Construction and Effect Analysis of Artificial Reefs in the Pipakou Waters of Haiyang City

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Artificial reef construction is an important part of fishery resources restoration action plan in Shandong Province. Shandong Province has carried out large-scale artificial reef construction in the coastal areas of the Yellow Sea since 2005. By the end of 2017, there are more than 100 financial support construction projects above the provincial-level, with a total investment of nearly 2 billion yuan. Furthermore, accumulatively about 10 million cubic meters artificial reefs of various types have been deployed, of which more than 200 artificial reefs with an investment of over 1 million yuan have been built. Nearly 20 thousand hectares of sea areas have been repaired, and more than 30 artificial reef groups and 7 large artificial reef zones have been formed. The construction of artificial reefs has obvious effects on the protection of spawning grounds of main fishery resources in the Yellow Sea and Bohai Sea, increasing fishery resources, and restoration of the Yellow Sea Large Marine Ecosystem. The Pipakou waters of Haiyang city is one of the main spawning grounds for many economic fishes in the Yellow Sea and Bohai Sea, and it is also an important part of the Yellow Sea Large Marine Ecosystem. The government of Shandong Province give support to the artificial reef projects of Shandong Fuhan Marine Technology Co., Ltd. with 12-million-yuan funding in 2012 and 2015, and the company also invest 35 million yuan, constructing more than 210000 m^3 of proliferative and ecological artificial reefs. Here, the status and effects of artificial reef construction are analyzed to provide references for maintaining the health of the Yellow Sea Large Marine Ecosystem.

1. Current construction status of artificial reefs

1.1 Construction duration

Construction period of artificial reefs in the Pipakou waters of Haiyang city is divided into two phases: the first period is from 2013 to 2015, and the second period is from 2016 to 2017.

1.2 Reefs materials

The main materials used for artificial reef construction in the Pipakou waters of Haiyang city are stones, concrete components, steel components, cluster oyster shells, waste fishing vessels and so on. Among them, stones account for the largest proportion of 69.28%, and the corresponding deployment area is 150000 m^3; followed by concrete components, steel components, cluster oyster shells, waste fishing vessels, the proportions are 16.34% (35371 m^3), 4.97% (10752 m^3), 5.54% (12000 m^3), 3.88% (8400 m^3) respectively (Table 1).

Table 1 Construction components and scale of artificial reefs in the Pipakou waters of Haiyang city (m^3)

Construction components	Phase 1 (m^3)	Phase 2 （m^3）	Total (m^3)	Proportion （%）
Stone	58027	91973	150000	69.28
φ0.5×1 m Tubular concrete components	1869	8071	9940	4.59
0.4×0.2×0.2 m Rectangular concrete component	1869	139	2008	0.93
0.4×0.4×0.2 m Rectangular concrete component	9347	576	9923	4.58
4×4×4 m Steel frame component	10752	0	10752	4.97
3×3×3 m Square concrete component		13500	13500	6.23
Cluster oyster reefs		12000	12000	5.54
Waste fishing vessels		8400	8400	3.88
Total	81864	134659	216523	100

1.3 Construction scale

Over two-phase five-year construction, about 216,523 m^3 of artificial reefs had been

built in the artificial reef area of the Pipakou waters. Artificial reefs in the first construction phase mainly belong to proliferative type, and the main reef types are stone reefs, concrete components and steel components. Construction scale is 81864 m^3 after 3 years of construction. Artificial reefs in the second construction phase mainly belong to ecological type, and the main reef types including waste fishing vessels, concrete components, cluster oyster shells, and stones. Construction scale in the second phase was 134,659 m^3.

1.4 Construction area

The construction area of artificial reef in the Pipakou Waters of Haiyang City is 57.3784 hectares.

2. Construction effects

2.1 Seabed algae field in the artificial reefs area has been formed and fishery ecological environment has been restored

The follow-up survey shows that marine ecology of the former desertified sea areas have been significantly improved after the scientific and rational artificial reefs construction. Adhesion organisms such as algae and shellfish start sticking to the reefs after 1 year of reefs are deployed. At present, the main attached species are *Ulva pertusa*, *Sea mustard*, *Ostrea plicatula* and so on, and their total coverage have reached over 50% of the reef area.

2.2 Economic species have been protected and their abundance increased significantly

The construction of artificial reefs has significantly increased the abundance of nektons and benthos in the reef area. Fish cage survey shows that the abundance of fishery resources such as fishes, shrimps, and crabs in the reef area have increased significantly in October 2017. Specifically, compared to the abundance in October 2012, the abundance of the 23 economic species in the reef area have increased 2.29 times after

construction.

The number of fish caught per net is 90, which has increased 3.50 times than before. In addition, catch per unit of time is 7,154 g/net, which has increased 2.82 times than previous level (Table 2). The dominant species are reef-dependent speices such as *Stichopus japonicas*, *Hexagrammos otakii*, *Sebastes schlegelii*, *Sebastiscus marmoratus*, *Pseudopleuronectes yokohamae*, *Oratosquilla oratoria*, *Charybdis japonica*. Species in the artificial reef area are significantly different from its previous state. Artificial reefs construction has increased the richness and diversity of marine species, thus forming a healthy and friendly ecosystem.

Table 2 Comparison of biological resources in the artificial reef areas before (October 2012) and after (October 2017) reef construction

Species	October 2012		October 2017		Increments	
	Quantity (tail/net)	Weight (g/net)	Quantity (tail/net)	Weight (g/net)	Quantity (%)	Weight (%)
Hexagrammos otakii	2	224	22	1369	20	1145
Sebastes schlegelii	4	198	19	675	15	477
Symechogobius hasta	4	1054	6	1333	2	279
Oratosquilla oratoria	3	78	4	111	1	33
Charybdis japonica	4	239	5	320	1	81
Trachypenaeus curvirostris	2	11	4	1221	2	1209
Octopusocellatus	1	68	2	120	1	52
Stichopus japonicus			2	320	2	320
Sebastiscus marmoratus			3	260	3	260
Pseudopleuronectes yokohamae			1	25	1	25
Trypauchen vagina			3	20	3	20
Triaenopogon barbatus			1	13	1	13
albiflora croaker			1	160	1	160
Argyrosomus argentatus			1	180	1	180
Johnius grypotus			5	293	5	293
Conger myriaster			2	119	2	119
Portunus trituberculatus			1	145	1	145
Sepia esculenta			1	180	1	180
Alpheus japonicus			1	3	1	3
Alpheus distinguendus			2	7	2	7

Metapenaeopsis dalei			3	8	3	8
Octopus variabilis			1	260	1	260
Diogenes edward-sii			2	12	2	12
Total	20	1872	90	7154	70	5282

2.3 Fishery economic benefits have increased and fishermen also get benefits

After the completion of the first phase of artificial reefs construction in 2016, the surrounding fishermen begin to develop cage net fishery production in the artificial reef area. According to incomplete statistics, there are six fishing vessels using cage nets in the artificial reef area, and their total catches are 10,800 kg. The number of marine fishing reception up to 9200, and the corresponding catches are 60,604 kg. About 630 people capture sea treasures such as *Stichopus japonicus* by diving in spring and autumn with the catches of 28,350 kg. The total fishery output value is 7.44 million yuan (Table 3).

Table 3 Fishery production statistics in 2016-2017

Year	2016	2017	Total
Number of fishermen (person)	4	10	14
Number of fishing vessels (vessel)	2	4	6
Number of cage nets (unit)	60	120	180
Production of cage nets (kg)	27000	81000	108000
Number of sea fishing vessels (vessel)	3	8	11
Number of marine fishing reception (person)	2160	7040	9200
Marine capture production (kg)	14040	46464	60504
Number of people that fishing by diving (person)	105	525	630
Production for diving fishing (kg)	4200	24150	28350
Output value	1821000	5619800	7440800

3. Prospect analysis and suggestions

①. Further expand the construction scale of artificial reefs and generate scale effects.

Shandong Fuhan Marine Science and Technology Co., Ltd. owns 600 hectares sea area

of confirmed rights. At present, only 57.3784 hectares of artificial reef areas have been built, so area which is suitable for artificial reefs construction is still very large. It plans to further expand the construction scale and play the role of artificial reefs, and thus make contributions to the restoration of the Yellow Sea Large Marine Ecosystem.

②. Expand the construction scale of ecological artificial reefs and restore ecological environment.

The ecological benefit of artificial reefs is obvious to all, and it plays a significant role in protecting spawning grounds. Prior to the construction of artificial reefs in the Pipakou waters, fishery resources such as *Sepia esculenta* and *Sepiella maindroni* are extinct. The construction of artificial reefs provides rich and high quality adherent bases for these viscous fertilized eggs, so these depleted resources have been recovered and the function of natural spawning ground has now been restored.

③. Increase scientific research efforts and improve science and technology support for artificial reefs construction.

Carry out relevant theoretical and empirical system research such as artificial fish reef (group) construction techniques, formation mechanism of fishing ground, assessment technology for fish reef effects, anti-germplasm degradation fishing technology in the proliferating reef area by using the support of UNDP project and the advantages of scientific and technological resources of Taishan scholar leader team from Shandong Fuhan Marine Technology Co., Ltd. and Modern Fisheries Research Institute of Yantai University, adapting the way of industry-university-research cooperation, and increasing science and technology investment. Thus, forming a technical system according to our national conditions.