Preliminary Evaluation on Resources Enhancement of Artificial Reef in the East Corner of Zhelang Shanwei

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Abstract In order to analyze the improvement of fish resource, the trawl net and gill net were used in the background survey and investigation in the artificial reef area and control area of the east of corner was discussed in Zhelang Shanwei in January 2003 and April 2010 respectively. Margalef species richness index, Shannon – Winener diversity index and Pileou uniformity index were chosen to analyze the multiformity of biological population and community structure. Resource density index of trawl net investigation and catch rate of gill net were chosen to estimate the variance of biomass. The results of the trawl net showed that the resources density of the artificial area increased by 3.078 times, and numbers of species increased by 1.875 times, squilla being the dominant group instead of the fish, and the first dominant species being squilla oratoria (Oratosquilla oratoria), which increased by 4.372 times before the artificial reef dropped. The results of the gill net showed that the catch rate of the artificial area increased by 12.043 times, numbers of species increased by 1.333 times, the dominant group was fish, it increased greatly, the first dominant species was golden small fish (*Sardinella aurita*), which increased by 13.035 times before the artificial reef dropped. Both the results of trawl net and gill net indicated that the effect of fish assemblage were evident, and the community structure had improved greatly. It showed a wonderful effect on conservation and assemblage of fishes resource. The artificial reefs developed a new resource enhancement system in the east corner of Zhelang Shanwei accomplished basically.

Key words Artificial reef, Nekton organism, Zhelang Shanwei, Resources enhancement

Artificial reef is to throw cement and concrete into the sea to create artificial bank for aquatic organisms so as to recover and reproduce fishery resources[1]. In recent years, influenced by the over – exploitation of fishery resources and the mass construction of offshore oceanic project, the fishery resources have being degraded and the narine environment has being deteriorated. Developed countries such as America, Norway and Japan have made great achievements in fishery resources and marine environment. Massive artificial reef has been constructed in China.

The artificial reef in Zhelanglies in the east part of Shanwei city in Guangdong Province. The reef is a kind of large ecological artificial reef. The body of reef is 7.04×10^4 m^2 and the reef cover 8.07×10^6 m^2. The water in the reef area is ten to twenty – one meter deep. The northeast part of the reef is Jingyu Island, the southwest part is Nanao Mountain and the southeast part is the massive South Sea. In order to provide more effective management and to offer reference on further construction, the trawl net and gill net were used in the background survey and investigation in the artificial reef area and control area of the east of corner was discussed in Zhelang Shanwei in January 2003 and April 2010 respectively.

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1 Materials and methods

1.1 Distribution of sample stations Situations in the reef station and comparison station were compared based on background survey and tracking investigation, and trawl net and grill net were applied for the study. The background investigation was carried out in January 2003 and the reef station was in the center of the reef (No. 5 in Fig. 1). The comparison station was about 3.7 km away from the south part of reef (No. 6 in Fig. 1). The tracking investigation started in April 2010. Because tracking net can not be operated in the center of the reef, the station is close to the edge of reef is considered as reef station. The location of compared station is same as the background investigation.

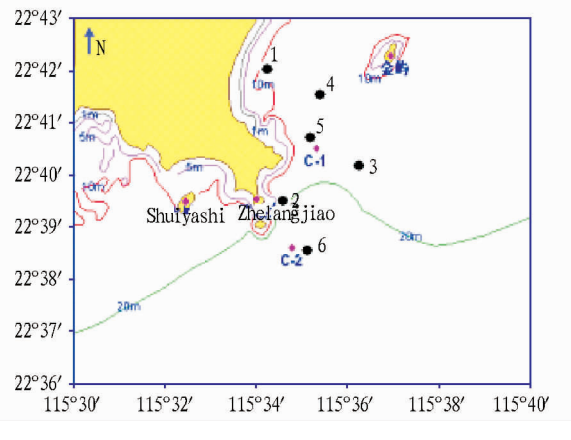

Fig. 1 Survey station in Dongjiao area in Zhelang

1.2 Sample collection and analysis The sample collection

and analysis of marine organism were carried out based on Marine Observation Standard (GB17378 – 2007)[2] and Marine Investigation Norm (GB12763 – 2007)[3]. Species of all caught animals were classified and measured. The data were analyzed in the lab.

The density index of trawl net of marine organism (D) is evaluated by trawl net and the unit was kg/km^2. The calculation formula was $D = \frac{y}{vl}E$. y is the catch rate of trawl net. v is the average trawl speed. l is the width of net mouth, and E is the evasion rate (0.5).

The catch rate of marine animals through grill (D′) is calculated based on the catch amount of grill per acre per hectare[6]. The unit is kg/hm^2 · h, ind/hm^2 · h. The calculation unit is $D' = \frac{C \times 10^4}{T \times H \times L}$. In the formula, C stands for the total harvest amount. T is the duration of using grill. H stands for the height of grill and L indicates the length of grill.

Margalef was applied to indicate the richness index (R)[7]. Shannon – Winener diversity index (H')[8] and Pileou uniform index (J')[9] were adopted to study the diversity of species. The calculation formula was as follow:

$$R = \frac{S1}{\ln N}$$

$$H' = \sum_{i=1}^{S} P_i \log_2 P_i$$

$$J' = \frac{H'}{\log_2 S}$$

Here, R stands for the richness of diversity. S stands for the total population of caught marine animals in each station. N stands for the total amount of caught marine animals in each station. H' is the diversity index and P_i is the ratio of caught animals in the total amount of animals. J' is the uniformity index. The degree of dominance of major marine species[10] is as follow:

$$Y = \frac{n_i}{N} f_i$$

Here, n_i is the number of the ith marine animal. f_i is the frequency of such species in each station. N is the number of each species in all stations.

2 Results and analyses

2.1 Changes of the density of marine resources According to the result of background and tracking investigation of trawl (Fig. 2), the density of total resource of each kind of marine animals increased significantly than ever before, from 374.730 kg/km^2 to 1153.584 kg/km^2, which was 3.078 times of that before throwing stones. The numbers of species increased by 1.875 times, squilla being the dominant group instead of the fish, and the first dominant species being squilla oratoria (Oratosquilla oratoria), which increased by 4.372 times before the artificial reef dropped. The variance of general species increased from 131.210 to 355.830 kg/km^2, which was 2.711 times before dropping the artificial reef. After dropping the reef, the density of biomass is 3.242 times of that during the same period.

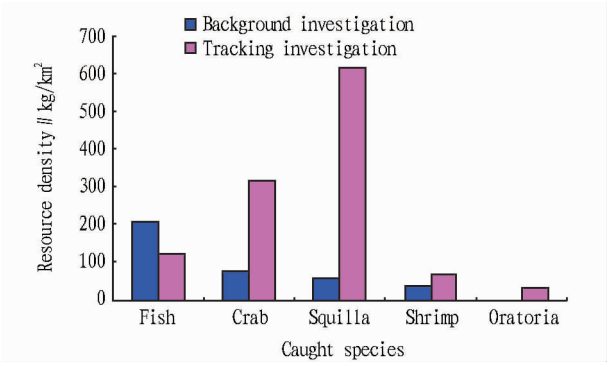

Fig. 2 The density of marine biomass in the reef through trawl investigation

According to Fig. 3, the catch rate of various marine animals increased dramatically after dropping the reef. The general catch rate increased from 2.556 kg/hm^2 · h to 30.782 kg/hm^2 · h, which was 12.043 times of that before dropping the reef. Fish rose the most, from 1.907 kg/hm^2 · h to 28.253 kg/hm^2 · h, which was 14.815 times before dropping the reef.

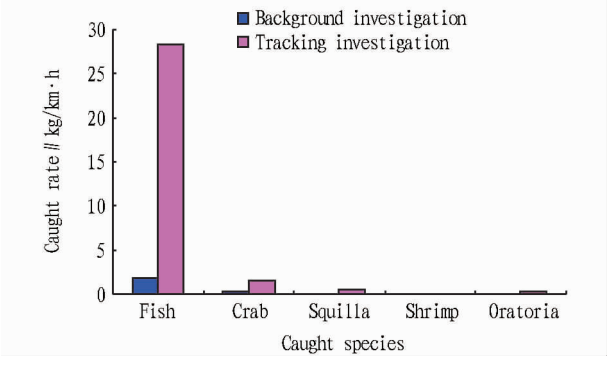

Fig. 3 Caught rate of marine animals in the reef area in grill investigation

Both the results of trawl net and gill net indicated that the effect of fish assemblage were evident, and the community structure had improved greatly. Thus, the artificial reef is a feasible way to attract fish.

2.2 Variance of marine species According to the trawl investigation (Fig. 4), the marine species in the reef area is much more abundant than that before dropping the reef. The total species increased from 16 kinds to 30 kinds, which was 1.875 times of background investigation before dropping reef. The amount of fish and crab rose quickly, fish increasing from four kinds to eight kinds and crab rising from five kinds to nine kinds, and shrimp enhancing from four kinds to seven kinds. There was no oratoria in the background investigation, Loligo duvaucelii and Euprymna berryi. The species of marine animals in the area was more diverse after dropping the reef than that before dropping the reef. The total species increased from eight kinds to nineteen kinds. The crab enhanced more significantly, rising from two kinds to seven kinds., while the shrimp increased from one kind to four kinds.

According to the investigation result of grill (Fig. 5), the species of marine animals was more abundant after dropping the

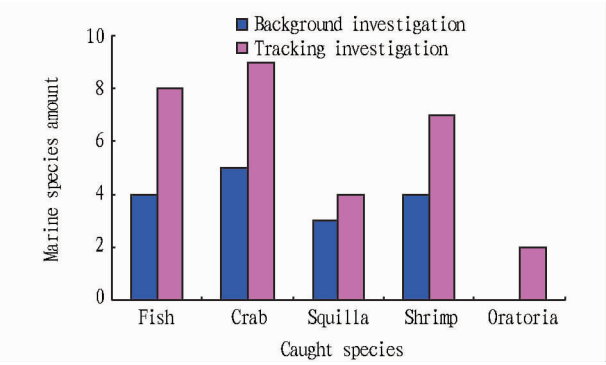

Fig. 4 Caught species amount of marine animals through trawling investigation

reef than before dropping the reef. The general species increased from 18 kinds to 24 kinds, which was 1.333 times before dropping the reef. The increase span of fish was the most, from eleven species to fifteen species. The squilla rose from two species to three species while the species of crab and oriatoria stayed the same. There was not any shrimp in the background investigation, but there was Penaeus penicillatus. After drooping the reef, the general species reduced from 27 species before dropping the reef to 10 species after dropping the reef. The amount of fish reduced from 22 kinds to eight kinds. The species of shrimp deceased from two kinds to one kinds. In the tracking investigation, there was not any crab or squilla and there was only one species of oriatoria before and after dropping the reef.

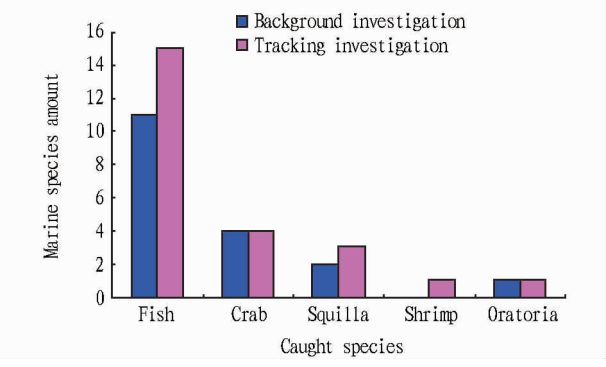

Fig. 5 Catch species of marine animals in the grill investigation

The changes of marine species before and after dropping the reef in Dongjiao area and its surroundings indicated that after dropping the reef, the new artificial background came into being, which showed evident attraction result to marine species (fishes and shrimps).

2.3 Changes of animal variance The investigation result indicated that the diversity index of species after dropping the reef increased from 5.438 to 3.694, which was 1.472 times before dropping the reef. The diversity of reef reduced from 3.576 to 3.380, which was 0.945 times before dropping the reef. However, the diversity index rose from 2.429 to 3.760, which was 1.547 times before dropping the reef. The uniformity indicators showed same change tendency. The uniformity index decreased from 0.894 to 0.688, which was 0.770 times as much as that before dropping the reef. Fig. 7 indicated that the species abundance after dropping the reef enhanced, which was 1.010 times of that before dropping the reef. The diversity index of reef area and comparison area decreased by 0.990 and 0.802 times. After dropping the reef, the uniformity index decreased, which was 0.900 times before dropping the reef.

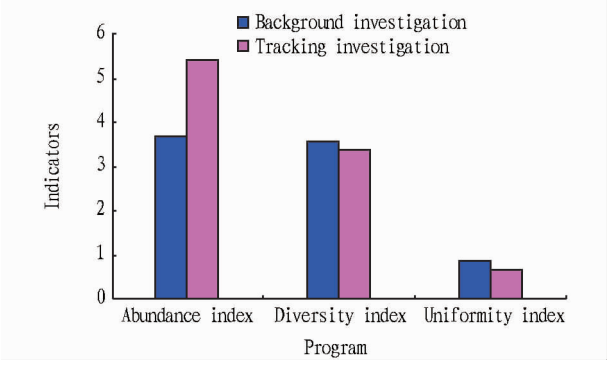

Fig. 6 The diversity index of marine biomass in the reef area through trawl investigation

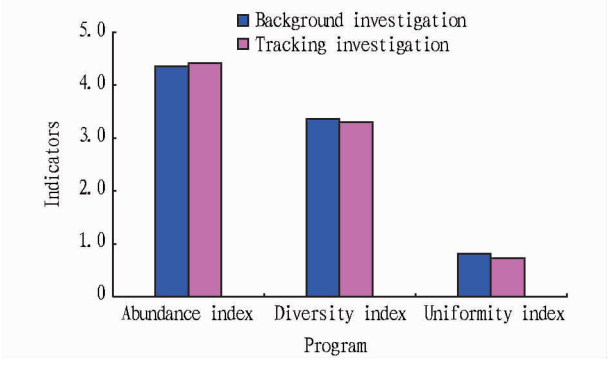

Fig. 7 The diversity index of marine species in the reef area through grill investigation

2.4 Changes of dominant species The trawl investigation suggested that the dominant species before dropping the reef was fish. The first dominant species was Johnius dussumieri at a density of 107.991 kg/km^2. After the reef being dropped, the first species was Oratosquilla costata at a density of 472.189 kg/km^2, which was 4.372 times before dropping the reef. The dominant species in the comparison area was crab and the first dominant species was Charybdis truncata at a density of 18.152 kg/km^2, which was 1.528 times as much as that before the reef being dropped.

Tracking investigation suggested that the dominant species after the reef being dropped was fish, however, the catch rate of first dominant species increased significantly. Before the reef being dropped, the dominant species was Siganus oramin at a catch rate of 1.074 kg/hm^2 · h, while the dominant species in the comparison area was Thrissa dussumieri at a catch rate of 0.003 kg/hm^2 · h. After the reef being dropped, the dominant species was *Sardinella aurita* at a catch rate of 14.000 kg/hm^2 · h, while the dominant species in the comparison area was Gerres macrosoma at a catch rate of 0.829 kg/hm^2 · h.

Table 1 Leading dominant species and resource density of marine animals in the background investigation and tracking investigation through trawl

Investigation time	Study area	Dominant species	Resource density//kg/km^2	Dominance
Background investigation	Reef area	*Johnius dussumieri*	107.991	0.16
		Trypauchen vagina	89.093	0.14
		Charybdis bimaculata	10.799	0.14
		Chaeturichthysstigmatias	7.019	0.10
		Solenoceracrassicornis	3.780	0.10
	Compared place	*Charybdis bimaculata*	11.879	0.48
		Bombayduck	102.592	0.10
		Pennahiapawak	5.940	0.10
		Harpiosquilla_harpax	3.780	0.10
		Chaeturichthysstigmatias	2.700	0.10
Tracking investigation	Reef area	*Oratosquilla costata*	472.189	0.33
		Charybdis bimaculata	89.191	0.21
		Parapenaeopsis tenella	12.461	0.10
		spinous process	124.605	0.05
		Alpheoidea	11.805	0.05
	Compared place	*Charybdis truncate*	18.152	0.14
		Charybdis bimaculata	13.047	0.13
		Oratosquilla costata	70.905	0.12
		Oratosquillinainterrupta	45.379	0.12
		Parapenaeopsis tenella	2.836	0.10

Table 2 Dominant species and catch rate in background investigation and tracking investigation by trawl

Investigation time	Study area	Dominant species	Resource density//kg/km^2	Dominance
Background investigation	Reef area	*Siganus oramin*	1.074	0.30
		Portunus sanguinolentus	0.370	0.22
		Psenopsisanomala	0.319	0.08
		Oratosquilla costata	0.063	0.06
		Monacanthus chinensis	0.060	0.04
	Compared place	*Thrissa dussumieri*	0.003	0.18
		Charybdis annulat	0.006	0.17
		Sebastiscusmarmoratus	0.006	0.13
		Archamia lineolata	0.002	0.10
		Siganus oramin	0.005	0.07
Tracking investigation	Reef area	*Sardinella aurita*	14.000	0.35
		Johnius belengerii	4.156	0.15
		Johniusdussumieri	1.973	0.08
		Pennahiaargentata	1.876	0.08
		Siganus oramin	3.222	0.07
	Compared place	*Gerres macrosoma*	0.829	0.27
		Sebastiscusmarmoratus	0.459	0.13
		Siganus oramin	0.388	0.13
		Johnius belengerii	0.346	0.07
		Osteomugil ophuyseni	0.247	0.07

3 Conclusions and discussions

Study of experts in China and abroad suggested that the artificial fishery reef plays a significant role in the protection and multiplication of marine resources and the improvement of ecological environment [1,11]. Through the comparison of background investigation and tracking investigation, the density and diversity of species of various kinds of marine animals in Zhelangjiao were higher than that before the reef being dropped. The large increase of resource density and caught species of fish reflected the attraction of some economic fisheries and dominant fisheries.

There have been many reports on the evaluation of the multiplication of artificial fishery reef. Du Zhong et al. studied the cultivation of marine animals in the artificial fishery reef and concluded that the artificial fishery had significant influences on marine animals and plants. Wang Zhenghua et al. [13] studied the influences of fish and large animals in Sanheng Mountain and proved that the natural habitats have been reshaped successfully from four aspects, resources, economic species, species abundance and diversity. In the study of caught marine species in the artificial reef by Chen Pimao [14-15], the effect of young fish and shrimp provides favorable habitats for fishes. The effect of artificial fish reef was significantly higher than that around the natural fish reef.

Through the comparison of Margalef abundance index, Shannon – Winener diversity and Pielou uniformity, the abundance of

species enhanced. The diversity index and uniformity index didn't change. As Wang Zhenghua et al. [13] concluded that the increase of resource density, improvement of species abundance and diversity doesn't mean the improvement of diversity. On the contrary, the rising diversity is caused by species abundance and resource density[13]. Scholars in China and abroad studied the similarity index of CPUE[12] and Jaccard[17]. The diversity of species improved to different degrees. The complicated group structure was stable as time went by[14-20].

Through the study on the changes of dominant species before and after the reef being dropped, it was proved that squilla became the dominant species in the reef area. Therefore, the quality of design determines whether the fish reef can meet the expectation. During the design process, the actual geography and hydraulic situation were considered[21-22]. Both the background investigation and the tracking investigation applied the trawl and grill method, which reduced the selection of nets and improved the accuracy of evaluation. However, both methods were destructive. Modern technologies[24] should be applied to reduce destruction. Therefore, in future, the tracking investigation should be practiced more often so as to be more accurate.

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developing geological tourism. Core competitiveness of Geo-parks is to be formed with the organic combination of subject, object and medium, forming stable competition advantage, being the key element of carrying out geological tourism and achieving the sustainable development of geological parks.

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