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## Final report

### Experiment of coral transplantation as the tool for rehabilitation of degraded coral reefs in Ha Long Bay Natural World Heritage Site, Viet Nam



**Project leader:**

**Nguyen Van Quan  
Institute of Marine Environment and Resources  
246 Danang Street, Hai Phong City, Vietnam**

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## **ACKNOWLEDGEMENT**

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## **I. INTRODUCTION**

The Ha Long, Cat Ba and Long Chau areas, the place where the coral reefs maintain the highest biodiversity in north Vietnam. Cat Ba island has been considered as the World Biosphere Reserve and the Ha Long Bay with twice times recognized by UNESCO as the Natural World Heritage Site due to its spectacular beauty of landscape, geology and biological values. However, in recent years the degradation of the marine ecosystems in general and coral reef ecosystem in particular are highly warned. Several reef sites were totally mass mortality such as Nam Dam, Vung Vieng and Bai Beo in connection with the reduction of the diversification for the coral dwelling species. There were many causes related to this phenomenon but according to the initial results of N.H. Yet and N.D Ngai (1999, 2002, 2004), main reasons of the coral degradation in the area directly related with the destructive fishing practices, urbanization, tourist activities and economic development that caused the environmental pollution and habitat destroy (coral reefs). In fact, the endangered species list was yearly rising up with some of them become the extinction species very soon.

In facing with the negative effects of the human factors to the coral reef health in this area, the rehabilitation works should be the urgent tasks to conserve the biodiversity in region and living associated resources as well. Several coral experimental transplantation projects have been carried out in the area, for example, N.H. Yet (1999) planted the coral fragments on the cemented plates in Cat Ba Island, T.H. Dan (2004) applied the artificial reefs for the new coral recruitments in several reef sites of Cat Ba Island. Though, these trial works contributed the valuable references for the coral conservationists they still met some challenges with the long term growth out of the transplanted reefs. Under the support comes from the People's Trust for Endangered Species Foundation, U.K based on the small grant concept in duration of 2004-2005, this project focused on the trial coral transplantation techniques by using various artificial substrate deploying on the different degraded reef sites with the coral fragments were collected in the near by reef sites. In addition, the project also organized the public awareness education program that aims involving the local communities in the protection of coral reefs for future generation. A process of the technical transferring for technical staffs has been established with the Ha Long Bay Management Department via the signed MOU between Institute of Marine Environment and Resources (IMER) and the Ha Long Bay Management Department.

## 2. OBJECTIVES

The project aimed to:

1. Carry out trials of coral transplantation in different degraded habitat types: shallow water high energy reef flat areas; rubble dominated reef sites resulting from dynamite fishing, coral harvesting and post bleaching stage; and sand dominated reef sites where coral larvae can not settle but where corals grow well once they are established.
2. Assessment of coral recovery and fish stock in order to determine the effectiveness of coral transplantation.
3. Involvement of local community and reef users in the restoration of coral reefs via the project activities and technical transferring.

## 3. METHODOLOGY

### ***Water quality monitoring***

The water quality in the transplanted reef sites were measured by the TOA quick meter for the temperature, DO, transparency, salinity, TSS, pH and oxygen while other nutrient factors such as nitrate, phosphate, silicate and cyanide were followed the standard analysis methods of ASEAN and CANADIAN criteria for the seawater. The water sampling was sampled and analyzed based on before/after transplanted works and monitored as the quarterly period.

### ***Monitoring of the sediment transportation***

The sediment flowing on the surface of the coral reefs at the trial reef sites was monitored by using the sediment trap design under the Manual Guide Book of English *et al*, 1997. The sediment traps were made from PVC and deployed at the reef slope zone (6-10m depth) and reef flat zone (0-5m) in 48 hours before brought back to the laboratory for further analysis. 2 sampling times have been set up based on the seasonal characteristics: dry season (January – May 2005) and rainy season (June - September 2005)

### ***Assessment of the coral recovery and reef fish associated***

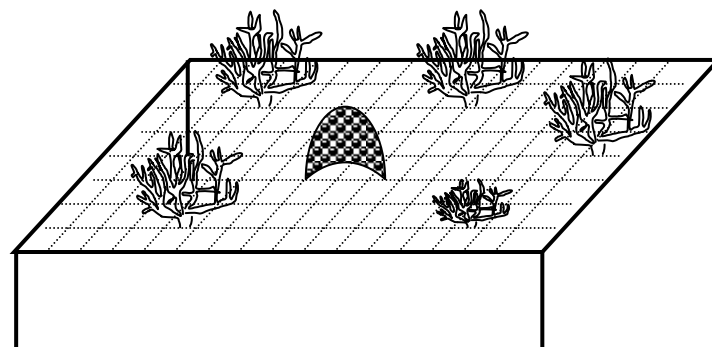
The survival rate of the new coral colonies at the degraded reefs were determined by accounting the number of marked coral colonies before deployment after 3 moth period. For the associated reef fishes that have been used as the bio indicator, the underwater fish visual census was used to account the occurrence of the small cryptic species such as the chatodontids and pomacentrids. All the data were grouped and compared based on the before/after time frame and in-out transplanted reefs.

### ***Transplantation techniques***

The hard coral group contains species mainly adhere on the hard substrate (rock, shells and other materials) and distribute in the area with suitable environment conditions such as the salinity - 20-35‰, water temperature 18-32°C, high water transparency and the moderate hydro dynamic. Logically, there are no coral occurring at the estuary area and soft bottom place. Thus, in order to provide the suitable substrate to attract the recruitment of new coral colonies and boost up the natural recovery process through transplantation of the

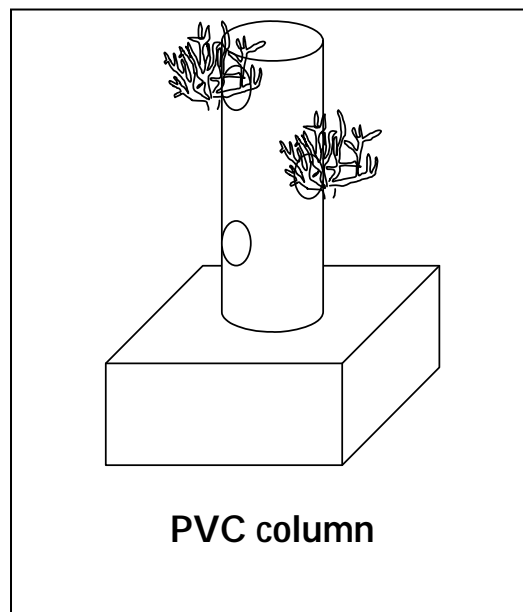
coral fragments at the artificial substrate, replacing the depredated reefs needs to be carried out ahead. In this project 4 substrate types have been selected for the trial purpose of the coral plantation such as:

- Metal frame: This model was designed as the rectangle shape 1m x 2m, surrounding by the steel frame and the surface was covered by the steel net. It was painted in order to prevent the corrosion and extended the longevity when to be deployed in the marine environment. The coral fragments were attached on the metal frame with the nylon and aluminum lines. The plantation density was 15 - 20 colonies/m<sup>2</sup>. Each colony was marked by the numbered PVC plate, measured the diameter (colonies have platform form) or the length of branch (colonies have branching form) and identified until the species level. All these data were recorded in the database for future reference. The metal frame was deployed at the water depth of 6-10m and 20-50cm above of the bottom to avoid the mud covering.



**Metal frame**

- PVC column: This model was designed by the PVC tube with the diameter of 14cm and 60cm in height. There were several drilled holes on the body with the diameter of 10 cm for attachment of the coral fragments. The PVC tube was fixed into the concrete platform 30x30x10cm avoiding the fall out of the substrate by the current and tide. Each tube accommodated 4-5 coral colonies. they were all marked by the numbered PVC plate, measured the diameter

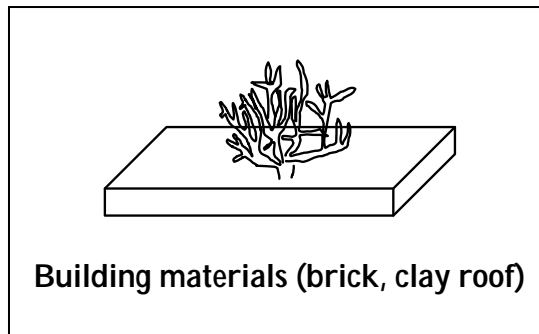


**PVC column**

(colonies have platform form) or the length of branch (colonies have branching form) and identified until the species level.

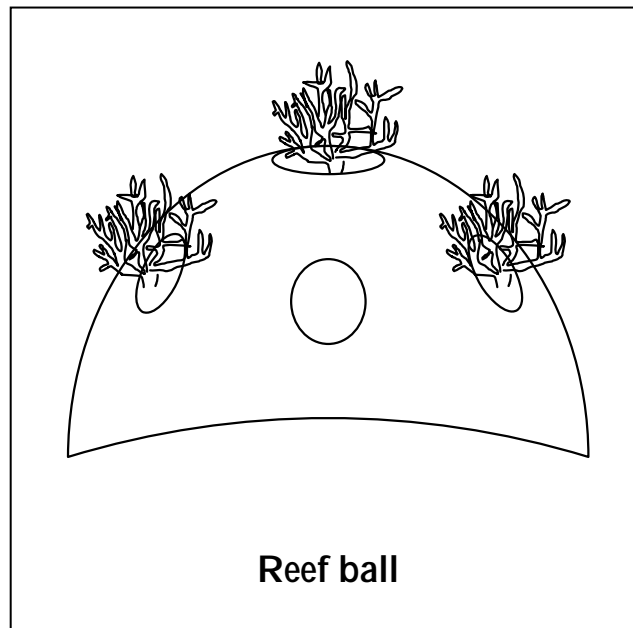
- Building materials (brick, clay roof): The clay roof with the size of 20x30cm, each piece was attached by one coral colony and deployed at the area covering by sand, dead coral or coral rubber.

- Reef ball: this model was designed as the round shape with the bottom diameter of



50cm, 35cm in height and a vacant area inside. There were 6 holes surrounding with the diameter of 10cm each and one located on the top for the attachment of the coral colonies and provided space for other marine organisms to recruit. It was deployed in the area where the bottom substrate characterized by sand, rock or coral rubber.

Time frame and experimental sites: 2 deployment times were divided based on the



seasonal character of the area: the 1<sup>st</sup> deployment in April/2005 (dry season) at Long Chau bad Dau Be reef sites with most of the designed substrate: metal frame, PVC column, reef ball and building materials; the 2<sup>nd</sup> deployment was carried out in 7/2005 (rainy season) at Soi Van and Tra San with the using of reef ball, PVC column and building materials.

A total of 841 coral colonies belonged to 19 general were planted in the 4 reef sites of Vung Cay Bang (Long Chau), To Cac Be (Hang Trai, Cat Ba), Soi Van and Tra San (Ha Long).

Coral fragment source and transportation techniques: The coral fragments were collected at the nearby reef sites based on several selection criteria such as they must be the common distribution species in the area; if it is possible to collect the cracked fragments by the fishing activities or storm destruction avoiding to destroy the natural reef sites. The branching coral and massive coral colonies were collected by hand or hammer. The coral fragments were arranged in plastic baskets avoided the direct sunlight and kept humidity for transportation from reef sources to the transplantation sites.

## 4. RESULTS

### 4.1. Water quality (See Annex)

- The transparency of the seawater in Ha Long Bay ranged between 2-6m
- The water temperature at the bottom layer: 23,3 – 31,6°C.
- The average of salinity at the bottom layer: 28 - 32‰ .
- The average of pH at the bottom layer: 7.97-8.25
- The average of Do at the bottom layer: 5.2-6.2mg/l
- The TSS at the bottom layer: 11-68mg/l
- The average of NO<sub>3</sub><sup>-</sup> at the bottom layer: 54 - 98µgN/l
- The average of PO<sub>4</sub><sup>3-</sup> at the bottom layer: 10 – 30µgP/l.
- The average of SiO<sub>3</sub><sup>2-</sup>: 314 – 643µgSi/l.
- The CN<sup>-</sup> at the bottom layer: 0,75 – 5,95µg/l

According to the Vietnamese Environmental Standard for coastal water utilization in aquaculture sector TCVN 5943-1995, the water quality in the transplanted reefs was still in good condition and suitable for the development of coral reefs.

### 4.2. Sediment transportation on the reef surface at the transplanted reefs

The transportation of the sediment over the surface of reef at the transplanted sites reached 5.27g/m<sup>2</sup>/day (dry season) to 12.33 g/m<sup>2</sup>/day (rainy season) at Tra San island and 17.28g/m<sup>2</sup>/day (dry season) to 20.84 g/m<sup>2</sup>/day (rainy season) in Soi Van island.

The suspended sediments in Tra San island mainly composed of clay Md = 0,003 - 0,004mm, S<sub>0</sub>= 1,866-2,347 and the values of Md = 0,003-0,005mm, S<sub>0</sub>= 2,336-2,530 in Soi Van island (See Annex). The initial monitoring results of the sediment flow showed that these values were acceptable for the coral reefs to develop in the normal condition.

### 4.3. Transplanted reefs

#### The 1<sup>st</sup> deployment

The 1<sup>st</sup> transplantation trip was carried out in April/2005 at Vung Cay Bang (Long Chau) and To Cac Be (Hang Trai) with the total of 450 coral colonies have been planted at Vung Cay Bang: 300 colonies belonged to 14 genera in 6 families. The coral colonies of the *Acropora* genus were dominated with 165 colonies, *Echinopora* -32 colonies, *Galaxea* -28 colonies and *Pavona* -24 colonies. Last 10 colonies were selected in each individual genus. The trial substrates used in this area were the metal frame, clay roof and PVC column. This area was characterized by the stable environment, strong water transparency due to locating far from the main land. The water depth at the deployment site ranged between 6-12m at the reef slope and platform.

In To Cac Be reef site, there were total of 150 planted colonies belonged to 6 genera. Among of them the *Acropora* also maintained the highest number of planted colonies with 84 colonies and the second order to the *Galaxea* -44 colonies. The average diameter of the coral colonies was 10 - 15cm and the trial substrates used in this site were the reef ball made from concreted cement.

The results of the monitoring trip in July/2005 showed that after 3 months trial plantation all the coral colonies at the transplanted substrate developed well with the high

coral survival rate in range of 85-90%. Especially, the branching coral of the *Acropora* genus developed the platform that would attach on to the surface of substrate. Some colonies were dead by several reasons such as shock or stress during the collection time or affected by the strong current that not be able to attach on the substrate. It also was not the exception that the durable of the nylon ropes influencing the results of the experiment.

### **The 2<sup>nd</sup> deployment**

The 2<sup>nd</sup> transplantation trip was carried out in July/2005 at Tra San and Soi Van. There were 3 priority substrate types used in this trip: clay roof, PVC column and reef ball. All the substrate was deployed at the water depth of 5-8m from reef slope to platform.

**Table 4. Number of the coral colonies at the transplanted sites**

No	Genus	Long Chau	Hang Trai	Tra San	Soi Van
1	<i>Arcropora</i>	165	84	94	89
2	<i>Galaxea</i>	28	44	66	37
3	<i>Favia</i>			7	8
4	<i>Porites</i>	10		4	
5	<i>Goniastrea</i>	2	1	6	
6	<i>Cyphastrea</i>	6		2	
7	<i>Turbinaria</i>			10	
8	<i>Lithophyllon</i>			3	
9	<i>Goniopora</i>	8		9	37
10	<i>Symphyllia</i>			3	
11	<i>Favites</i>	3		9	
12	<i>Lobophyllia</i>		4	1	6
13	<i>Montipora</i>	4			
14	<i>Pavona</i>	24			
15	<i>Oxypora</i>	1			
16	<i>Echinopora</i>	32	1		
17	<i>Psammocora</i>	3			
18	<i>Platygyra</i>	9	16		
19	<i>Astreopora</i>	5			
	Total	300	150	214	177

### **Monitoring results of the November 2005**

The monitoring results based on the November 2005 trip showed that most of the coral colonies planted in Long Chau reef site haven been died due to the broken down of the substrate and strong wave flew through during the super strong tropical storms occurred in August and September 2005. The natural coral colonies also were turned upside down and broken down to the coral rubber stage. However, 15% of remained substrate where the coral colonies attached well to the surface of the substrate and tent to recover after the tropical storm.

In To Cac Be, most of the deployed substrate were died while 5% of the remained substrate where the coral colonies kept growing. Based on the direct observation at the reef sites, there were numerous fish school floating at the surface as the results of the large scale destruction by the dynamite fishing practice in this area.

In Tra San and Soi Van, the number of transplanted coral colonies remained 50% survival rate (PVC column model) and they were at the development stage.

**Causes and consequences**

- The actual observation through repeat monitoring process pointed out that most of the deployed substrates were broken down as the similar situation and many of them were lost or changed the position. In the surrounding natural reefs, many coral colonies also to be broken down and died. These were the evidence of the strong wave acted, shattered the transplanted substrate and the natural coral colonies in this area. Logically, there were two super strong tropical storms occurred in the August and September 2005 that damaged coastal dam system, lost of residential houses and crop fields. In consequences, these two strong storms could be the main causes of the destruction to the transplanted reefs through broken down the substrate or removed them away.

- In addition, the dynamite fishing practice kept going on in the transplanted reef site also contributed for the lost of the transplanted substrate. Though, this fishing practice was banned but the enforcement patrol of the Ha Long Bay Management Department lacked of the human resource so could not be able frequently patrol all the reef sites in Ha Long Bay.

**4.4. Biological aspects of reef recovery**

There were significant changes in reef fish species indicators within and outside transplanted reefs (Table ). For example, most juvenile cryptic species such as *Chaetodon octofasciatus* and *Cephalopholis boenack* found inside the holes of reef ball and branching coral colonies at the transplanted reefs. With the evidences of new recruitment found in the study sites have contributed for the recovery of reef fish stock at the damaged reef sites at the larger scale while the local government put more efforts in the procedure of reef restoration.

**Table 5. ANOVA test for the abundance of bio indicator reef fish species before and after to carry out the transplanting work**

Family	Reef types	F	P
Pomacentridae	Transplanted reefs	38.45	0.000001*
	Natural reefs	2.45	0.13
Chaetodontidae	Transplanted reefs	4.28	0.04*
	Natural reefs	1.17	0.28
Serranidae	Transplanted reefs	19.70	0.0001*
	Natural reefs	0.011	0.91

\*  $p < 0.05$

#### **4.5. Public awareness**

Understanding the social concepts that without the support come from local people will lead to the collapse of any conservation project after the project ended. In this project 02 onsite training targeted on the elementary students (120 students) based at the “floating villages”, where the fishing boats also was considered as the home, have been organized. Besides, 2000 leaflets also were given to the tourists at the passenger port before departure for Ha Long Bay tours. A poster was constructed at the passenger port with the slogan “Let Protect Our Coral Reef” seems become the beautiful landscape for background photo of the tourist. With all the efforts have been made, the project leaders were received the strong support come from the National Television Broadcasting and daily papers to delivery the values of our works. Especially the Germany National Television channel when visited Ha Long Bay in 2006 also made a good documentary about the coral restoration work in the Ha Long Bay. We believed that with the good start step come from Ha Long Bay Management Department to consider our work as *the valuable contribution for the maintain the biodiversity of the World Natural Heritage* (extracted from acknowledge letter of the director of Ha Long Bay Management Department), the transplantation techniques will be soon applied at the larger scale at the damaged reef sites.

### **5. DISCUSSION**

The transplantation of the coral colonies in order to boost up the recovery of the coral reef at the degraded reef sites can be carried out feasibly by using the artificial substrate with the coral fragment as the sources collected at the near by natural reef sites. After 3 months planted (April to July 2005), the coral survival rate was relatively high (85-90%). Many coral colonies have attached to the surface of substrate, only few of them fell out of the substrate. Unless the strong storm influencing during August and September 2005, the remained coral colonies still kept development and contribute the coral larval sources in the near future. The lessons learned through the experimental works were below:

- The selection of site: it is necessary to do the transplant work at the high embayment or leeward sites to avoid the direct strong wave that can mitigate the influencing of the tropical storm that normally occur during the August and September in Ha Long Bay.

- The selection of the substrate model: this work contributes the crucial role to the successful result of any coral rehabilitation project. The suitable substrate has to balance between the effective conservation value (high coral survival rate) and the economic value (low cost technique). In this project, the low cost technique has been applied and got the positive feed back as the easy follow technique by the staffs of the Ha Long Bay Management Department. The annual tropical storms occurring in North Vietnam request the durable materials for making the artificial substrate.

- Public education awareness program: ideally if this program can involve the fishermen to participate in the coral restoration work. The experiences learned at the Tra San and Soi Van pointed out that with the support come from the local fishermen, the transplanted substrate were not affected by the destructive fishing activities. The technical transferring process has been carried out by involvement of the staffs of Ha Long Bay Management Department through the signed agreement with the Institute of Marine Environment and Resources. The enforcement team of Ha Long Bay Management Department played the vital role to protect the trial reef sites that will bring benefits for both side research institution and management organization.

### **6. CONCLUSION**

The initial successful coral transplantation at the degraded reef sites in the Ha Long Bay has been illustrated by the coral survival rate of 85-90% after a year project supported by PTES. Though, the planted sites were damaged by the two strong tropical storms in 2005, the coral colonies remaining still develop. These planted coral colonies will contribute the future coral larvae source at the reef sites were damaged by the human activities. The Ha

Long Bay Management Department has received the transplantation technique and decided to put more efforts in the coral rehabilitation work in following years. The support comes from PTES and other donors acted as the seed money bringing the future hope to maintain the healthy coral reefs in Ha Long Bay, one of the World Natural Heritage Site, promote the young scientists to enter the field of coral restoration ecology. Thanks for all the valuable assistances from PTES, other donors, IMER and the Ha Long Bay authority contribute for the successful of the project.

## 7. ANNEX

**Table 1. Water quality monitoring at the transplanting sites**

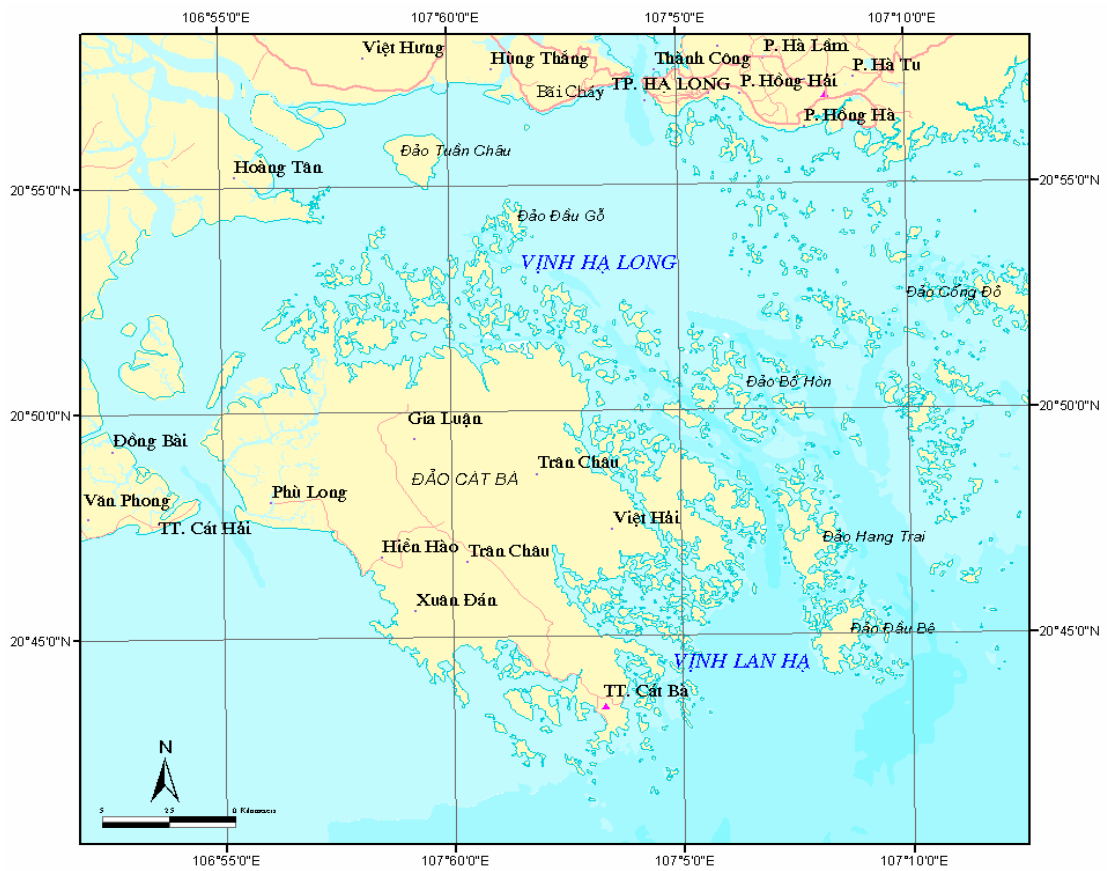
Location	Date	Water layer	Temperature (°C)	Salinity (‰)	Transparency (m)	pH	DO (mg/l)	CN <sup>-</sup> (µg/l)	NO <sub>3</sub> <sup>-</sup> (µgN/l)	PO <sub>4</sub> <sup>3-</sup> (µgP/l)	SiO <sub>3</sub> <sup>2-</sup> (µgSi/l)	TSS (mg/L)
<b>Long Chau</b>	15h, 27/7/2005	Surface	31,0	30	3,5	7,97	6,4		119	25	509	13,2
Depth: 5.5m		Bottom	31,5	30		8,02	6,2	0,30	110	23	492	13,3
<b>To Cac Be</b>	14h, 28/7/2005	Surface	32,4	30	3,5	7,92	6,4		133	43	682	7,7
Depth: 3.5m		Bottom	32,2	30		7,99	6,2	0,77	106	45	747	8,9
<b>Soi Van</b>	10h, 30/7/2005	Surface	31,3	30	3,5	7,95	5,7		105	30	571	10,8
Depth: 5,1m		Bottom	30,9	30		7,92	5,6	0,68	90	22	673	11,4
<b>Cong Do</b>	11h, 29/7/2005	Surface	32	28	3,0	7,86	5,3		121	36	694	0,4
Depth: 4,0m		Bottom	31,8	28		7,93	5,5	1,23	87	30	661	12,8

**Table 2. Composition of sediment overflow at the surface of the transplanted reefs (July, 2005)**

Sample code	Percentage of the sediment seed (mm)				Sediment factor			Type of sediment
	0,1-0,05	0,05-0,01	0,01-0,005	0,005-0,001	Md (mm)	S <sub>0</sub>	S <sub>k</sub>	
SV 1	5,90	41,00	8,70	44,40	0,008	3,090	0,958	Fine clay
SV 2	0,90	24,80	9,50	64,80	0,003	2,332	1,571	Muddy clay
SV 3	0,50	11,30	9,30	78,90	0,003	1,665	1,000	Muddy clay
TS 1	0,00	17,50	10,80	71,70	0,003	1,878	1,148	Muddy clay
TS 2	0,00	18,40	9,40	72,20	0,003	1,876	1,155	Muddy clay
TS 3	0,00	17,30	10,20	72,50	0,003	1,844	1,121	Muddy clay

**Table 3. Analysis of the sediment deposited velocity at the surface of transplanted reef sites (July, 2005)**

Location	Sample code	Time duration (h)	Area of the trap's surface (m <sup>2</sup> )	Volume (g)	Deposited velocity (g/m <sup>2</sup> /day)
Soi Van Is.	SV 1	19,67	0,024	0,40	20,33
Soi Van Is.	SV 2	19,67	0,024	0,40	20,33
Soi Van Is.	SV 3	19,67	0,024	0,43	21,85
Tra San Is.	TS 1	24,07	0,024	0,31	12,88
Tra San Is.	TS 2	24,07	0,024	0,29	12,05
Tra San Is.	TS 3	24,07	0,024	0,29	12,05



**Figure 1. Map of the study sites at Ha Long Bay**

## Photo plates of the fieldtrip activities



**Substrate at the transplanting sites**



**Preparation of the coral fragments**



**Water quality measurement**



**Reef ball substrate**



**Clay as the good substrate for coral planting**

**Metallic frame substrate**



**PVC Column substrate**



**Home for fishes**

**Quarterly monitoring in a year**



**PVC Column substrate**



**Metallic frame substrate**



**Clay substrate**



**Reef ball substrate**

**Education awareness**



**Poster built up at the tourist port**



**Gifts delivery with the conservation slogan**



**Technical transferring for the staffs of the Ha Long Bay Management Department**



**Boat training**



On the way to the school



Onsite training

Materials used for the education awareness program



Notebook for students



Leaflet to delivery for tourists

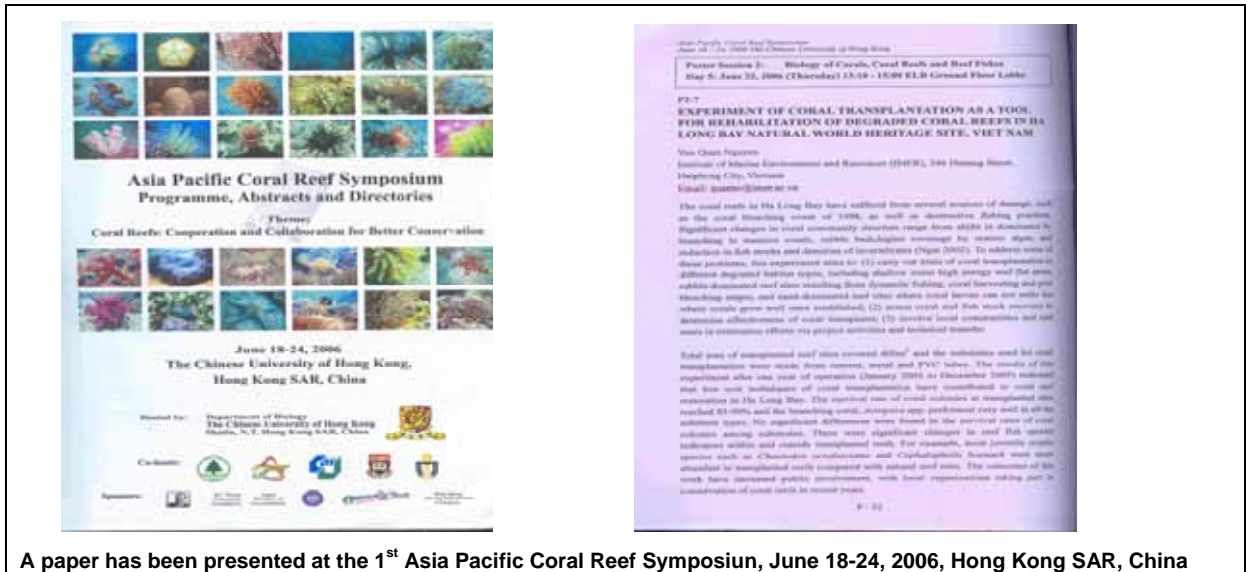


A poster design



School bags with the conservation slogan

## Final products



A paper has been presented at the 1<sup>st</sup> Asia Pacific Coral Reef Symposium, June 18-24, 2006, Hong Kong SAR, China

## **8. REFERENCES**

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