

Comparative study on coral reef related fishery resources at the areas of Vietnam representative for the western South China Sea and eastern Gulf of Thailand

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Abstract Coral reef related fishery resources were studied at 4 reef areas during 2010-2014, using brainstorming consultations with local experienced fishermen. The calculated yields per square kilometer per year ranged greatly among areas, the lowest in Ninh Hai waters (19 tons) to the highest in Tho Chu islands (200 tons). The studied reefs supported important fisheries with the calculated revenues ranging between 500-800 thousands USD per area. Collection of juveniles for cage culture also contributed high revenue for fishermen, around 1 and 1.5 millions USD from lobster juvenile in Ninh Hai waters and Nha Trang bay respectively, and approximately 600,000 USD from grouper juvenile in Phu Quoc islands. The calculation suggested a discussion about uncertainty in making reliable yield estimation, considering reef area calculation and fishing grounds. In addition, the recorded data indicated differentiae of reef resources at the regional and areal scale. The resources in areas of the Gulf of Thailand were characterized by dominance of fin fish in which fusiliers contributed around 40-50% of total production and diversity of deep water mollusks. Meanwhile, resources in the western South China Sea (SCS) varied among areas, considering the presence of lobster and *Tripneustes* sea urchin, both of which were absent in the eastern Gulf of Thailand. There existed the serious reduction of predator species and over-exploitation of some other resources under continuous pressures of over-capacity, taking account of recent development of night diving for fishing in almost reef areas and illegal fishing at remote reefs.

Keywords: coral reefs, reef fisheries, South China Sea, Gulf of Thailand

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Introduction

Vietnam is a tropical country with the shoreline of more than 3,200 km and its EEZ of one million square kilometers. The richness of marine living resources supports for development of marine fisheries with the provision of the total yield of 2.5 million tons from the capture in 2014. The authorities had counted well catching yield for traditional resources but ignored data on coastal habitat related resources such coral reefs, seagrass beds, and mangroves. In consequence, it had been quite hard to find a publication on such resources in Vietnam.

Materials and methods

Study areas

The studies on coral reef related resources had been conducted in the framework of different projects during 2010-2014. Two areas were considered for western South China Sea (SCS), including Nha Trang Bay and Ninh Hai coastal waters, both of which located in the most eastern mainland of Vietnam facing to the SCS. Another two areas located in eastern part of the Gulf of Thailand, composing of Phu Quoc islands in coastal waters and Tho Chu islands further offshore. All the 4 areas were characterized by abundance of coral reefs (Fig 1).

Data collection

The data on coral reef related fisheries resources were collected through application of brainstorming consultation with local communities. Scientists with adequate knowledge on reef biology had conducted a series of consultations at each commune or village where fishermen depended on reef resources. The six, five, four, and one consultations were convened in Nha Trang bay in 2014, in Ninh Hai waters in 2011, in Phu Quoc islands in 2010, and in Tho Chu islands in 2013, respectively. At each consultation, the questions were raised by biological scientists for group discussion (around 20 experienced fishermen and fisheries management authorities of each consultation, except 55 ones for Tho Chu islands) in order to obtain data on target fisheries resources which were identified as species or group of species contributing high yield and revenue for the local communities. Then, number of boats, fishing gears and time of fishing of each resource group, average production of each resource per time unit and farm gate price of each resource group were brainstormed and agreed.

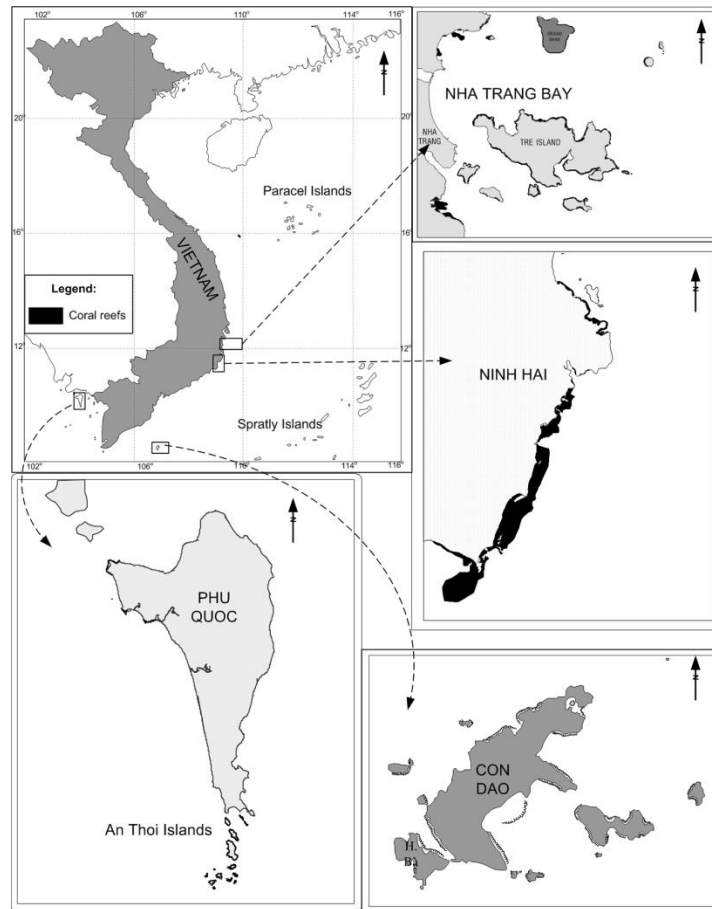


Fig. 1 Map of Vietnam indicating four study areas

The calculation were made to have values of annual yield of each resource=number of boats*fishing time*average yield per time unit (CPUE), and revenue of each resource=annual yield*farm gate price at a study period.

Results

Reefs related fishery resources in Nha Trang bay

Coral reef fisheries in Nha Trang bay were diverse and mixed a little bit with other fishing activities. There existed 107 boats using gillnets to catch rabbitfish on reefs and also others from soft bottom habitats. 91 hookar diving boats operated for collecting mainly reef snails, abalone, sea cucumber, sea urchin, lobster juvenile, and rabbitfish. Lobster juveniles were also caught seasonally by 77 fishing boats using light nets and 23 boats using traps. Twenty boats used line fishing and 10 ones for

trapping cuttlefish. Fishing season was mainly in the months of dry period and southwest monsoon (March-October). Reef related fisheries resources were estimated around 328 tons year⁻¹ (data of 2014) with the total revenue of more than 11 billion VND (more than 500,000 USD). Rabbitfish contributed the highest yield (nearly 138 tons, 42% of the total) with the catch per unit effort (CPUE) of 20 kg boat⁻¹ day⁻¹, followed by *Tripneustes* sea urchin (109 tons, 33% of the total, 50 kg boat⁻¹ day⁻¹). The shallow water snails provided significant amount in the total yield caught in the bay (Table 1). *Sargassum* seaweeds was also exploited extensively in summer but no production recorded. It was noted that Nha Trang bay and surrounding areas was a centre for cage lobster culture of Vietnam with juveniles collected from the nature. Coral reefs and other habitats in the bay provided large amount of juveniles for this purpose annually. The data consulted in 2014 indicated that approximately 220,000 juveniles of two species (*Panulirus ornatus* and *P. homarus*) were collected for culture, providing around 32 billion VND (equivalent to 1.5 million USD).

Reefs related fishery resources in Ninh Hai waters

Communities from 5 commune of Ninh Hai district depended on reef related resources with the dominance of 320 line fishing boats used for catching cuttlefish and 250 hookar diving boats for snails and lobster juveniles. Large tidal flats were locations for 150 people collecting mainly seaweeds and also some clams and snails during low tide. Tidal flats were also fishing grounds where 35 people used small gillnet to catch rabbitfish. There were around 200 small boats using gillnets at difference sizes and meshes to catch cuttlefish, needle fish, jack, emperors, rabbitfish and lobster juveniles. The data collected from the local consultations indicted the complexity of fishing activities in this large reef area. Fishing boats used multi-gears for fishing different resources at various time and seasons. Fishing activities were occurred all year round but quite different among resource species groups. The CPUE of resources was changed with high ranks among fishing season, gears and fishing grounds. In the other hand, collection of sea urchin depended on demands from outside market through middle traders who had statistics annum. Lobster juveniles were caught mainly in northeast monsoon months with high ranking of CPUE (2 or 5 ind day⁻¹ by diving depending on grounds; 10 ind day⁻¹ by netting). Coral reef related fisheries resources (Table 1) provided with the total yield of nearly 450 tons and revenue around 700,000 USD (data of 2011). Among them, cuttlefish was the most important resource with the annual production of 100 tons per year and needlefish contributed more than 50 tons per year. The intertidal benthic clams and snails, and

specially seaweed of *Glacillaria* genus were important for the livelihoods of poor people who has no fishing gears. The consultation indicated that grouper and lobster became rare on the reefs due to over-catching. Besides, coral reefs and neighboring areas provided more than 220,000 lobster juveniles for cage culture with the revenue for collectors nearly 1 million USD per year (data of 2011). In addition, it was also reported that the abundance of other fisheries resources in near-shore Ninh Hai waters with annual yield of 2,500 tons and revenue nearly 2 million USD mainly by catching of anchovy, flying fish, tunas, scads, mackerels.

Reefs related fishery resources in Phu Quoc islands

Coral reef fisheries in Phu Quoc islands is small scale, including mainly 108 hookah diving boats for catching grouper (adult for food and juvenile for cage culture) and benthic invertebrate (abalone, sea cucumber, Pearl oyster, Penguin's wing oyster, *Atrina vercilum*, Indian volute & Noble volute), 15 line fishing boats for mainly catching jacks, and 15 boats using barrier net for fusilier. The figures on fishing duration and average CPUE of each resource is quite complicated, depending on monsoon, fishing seasons and grounds. The fishing seasons of edible grouper were around the year but fishing grounds changed upon the monsoons with the CPUE averaged $0.5 \text{ kg boat}^{-1} \text{ day}^{-1}$ in south reefs and $3 \text{ kg boat}^{-1} \text{ day}^{-1}$ in the north. The CPUE of grouper juvenile depended on fishing gears: $2 \text{ ind boat}^{-1} \text{ day}^{-1}$ for traps and different number among grounds by using barrier net (6 or $10 \text{ ind boat}^{-1} \text{ day}^{-1}$). Especially, benthic invertebrates have been overexploited and caught casually during dives, therefore, their production were only calculated based on the estimation of average annual catches and revenues of diving boats.

The finfish dominated in coral reef fisheries in Phu Quoc islands, noting that fusiliers provided nearly 37% total yield year⁻¹ followed by jack (approximately 16%). Fusilier was caught by barrier nets with the CPUE of $30 \text{ kg boat}^{-1} \text{ day}^{-1}$ and jack by line fishing with the CPUE of $20 \text{ kg boat}^{-1} \text{ day}^{-1}$, providing relatively low cost products for fishermen. On contrary, the products from hookah diving brought high revenue due to high farm gate price of abalone and sea cucumber. Other diving products had still contributed a significant revenues (Table 1). Coral reefs in An Thoi area were characterized by richness of grouper fries which were collected for cage culture in the region. More than 51,000 individuals of the fries of species *Plectropomus maculatus* were caught in 2010, providing revenue nearly 300,000 USD for fishing divers.

Table 1 Yields and revenue of reef related fisheries resources in the study areas

Group	Yield (tons)				Revenue (*10 ⁶ VND)			
	Nha Trang	Ninh Hai	Phu Quoc	Tho Chu	Nha Trang	Ninh Hai	Phu Quoc	Tho Chu
Rabittfish	137.6	9.56		99	4,720	704		2,475
Needlefidh		51.75				2,902		
Parrotfish		18		14.5		480		217.8
Emperors		1		27.8		35		974.4
Grouper			8.13	24			1,997	840
Jack			42				2,520	
Fusiliers			96	264			1,201.5	9,240
Triggerfish				36.3				726
Barracudas				19.8				495
Ell				2				80.6
Lobster		1				400		
Cuttlefish	6.8	103.85	3.6	18.5	1,040	9,402	324	2404.4
Abalone	3.7	-	16	0.6	1,310	-	2,397.6	182.9
Cone shells	33.5	3		4.9	1,120	30		29.4
Intertidal clams		9.6				24		
Deep water bivalve & volutes			62.29				6229	
<i>Turbo</i> snail	16.3	5.76		16.3	360	57.6		228.7
<i>Strombus</i> snail		5.76				57.6		
<i>Lambis</i> snail	3.5	-			280	-		
<i>Murex</i> snail				1.63				57.2
<i>Tripneustes</i> sea urchin	109.3	80			390	2000		
Sea cucumber	11.1	-	30	11.1	390	-	1,355.9	277.2
<i>Gracilaria</i> seaweed	-	150	-		-	450	-	
Total	327.5	434.96	258.02	11.113		16,599.8	14,669	18,226.7

Reefs related fishery resources in Tho Chu islands

The waters around this remote islands were the fishing grounds for local and outside fishermen. Fishing activities occurred around the years, considering the main season between February and April with 15-20 days per month of good weather (5-12 days month⁻¹ for others). Regarding reef related resources, there existed 15 hookar diving boats for mollusk and sea cucumber, 16 line fishing for

emperor and grouper, 5 boats using barrier net for fusilier, rabbitfish, barracuda, triggerfish, parrotfish. Number of fishing boats used line fishing for cuttlefish changed seasonally, 48 boats during May to January but up to 90 in February to April. Tho Chu islands were also the fishing ground of non-reefal mackerel which was caught by 124 boats using line fishing around the year with the CPUE of 5 or 10 kg boat⁻¹ day⁻¹ depending used techniques.

Data collected in 2013 (table 1) indicated the diversity and abundance of fish resources, proving approximately 90% of total yield of 540 tons and more than 80% of total revenue (nearly 800,000 USD). Fusiliers contributed highest yield and revenue (approximately 50% of the totals). Other fishes contributed significant yields and income for fishermen thanks to high CPUE. Benthic resources remained quite poor, recording the present of abalone, sea cucumber and some snails. Cuttlefish contributed a significant yield and revenue resulted from high farm gate price. It was noted that mackerel approached nearshore all year round but was more abundant during north east monsoon (December-January), providing high yield (nearly 140 tons) and revenue (more than 10 billion VND, equivalent to 450,000 USD) for local and outside fishermen

Discussion

Uncertainty in making reliable yield estimation

The review of ISRS 2004 indicated that the average yield from over thirty fisheries studies is around 8 tons per square kilometer but the variation around this mean is larger than the mean itself, suggesting high variation among study sites and difficulties in making reliable estimation. This study in Vietnam showed that the estimated yields (Table 2) were very high and varied extremely among study sites (19-200 tons sq⁻¹ km⁻¹).

It was suggested that recorded yields depended on different concerns, firstly on measures of reef area. Recently, these values were mainly obtained through estimation of length and width of shallow reefs bordering shorelines but ignore deep and remote submersed reefs. Among four above-mentioned study areas, the reefs in Ninh Hai waters were studied quite carefully and almost reefs were measured. Meanwhile, the studies for reefs in the remote Tho Chu islands had been conducted preliminarily and the value of measured reef area may not yet reflect the sufficient reality. The second concern was related to biological aspects. Given the fact that many reef organisms could inhabited not only coral reefs but also other habitats such as rocky reefs bordering islands, submersed banks

and even soft bottom. In consequence, fishing grounds of reef resources were not only on reefs but also on other habitats, of which area were not measured.

Table 2 Yield of reef related fisheries resources in the study areas

Reef areas	Reef area (ha)	Total yield (ton)	Yield sq. km ⁻¹ year ⁻¹ (ton)
Nha Trang bay	754 ^a	327.5	43.43
Ninh Hai coastal waters	2,300 ^b	434.96	18.91
Phu Quoc islands	474 ^c	258.02	54.43
Tho Chu islands	270 ^d	540.51	200.19

Note: a by Hoang Xuan Ben et al. 2015, b by Vo Si Tuan et al. 2014, c by Vo Si Tuan 2013; d by Thai Minh Quang et al. 2014

Differentiation of reef resources at regional and a real scale

At the regional scale, it was found that lobster of *Panulirus* genus and *Tripneustes* sea urchin had never observed in the eastern Gulf of Thailand. In contrary, they were considered as the important resources for fishermen in central Vietnam (the western SCS), providing huge amounts of lobster juvenile for cage culture and high value sea urchin eggs for domestic and export markets. The resources in areas of the Gulf of Thailand were characterized by dominance of fin fish in which fusiliers contributed around 40-50% of total production. Meanwhile, *Sargassum* seaweeds developed as an important habitat during summer on reefs of the western SCS.

Reef morphology was observed different among the studied areas. Reefs in Ninh Hai waters with dominance of typical fringing reefs with large flats (Vo et al. 2014) which supported the richness of tidal living resources such as various clams, snails and edible seaweeds. Substratum morphology around An Thoi small islands (in Phu Quoc) with very diverse habitats, including not only coral but rocky reefs in deed water had provided favorable conditions for abundance of pearl oyster, penguin's wing oyster, making them becoming important resources in the area.

Sustainability of reef fisheries

Sustainability of reef fisheries in studied areas was also considered through local consultations and documentation. It was recorded in all areas about serious reduction of predator species such as grouper, snapper and lobster. This situation was resulted from high demand of live fish for export and domestic markets and related to popular utilization of poisoning fishing on reefs. Other resources,

especially high value mollusks as abalone, pearl oyster were over-exploited under continuous pressures of extensive dive fishing, taking account of recent development of night diving for fishing in almost reef areas and occurrence of dynamite fishing at remote places, especially in the western SCS.

Regarding the species which had still contributed significantly for local revenues, the consultations indicated decline trends of many resources. For example, catches of grouper and jack in Phu Quoc islands reduced around 70% in comparison with those of 10 years ago but no decline recorded for fusilier. Fishermen in Ninh Hai district made a rough estimates that almost living resources decline around 40-60% of their productions at 5-10 years ago.

Collection of fry juveniles for cage culture had been quite developed in South Vietnam and raised questions on sustainability of natural resources. As discussed in the local consultations, the production of fry juveniles had fluctuated in wide ranks among years depending on demands of cage culture at the local level and also non-understood changes of physical conditions. Given the fact that adult lobsters remained poorly in the wild of the coastal waters of South Vietnam, abundance of lobster juveniles herein should be related spawning in and dispersal from remote regions. The recent research (Học Tan Dao et al. 2015) found the population connectivity of lobster *Panulirus ornatus* among Vietnam, Indonesia and Australia. Meanwhile, no study had been done for understanding consequences of collections of grouper fries to sustaining wild biomass of grouper in the SCS. Recently, some efforts had been done in management of coral reef resources. The Marine Protected Areas were established in Nha Trang bay, Ninh Hai coastal waters and Phu Quoc islands. The authorities had also conducted measures to prevent or mitigate illegal fishing and supported initially to rehabilitation and resource restoration at a number places. Co-management approach with the involvement of tourist sector and local communities has been applied in Phu Quoc and Nha Trang bay MPAs, and Nui Chua National Park (including Ninh Hai waters) in order to improve habitat and fisheries management. However, the management effectiveness was still limited.

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References

- Ben HX, Tuyen HT, Hoang PK, Long NV, Tuan VS (2015) The status, trend and recovery of coral reef biodiversity in Nha Trang bay. Collection of Marine Research Works. Publishing House for Science and Technology, Ha Noi, pp 176-187
- Dao HT, Smith-Keune C, Wolanski E, Jones CM, Jerry DR (2015) Oceanographic currents and local ecological knowledge indicate, and genetics does not refute, a contemporary pattern of larval dispersal for the ornate spiny lobster, *Panulirus ornatus* in the South-East Asian Archipelago. PLoS ONE 10(5) [doi:10.1371/journal.pone.0124568]
- ISRS (2004) Sustainable fisheries management in coral reef ecosystems. Briefing Paper 4, International Society for Reef Studies, p 14
- Quang TM, Hoang PK, Tuan VS (2014) Coral community in the coastal waters of Tho Chu islands. Proceeding of the Second National Conference on Marine Biology and Sustainable Development. Publishing House of Natural Science and Technology, Ha Noi, pp 177-184
- Tuan VS (2013) Ecosystem related resources in Phu Quoc Marine Protected Area and issues on sustainable use. Proceeding of the Forum entitled “MPAs with Sustainable Development based on Marine and Islands Resources and Environment”. Publishing House of Science & Technology, Ha Noi, pp 32-53
- Tuan VS, DeVantier L, Tuyen HT, Hoang PK (2014) Ninh Hai waters (South Vietnam): a hotspot of reef corals in the western South China Sea. Raffles B Zool 62:513–520