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Development of Ecological Fishery in Poyang Lake Area

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Abstract Through in-depth analysis on history and current situations of fishery development in Poyang Lake area, this paper presents location, resource and environment advantages in development of ecological fishery. According to orientation of leading functions, Poyang Lake can be divided into breeding development, capture operation, enhancement protection and ecological rehabilitation functional zones. In accordance with industrial foundation and ecological advantages of cities and counties in Poyang Lake, it determines the reasonable distribution of 8 leading industries: river crabs, shrimps (Procambarus clarkia), eels, Pengze crucian carp, Siniperca chuatsi, Channa argus, Ietalurus Punetaus, and pearl. On the basis of systematically summing up exploration experience, it comes up with the development path "ecology oriented fishery and industrialization oriented ecological fishery" for ecological fishery in Poyang Lake area. It proposes a series of key technological measures, including reducing fertilizer and drugs, increasing output and benefits, low consumption and emission, high quality and safety, and standardization, to realize a benign cycle of "cost saving, benefit increasing, quality improving and low carbon" and the multi-win objective of coordination between ecology, economy and society.

Key words Ecological fishery, Fishery zoning, Development mode, Key technologies, Poyang Lake area

Poyang Lake is the largest fresh-water lake in China. In a narrow sense, Poyang Lake only includes 11 counties (Yongxiu, De'an, Xingzi, Jiujiang, Hukou, Duchang, Poyang, Yugan, Jinxian, Xinjian and Nanchang) along the lake. In a broad sense, it includes 38 counties (cities and districts) of Nanchang, Jingdezhen, Jiujiang, Yingtan, Ji'an, Yichun, Fuzhou, Shangrao, and Xinyu cities, covering an area of 51 200 km^2. The broad sense of Poyang Lake is more popular at present and is deemed as the concept of Poyang Lake ecological economic zone[1]. This zone covers 30% area of Jiangxi Province, but bears nearly 50% population of Jiangxi Province, creates 60% of economic aggregate, so it is a major agricultural product production base of Jiangxi Province, and also a major fishery production area of Jiangxi Province[2]. In order to bring into full play resource and location advantages of Poyang Lake, explore new mode of ecology and economy coordinated development and integrated development of Poyang Lake area, and realize strategic goal of rise of Jiangxi Province in central China, Jiangxi Provincial Party Committee and provincial government proposed the *Tenth-Five Year Plan for Deep Development of Poyang Lake Resources in* 2002, and made the strategic decision of construction of Poyang Lake Ecological Economic Zone in 2008. The decision formally approved by the State Council in the end of 2009 lifts the construction of Poyang Lake Ecological Economic Zone to national strategy. According to functional orientation of Poyang Lake Ecological Economic Zone, regional high quality agricultural product production base is determined as the ecological industrial construction project that gives priority to development. Fishery, as the basic industry of Poyang Lake area, with great resource development potential, has become an alternative industry for agricultural structural adjustment after restoring the reclaimed land to lake, and becomes an industry for people shaking off poverty and setting out on the road to prosperity[3]. Therefore, scientific and reasonable use of water and fishery resources in Poyang Lake area and energetic development of ecological fishery are major parts of building regional high quality agricultural product production base.

1 History and current situations of fishery development in Poyang Lake area

1.1 Development history of fishery in Poyang Lake area

With clean and fresh water and fishery resources, Poyang Lake has been well-known for Tenualosa reevesii, Coilia nasus, turtle, Siniperca chuatsi, and slender silvery-white fish. Superior fishery production condition gives Poyang Lake the name of "land of rice and fish". In history, Poyang Lake was always one of the areas with developed fishery in China. It has accumulated rich cultural heritage and technical experience. From the foundation of new China to the early stage of reform and opening-up, the fishery in Poyang Lake area was mainly capture. Due to increase in population pressure, and predatory resource development modes, such as excessive fishing and reclaiming parts of a lake for use as farmland, spawning ground and feeding ground for commercial fishes in the lake area have been damaged seriously, leading to constant decline of fishery resources in Poyang Lake[4-5]. Preliminary statistics indicates that from 1961 to 1984, spawning ground of Poyang Lake reduced from 37 places and 52 000 ha to 17 places and 26 000 ha (reaching 50%) due to reclamation of the Lake. Ac-

Received: October 11, 2013 Accepted: December 8, 2013
Supported by National Key Technology Research and Development Program of the Ministry of Science and Technology of China (2012BAD25B07); Special Project of Public Welfare Industry of Ministry of Agriculture (201303056); Project for Science and Technology Entering Parks in Jiangxi Province (2009DYN02300).

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cording to calculation, this results in annual loss of reserve resources up to 6500 tons, equivalent to 36.03% of the annual mean catches in the lake area. For the famous slender silvery-white fish of Poyang Lake, the spawning area reduced for 40% in recent years, and resources decline seriously. In the same period, fishing ground of Poyang Lake decreased about a half, while the quantity of fishing boats increased more than one time. At the early of the 1960s, the whole lake had 8 000 fishing boats. By the early of the 1980s, it exceeded 20 000 fishing boats. In 1978, the quantity of harmful fishing tackles was 27; in 1981, it rose to 809; in 1983, it soared to 2 400; in 1985, it surged to 9 889. Increase in capture intensity, especially sharp increase of harmful fishing tackles, badly damages fishing resources in Poyang Lake.

After 1978, the State adjusted agricultural policy, encouraged diversified economy, and started caring about conservation and reasonable use of fishing resources in Poyang Lake. Government at all levels in the lake area has taken many measures to control development of capture fishery and reduce capture intensity. Effective resource conservation measures make fishery resources in Poyang Lake able to rehabilitate. Through implementing protection of water environment, strengthening fishery administration, and opening the market circulation, it has realized reasonable use of fishery resources in Poyang Lake, promoted great-leap-forward development of aquaculture in the lake area. A good many commercial fish production bases is founded in the lake area. And a lot of specialized rural fish breeding households appear. The intensification degree of fish breeding becomes higher and higher, and output of aquaculture takes up a larger proportion in total output of fishery in the lake area year by year. From the 1950s to the early of the 1960s, the aquaculture output was less than 20%; in the middle of the 1970s, it accounted for 38.8%; since 1984, the aquaculture output had exceeded the capture production. Due to energetic development of aquaculture, with constant drop of capture output, the total fishery output in the lake area rises year by year. From the end of the 1950s, the annual total output was 21 300 tons; in the 1960s, it reached 24 500 tons; in the 1970s, it dropped to 22 500 tons; in the end of the 1990s, it rose to 47 900 tons.

1.2 Current situations of fishery development in Poyang Lake area After it came to the new century, Jiangxi Provincial Party Committee and provincial government attached great importance to fishery development of Poyang Lake area. In 2001 and 2002, they held on-the-spot conferences in Jinxian and Jiujiang counties for deep resource development of fishery resources in Poyang Lake, which play an active role in promoting deep resource development in the lake area. With extension and application of advanced and practical fishery technologies, industrial structural adjustment has made considerable achievements in the lake area. It has basically realized reasonable development of resources suitable for fishery in water area, low-lying land and grass beaches. Fishery output value of the lake area increased substantially. The proportion into agricultural output value increased from 5.25% in 1992 to 20.5% in 2010, higher than the provincial average level 7.2%. Fishery output value accounts for more than one third of the total amount of Jiangxi Province (as listed in Table 1), showing the important position of fishery in economic development of Jiangxi Province.

Table 1 Proportion of fishery output value of Poyang Lake area into total agricultural output value and the comparison with the provincial average level

Area	Total agricultural output value//10^8 yuan						Proportion of fishery
	Crop farming	Forestry	Animal husbandry	Fishery	Service industry	Total	
Jiangxi Province	729.7	161.8	541.5	231.2	69.7	1733.9	13.3
Poyang Lake area	175.4	14.0	102.1	76.7	6.3	374.5	20.5

* The above data were selected from *China Statistical Yearbook* 2010, *Statistical Yearbook of Jiangxi Province*, and statistical yearbook of Nanchang, Jingdezhen, Jiujiang, Yingtan, Ji'an, Yichun, Fuzhou, Shangrao, and Xinyu cities.

For capture fishery, from the end of the 1990s to the present, the capture fishery output of Poyang Lake fluctuated in 23 500 to 71 900 tons, as shown in Fig. 1. In 2003 – 2010, the capture fishery output of Poyang Lake was relatively steady and fluctuated at 30 000 tons, but the population structure of fishery resource changed greatly. The proportion of semi-migratory fishes, such as four major Chinese carps, dropped significantly to less than 5%; the lake sedentary fishes such as carp, Carassius auratus, catfish, and Pelteobagrus fulvidraco, exceeded 90%; migratory fishes, like Coilia nasus, become very rare; fish catches become younger, smaller and inferior[6], shown in Fig. 2.

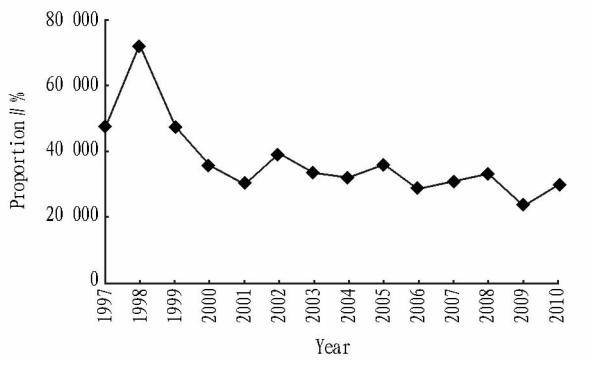

Fig. 1 Capture output of fishery in Poyang Lake in 1997 – 2010

2 Advantages of ecological fishery development in Poyang Lake area

2.1 Location advantages Poyang Lake area is situated in the central position of Changjiang Delta, Pearl River Delta, and Western Taiwan Straits Economic Zone. With southeastern Fujian area of Changjiang Delta in the east and joining the middle and upper reaches of Changjiang River in the west, Poyang Lake area has formed modern traffic network, including railway, highway and Changjiang River golden waterway. Shanghai, Wuhan,

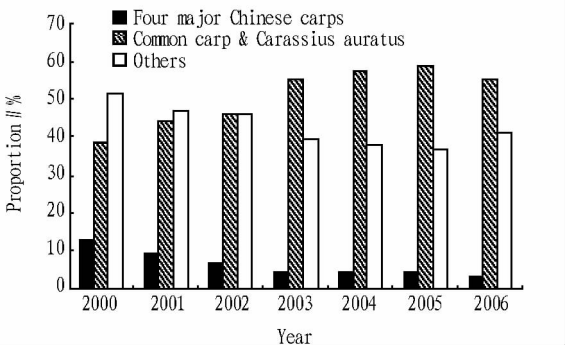

Fig. 2 Proportion of four major Chinese carps into fish catches (Huang Xiaoping and Gong Yan, 2007)

Fuzhou, Guangzhou, Shenzhen, Hong Kong, and Macao are within the 1000 km sales radius of fresh aquatic products of Poyang Lake area. Such location is very favorable for market circulation of fresh aquatic products. It is not only able to supply fresh aquatic products for Nanchang, Jiujiang, Jingdezhen, and Yingtan in Poyang Lake Ecological Economic Zone, but also has broader aquatic product sales space with the aid of convenient highway and railway. In June 2011, Jiangxi fresh aquatic products smoothly march into Hong Kong market and Jiangxi Province became the sole province that has the certificate to sell fresh fishes in Hong Kong.

2.2 Resource advantages As for developing ecological fishery, Poyang Lake is situated in subtropical climate zone. With gifted water and fishery resources, the space for developing aquaculture is large. Poyang Lake absorbs 94% river water of basin area of whole Jiangxi Province, where the annual average volume of water flowing to Poyang Lake from Ganjiang River, Fuhe River, Xinjiang River, Raohe River and Xiushui River reaches 128.57 billion m^3, and the annual volume of water flowing to Changjiang exceeds the sum of that from Yellow River, Huaihe River and Haihe River. Abundant rainfall renders Poyang Lake an important ecological wetland in the world. However, since Poyang Lake is a water-carrying lake, it changes with water volume and water level fluctuates widely, and the lake area changes greatly. In flood season, water level rises. At high water level, it is lacustrine facies, the lake surface rises sharply, showing a broad expanse of water. In dry season, it is fluviatile facies, beaches are exposed, water flows to main channel, and the lake surface is only several winding water ways. Before flood season arrives, the lake takes on the landscape of beach grassland. Such hydrological characteristic is very favorable for multiplication and growth of Poyang Lake sedentary fishes, and broad grass beaches and wetland become natural spawning ground of carp and Carassius auratus[7]. According to survey and statistics, Poyang Lake is rich in fishery resources, including 21 families and 136 species, accounting for 46.7% of fishes in Changjiang River system. Carp family is a dominant species, mainly including Common carp, Carassius auratus, Parabramis pekinensis, Megalobrama skolkovii, culter, Ctenopharyn odon idellus, Mylopharyngodon piceus, Hypophthalmichthys molitrix and Hypophthalmichthys nobilis. In recent 10 years, more than 10 varieties of aboriginal fishes have broken the artificial breeding technology, and the industrial development is rapid. Besides, Poyang Lake has 87 shellfish varieties, including 40 unique to China. There are 8 varieties of shrimps: Exopalaemon modestus and Macrobranchium nipponense are aboriginal dominant species, but in recent years, Procambarus clarkia gradually becomes the dominant species and the main income of fishermen in Poyang Lake area. In high-water years, like this year, fishermen in Poyang, Duchang and Yugan can increase their income for nearly 10000 yuan only from catching shrimps.

2.3 Environmental advantages For a long time, Jiangxi Province has made enormous contribution to protection of ecological environment in Poyang Lake and low reaches of Changjiang River. In the industrial structure, Poyang Lake area is basically crop farming and fishery, and has little industrial pollution. In addition, as a water-carrying and alternately filled lake, Poyang Lake has broad water area connected with Changjiang River, and has high self-purification capacity. In the 1960s, water of Poyang Lake was oligotrophic; in the 1980s to the present, it was intertrophic, and not eutrophicated. At present, water quality of Poyang Lake is above second level. Poyang Lake is one of the few lakes not polluted, and reputed as a lake of clear water. It has excellent ecological environment for developing ecological fishery and producing green organic aquatic products. Nevertheless, influenced by climate change and large water conservancy projects such as the Three Gorges Projects, dry season of Poyang Lake is longer, water level becomes lower and lower, and water storage capacity falls. As a result, natural spawning ground gets damaged, and ecological adjustment functions such as water storage and flood discharge gradually lose, thus the lake area is faced with tremendous ecological environmental pressure[8-10].

3 Study on development of ecological fishery in Poyang Lake area

3.1 Functional zoning is the foundation of developing ecological fishery in Poyang Lake area Water resource is the foundation for development of fishery industrialization. From the perspective of protection of ecological environment and sustainable use of resources, development of ecological fishery in Poyang Lake should make proper planning and make clear leading functions of various waters in Poyang Lake area. According to requirements of Technical Specifications for National Water Functional Zoning, in combination with water resource situations, current development and utilization situations of water resources in Poyang Lake, and requirements of social economic development for water capacity and quality, Poyang Lake waters are divided into protection zone, conservation zone, buffer zone and development and utilization zone for the first level zoning; in waters involved in development and utilization zone, the second level zoning is carried out, and fishery water area is defined. Specifically, protection areas related to fishery resources in Poyang Lake include the provincial level river clam nature reserve, carp and Carassius auratus natural

spawning ground nature reserve, slender silvery-white fish nature reserve, and national level Neophocaena phoconoides nature reserve, Siniperca chuatsi, Erythroculter ilishaeformis conservation zone, and leading function is enhancement protection function of fishery resources. Leading function of fishery water area is capture and aquaculture development of fishery resources.

3.2 Ecological fishery zoning and regional distribution of Poyang Lake area

3.2.1 Ecological fishery zoning. According to leading function orientation, ecological fishery zoning of Poyang Lake can be divided into aquaculture development zone, capture operation zone, enhancement protection zone and ecological rehabilitation zone (listed in Table 2).

3.2 Distribution of ecological fishery development Since the Eleventh Five-Year Plan period, Jiangxi fishery competent authorities started from reasonable development and use of resources in Poyang Lake area, combined local fishery foundation, took market as orientation, and adjusted industrial structure. Lakes and reservoirs around Poyang Lake energetically develop crab and mantis shrimp ecological breeding and multiplication; other areas in Poyang Lake basin develop four major Chinese carps and characteristic aquaculture with the aid of advantages of reservoirs and pools. Now, it has preliminarily set up regional distribution of ecological fishery industrialization in Poyang Lake. The fishery industrialized development mode of "one industry for one variety of fishes" and "one variety of products in one county, and a block for several counties" in counties of Poyang Lake area has made considerable progress. More than half of counties have their own characteristic species and leading industries. Counties with proportion of fishery output value into total agricultural output value higher than 30% have reached 6 and counties with that proportion in excess of 20% have reached 12. At present, Poyang Lake has preliminarily established 8 leading industries: river crabs, shrimps (Procambarus clarkia), eels, Pengze crucian carp, Siniperca chuatsi, Channa argus, Ietalurus Punetaus, and pearl[11-12], as listed in Table 3.

Table 2 Ecological fishery zoning of Poyang Lake

Functional zones	Enhancement protection zone	Capture operation zone	Ecological rehabilitation zone	Aquaculture development zone
Range	Core area of all levels of existing nature reserves in Poyang Lake area	Areas other than core area of all levels of existing nature reserves in Poyang Lake area	Estuary area entering Poyang Lake at Ganjiang River, Raohe River and Xinjiang River	Beaches of 11 counties around Poyang Lake, including dual-purpose fields and streams
Leading functions	Enhancement protection of aquatic organism	Fishery capture	Lakes, low-lying fields, streams (including pools and reservoirs) in 11 counties around Poyang Lake	Aquaculture (mainly three-net aquaculture)
Existing problems	Multiple management, not clear boundary, and backward construction	Enclosure of lake and excessive fishing	Water polluted, spawning ground and feeding ground damaged	Inadequate development and utilization of aquaculture waters, and backward supporting technologies and measures

Table 3 Distribution of development of ecological fishery in Poyang Lake area

Leading industries		Model base counties (cities, districts)	Foundation base counties (cities, districts)
River crab ecological breeding		Jinxian	Poyang, Yugan, Jiujiang, Hukou
Shrimp ecological breeding	Penaeus vannamei	Xinjian	Nanchang, De'an, Yongxiu
	Freshwater shrimp	Duchang	Nanchang, Ruichang, Poyang
	Procambarus clarkia	Poyang, Duchang, Yugan	Jiujiang, Hukou, Yongxiu, Nanchang
Eel ecological breeding		Yanshan, Ruijin	Yushan, Shanggao, Yuanzhou, Shicheng
Siniperca chuatsi ecological breeding		Yongxiu	Hukou, Nanchang, Yugan
Carassius auratus ecological breeding		Pengze	Fengcheng, Nanchang, Zhangshu, Yuanzhou, Linchuan
Pearl ecological breeding		Duchang, Wannian	Xinjian, Nanchang, Nancheng
Channa argus ecological breeding		Yugan, Poyang	Yongxiu, Nanchang
Ietalurus Punetaus ecological breeding		Xiajiang	Ji'an, Taihe, Wanan, Yongfeng, Poyang, Nanchang

3.3 Development modes and feasible paths for ecological fishery in Poyang Lake area

3.3.1 Development modes of ecological fishery. In recent years, on the basis of developing ranching type cage ecological breeding for Hypophthalmichthys molitrix and Hypophthalmichthys nobilis, and traditional ecological fishery modes, such as mulberry fish pond, and "pig - marsh gas - fruit (vegetable) - fish (pearl)" integrated breeding, scientific and technical personnel of Poyang Lake area actively carried out introduction and test of individual technology, conducted systematic improvement and integrated innovation, and made breakthrough in assembly and integration of ecological breeding industrial chain for grass carp, Siniperca chuatsi, Micropterus salmoides and Ietalurus Punetaus. Now, it has established 9 high benefit ecological fishery modes suitable for ecological conditions of Poyang Lake area. These 9 ecological fishery modes are "Siniperca chuatsi - shrimp - rice" ecological cultivation and aquaculture mode, Siniperca chuatsi reservoir intercropping mode, Siniperca chuatsi pond mono-culture

mode, large water area crab and Siniperca chuatsi (famous and high quality fishes) poly-culture mode, "pond-wetland (ecological channel)" aquaculture pollutant cleaning mode, pond micro cycle high density fish breeding mode, Micropterus salmoides cage ecological breeding mode, high-benefit ecological breeding mode adding oxygen through porous pipes on cages, and stream ecological mono-culture mode. With several years of test and constant improvement, these modes have become comparatively mature, and the extension area is constantly increasing.

3.3.2 Feasible paths for development of ecological fishery. As a less economically developed area of Jiangxi Province, Poyang Lake area has many difficulties in developing ecological fishery, including low educational level of fishermen, backward concept, lack of technology, and weak economic risk bearing ability. Thus, Poyang Lake area should face the reality, make overall planning, and deal with these difficulties step by step. And the key is to select proper development paths. There are three major measures: (1) enhancing education, guiding fishermen to get rid of traditional backward concepts of excessive fishing and draining the pond to get all fishes; (2) adapting to urgent desire of fishermen for getting rich, and enhancing fishermen's confidence in increasing breeding benefit and getting rich through developing ecological aquaculture; (3) attaching special importance to cultivation of new fishery operating entities such as family farm (fishing ground), crop farming (fishery) cooperatives and leading enterprises, to promote industrialized development of ecological fishery. Many domestic and foreign successful cases indicate that only through really realizing ecological development of fishery, can ecological balance of Poyang Lake area be kept, sustainable use of fishery resources be realized, and beautiful homeland (the long sky emerges into one hue with the autumn water, songs and music from the fishing boat drift all the way to the banks of Poyang Lake") be realized. In addition, only through really realizing ecological development of fishery, can the vitality and huge driving force of market mechanism be brought into full play. Through specialized labor division, large-scale operation, industrialized organization and management, and information-based marketing and circulation, it is able to enlarge and strengthen enterprises, reinforce development strength and risk-resisting ability, and really realize the objective of prosperity of Poyang Lake area.

In practical exploration, the key technology of ecological fishery of Poyang Lake area should take full advantage of natural ecosystem and functions of natural ecosystem, to maintain and improve ecological balance of fishery ecosystem, realize benign cycle of "cost saving, benefit increasing, quality improving and low carbon", and achieve multi-win objective of coordinated ecological, economic and social benefits, and to ensure healthy operation and sustainable development of ecological fishery.

(1) Reducing fertilizer. It is recommended to improve fertilizer application technology, apply fertilizer through testing water, according to demand and in an accurate manner. Also, it should take maintenance of biological diversity of water ecosystem and improvement of primary productivity as objectives, reasonably use biological organic fertilizer and water quality adjustment agent, popularize reasonable match of organic and inorganic fertilizer, and reduce application of chemical fertilizer.

(2) Reducing drugs. Through application of environment-friendly fishery technologies and preparation, such as ecological regulation of aquatic product diseases and insect pests, biological prevention and control and vaccine, immunopotentiator, and Chinese herbal medicines, it is expected to realize scientific, safe and high efficient use of fishery drugs, reduce use of chemicals including fishery drugs, and to improve quality and safety of aquatic products.

(3) Increasing output. Namely, it should take full advantage of all outstanding achievements of modern science and technology, improve productivity of harmless, green and organic aquatic products with the aid of sci-tech progress and material input, and satisfy quantity and quality demands of people for aquatic products on the basis of highly stressing quality, sanitation and safety of aquatic products.

(4) Increasing benefits. The development of ecological fishery should highly coordinate social, economic and ecological benefits. Ecological fishery should not only pay attention to reasonable development of resources, protection of ecological environment, and food safety, but also should attach importance to economic benefits of aquaculture. Currently, "ecological, green, organic and harmless" ideas suit dominant consumption idea at market. Thus, as long as fish species is suitable and the technology is mature, ecological breeding will definitely have higher comparative benefits.

(5) Reducing consumption. This means using local wild fishes to develop predatory fishes with higher economic value, or using rural agricultural wastes to develop clean energy and new energy, and promoting energy, environmental pollution and resource integrated low carbon fishery through comprehensive use and extension of predatory fishes, shrimps and crabs multiplication technologies.

(6) Low emission. Fishery has dual characteristic of carbon sink and carbon source (*i. e.* carbon emission). Developing the fishery is to constantly strengthen carbon sink function, and reduce carbon emission. Therefore, it is recommended to enhance research on carbon sink technologies. On the one hand, it should increase carbon fixation ability of fishery water and reduce emission of greenhouse gases. On the other hand, it should efficiently use primary productivity of fishery water, optimize culture result, and develop large-scale healthy culture, to reduce aquaculture pollution and its carbon emission.

(7) High quality. In the whole process of fishery production, it is proposed to organize production in accordance with ecological laws, keep and improve ecological balance of production areas, safeguard water from pollution, keep dynamic balance of aquatic organism population and proper structure of food chain, and effectively improve quality of aquatic products on the precon-

dition of reasonably and standardized use of fishery drugs, feeds, and fertilizers.

(8) High safety. In the process of ecological aquaculture, it is required to take whole process quality control. Both ground environment and inputs of means of products should be strictly certified. Quality standard should be clearly defined for internal quality, production technology, and operating procedures of aquatic products. From pre-production, production and post-production, breeding, processing, management, storage, packaging and sales, as well as waste use, the whole process should be monitored, and traceable management is implemented, to practically ensure food safety and harmless environment of circulation and processing process.

(9) Standardization. Namely, it is recommended to pay special attention to standardization of ecological fishery technology and production of harmless, green and organic aquatic products. Through implementing certification of outstanding ecological environment of aquatic products and standardized ecological breeding technology, it is expected to set up market image of "ecological Poyang Lake and green aquatic products", raise competitive power of aquatic products of Jiangxi Province at both domestic and foreign markets, and increase aquaculture benefits.

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a low-carbon village evaluation system with 3 levels and 20 indicators. On this basis, taking Yuanjiang County as empirical research object, we use distance function model method to analyze and evaluate the low carbonization of village in Yuanjiang County, in order to provide a reference for the low-carbon village evaluation. In order to promote low-carbon village construction, it is necessary to form a set of scientific and authoritative indicator system and evaluation methods, namely to establish a universal theory and method for guiding the theory and practice of low-carbon village development evaluation. For the differences in the rural development, the establishment and application of evaluation indicator system for low-carbon village should be combined with specific objects.

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