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The Present Situation and Ecological Restoration Methods of Marine Pollution in China

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Abstract

The trend of ecosystem degradation becomes more and more serious with the marine ecological environmental problem. The restoration of marine ecological environment has caused extensive concern of domestic and overseas experts; it is relatively weak at present in China comparing with abroad. The paper focuses on the main problems of our marine environment and summarizing the main means and problems of marine ecological restoration. It is suggested that it is necessary to develop the theory and practice of the marine ecological restoration, formulate the strategy of marine ecological restoration systematically to protect marine ecological system.

Keywords: Marine; Ecological restoration; Pollution; Situation; China

Introduction

The sea area in China is extremely wide with more than 300 million km2 including huanghai, bohai sea, yellow sea and east China sea and south China sea. With the fast development of marine economy and increment of actions on opening up marine, it leads to great contamination along the coastal areas, the marine ecological system suffers unprecedented threat and damage such as the exorbitant nutrient elements of nitrogen and phosphorus, eutrophication, increasingly impaired function of ecological system, high frequency of red tide, sharp decline in biodiversity, increment of harmful species and population density in marine ecological system and so on. The protection and restoration of the marine ecological system should have been taken measures immediately in China.

Present situation of offshore environmental pollution in China

Quality of seawater environment: The contamination of marine environment has been serious since 1990 in China; the area of offshore seawater lower than Grade One of the standard of seawater quality has reached from 100,000 km2 in 1992 to 202,000 km2 with a speed of 14.6% in average annual [1]. By the summer of 2012, the seawater environment is better overall, but the situation of coastal water is still serious. Area of Grade one of the sea water quality is nearly 94%,and the that of Grade Two ,Grade Three ,Grade Four of seawater is about 46,910 km2,30,030 km2and 24,700 km2 in turn. The areas of lower than the Grade Four are in the coastal areas of north of Yellow Sea, Liaodong Gulf, Bohai Gulf, Laizhou Bay, Jiangsu coast, Hangzhou Bay, the Pearl River estuary. The main pollution factors in the coastal areas are inorganic nitrogen, labile phosphate and petroleum. The quality of seawater in the central and southern South Sea and Spratly Islands is better; the factors of inorganic nitrogen, active phosphate, COD, and petroleum are at Grade One of seawater quality standard [2].

Pollution conditions of main estuary: Due to vast land-sourced pollutants carried by rivers to marine, two-thirds of coastal areas in China have been polluted since the end of the twentieth century. Liaohe estuary, Dalian Bay, Jiaozhou Bay, Yangtze River Estuary, Hangzhou Bay, Xiangshan Bay, Yueqing Bay, Minjiang Bay and the Pearl River Estuary appear in heavy pollution with a trend more and more serious. By 2012, the contents and kinds of pollutants carried by seventy-two rivers into coastal areas are CODcr of 1,388 million tons, ammonia nitrogen of 32.8 million tons, nitrate nitrogen of 228 million tons, nitrite nitrogen of 6.2 million tons, total phosphorus of 35.9 million tons, petroleum of 9.3 million tons, heavy metals of 4.6 million tons, arsenic of 3758 tons. The data of 50 rivers monitored for two consecutive years suggest that the pollutants of CODcr carried by rivers into coastal areas have decreased 14% in 2012 compared last year, but nitrate nitrogen and total phosphorus have increased 38%, 47% in turn.

Biodiversity and status of species in marine: The changes of seawater and sedimental environment will affect the survival of species in marine, and the pollutants have a cumulative effect on marine biological quality. The contents of pollutants in living beings reflect the living quality of them; the living quality of species that can be eaten by human beings has a direct effect on human beings. At present, the quality of living beings in marine appears a serious situation such as maladjusted structure of species, decrease of endangered species, exorbitant hazardous material remained in economic species and so on [3].

Condition of outbreak of red tides: In the year of 2012, it's found that the frequency of outbreak of red tides has reached 73 times, 12 times of them caused disaster and made an economic loss up to almost 2 billion yuan in China. The outbreak of red tides mostly occurred among May and September. In May, it's found 31 times and the areas reached 3,746 km^2. In June, it's found 11 times and the areas reached 3,909 km2.The types of alga's which caused red tides are michaelis karen bath, skeletonema costatum, noctiluca scientillans and so on.

Research Conditions of Marine Ecological Restoration

Marine algae in eutrophication control

Seaweed is an important primary producer in marine ecosystem, with its long life cycle and fast growth, it can absorb some nutrients such as N and P by photosynthesis in marine and it's also regard as an

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effective biological filter to nutrients. Each 1000t porphyra can remove 50~60t N and 10t P from marine, each 1000t laminaria japonica can remove 30~40t N and 3t P, each gracilaria verrucosa can remove 50~60t N and 3t P, and each enteromorpha prolifera can remove 45t N and 5.5t P [4]. Huang has studied the total nitrogen in aquaculture area near zhuhai where plant gracilaria verrucosa, laminaria japonica and porphyra, the result suggested that the average concentration of TN is about 4.076%~5.460% [5].

As the seaweeds can not only absorb the superfluous nutrients, promote the aquatic quality of aquaculture area ,but also produce high economic value, so artificial cultivation of seaweeds is a feasible biological treatment technology to seawater eutrophication. At present, the research on restoration of eutrophication with seaweeds in aquaculture area is very hot [6]. The large algae and aquatic animal (fish, shellfish and others) have complementary in ecology, it can absorb the superfluous nutrients discharged by animals, and the absorbed superfluous nutrients can be turned economic materials and also have the function of carbon fixation and oxygen production. Adjustment of aquatic pH value [7]. Xu suggested that when the N and P exist input, the growth speed of gracilaria verrucosa has an obvious acceleration and but the decrease of the nutrients concentration in aquatic areas [8].

The contents of N and P in algae in eutrophication area are much higher than low nutrient areas, especially obvious in the high nutrient marine areas of N and P [9]. Naldiu showed that the rigida can absorb a lot of N in eutrophication areas [10]. Based on the living habits and seasonal changes of different algae in the same eutrophication area, cultivating asparagus and porphyra yezoensis alternately and taking harvest to ashore can purify water effectively [11].

Marine algae in accumulation of heavy metals

The mechanism of heavy metals absorbed and accumulated by algae is fixed to the surface of algal cell or binded with intracellular ligand, and the hydroxyl radical played a major role [12]. Many algae can accumulate the heavy metal and purify the sea water of heavy metal contamination, but it is significantly different on the enrichment amount by various algae. Ulva and Enteromorpha compeessa have strongest enrichment of Co, Cr, Cu, Fe and a considerable enrichment of Zn, by culturing in seawater for 21 days with the concentration of Zn2+ 100ug / L, the maximum concentration of dry weight reached (580 to 680)×10-6ug/L [13]. Laminaria longicruris and fucus distichus have strongest enrichment of As and Cd, but a minimal amount of Hg enrichment [14].

There are many factors affecting the heavy metals accumulation by algae, such as temperature, pH, the anion and cation in the water, the form of heavy metals and different growth stages of algae [15]. Herrero [16] studied the bag chain algae at the pH of 4.5, 6.0 and the enrichment amount of Hg is 0.178×10^{-6} and 0.329×10^{6} respectively. Martin [17,18] has studied the fucus ve Huang has studied the siaulosus in Severn Estuary with persistent sampling analysis for 20 years, the results show that it has significant accumulation of Cd, Cu and Zn, and the effect changes with seasonal changes.

Marine algae in degrading of organic pollutants

Pavoni [19] analyzed the concentration of organic pollutants in ulva, gracilaria and sac chain algae which influenced by PAHs, PCBs and pesticides. The result showed that the ulva and sac chain algae have higher enrichment content up to 56×10^{-9}. Gracilaria and sac chain algae have relative high contents for PCBs and pesticides. Research suggested that DMP, DEP, DBP, DEHP can reduce the relative growth rate and content of chlorophyll of asparagus, but asparagus have a certain ability to accumulate these phthalates and the highest residues content in the body are 0.14×10^{-6}, 0.83×10^{-4}, 1.89×10^{-6} and 10.4×10^{-6} respectively. Also the content increasing with the treating time [20]. Radwan [21] found that there were many oil decomposing bacteria absorbed to the gracilaria, gelidium amansii Lamx., sargassum and other large scale algae, the common action of algae and bacteria can degrade petroleum pollutants effectively.

Mangrove Plants for Restoration of Contaminative Seawater

Mangrove plants are grown in tropical, subtropical intertidal zones with woody plants; they play significant roles in maintaining the ecological balance of marine ecosystem. The mangroves around the world reach the amount to 20 families 27 genera 70 species, China has identified the mangrove amounts up to 12 families 16 genera 27 species and 1 variety. Mangrove has good tolerance on the pressure of heavy metals, eutrophication and organic pollution [22].

Mangrove plants for the degradation of heavy metal pollution in coastal areas

Mangrove plants can absorb heavy metals in seawater and sediments by root, then through the process of cell wall deposition, vacuolar localization, chelating effect and antioxidant enzymes can reduce the toxicity of heavy metals which are absorbed and stored in the root and trunk, so it can restore the contamination of heavy metals effectively [23]. Chen guikui [24] used the sewage with Ni to irrigate avicennia marina, she found that the net absorption of avicennia marina plants to Ni increased with the increase of the concentration of sewage, and concentration of the root was the highest which accounted for an average of 58.67% of the whole plants. Macfarlane [25] studied that the enrichment capacity of avicennia marina to Cu, Pb, Zn increased with the rising concentration of heavy metals in sediments, and the dry weight accumulation concentration of root was balance to the sediments.

The ability of accumulation to heavy metals by mangrove plants rested with the species of plants, organs, forms of heavy metals and so on. Zhen [26] studied the absorption, accumulation and distribution of mangrove to Cr, Ni, Mn in the Natural Protection Area in Shenzhen Futian, the results showed that the accumulation concentration of Cr, Ni in three different types of community leaf layers in ascending order of kenaelia candel, aegiceras corniculatum, avicennia marina, the ascending order of Mn is aegiceras corniculatum, avicennia marina, kenaelia candel. Lin [27] used the nutrient solution with Cd to dispose kenaelia candel, the accumulation concentration of Cd in different parts of organs increased with the raise of concentration of treating solution, but the contents in different organs were different in an ascending order of leaf, stem, hypocotyls root. The Cd content in root was 11.2~18.7 times higher than the substrate concentration and showed an apparent accumulative effect.

Mangrove plants for absorption of N, P

A large number of land-based pollutants discharged into offshore are the most important pollution source, establishing mangrove intercepting pollution belts in coastal and estuarine areas can control eutrophication. Mangrove plants can grow normally under high nutrient conditions with strong anti-pollution ability, beside the absorption and accumulation of N,P. The whole ecosystem plays a combined effect on eutrophication control, and it has an strong ability to absorb and accumulate nutrients such as N and P [28]. Ye[29] presented that the removal efficiency of kenaelia candel and bruguiera lam to N,P in marine is higher than in fresh water, and the ability to absorb N by kenaelia candel is better than reed both in marine and fresh water. Zhang [30] presented aegiceras corniculatum was irritated by the sewage with high concentration P ,and the P content in stem had an obvious increase, it showed that aegiceras corniculatum can absorb and accumulate P in solution effectively.

High nutrient generally can promote the growth and activity of mangrove plants. Chen [31] simulated the wetland by using artificial sewage to irritate avicennia marina continuous which grown well and showed the characteristics of good tolerance and adaptability. Mangrove plants with the compound system of planting-breeding mode can reduce the nutrient concentration of N, P in water and improve the water quality. The circle of substances in the compound system is multifunctional, and the mangrove itself can absorb nutrients, the other factors in system played important roles in treating sewage [32]. Meanwhile, the mangrove plants can reduce BOD and COD effectively [33]. Jin [34] used the sewage of concentration of CODCr 210mg/L, BOD5 95mg/L, TN 15mg/L to irritate sonneratia caseolaris, aegiceras corniculatum and bruguiera lam for 1 year, the height of three corresponding plants increased 134cm,32cm and 21cm in turn.

Assessment on Restoration of Typical Marine Ecosystems in China

As we all know, marine ecosystems are one of China's most valuable resources, providing a wide range of services and benefits to human and other species. However, the explosion of industrialization and urbanization have created severe environmental problems along China's vast coastline since late 1970s.Consequently, marine ecosystems have been seriously stressed and degraded. In recent years, For example, about a total area of 2.19 million costal wetland area of China has been destroyed and occupied due to enclosing the sea and building cropland projects [35]. As a result, the covering area of mangrove areas decreased by 68.7% during 1950-1990 in China. For avelliating and restoring the ecosystems, China has launched a series of restoration programs in order to preserve and restore the qualities of these significant ecosystems. Subsequently, a framework for assessing marine ecosystem restoration projects was formed as following:

- Enough baseline information collected, including survey of historical or pre-disturbance conditions, degree of present alteration, present ecological conditions and other factors?
- Analysis of causes, types, process and degree of the degradation;
- Determination of clear goals and performance criteria, brief, which is achievable and measurable as much as possible;
- Restoration scheme covering engineering design, schedule and budget;
- Assessment of the ecological effect of restoration project;
- Monitoring program developed and implemented?
- Adaptive management conducted during the whole restoration process;
- Application and spread of the restoration results.

Program I: Mangrove restoration in Quanzhou Bay

Quanzhou Bay is located in the southeastern coastal area of Fujian province, China, covering 128 km2, and this area was historically inhabited by a large area of mangroves. In the 1960s, there were more than 600 ha mangroves in Quanzhou Bay, but the area decreased sharply due to heavy reclamation and mariculture since then [36]. The more serious damages to mangroves in Quanzhou Bay occurred after 1980s, when the population boom and rapid economic developments started in the coastal areas of China. Until the end of 2001, only 17.112ha mangroves were recorded , and the species diversity was also very low, dominated by Aegiceras comiculatum with few Kandelia candel and Avicennia marina . In 2002, a series of transplantation efforts were initiated by local governments in order to restore mangrove ecosystem in Quanzhou Bay.

With the detailed investigation for Quanzhou Bay, several important restoration principles have been focused on, which including the selected mangrove species, planting density, scientific detailed date of site such as hydrological factors and so on. The mangrove species selected should contain properties of cold resistant, cold tolerant, ocean orientated and ecologically safe. According these demands, the selected mangrove species including three local ones (*A. comiculatum*, *K. candel* and *A. marina*) and three introduced ones (*Acanthns ilicifoliu,Bruguiera gymnorrhiza* and *Rhizophora stylosa*) were chosen for transplantation. The survival rates could reach over 83% for *A. comiculatum*, when transplanted with small natural seedlings, and for K. candelwhen transplanted with hypocotyls. Planting density was also proven to be very important for successful transplantation, and proper planting spaces of 0.5 m ×1.0 m favored the survival and growth of both *A. comiculatum* and K. candel. Faunistic impacts have also been taken into account during species selection, because these impacts may change mangrove vegetation structure and ecosystem function [37]. Mono-species and alien species are often used in the mangrove reforestation in China, which reduces the biodiversity of replanted forests [38].Since 2006, the transplantations were successful with a total area of 300 ha between 2002-2006 [39].They are still present and continue to spread. Until 2008, the average tree height has reached 1.0 m, and the crab population density has increased by nearly 5 times compared to that in 2002.

Program II: Entrophicated semi-closed bay restoration in Xiamen western waters

During the past 50 years, the reclamation largely occurred in Xiamen western waters, with three dikes constructed and large areas reclaimed in this are. Currently, Xiamen western waters has become into a semi-closed bay area. All these reclamation activities has decreased the tidal prism and thus the exchange rate of seawater between inside and outside the bay, followed by intensive eutrophication. In 1980, N/P in the restoration site was about 64, but this ratio has decreased to 24 until 2003, which was very favorable for algal blooming. Actually, red tide occurrence has been recorded every year since1986 in this area .In order to restore the eutrophicated waters in Xiamen western harbors, a trial restoration effort was conducted during 2007-2008.

In the case of Xiamen western waters, the choice of macro algae species have several properties. The first one is that it needs to be of high economic value and to be of high efficiency in N and P absorption and utilization. Following the demands, *G. lemaneaformis* was selected. The seedlings were attached onto the polyethylene ropes, which were bound and cultured on the anchored raft with the size of 50-65 m × 4.5-5.5m,respectively.The very similar choices of species and cultivation techniques were used in other programs[40].The growth of macro algae were measured once a week. Total nitrogen (TN) and phosphate (TP) concentrations in the algae and water body around (5 m away from the raft) were monitored every 15 days, and one reference site was chosen about 1.0 km from the culture site. The results showed that

G. lemaneaformis grew very quickly, and 1 ha of macro algae absorbed nitrogen of 109.7 kg and phosphate of 7.2 kg after three months. After one month, TN and TP concentrations in the water around the algae culture location decreased significantly compared to those at the beginning, and these parameters were also much less than those in the reference site [39].

Problems of Marine Ecological Restoration in China

In recent years, with advanced technical's and programs applied in restoration of marine ecological restoration in China, the ecosystems recovered better and better. However, there are also many defects in these programs:

- Generally, no comprehensive insights into ecological, socioeconomic, political factors were made during the planning stage. The objectives and targets of the programs were consequently very unclear.

- Ecological functions of the coastal ecosystems were generally neglected. Actually, the ultimate objective of a restoration project should be to restore the ecosystem, including the ecological structure, ecological function,

- Most of the programs focused on the restoration measures, but little attention was paid to degradation causes diagnosis, monitoring strategies and techniques, assessment and evaluation, and management.

- Monitoring and performance assessment were carried out nearly in all marine ecosystem restoration projects, but the adaptive management and results dissemination are far from enough.

Prospect for Marine Ecological Restoration

Application of phyto-remediation to treat marine pollution has to choose the plants which have the characteristics of tolerance on high salt concentration and strong ability to absorb pollutants. The theory, practice, evaluation research on marine ecological restoration systematically, summarizing the success experience abroad, drawing up the guidelines for restoration of typical marine ecosystem should be carried out.

References

1. Wang M, Hu BQ (2006) Status, reasons and restoration of marine environmental pollution in China. Journal of Ocean University of China.
2. Quality bulletin of marine environment in China [EB/OL]. Network of marine information.
3. Xu C, Qiu ZY (2004) The sustainable development of environment and coastal mudflat. Development and management of marine 6: 9-10.
4. He P, Xu S, Zhang HY (2005) Application Research of algae in the marine ecological restoration and comprehensive farming in seawater. Fishery modernization 4: 15-16.
5. Huang D, Huang XP, Yue WZ (2005) The significance of concentration of TN and TP in algae to restoration of offshore environment. Taiwan Strait 24: 316-321.
6. Yang Y, Song JM, Lin XT (2005) The ecological roles of marine seaweed in offshore environment. Marine Environmental Science 24: 77-80.
7. Zhou Y, Yang HS, Hu HY (2006) Bioremediation potential of the macroalga Gracilaria lemaneiform is integrated into fed fish culture in coastal water of north China. Aquaculture 252: 264-276.
8. Xu YJ, Qian LM, Jiao ZN (2005) The effect to eutrophication with nutrient pluse at different stocking densities in Gracilaria lichevoides. Taiwan Strait 24: 150-156.
9. Glathery M, Oldendorf KJ (1992) Physiological controls on the distribution of the macroalga Spyridea hypnoides pattems along a eutrophication gradient in Bemuda. Marine Ecology Progress Series 87: 173-182.
10. Naldi M, Viaroli P (2002) Nitrate uptake and storage in the seaweed ulva rigida. Agardh in relation to nitrate availability and nitrate content in eutrophic coastal lagoon. Experimental Marine Biology and Ecology 269: 65-83.
11. Yang Y F, Fei XG (2003) Research and Prospect of large algae in eutrophic Mariculture Zone. Journal of Ocean University of China 33: 53-57.
12. Giusti L (2001) Heavy metal contamination of brown seaweed and sediments from the UK coastline between the Wear River and the Tees River. Environment International 26: 275-286.
13. Phaneuf D, Cote I, Dumas P (1999) Evaluation of the contamination of marine algae from the St Law rence River and likely to be consumed by humans. Environmental Research Section 80: 175-182.
14. Amadofilho G, Karezc S (1997) Effects on growth and accumulation of zine in six seaweed species. Ecotoxicology and Environmental Safety 37: 223-228.
15. Mehta S K, Gaur JP (2005) Use of algae for removing heavy metal ions from wastewater. Progress and prospects. Critical reviews in Biotechnology 25: 113-152.
16. Herrero R, Lodeiro P, Castro C R (2005) Removal of inorganic mercury from aqueous solutions by biomass of the marine macroalga Cystoseira baccata. Water Research 39: 3199-3210.
17. Martin M H (1997) Concentration of cadmium, copper lead, nickel and zinc in the alga fucus serratus in the sevem esruary from 1971 to 1995. Chemosphere 34: 325-334.
18. Crist RH, Martin JR, Carr D, Watson JR, Clarke HJ et al. (1994) Interaction of Metals and Protons with Algae. 4. Ion Exchange vs Adsorption Models and a Reassessment of Scatchard Plots; Ion-Exchange Rates and Equilibria Compared with Calcium Alginate. Environ Sci Technol 28: 1859-1866.
19. Chen JR, Fany Tendeyong , Sotira Yiacoumi (1997) Equilibrium and kinetic studies of copper ion uptake by calcium alginate. Environment and Science 31: 1433-1439.
20. Schiewer S, Volesky B (1995) Modeling of the proton-metal ion exchange in biosorption. Environ Sci Technol 29: 3049-3058.
21. Wurl O, Obbard JP (2004) A review of pollutants in the sea-surface microlayer (SML): a unique habitat for marine organisms. Mar Pollut Bull 48: 1016-1030.
22. Pavonib, Calicetim, Spernil (2003) Organic micropollutants in seaweeds of the lagoon of Venice. Oceanologica Acta 26:585-596.
23. Wu Z.,Yang Y.,Nie Xi P, et al. Research on ecological toxicology of phthalates in Gracilaria. Marine Science,2006, 30:46-50.
24. Radwan SS, Hasan RH, Alamah SS, Al-Dabbous S (2002) Bioremendiation of oily seawater by bacteria inmobilized in biofilms coating macroalgae. International Biodegradation 50: 55-59.
25. Liao BW, Zheng SF, Chen YJ et al. (2005) Research on progress of mangrove wetland restoration technology. The science of ecology 24: 61-65.
26. Zhang FQ, Wang YS, Yin JP (2005) Progress of research on heavy metal pollution in mangrove plants. Research of Yunnan plant 27:225-231.
27. Chen GK, Chen GZ (2005) Simulation analysis of distribution and circula of Ni in Avicennia marina wetland system. Marine Environmental Science 24:16-19.
28. MacFarlane GR, Pulkownik A, Burchett MD (2003) Accumulation and distribution of heavy metals in the grey mangrove, Avicennia marina (Forsk) Vierh: biological indication potential. Environ Pollut 123: 139-151.
29. Zheng WJ, Lin Peng (1996) Cumulation and distribution of Cr, Ni, Mn in Shenzhen Futian. Journal of Applied Ecology 7:139-144.
30. Lin ZF, Zhong P, Yin KD et al. (2003) The effect of accumulation and toxicity on methamidophos mixture by kandelia cande. Ecological Sience 22: 346-348.
31. Chu HY, Chen NC, Yeung MC, Tam NFY and Wong YS (1998) Tide-tank system simulating mangrove wetland for removal of nutrients and heavy metals from wastewater. Water Science and Technology 38: 361-368.
32. Ye Y, Tam NF, Lu C (2003) Effects of livestock wastewater on seedlings of two mangrove species]. Ying Yong Sheng Tai Xue Bao 14: 766-770.
33. Zhang JH, Li M, Chen GZ (1999) Absorption and purification of N, P in sugar wastewater in mangrove wetland. Chongqing Environmental Science 21: 39-41.
34. Chen GK, Chen GZ (2005) The effect on physical and chemical properties of soil with the release of Artificial sewage into Avicennia marina. Marine Environmental Science 24: 26-28.

35. State forestry Administration of China, 2004, Statistical report of forest resource. State Forestry Administration of China, Beijing, People's Republic of China.

36. Zhuang X (2008) A brief introduction of mangrove restoration and conservation strategies in Quanzhou Bay. Anhui Agricultural Science Bulletin14: 54-54.

37. Cannicci S, Burrows D, Fratini S et al. (2008) Faunistic impact on vegetation structure and ecosystem function in mangrove forests:a review. Aquatic Botany 89: 186-200.

38. Chen S, Uitto J (2002) Governing marine and coastal environment in China: building local government capacity through international cooperation. China Environmental Series 67-80.

39. Li W, Cui LJ, Zhang MY, WANG Yi-Fei (2009) Landscape pattern change of mangrove wetlands and its surrounding region in the estuary of Luoyang River, Fujian Province. Wetland Science 7: 53-59.

40. Fei X (2004) Solving the coastal eutrophication problems by large scale seaweed cultivation. Hydrobiology 512: 145-151.