitats					
Initial area (ha)	3,567	7,162	10,804	14,535	13,271
Loss to aquaculture (%)	0.0	3.6	31.7	36.2	16.9
Loss to other sources (%)	14.8	37.9	6.1	2.0	0.9
Total Loss (%)	14.8	41.4	37.8	38.2	17.8
Gain from mudflats (%)	85.5	72.0	53.6	20.9	23.3
Gain from other sources (%)	29.8	17.9	18.7	8.6	3.5
Total Gain (%)	115.3	89.9	72.3	29.5	26.8
Net change over period (%)	100.6	48.4	34.5	−8.7	9.0

coverage of 20%–60% of Common Seepweed (Jiang *et al.* 2002), breeding sites will disappear if no management measures are taken to prevent expansion of Smooth Cordgrass in the short-term.

Although this alien plant has expanded extensively in the study area, the coastal wetland from Liangduo River to Xingang River has not been occupied by this plant and the area of Common Seepweed habitat is still increasing. This area was occupied by Saunders's Gull in 2007 (site code 9 in Figure 1) and is a potential breeding site for the gull if no land reclamation occurs in the future.

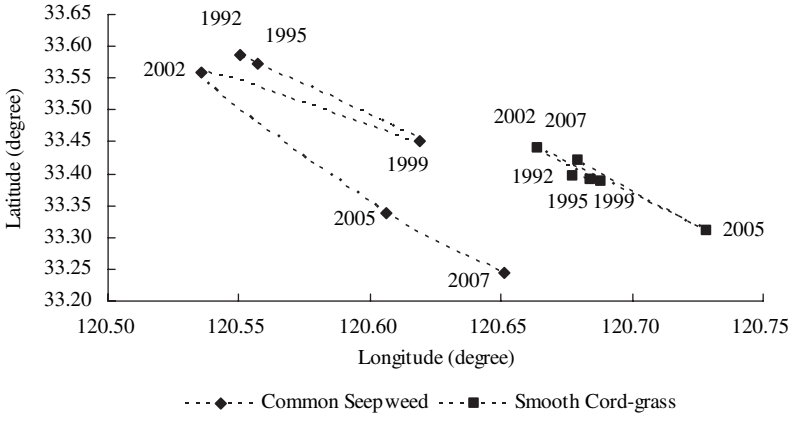

Figure 5. Mean centres of Common Seepweed and Smooth Cordgrass communities in Yancheng NNR 1992–2007.

Table 4. The number and density of nests of Saunders's Gull in different nesting areas in the south of core area of Yancheng NNR, 1999–2007.

Year	Total No. of nests	Nest density per ha	Zhonglugang		Sanlizha	
			Nest no.	Nest density per ha	Nest no.	Nest density per ha
1999	272	1.78	258	1.86	14	1.00
2000	270	1.85	246	1.91	24	1.41
2001	216	2.30	216	2.30	0	0.00
2002	184	2.88	184	2.88	0	0.00
2003	190	1.51	162	1.54	28	1.33
2005	226	1.82	152	2.11	74	1.42
2006	179	2.45	99	2.20	80	2.86
2007	109	1.22	32	1.23	77	1.22

Threats to the Saunders's Gull population

Saunders's Gull is dependent upon salt marshes and tidal mudflats, both for breeding and for its specialised diet, which mainly comprises crabs, but also includes small fish, shellfish and Common Clamworm *Perinereis kinberg* (Brazil and Melville 1991, Brazil 1992). The main threats to this species include habitat loss and degradation, invasion of Smooth Cordgrass, direct and indirect human disturbance and cumulative predation risk.

Using a non-dense dimidiate pixel model of remote-sensed normalized difference vegetation index (NDVI) data, Liu *et al.* (2009b) concluded the mean Common Seepweed coverage of nesting sites of Saunders's Gull was 34.98 ± 6.8% based on 184 nests in 2002 and 109 nests in 2007. Due

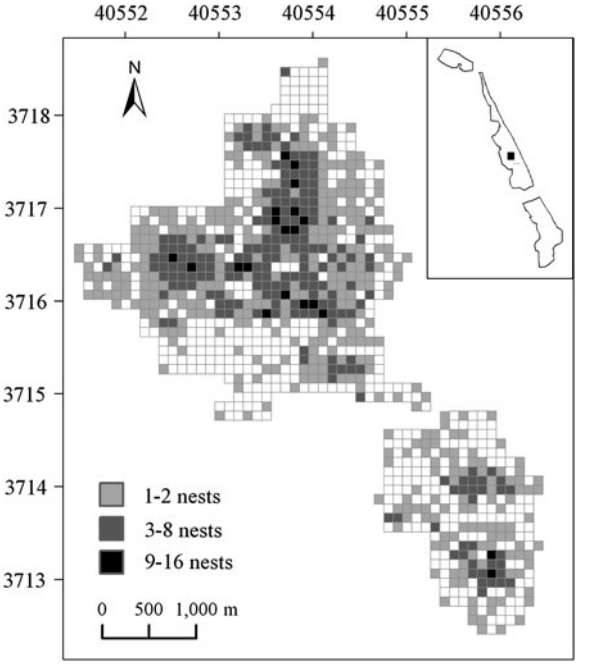

Figure 6. Nest-site density of Saunders's Gull in the south of core area of Yancheng NNR 1999–2007.

Table 5. Turnover rates of nest-sites of Saunders's Gull in the south of core area of Yancheng NNR, 1999–2007.

Turnover rate	1999–2000	2000–2001	2001–2002	2002–2003	2003–2005	2005–2006	2006–2007
Overall	0.78	0.81	1.00	0.82	0.89	0.81	0.77
Zhonglugang	0.78	0.80	1.00	0.81	0.93	0.75	0.88
Sanlizha	0.80	0.57*	0	0	1.00	0.92	0.64

The asterisk indicates that the turnover rate is 2000–2003 rather than 2000–2001.

to the expansion of Smooth Cordgrass and a lack of regular seawater flushing in the core area of Yancheng NNR, the mean coverage of Common Seepweed habitats increased from 27.6 ± 3.8% in 1992 to 35.4 ± 2.0% in 2002, and then to 53.1 ± 4.5% in 2007 (Liu et al 2009b). In this case, the suitable nesting habitats for Saunders's Gull increased in 1992–2002, and then decreased 2002–2007.

In a stable and high quality breeding area, site fidelity can lead to higher reproductive success through the avoidance of predation and nest predation, improved feeding skills, and better adaptation to local circumstances in general (Vadász *et al.* 2008). Saunders's Gull appeared to have a very high spatial turnover of nesting sites in the core area of Yancheng NNR and presumably also low site tenacity of individuals, which indicates that the gull is probably susceptible to disturbance in the same way as Lesser Black-backed Gull *Larus fuscus* (Virkkala 2006).

Disturbance caused by human activities, such as collection of Common Seepweed, Common Clamworm and small crabs, has disrupted incubation and caused desertion of breeding sites. Other activities such as collection of Say's Paper-bubble *Bullacta exarata*, *Onchidium struma* and *Lunatica gilva* could disturb foraging birds and increase the risk of egg collection by local farmers. Meanwhile, fences for collection of small crabs will increase the risk of chicks falling into small jars placed along the fence (Jiang 2008). At present, the regulations in Yancheng NNR are lax and do not prevent continued building of new factories or restrict the increasing human activities.

Concluding remarks

Knowledge of population dynamics and habitat changes of Saunders's Gull can help development of management strategies for this 'Vulnerable' species. Preserving the breeding sites is a challenging task due to the species's spatio-temporal dynamics. New sites are continuously colonised and earlier inhabited sites become unoccupied. This is typical of colony-breeding gulls, such as Saunders's Gull, Black-headed Gull *Larus ridibundus* (Ulfvens 1993) and Lesser Black-backed Gull (Virkkala 2006). Thus, it is recommended to conduct annual monitoring and to define a large enough range in one year to control disturbance to nesting, incubation and foraging, and increase breeding success.

In addition, habitat management is an important measure to prevent or reverse the direction of vegetation succession. Management of intertidal areas has also involved control of Common Reed and Smooth Cordgrass. It is recommended to use herbicide or mechanical disturbance to limit the expansion of Smooth Cordgrass, as has been applied in Europe to control Common Cordgrass *Spartina anglica* (Frid *et al.* 1999). In addition, artificial intervention or burning to create suitable vegetation cover of Common Seepweed is also a critical aspect of habitat manipulation to provide suitable nesting areas for gulls.

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