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Evaluation of the red-crowned crane habitat in the Yellow River Delta Nature Reserve

Hong Wang [1, a], Yan Kong, He Li, Ling Li and Liliang Ren[2]

[1]*School of Earth Sciences and Engineering, Hohai University, Nanjing 210098, China.*
[2]*State Key Laboratory of Hydrology-Water Resources and Hydraulic Engineering, Hohai University, Nanjing 210098, China.*
[a]*HongliWang020@126.com*

Abstract

As a consequence of wildlife habitat is in constant evolution, periodic monitoring is essential to assess habitat quality. In this study the change to the red-crowned crane habitat in the Yellow River Delta Nature Reserve (YRDNR) was detected from multi-temporal remote sensing data from 1992 to 2008 in a geographic information system (GIS). The changing quality of the habitat was evaluated from both physical constraint and human disturbance. The results indicate that potential habitat shank 37.8% during 1992-2001, but recovered 96.8% by 2008. Human disturbance in the forms of roads, oil wells and residential areas caused a high degree of behavioral fragmentation. Suitable habitat shrank by 1,569 ha to a level below that of 1992 despite an increase of 4,450 ha in potential habitat due to an increase of 6,019 ha in fragmented areas. Therefore, efforts should also be directed at improving habitat quality by minimizing human activities in the Reserve

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Keywords: Red-crowned crane, Habitat change, Human disturbance, Remote sensing, the Yellow River Delta Nature Reserve

1. Introduction

Coastal wetlands are disappearing at an annual rate of about 1% around the world and 57% since the 1950s in China as a result of severe degradation [1,2]. This reduction in the potential habitat has implicated the decline of many coastal wetland-dependent bird populations [3], especially those endemic species whose survival requires special habitats. Red-crowned crane (*Grus japonensis*) is an endangered species of waterfowl [4] with a worldwide population estimated at 1,000–2,000, the majority of which is found in China [5]. Habitat loss and degradation threaten its population and survival around the world [6]..

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It is very important to monitor crane habitat that tends to change rather quickly even within a short period of time. Remote sensing has been used increasingly for wildlife habitat evaluation, modeling and monitoring, and for meeting overall wildlife conservation and management objectives effectively [7]. Use of remote sensing images allows the acquisition of information on crane habitat types, areas, and spatiotemporal structure. Analysis of habitat change can identify its most critical implications on the complex interactions between natural environmental changes and anthropogenic activities [8]. An understanding of the causes of habitat loss is important to developing effective management plans for habitat recovery [9].

Human activities, such as oil exploitation and road construction, have strongly fragmented the coastal landscape and resulted in pronounced ecological consequences [10]. Significant fragmentation of the coastal wetlands have negatively impacted red-crowned crane in China owing to the decreased probability of successful dispersal [11,12]. In response to this decline, the Yellow River Delta Nature Reserve (YRDNR) was created in 1992 with the aim of protecting the coastal wetland ecosystem and rare and endangered birds, including the red-crowned crane.

Establishment of protected areas is one of the main means of natural conservation. However, it is questionable whether such protected areas are effective at protection [13] as high-quality habitat inside a reserve was lost and fragmented at a higher rate after the recreation of the reserve than before [14]. This failure brings out the need to monitor habitat evolution and evaluate the effectiveness of protected areas. In this study we attempt to develop an appropriate remote sensing and GIS method for properly monitoring the evolution of the red-crowned crane habitat in the YRDNR and evaluating its evolving quality. The specific objectives are: (1) to map and to characterize the spatiotemporal changes that have taken place to the habitat over the last 16 years; (2) to determine the level of human disturbance to the habitat quality; and (3) to evaluate the effectiveness of the YRDNR in preventing the habitat from deterioration.

2. Materials and methods

Study area. The YRDNR (37°35′–38°12′ N, 118°33′–119°20′ E) is located in the estuary of the Yellow River in Dongying City, Shandong Province, China. It has a warm temperate continental monsoon climate with distinctive seasons and a rainy summer. Annual temperature averages 12.1°C. It receives an annual rainfall of 551.6 mm, against an annual evaporation of 1,962 mm. The YRDNR is the most important stopover site for red-crowned crane in China. Protection of the crane habitat is thus internationally significant [15]..

Nevertheless, this area has experienced huge habitat changes caused by worsening freshwater deficiency, rapid economic development and sea-level rise. The Yellow River flux has been decreasing dramatically; the volume of water and sediment discharges have dropped markedly since the 1950s, resulting in frequent and lengthy events of downstream channel dry-up since the 1970s [16]. Furthermore, oil exploitation, agriculture and aquaculture have all significantly impacted wetlands in the YRDNR [17]. Habitat protection for rare and precious birds typified by red-crowned crane faces ever large uncertainties..

Data and processing. Three Landsat images obtained in 1992, 2001 and 2008 with no or little cloud cover were selected in this study. These images were acquired in the late rainy season from August to September ideal for extracting water and vegetation information. The mean high tide mark was detected from each of the three composite images of TM751 as TM bands 5 and 7 have information content highly sensitive to water. Water areas were extracted from TM751 images using supervised classification in each of the three years. Nine land covers, including meadow, farmland, freshwater, aquaculture, high saline tidal flats, shrub-grass, forest, reed marshes and seablite tidal flats, were mapped using the maximum likelihood classifier in ENVI v4.5. Identical mapping was repeated 3 times, with one satellite image.

Classification accuracy was assessed using an independent set of test samples collected in the field. The constructed confusion matrix had a Kappa coefficient ranging from 0.84 to 0.96. The year 2001 was studied because channel flow and sediment discharges from the Yellow River changed a lot around this time. Human intervention to regulate water and sediment so as to increase the downstream flow of the Yellow River was initiated in 2002.,

In order to assess human disturbance, SPOT images of 5 September 2005 and ALOS images acquired on 24 August 2008, both having a spatial resolution of 2.5 m, were used to map roads, residential areas, and oil wells. The change in the potential habitat area was detected from the 1992, 2001 and 2008 land cover maps through overlay analysis in ArcGIS

Habitat fragmentation analysis. In assessing habitat quality, it is essential to quantify landscape fragmentation because red-crowned crane's favorite habitat is near water area with little disturbance [18]. Habitat fragmentation falls into two categories, physical and behavioral. Physical fragmentation refers to the physical distance of a potential habitat to the nearest water. A distance of >15 m was used to derive physical fragmentation from the unioned potential habitat and water area layers. Behavioral fragmentation is induced by human disturbance. Patchy spotted oil wells, residential areas and linear roads were selected as fragmentation causes as they impose barriers on the behavior of crane that is highly sensitive to human disturbance. The physical distance at which artificial structures cease to impact on crane is reportedly at least 200 m from roads, 300 m from oil wells, and 750 m from residential areas [18]. Behavioral fragmentation was calculated under the assumption that roads are 30 m wide, and oil wells have a diameter of 100 m. Buffers of appropriate widths were generated from respective features. This behavioral fragmentation was combined with the physical fragmentation in derive the suitable habitat from the potential habitat via subtraction. All processing was carried out in ArcGIS 9.2.

3. Results

Habit evolution. The potential habitat size varied widely over the study period (Fig. 1). This variation is characterized by two trends, a general decline from 19,907 ha in 1992 to the lowest of 12,376 ha in 2001, and a steady and mostly gradual expansion afterwards to 24,359 ha until 2008. Habitat area in 2001 is only two third of that in 1992. The change is the more drastic during the second period when its area nearly doubled. Unlike this total area of potential habitat, the area of reed marshes and seablite tidal flats, however, does not exhibit a uniform trend of change. The area of reed marshes fluctuates widely, even though it tends to be larger in the second half of the period than the first. Reed marshes are distributed mainly along both sides of the Yellow River (Fig. 2). They gradually decreased until near disappearance from 1992 to 2001. However, this decreasing trend was reversed after 2001, and by 2008 they had spread to both east and north of the Reserve. The spatial distribution of seablite tidal flats is characterized by a gradual merging of numerous small patches in 1992 to form fewer but larger patches in 2008.

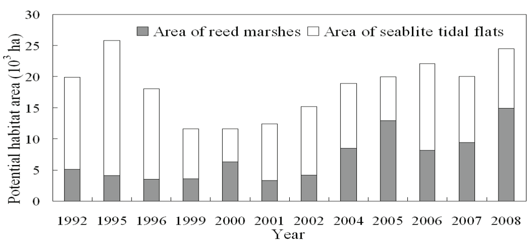

Fig. 1 Variation of potential crane h abitat from 1992 to 2008

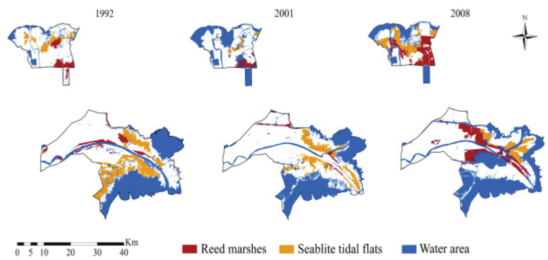

Fig. 2 Distribution of the red-crowned cranepotential habitat and water area in 1992, 2001 and 2008

Quantitatively, reed marshes gained 1,929 ha but lost 2,918 ha during 1992-2001, resulting in a net loss of 989 ha (Table 1). This net loss combined with that of seablite tidal flats totals 7,530 ha. Therefore, the crane habitat was in a state of decline during this period. During the second period, reed marshes gained net increase of 10,150 ha far exceeds the net loss of 989 ha experienced in the first period. Compared to reed marshes, seablite tidal flats gained only 1,992 ha. Therefore, 1992-2001 is the period when the potential habitat experienced decline while this trend was reversed during the second period. This reversal in the changing trend is caused primarily by the largest conversion from meadow and shrub-grass.

Table 1 Changes to reed marshes and seablite tidal flats during 1992-2001 and 2001-2008 (ha)

Land cover	1992-2001				2001-2008			
	Reed marsh		Seablite tidal flat		Reed marsh		Seablite tidal flat	
	Gain	Loss	Gain	Loss	Gain	Loss	Gain	Loss
High saline tidal flat	31	441	**2,525**	**7,569**	62	121	**4,011**	**3,445**
Meadow	437	220	768	665	**5,999**	145	43	9
Shrub-grass	974	164	**1,399**	738	**3,872**		**1,380**	51
Freshwater	54	299	259	163	354	318	224	**1,841**
Aquaculture			6	**2,362**	8	5	12	36
Farmland	402	**1,679**	11	31	883	880		11
Forest	27	110	42		510	53		
Seawater	4	5	335	358	3	19	**1,826**	211
Total	1,929	2,918	5,345	11,886	11,691	1,541	7,496	5,604

Human disturbance. During the study period the Reserve was severely disturbed by intensified human economic activities (Table 2). The number of oil wells more than doubled from 205 in 1992 to 575 in 2008. The increase was rather slow during 1992-2001, but it accelerated during 2001-2008. This expansion could not have been possible without the support of a sound road infrastructure. The 372 km road in 1991 was extended to 399 km by 2001. It more than doubled to 810 km by 2008. Again, human disturbance during the second period is much stronger than the first. Dissimilar to roads and oil wells, human settlement expanded at nearly the same pace in both periods. Aquaculture, on the other hand, experienced an explosive growth from 848 ha to 4,434 ha in 2001, but gained only 552 ha during the second period. Farmland, on the other hand, remained mostly unchanged at all times.

Table 2 Level of human disturbance in the YRDNR for 1992, 2001 and 2008

Year	No. of oil wells	Roads (km)	Settlement area (ha)	Aquaculture (ha)	Farmland (ha)
1992	205	372	125	848	23,480
2001	332	399	154	4,434	18,973
2008	575	810	182	4,986	21,599

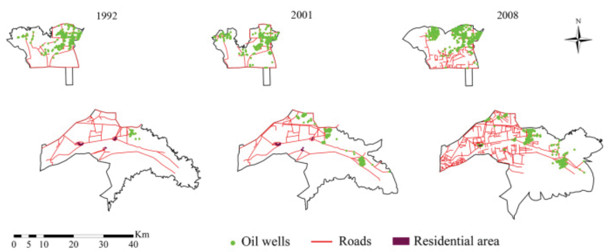

Fig. 3 Distribution of roads, oil wells and residential areas in 1992, 2001 and 2008

Spatially, no human settlement was distributed in the northern patch in 1992 (Fig. 3). The large majority of oil wells were confined to the northeast of the northern patch. Only a few was located in the southern patch distant from human settlements. By comparison, most of the roads were distributed in the southern patch where settlements were clustered at chiefly three locations. This pattern held almost unchanged in 2001 except the wider scattering of oil wells in both patches. However, huge changes occurred to both roads and oil wells by 2008. There were many more roads at a higher density in both patches, confined to the south of the northern patch, and to the northwest of the south patch. Oil wells spread out more widely further from the previous locations, but still had a clustered distribution.

Habitat fragmentation. Physical fragmentation, derived from proximity of potential habitat to water, is subject to water distribution. Physically fragmented area was very high at 4,919 ha in 1992, but dropped to 1,898 ha in 2001 (Table 3). It bounced back to 3,417 ha in 2008, but never reached the 1992 level. Its contribution to total fragmentation far exceeded behavioral fragmentation in both 1992 and 2001. However, its relative influence was drastically weakened in 2008 when human disturbance exerted a far larger influence.

Table 3 Comparison of physical and behavioral habitat fragmentation in 1992, 2001 and 2008 (ha)

Year	Potential habitat	Physical fragmented	Behaviorally fragmented				Suitable habitat
			Oil wells	Roads	Resident areas	Total	
1992	19,907	4,919	530	1,063	35	1,628	13,360
2001	12,376	1,898	711	1,255	2	1,968	8,509
2008	24,357	3,417	3,568	4,912	669	9,149	11,789

Behaviorally fragmented areas were determined from the development of oil wells, roads and residential area (Table 3). The disturbance caused by residential areas was the smallest among the three factors. By comparison, the influence of oil wells is much more profound. The fragmented area rose gently from 530 ha in 1992 to 711 ha in 2001, but exponentially to 3,568 ha in 2008. This ever expansion in fragmented area corresponds closely to a large increase in the number of oil wells (Table 2). Unlike human settlements, oil wells must be spread out in space in order to maximize their yield. More oil wells mean more fragmentation of more habitats, even though oil wells are point features themselves. Despite this, the most influential factor among behavioral fragmentation is roads. In any given year they fragment an area that is several times larger than the combined area of settlements and oil wells. This expanded influence is attributed to the linear structure of roads that can exert more widespread fragmentation than point features.

Regardless of the specific types of human activities, all behaviorally fragmented habitat totaled 1,628 ha in 1992. This value increased by 19% to reach 1,968 ha in 2001, and to 9,149 ha in 2008. Therefore, in the early years physical fragmentation played a more important role than behavioral fragmentation to the quality of the potential crane habitat. In the second period behavioral fragmentation was more important than physical fragmentation, a fact reflective of intensified human activities over this period.

4. Discussion

The calculated physical and behavioral habitat fragmentation areas (Table 3) indicate a worsening habitat quality as a result of intensified human activities. As one of the most important regions of petroleum production in China, the Yellow River Delta has been subject to increasing human disturbance (e.g., oil exploitation) since the early 1960s [19]. Oil wells and roads have contributed to the considerable fragmentation of the potential crane habitat. Their influence far exceeded the physical fragmentation during 2001-2008. Thus, anthropogenic influences have become the main factor behind the observed habitat change. Because of such human disturbance as wetland reclamation for farmland and aquaculture, oil development and roads construction, there were only 11,791 ha of suitable habitat in 2008, still 1,569 ha less than 13,360 ha in 1992, in sharp contrast to the increase in potential habitat from 19,907 ha to 24,359 ha during the same period. Therefore, creation of the Nature Reserve is conducive to the expansion in potential habitat. However, it cannot halt the decrease in suitable habitat and deterioration in its quality. Such negative impacts can be minimized by sealing off important natural corridors from oil wells and roads, forbidding oil exploitation in the vicinity of crane habitat, and blending landscape-level planning with biodiversity offsets

5. Conclusions

Potential habitat of red-crowned crane in the Reserve increased 22.4% during period of 1992-2008. Of the two components of potential habitat, reed marshes and seablite tidal flats shrank (37.8%) from 1992 to 2001 and expanded (96.8%) from 2001 to 2008. Intensified human activities such as oil exploitation and roads construction have played a substantial role in habitat fragmentation and degradation. Consequently, suitable crane habitat lost 11.8% (1,571 ha) despite the increase in potential habitat by 3,452 ha over the whole study period. Suitable habitat has a smaller area (11,791 ha) in 2008 than that (13,360 ha) in 1992. Thus, it is insufficient to just create the Nature Reserve for the protection of the red-crowned crane habitat. Commensurate efforts should also be directed at minimizing anthropogenic influences on habitat quality within the Reserve. Anthropogenic disturbances can be minimized by protecting important natural corridors through appropriate deployment of roads, oil wells, and settlements.

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