Reef Fish Diversity and IUCN Status at Racha Yai Island, Thailand

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Abstract

In this study, the purpose was to study the diversity and status of fish species in Coral reefs (i.e., reef fish diversity, richness, evenness, and IUCN conservation status) were studied at Patok and Khonkae Bays, Racha Yai Island, southern Thailand. In Patok bay, three 50-m permanent line transects, and in Khonkae bay, four 50-m permanent line transects (each covering 250 m^2) were set up along the reef slope at 8-10 m depth. Each transect area was separated from each other by 10 m. All reef fishes from each transect were identified, counted, and recorded. The IUCN conservation status of each fish species was recorded. Shannon index (H), Margalef's richness (D), and Pielou's evenness (e) were calculated. The differences in fish diversity, richness, evenness, and IUCN conservational status were tested between Patok and Khonkae Bays. We observed that numbers of fish species, individuals, orders, families, Shannon diversity, and species richness did not differ between Patok and Khonkae Bays but evenness was higher in Khonkae Bay than in Patok Bay. In addition, numbers of fishes from different orders were not different between two bays, whereas, more fishes were observed from Perciformes order than other orders (i.e., Tetraodontiformes, Syngnathiformes, and Scorpaeniformes) in both bays. Based on IUCN conservation status, most of the fish species were from 'not evaluated' and 'data deficient' groups, whereas, only one fish species (*Epinephelus malabaricus*) from Patok Bay was nearly threatened. Our results show that fish species was more evenly distribute in Khonkae Bay than in Patok Bay. This is because in Patok Bay, there were high numbers of *Lutjanus biguttatus* with tatoal of 62% compared to other fish species.

Keywords: IUCN conservational status, Khonkae Bay, Margalef's richness **(D)**, Patok Bay, Pielou's evenness **(e)**, Racha Island, Shannon index **(H)**

Introduction

Coral reefs are very complex marine ecosystems [1], in where fish diversity is very high [2]. These reefs provide refugees, and nursery or settlement habitats for various fish species [3,4]. Coral reefs are ideal for field experiments, as well as long-term observations of fish diversity due to higher numbers of fish species. Several studies have been done on coral reef fish ecology, behaviour, fisheries biology, and conservation biology [5].

Several factors such as overexploitation, pollution, disease and climate change are responsible for reduction of live corals. Reduction of live corals is responsible for declining of fish species that live and feed on live corals [6-8]. Another important factor for coral reefs declining is overgrowing tourism [9], especially diving tourism [10-12].

Andaman Sea (1200 km long X 650 km wide) is characterised by its high fish diversity and endemic fish species [13,14], but information on fish diversity in very limited in this area due to very few studies on fish diversity [15,16]. More research should be conducted on fish diversity in Andaman Sea. In this study, the reef fish diversity, richness, evenness, and IUCN conservational status were compared between Patok and Khonkae Bays in January 2017.

The conservation status of a group of organisms (for instance, a species) indicates whether the group still exists and how likely the group is to become extinct in the near future. The IUCN Red List of Threatened Species is the best known worldwide conservation status listing and ranking system. Species are classified by the IUCN Red List into nine groups set through criteria such as rate of decline, population size, area of geographic distribution, and degree of population and distribution fragmentation (i.e., Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Conservation Dependent (CD), Least Concern (LC), Data Deficient (DD), and Not Evaluated (NE). [17,18]

Materials and Methods

Study site

Data of the coral reef fishes were collected at Khonkae Bay (7º36’17”N, 98º22’35”E) and Patok Bay (7º36’34”N, 98º21’56”E) Racha Yai Island, Phuket province, Thailand (Figure 1).

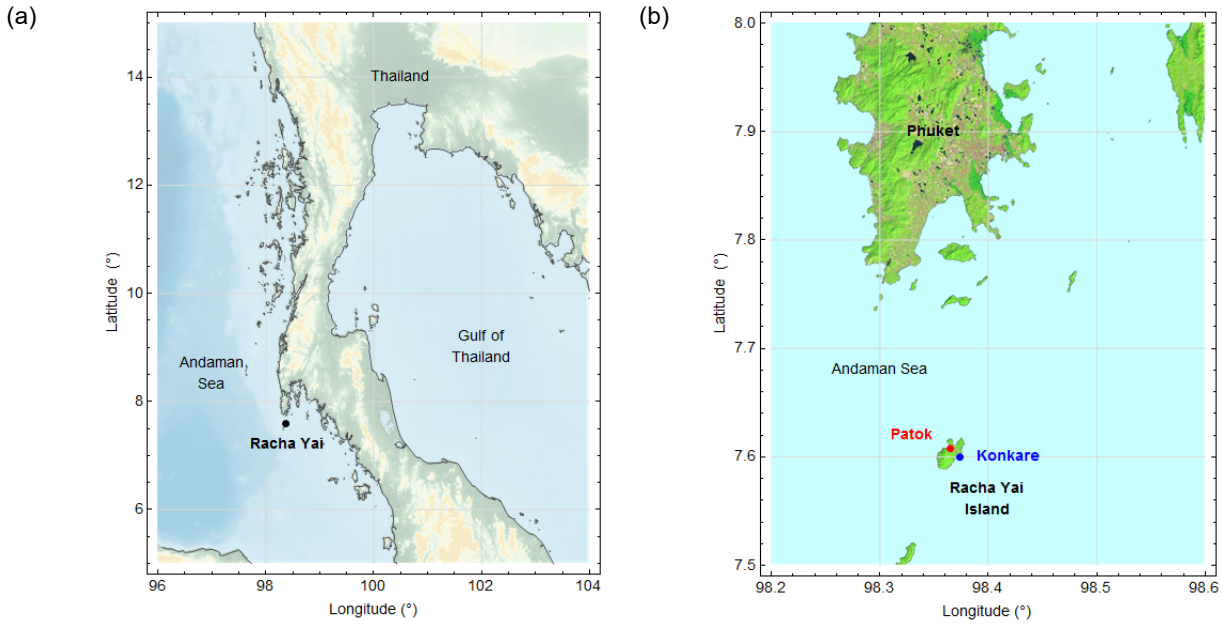

Figure 1 (a) Map of Southern Thailand and (b) Location of study sites (Patok and Konkae Bays) in Racha Yai Island, Thailand.

Coral reef fish census

At Khonkae and Patok Bays, visual census technique was used. The census was done using Line Intercept Transects (LIT) method in both bays in January 2017. At Patok Bay, three permanent transect lines, and in Khonkae Bay, four permanent transect lines along the reef slope were made using scuba diving in 8-10 m depth. Each census area covered 250 m^2 extended 2.5 m at both right and left hand sides of a 50 m line transect, and the total coverage census area with three replicates for each Bay was 750 m^2. Each transect line was extracted from each other by 10 m. We identified, counted, recorded and classified based on its IUCN conservation status of all fish in each line transect in Patok and Khonkae Bays.

Data analysis

Shannon index, $H = -\Sigma Pi \ln Pi$ [19]; Margalef's richness index, $D = (s-1)/\ln N$ [20], and Pielou's evenness index, $e = H/\ln S$ [21] were used to measure the fish diversity, where H is the diversity index, Pi is the relative abundance (S/N), D is the richness index, S is the number of individuals for each species, N is the total number of fish per transect line, e is the similarity or evenness index and ln is the natural logarithm, and S is the total number of species. Before analysis the data, normality was assessed. Parametric statistics were used when normality or other assumptions of parametric tests were met. We used t-tests to test the differences in number of fishes, species, families, orders, Shannon diversity, species richness, and evenness between Patok and Khonkae Bays. Two-way ANOVA tests with post-hoc Bonferroni adjustment were used to test the differences in numbers of fish species/order between two bays, and numbers of fish species among fish orders.

Results

Fish biodiversity in Patok and Khonkae bays:

In Patok Bay there were 46 fish species and 4,830 individuals belonging to 3 orders and 12 families, whereas in Khonkae Bay, there were 50 fish species and 890 individuals belonging to 4 orders and 21 families (Table 1). Numbers of fish species, individuals, orders, families, Shannon diversity, and species richness did not differ between Patok and Khonkae Bays, but in Khonkae bay had higher evenness than in Patok Bay (Table 2).

Table 1 Fish fauna with orders, families, scientific names, IUCN Status (LC= Least concern, NE= Not evaluated, DD= Data deficient) and feeding habits (FH) (PV= planktivore, CV= carnivore, HV= herbivore, CLV= corallivore, IC= invertebrate consumer, OV= omnivore, PCV= piscivore), and percentage from Khonkae and Patok Bays.

Order	Family	Scientific names	FH	IUCN Status	Khonkae 2017	Patok 2017
Perciformes	Acanthuridae	*Acanthurus leucosternon*	HV	LC	2.02	
		Acanthurus nigricauda	HV	LC	0.22	0.50
		Acanthurus tennenti	HV	LC	0.22	
		Acanthurus tristis	HV		0.79	0.12
		Ctenochaetus striatus	HV	LC	0.34	0.02
		Naso brevirostris	PV	LC	0.11	0.02
		Naso elegans	HV	LC		0.02
	Caesionidae	*Caesio caerulaurea*	PV	LC	1.12	4.97
		Caesio cuning	PV	NE		0.41
		Caesio lunaris	PV	NE		0.02
		Pterocaesio chrysozona	PV	NE		5.18
	Carangidae	*Atule mate*	CV	NE		0.02
		Caranx heberi	CV	NE		0.04
	Chaetodontidae	*Chaetodon andamanensis*	CLV	DD		0.06
		Chaetodon auriga	CLV	LC	0.45	0.04
		Chaetodon collare	CLV	LC	0.45	0.17
		Chaetodon decussatus	CLV	LC		0.08
		Chaetodon lunula	CLV	LC	0.22	0.04
		Chaetodon triangulum	CLV	LC	0.11	0.04
		Chaetodon trifasciatus	CLV	LC	0.45	0.12
		Chaetodon vagabundus	CLV	LC	0.22	0.04
		Heniochus singularius	CLV	LC	0.22	0.12
	Gobiidae	*Amblygobius hectori*	OV	LC		
	Kyphosidae	*Kyphosus vaigiensis*	CV	LC	1.01	
	Labridae	*Bodianus axillaris*	CV	LC	0.11	0.02
		Bodianus mesothorax	CV	LC		0.41
		Cheilinus fasciatus	IC	LC	0.22	
		Cheilinus trilobatus	IC	LC	0.11	
		Cirrhilabrus cyanopleura	PV	DD		2.07
		Coris batuensis	IC	LC	0.22	0.02
		Coris cuvieri	IC			
		Epibulus insidiator	CV	LC	0.11	0.04
		Gomphosus caeruleus	CV	LC	0.11	
		Halichoeres hortulanus	IC	LC	2.47	0.02
		Halichoeres scapularis	IC	LC	0.11	
		Halichoeres timorensis	IC	LC	0.11	
		Hemigymnus fasciatus	IC	LC	0.22	0.02

Order	Family	Scientific names	FH	IUCN Status	Khonkae 2017	Patok 2017
		Hemigymnus melapterus	IC	LC		0.04
		Labroides dimidiatus	IC	LC	0.56	0.17
		Oxycheilinus digrammus	CV	LC		0.08
		Scarus ghobban	HV	LC	5.84	0.41
		Scarus niger	HV	LC	1.24	0.52
		Scarus prasiognathos	HV	LC	0.56	0.04
		Scarus quoyi	HV	LC	0.22	0.04
		Scarus rubroviolaceus	HV	LC		0.25
		Scarus scaber	HV	LC		0.02
		Thalassoma lunare	CV	LC	0.34	0.04
	Lethrinidae	*Lethrinus crocineus*	CV	NE	0.11	
		Lethrinus lentjan	CV	NE	0.56	0.04
		Lethrinus ornatus	CV	NE	1.12	
	Lutjanidae	*Lutjanus bohar*	CV		0.11	
		Lutjanus biguttatus	CV	NE		62.11
		Lutjanus decussatus	CV	LC	0.22	0.04
		Lutjanus fulviflamma	CV	NE	0.22	0.17
		Lutjanus quinquelineatus	CV	NE	0.67	0.41
	Mullidae	*Mulloidichthys vanicolensis*	IC		11.24	1.04
		Parupeneus cyclostomus	CV	NE	0.22	
		Parupeneus macronemus	CV	NE	0.11	0.02
		Parupeneus pleurostigma	IC	NE	0.11	0.04
		Upeneus tragula	CV	NE		0.08
	Nemipteridae	*Scolopsis bilineata*	CV	NE	0.45	0.08
		Scolopsis ciliata	CV	NE	12.58	
		Scolopsis lineata	CV	NE	0.67	
		Scolopsis monogramma	CV	NE	0.11	0.04
		Scolopsis xenochroa	CV			0.04
	Pempheridae	*Pempheris schwenkii*	PV	NE		
		Pempheris vanicolensis	PV	NE		0.41
	Pinguipedidae	*Parapercis hexophtalma*	CV	NE	0.22	0.04
	Pomacanthidae	*Centropyge eibli*	HV	NE	0.11	0.06
	Pomacentridae	*Abudefduf sordidus*	OV	NE	1.12	3.11
		Abudefduf notatus	OV	NE		1.04
		Abudefduf vaigiensis	OV	NE	5.62	1.24
		Amblyglyphidodon indicus	OV	NE	0.11	
		Amblyglyphidodon leucogaster	OV	NE		0.21
		Amphiprion akallopisos	OV	NE		0.04
		Chromis dimidiata	PV	NE		0.04
		Chromis flavipectoralis	PV	NE	1.12	
		Chromis opercularis	PV	NE	1.12	4.14
		Chromis ternatensis	PV	NE		
		Chromis xanthochira	PV	NE		1.04
		Dascyllus carneus	PV	NE		1.04
		Dascyllus trimaculatus	PV	NE	4.94	
		Dischistodus perspicillatus	HV	NE	1.91	
		Neopomacentrus cyanomos	PV	NE	2.25	
		Neopomacentrus sororius	PV	NE	5.62	
		Plectroglyphidodon lacrymatus	HV	NE	0.11	0.04
		Pomacentrus amboinensis	OV	NE	0.22	0.21
		Pomacentrus chrysurus	OV	NE	1.12	

Order	Family	Scientific names	FH	IUCN Status	Khonkae 2017	Patok 2017
		Pomacanthus imperator	OV	LC	0.11	
		Pomacentrus moluccensis	OV	NE	2.25	4.14
		Pomacentrus pavo	OV	NE	1.12	
		Pomacentrus philippinus	OV	NE	2.70	0.41
		Pomacentrus similis	OV	NE	0.11	
	Scaridae	*Cetoscarus bicolor*	CLV	LC	0.11	
		Chlorurus capistratoides	HV	LC	0.45	0.70
		Chlorurus sordidus	HV	LC	1.80	0.33
		Chlorurus strongylocephalus	HV	LC	0.11	
		Chlorurus troschelii	HV	LC	0.11	
	Serranidae	*Aethaloperca rogaa*	CV	DD	0.11	
		Cephalopholis argus	CV	LC	0.11	0.02
		Cephalopholis formosa	CV	LC	0.11	
		Cephalopholis miniata	CV	LC	0.11	
		Epinephelus caeruleopunctatus	CV	LC	0.11	
		Epinephelus malabaricus	CV	LC		0.02
	Siganidae	*Siganus canaliculatus*	HV	NE		0.41
		Siganus guttatus	HV	NE	0.34	
		Siganus javus	HV	NE		0.14
		Siganus puelloides	HV	LC	0.22	0.04
		Siganus virgatus	HV	NE		0.04
	Sphyraenidae	*Sphyraena obtusata*	CV		8.99	
	Zanclidae	*Zanclus cornutus*	IC	NE	2.58	0.48
Scorpaeniformes	Scorpaenidae	*Scorpaenopsis diabolus*	CV	NE	0.11	
	Fistulariidae	*Fistularia commersonii*	CV		0.11	0.04
Tetraodontiformes	Balistidae	*Balistapus undulatus*	IC	NE	0.22	0.04
		Balistoides viridescens	IC	NE	0.11	0.06
		Melichthys indicus	OV	NE		0.08
		Odonus niger	OV	NE	2.25	
		Sufflamen bursa	IC		0.37	
	Ostraciidae	*Ostracion cubicus*	HV	NE	0.14	
		Ostracion meleagris	HV	NE	0.25	
	Tetraodontidae	*Arothron nigropunctatus*	CV	LC	0.15	0.04
		Melichthys indicus	OV	NE	0.15	

Numbers of fish species/order and its conservation status

There were four fish orders found in both bays: Perciformes, Tetraodontiformes, Syngnathiformes and Scorpaeniformes (Figures 2a,b). Patok Bay had the same the number of fish species/order as Khonkae Bay ($F_{1,20}$ = 3.7, P = 0.095) but there were different numbers of fish species among fish orders ($F_{1,20}$ = 19.87, P <0.001, Figures 2a,b). Numbers of fish species from Perciformes order was higher than other orders (P<0.05) in both bays. There was some interaction between bays and fish orders on numbers of fish species (Bays*fish orders: $F_{1,20}$ = 4.35, P <0.05, Figures 2a,b). Most fish species were from 'not evaluated' and 'least concern' groups (Figures 3a,b). In Patok bay, only one species (*Epinephelus malabaricus*) was 'nearly threatened'.

Table 2 (Mean ± SE) of fish species, diversity, species richness and evenness in 2016 for Khonkae and Patok Bays; '*' indicates $P < 0.05$.

Parameters	Patok Bay	Khonkae Bay	Statistical tests
No. of fish species /transect line	34.67±7.22	33.50±2.25	t_5 = 0.18
No. of individuals / transect line	1610.00±1041.16	222.50±61.75	t_5 = 1.59
No. of fish orders / transect line	2.00±0.58	2.50±0.29	t_5 = -0.85
No. of fish families / transect line	13.67±2.03	13.50±1.19	t_5 = 0.08
Shannon index (*H*)	1.84±0.55	2.51±0.22	t_5 = -1.28
Species richness (*D*)	4.95±1.18	6.20±0.33	t_5 = -1.18
Evenness (*e*)	0.42±0.09	0.72±0.07	t_5 = -2.70*

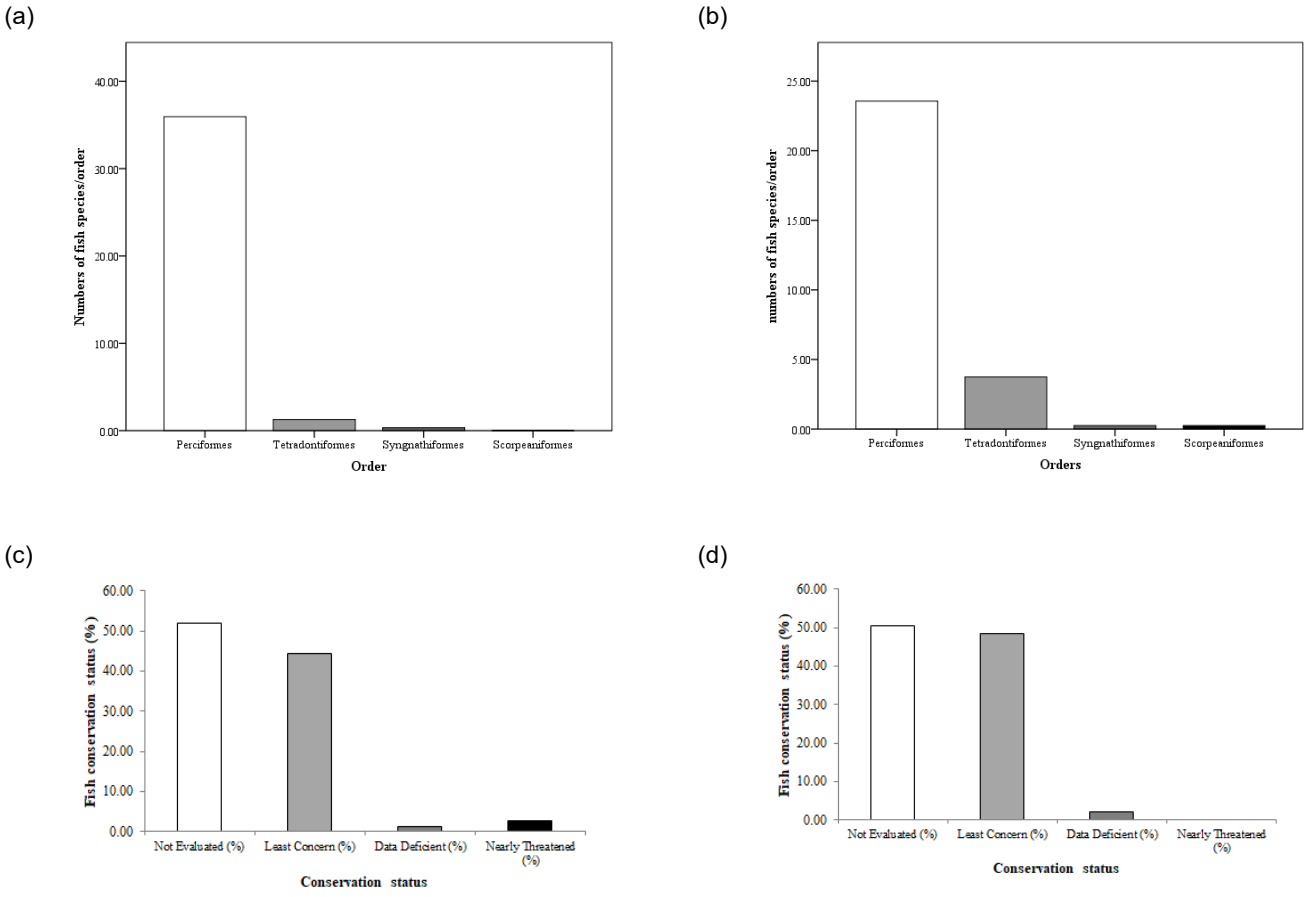

Figure 2 Mean (±SE) numbers of fish species/order and Conservational status of fishes from different orders in (a, c) Patok Bay and (b, d) Khonkae Bay, Racha Yai Island, southern Thailand**.**

Discussion

We observed that in Patok Bay there were 46 fish species and 4830 individuals belonging to 3 orders and 12 families, whereas in Khonkae Bay, there were 50 fish species and 890 individuals belonging to 4 orders and 21 families. Previously, Monkolprasit and Sontirat [22] recorded 230 species in many Islands around Phuket. Wongratana [23] collected demersal fishes along the Andaman Sea coast of Thailand at depths of about 30-420 m, and recorded 256 species in 91 families. Pokapunt and Tantivala [23] reported 182 species of demersal fishes belonging to 66 families from Andaman Sea at water depths less than 90 m. Allen *et al.* [24] listed 187, 171, 162, 160 and 159 fish species from Koh Tachai, Koh Bon Island, Phi Phi Islands, Surin Islands, Racha Yai Island, and Phuket Island, respectively. Allen *et al.* [25] found higher number of fish species in Racha Island than us; the main reason behind this could be that they covered 1000 m^2 area per transect, but we covered 250 m^2 area per transect. A recent study by Noonsang *et al.* [16] in Khonkae and Patok Bays observed 50 fish species and 1683 individuals belonging to 3 orders, and 16 families in Khonkae bay, and 66 reef fish species and 3219 individuals belonging to 2 orders, and 19 families in Patok bay in 2015.

Our results showed that numbers of fish species, individuals, families, orders, Shannon diversity, and species richness did not differ between these two bays, but fish evenness was higher in Khonkae Bay than in Patok Bay. This could be that during our study, we found higher numbers *(*62*%)* of *Lutjanus biguttatus* from perciformes group. Perciformes are the most numerous order of vertebrates, containing about 41% of all bony fish, same with the Andaman Sea, find this fish most. They belong to the class of ray-finned fish, and comprise over 10,000 species found in almost all aquatic ecosystems [26]. This fish species was a dominant species in Patok Bay, but in Khonkae Bay, we did not find any dominant species. A previous study [16] observed that *Abudefduf vaigiensis* from perciformes group was a dominant species in Khonkae bay in 2014 that is not the case in 2017.

Our results showed that fish species from perciformes order was higher than other orders in both bays. A previous study [16] also observed the same result in Racha Yai Island. Based on IUCN conservation status, we observed that most of the fish species were belong to *'*not evaluated*'* and *'*least concern*'* groups. In Patok Bay, only one species *(Epinephelus malabaricus)* was *'*nearly threatened*'*. We should take initiatives to conserve this species. Research should be conducted to know their biology and behaviour for conservation purpose.

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