# Diversity of Coral Reef Fishes at Racha Yai Island, Thailand

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## ABSTRACT

The coral reef fish diversity, richness, evenness and fish feeding habits were examined in Khonkae Bay from 2013-2015, and in Patok Bay from 2014-2015 at Racha Yai Island, Phuket. At each Bay, three 50-m permanent line transects (each covering 250 $m^2$) were made 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. Afterwards, Shannon index (*H*), Margalef's richness (*D*), and Pielou's evenness (*e*) were calculated. The differences in fish diversity, richness, and evenness were tested between/among years for each Bay. In addition, the differences in feeding habits for each year in each Bay were tested. In Khonkae Bay, from 2013-2015, 6326 fish individuals were observed belonging to 94 species, 53 genera, 27 families, and 4 orders. Shannon index (*H*) were 2.06, 0.96 and 1.66. Margalef's richness index (*D*) were 4.42, 4.03 and 3.94. Pielou's evenness index (*e*) were 0.64, 0.29 and 0.52. In Patok Bay, from 2014-2015, 5542 fish individuals were observed belonging to 89 species, 47 genera, 23 families, and 3 orders. Shannon index (*H*) were 2.20 and 1.69 Margalef's richness index (*D*) were 5.54 and 5.22. Pielou's evenness index (*e*) were 0.67 and 0.49. Fish diversity and evenness in Khonkae Bay were lowest in 2014 than other two years. This might be because in 2014, *Abudefduf vaigiensis* was a dominate species with 69.82%. On the other hand, at Patok Bay, fish diversity, species richness and evenness did not vary between years due to no dominant fish species. This indicates that reef and reef fish status at Patok Bay might be in a better condition and less stressed for less coral bleaching and fewer number of tourists than at Khonkae Bay.

**Keywords:** Khonkae bay, Margalef's richness (*D*), Patok bay, Pielou's evenness (*e*), Racha Island, Shannon-Weaver diversity (*H*).

## INTRODUCTION

Coral reefs provide structure and act as focal points for secondary production. As a consequence, coral reefs provide a number of complex marine ecosystems (Moberg and Folke 1999), in where we can find the highest degree of fish diversity (Harmelin-Vivien, 1989). Reef fish are among the most observable and diverse assemblages of

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vertebrates on the planet, and are ideal for field experiments, as well as long-term observations. Studies of reef fishes have contributed immensely to the general sciences of ecology, behaviour, fisheries biology, and conservation biology by serving as model species (Sale, 1991, 2002). Importantly, reef fishes account for about 10% of the global fisheries catch and are the major source of protein for many island nations (Polunin and Roberts, 1996). The diversity and abundance of coral reef fish species increase with increasing of island area (Sandin *et al*., 2008), refuge availability (Caley and St. John, 1996; Gratwicke and Speight, 2005), as well as nursery or settlement habitats (Nagelkerken *et al*., 2001; Harrington *et al*., 2004; Mumby *et al*., 2004).

Nowadays, many factors such as overexploitation, pollution, disease and, more recently, climate change are responsible for reduction in the availability of live corals that directly affect the distribution and abundance of fish that live and feed on live corals (Cheal *et al*., 2002; Bellwood *et al*., 2004; Halford *et al*., 2004). Mortality of corals due to bleaching has become increasingly more frequent (Hoegh-Guldberg, 1999; Douglas, 2003). Coral mortality due to mass coral bleaching has negative impacts on fish diversity, and several studies observed that fish species number and density declined due to high coral mortality (Feary *et al*., 2007; Adjeroud *et al*., 2009; Leray *et al*., 2012). The other important factor for coral reefs declining is overgrowing tourism. Now, the tourism industries are associated with coral reef ecosystems estimated to be worth $9.6 billion annually (Ehrenfeucht, 2014). The overexploitation of coral reef ecosystems by the reef tourism industries is one major cause of reef decline (Ehrenfeucht, 2014), especially diving tourism (Fishelson, 1995; Rinkevich, 1995; Harriott *et al*., 1997).

The Andaman Sea is approximately 1200 km long and 650 km wide body of water to the southeast of the Bay of Bengal. Approximately 1000 km long Andaman Sea coast of Thailand contains a variety of coastal and marine habitats such as mangroves, mud-flats, seagrass beds, rocky shores, coral reefs etc. on the continental shelf (Satapoomin, 2011). Andaman Sea is characterised by its high fish diversity and the endemism of fish fauna (McManus, 1985; Randall, 1998; Randall and Satapoomin, 1999). Unfortunately, informationon fish diversity in this area is still limited, very few studies have been conducted to know the fish species from this area (Satapoomin, 2011).

In Thailand, a severe mass coral bleaching event happened in 2010, and coral mortality in Racha Yai Island was 72.17% (Chavanich *et al*., 2012). Khonkae Bay in Racha Yai Island was more affected than Patok Bay in the same Island. Until now, Khonkae Bay is known as a coral beaching site, but Patok Bay as a non/very less bleaching site (Phongsuwan and Chansang, 2012; Pongsuwan, 2014). Khonkae Bay is more touristic than Patok Bay (pers. obs.). Most of the studies (Fowler, 1939; Monkolprasit and Sontirat, 1980; Allen *et al*., 2005) on coral reef fish have been conducted in Krabi, Phuket and Racha Yai Island before mass coral bleaching event (Phongsuwan and Chansang, 2012; Pongsuwan, 2014). To our knowledge, no research has been conducted to investigate the reef fish status after mass coral bleaching event. This is the first study for getting information about the reef fish status from Racha Yai Island after the mass coral bleaching event in 2010. In this study, the reef fish diversity, richness, evenness and fish feeding habits were studied at Khonkae Bay from 2013-2015, and in Patok Bay from 2014-2015 at Racha Yai Island, Phuket to compare these parameters between/among years.

## MATERIALS AND METHODS

### Study sites

We conducted our study at Khonkae Bay (7° 36' 17" N, 98° 22' 35" E) and at Patok Bay (7° 36' 34" N, 98° 21' 56 E) Racha Yai Island, Phuket province, Thailand (Fig. 1).

### Coral reef fish census

At each Bay, visual census technique was used (English, 1999; Noonsang *et al.*, 2013, 20014, 2015). The census was done using Line Intercept Transects (LIT) method in Khonkae Bay in April, 2013 and in Patok Bay in April, 2014 to observe fish status. At each Bay, three permanent transect lines along the reef slope were made using scuba diving in 8-10 m depth. Each census area covered 250 $m^2$ extending 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 separated from each other by 10 m. One fish expert from Phuket Marine Biological Centre (PMBC) dove, and

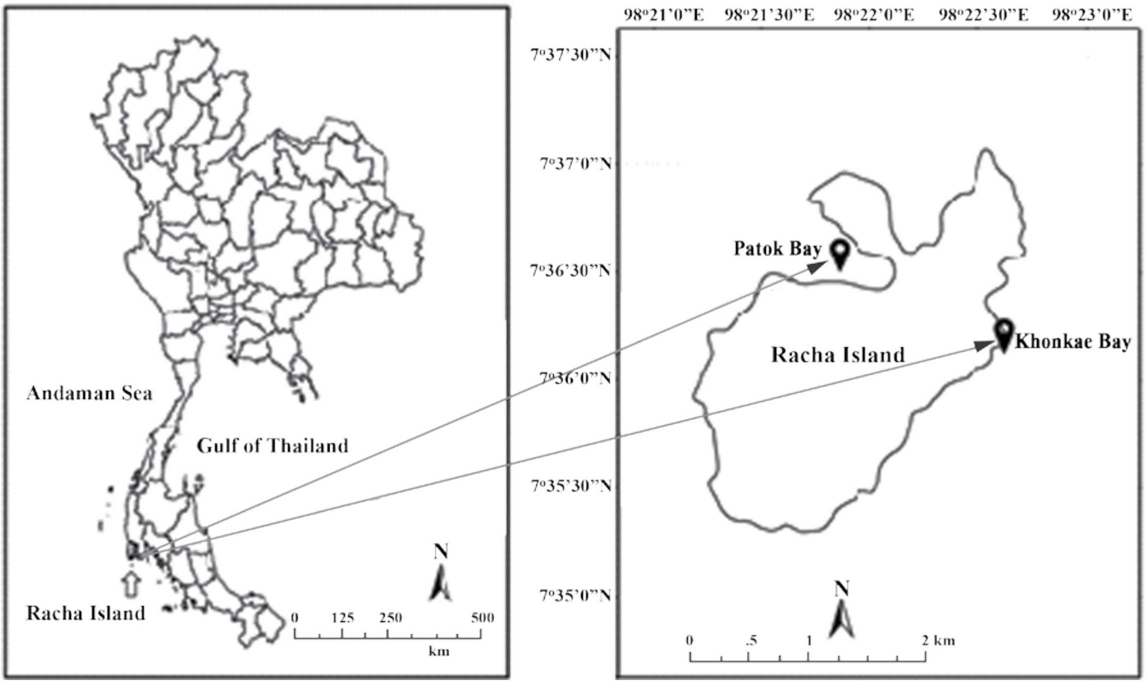


Figure 1. Location of study sites (Patok and Khonkae Bays) in Racha Yai Island, Thailand.

identified, counted and recorded all fish in each line transect in Khonkae Bay in 2013, 2014 and 2015, and in Patok Bay in 2014 and 2015. All fish species were classified into feeding habits (planktivore, herbivore, carnivore, invertebrate consumer, piscivore, omnivore and corallivore), based on Durville *et al*., (2003), Randall (2005) and Froese and Pauly (2012).

**Data analysis**

Shannon index, $H = -\sum Pi \ln Pi$ (Shannon and Weaver, 1949), Margalef's richness index, $D = (s-1)/\ln N$ (Margalef, 1968), and Pielou's evenness index, $e = H/\ln S$ (Pielou, 1966) 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 analysing the data, normality was assessed. Parametric statistics were used when normality or other assumptions of parametric tests were met. The *t*-tests, and one-way ANOVA tests were used to test the differences in the number of fish species, the number of fish individuals, fish diversity (*H*), fish richness (*D*) and fish evenness (*e*) between the years 2014 and 2015 for Patok Bay, and among the years 2013, 2014 and 2015 for Khonkae Bay, respectively.

## RESULTS

**Fish status from Khonkae and Patok Bay in different years**

At Khonkae Bay, the number of fish species, the number of fish individuals, and species richness (*D*) of fish did not vary among years, but Shannon index (*H*) and evenness (*e*) of fish varied among years (Table 1). Post-Hoc Tukey test showed that

Table 1. Fish species, diversity, species richness and evenness between/among the years for Khonkae and Patok Bays; '*' indicates $P < 0.001$

| | Parameters (mean ± SE) | Years | | | Statistical tests |
|---|---|---|---|---|---|
| | | 2013 | 2014 | 2015 | |
| **Khonkae Bay** | | | | | |
| | No. of fish species /transect line | 25±1 | 29±4 | 25±2 | $F_{2,6} = 0.68$ |
| | No. of individuals / transect line | 259±52 | 1290±398 | 561±196 | $F_{2,6} = 4.22$ |
| | Shannon index (*H*) | 2.06±0.02$^{a}$ | 0.96±0.08$^{b}$ | 1.66±0.02$^{c}$ | $F_{2,6} = 102.11$* |
| | Species richness (*D*) | 4.42±0.20 | 4.03±0.68 | 3.94±0.28 | $F_{2,6} = 0.33$ |
| | Evenness (*e*) | 0.64±0.01$^{a}$ | 0.29±0.03$^{b}$ | 0.52±0.01$^{c}$ | $F_{2,6} = 73.24$* |
| **Patok Bay** | | | | | |
| | No. of fish species / transect line | - | 28±2 | 32±2 | $t_4 = -1.17$ |
| | No. of fish individuals / transect line | - | 774±705 | 1073±883 | $t_4 = -0.26$ |
| | Shannon index (*H*) | - | 2.20±0.53 | 1.69±0.51 | $t_4 = 0.71$ |
| | Species richness (*D*) | - | 5.54±0.89 | 5.22±0.62 | $t_4 = 0.79$ |
| | Evenness (*e*) | - | 0.67±0.17 | 0.49 ± 0.15 | $t_4 = 0.29$ |

Shannon index (*H*) and evenness (*e*) of fish were significantly lower in 2014 than in 2013 ($P < 0.001$), and then increased in 2015 from 2014 ($P < 0.001$), but was still lower than in 2013 ($P < 0.01$). At Patok Bay, the number of fish species, the number of fish individuals, Shannon index (*H*), species richness (*D*), and evenness (*e*) of fish did not vary between years (Table 1).

**Fish diversity in the two Bays**

Fish orders, families, genera, species, feeding habits and percentages in Khonkae and Patok Bays are shown in Table 2. At Khonkae Bay, in 2013, 50 reef fish species and 776 individuals belonging to 4 orders, 19 families and 34 genera were found. In 2014, 52 reef fish species and 3867 individuals belonging to 4 orders, 20 families and 31 genera were found. In 2015, 50 reef fish species and 1683 individuals belonging to 3 orders, 16 families and 34 genera were found. In these three years, there were fish from four orders: Perciformes (95.04%), Tetraodontiformes (0.22%), Beryciformes (3.88%) and Syngnathiformes (0.88%). Fish from Beryciformes and Syngnathiformes orders were only found in Khonkae Bay which has mainly planktivores and corallivores.

At Patok Bay, in 2014, 62 reef fish species and 2323 individuals belonging to 3 orders, 22 families and 38 genera were found. In 2015, 66 reef fish species and 3219 individuals belonging to 2 orders, 19 families and 37 genera were found. In these two years, there were fish from three orders: Perciformes (99.74%), Tetraodontiformes (0.19%) and Anguilliformes (0.08%). Fish from Anguilliformes were found only in Patok Bay which has mainly corallivores.

**Fish feeding habits in Khonkae and Patok Bays**

In Khonkae Bay, the mean (±SE) number of fish individuals with different feeding habits were different in 2013, 2014 and 2015 (one-way ANOVA tests: in 2013: $F_{5,70} = 5.16$, $P < 0.001$; in 2014: $F_{5,82} = 5.23$, $P < 0.001$; in 2015: $F_{5,70} = 4.55$, $P < 0.005$). Post Hoc Tukey showed that in 2013 and 2015 fish numbers from omnivore feeding habit was higher than invertebrate consumer, carnivore and herbivore feeding habits ($P < 0.05$, Figure 2), while in 2014, fish numbers from omnivore feeding habit was higher than invertebrate consumer, carnivore, corallivore and herbivore feeding habits ($P < 0.05$, Figure 2).

In Patok Bay, fish numbers with different feeding habits did not differ in 2014 and 2015 (one-way ANOVA tests: in 2014: $F_{5,78} = 1.39$, *ns*; in 2015: $F_{5,89} = 2.19$, *ns*, Figure 2).

Table 2. Fish fauna with orders, families, scientific names, and feeding habits (FH) (PV= planktivore, CV= carnivore, HV= herbivore, CLV= corallivore, IC= invertebrate consumer, OV= omnivore), and percentage from Khonkae and Patok Bays.

| Order | Family | Scientific names | FH | Khonkae | | | Patok | |
|---|---|---|---|---|---|---|---|---|
| | | | | 2013 | 2014 | 2015 | 2014 | 2015 |
| Anguilliformes | Muraenidae | *Gymnothorax fimbriatus* | CV | | | | 0.05 | |
| | | *Gymnothorax javanicus* | CV | | | | 0.10 | |
| Beryciformes | Holocentridae | *Myripristis hexagona* | PV | | | 0.41 | | |
| | | *Myripristis murdjan* | PV | 0.51 | | | | |
| | | *Neoniphon sammara* | CV | | | 10.69 | | |
| | | *Sargocentron melanospilos* | CV | | 0.02 | | | |
| Perciformes | Acanthuridae | *Acanthurus bariene* | HV | | | | | 0.13 |
| | | *Acanthurus leucosternon* | HV | | | 0.52 | | |
| | | *Acanthurus lineatus* | HV | | 0.04 | | | |
| | | *Acanthurus nigricauda* | HV | | 0.02 | | 0.09 | 0.17 |
| | | *Acanthurus thompsoni* | HV | | | | | 0.07 |
| | | *Ctenochaetus striatus* | HV | 0.38 | | 0.58 | | 0.10 |
| | | *Naso elegans* | HV | 0.12 | | | | |
| | | *Zebrasoma scopas* | HV | | | 0.05 | | |
| | Apogonidae | *Cheilodipterus macrodon* | CV | 0.38 | | 0.18 | | |
| | Caesionidae | *Caesio caerulaurea* | PV | 0.38 | | | 6.11 | 0.04 |
| | Chaetodontidae | *Chaetodon andamanensis* | CLV | 0.13 | | | 0.09 | |
| | | *Chaetodon auriga* | CLV | 0.26 | | | | |
| | | *Chaetodon collare* | CLV | 1.93 | 0.30 | 0.36 | 0.39 | 0.94 |
| | | *Chaetodon lineolatus* | IC | 0.13 | 0.05 | | | |
| | | *Chaetodon lunula* | CLV | | 0.05 | | | 0.04 |
| | | *Chaetodon triangulum* | CLV | 0.26 | 0.05 | | 0.30 | 0.10 |
| | | *Chaetodon trifasciatus* | CLV | 0.39 | 0.09 | 0.12 | 0.09 | 0.13 |
| | | *Chaetodon vagabundus* | CLV | 0.26 | | | | |
| | | *Heniochus pleurotaenia* | CV | | 0.02 | | | |
| | | *Heniochus singularius* | CLV | | 0.03 | | 0.09 | 0.07 |
| | Ephippidae | *Platax teira* | OV | | | | 0.04 | |
| | Haemulidae | *Plectorhinchus chaetodonoides* | CV | 0.13 | | | 0.04 | |
| | | *Plectorhinchus vittatus* | CV | | | | 0.09 | |
| | Kyphosidae | *Kyphosus vaigiensis* | CV | | 0.08 | 0.12 | 0.04 | |
| | Labridae | *Anampses lineatus* | CV | | | | | 0.03 |
| | | *Anampses meleagrides* | CV | 0.13 | | 0.12 | | |
| | | *Bodianus axillaris* | CV | | 0.03 | | | |
| | | *Cheilinus fasciatus* | IC | | 0.13 | 0.06 | | 0.06 |
| | | *Cirrhilabrus cyanopleura* | PV | | | 0.36 | | 0.62 |
| | | *Coris batuensis* | IC | | | | | 0.06 |
| | | *Coris cuvieri* | IC | | | | | 0.06 |
| | | *Epibulus insidiator* | CV | | | 0.18 | | |
| | | *Gomphosus caeruleus* | CV | | 0.05 | | 0.04 | |
| | | *Halichoeres argus* | IC | 0.13 | | | | |
| | | *Halichoeres hortulanus* | IC | 0.26 | | 0.36 | 0.04 | 0.06 |
| | | *Halichoeres marginatus* | IC | | | | 0.04 | |
| | | *Halichoeres vroliki* | IC | | | | | 0.12 |
| | | *Hemigymnus fasciatus* | IC | | 0.08 | | | 0.03 |

Table 2. continued. Fish fauna with orders, families, scientific names, and feeding habits (FH) (PV= planktivore, CV= carnivore, HV= herbivore, CLV= corallivore, IC= invertebrate consumer, OV= omnivore), and percentage from Khonkae and Patok Bays.

| Order | Family | Scientific names | FH | Khonkae | | | Patok | |
|---|---|---|---|---|---|---|---|---|
| | | | | 2013 | 2014 | 2015 | 2014 | 2015 |
| | | *Hemigymnus melapterus* | IC | | 0.05 | 0.06 | 0.09 | |
| | | *Labroides dimidiatus* | IC | 0.39 | | 0.18 | 0.13 | 0.03 |
| | | *Scarus ghobban* | HV | | | 0.30 | | 0.12 |
| | | *Scarus niger* | HV | 1.03 | 0.21 | 1.54 | 0.26 | 0.22 |
| | | *Scarus prasiognathos* | HV | | 0.05 | 0.24 | 0.04 | 0.03 |
| | | *Scarus quoyi* | HV | | 12.96 | 0.12 | 0.09 | 0.09 |
| | | *Scarus rubroviolaceus* | HV | 0.13 | | 0.18 | 0.04 | 0.03 |
| | | *Scarus scaber* | HV | | 0.05 | | 0.13 | |
| | | *Scarus tricolor* | HV | | | | 0.04 | |
| | | *Stethojulis trilineata* | CV | | | 0.12 | 0.04 | |
| | | *Thalassoma lunare* | CV | 0.64 | 0.21 | 1.07 | 0.56 | 0.06 |
| | Lethrinidae | *Lethrinus crocineus* | CV | | 0.05 | | 0.04 | |
| | | *Lethrinus lentjan* | CV | | | 0.18 | | 0.06 |
| | | *Lethrinus nebulosus* | CV | | 0.03 | | | |
| | | *Lethrinus ornatus* | CV | | 0.08 | 0.06 | | |
| | | *Monotaxis grandoculis* | IC | | | | 0.04 | |
| | Lutjanidae | *Lutjanus decussatus* | CV | | 0.13 | 0.06 | 0.13 | 0.28 |
| | | *Lutjanus fulviflamma* | CV | 0.13 | 0.08 | 0.36 | | |
| | | *Lutjanus kasmira* | CV | | | | 0.22 | |
| | | *Lutjanus quinquelineatus* | CV | | | | 0.04 | 0.03 |
| | Mullidae | *Mulloidichthys flavolineatus* | IC | | | | | 0.03 |
| | | *Mulloidichthys vanicolensis* | IC | | 0.03 | 0.36 | | 0.03 |
| | | *Parupeneus barberinus* | IC | 0.26 | | 0.06 | | 0.06 |
| | | *Parupeneus cyclostomus* | CV | | | | | 0.03 |
| | | *Parupeneus macronemus* | CV | 0.13 | 0.03 | | 0.04 | |
| | | *Parupeneus pleurostigma* | IC | | | | 0.04 | |
| | | *Upeneus tragula* | CV | | | 0.06 | | |
| | Nemipteridae | *Scolopsis bilineata* | CV | 0.13 | | | 0.09 | 0.12 |
| | | *Scolopsis ciliata* | CV | | | | 0.09 | 0.06 |
| | | *Scolopsis margaritifera* | CV | | | | 0.04 | 0.12 |
| | | *Scolopsis monogramma* | CV | 0.13 | 0.03 | | | |
| | Pempheridae | *Pempheris oualensis* | CV | | 0.03 | | | |
| | | *Pempheris schwenkii* | PV | | | 13.67 | | |
| | | *Pempheris vanicolensis* | PV | 25.77 | | | | |
| | Pinguipedidae | *Parapercis clathrata* | CV | | | | 0.13 | 0.03 |
| | | *Parapercis hexophtalma* | CV | 0.13 | | | | |
| | | *Parapercis snyderi* | CV | | | | | 0.03 |
| | Pomacanthidae | *Centropyge eibli* | HV | | 0.03 | | 0.04 | 0.09 |
| | Pomacentridae | *Abudefduf notatus* | OV | | 1.03 | 11.88 | | |
| | | *Abudefduf vaigiensis* | OV | 1.29 | 69.82 | 5.94 | 0.04 | 6.21 |
| | | *Amblyglyphidodon leucogaster* | OV | 3.99 | | | | |
| | | *Amphiprion akallopisos* | OV | | | | 0.13 | |
| | | *Chromis atripectoralis* | PV | | | | 0.69 | 62.13 |
| | | *Chromis dimidiata* | PV | | | | 0.09 | 0.03 |

Table 2. continued. Fish fauna with orders, families, scientific names, and feeding habits (FH) (PV= planktivore, CV= carnivore, HV= herbivore, CLV= corallivore, IC= invertebrate consumer, OV= omnivore), and percentage from Khonkae and Patok Bays.

| **Order** | **Family** | **Scientific names** | **FH** | **Khonkae** | | | **Patok** | |
|---|---|---|---|---|---|---|---|---|
| | | | | **2013** | **2014** | **2015** | **2014** | **2015** |
| | | *Chromis ternatensis* | PV | | | | 64.57 | 6.21 |
| | | *Chrysiptera rollandi* | PV | | | | 0.09 | 0.16 |
| | | *Dascyllus carneus* | PV | | | | 0.43 | 1.55 |
| | | *Dascyllus trimaculatus* | PV | 0.26 | 0.28 | 0.77 | 0.82 | 0.43 |
| | | *Dischistodus perspicillatus* | HV | | | | | 0.09 |
| | | *Neopomacentrus cyanomos* | PV | 0.26 | | | | |
| | | *Neopomacentrus filamentosus* | PV | | | | 6.07 | 0.06 |
| | | *Neopomacentrus sororius* | PV | 4.51 | | | | |
| | | *Plectroglyphidodon lacrymatus* | HV | 2.45 | 0.05 | 0.06 | 0.09 | 0.03 |
| | | *Pomacentrus adelus* | OV | 0.26 | | | | |
| | | *Pomacentrus amboinensis* | OV | | | | 0.17 | 0.31 |
| | | *Pomacentrus azuremaculatus* | OV | | | | | 0.06 |
| | | *Pomacentrus chrysurus* | OV | 0.64 | 0.03 | 0.89 | | |
| | | *Pomacentrus lepidogenys* | OV | | 11.38 | 44.56 | 2.80 | 0.93 |
| | | *Pomacentrus moluccensis* | OV | 14.18 | 0.03 | 0.30 | 12.91 | 15.97 |
| | | *Pomacentrus pavo* | OV | | | 0.48 | | 0.06 |
| | | *Pomacentrus philippinus* | OV | 25.90 | 0.10 | 0.12 | 0.34 | 0.12 |
| | | *Pomacentrus similis* | OV | | | 0.18 | | 0.16 |
| | | *Pomacentrus xanthosternus* | OV | | | | 0.09 | |
| | Priacanthidae | *Priacanthus macracanthus* | CV | | 0.03 | | | |
| | Scaridae | *Chlorurus atrilunula* | HV | | | 0.24 | | 0.19 |
| | | *Chlorurus capistratoides* | HV | | 0.10 | | | |
| | | *Chlorurus sordidus* | HV | 1.55 | 0.21 | 0.65 | 0.04 | 0.06 |
| | | *Chlorurus troschelii* | HV | 0.64 | 0.08 | 0.18 | | |
| | Serranidae | *Aethaloperca rogaa* | CV | 0.13 | 0.03 | 0.06 | | |
| | | *Cephalopholis argus* | CV | 0.13 | 0.03 | | 0.09 | 0.03 |
| | | *Cephalopholis polyspila* | CV | 0.13 | | | | |
| | | *Epinephelus quoyanus* | CV | 0.13 | | | | |
| | Siganidae | *Siganus canaliculatus* | HV | 0.13 | | | | 0.31 |
| | | *Siganus guttatus* | HV | 0.26 | | 0.30 | 0.04 | 0.09 |
| | | *Siganus javus* | HV | 3.99 | 1.01 | 0.12 | 0.04 | |
| | | *Siganus magnificus* | HV | | 0.13 | 0.12 | | |
| | Tripterygiidae | *Helcogramma striatum* | PV | 1.29 | | | | |
| | Zanclidae | *Zanclus cornutus* | IC | 0.39 | 0.34 | 0.24 | 0.30 | 0.22 |
| Syngnathiformes | Centriscidae | *Aeoliscus strigatus* | PV | 2.58 | | | | |
| | Fistulariidae | *Fistularia commersonii* | CV | | 0.05 | | | |
| Tetraodontiformes | Balistidae | *Balistapus undulatus* | IC | 0.26 | 0.05 | | | 0.06 |
| | | *Balistoides viridescens* | IC | | | | | 0.03 |
| | | *Sufflamen bursa* | IC | | | | 0.04 | |
| | Monacanthidae | *Cantherhines pardalis* | IC | | | | 0.04 | 0.03 |
| | Ostraciidae | *Ostracion cubicus* | HV | | 0.03 | | | 0.03 |
| | Tetraodontidae | *Arothron nigropunctatus* | CV | | 0.10 | 0.18 | 0.04 | 0.06 |
| | | *Canthigaster solandri* | HV | | | | 0.04 | |

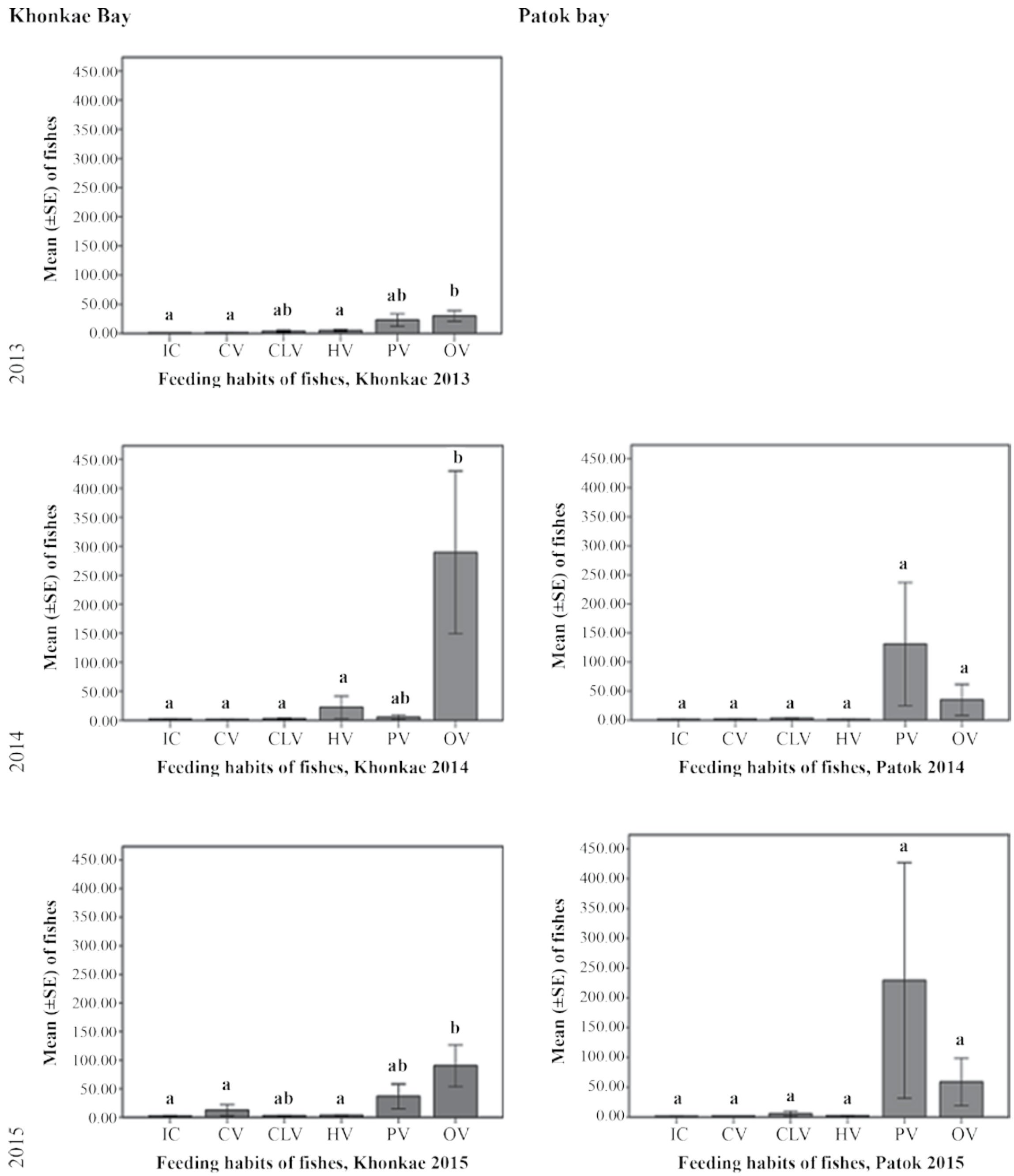


Figure 2. Feeding habits of fishes from Khonkae and Patok Bays, Phuket, Thailand during 2013-2015. IC= invertebrate consumer, CV= carnivore, CLV= corallivore, HV= herbivore, PV= planktivore, and OV= omnivore.

## DISCUSSION

We observed a total of 94 fish species from Khonkae Bay from 2013-2015, and 89 fish species from Patok Bay from 2014-2015. Fowler (1939) reported 81 marine fish species from Krabi, those are more or less similar in numbers with the fish species those we have found from Racha Yai Island. Monkolprasit and Sontirat (1980) recorded 230 species in many Islands around Phuket and several small islands in Indian Ocean from 1976-1978. They found a higher number of fish species than us, because they covered many islands together, but in our study, we covered only two Bays in Racha Island. Allen *et al*., (2005) 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*., (2005) found higher number of fish species in Racha Island than us, there are two main reasons behind this- (1) they covered 1000 $m^2$ area per transect, but we covered 250 $m^2$ area per transect, and (2) this study was conducted in 2005 that was before the mass coral bleaching that happened in 2009-2010. Probably after the mass coral bleaching event in 2010, fish species might reduce in numbers.

Ray *et al*. (2013) observed that fish diversity, species richness, and evenness in North Bay Reef, Andaman Sea, India, were 1.57, 18.98 and 0.31, respectively. Our results showed that in Patok Bay, Shannon index ($H$=1.45 in 2014 to $H$=1.48 in 2015), species richness ($D$=7.87 in 2014 to $D$=8.05 in 2015) and evenness ($e$=0.35 in 2014 and 2015) of fish did not change between 2014 and 2015. On the other hand, in Khonkae Bay, fish diversity and evenness decreased significantly from 2013 to 2014, and after that increased in 2015 but still were significantly lower than in 2013. Fish species richness also showed a tendency like fish diversity and evenness but the result was non-significant, probably due to high variability of number of individuals per species per transect line. Fish diversity and evenness decreased in 2014 and 2015 than in 2013, probably due to decrease in coral coverage because of coral bleaching, as Khonkae Bay is known as coral bleaching site (Jaroensutasinee *et al*., 2015). According to Phongsuwan and Chansang (2012) and Pongsuwan (2014), during large scale coral bleaching in Racha Island in 2010, 44.2 % of coral died; and 30-40% coral mortality was observed in Khonkae Bay, and 5% in Patok Bay. There is a strong positive correlation between reef fish diversity and coral coverage. One study observed that in the lagoon of Mataiva Atoll, Tuamotu Archipelago, fish diversity increased and/or decreased with increasing and/or decreasing of live coral cover percentage (Bell and Galzin, 1984). In Patok Bay, species richness and evenness of fish did not change between 2014 and 2015, as this site is not a coral bleaching site, and probably coral coverage did not change between 2014 and 2015.

In Khonkae Bay, the trophic types are mainly represented by omnivore feeding habit group, those all were from Pomacentridae family. The majority of the Pomacentridae are small, territorial, and live close to the substratum for shelters; they are influenced mostly by the morphological characteristics of the substratum, and use corals more as a habitat or shelter than as a food resource (Sano *et al*., 1984, 1987; Roberts and Ormond, 1987; Jones, 1991). In this study, we did not test the substratum types of the reefs. All fish species belonging to corallivore feeding habits in both Khonkae and Patok Bays were from Chaetodontidae family.

In Khonkae Bay, in 2013 we observed seven fish species (in 2013: *Chaetodon andamanensis*, *C. auriga*, *C. collare*, *C. linealatus*, *C. triangulum*, *C. trifasciatus*, and *C. vagabundus*) belonging to corallivore feeding habits. In 2014, the number of fish species was the same, but three species got lost (*C. andamensis*, *C. auriga* and *C. vagabundus*), and three species joined (*C. lunula*, *Heniochus pleurotaenia*, and *H. singularius*). In 2015, only two species remained (*C. collare*, and *C. trifasciatus*). We did not observe three fish species (*C. andamanensis*, *C. auriga* and *C. vagabundus*) after 2013, probably those fish species moved to other reefs. On the other hand, in Patok Bay, in 2014 we observed five fish species (*C. andamanensis*, *C. collare*, *C. triangulum*, *C. trifasciatus* and *H. singularius*), and in 2015, the fish number was same, though one fish species got lost (*C. andamanensis*) and another species joined (*C. lunula*). The reason of losing more corallivore fishes in Khonkae Bay is probably due to reduction of percentage coral coverage that did not occur in Patok Bay. Previous studies (Bell and Galzin, 1984; Chabanet *et al*., 1995) reported that there was a positive correlation between abundance of Chaetodontidae and the percentage of live coral coverage. Living coral is used as a direct food resource for this fish (Harmelin-Vivien and Bouchon-Navaro, 1981, 1983).

The abundance of planktivore and carnivore fishes do not depend on the coral substratum, but their abundance may respond to other biotic and abiotic environment which characterise the outer reef slope, including the reef pass (Chabanet *et al*., 1997). Thresher (1983) observed that abundance of planktivore fishes depends on the speed of currents transporting the plankton onto the reef. Both in Khonkae and Patok Bays, the fish numbers from invertebrate consumer feeding habit were less. It is difficult to explain the reason behind this, but probably their abundance depends on prey whose occurrence and abundance are related to the availability of live coral (Bell and Gazlin, 1984).

Worachananan *et al*., (2008) observed family Labridae and found 27 genera, 69 species in North Andaman during February 2003-2004. We found 12 genera and 19 species at Khonkae Bay and, 11 genera and 21 species at Patok Bay. Worachananan *et al*. (2008) found new eight species (*Halichoeres melanochir*, *Halichoeres zeylonicus*, *Iniistius baldwini*, *Iniistius* sp., *Oxycheilinus celebicus*, *Oxycheilinus orientalis*, *Suezichthys* sp. and *Wetmorella nigropinnata*) that were not found at Racha Island. Allan *et al*., (2005) listed three species (*Pomacentrus polyspilus*, *Ecsenius lubbocki*, and *Siganus magnificus*) associated fishes that are endemic to the East Andaman Sea. Only Siganus magnificus found 0.13% in 2013, and 0.12% in 2014 at Khonkae Bay. Vilasri *et al*., (2015) annotated checklist of marine fishes from Phuket market found 13 orders, and 47 families. In 2015 at Racha Island, we found 2 orders, 17 families, 74 species in 13 orders that found in market but not found at Racha Island in 2015.

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