Fish visual census technique – an alternative method for the assessment of fish assemblages on artificial reefs

Ukkrit Satapoomin
Phuket Marine Biological Center, P.O. Box 60, Phuket 83000, Thailand

BACKGROUND

Artificial reefs (ARs) have been used as part of coastal zone management or in fishery management to provide new habitats (that increase number and biomass of fishery resources), to restore habitats, to protect sensitive area (such as spawning and nursery grounds), to protect biodiversity, to reduce fishing pressure in certain areas, to reduce fishery conflicts, e.g., by limiting trawling in nearshore areas where commercial trawling completes with artisanal fishermen, and also to support recreational uses, e.g., recreational fishing, diving, and tourism (Bohnsack and Sutherland, 1985; White et al., 1990; Seaman and Jensen, 2000). Particularly in Southeast Asian countries where coastal marine resources have been heavily exploited (Pauly and Chua, 1988), ARs have become a popular resource enhancement technique (White et al., 1990). In most countries, AR construction is supported and sponsored largely by government.

In Thailand, ARs have been in use since 1978 as part of a marine conservation program of the Department of Fisheries (Boonkird, 1984; Boonprakob, 1986). ARs have been installed in many places both in the Gulf of Thailand and the Andaman Sea (Sinanuwong et al., 1986; Awaiwanont, 1991). The plan for construction and installation of ARs is still kept going on. Although without sufficient scientific evaluation for the effectiveness of ARs installed so far since the past 25 years, local communities, especially fisher-folk, still appreciate the AR construction plan. They have positive attitude to the effect of AR against the degradation of coastal resources, in particular by preventing destructive fishing gears like push nets and trawlers - on one extreme in their opinion, AR is the ultimate tool. More ARs are continuously proposed by local fishermen through local governmental organizations. Their requests always attract political concerns. This (political influence) is why AR installation plan is easily adopted as a national policy.

From scientific stand point, there have been serious criticisms over failure or success of AR construction program worldwide. Bohnsack and Sutherland (1985), for example, warned that: “Perhaps too much effort has been expended in building ARs and not enough in research….not all ARs have increased fish harvest or productivity. In many areas, managers have the mistaken belief that they can proceed with large-scale programs without research.” There are also several other serious critics, but very useful for further consideration:

- The present state of knowledge can not as yet give a clear understanding of AR biological and ecological functions (White et al., 1990).
- Lack of knowledge concerning ecology of ARs is a central problem in the debate on their proper use in fishery management (Bohnsack et al., 1991).
- Inadequate long-term monitoring of ARs precluded explanation of their functions and inevitably results in an inability to evaluate the degree to which the habitat meets its original objectives (Seaman and Sprague, 1991).

Evaluation schemes for AR, spanning from biological to socioeconomic aspects, had been set up along with nearly all construction and installation programs in Thailand (Sinanuwong et al, 1986; Artificial Reefs Study Team, 1989; Boonchuwong, 1994) but most of the results are less substantive. Although limitations of budget and scientific personnel were always claimed to be major problems, in my opinion inadequate sampling protocol as well as its associated methods for each evaluation scheme was the real problems. The limitations of sampling methodology remain a major obstacle to our understanding of AR ecology (Bohnsack and Sutherland, 1985). Fishes and fisheries within and around ARs are among the most important components for AR evaluation. However, there is still limited number of studies regarding biological and ecological impacts of ARs on associated fish populations. As pointed out by Polovina (1991), such limitation is certainly not due to a lack of interest but rather to the difficulty in collecting the appropriate data. Rather than criticizing the AR evaluation program (a tough job to touch), this article aim to recommend a useful methodology, visual census technique (VCT), which is applicable for studying fish populations or fish assemblages at artificial reefs. Some results of my previous studies applying VCTs at selected AR sites in Thailand are exemplified.

■ VISUAL CENSUS TECHNIQUES

AR assemblages are dynamic and respond to the same ecological factors (i.e., physical disturbances, recruitment, competition, and predation) that operate on natural reefs. Interestingly, much of what we know about natural reef ecology, particularly on the ecology of fishes, is based on experimental studies using artificial or manipulated habitats (e.g., Sale and Dybdahl, 1975, Ogden and Ebersole, 1981, Bohnsack, 1983, Walsh, 1985, Caley, 1995, and Kawasaki et al., 2003). To date, fish visual census technique is widely used for studying fish assemblages on natural coral reefs (e.g., Williams, 1982, Alevizon et al., 1985, and Letourneur, 1996) as well as other subtidal habitats such as rocky reefs (e.g., Berry et al., 1982 and Tuya et al., 2004) and macrophytic communities (e.g., Nakamura and Sano, 2004). The techniques can also be applicable in ecological study of fishes at ARs. There is a variety of sampling performances for the so called VCT which have been described in details elsewhere (e.g., Bortone and Kimmel, 1991, Halford and Thompson, 1994, Cappo and Brown, 1996, English et al., 1997, and Hill and Wilkinson, 2004). In this regard, only brief description is provided here.

***VCT – with predetermined area or belt transect*:**

For the case of predetermined area, sampling area will be defined in the first place, usually as experimental plots, grids, or permanent quadrats. Fishes in each sampling area will be censused (i.e., each individual species is identified and counted) within a fixed period of time. For the case of belt transect, transect line has usually been used as a leading line or a reference for the exact length of the censused area. Transect lines will be laid down first then one or a pair of observers census fishes within a restricted length either side of (as belt or strip) and above transect. Number of transects (as sampling replicates), length of each transect, and width can be adjustable according to situations and purposes. Narrower width (e.g., 5m [2.5 m either side]) is applied in low visibility condition. The width (1 m either side) is recommended for studying juvenile-fish recruitment. The number of replicate transects must be determined on the basis of statistical approach, i.e., as to represent fish populations in the area. Duration of observation for each belt-transect must be standardized in order to minimize observer's bias. For working in an area with heterogeneous bottom topography, such as coral reefs, observer has to swim in a zigzag fashion in order to increase ability to detect fishes within the observed area.

***VCT – timed swim (species-time random count)*:**

For this technique, observer swims haphazardly and records fishes in a field of vision (sighting range) within a set time. Usually, this technique increases a chance to recount the same individuals, hence increasing observation error. Particularly in coral reef area where physiographic zones (each with unique assemblage of associated fishes) are pronounced, haphazard swimming path must be avoided, unless zonation of assemblages is not a matter for consideration. If mixing up of species assemblages from different zones is preferably avoided, observer should restrict the sighting range to certain depth contour or just keep the swimming path in a specific zone. Although swimming time is fixed, swimming performance (i.e., speed) must also be standardized as to ensure comparable observed distance or area among sampling sites.

***VCT – point count*:** Observer will count the fishes within a confined area, either as circular shape or square. From the first sampling point, observer goes to the next randomly. Taking a fixed number of fin-kicks from one point to another is a good practice. For this technique, a reference line (measure tape or rope) can be used to determine the radius (in case of circular area) or the length (in case of square area) of observed field at each sampling point.

***Data achievable*:**
Basic information to be achieved from VCT includes:

- Species composition and richness.
- Species diversity index (by applying appropriate formulae).
- Quantitative abundance data (by counting actual number of individuals present).
- Semi-quantitative abundance data (by using rank or scale for enumeration).
- Size and/or biomass (size is first estimated as length and later converted into weight (biomass) using the data from studies on length-weight relationships.

Note that for enumeration, if possible, counting actual number of individuals present is recommended. The data can then be used for parametric statistic, which is the most powerful testing. However, the way to overcome errors or biases while counting supra-abundant or schooling species is just to use abundance scale – no other good choice. An example of log 4 abundance categories is shown in Table 1. If the most dominant species in the observed area in certain habitat is not more than the magnitude of thousand, log 3 scale can be applicable. The mid-point value of each category is used to represent the best estimate for number of individuals. Except for the two highest categories, the lower quartile of each category is used as to avoid overestimation. Log abundance scale is actually developed by statistic thinking – normally before any statistical analysis, raw data is usually normalized by applying logarithmic transformation.

Table 1. Logarithmic abundance categories used in estimates of abundance of fish species.

Log 4 abundance category	Number of fishes	Estimate value for enumeration
1	1	1
2	2-4	3
3	4-16	10
4	17-64	40
5	65-256	160
6	257-1,024	640
7	1,025-4,096	1,025
8	4,097-16,384	4,097

***Advantages of the VCT*:**

- It is rapid.
- It is flexible and can be adapted to a variety of different situations, purposes, and habitats.
- It is less selective when compared to most other sampling methods.
- It is nondestructive (for both habitats and associated fauna) and can be used to resurvey the same area through time, i.e., monitoring purpose.
- It is inexpensive, requiring no sophisticated equipment.
- It utilizes a minimum of personnel.
- It has the potential to produce large databases rapidly.

***Disadvantages of VCT*:**

- Observers must be well-trained and experienced.
- Observers' errors and biases occur in estimating numbers and sizes.
- There is low statistical power to detect change in rare species.

- The use of abundance categories reduces the power to detect small changes.
- It is not applicable for censusing small and cryptic or secretive species.
- Fish may be attracted towards or dispersed away from observer.
- Inadequate visibility limits the use of this technique.
- Strong surges, waves, and current can prevent diver surveys.
- The technique is restricted to shallow depths due to decompression constraints.

Case study 1: Ranong Artificial Reefs

Investigation of fish assemblages at AR in Ranong Province, Anadaman Sea, was carried out in early 1992, about 3 years after installation (Satapoomin, 1994). This AR is one among many AR sites of the past extensive AR installation program conducted by the Department of Fisheries. The Ranong AR was a typical heterotrophic community (Fig. 1) with a variety of invertebrate taxa flourishing on the surfaces of AR structures (Phongsuwan et al., 1994). The objectives were to provide general description of fish assemblages at the AR and also to compare the pattern of fish assemblages at the AR to nearby natural subtidal habitats including coral reef and rocky reef. VCT incorporating belt transect (10 x 50 m) is used. Two replicates of belt transect were used at each habitat type in each sampling occasion. Three successive surveys were conducted in February 1992, December 1992, and April 1993, respectively. Log4 abundance category was applied for abundance estimate of fishes in the censused area. In addition, underwater observation outside the censused area was also made in order to detect as much species as possible.

Figure 1. Fouling community on the structures (made of 2x2x2 m open concrete cubes) of AR in Ranong Province about 3 years after installation.

***General description of fish assemblages*:**

The Ranong AR was effective in attracting and holding fishes; 101 species in 42 families being encountered. Typical assemblages of fishes at the AR were classified into 5 groups with respect to the patterns of habitat utilization and/or association of fishes in the area (Fig. 2).

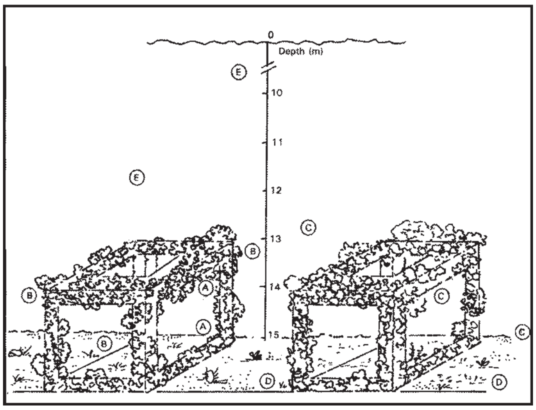

Figure 2. Typical assemblage (groups A-E) of fishes at Ranong AR.

- Type A fish (15% of total species recorded) preferred physical contact with reef, and occupied hole, crevices and complex surfaces. They were several benthic dwellers, such as groupers (*Cephalopholis* spp. and *Epinephelus* spp.), dottybacks (*Pseudochromis* sp.), blennies (*Ecsenius bicolor*), and lionfishes (*Pterois miles*, *Dendrochirus zebra* and *Scorpaenopsis* sp.)

- Type B fish (20%) usually swam close to the modules and also occupied complex surfaces as shelter. They included members of such families as Pomacentridae, Apogonidae, Diodontidae, Monacanthidae, Ostraciidae, Tetraodontidae and also certain blennid (*Plagiotremus rhinorhynchos*).
- Type C fish (28%) preferred to swim through and around the modules while remaining near the bottom or up to a meter above the modules. They included snappers (Lutjanidae), sweetlips (Haemulidae), wrasses (Labridae), parrotfishes (Scaridae), rabbitfishes (Siganidae), butterflyfishes (Chaetodontidae), angelfishes (Pomacanthidae), triggerfishes (Balistidae), surgeonfishes (Acanthuridae), and moorish idol (*Zanclus cornutus*).
- Type D fish (22%) preferred to orientate themselves close to the bottom, sometimes moving around the base of modules or extending their range over the open sand substrate within the reef. They included goatfishes (Mullidae), monocle breams (*Scolopsis* spp.), emperors (*Lethrinus* spp.), sandperch (*Parapercis punctata*), lizardfish (*Synodus* sp.), cobia (*Rachy centron canadum*), spotted sicklefish (*Deprane punctatus*), pipefish (*Trachy rhamphus bicoarctatus*), flutmouth (*Fistularia petimba*), whiting (*Sillago sihama*), dragonets (*Callionymus* sp.) and blue-spotted stingray (*Dasyatis kuhlii*). There were also some cryptic and burrowing species (e.g., gobies and moray eels).
- Type E fish (15%) tended to hover above the reef while remaining in the middle and upper part of water column. They were mainly pelagic species which usually form schools. These included fusiliers (Caesionidae), jacks and trevallies (Carangidae), batfish (*Platax teira*), baracudas (*Sphyraena* spp.), anchoby (*Stolephorus* sp.), halfbeaks (*Hemiramphus* sp.), suckerfish (*Echenius naucrates*), and eagle ray (*Aetobatus narinari*).

***Habitats comparison*:**

The survey results applying VCT at artificial reef (AR), natural coral reef (CR) and rocky reefs (RK) in Ranong are presented in Table 2. The total population density and species richness of fishes were highest at CR, whereas AR had the lowest values. The population of economically important (target) fish, in terms of both species richness and density, found at the CR and RK were also comparatively higher than those at AR. However, in terms of relative density, the target fishes contributed 57% and 47% of the total fish at the RK and AR, respectively. Only 20% of the total fish were target species at the CR.

Ranking the ten most common fish families showed a general pattern of similarity in the composition of fishes at CR and RK, as compared to the AR (Table 3). The multivariate statistical procedures (cluster analysis and MDS) also showed a clear separation of fish assemblages among habitat types (Fig. 3). CR and RK had much more similarity of fish assemblages, as compared to AR. Several most common species shared among the three habitats included some damselfishes (*Neopomacentrus azysron*, *N. cyanomos*, and *Pomacentrus similis*) and a wrasse species (*Thalassoma lunare*). Fishes dominantly found on CR and RK but were either less represented or absent from the AR including certain fusiliers (*Pterocaesio chrysozona* and *Caesio caerulaurea*), butterflyfish (*Chaetodon octofasciatus*), and several damselfishes (*Chromis cinerascens*, *Pomacentrus moluccensis*, *Amphiprion ocellaris* and *A. akallopisos*). Fishes those were common and exclusively found (so called as characteristic or conspicuous species) on CR were certain damselfishes (*Neopomacentrus anabatoides*, *Abudefduf vaigeinsis*, and *Pomacentrus adelus*). The characteristic or conspicuous fish species at the AR included certain dottyback (*Pseudochromis* sp.), bannerfish (*Heniochus acuminatus*), angelfish (*Pomacanthus annularis*), and sandperch (*Parapercis punctata*). Some fishes are commonly found at both AR and RK but less represented on CR. These included certain monocle bream (*Scolopsis vosmeri*), snapper (*Lutjanus vitta*), wrasse (*Halichoeres nigrescens*), and rabbitfishes (*Siganus javus* and *S. canaliculatus*).

Table 2. Summary of parameters from the census data obtained during the three surveys (I: February 1992; II: December 1992; III: April 2003) at each habitat type (AR: artificial reef; CR: coral reef; RK: rocky reef). Values in parentheses are the total number of records.

Parameter	AR				CR				RK			
	I	II	III	Avg.	I	II	III	Avg.	I	II	III	Avg.
Total number of species/1,000 m^2	38	34	51	41	63	70	63	65	-	62	53	57
	(46)	(60)	(86)	(64)	(68)	(80)	(89)	(79)	-	(67)	(60)	(63)
Total number of fish/1,000 m^2	1805	1849	3158	2271	5172	6584	4454	5403	-	3787	2870	3328
Number of target species/1,000 m^2	14	12	11	12	16	15	17	16	-	20	15	17
	(19)	(28)	(29)	(25)	(16)	(18)	(24)	(19)	-	(20)	(17)	(18)
Number of target fish/1,000 m^2	1282	928	1008	1073	359	1904	1017	1093	-	2194	1615	1904

Table 3. The 10 most speciose families of fish fauna observed at artificial reef (AR), natural coral reef (CR), and rocky reef (RK) in Ranong Province.

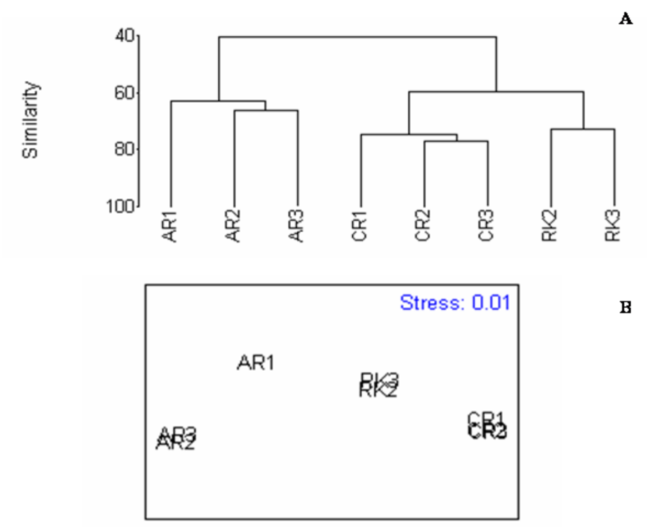

Figure 3. Dendrogram (A) and MDS ordination (B) from Bray-Curtis similarity matrix of species abundance data obtained from three successive surveys at artificial reef (AR1-AR3), natural coral reef (CR1-CR3), and rocky reef (RK1-RK3) in Ranong Province.

Case study 2: Small AR structures deployed in natural coral reef

This case study was part of the coral reef rehabilitation project initiated in 1994 by the Phuket Marine Biological Center (Satapoomin, 2002). Coral reef on the northeast coast of Maithon Island was selected to test the success of coral reef rehabilitation by a provision of artificial substrate specifically in the area where natural substrates were not suitable for settlement and colonization of coral larvae. This reef was damaged by storm in 1986 and unconsolidated substrate remains (mainly *Acropora* fragments) prevented recovery of the reef through natural recruitment of coral larvae. Three different complexities of concrete modules (Fig. 4) were used to test their relative effectiveness in enhancing natural recruitment of corals (Thogtham and Chansang, 1999). For each type of the modules, three 5x5 m plots were manipulated on open sand/coral fragment sea floor within the reef. In each plot, 25 modules of the same type were installed. Another 3 (5x5 m each) plots assigned in the area with 10-20% live coral cover were treated as control. Fish abundances in all experiment plots were periodically monitored applying VCT (adopting an actual count for the number of individuals with a fixed 5-minute census) in 4 sampling occasions, including the first sampling in August 1994 (as T0), about one month before placement of the concrete modules, and the other three subsequent samplings at the fourth (T4), nineteenth (T19), and eighty-fifth (T85) months after placement of the modules.

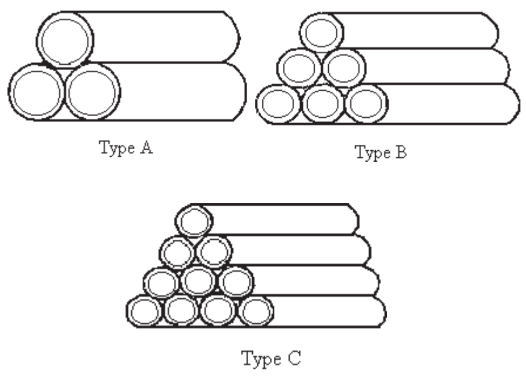

Figure 4. Tree types of concrete modules used for coral reef rehabilitation project at Maithon Island. The dimension at base and the height of each module is 0.5x0.x0.5 m.

Early colonization of fishes, in terms of both numbers of species and individuals, in all manipulated plots was rapid being contributed largely by immigration of fishes from nearby coral patches in the reef. Most parameters measured at T4 of all types of the modules were significantly greater compared to T0, but not with the following samplings, T19 and T85 (Figs. 5-7). Fish assemblages did not differ among the plot types of different concrete modules, but they were distinguishable over time (Fig. 8). At T0, before placement of the modules into the assigned plots, the unique assemblage of fishes on the open sea floor with coral fragments and sand included certain damselfish (*Pomacentus chrysurus*) and some wrasses (*Coris batuensis*, *Halichoeres hortulanus* and *Thalssoma lunare*). First colonization (T4) and early establishment of the assemblages (T19) of fishes on those manipulated plots lacked uniqueness because of variation in the composition of assembled species. Although their occurrence and abundance were uneven among plots, fishes those became much more obvious at T4 and T19 assessments including some damselfishes (*Pomacentrus adelus*, *P. similis* and *Chromis weberi*), wrasses (*Halichoeres timorensis*, *H. vrolikii* and *Stethojulis interrupta*), monocle bream (*Scolopsis bilineatus*), goatfish (*Parupeneus macronema*), and sandperch (*Parapercis clathrata*). At T85, there was a similarity in the composition of fishes among all experiment plots, including the controls. This also suggested that fish assemblages in the manipulated plots become much more similar to that of natural coral reef in the area. Conspicuous fish populations in the plots included certain damselfishes (*Pomacentrus adelus*, *P. chrysurus*, and *P. moluccensis*), wrasses (*Halichoeres hortulanus*, *H. vrolikii* and *Thalassoma lunare*), parrotfishes (*Scarus quoyi* and *Chlorurus sordidus*), butterflyfish (*Chaetodon trifasciatus*), morrish idol (*Zanclus cornutus*), and grouper (*Cephalopholis polyspila*). The development of fish assemblages seems to relate to habitat-use patterns of fishes which also coincides with he establishment and development of fouling community, particularly corals, on the concrete structure (Fig. 9). Along with such development, the manipulated area has either increased in or diversified both food resources and microhabitats (for fishes) and both of which can play a key function in regulating fish assemblages in the area. Figures 10 and 11 exemplified the establishments of two populations of damselfishes (*P. adelus* and *P. moluccensis*) in the manipulated plots. Marked increasing in their population densities notably at the time of 103 months (about 8.5 years) after installation seems to relate to a well development of coral community in the plots. Particularly for *P. moluccensis*, the fish has a strong habitat preference for corymbose or digitate *Acropora* colonies.

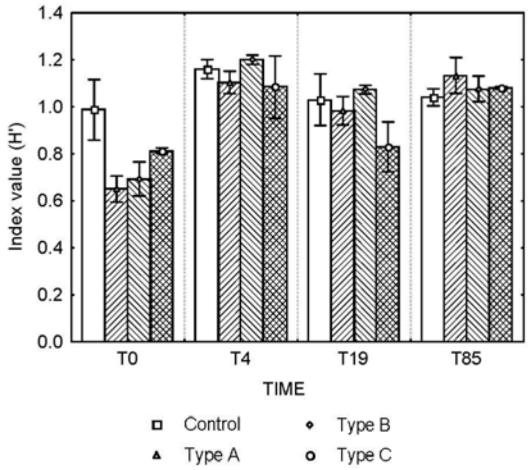

Figure 7. Species diversity, Shannon-Weaver index (mean ± SD) in each experiment plot at four sampling times (T0-T85).

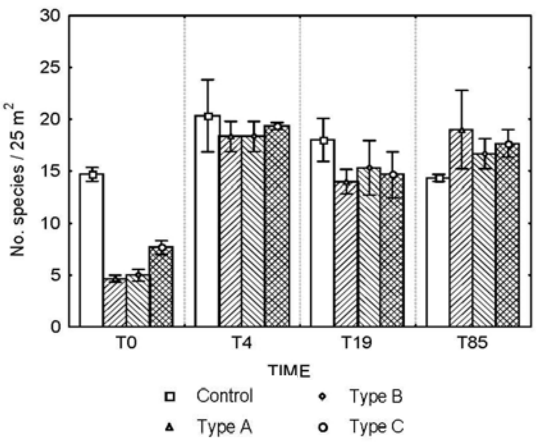

Figure 5. Total number of fish species (mean ± SD) in each experiment plot at four sampling times (T0-T85).

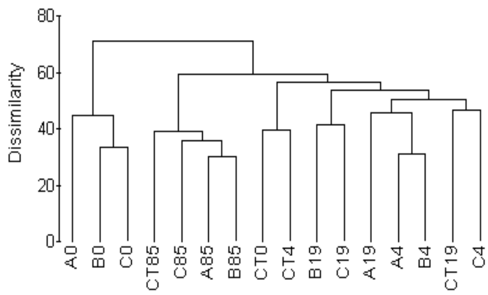

Figure 8. Dendrogram from Bray-Curtis dissimilarity matrix of logarithmic (log (n + 1)) transformed species abundance data obtained from four types of experiment plots (CT, A, B, and C) at four successive samplings (0, 4, 19, and 85).

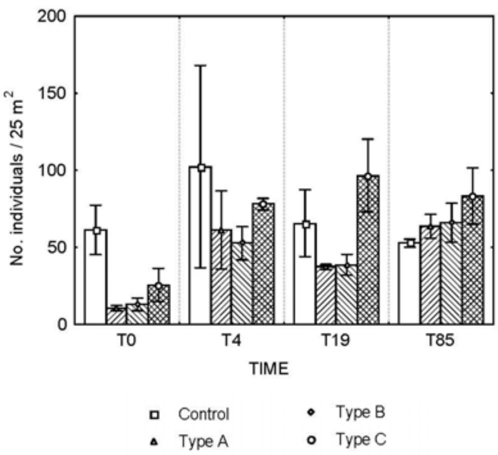

Figure 6. Abundance of fishes (mean ± SD) in each experiment plot at four sampling times (T0-T85).

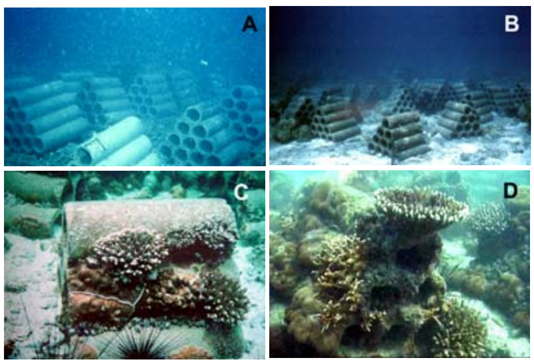

Figure 9. Subsequent changes and development of coral communities in selected manipulated plots from the project site at Maithon Island: (A) one month; (B) 19 months; (C) 85 months; and (D) 96 months after installation of the modules.

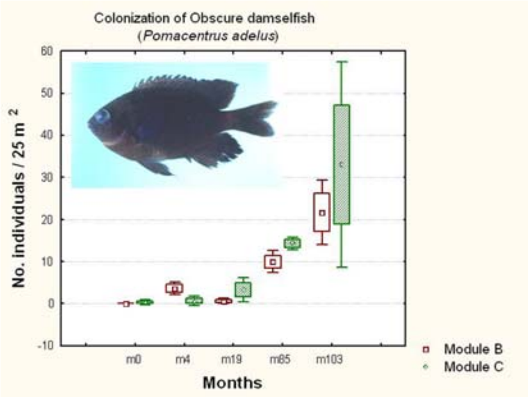

Figure 10. Changes in population densities of Obscure damselfish (*Pomacentrus adelus*) in the manipulated plot types B and C from the month 0 to 103.

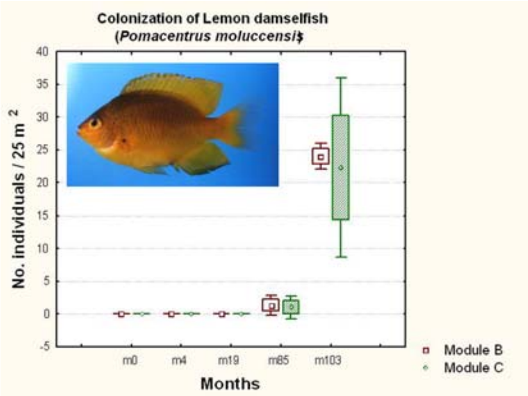

Figure 11. Changes in population densities of Lemon damselfish (*Pomacentrus moluccensis*) in the manipulated plot types B and C from the month 0 to 103.

Case study 3: Railroad goods-van AR in Pattani Province

AR construction program in Pattani and Narathiwat Provinces, southern part of the Gulf of Thailand, was established as part of the Coastal Resource Rehabilitation Project. The project was actually conceived as a result of Her Majesty's attention over the plight and hardships of local fishermen due to the decline in coastal marine resources in the areas. Various governmental agencies have cooperated in this royal project. As for the first phase of AR construction program, the Department of Highway and the State Railway of Thailand donated 707 concrete drainage pipes and 208 ex-railroad goods-vans, respectively, to be used as AR structures. The Department of Fisheries is the agency in charge of installation program. Installation of the goods-van AR took place in April 2002. All goods-vans were installed along the coast off Saiburi District, Pattani Province, 11-12 km offshore, at the depth of 26-30 m, arranged in five groups of about 2-4 km apart, and each group consisting of 41-42 goods-vans. A quick assessment of the AR condition was done in May 2003, one year after installation. VCT incorporating belt transect (10 x 30 m) is used and log 4 abundance scale was applied for abundance estimate of fishes. With a restriction to the period of 2-day survey trip, only 2 out of 5 AR sites (= groups) were assessed and only one belt-transect is possible at each site due to a decompression constraint at the depth of 105 feet where the goods-vans had been found. In order to avoid a dive-decompression practice, only 15 minutes were spent for underwater observation at each site.

Flourishing sessile organisms on the AR structures within one year after installation (Fig. 12) suggests that colonization as well as succession processes were very fast. In all, 27 species representing 17 families of fishes were found. Species richness and abundance of fishes in the area were 19-22 species/300 m^2 and 1,207-1,739 individuals/300 m^2, respectively. Orientation of fishes in relation to the goods-van structures were simply classified and depicted in Figure 13. The criteria of this classification were the same as those used for Ranong AR (case study 1), except for type A which is an inclusion of types A and B of the case study 1.

- Type A fish used the AR structures as refuges or microhabitats. They accounted for 33% and 23% in terms of relative numbers of species and individuals, respectively. These included certain damselfishes (*Neopomacentrus cyanomos* and *N. bankieri*), groupers (*Cephalopholis boenak*, *Epinephelus* *bleekeri* and *E. coioides*), squirrelfish (*Sargocentron rubrum*), lionfish (*Pterois russelli*), and bamboo shark (*Chiloscyllium punctatum*), puffers (*Arothron stellatus*) and boxfish (*Ostracion cubicus*). Among these *N. cyanomos* was the most abundant species.

- Type B fish had lesser dependent, as compared to A, on the AR structures as refuges or habitat. However, they were mainly invertebrate feeders which tend to dependent on AR structures as the source of foods. This group had the most diverse number of species (41%), but relatively low in number of individuals (4%). These included several common fishes, such as sweetlips (*Diagramma pictum*), wrasses (*Labroides dimidiatus* and *Leptojulis cyanopleura*), snappers (*Lutjanus russelli* and *L. vitta*), rabbitfishes (*Siganus canaliculatus* and *S. javus*), soapfish (*Diploprion bifasciatus*), and angelfish (*Pomacanthus annularis*).
- Type C fish preferred open sand area as for either habitat or foraging ground. This group had lowest contribution in terms of both numbers of species (11%) and individuals (1%). These included certain species of shrimp-goby (*Myersina crocatus*), sand perch (*Parapercis xanthozona*), and monocle bream (*Scolopsis vosmeri*).
- Type D fish was typical pelagic species. The group contributed the greatest in terms of number of individuals (72%), but only 15% for species composition. They were mainly schooling species, such as a snapper (*Lutjanus lutjanus*), fusiliers (*Caesio cuning* and *Pterocaesio chrysozona*), and trevally (*Selaroides leptolepis*). *Lutjanus lutjanus* was the most abundant species although the individuals were mainly found as juveniles or sub-adults.

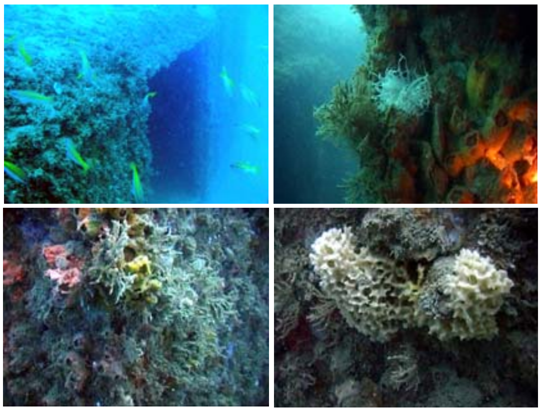

Figure 12. The condition of goods-van AR in one year after installation.

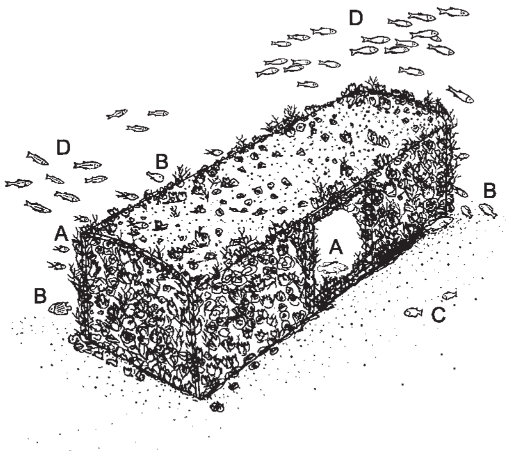

Figure 13. Typical assemblage of fishes (groups A-D) at the goods-van AR.

■ CONCLUDING REMARKS

Fisheris and stock assessment data are usually considered as useful parameters for evaluating the effectiveness of AR construction program. For earlier case studies in Thailand, the data regarding fish species composition, catch, and fishing efforts were either directly collected by researchers using various types of fishing gears (e.g., Yanagawa, 1989 and Aosomboon, 194) or indirectly obtained from fisheries-based operations conducted by local fishermen (e.g., Yonesaka, 1989 and Yodee, 1994). The latter is useful for socioeconomic evaluation (Yonesaka, 1989; Boonchuwong, 1994; Yodee, 1994) but seems to have limited use for evaluating biological or ecological impacts of the ARs. Most of the commonly used fishing gears for fish assessment in ARs (e.g., fish trap, hand line, bottom gillnet, trammel net, bottom longline, and bottom vertical longline) are highly selective for fish species and provide only qualitative species composition. Underwater observations applying sighting, taking picture, and recording VDO were also incorporated in certain AR evaluation programs (e.g., Sinanuwong et al., 1986 and Munprasit, 1989). Although these methods are less selective compared to those commonly used fishing gears, the data achieved and presented in those studies were non-quantitative.

As have been shown in the present case studies, VCT can give either semi-quantitative (case studies 1 and 3) or absolute values (case study 2) of fish abundances, depending on the choice of enumeration approach. VCT are easily modified to the special circumstances of the situation and also to the specific purpose of the study. However, care must be taken to assure that the sampling protocol is well-defined. For the case studies 1 and 3, none (single transect at each site) and inadequate (two transects at each site) replicates, respectively, can not permit reliable comparisons for the variables of interest using univariate statistic. Case study 3 shows the depth constraint for VCT. To get adequate transect replicates at such depth, much longer length of sampling period must be taken at each site. Case study 2 shows an importance of long-term study for an AR construction program. Changes in community organization of fish populations including influencing factors and processes involved over time are essential for AR evaluation as well as for an understanding of AR ecology. For monitoring purpose, sampling frequency is also needed special attention. Time frame and sampling frequency must be seriously designed on a systematic basis (i.e., with specific purposes or questions to be answered) rather than on a chance basis. Temporal basis for studies can be day to night, to account for diurnal-nocturnal changes of fish populations; one or a few months, for evaluation of tidal and lunar effects; several months in a year, to evaluate seasonal influences; or many years, to account for long-term changes. Although logistic constrains (i.e., availability of time, equipment, budget or man-power) are always the problems for any study program, these, on the other hand, are useful for researcher to postulate very specific objective(s) of study and also can be used as a factor to determine minimal but adequate number and frequency of samplings. It is highly recommended that VCT with well defined sampling protocol and strategy should be incorporated into any ongoing or future AR construction programs.

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