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SPATIAL PATTERN AND FUNCTION OF CORRIDORS IN WETLANDS OF LIAOHE DELTA

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ABSTRACT: Corridors are special patches with narrow and long shape, and often have the functions as transportation, protection, resources and aesthetics. Corridors in the study area can be classified into 8 types, with a total length of 5167. 2 km, and corridor density of 1. 25 km/km^2. The corridors are mainly composed of irrigation and drainage canals, the total length of which is 2794 km, about 54. 1% of all the corridors. The corridors have segmented the landscape, and changed the original situation of the natural landscapes. The types of corridors are closely related to the landscape types they are distributed in. Canals are mainly distributed in the wetland landscapes, while roads are mainly in the built-up area. Dikes are always along rivers or coastlines. The corridors are most densely distributed wherever human activity occurs most frequently, such as in the artificial wetlands of paddy fields.

KEY WORDS: corridor; Liaohe delta; landscape ecology

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1 INTRODUCTION

Corridors are special patches with narrow and long shape, and often have the functions as transportation, protection, resources and aesthetics (FORMAN, 1986; ALMO, 1998) . Corridors connect various landscapes by transporting materials, energy and information. New corridors created by human activities are important factors leading to landscape fragmentation. In the meanwhile, they are also barriers to the connections of different ecosystems (WANG *et al.*, 1996) . The corridors have fragmented the landscape, and changed the original situation of the natural landscapes. For example, in the Liaohe delta, the construction of canals brings up large area of artificial wetlands, and postpones the succession from semi-natural wetland to dry-farmland. The desalinization process by drainage also led to the degradation of marsh.

The increase of corridors is the driving factor of landscape fragmentation. The canals and roads provide more convenient conditions for human activity, and thus deteriorated the disturbance in the wetlands. Apart from the transportation function of some corridors, such as canals and roads, others may act as barriers for materials, energy, and species, such as dikes. The corridors also have the ability to absorb and transform materials.

The Liaohe delta is situated in the southern part of Liaoning Province, to the north of Liaodong Bay, within the range of 121°35′ - 122°55′E and 40°40′ - 41°25′ N. The total area of this delta is about 13, 000 km^2. Main landscape types include open water, beach, reed swamp and paddy fields, etc.

2 CORRIDORS IN THE LIAOHE DELTA

The exploitation of the Liaohe delta started in the early 1960's has established a complex and effec-tive

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corridor network in this area. Therefore, studying the patterns and functions of the corridors are very useful for designing new corridors and reconstructing existing ones. Corridors in the Liaohe delta mainly include canals, roads/railways, rivers and dikes (Table 1). The average corridor density was about 5 km/km^2 in 1994. From Table 1, we can find that the total length of canals occupy more than half (54.1%) of all the corridors, and the hydrological corridors (including canals and rivers) make up 64.3% of the total. The total length of dikes is almost the same as that of the main rivers, about 7.7% of the total. Roads are the secondary important artificial corridors in the studied area, accounting for 26.2% of the total. Generally, the landscape fragmentation increases with the intensification of human activities, which means, the length of landscape boundaries will increase with the fragmentation process, including the types and lengths of corridors. Because the Liaohe delta has been exploited recently (since the 1960's), it provides a very convenient example for us to understand and observe those changes.

3 CORRIDOR DISTRIBUTION

Corridors distributed in different landscapes vary with types and length. They are mainly distributed in paddy field, reed swamp and built-up area in the Liaohe Delta. In Table 2, it's clear that most of the canals are distributed in paddy field and reed swamp, while roads are distributed in paddy field, reed swamp and built-up area. Because more than half of the reed fields are landscape managed, human activities' impacts are very important to those landscapes. Human activities showed very different effects. The positive aspect is that human activities created new artificial landscapes, so as to get more productions, and a more suitable environment for living and inhabitant. The negative aspect is the abuse of natural resources due to misunderstanding or unknown of natural principles.

Generally speaking, the types of corridors are closely related to the landscape types where they are distributed. Canals are mainly distributed in the wetland landscapes, while roads are mainly in the built-up area. Dikes are always along rivers or coastlines. The corridors are most densely distributed wherever human activity occurs most frequently, for example in the artificial wetlands of paddy fields.

Table 1 Corridor types in the Liaohe delta

Corridor type	Length(km)	Proportion(%)	Functions
Main canal	489.845	9.5	Irrigation and discharge
Secondary canal	2304.132	44.6	Irrigation and discharge
Main road	569.478	11.0	Transportation
Secondary road	783.452	15.2	Transportation
Main river	403.082	7.8	Way of pollutants and water to the sea
River branch	119.749	2.3	Way of pollutants and water to the sea
Dike	395.416	7.7	Protection or tidal proof
Railway	102.034	2.0	Transportation
Total	5167.188	100.0	

4 CORRIDOR DENSITY

The corridor length and corridor densities in different landscapes are not closely related each other. For example, the corridor lengths in paddy fields and reed swamp are ten to hundred times that of the others, but the corridor densities of them are not so big. In this case, all the corridors are important to the vitality and production of these landscapes. We can say that these two landscapes are well managed. According to the results above, the corridor density in the research area is 1.251 km/km^2, in which, the canal density is 0.677 km/km^2, the density of traffic line is 0.328 km/km^2, the solid corridor (road and dike) density is 0.448 km/km^2, and the density of hydrological corridor is 0.803 km/km^2.

5 FUNCTIONS OF CORRIDORS

5.1 Irrigation

There are 162 611.2 ha of paddy field and

Table 2 The distribution of corridors in various landcovers of the Liaohe delta (km)

Landcover	Total	Main canal	Secondary canal	Main road	Secondary road	Main river	River branch	Dike	Railway
Built-up area	499.421	29.868	142.189	150.853	123.464	10.127		24.345	18.576
Pond reservoirs	61.425	0.636	14.527	3.137	4.488	0.321	3.334	34.180	0.801
Prawn crab pond	56.050	0.466	25.217	4.635	16.098	0.896	0.878	7.860	
Dry-farmland	206.307	4.590	64.671	20.126	59.939	22.312		30.020	4.650
Paddy fields	2667.210	302.922	1471.936	260.479	427.555	36.145	0.025	130.996	37.153
Reed swamp	1098.228	130.027	459.428	117.260	116.254	104.034	72.337	63.278	35.609
Forest	36.416	6.994	23.136	1.974	4.202	0.110			
Suaeda spp	125.768	3.668	68.744	3.175	14.685	11.618	9.095	14.782	
Cattail marsh	13.084	3.263	7.553	0.167	0.464	0.047	1.589		
Meadow	47.196	1.950	2.238	1.348	0.961	8.864	16.041	14.533	1.261
Shrubs	10.382		4.309	2.123	3.866	0.085			
Large River & riverside	142.788	0.013	1.196	0.615	0.447	134.252		6.086	0.178
Bare soil	149.148	1.606	14.143	3.360	10.254	38.101	8.594	69.300	3.791
Total	5167.187	489.845	2304.132	569.478	783.452	403.082	119.749	395.416	102.034

90 019.3 ha of reed field in the research area (Table 3). Canals in these landscapes are very important for the survival of the ecosystems. The rice needs water in most part of the growth season, as is well known. The reed also needs irrigation to get a higher production (LI, 1999). Actually the canal network is built mainly for these two types of landscapes.

There were only 5 uncompleted small-scale canal systems before the liberation in Panjin. By the end of 1990, there had been 4 irrigation systems being built including Panshan County and Dawa County irrigation regions (including 11 canal systems), Wujia independent irrigation system, reed swamp irrigation system etc. The total irrigation area was 104 137 ha, total pumping ability was 877.73 m^3/s. The total drainage discharge of the irrigation/drainage stations was 810.90 m^3/s, which managed 192 608 ha of field. (Table 3).

Table 3 Landscape features of paddy field and reed swamp

Landcover	Paddy-fields	Reed swamp
Number of patches	85	139
Area(km^2)	1626.112	900.193
Average patch area(km^2)	19.131	6.476
Water demanding(m^2/ha)	12000	300-5000
Productivity(t/ha)	10.34	14.00
Production(t/a)	1681400	1260280

According to the formal irrigation standard, 12 000 - 18 000 m^3/ha for the paddy field, 3000 - 4500 m^3/ha for the reed marsh, there should be $195 \times 10^6 - 2930 \times 10^6$ m^3 and $270 \times 10^6 - 410 \times 10^6$ m^3 water provided by the canal system in Panjin City.

5.2 Drainage and Desalinization

Canals are also important for drainage and desalinization. The seasonal distribution of precipitation in the Liaohe delta is not the same as the seasonal need of the plants, especially paddy and reed. Irrigation is needed in spring and early summer, while drainage is needed in July and August. The canals can also lower the groundwater level down when the inundation period lasts too long. There are 27 irrigation/drainage stations, 10 irrigation stations, and 11 drainage stations above 500 kw power in the delta.

Many paddy fields are originally salty lands before they were cultivated. After irrigation and discharge with the canal system, most of the salt is washed away. According to ZHAO Yi (1994), about 5450 kg of salt can be removed from the paddy fields per hectare per year. It's especially important in early spring, when evaporation is much higher than precipitation, and salt content in the surface soil is quite high. In the reed fields, the reed itself can also take part of the soil salt away.

5.3 Purification of Pollutants

Rivers flow across the Liaohe delta with a great amount of pollutants every year (Table 4), which is the

Table 4 The main rivers flowing into Liaodong Bay and their pollutants

River	Discharge($\times 10^9$ m^3/a)	COD(t/a)	NH_4^+ - N(mg/L)	NO_2^- - N(mg/L)	NO_3^- - N(mg/L)
		21697	0.37 - 4.23	0.002 - 0.04	0.11 - 1.4
Daliao River	4.0	53903	2.3 - 104	0.0 - 0.088	0.0 - 2.38
Daling River	2.0	49432			
Xiaoling River	0.4	2245			
Sum	8.5	127277			

main reason for the pollution of coastal waters. Except for the natural wetlands, the canals also have purification function to pollutants such as COD, N and P (LI, 1999). Almost half of the pollutants can be removed from the water (Fig. 1), as it flows through a 6000-m-long canal, either because of bio-chemical decomposition or because of sedimentation. The total length of canal was 2800 km in the Liaohe delta, and about half of them distributed in the reed swamp. With the development of reed swamp management level, more canals will be built. By the way, there will be a bigger potential for the canals as part of the polluted water purification system.

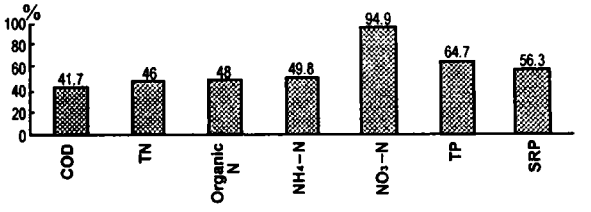

Fig. 1 The purification ability of canal system to some pollutant elements

5.4 Natural Tide Ditches Providing Food to Shore Birds

Corridors are also important to the conservation of animals especially birds, which is becoming a key topic whenever study the corridors (BEIER, *et al.*, 1992; BENNET, 1991; LINDENMAYER, 1993; STOLZENBURG, 1991). The daily tidal ebb and flow bring large amount of seafood to the beach. As the natural tidal ditches are often irregular, small fishes and crabs are often retained in the tidal ditches, and become food of many sea birds, such as *Larus saundersi* and *Cygnus cygnus* etc. For example, there are 172.1 ± 39.8g/m^2 of *Helice tientsinonsis* in the ditches, which is the main food of sea birds such as *Larus saundersi* etc. Tide ditches longer than 1 km includes Hunjiang, Ganyugou, Jieguanting, Erjiegou ditch etc.

6 THE REASONABLE CORRIDOR DENSITY AND CORRIDOR PATTERN IN THE WETLANDS OF LIAOHE DELTA

The reasonable corridor density and pattern depend greatly on the landscape types in which they are distributed. In the paddy fields, corridors are reticulatedly distributed that partitioned the landscape with cells of several hundred meters to several kilometers of side length. Corridors mainly include branch canal, main canal and road. Reed fields (managed) have almost the same patterns of corridor distribution and composition with that of paddy fields except that the cells are larger. Functions of these corridors are mainly for irrigation and drainage, on which the ecosystems sustain. Hydrological corridors are also very important to the transportation of material, energy and species, and in the meanwhile, they are barriers to the connections of different ecosystems.

7 CONCLUSIONS

(1) Corridors are the most important element of the river delta landscape. Corridors have segmented the landscape, and changed the original situation of the natural landscapes. The construction of canals brings up large area of artificial wetlands, and postpones the succession from semi-natural wetland to dry-land. The desalinization process by drainage also led to the degradation of marsh.

(2) Corridors in the studied area can be classified into 8 types, with a total length of 5167.2 km, and corridor density of 1.25 km/km^2. The corridors are

mainly composed of irrigation and drainage canals, the total length of which is 2794 km, about 54.1% of all the corridors. The canals constitute the "artery" of the artificial and semi-natural wetland landscapes in the study area.

(3) The increase of corridors is the driving factor of landscape fragmentation. The canals and roads provide more convenient conditions for human activity, and thus deteriorated the disturbance in the wetlands. Apart from the transportation function of some corridors, such as canals and roads, others may act as barriers for materials, energy, and species, such as dikes. The corridors also have the ability to absorb and transform materials.

(4) The spatial distribution of corridors. The types of corridors are closely related to the landscape types they are distributed in. Canals are mainly distributed in the wetland landscapes, while roads are mainly in the built-up area. Dikes are always along rivers or coastlines. The corridors are most densely distributed wherever human activity occurs most frequently, such as in the artificial wetlands of paddy fields.

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