AN IMPACT AND MANAGEMENT STUDY OF TAIWANESE ARTIFICIAL REEF DEPLOYMENT

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ABSTRACT

For the past decades, around 20% of the natural coral reefs were lost and > 20% more is currently deteriorating. Due to the recognition of positive impact to fishery resources enhancement by artificial reefs (ARs) deployment, Taiwanese government has started deploying ARs as a measure to improve the environment of fishing grounds since 1974. At present, there are 88 ARs deployment areas that have been established in Taiwan, which account for more than 180,000 sets of fishing grounds. However, fisheries enhancement is not the unique purpose of ARs deployment, it also include marine ecotourism as well as protection or restoration of certain habitats. Due to the nature of public goods, this results in dispute about cost and effectiveness of ARs deployment. This study analyzed the experience of Taiwan throughout the four decades of ARs deployment, and examined the value of ARs and the mechanism of self governance. A questionnaire was designed to explore the perception on ARs of different stakeholders, and results show a certain level of achieving fisheries enhancement objectives. Increased incidences of conflicts upon territories of ARs fishing grounds among stakeholders were observed. It also implied that cooperatives of fishermen associations and community are essential in the management stage of planning ARs deployment. Based on Taiwanese experience, effective ARs should take into account all variables including reef design, site selection, depth, materials etc. It is also recommended that in the process of ARs deployment, one can not take the current economic benefit as the only criterion; decision-makers should also consider the impacts on the natural environment, the efficient use of resources, as well as humanities and social aspects.

Keywords: Artificial reefs, Deployment, Management, Taiwan.

INTRODUCTION

Over the last several decades, nursery habitats for fishes and shellfishes have been significantly reduced by the development of the coastal areas (www.floridaoceanographic.org, 2007). The reduction of these habitats, along with increased pressures on remaining coastal resources, has led to tremendous decline in the marine life population demonstrating the importance of artificial reefs (ARs). ARs are manmade structures defined by the European Artificial Reef Research Network (EARRN) as “submerged structures placed on the substratum (seabed) deliberately, to mimic some characteristics of a natural reef” (Baine, 2001). However, that definition differs with the traditional use of structures like breakwaters and oil platforms. Likewise, the requirement for reef deployment to be a deliberate act, disassociates the true ARs from structures that traditionally have been named as ARs. Nowadays, ARs are more than just for fish. They also provide alternate areas for scuba divers, anglers and fisherman to use, reducing the "user-pressures" that natural reefs endure.

Almost anything placed on the ocean floor can become the hard base needed for reef development under the right conditions. To create a permanent reef, however, the base material must not be tossed around by wave action or rust away, and it must be relatively stable and hard, thus preventing the new reef base from sinking into the sand. The restoration of coral reefs is another aspect to be taken into account because coral reefs are one of the most productive ecosystems, providing habitat for numerous species and serving important ecological functions. To successfully restore a degraded reef, one must examine the important processes that exist within and outside the spatial and temporal boundaries of a specific reef area (Precht, 2006). Taiwan has developed ARs projects as early as 1973, becoming an important policy in fishery management. During the past 40 years, more than 180,000 reef units have been constructed and placed at 88 sites in coastal waters, and Taiwan has achieved great experiences (both success and failures) on deployment and management of ARs.

Even though ARs have been suggested as a tool for reef conservation and rehabilitation, their effectiveness to mimic the natural reefs or match the high biological production of natural reefs is still debatable at this time. Some studies have compared the characteristics of the natural reefs versus the ARs (Perkol-Finkel et al., 2006). Wilson (2002) suggests that ARs, beyond a tool for rehabilitation and management, is a waste of materials and a source of ocean pollution. Others consider ARs structures to be inferior to natural habitat in their ability to support commercial reef fisheries. The controversy of the effectiveness of ARs to mimic the natural reefs, and the benefits versus negative impacts, is an issue not to be resolved in the short term. Some see ARs as a way to recycle waste materials, like used tires which are considered as useful, non-expensive, durable and readily available material for ARs Australia, Jamaica and the Philippines. But to some European countries, this material is seen as a source of pollution when used in reef construction. Many people refer to the ARs as “ocean dumping.” Governments have to regulate these kinds of projects and consider all environmental issues along with the costs and benefits of the proposed projects as they impact the society as a whole.

This study examined the experiences of Taiwan throughout the four decades of ARs deployment and management, including their most successful projects as well as those projects which have failed. This research is basically a documental analysis comprised of data collected from literature review and interviews among Taiwanese ARs experts. Characteristics like materials used, purpose of the ARs, and appropriateness of location of deployment were analyzed. Twenty-four (24) ARs sites were specifically studied through questionnaires in order to assess the reef performance. The questionnaire collected information like achievement of objectives, management, location, impacts on sea user or marine environment. These were then analyzed and combined into a matrix which allocates the reef performance of the ARs site.

ARs PERFORMANCE AND DESIGN

Objectives and Performance of ARs

Even though the main purpose of ARs is the enhancement of marine life and shore protection, the objectives vary worldwide. These include increase of fisheries yield and production in Japan, recreation and diving in the United States, and prevention of trawling in Europe (Baine, 2001). The use of ARs for environmental mitigation is a fairly recent development. The perceived primary application of ARs has been stock enhancement. However, ARs can also function other roles including coral reef restoration (Thamasak et al., 2006), recreation (Kaiser, 2006) and rehabilitation of coastal ecosystems (Pickering, 1996). There are many studies on ARs’ performance around the world, but scientific data available is limited since in most cases, analyses are only based on scuba surveys or underwater pictures. Some studies (several done in Taiwan) documented the biomass of marine living resources and measured the composition of species of economic interest. Baine (2001) reviewed 249 abstracts of similar ARs projects worldwide, and found that about 60% showed some achievements in their objectives. Most, however, did not meet their objectives in full and with limited success. Albeit significant success in certain cases, it proves the limited effectiveness of ARs to fulfill the set objectives. In addition, planning and ongoing management are key factors in the success or failure of any ARs. It has been demonstrated that not all

ARs resulted in increased fish harvest or productivity. Therefore, decisions should consider biological, economic and social factors, to ensure or increase the chance of success.

Types and Designs of ARs

There are several kinds of materials and designs for ARs, which can be divided into three categories: first are the materials that people do not want on land basically (e.g. tires, junk cars, old boats, etc); second are those constructed on land (either made of concrete, plastics, fiberglass and steel) and then deployed into the ocean, the most common type is the Reef Balls; third are those reefs made of limestone which are constructed under the sea by means of electric currents to build limestone rock onto artificial reef frames through the process called "mineral accretion" (Malaspina, 2007). In recent years, the trend in AR development has turned toward the designs to efficiently function as reefs. Leading the way was the Reef Ball Foundation through the introduction of Reef Balls in 1993. The designed systems can be modified to achieve various end-use goals including coral reef rehabilitation, fishery enhancement, snorkeling and diving trails, beach erosion protection, surfing enhancement, fish spawning sites, planters for mangrove replanting, enhancement of lobster fisheries, creation of oyster reefs, estuary rehabilitation, and even unique uses such as deep water coral replanting. The systems also overcame the problems associated with "materials of opportunity" such as stability in storms, durability, and biological fit, lack of potential pollution problems, availability, and reduction in artificial reef costs. They are much more sophisticated than materials of opportunity with specialized surface textures, and include features such as coral planting attachment points, specialized pH neutral surfaces (such as neutralized concrete, ceramics or mineral accretion surfaces), holes to create currents for corals, and materials other than iron, which can cause algae to overgrow coral. Other designed systems include enhanced surfing, control of erosion on beaches, create aquaculture opportunities for lobster, create oyster beds, or can also be used for a large variety of other specialized needs (Reef Ball Foundation, 2007)

ARs IN TAIWAN

As early as 1957, pioneer work on ARs was carried out by local government agencies. In coastal waters of Linbien in south Taiwan, a total of 384 small concrete blocks of 1 m^3 were deployed to increase the catch ofcoastal fisheries. In 1970, another site chosen for the experimental deployment of AR was the offshore waters of Miao-li in northwestern Taiwan (Jan, 2003). However, other authors reported that Taiwan began installation of ARs in 1973. Over three decades, the number of ARs have been increasing (Lin and Wang, 2006; Table 1) and in 2008, a total of 88 AR sites were established throughout Taiwan (Table 2; Figure 1). These account for a total of 2.2 million m^3 of reefs in various forms, and more than 180,000 reef units. The total area covered by ARs in Taiwan is 232.14 km^2. According to Chang and Jan (1984) the procedure followed for AR deployment is: 1) site survey and selection; 2) material selection and reef design; 3) reef construction and deployment; and 4) evaluation of effectiveness. Initially (in 1973), the sites were selected through the following criteria: 1) not closer than ½ miles from nearest natural reefs; 2) at a depth of 20-30 m; 3) with a wide, flat substratum, composed on sand pebble; 4) non-polluted or non-turbid waters; 5) protected from strong currents (current velocity not more than 1.5 knots) (Chang and Jan, 1984; Chang and Shao, 1988). Nowadays it also considers a fact that no ARs can interfere in the navigation rout of ships.

Table 1. Stages of the Taiwanese ARs Development

Year	*Stage*	*Significant features*
1957	Beginning of Artificial Reef Deployment in Taiwan	384 small concrete blocks of 1 m^3 were deployed in Lin-bien, southern Taiwan.
1973-1981	Growth Period	In 1973, Taiwan experienced a drop in fish catch volume for first time, and the government launched ARs along the west coast of Taoyuan, Hsinchiu, Miaoli, and Penghu.
1982-1996	Promotion of Artificial Reef Installation	The installed volume gradually grew from a few thousands cubic meters in early 1980's to 200,000 m^3 in 1996, including tire reefs, ship reefs, square reefs (1m-1.5m), double-layer reefs (1.9m-2m), abalone reefs, lobster reefs, ball reefs, fly ash reefs. cross reefs, etc.
1996-present	Transformation and Conservation Period	Starting from 1996, the Fisheries Agency initiated a series of studies to polish the techniques of artificial reef installation, particularly on the structure, design, anchor, satellite positioning etc. National Sun Yat-sen University applied Side Scan technique in the investigation of ARs for first time. Net fishing vessels were banned from entering and operating in artificial reef areas. The fishery agency has installed 13 warships as ARs since 1999 for ecological restoration and conservation. Since 2000, the Fisheries Agency began to instruct the Fishermen's Associations to establish a mechanism of maintaining ARs.

Source: Lin and Wang, 2006

Table 2. Distribution of ARs Sites in Taiwan

Administrative Region	***Number of ARs***	***Average Depth (m)***	***Total Area (km^2)***
Keelung City	3	27.00	8.08
Ilan City	5	21.00	13.92
Taipei County	8	23.88	19.86
Taoyuan County	3	26.67	8.08
Hsinchu County	2	30.00	5.39
Hsinchu City	3	28.33	8.08
Miaoli	7	23.29	21.99
Taichung County	4	23.00	10.78
Chiayi	1	30.00	2.69
Tainan	4	27.25	12.57
Kaoshung County	12	23.25	32.33
Pintong County	10	30.80	34.11
Hualien	6	25.17	16.16
Taitung	5	25.00	13.47
Penhu County	13	25.46	26.55
Kimen	1	NA	0.79
Total	**88**	26.01	**234.85**

Source: http://www.fa.gov.tw/

Figure 1. Distribution of ARs in Taiwan

Source: http://www.fa.gov.tw/

Materials and Construction of ARs

In Taiwan, several types of materials, including scrapped boats, old tires, concrete blocks as well as fly ash have been used (Chang and Shao, 1988). Among these, the concrete blocks (small -1 m^3 and giant -12 m^3) are the most common for the construction of ARs. Compared to other materials used, concrete blocks demonstrated to be the most desirable because of its durability which is important for an effective artificial reef. Junk or scrapped boats showed to be the most effective in attracting fish populations, but its durability is only up to 3 year at the most (Jan et al., 2003). In selecting materials for ARs, factors pertaining to initial cost, fabrication or preparation, transportation and durability have to be evaluated. Since fishes are attracted to reefs with many hiding places, the ARs must be constructed with internal cavities. Currently reef materials that fulfill this criterion are limited to several types of high density materials of opportunity, such as concrete utility poles and 2 m^3 concrete cubes. During deployment, concentrating material or shelter units on the selected sites proved to be a major difficulty. As a result, most of the recent ARs construction employed the use of giant concrete blocks for easy maintenance and handling. Since 1976, the Taiwan Fishery Bureau assumed the responsibility of making all the giant concrete blocks and installing the reefs with barges equipped with mechanical cranes. Less dispersion has been found when those reefs were installed intensively in a shorter time. Furthermore, the rough sea condition during the northeastern monsoon season has also contributed to the difficulty in deployment and monitoring of ARs. Other problems include high waves and long surges during typhoons which resulted to damage in the marker buoys and destroyed some of the ARs (Jan et al., 2003).

Objectives of ARs Deployment in Taiwan

The ARs projects in Taiwan have had different objectives along its four decades of history. In the beginning, the main objective was focused on fisheries enhancement due to the depletion of coastal fisheries resources. This objective can be traced back since the beginning of AR deployment as early as 1957, and continued during the growth period (1973-1981). It was because ARs then were used as fish attraction devices, as fishermen experienced increasing catches. During the promotion and reef installation period (1982-1996), fishermen started to protest against ARs because they claimed that ARs reduced fish gathering capability once covered by fishing nets. So it was not until the transformation and conservation period (1996-present) that other objectives were realized including water sports and marine ecotourism, with emphasis on reuse of materials. According to Liao (1997), stock enhancement started in Taiwan with the building and casting of ARs in 1973. It was not until 1987, that an integrated program on the operation and establishment of a stock enhancement system was developed, declaring 25 fisheries resource protected zones. From 1976 until 1996, Taiwan Fisheries Research Institute had restocked seven species of finfish, four species of mollusks, and six species of crustaceans for stock enhancement. Taiwan has spent considerable amounts of resources in deployment and management of ARs. According to the Taiwan's Fishery Research Agency, a total of NT$1.782 billion were spent in AR programs. This number gives an idea on the importance of the AR projects in Taiwan.

Evaluation of ARs Effectiveness

The evaluation of ARs in Taiwan started as early as 1976 through a film recorded by Academia Sinica's investigative research (Chang et al., 1977). Other research studies followed including assessment of invertebrate communities and species composition and standing crops of marine organisms around numerous reef areas until 1980 (Chang and Jan, 1984). Chang and Shao (1988) also studied the performance of ARs sites and Jan et al. (2003) studied the relationship between production and reef pile size, using standing stocks of fishes surveyed at three established AR habitats in subtropical waters of northern coast of Taiwan. Some major findings of the above studies show that reef sites that were constructed in bay areas were more effective than those constructed in open waters exposed to strong currents. Invertebrates with hard calcareous shells or tubes (e.g. polychaetes, barnacles, ectoprocts and stony corals) were among the initial colonizers, followed by free-living invertebrates with high self-protective ability (e.g. crabs and gastropods). Gradually, more encrusting invertebrates with less protective ability (mainly solitary and colonial sea squirts and sponges) and soft sea slugs, sea cucumbers, amphipods, clams, shrimps, flat worms and sea urchins appeared. A rich fish community was also found. In Nan-wan, as example, a total of 85 species of fishes were counted; among them, the schooling *Spilotichthys pictus* were the most conspicuous since most those observed were large in size. Others, such as spade fishes, snappers, and sea breams were found in swarms. Similar fish populations were found in Penhu. Chang and Shao (1988) studied the effectiveness of seven ARs through scuba diving observation. Economically important fish species comprised 64% of the fish fauna in the ARs, representing more than 90% of the total biomass (Table 3).

Table 3. The Importance of Economic Fish Species on the ARs in Taiwan

Localities	*Wan-hai-Shang*	*Ta-wu-lu*	*Kuei-hou*	*Shih-cheng*	*Tung-ao*	*Sou-kang*	*Nan-wan*
Number of species	33	30	34	33	23	28	85
Economic fish species (%)	22 (66.7%)	19 (63%)	24 (70.6%)	17 (51.5%)	20 (87.0%)	20 (71.4%)	32 (37.6%)
Coral fish species (%)	11 (33.33%)	11 (36.7%)	10 (29.4%)	16 (48.5%)	3 (13.0%)	8 (28.6%)	53 (62.4%)
Biomass of economic species (%)	94	92	91	89	97	94	93

Source: Chang and Shao, 1988.

Early studies have demonstrated that depth is an important aspect that affects the effectiveness of the ARs. Chang (1985) studied wooden fish boats (8 m x 3m x 3m) placed in the same bay (Nan-wan): one was situated at a depth of 35 m near a natural reef; and two were in open sandy areas at depths of 25 and 18 m. Results showed remarkable differences in biotic complexity and abundance. Higher density (8.22 and 6.60 fish/m^3) and biomass (285 and 325 g/m^3) were observed in ARs in shallow water (18 and 25 m, respectively) than in deep water depth of 35 m (density = 0.15 fish/m^3; biomass = 5.49 g.m^3). More recently, Jan et al. (2006) surveyed 17 ARs sites (covering six electric utility poles sites, five steel-frame sites, and nine obsolete vessels sites) and six natural reefs for comparison of fish fauna. A total of 232 fish species in 81 assemblages were observed among the ARs and natural reefs surveyed. Grouping the sites in four geographical regions (northern coast, eastern coast, southern coast and Penhu islands), the smallest fish assemblage (7 species) in ARs was found in northern coast, while the largest (83 species) was found in the south. Higher number of fish species was observed among natural reefs, 28-76 species in northern coast and 69-73 species in southern coast. Comparing the fish fauna among different reef types, higher number of species were observed around natural reef flats (mean of 59 species), followed by isolated natural reefs (mean of 52 species). The ARs, on the other hand, have mean number of species between 25 and 28 and predominantly composed of smaller fish species.

Electrical Poles and Old Ships as ARs, the Taiwanese Experience

Over the past three decades, Taiwan has deployed large numbers of ARs made from discarded utility poles, decommissioned naval vessels and discarded tires, at designated areas along the coastline to enhance fishery resources. The use of utility poles as ARs is one of the most represented projects in Taiwan. The reefs were constructed under a long-term cooperative program between the Council of Agriculture's (COA's) Fishery Administration and state-owned Taiwan Power Co. (Taipower). With underground electrical wiring becoming a general trend, Taipower has donated many cement utility poles for the creation of more than 10,000 ARs in eight coastal regions. In addition to enhancing fishery resources, the ARs areas have also become points of interest and create new businesses in such areas as deep-sea diving, leisure fishing and recreational scuba diving. In recent years, discharged warships with spacious surface area and multiple habitats for fish became a part of ARs project. With the hopes of creating new fisheries and habitats for fish, the Fisheries Agency launched the “Reef Diversification & Resource Reuse” project in 2002. Through the efforts of the Fisheries Agency and the Navy, 13 warships were deployed as ARs in different parts of Taiwan up to April 2003. Ship reefs possess several advantages over general reefs. Through comprehensive planning and reconstruction of old navy vessels, they were turned into effective life-luring reefs. Over time, a prime marine ecological system was created that in turn became an excellent fishing ground, thus, will add substantially to local fisheries income. Furthermore, not only can ship reefs kept their original form and reminded people of war history, but they also provide supreme spots for underwater sightseeing, diving and recreational fishing.

CASE STUDIES

In order get a closer and more detailed examination of reef materials, purpose and environmental conditions, management and performance case studies were performed through interviews among Taiwanese experts in ARs deployment and management. From the 88 artificial reef sites, 24 were chosen as study cases based on the existing available information (Table 4). The 24 selected ARs sites also represented different types of ARs in Taiwan and the different regions where these ARs were deployed. Information collected for each site and data gathered during the interviews were compiled and a matrix, which evaluates reef performance, was formulated based on the criteria listed in Table 5. Results are shown in Table 6.

Table 4. List of artificial reef sites chosen as case studies

Number	***Site***	***Coordinates***	
		Latitude	***Longitude***
1	Ilan Shicheng	N24°57.466	E121°56.548
2	Keelung Dawu-lu	N25°10'45"	E121°42'40"
3	Ian Dangao	N24°30'18"	E121°50'12"
4	Ilan Nanao	N24°25'30"	E121°47'36"
5	Taipei Yeliu	N25°12'29"	E121°41'56"
6	Taipei Aodi	N25°03'48"	E121°56'48"
7	Taoyuan Zhuwei	N25°09'42"	E121°14'00"
8	Mioali waipu)	N24°39'36"	E120°44'30"
9	Tainan Anping II	N22°55'00"	E120°06'52"
10	Tainan Anping III	N22°54'00"	E120°06'30"
11	Tainan Anping IV	N22°56'54"	E120°03'54"
12	Kaoshung linyuan I	N22°27'00"	E120°21'00"
13	Kaoshun Linyuan II	N22°27'00"	E120°21'30"
14	Kaoshun Linyuan III	N22°26'00"	E120°18'00"
15	Pintung Haikou	N22°06'24"	E120°41'12"
16	Pingung Linbian I	N22°22'00"	E120°28'30"
17	Pingung Linbian II	N22°22'30"	E120°28'00"
18	Pingung Linbian III	N22°23'00"	E120°28'00"
19	Penhu Ding-gouyu Point A	N23°36'32"	E119°41'40"
	Point B	N23°36'11"	E119°41'40"
	Point C	N23°36'11"	E119°42'03"
	Point D	N23°36'32"	E119°42'03"
20	Penhu Neianbei Haiyu Point A	N23°34.654'	E119°29.197'
	Point B	N23°34.654'	E119°28.796'
21	Keelung Whangai-hang	N25°08'36"	E121°48'18"
22	Pintung Nanfucun	N22°19'05"	E120°21'25"
23	Miaoli Baixin	N24°34'30"	E120°40'30"
24	Taitung Zhuhu	N23°15'30"	E121°21'26"

Source: http://www.fa.gov.tw/

Table 5. Matrix used to evaluate reef performance of case studies.

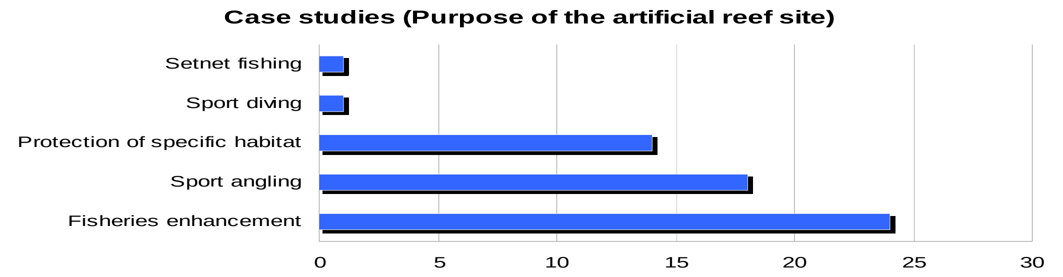
Scale	**Reef Performance**
-3	**The reef has failed in its objectives and has negatively impacted the local environment or sea users.**
-2	The reef has had inappropriate location; It does not exhibit any achievement of objectives nor any effect in terms of the local environment or sea users; poor or none research has been done.
-1	**The reef has had inappropriate location, but it exhibits some achievement of objectives and also other beneficial effects in terms of the local environment or sea users. Some research has been done but is poor and not conclusive**
0	The reef's performance in terms of its objectives is inconclusive. Some positive aspects are identifiable but the overall success of the reef is indeterminable. The reef has had poor management
+1	**The reef has only succeeded in meeting its objectives with limited success. Beneficial effects are recognizable. Research is fair enough to determine their performance; management has been good but needed to be improved.**
+2	The reef has succeeded in meeting its objectives. It also shows positive effects over the local environment or sea users. Research is fair enough and conclusive and has good management but still needs improvement.
+3	**The reef has successfully met all of its objectives. There are no social or ecological concerns; research is fair enough and conclusive; the management is considered very well so it does not require any change.**

Table 6. Allocation of reef performance in the case studies

	Reef Allocation scale -3	-2	-1	0	1	2	3
Artificial Reef sites		4,5,20	7	9,10,11,12, 13,14,22,23,24	16,17,17	1,2,3,6, 15,19,21	1
Total		3	1	9	3	7	1

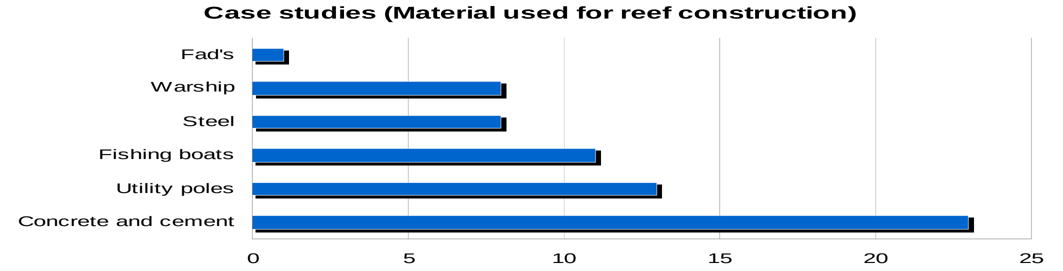
Reef Purpose and Material Used

Figure 2 provides a general perspective on the purposes of ARs in Taiwan. As we can see, fisheries enhancement has been the main purpose of the deployment of ARs (100% of the case studies). In fact, the first AR projects in Taiwan came from fishermen's suggestions after they observed that some aircrafts which crashed into the sea became shelters for many fish species, mostly those with economic importance. At present, ARs deployed in Taiwan also fulfill other purposes such as sport angling, diving and other activities related with marine ecotourism, as well as for protection or restoration of certain habitats. Most of the case studies show a combination of these purposes as their objectives for deployment, e.g. fisheries enhancement and sport angling or protection of a specific area. Figure 3 shows the different types of materials used for reef construction. By far, the most favored reef material was concrete, followed by utility poles. Concrete has also been combined with other reef materials, mainly with warships and fishing boats. It is noted that ARs made of concrete are present in 95.8 % of the case studies (23 cases). Meanwhile, utility poles are present in 13 cases (54%), followed by those made of old fishing boats (45%), steel (33%) and old warships (33%). Some combinations on the use and arrangement of materials can also be noted in some cases, e.g. warships often have some reef structures built on their deck, mainly made of utility poles.



	Fisheries enhancement	Sport angling	Protection of specific	Sport diving	Setnet fishing
Number of sites	24	18	14	1	1

Figure 2. Main purpose of the artificial reefs



	Concrete and cement	Utility poles	Fishing boats	Steel	Warship	Fad's
Number of sites	23	13	11	8	8	1

Figure 3. Main materials used in reef construction

Reef Performance

Taiwan has formulated basic criteria to deploy ARs in the past, but some of the ARs were not properly deployed. This study shows that 17 % of the ARs cases (4 of 24) were deployed on an inappropriate seabed, e.g. at Yeliu and Penhu Neianbei Haiyu where ARs were deployed too near natural reefs. In other cases, strong currents were not taken into account, e.g. Taoyuan Zhuwei and Nanao in Ilan County, resulting in the destruction of the ARs one year after deployment. Today, Taiwan follows strict requirements before ARs deployment assuring the success of the projects. Table 4 describes the criteria for ARs reef sites based on reef performance therein a scale from -3 (worst) to +3 (best). However, all positive qualifications (+1, +2 and +3) mean a certain level of achievement of objectives and in general a certain level of good performance. The conclusions of that analysis were complemented with other data collected from literatures reviewed for each of the ARs sites studied, and the overall results are presented in Table 5. Based on the results, one AR site (Ilan Shicheng) falls under category +3, which clearly implies that this site is well documented and properly managed with benefit impacts over marine environment and sea users. Ten other ARs sites (42%) fall into the positive category (+1 to +2), demonstrating certain degrees of successes. Nine cases (37%) fall under 0 categories, mainly reflecting inconclusive reef performance in terms of its objectives. These ARs sites also show some positive effects but limited research has been done to evaluate their overall performance. The case studies also demonstrated that 4 sites (18%) fall into negative categories (-2 and -1), not just because those ARs sites failed to achieve their objectives, but also because there exists some ecological or social concerns. None of the sites studied fall under category -3.

To assure the effectiveness of any ARs deployment, experts suggested to follow the following criteria: 1) not closer than 1,000 m from nearest natural reefs; 2) at a depths between 18 to 28 meters; 3) with a wide, flat substratum, composed on sand pebble; 4) avoid polluted or turbid waters; 5) a preferable site shielded from strong currents greater than 1.5 knots (1.852 km per hour); 6) do not interfere in the navigation rout for ships. Different reef materials have different effectiveness, but there is not much data to do an appropriate assessment. Further studies or programs should, therefore, be conducted in this regard. Besides, ARs can attract fishes and enhance recruitment, its exploitation as “fishing tool” has to be avoided or at least minimized. One to two kilometer diameter protected area could be a good distance to protect stocks from depletion (Shao, 2006). Taiwanese experience has demonstrated that concrete is an inexpensive material and it has an acceptable level of effectiveness. Thus it could constitute the most appropriate material to reef construction.

DISSCUSION

There is fair enough information that proves the effectiveness of ARs deployed for different purposes. These submerged structures can attract many marine organisms and up to a certain point, can hold pelagic fish species including species with economic importance (Chang and Jan, 1984; Chang and Shao, 1988; Jan et al., 2006). However, not all AR projects are successful, as some did not follow the set guidelines for deployment. This study shows four of the 24 cases studied were deployed in inappropriate locations resulting in the failure of the project. Some AR projects have damaged living coral reefs, such as the “pole reef” deposition in Green Island, one of the most pristine reefs in Taiwan. Concrete and cement is largely used in Taiwan due their lower cost and durability. Recently, however, Taiwan has started using reused materials like utility electric poles and warships. The utility poles, like cement and concrete, are relatively cheap and readily available, and they have been recycled into structures that can help marine environment along the coasts of Taiwan. On the other hand, the Taiwanese experience of converting warships into ARs is more than the recycling of materials, but a philosophic concept of reusing an instrument of war for peace and prosperity. However, some of them had not fully accomplished their objectives, like Neianbei Haiyu on the island of Penhu.

Fisheries enhancement is the goal of almost every ARs project, especially during the early stages of AR deployment. This is understandable due to the long history of Taiwan's very close relationship with the sea as a source of food and also a source of foreign exchange. At present, ARs are also deployed as a source of leisure, recreation and spiritual renewal, along with protection of specific marine habitats. Wit regard to research status in Taiwan, 54% of the ARs have been studied for the last four decades, while the rest were poorly studied (42%) or no research was done at all (4%). Most of the research studies were done by scuba diving observation (Shao, 2007) which was recognized to have limited range of observation. The sampling frequency was also insufficient, thus, it is difficult to get convincing quantitative data and assessment results.

CONCLUSION

Taiwan has come a long way in the development of ARs, and this experience gives Taiwan an excellent position among the nations which have implemented ARs projects around the world. This study gives valuable information, such as durability of material, roles played by depth and speed of marine currents, which are useful in the deployment of ARs. Although there may not be much scientific data supporting the ability of ARs to increase biomass of living marine resources, evidences on this aspect are available in some studies. According to researches done on the effectiveness of ARs in Taiwan, 50% of the case studies show full achievement of objectives and 12% have not achieved their objectives at all. Several types of ARs have been used in Taiwan, including fishing boats, tires, utility poles, concrete, electric poles and warships. Concrete and cement are the dominantly used materials for ARs due to their lower cost and durability. In this study, almost all (23 of 24) ARs sites studied include concrete ARs that were deployed. Other considerations are taken into account for some important projects, such as recycling purposes, like the project on the electrical utility poles made into reefs. Fisheries enhancement is the main objective for reef deployment (100% of the case studies). Today, Taiwan does try to combine sport, leisure and marine tourism with fisheries enhancement. Many factors can affect the effectiveness of ARs, and to assure the utmost efficiency of any ARs deployment, the formulation of standard operating procedures (SOP) is needed. Among these factors and criteria are purposes, materials and design, site selection, placement techniques, and supervision and management. Thus it is necessary to take all those variables into account in an integrated framework during the process of planning, and for that purpose, it is necessary to standardize these criteria through decision making matrices or other methods in order to achieve this objective.

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