Evaluation on Fishery Resources in Daxingshan Artificial Reef Area of Huidong County

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Abstract In order to evaluate placement of artificial reefs in Huidong County and observe biological aggregating effect of fishery resources, background investigation and follow-up investigation were carried out for trawl fishing and gill-net fishing in Daxingshan artificial reef area. The biological resource density index (D), Margalef species richness index (R), Shannon - Winener diversity index (H'), and Pileou evenness index (J') were used to study diversity of water biological population and resource density. Trawl fishing investigation indicated that after placement of reefs, there was significant increase in quantity of species of nekton, total resource density, species richness index, and diversity index in reef area, which were 1.321, 2.07, 1.012 and 1.084 times the value before placement of reefs respectively. Gill-net fishing investigation indicated that after placement of reefs, the quantity of species of nekton, total resource density, species richness index, and diversity index in reef area were 2.571, 7.976, 2.399 and 2.667 times the value before placement of reefs respectively. After reef placement, fishes and crabs become dominant population. It showed that after reef placement, attraction effect of fishes is significant, community structure is obviously optimized, and water environment in reef area is significantly improved. Thus, it proved that the multiplication system through artificial reefs has been basically established in Daxingshan reef area of Huidong County.

Key words Artificial reef, Fish - aggregating effect, Resource multiplication, Daxingshan of Huidong County

Sustained excessive fishing, serious pollution of marine environment and changeable climate lead to severe decline of Guangdong coastal fishery resources and increasing deterioration of marine environment. An artificial reef is a human-made underwater structure, built to attract fishes, protect aquatic resources like multiplication fishes, improve water environment, and conduct leisure fishery activities[1]. It provides excellent habitat, growth and breeding place for marine organisms. Practice of artificial reefs in many countries has proved that it is able to create favorable marine ranching environment and improve fishery resource environment through proper placement and construction of artificial reefs. In 2001, Guangdong Province formally promoted large-scale construction of coastal artificial reefs in the form of motion of People's Congress. It planned to build 12 artificial reef areas (including a total of 100 artificial reefs) in about 2.4 million hm^2 young fishes and shrimps in Guangdong coastal regions. *Provisions of Guangdong Province on Administration of Artificial Reefs* issued later also stipulate the implementation as of November 1, 2004. The artificial reef project of Huidong County includes Daxingshan ecological public-welfare artificial reef, Xiaoxingshan quasi-ecological artificial reef and Dayawan marine ranching model artificial reef. Daxingshan artificial reef was built in 2009 with investment of 13.2 million yuan by Guangdong Province. On the basis of data of background investigation and follow-up investigation, we preliminarily evaluated multiplication effect of fishery resources in Daxingshan artificial reef area, in the hope of providing basis for management and further construction of this area, and providing reference for construction and scientific research of artificial reefs in Guangdong Province or even the whole country.

1 Materials and methods

1.1 Materials Both background investigation and follow-up investigation applied trawl fishing and gill-net fishing joint investigation. We set two stations: reef area station (No. 5 station) and control station (No. 6 station), as shown in Fig. 1. At the time of follow-up investigation, since reef in central area hinders trawl fishing, we had to select side reef area adjacent to central area as the reef station, and adopted the same control station as in background investigation. In May, 2008, we carried out the background investigation before placement of reefs in Daxingshan artificial reef area of Huidong County; in June, 2011, we carried out follow-up investigation after placement of reefs. In both investigations, we rented the single-boat bottom trawl with the same specification.

1.2 Methods We identified and measured all fish catches in site, and analyzed nekton according to relevant provisions of the *Specification for Marine Monitoring* (GB17378 - 2007)[2] and *Specifications for Oceanographic Survey* (GB12763.6 - 2007)[3]. On the basis of fish catch data obtained by different investigation methods in each station and species, we calculated related parameters, including composition of fish catches in each station, resource density or fish catch rate, and biological diversity index.

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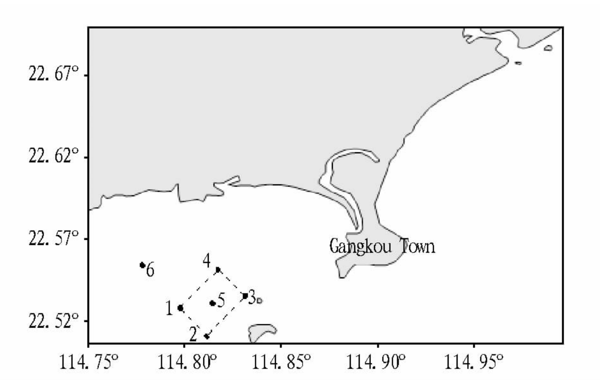

Fig. 1 Investigation station of Daxingshan artificial reef area in Huidong County

Fishery resource density (D) of shrimp trawl is calculated by bottom trawling swept area method[4-6] in accordance with following equation:

$$D = \frac{c}{Q \times a} \quad (1)$$

The fish catch rate (D') is calculated as per following equation:

$$D = \frac{C \times 10^4}{t \times H \times L} \quad (2)$$

where D is fishery resource density of shrimp trawl (kg/km^2), c signifies the average hourly fish catch by trawling (kg/trawl · h), Q is the fish catch rate of fishing net (take 0.5 in this study), a is the hourly sampling area of fishing net (km^2/net · h), D' refers to the fish catch rate of gill-net [kg/ (hm^2 · h)], C is total fish catch (kg), t is time of gill-net fishing (h), H is the height of gill-net (m), and L is the length of gill-net (m).

Shannon – Winener diversity index (H')[7], Pileou evenness index (J')[8] and Margalef species richness index (R)[9] are used to study diversity of water biological community structure. Shannon – Winener diversity index (H') is used to measure nekton diversity, calculated by following equation:

$$H' = -\Sigma \frac{S}{i=1} P_i \log(P_i, 2) \quad (3)$$

where H' is the species diversity index, S is total species of fish catch in each station, P_i signifies the ratio of the i-th individual to total individuals. Pielou evenness index (J') is used to measure nekton evenness, calculated as per following equation:

$$J' = H'/\log(S, 2) \quad (4)$$

where J' is the evenness index, H' is species diversity index and S is total species of fish catch in each station.

Margalef species richness index (R) is calculated as per following equation:

$$R = \frac{(S-1)}{\ln N} \quad (5)$$

where R is species richness index, S is total species of fish catch in each station, and N is total fish catch in each station.

2 Results and analyses

2.1 Changes in composition of nekton species Shrimp trawl fishing investigation indicated that in the reef area, after placement of reefs, nekton species is richer than before placement of reefs; total species increased to 37 from 28, follow-up investigation is 1.321 times the background investigation. Fish species increased from 14 to 16, 1.142 times the background investigation; shrimp species was 5 before and after reef placement; crab species increased from 7 to 9, 1.286 times the background investigation; mantis shrimps species increased from 1 to 6, 6 times the background investigation; cephalopod species was 1 before and after reef placement, as shown in Fig. 2. In the control area, changes were little. Before reef placement, the total species was 27; after reef placement, the total species was 30, 1.111 times the background investigation; fish species was 13 before reef placement and 14 after reef placement, 1.077 times the background investigation; shrimp species was 4 before reef placement and 1 after reef placement, 0.25 times the background investigation; crab species was 7 before reef placement and 10 after reef placement, 1.429 times the background investigation; mantis shrimps species was 1 before reef placement and 4 after reef placement, 4 times the background investigation; cephalopod species was 1 before and after reef placement.

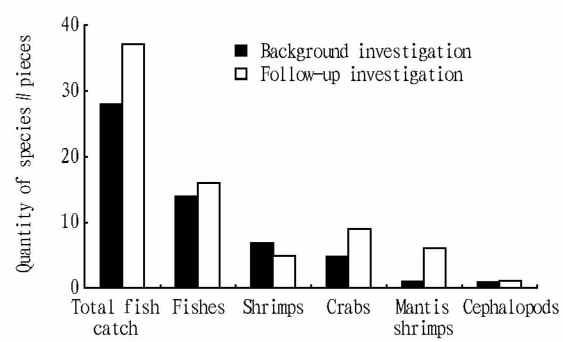

Fig. 2 Total fish catch of nekton species in reef area through trawling background investigation and follow-up investigation

Gill-net fishing investigation indicated that in the reef area, after placement of reefs, nekton species is richer than before placement of reefs; total species increased to 18 from 7, follow-up investigation is 2.571 times the background investigation. Fish species increased from 7 before reef placement to 12 after reef placement, 1.714 times the background investigation; before reef placement, there were no shrimps, crabs and mantis shrimps; after reef placement, shrimp, crab and mantis shrimp species were 1, 2 and 3 separately, as shown in Fig. 3. In the control area, the total species after reef placement was slightly greater than before reef placement; before reef placement, the total species was 4, after reef placement, it was 11, 2.75 times the background investigation; fish species increased from 4 to 10, 2.5 times the background investigation; before reef placement, there was no mantis shrimp, after reef replacement, the mantis shrimp species was 1; in both before and after reef placement, no shrimp or crab was caught.

2.2 Changes in composition of nekton resource density Ac-

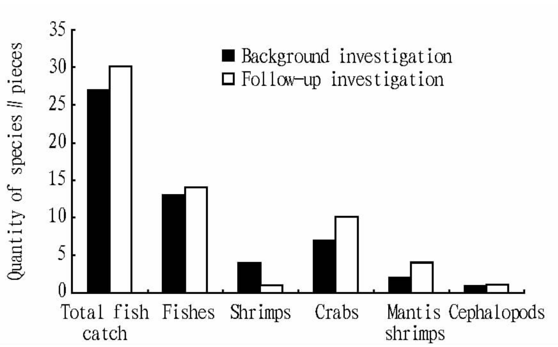

Fig. 3 Total fish catch of nekton species in reef area through gill-net fishing background investigation and follow-up investigation

cording to comparison between trawling background investigation and follow-up investigation, in the reef area, the resource density of all nekton species after reef placement increased significantly: total resource density increased from 1 613.430 kg/km^2 to 3 340.434 kg/km^2, 2.07 times the background investigation; resource density of fishes, shrimps, crabs, mantis shrimps and cephalopods was 0.791, 4.159, 1.795, 68.598 and 3.425 times the background investigation, as shown in Fig. 4. In the control area, the total resource density increased from 1 910.622 kg/km^2 to 2 667.802kg/km^2, 1.396 times the background investigation; the resource density of fishes, shrimps, crabs, mantis shrimps and cephalopods was 0.709, 0.899, 1.078, 182.441 and 0.399 times the resource density before reef placement. According to comparison between gill-net fishing background investigation and follow-up investigation, in the reef area, after reef placement, the fish catch rate of various nekton species was obviously improved: the total fish catch rate increased from 187.827 kg/(hm^2 · h) to 1 498.050 kg/(hm^2 · h), 7.976 times the background investigation; the fish catch rate of fishes was 7.803 times the background investigation; no shrimp, crab and mantis shrimp were caught in the background investigation; the fish catch rate of shrimp, crabs and mantis crabs in follow-up investigation was 0.850, 21.100, 3.550 kg/(hm^2 · h), as shown in Fig. 5. In the control area, the fish catch rate of nekton species had certain increase after reef placement: the total fish catch rate increased from 28.646 kg/(hm^2 · h) to 128. 350 kg/(hm^2 · h), 4.481 times the background investigation; the fish catch rate of fishes was 4.376 times the background investigation; in the background investigation, no mantis shrimp was caught; in the follow-up investigation, the fish catch rate of mantis shrimp was 3.000 kg/(hm^2 · h); no shrimp or crab was caught in control area in both the background investigation and follow-up investigation.

These indicated that the resource density of various species after reef placement was obviously higher than that before reef placement, especially fishes having significant increase of resource density, reflecting the effect of artificial reef in attracting nekton species.

2.3 Changes in dominant species of nekton From comparison of the background investigation and follow-up investigation be-

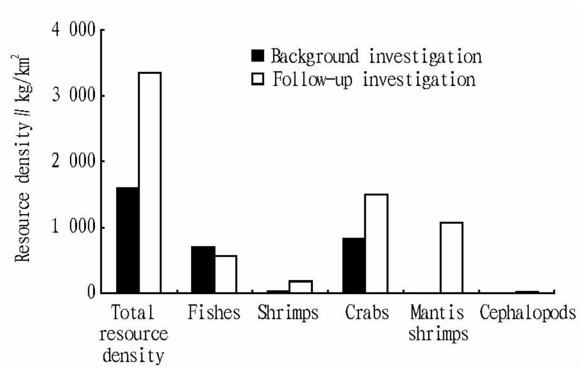

Fig. 4 Resource density of nekton species in reef area through trawl fishing background investigation and follow-up investigation

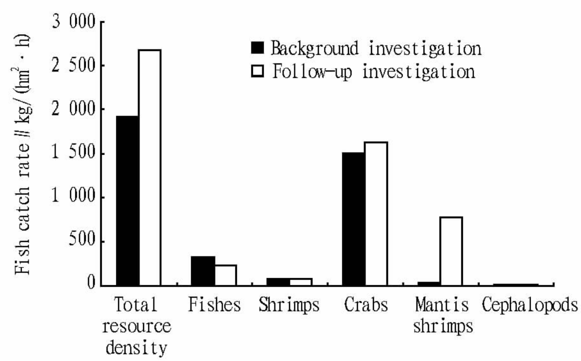

Fig. 5 Fish catch rate of nekton species in reef area through gill-net fishing background investigation and follow-up investigation

fore and after reef placement, it is found that there were significant changes in dominant population and major dominant species in both reef area and control area. The trawl fishing investigation indicated that before reef placement, the dominant population in the reef area was crabs, fishes, shrimps, mantis shrimps and cephalopods, with the resource density of the first dominant species *Calappa philargius Linnaeus* up to 439.819 kg/km^2; in the control area, the dominant population was crabs, fishes, shrimps, cephalopods and mantis shrimps, with the resource density of the first dominant species *Calappa philargius Linnaeus* up to 569.409 kg/km^2. After reef placement, the dominant population was crabs, mantis shrimps, fishes, shrimps and cephalopods, with the resource density of the first dominant species Eucrate crenata up to 693.043 kg/km^2; in the control area, the dominant population was crabs, mantis shrimps, fishes, shrimps and cephalopods, with the resource density of the first dominant species Eucrate crenata up to 835.450 kg/km^2. Gill-net fishing investigation showed that before reef placement, in the reef area, there were only fishes, and the resource density of first dominant species Abudefduf richardsoni was 169.478 kg/(hm^2 · h); in the control area, there were also only fishes, and the resource density of first dominant species Siganus oramin was 17.526 kg/(hm^2 · h). After reef placement, the dominant species in the reef area was fishes, crabs, mantis shrimps, and shrimps, with the resource density of first dominant species Argyrosomus argentatus up to 800.800 kg/(hm^2 · h); in the control area, the dominant species was fishes and mantis shrimps, with the resource density of first dominant species Argyrosomus aneus only 77.550 kg/(hm^2 · h), as listed in Table 2.

Table 1 Major dominant species and resource density of nekton in reef area and control area in trawling background investigation and follow-up investigation

Investigation location	Background investigation		Follow-up investigation	
	Major dominant species	Resource density//kg/km²	Major dominant species	Resource density//kg/km²
Reef area	Calappa philargius Linnaeus	439.819	Eucrate crenata	693.043
	Aploactis aspera	313.371	Oratosquilla oratoria	455.700
	Charybdis variegata	156.293	Charybdis variegata	303.800
	Portunus trituberculatus	125.663	Harpadon nehereus	277.692
	Epinephelus awoara	106.028	Oratosquillina interrupta	196.995
Control area	Calappa philargius Linnaeus	569.409	Eucrate crenata	835.450
	Charybdis feriatus	337.718	Oratosquilla oratoria	403.484
	Portunus trituberculatus	310.230	Charybdis variegata	327.534
	Charybdis variegata	215.197	Miyakea nepa	264.045
	Cynoglossus macrolepidotus	69.900	Charybdis feriatus	188.095

Table 2 Major dominant species and fish catch rate of nekton in reef area and control area in gill-net fishing background investigation and follow-up investigation

Investigation location	Background investigation		Follow-up investigation	
	Major dominant species	Resource density//kg/km²	Major dominant species	Resource density//kg/km²
Reef area	Abudefduf richardsoni	169.478	Argyrosomus argentatus	800.800
	Halichoeres argus	7.027	Johnius dussumieri	538.000
	Stethojulis interrupta	3.927	Polydactylus sextarius	47.000
	Parargyrops edita	2.935	Harpadon nehereus	35.800
	Stethojulis kalosoma	2.935	Charybdis feriatus	12.450
Control area	Siganus oramin	17.526	Argyrosomus aneus	77.550
	Parargyrops edita	8.143	Johnius dussumieri	19.500
	Abudefduf richardsoni	1.984	Sardinella jussieu	15.650
	Daicocus peterseni	0.992	Parargyrops edita	2.900
			Sardinella sindensis	1.850

Trawl fishing investigation before and after reef placement indicated that the crab in reef area was the first dominant population in both before and after reef placement, with the resource density of the first dominant species 2.070 times the value before reef placement; in the control area, the crab was the first dominant population, with the resource density of the first dominant species 1.078 times the value before reef placement. Gill-net fishing investigation before and after reef placement indicated that the fish catch species in reef area significantly increased after reef placement, with the resource density of the first dominant fish species in reef area 7.803 times the value before reef placement, and high quality fishes were caught; the resource density of the first dominant species in the control area was 4.376 times the value before reef placement. These changes showed the placement of artificial reefs is very effective to attracting fish gathering, and resource multiplication preliminarily showed its effect.

2.4 Changes in biological diversity of nekton To further evaluate impact of artificial reef on multiplication effect of fishery resource, we carried out calculation, analysis, and comparison of background investigation and follow-up investigation data. Results showed that the quantity of species, evenness index, diversity index, and resource richness of fishery resource in reef area after reef placement were greater than that in the control area and that before reef placement. From Fig. 6, we can see that 3 indicators reflected, from different aspects, changes in nekton population in reef area after reef placement through trawl fishing investigation. Trawl fishing investigation indicated that after reef placement, Pileou evenness index (J') was basically balanced, the evenness index (J') after reef placement was 0.999 times the value before reef placement; the Shannon – Winener diversity index (H') in the reef area was 1.084 times the value before reef placement; Margalef species richness index (R) also took on ascending trend, getting 1.012 times the value before reef placement.

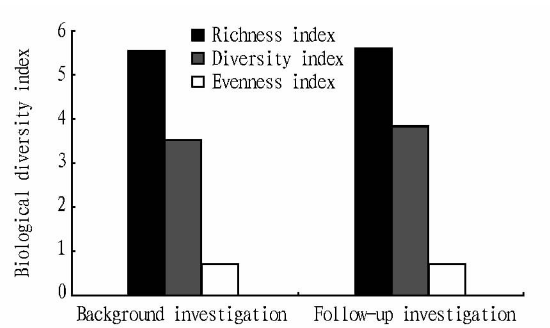

Fig. 6 Changes in biological diversity index in the reef area through trawl fishing background investigation and follow-up investigation

From Fig. 7, we can see the Pileou evenness index (J') in the reef area after reef placement was 1.795 times the value before reef placement; Shannon – Winener diversity index (H') significantly increased to 2.667 times the value before reef placement; Margalef species richness index (R) got to 2.399 times the value before reef placement. These results proved the biological diversity and species richness of the reef area after reef placement were improved to some extent. After reef placement, the biological community structure of fishery resources in reef area became more stable, complex and sustained, and the overall biological community structure was better than the control area and the situation before reef placement. Generally speaking, the reef area environment after reef placement was significantly improved. This proved that Daxingshan artificial reef area of Huidong County has showed favorable ecological effect. With time advances, such effect will become more and more remarkable.

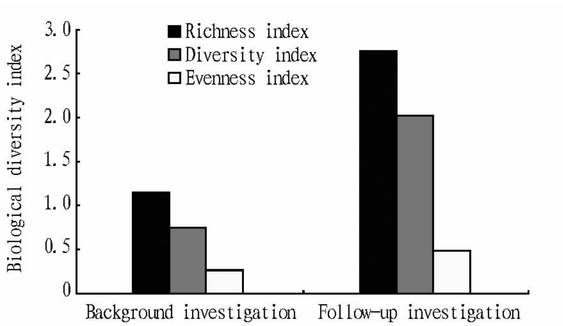

Fig. 7 Changes in biological diversity index in the reef area through gill-net fishing background investigation and follow-up investigation

3 Discussion

There are many domestic and foreign reports and documents about researches on evaluation of artificial reef effect[4-6]. Through bottom trawl fishing investigation by seasons in 1959 – 1999, Jin Xianshi *et al.* [10] pointed out that community structure of fishery resources in Laizhou Bay is simple, and remains relatively unbalanced state at present. On the condition of substantial reduction of external perturbation, small pelagic species with high restoring force can restore and grow very rapidly. Rooker *et al.* [101] investigated Flower Garden Banks National Marine Sanctuary in Gulf of Mexico, and got the result that artificial reef had significant effect on gathering of fishes and biological diversity of reef area obviously increased. Chen Pimao investigated effect of float type artificial reef in Zhongshan sea area and the fish catch in Zhongshan artificial reef area, got the result that artificial reef has significant effect on attraction of fishes, and it can obviously promote improvement in marine ecological environment. A lot of documents and reports have proved that placement of artificial reefs promotes improvement and adjustment in marine ecological environment in varying degrees. Through investigation, processing, analysis and comparison of data before and after reef placement in the reef area and control area, we obtained similar results, including quantity of species and resource density of nekton before reef placement in the reef area higher than the value before reef placement and the control area. Trawling investigation results showed that in the reef area, various nekton species after reef placement was 1.321 times the value before reef placement; the total resource density increased from 1 613.430 kg/km^2 before reef placement to 3 340.434 kg/km^2 after reef placement, 2.070 times the value before reef placement; gill-net fishing investigation indicated that the total species quantity after reef placement was 2.750 times the value before reef placement; the total fish catch rate increased from 187.827 kg/(hm^2 · h) before reef placement to 1 498.050 kg/(hm^2 · h) after reef placement, 7.976 times the value before reef placement, manifesting preliminary effect of construction of artificial reefs.

Trawl fishing investigation before and after reef placement indicated that the crab in reef area was the first dominant population in both before and after reef placement, with the resource density of the first dominant species 2.070 times the value before reef placement; in the control area, the crab was the first dominant population, with the resource density of the first dominant species 1.078 times the value before reef placement. Gill-net fishing investigation before and after reef placement indicated that the fish catch species in reef area significantly increased after reef placement, with the resource density of the first dominant fish species in reef area 7.803 times the value before reef placement, and high quality fishes were caught; the resource density of the first dominant species in the control area was 4.376 times the value before reef placement. This indicated that artificial reefs provide excellent growth and breeding environment and habitat for fishes and shellfishes, and its economic benefit is great.

Domestic and foreign scholars often used Margalef species richness index (R), Shannon – Winener diversity index (H'), Pielou evenness index (J'), Jaccard similarity index (CP)[14] and CPUE to analyze effect of artificial reefs. Diversity index is a common evaluation parameter and basic index for studying biological community. We studied changes in biological diversity index of the reef area and control area before and after reef placement through background investigation and follow-up investigation, and evaluated influence of placement of artificial reefs on composition and structure of biological community. Trawl fishing investigation indicated that the evenness index (J') of the reef area after reef placement was 0.999 times the value before reef placement, Shannon – Winener diversity index (H') was 1.084 times the value before reef placement, and Margalef richness index (R) was 1.012 times the value before reef placement. Gill-net fishing investigation indicated that Pileou evenness index (J') of the reef area after reef placement was 1.795 times the value before reef placement, Shannon – Winener diversity index (H') was 2.667 times the value before reef placement, and Margalef richness index (R) was 2.399 times the value before reef placement. Results showed that ecological structure of the sea area after reef placement becomes more stable, indicating artificial reefs having significant promotion effect on stability of biological community structure, restoration and long-term sustainable development of fishery resources.

For fish attraction mechanism of artificial reefs, many scholars have made elaboration. Through research on ecological attraction of artificial reefs, Zhou Yanbo *et al.* [15] believed that ascending current formed after reef placement and took nutrient salts at the bottom to upper water area with abundant sunshine, so as to increase primary productivity of the sea area and provide new habitat for organisms. Besides, after reef placement, the undersea physical environment, flow field change effect, bait composition effect, acoustic change effect, and reef shadow effect will attract gathering of nekton in varying degrees, and bring about obvious fish gathering effect. Artificial reef technology is a way of transforming habitat of marine ranching environment, but its ecological and economic benefits need a long term. This study shows that artificial reef has manifested its remarkable fish gathering and ecological environment improvement effect. Thus, reef placement is an effective measure for restoring fishery resources and improving marine ecological environment. It should be energetically popularized and developed in coastal suitable regions, to strengthen sea area management system and lay a solid foundation for marine ranching development.

References

[1] TAO F, JIA XP, CHEN PM, *et al*. Advance in the research on artificial reef design[J]. South China Fisheries Science, 2008, 4(3) : 64 – 69. (in Chinese).

[2] The National Marine Environmental Monitoring Center. GB17378 – 1998, The specification for marine monitoring[S]. Beijing: Standard Press of China, 2008: 426 – 434. (in Chinese).

[3] National Marine Data and Information Service (NMDIS), North China Sea Branch of State Oceanic Administration. GB12763 – 2007, The specification for oceanographic survey[S]. Beijing: Standard Press of China, 2007: 5 – 10. (in Chinese).

[4] CHEN YH, LI HQ, CHEN PM, *et al*. Preliminary evaluation on construction effect of artificial reef area in South Dalajia Island of Daya Bay[J]. Ocean and Fishery, 2007(7) : 13 – 15. (in Chinese).

[5] WILHM J L. Use of biomass units in Shannon's formula[J]. Ecology, 1968, 49(1) : 153 – 156.

[6] WANG H, CHEN PM, LI HQ, *et al*. Preliminary evaluation on fish-aggregating effects of artificial reefs in Chenghai Coast, Guangdong, China[J]. South China Fisheries Science, 2008, 4(6) : 63 – 69. (in Chinese).

[7] WILSON J P, SJEAVES M. Short-term temporal variation in taxonomic composition and trophic estuarine fish assemblage[J]. Marine Biology, 2001, 139(4) : 787 – 796.

[8] LIU SB, WANG ZH, LIN LW, *et al*. Evaluation on the initial effect of artificial reef construction in Shengsi[J]. Journal of Shanghai Fisheries University, 2007, 16(3) : 297 – 302. (in Chinese).

[9] REN YP, XU BD, YE ZJ, *et al*. Preliminary study on structure characteristics of fishery resources community in spring and winter in Qingdao coastal water[J]. Journal of Ocean University of China, 2005, 35(5) : 792 – 798. (in Chinese).

[10] JIN XS, DENG JY. Variations in community structure of fishery resources and biodiversity in the Laizhou Bay, Shandong[J]. Chinese Biodiversity, 2000, 8(1) : 65 – 72. (in Chinese).

[11] ROOKER J R, DOKKEN Q R, PATTENGILL C V, *et al*. Fish assemblages on artificial and natural reefs in the Flower Garden Banks National Marine Sanctuary, USA. [J]. Coral Reefs, 1997, 16(2) : 83 – 92.

[12] CHEN PM. Study on the effects of floating artificial reef in Zhongshan area [J]. Journal of Zhanjiang Ocean University, 2005, 25(3) : 85 – 89. (in Chinese).

[13] CHEN PM. A survey on catch in artificial reef area of Zhongshan City[J]. Journal of Tropical Oceanography, 2005, 24(3) : 73 – 80. (in Chinese).

[14] MIGUEL NEVES SANTOS, CARLOS COSTA MONTEIRO. The Olhao artificial reef system (south Portugal) : Fish assemblages and fishing yield [J]. Fisheries Research, 1997, 30: 33 – 41.

[15] ZHOU YB, CAI WG, CHEN HG, *et al*. The mechanism and research progress on fish attraction technique for artificial reefs[J]. Marine Fisheries, 2010, 32(2) : 225 – 230. (in Chinese).

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[9] FU BH, WANG QQ. Study on problems and its counterplan of agricultural landuse in the Northwest Area, Yunnan[J]. Territory & Natural Resources Study, 2003(2): 30 – 31. (in Chinese).

[10] ZHANG JF, ZHOU H, GENG YF. Restoration approach of sub-alpine degraded ecosystem in Northwest Yunnan – "Close to Nature Forestry" theory and methods[J]. Forest Resources Management, 2005(5): 33 – 37. (in Chinese).

[11] SHI HF. Reasons for ecological degradation of Northwest Yunnan and strategies for ecological protection and construction[J]. Journal of West China Forestry Science, 2004, 33(4): 80 – 84. (in Chinese).

[12] ZHANG Q, MA YX, LIU WJ, *et al*. Regional land use dynamics of plateau wetlands in the northwest of Yunnan Province, China[J]. Journal of Mountain Science, 2007, 25(3): 265 – 273. (in Chinese).

[13] LI NY, TIAN K, YANG YM, *et al*. Landscape change and assessment of Napahai Wetland in Northwestern Yunnan[J]. Journal of West China Forestry Science, 2012, 41(2): 27 – 32. (in Chinese).

[14] TIAN K, MO JF, LU M. Human disturbances on the ecological environment degradation of Napahai Wetland in the upstream of Yangtze River [J]. Resources and Environment in the Yangtze Basin, 2004, 13(3): 292 – 297. (in Chinese).

[15] XU HM. Study on disturbances factors of forest in Subalpine Mountain of Northwest Yunnan[D]. Southwest Forestry University, 2008: 1 – 2. (in Chinese).

[16] WANG WB. Forest resources of Northwest Yunnan and strategies for conservation and management[J]. Yunnan Forestry Science and Technology, 2003(1): 18 – 21. (in Chinese).

[17] GAO S, CAO XJ. Exploitation of mineral resources and protection of geological environment in Northwest Yunnan[J]. Hydrogeology and Engineering Geology, 2008(4): 123 – 125. (in Chinese).

[18] HAN QF, LUO HS, HAN JQ. On study of the geological hazards based on human-land relationship-Lanpin County in three rivers as an example[J]. Journal of Yunnan Normal University, 2005, 25(1): 55 – 59. (in Chinese).

[19] JUE YM, WANG JL, MA J. The factors of land use/cover changes in the three rivers region of Northwestern Yunnan[J]. Journal of Yunnan Normal University, 2002, 22(3): 59 – 65. (in Chinese).

[20] YUE CR, LU P, ZHAO XW. Simulation of landuse change of Shangri-La County based on Cellular Automata[J]. Journal of Anhui Agricultural Sciences, 2011, 39(4): 2380 – 2383. (in Chinese).

[21] SUN KQ. Issues and approaches of the three parallel rivers Yunnan protected areas of the world natural heritage[J]. Resources & Industries, 2012, 12(6): 118 – 124. (in Chinese).

[22] LUO S. Study on the influence of tourism activities on soil nature of typical plateau wetlands in the Napahai[D]. Southwest Forestry University, 2008: 21 – 2. (in Chinese).

[23] YAO P. The influence of tourism development on the ecological environment of Shangri – La in Diqing[J]. Journal of Sichuan Higher Institute of Cuisine, 2011(3): 32 – 34. (in Chinese).

[24] Protection of biodiversity and against the intrusion of alien species in Yunnan[N]. China Environment News, 2001 – 9 – 3(version 4). (in Chinese).

[25] YANG JT, ZHAO JX, MU JH, *et al*. Study and strategy of rural energy problem in Laojunshan area of Northwest Yunnan[J]. Ecological Economy, 2007(5): 134 – 136. (in Chinese).

[26] FAN ZQ. On the protection of the variety of the traditional minority cultures and bio-resources in the three-parallel-running-river area[J]. Journal of Yunnan Nationalities University(Social Sciences), 2004, 21(2): 42 – 47. (in Chinese).

[27] REN WD. The construction of green ecological barrier in Northwestern Yunnan – Notes about ecological civilization building of Diqingzhou[N]. Guangming Daily, 2012 – 0 – 18(0030). (in Chinese).

[28] ZHENG JS, ZHANG J, ZI M. The protection of biodiversity of Northwestern Yunnan – An abstract of the speeches made at the meeting for biodiversity protection of Northwestern Yunnan[R]. 2008 – 03 – 19. (in Chinese).