Journal of Environmental Sciences Vol.16, No.3, pp.490—496, 2004

ISSN 1001-0742
CN11-2629/X

Article ID: 1001-0742(2004)03-0490-07 **CLC number**: Q149 **Document code**: A

Landscape eco-environmental research on littoral zone in China

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Abstract: Littoral zone is a special land/ landscape type. As an important kind of land resource in support, the use of littoral zone is vital to eastern coastal areas in China. And the research on littoral zone relates to the key theory of landscape ecology. Based on the theory of landscape ecology, the littoral zone was divided into four types: mud flat, sand beach, bench, and biological flat. The distribution of each type in China is pointed out. As a typical open system, littoral zone has six landscape ecological characteristics: (1) high sensitivity to disturbance; (2) distinct edge effect; (3) spatial aggregation of natural resources; (4) frequently spatial oscillation; (5) obviously spatial heterogeneity; and (6) noticeably spatial differentiation. Some proposals are also put forward on the land use and development of littoral zone for environmental protection and environmental management.

Keywords: landscape eco-environment; littoral zone; China

Introduction

As for the concept of littoral zone, it is not identical in views in China till now. Some scholars consider littoral zone only as the new aggraded bottomland in the tideland (Chen, 1982; OGCCGI, 1996), while others clearly defined the downward depth of littoral zone in the sea (Zhu, 1986; Chen, 1989). In fact, from different points of view, seen as an area, littoral zone can be comprehended in a narrow or broad sense. On one hand, from the pure scientific view, littoral zone only refers to tidal zone. On the other hand, in a broad sense, from the view of exploitation, littoral zone not only refers to tidal zone, but also includes areas that are useful around the tidal zone (Fig.1). Littoral zone mentioned here all refers to the littoral zone in a broad sense.

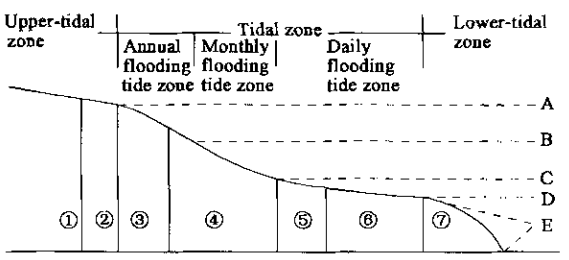

Fig.1 The sketch map of littoral zone

1. terrestrial forest; 2. coastal boscage; 3. bulrush and grass in salt marsh; 4. *Spartina anglica* and mangrove; 5. pioneer plant of mangrove; 6. bare beach; 7. seaweed, alga and plankton; A—high water of spring tide; B—high water of average tide; C—high water of neap; D—low water of spring tide; E—slope below seawater

With the rapid population growth and economic development, the quantity of cultivated land resource declines sharply in China, especially in eastern coastal areas. There is no time for hesitation to exploit land resources in support, in order to ensure the food security of China (Zhu, 2000). As an important component of coastal zone, littoral zone is an important kind of land resource in support in China. According to the national investigation, there is 2170900 hm^2 littoral zone in 11 coastal provinces (excluding Taiwan Province) along the four seas of China (EGLUAICLC, 1989). And most of littoral zone in China is being silted up, except some in the state of erosion. It is also estimated that littoral zone in China can be added up to about 30000 hm^2 annually (Wang, 1983). So we can get the conclusion that the quantity of littoral zone in China is abundant. Furthermore, the development of littoral zone is the most economical and feasible one in the six kinds of land resource in support in China (Lian, 1990; Lu, 1996). Therefore the development of littoral zone is an important project of land use in coastal areas (Wang, 1983).

The key theory of landscape ecology focuses on spatial heterogeneity and ecological integration (Golley, 1991; Hobbs, 1997; Wang, 1998). As the boundary of the sea and the continent, littoral zone is a distinguishing integrative system with distinct spatial heterogeneity, while the ecological integration is an effective way to realize the sustainable development of littoral zone. It seems the research of littoral zone relates to the key theory of landscape ecology. But there are little researches of landscape ecology on littoral zone (Peng, 2000). Therefore, based on the landscape ecology, the objectives of the present study are to (1) make a landscape ecological classification of littoral zone; (2) analyze the landscape ecological characteristics of littoral zone.

1 Landscape ecological classification of littoral zone

Landscape ecological classification is the division of landscape ecosystems. Its consequence in space is the combination of different land types in an area, that is land

Foundation item: The National Key Project for Basic Research in China (No. G2000046807) and the Key Project of National Natural Science Foundation of China (No. 90102018)

mosaics (Forman, 1995). It is agreed that landscape ecological classification deepens traditional land classification (Wang, 1996; Xiao, 1998; Fu, 2001). It is the basis of landscape research, which comprehensively reflects the genetic landscape characteristics and the direction of landscape evolution.

According to the characteristics of material components and species distribution of landscape matrix, littoral zone can be divided into 4 basic landscape ecological types.

1.1 Mud flat

Mud flat is also called tidal flat. It specially refers to the shoal of tidal zone in muddy coast, which covers over 80% of littoral zone in China(Zhang, 1991). Tideland shoal in muddy coast, which is about 4000 km in China, can be divided into mainly two types: plain type and embayment type(Zhu, 1986). The former distributes in the estuary of rivers, such as Liaodong Bay, Bohai Bay, Hangzhou Bay, and the seacoast of Jiangsu Province; the latter distributes in some bays of Zhejiang, Fujian, and Guangdong Provinces (Wang, 1990).

In general, mud flat is soft, broad (5—10 km), and of great viscosity. Its bearing capacity is low. The size of component grain is small, from arenaceous (4—63 μm) to silty (<4 μm), which is easily to be lifted by stormy waves and be suspended in water. The gradient of mud flat is very small (0.15‰—1‰), with distinct tidal process and developed tidal creek and pothole. And tidal bedding, the characteristic sediment structure, comes into being, which mainly is the bedding of thick, middle, thin, and minute powder sand, with only a little clayey grain (<4 μm) (Ren, 1985).

The soil of mud flat is well developed, and it is mainly marsh tidal saline soil. There is also meadow soil distributed in the estuary of rivers where water resource is abundant. The component grains of the soils are thin, with high organic matter content(1%—2%) and low salt content (2‰—5‰) (Zhang, 1994). There are always some salt tolerant marsh plants in the high land of mud flat, such as *Phragmites communis* and *Suaeda salsa*, which provide the wetland habitat for such wide animals as *red-crowned crane* and *Elaphurus davidianus*. It also can be used for agriculture. There are a lot of marine creatures buried or living in caves of the middle and low land of mud flat, which are adapted to marine aquaculture.

1.2 Sand beach

Sand beach is also called coastal beach, which refers to the tideland shoal of sandy coast. Sand beach is a component of rock coast, which alternates with bench. In China, sand beach mainly distributes in the following areas: from Laoyingyu to Chengshantou and from Longtou to bayou of Yinma River in Liaoning Province, from Hutouya to Shuangdaowan in Shandong Province, from Liangyu bayou to Xinzhuang bayou in Jiangsu Province, Zhenhai in the south of Qiantang River, from Meihuajiao to Jiangtian in Fujian Province, west coast in Taiwan Province, from Haifeng to Huilai and from Wuchuan to Dianbai in Guangdong Province, east and west coast in Hainan Province, Beihai in Guangxi Province and so on.

Because of the component grains mainly come from coastwise tide and the sea, the diameter of sand is more than 60 μm. In general, the area of sand beach is small with narrow breadth(2—5 km) (Deng, 1988), and the gradient of sand beach surface is 5‰. The ridge system of sand beach is well developed and sand dam is developed concomitantly with lagoon. There is mainly saline soil with short soil-forming time. It has low organic matter content (<5‰) and high salt content(8‰—10‰) (ECSCNRFV, 1995).

Sand beach always lies in areas suffering from strong sea dynamics, and the materials in beach surface are often in the process of recombination under the action of stormy waves (ECSCNRFV, 1995). So it is not adapt to the growth of plants. But there are still many kinds of creature, and it is adapt to the growth of benthos, especially the aquaculture of economic seashell. Meanwhile, it is an important land use of sand beach to develop sand mining and coastal tourism, especially bathing beach.

1.3 Bench

Bench mainly lies in the area of rock coast facing the wind and wave. It results from the erosion of seawater dynamics to rock coast and constant backing off of the latter. Bench coastline is about 5000 km long, over 1/3 of all coastline in China(ECSCNRFV, 1995). It mainly distributes in the south of Liaodong Peninsula, from Shanhaiguan to Hulu Island, Jiaodong Peninsula, Lianyungang in Jiangsu Province, south of Hangzhou Bay, and eastern coast of Taiwan.

With steep beach surface, there are thin sand and gravel or shiver of rock on the base of rock coast, and channels are developed. But no soil can be developed in bench. Because of the difference of many factors, such as lithology, energy of wave and microlandform, the breadth of bench ranges from meters to kilometers.

There is little creature in bench. But on lower-tidal zone of bench, there are many flat mesas and bevies of islands and reefs, which are the good places for sea creatures to prey, inhabit and propagate. It is traditionally breeding area of alga and marine animals, adapting to the growth of many kinds of alga, seashells, fish, shellfish and echinoderm. On the other hand, with favorable conditions, bench can be considered to develop ports of deep water, to generate electricity with the energy of wave and tide, and to develop seashore tourism.

1.4 Biological flat

Biological flat is a special type of littoral zone with high biodiversity and biology quantity, where one or several kinds of creature grow and propagate in such a great deal that they gradually form the climax ecosystems, which comprise

landscape matrix of biological flat. At present, there are mainly two kinds of biological flat, coral reef flat and mangrove flat.

1.4.1 Coral reef flat

Being an important component of coral reef coast, coral reef flat is a special biological coast in tropical sea, which comes from the accumulation of coral and its chipping. Coral reef flat distributes mainly in areas far from estuaries in South China Sea Islands and Hainan Province, and fragmentarily in coast of Taiwan and Penghu, Guangdong and Guangxi.

In general, coral reef flat is narrow, no more than 1000 m(Zhang, 1994). There is thin, or even none sand layer on the surface. In coral reef flat, reef flat is well developed, soil undeveloped, and little plant is grew. But there are abundant sea creatures with high economic value, which can be used for ornamentation, food, medicine and material of industry. So coral reef flat is an important place for fishing and breeding. Meanwhile, it is also a significant area for tourism and scientific research, along with the construction of ocean parks or protected area in coral reef.

1.4.2 Mangrove flat

Mangrove flat comes into being after mangrove grows and propagates a great deal in silty tidal flat in tropic and subtropics, appearing concomitantly with tidal flat. Mangrove flat distributes mainly in the ports and bayous well protected from wave in Hainan, Guangdong, Guangxi and Taiwan gulf, and Fuding of Fujian Province is its north limit of natural distribution. But now it can distribute in Leqing Bay in south of Zhejiang Province after manual cultivation.

The sea power in mangrove flat is not strong because mangrove can block tide. So tidal channel developed with evident alluvium, and the breadth of appearing surface is about 1—5 m. Salt soil is developed, which mainly are clunch or loam with low salt content (1‰—2‰), high organic content (2‰—5‰, highest to 14.5‰) and acid reaction (pH 2.5—6.0) (Ba, 1997). The communities in mangrove flat is distributed zonally in evidence: salt-resistant continental plant grow in the area up the average high tidal line, mangrove grow in the lower margin of high tidal area and middle tidal area, and the low tidal area is bare flat which is the habitat of many sea creatures and birds, except its front margin where grow some pioneer mangrove. In case of protection of its ecological function, mangrove flat is adapted to fishery and tourism, especially with the construction of mangrove nature reserve.

Along with the spread of *Phragmites communis* in Liaohe Delta (Zhang, 1990), and the quality improvement and spread of *Spartina anglica* in Jiangsu Province (Zhong, 1983), the components of communities in such areas tend to be complex. Ultimately, new types of biological flat come into being, such as *Phragmites communis* flat and *Spartina anglica* flat, whose landscape matrix respectively is *Phragmites communis* ecosystem and *Spartina anglica* ecosystem.

At present, four types of littoral zone in China can be utilized and developed in 18 kinds of land use types involved in 12 kinds of industries(Peng, 2000) (Fig. 2).

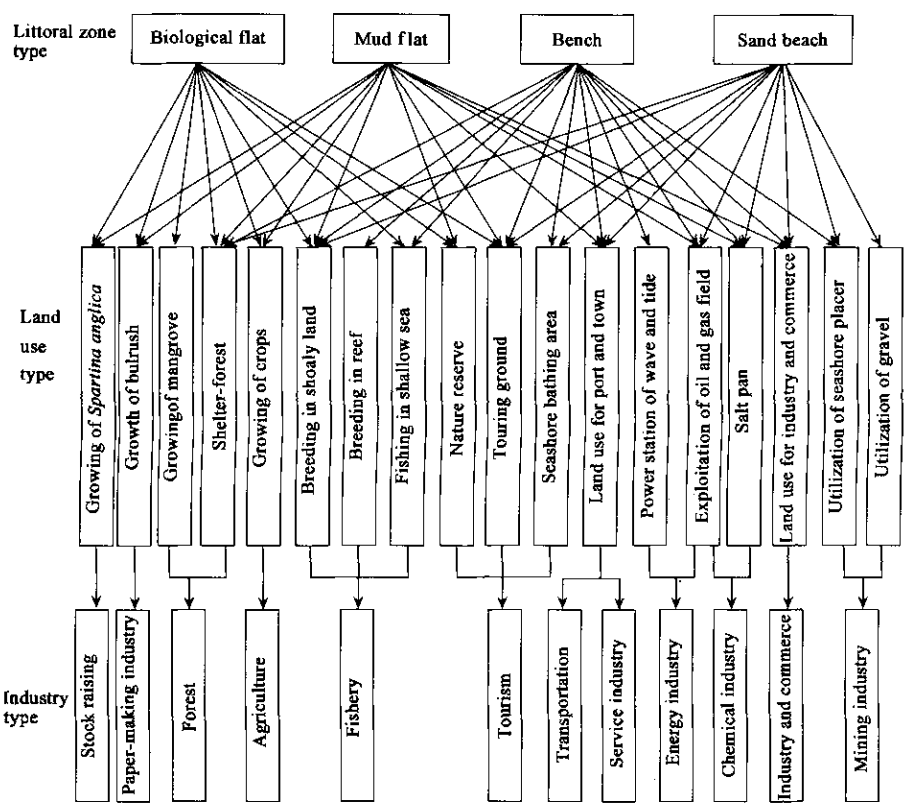

Fig.2 Land use in different kinds of littoral zone

2 Landscape ecological characteristics of littoral zone

Landscape ecology examines relationship between landscape patterns and ecological process (Forman, 1986; Turner, 1989; Gustafson, 1998). Scale, pattern and process are keywords with the highest frequency in landscape ecology (Risser, 1984; Turner, 1989; Pickett, 1995; Wang, 1997; Wu, 2000). Therefore the key of landscape ecology is to analysis landscape ecological pattern, process and their relationship. Under the reference of landscape ecological theories and emphasizing on landscape pattern and dynamics, the littoral zone has six landscape ecological characteristics as a typical open system.

2.1 High sensitivity to disturbance

Before the utilization of littoral zone, close exchanges of matter and energy occur between shoal land and ocean-continent-atmosphere system, and a certain food chain and ecological balance forms and holds in littoral zone. Furthermore, the exchanges of matter and energy between littoral zone and the ocean are stronger than that between littoral zone and the continent.

After human utilization, littoral zone and the ocean-continent-atmosphere system keep the close exchanges of matter and energy through food chains including human being. The exchanges of matter and energy between littoral zone and the continent are stronger than before. Along with the understanding of economic value of natural resources in littoral zone, especially some creatures with high economic value, human beings more and more largely use natural resources, and the formation and development of natural resources are affected or controlled by human activities in some extent. Therefore, the original ecological balance in littoral zone is broken and a new open system far away from system balance comes into being. According to the theory of dissipation structure, littoral zone should exchange matter and energy constantly with external environment through the open system to forms a new system balance by the dissipation of matter and energy.

Littoral zone is the area with the most frequent and centralized exchanges of matter and energy in the ocean-continent-atmosphere system. Due to its much smaller size comparing with the system, littoral zone shows sensitive response to the coupling power of the ocean-continent-atmosphere system, which showed that littoral zone is affected deeply by internal and external power. The sensitivity to disturbance of littoral zone appears in many ways, such as high content of soil salt, few vegetation and weak resistance to disaster. In a long time, a series of natural phenomena and disasters intimidate the landscape of littoral zone badly, such as the global climate change, the raise of sea lever, earthquake, typhoon, rainstorm, storm tide and groundswell. What's more, the sensitivity of landscape to natural or human disturbance is strengthened by resource exhaustion, environment deterioration, and ecological unbalance resulting from unscientific utilization of littoral zone.

2.2 Distinct edge effect

Edge effect means the variety of some system components and behavior (such as density of community, biological productivity and biodiversity) resulting from the difference and consonance of some ecological factors (such as material, energy, information, opportunity and region) or system properties in the interaction area of two or several ecosystems, or other systems of different properties (Wang, 1985). Located in the edge of the sea and the continent, littoral zone is an ecotone, showing distinct edge effect: (1) Ecological environment of littoral zone is complex and highly changeable. Compared to the sea and the continent nearby, the landscape patches of littoral zone tend to be more complex and diverse along with the increasing of interface heterogeneity. There are near-continental environment at upper-tidal zone, near-marine environment at lower-tidal zone and continental-marine environment at tidal zone. Littoral zone keeps the power of spatial evolution under the help of sustainable input of material and energy from the sea and the land, which makes its ecological environment more complex and changeable. (2) There is high biodiversity in littoral zone. At the edge of the sea and the land, complex environment of littoral zone results in various edge ecosites and species. The diverse species not only come from marine or continental ecosystems, but also consist of some individual species and edge species. The increasing of species is bound to lead to the keen competition of species and further differentiation of edge ecosite, so more community can be hold in the same area, and biodiversity increases. It is reported that in China there are about 1590 kinds (belong to 310 families) of marine species in tidal zone, including 513 kinds of mollusc, 358 kinds of alga, 308 kinds of shellfish and 61 kinds of fish (Ba, 1997). And there are more than 500 kinds of continental species, including 146 kinds of land vertebrate (GDEAJY, 1988). In many sections of littoral zone, especially biological flat, plenty of species are symbiotic. For example, more than 2000 kinds of species live together in mangrove flat, over 1 million kinds of species in coral reef flat, and about 3000 kinds of species in a single coral reef (Zhang, 1999). (3) Littoral zone shows high bio-productivity. With superior climate and plenty of organics and nutrient supplied by river, phytoplankton propagates in a great deal. With high biological productivity, littoral zone becomes the important place for fish, shrimp, shellfish and holothurian to swim back for food, habitat and propagation. In general, the use ratio of solar energy in littoral zone is 10 times of that in grassland in the temperate zone, and bio-productivity in littoral zone is 10—15 times of that in grassland in the temperate zone (Qin, 1999). It is also reported that net primary productivity of mangrove flat and

coral reef flat is equivalent to that of rain forest in the tropics (Zhang, 1999). In addition, it is estimated that the quantity of biological resources in littoral zone in China, is 533.8×10^4 t/a, which is more than the average of ocean (ECSCNRMV, 1995).

2.3 Spatial aggregation of natural resources

Littoral zone locates in the coupling area of continent-ocean-atmosphere system, which is a special area gathering natural resources together. It mainly shows as follows: (1) distinct superiority of land resource. There is large amount of land in littoral zone, and most are integrated together, which adapts to centralized exploitation in a large scale and intensive management with high technology. (2) Obvious oceanic climate, with small annual range of temperature (10—28℃), large amount of rainfall (474—1775 mm/a), abundant illumination [7—15 therm/(cm^2·mon)], plenty of heat (no-frost days 150—300 d, annual average temperature 8—25℃). (3) Diverse species and considerable quantities of natural resources. (4) Sufficient water and chemistry resource of seawater. (5) Natural and cultural tourism resource gathered together. (6) The unique passage to the ocean from the continent. All kinds of seaports in the world are built in littoral zone. (7) A lot of energy resources and mine resources, such as oil, gas, terrestrial heat, wind power and tide energy, and gravel and grit mine. (8) High environmental quality with little pollution.

2.4 Frequently spatial oscillation

The development of littoral zone is affected by many factors, such as the supply of sand, seawater dynamics, and primitive environment of coast, especially landform and vegetation. And the most important factors are the quantity of sand supply and size of tide range. It is reported that littoral zone develops widely where the size of tide range is big and the sand supply is abundant, and the erosion of wave and tide will narrow littoral zone when sand supply reduces (Wang, 1983; Ren, 1983). Therefore as the landscape edge of the ocean and continent, littoral zone is obviously unsteady under the action from the two parts, and its location is moving constantly. According to the characteristics of landscape dynamics, littoral zone can be divided into three types: stabilization type, erosion type and deposition type. Stabilization type few distribute in China. Majority of littoral zone in China are in deposition, mainly distributing in seacoast of North Yellow Sea, Liaohe River bayou, Yellow River delta, Yangze River delta, and Zhujiang River bayou, and seacoast of east of Heibei Province, Jiangsu Province, and Zhejiang Province. Erosion type is mainly sand beach, and it is reported that sand beach in Liaodong peninsula, Shandong peninsula and seacoast of Fujian Province are eroded at the average rate of 1—4 m/a (Wang, 1993). And littoral zone in both sides of old Yellow River bayou, changes from deposition to erosion because seashore dynamics increases and supply of sand reduces resulting from Yellow River's changing its course northward in 1955 and the southward movement of the estuary of modem Yangze River.

Besides sand supply and tide energy, many factors can lead to landscape dynamic of littoral zone, such as sea level change resulting from global climate change, underground funnel and seawater flowing backward resulting from over-exploitation of groundwater in coastal areas.

2.5 Obviously spatial heterogeneity

From the continent to the sea, because of the difference of distance to the sea, the flooding time by seawater and soil salt content are different in different sections of littoral zone in China. The communities growing there are distinct from each other. Therefore zoning in parallel to coastline becomes the characteristics of landscape structure of littoral zone, which shows obviously spatial heterogeneity.

According to the relative position to tidal line, from the continent to the sea, littoral zone can be divided into upper-tidal zone, tidal zone and lower-tidal zone, and tidal zone can also be divided into annual-flooding tide zone, monthly-flooding tide zone and daily-flooding tide zone (Fig. 1). Various zones differ in biological productivity, community and habitat. In general, the biological productivity of lower-tidal zone is highest, tidal zone lower and upper-tidal zone lowest.

Upper-tidal zone and annual-flooding tidal zone are flooded only 1—2 times by spring tide or storm tide, and tidewater does little action to soils where there is low soil salt content and high organic content. Therefore upper-tidal zone can be seen as continent environment, where mainly grows continental salt-resisting vegetation, such as grove and shrubbery. And annual-flooding tidal zone can be seen as near-continent environment, where grows swampy salt-resisting vegetation, such as *Suaeda salsa*, as well as *Spartina anglica* and mangrove once in a way.

Monthly-flooding tidal zone is the key zone affected by deposition and erosion with higher soil salt content and lower organic content, so it is the main distribution area of salt-resisting, flood-resisting and arid-resisting vegetation, such as *Spartina anglica* and mangrove. In this zone, creatures on land surface increase obviously, which are mainly bottom-inhabiting invertebrate. Bulrush is widely distributed in all zones mentioned above while mainly between upper-tidal zone and annual-flooding tidal zone.

Daily-flooding tidal zone is the widest and no soil is developed. Because of over flooded by seawater, it is merely bare except some pioneer plants on its upper part, such as *Spartina anglica* and mangrove. But with abundant biological resources, it is the main area of aquaculture.

Flooded by seawater all the year around, lower-tidal zone is a highly concentrating area of seaweed, alga and plankton.

Under natural conditions, the succession of locations of various zones is regular along with the deposition and erosion

of littoral zone. That is, in deposited littoral zone, they succeed to the sea in the sequence of lower-tidal zone, tidal zone and upper-tidal zone, while in eroded littoral zone succeeding to the continent in the sequence of upper-tidal zone, tidal zone and lower-tidal zone. Such successions can be blocked or controlled by human disturbance.

2.6 Noticeably spatial differentiation

Composed of different ecosystems, coastal zone shows distinct provincialism (Bartlett, 1988). In China, coastal zone winds from 41° N to 18° N and spans temperate zone, subtropics and tropics, which leads to obviously spatial differentiation of geographic environment. In different sections along the coastline, differentiation of littoral zone exits in many physical conditions, such as seashore dynamics, sand and water dynamics, height and breadth of appearing surface, soil texture, soil salt content, soil organic content, coast type, climate type, salinity of seawater, freshwater resource and community characteristics. Affected by latitude and south-north differentiation of climate zones, the spatial differentiation of littoral zone is mainly south-north differentiation (Sun, 1981; 1995) (Table 1). Spatial differentiation can also be considered as the appearance of landscape heterogeneity of littoral zone in a higher spatial scale.

Table 1 The difference of environment in various coastal zones of China

Items		Bohai Sea	Yellow Sea		East China Sea	South China Sea
			North Y.S.	South Y.S.		
Temperature of surface water near shore	Annual D-value, ℃	27—28	20	24	14—20	9—10
	In winter, ℃	-1—0	-1—2	3—5	6—14	16—22
	In summer, ℃	26—28	23—24.5	24—7	27—8	28—9
Density of surface water		21.5—24.5	23.0	24.0—24.5	<24.0	23.0—24.0
Salinity of surface sea water, ‰		27—30	29—31	30—31	32—34	32.5—34
Salinity of bayou water, ‰		<24 (Estuary of Yellow River)	27—29 (Estuary of Yalv River)		15.4 (Estuary of Yangtze River)	10.0 (Estuary of Pearl River)
Diaphaneity, m		<5	<8		3—15	20—30
Range of tide (average), m		2—3	2—7		4—7	1—4
Annual precipitation, mm		474—684	562—775		900—1342	625—1775
Solar radiation gross /(therm/month·cm^2)	In winter	7—8	5—7		7	8—9
	In summer	13—15	12—14		14—15	11—14
Air temperature	Annual D-value, ℃	27—28	20—21		16—20	10
	In winter, ℃	-4—0	-2—2	2—7	8—20	16—20
	In summer, ℃	24—26	23—24	24—26	26—29	28—29

3 Discussions

Landscape ecological characteristics discussed above is the internal law of littoral zone, which should be the basis of research on littoral zone in the view of landscape ecology, and also should be taken into account in the land use planning of littoral zone.

As an open system, littoral zone is sensitive to environmental disturbances. Distinct edge effect can not only enrich the biological resources of littoral zone, but also congregate so much pollution from the sea and the continent that it has become one of the most polluted areas in the world. Some actions must be taken to prevent littoral zone from environmental pollution, and more attention must be paid to environmental protection planning and design in regional development planning of littoral zone.

Although till now the total quantity of littoral zone in China is increasing year after year, we must get a clear understanding of the fact that the increase of littoral zone is under the expense of the water and soil erosion of the watershed. Once the soil erosion has been controlled (In fact, this is an important aim of many environmental protection actions in China), the sand in the rivers flowing into the sea will reduce and littoral zone will be in erosion instead of increasing. So we must recognize the resource limitation of littoral zone, highly value natural resources in littoral zone, and pay more attention to its land use planning and design.

As described above, kinds of natural resource centralize in littoral zone. There are several ways of utilization of littoral zone. Obviously, it is not recommendable that the use of littoral zone aims at only one kind of natural resource, for such kind of utilization is bound to leave other kinds of natural resource unused or wasted, especially those renewable resources. On another hand, it will also reduce the landscape diversity of littoral zone, weaken environmental stability, and increase the risk of economic exploitation of littoral zone. Therefore littoral zone should be exploited synthetically and in multi-levels, to realize the diversification of exploitation and economic structure of littoral zone, and to increase environmental stability and reduce the risk of land investment.

Littoral zone shows obviously spatial heterogeneity. In different sections of coast and different levels of landform, there is difference, and they adapt to different type of land use and environmental management. Littoral zone should be exploited by levels and sections. In each section and each level of littoral zone, the dominant resources should be fully used and avoid doing harm to the exploitation of other

resources. Furthermore, environmental management of littoral zone should aim to keep the ecological integration of the whole littoral zone, which can be realized by linking together each stage of exploitation through ecological food chain and industrial product chain.

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(Received for review April 8, 2003. Accepted May 10, 2003)