Effects of Tourism on herbivore community composition in Coral Reefs in the Gulf of Thailand

Diplomarbeit

vorgelegt von

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Für meinen Vater, meine Mutter

und Lukas

Erklärung

Ich versichere hiermit, dass ich die vorliegende Arbeit selbstständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe.

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Contents

Abstract

Since the early 1990s, tourism in the area of the Gulf of Thailand increased rapidly. Especially the famous dive sites around the islands of *Koh Phangan* and *Koh Tao* attract lots of tourists each year. The increasing tourist densities accompanied with water pollution and overexploitation of marine resources lead to a change in fish and sea urchin species richness, affecting the diversity and growth of the benthic community. Through the elevated fishing and dive activities, a decreasing herbivore species richness was expected, leading to an increased growth of benthic algae. These increasing algae cover negatively affects the growth, reproduction, and survivorship of the corals. To investigate these changes, bays with different tourist densities on each island and one site in the barely populated *Ang Thong National Park* was surveyed along the reefs, counting the abundance of all occurring herbivorous fish species and sea urchins. Additionally, the total number of carnivorous fish species was recorded to analyze differences of total fish abundance between the sites. On *Koh Phangan*, changes of species richness during high season from February to March and low season from April to May was investigated conducting surveys in both seasons. To test differences in algae growth due to influence of herbivore species, exclusion cages were deployed on one site which excludes either fishes or sea urchins or both. Results showed significantly higher herbivore species richness and total fish abundance in the reef of *Ang Thong Marine Park* than on *Koh Phangan* or *Koh Tao.* The stronger frequented island of *Koh Tao* didn`t reveal significantly lower fish or sea urchin abundances than the less visited *Koh Phangan.* Lower frequented study sites on the islands showed significantly higher fish abundances than the tourist influenced sampling bays. Numbers of sea urchins tend to be higher on both islands on study sites with high tourist densities. Significant changes in fish species abundance with the beginning of low season was verifiable in 2 of 3 surveyed coral reefs, whereas sea urchin abundance didn`t change significantly. Exclusion experiments showed increased algal abundance, but algae growth inside cage designs didn`t differ significantly.

This study is linked with further analysis of water, sediment and benthic community at identical reefs. Several results of these studies were considered at the interpretation of own results to gain a comprehensive data set about the condition of surveyed coral reefs.

1. Introduction

Coral reefs are among the most biologically diverse and important ecosystems on earth (Ruengsawang 2000). Although covering less than 0,25% of the marine environment (Bryant et al. 1998), reefs provides shelter for more than a quarter of all known marine fish species (Mulhall 2008). Furthermore, coral reefs supply millions of people with goods and services such as living resources (fish, seafood), coastal protection as well as cultural and aesthetic benefits (Moberg et al. 1999, Kühlmann 1988, Done et al. 1996).

1.1. Effects of human activities on coral reefs

Over the last decades, coral reefs worldwide are experiencing a recent period of decline (Szmant 2002). Human activities such as overfishing, marine pollution, coastal development , pollution and sedimentation from inland sources are considered a major cause of this decline (Juhasz et al. 2010). Especially the reefs in South-East Asia, classified as the most species-rich coral reefs on earth (Burke et al. 2002), are threatened by this development. Different studies (Bryant et al. 1998, Burke et al. 2002) concluded that more than 80% of all coral reefs are at risk, over half of them at high risk. A bigger part of these destructive activities are consequences of the growing tourism industry, one of the fastest growing sectors of the global economy (Cesar et al. 2003).

About 57 million tourists visited the countries of South East Asia in 2007 (www.trails.com, 15.07.2011), about 15 million of them came to Thailand (www.thaiwebsites.com, 13.07.2011). Primarily the islands of the Gulf of Thailand (GoT) attract an increasing number of visitors every year (UNTWO World Tourism Organisation, 2010). The local coral reefs are a popular draw for snorkelers, scuba divers and those seeking recreation on the fine beaches, arised by natural erosion of nearby reefs. The increased stream of visitors enhances negative inputs to nearby coral reefs such as nutrient input, building of new hotel resorts and harbours (Sandin et al. 2008,UNEP 2001), and physical disturbances due to dive tourism (Jackson et al. 2001, Hawkins et al. 1993). Sewage water of hotels and resorts is discharged directly into the ocean (Cheevaporn et al. 2003, Hungspreugs 1989, personal observations, see Fig.1.1), thereby potentially polluting reefs permanently, as described for other locations by Bryant et al. (1998) or Pastorok et al. (1985). Beside these factors, overexploitation of fish species due to increased demand for fish by tourists is one of the major problems facing the reef ecosystem (Bellwood et al. 2004, Hughes et al. 2003). Since the 1970s, the fisheries sector is one of the economically important sectors of the coastal cities of Thailand, producing about 2,3 million tons of fish and shellfish in 2007 (FAO 2009). The excessive fishing accompanied with destructive fishing practices lead to a continuous decline of total fish catch since the 1980s(FAO 2009).

Fig. 1.1.: Sewage water disposal of resorts on three study sites; A: Mae Haad (Koh Tao); B: Mae Haad (Koh Phangan); Haad Yao (Koh Phangan). Pictures are taken by the author.

1.2. The Role of Herbivory

Several previous studies (Lewis et al. 1986, Done 1992, Jayewardene 2009) provide evidence that changes in species composition due to human activities as overfishing of key species like herbivores can ultimately affect ecosystem functioning. The decline of herbivorous fishes and other keystone grazers like sea urchins has been identified as the leading cause of increased algal abundance on reefs (McCook 1999, Goreau et al. 2000), causing phase shifts from coral-dominated reef ecosystems to macroalgal-dominated states (Hughes et al. 2007, Norström et al. 2009). The study of Williams and Pollunin (2001) showed the relationship between herbivorous fish biomass and macroalgal cover on multiple Carribean reefs. Top-down control by abundant populations of herbivores facilitates a coral-dominated community by removing macroalgae that suppress the growth, reproduction, recruitment and survivorship of corals (Burkepile et al. 2008, Steneck 1988, Lewis et al. 1986). Furthermore, different studies provide evidence that herbivory has a positive impact on the resilience of coral reefs, defined as the ability of reefs to absorb shocks, resist phase shifts and regenerate after natural and human-induced disturbances (Nyström et al. 2000, Hughes et al. 2007). As described by Done (1992) and other studies (Roberts 1995, Hatcher 1984), reefs with more herbivores have greater potential to recover from damage by storms. In the Asia-Pacific Region, herbivorous fishes are the dominant group of herbivores (Green et al. 2009), but grazing by sea urchins is also recognized as one of the important factors controlling reef growth and development (Ruengsawang et al. 2000).

1.3. Functional groups of Herbivores

Herbivorous reef fishes are a diverse group with relatively large population sizes (Bruno et al. 2008), comprising several functional groups that differ in terms of how they feed, what they consume, and their impact on the underlying substratum (Green et al. 2009). The three groups occurring in the Gulf of Thailand-scrapers, grazers and browsers- play different roles to permit and alleviate growth and recovery of corals on the reef. Scrapers like *Scarus ghobban* and *Scarus rivulatus* (*Scaridae*) take non-excavating bites with their stout jaws, scraping the reef surface and remove algae, sediment and other material (Bellwood et al. 2004). Grazers (rabbitfishes, surgeonfishes, angelfishes) intensely graze on epilithic algae turfs, reducing coral overgrowth and shading by macro-algae (Hughes et al. 1994). Browsers like rudderfishes and batfishes feed on individual algae components and remove only algae and associated epiphytic material (Green et al. 2009). The occurring sea urchins in the Gulf (*Diadema setosum, Echinotrix calamaris*) play an important role in coral reef resilience, as they are the major group of bioeroders on the reef (Hunter 1977). With their protractile chewing apparatus, they are able to abrade the carbonate reef substrata, removing dead coral, and filamentous or turf algae growing on the reef substrate (Ruengsawang et al. 2000). Furthermore, the abrasive activities results in forming of burrows and cavities (Bak et al. 1993).

1.4. Study area

The Gulf of Thailand (GoT) is approximately 720 km in length, with a coastline of 2900 km and depths ranging from 50-80 m (Jitchum et al. 2009). Reef development is naturally limited by low salinities and high loads of sediments (Nordemar et al. 2000) caused by the effluents of four rivers in the area. The GoT is the major marine resource in Thailand concerning fisheries and aquaculture (Cheevaporn et al. 2003), providing 70 % of all harvested fishes in Thailand (Pauly et al. 2003).The islands in the lower Gulf represent an interesting study area, showing differences in terms of coastal development, population densities, and the amount of tourists per year. While a small amount of research (Nordemar et al. 2000, Yeemin et al. 2006) has been done on the status of coral reefs in the Gulf of Thailand, no research has focused on the impact of tourism and it`s concomitants on the nearby reefs around Koh Phangan, Koh Tao and Ang Thong.

In this study, the relationship between tourist abundance and species richness, especially abundance of herbivorous species, was investigated by analyzing the number and diversity of fishes and sea urchins on study sites with different tourist impact. Specifically, we tested the hypothesis that high abundance of tourists leads to low occurrence of herbivores in the adjacent coral reefs. Therefore, abundance of fishes and sea urchins was determined during high tourist season from February to March 2011, and low tourist season from April to May 2011. Additionally, surveys of benthic community structure were arranged simultaneously (see Schwieder 2011) to test the influence of herbivore species richness on growth rates of algae and corals.

These descriptive studies were linked with experimental in situ studies, using cage experiments in order to simulate extreme overfishing and following disappearance of benthic or pelagic herbivory. Different cage designs were used to test the effects of exclusion of occurring herbivores on algae growth.

To gain a comprehensive survey about the present condition of the analyzed reefs, further research was processed on all selected study sites with associated methods, investigating additional changes in reef ecosystem due to tourism. Studies occurred simultaneously to this survey, comprising measurements of sedimentary properties (see Bennecke 2011), organic matter concentrations (see Börder 2011), and analysis of inorganic nutrient availability and benthic community composition (see Schwieder 2011).

2. Materials and Methods

2.1. Study sites

Sampling was conducted on 6 different coral reefs around the islands of *Koh Phangan, Koh Tao* and the National Marine Park of *Ang Thong* in the GoT (Fig.2.1.). All study sites are influenced by the North-East Monsoon (dry season) from November to March, leading to a top water level at that time, and the Pre-Monsoon from March to mid-May with maximum temperatures of 35°C to 40°C (Singhrattna et al. 2005).

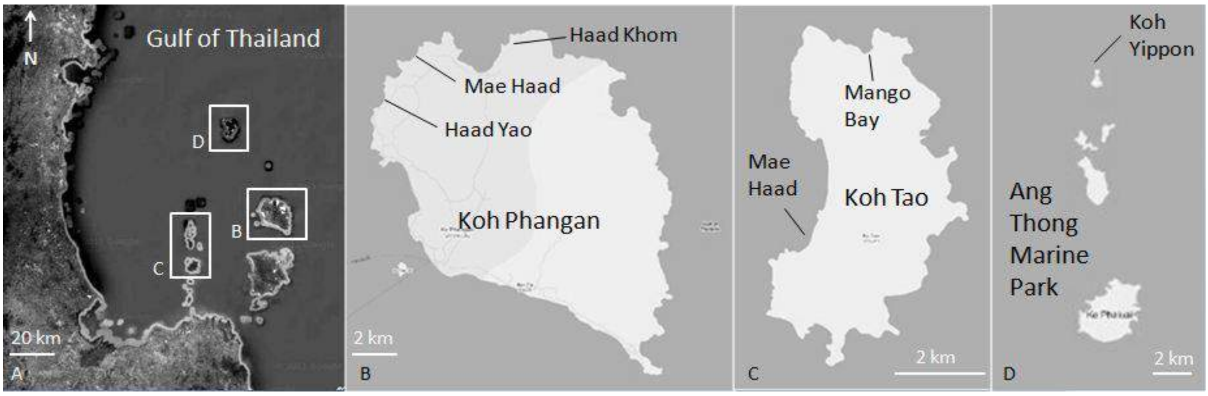

Fig. 2.1.: Locations of sampled islands in the Southern Gulf of Thailand (A); B-C: Locations of the study sites on each island (modified from http://maps.google.com)

Based on countings of resorts and bungalows along the beach, sampling sites were classified as under "high", "intermediate", and "low" influence of tourists. For more precise information about the present tourist number, hotel owners and workers were interviewed about the actual capacity utilization of the resorts on sampling days. Additionally, people on the beach were counted instantaneous after the actual surveying. To estimate the influence of fishing activities on fish species composition, fishing boats along the sampling bays were counted on survey days.

2.1.1. Koh Phangan (P)

Koh Phangan, situated about 90 km eastern of the mainland of Thailand, is the second-largest island of the Archipelago of Samui, covering 168 km² (www.sawadee.de/kohphangan, 02.07.2011). About 90 % of the calm island is still covered by rainforest, and lots of the 8.000 residents live on fishery (www.thailand.prd.go.th, 03.07.2011). While the neighbor islands of Koh Samui and Koh Tao are affected by increasing mass tourism (Green et al. 2005, Vorlaufer 2004) , just some backpackers and nature lovers find their way to the island (www.kohphangan-tourism.com, 03.07.2011).

Three different study sites on the island were selected, representing different tourist densities during the data collection.

Mae Haad. The 1,1 km long bay is located in the northwest of the island. With 101 bungalows (330 tourists per day at high season, 65 at low season) on the beach, this bay represented a study site with an intermediate tourist density. Although fishing in this area is prohibited, about 18 fishing boats trawled here every day. The adjacent shallow seafloor inshore relative to the 913 m long, coast-parallel coral reef was overgrown by algae, especially in the hot months in March and April. Transect lines were layed along the reef slope from a certain point (9°47’44.85”N/99°58’41.51”E) southbound (heading 210°).

Haad Yao. The bay in the west of *Koh Phangan* is one of the most famous beaches on the island. Due to the increasing popularity of the area, 309 bungalows arised along the beach during the last years. During high season from February to March, 434 tourists stayed in the accommodations each night, representing the highest visitor density of the surveyed sites in *Koh Phangan*. At low season from April to May, 124 visitors occupied the resorts of the bay per night. Contrary to the bay of *Mae Haad*, just 3 fishing boats were counted around *Haad Yao* on sampling days. The 700 m long coral reef parallel the bay was surveyed from 9°47’56.68"N/100°00’54.98"E in south-west direction with a heading of 210°.

Haad Khom. Located in the north of the island, the bay was considered under low impact of tourists, sheltering 126 tourists per night at high season and 61 visitors at low season. The 330 m long bay is a popular snorkeling spot due to the colorful coral reef, though it`s difficult to access by foot and snorkelers have to get to the reef by boats. Fishing is banned in this area and was noticed infrequently. Transects were layed from 9°47‘56.68"N/ 100°00‘54.98"E in south-west direction (heading 230°).

2.1.2. Koh Tao (T)

The 21 km² big island (www.sawadee.de/kohtao, 02.07.2011), 45 km north of *Koh Phangan*, has just one eight of the size of *Koh Phangan*, but comparatively high tourist densities. More than 400.000 people visit the famous scuba diving destination every year (Tourism Authority of Thailand, 05.07.2010), involving the construction of more than 137 resorts and 48 dive schools in the last years (Korn 2010). In times of high season, up to 15 dive boats reside at one dive spot (personal observations). Fishery is just rare on the island, the remained 5000 residents mainly live on tourism (www.kohtaoisland.net, 03.07.2011). Due to adverse weather conditions during the survey period, only two survey sites could be sampled on *Koh Tao*.

***Mae Haad*.** The 2,6 km long bay in the west of *Koh Tao* evolved into the central point of tourism in the last years, leading to the construction of more than 1410 bungalow installations and 32 dive schools along the beach (own countings). The former fishing village *Ban Mae Haad* in the south of the bay is the main harbour of the island and offers all kinds of accommodation, shopping facilities and restaurants. Beside *Ban Mae Haad* in the north of the bay, the most popular beach of *Koh Tao*, *Sairee Beach*, is located. Therefore, *Mae Haad* was considered under high impact of tourists on *Koh Tao* (3525 visitors during high season).Transects were laid out with a heading of 30° from 10°05’10.04"N/ 99°49’22.94"E northbound.

Mango Bay. This barely tapped bay in the north of the island is hard to reach by foot and therefore untroubled by the mass tourism on the island. Just six small houses are located in the area of the bay (25 tourists per night during high season), and the sewage of these accommodations isn`t discharged into the bay. Just few dive boats run this dive spot regular. Transects were situated northbound with a heading of 15° from 10°07‘20.18"N/99°50‘10.13"E.

2.1.3. Ang Thong Marine National Park (AT)

The 42 islands of *Ang Thong*, covering an area of 102 km², were gazetted a National Park in 1980 (www.ang-thong.com, 03.07.2011). A bigger part of the area (82%) is marine, while the islands compose just 18 km² of the Park (www.angthongmarinepark.com, 03.07.2011). Located 40 km south of *Koh Tao* and 35 km west of *Koh Phangan*, tourism is limited by strict regulations and laws (Department of National Parks Thailand, 04.07.2011). Housing and diving is just permitted in few parts of the park, and there is no permanent settlement on any of the islands. Altogether, just six bungalows reside in the park, providing space for 26 tourists. There are no known direct point sources of wastewater inputs within the range of the park, and the whole area is declared as a no fishing zone. Therefore, the *Ang Thong Marine Park* represented the natural standard in this study without tourist influences.

The study site is located north of the Park near the island *Koh Yippon* (9.706°N/99.659°E). Transects were deployed from a defined point southbound with a heading of 320°.

2.2. Collection of field data

All data were collected in the morning hours during high tide to facilitate access to the reefs. Exposed linear reef fronts on the six sites were surveyed along the reef slopes in a standardized water depth of 5m, using three 50m line transects, separated by 10m gaps. To ensure comparability of the surveys, transects were layed in a distance of 150m to the coast and the exact locations of the beginning and the end of the transects were marked with floaters. While sampling sites on *Koh Tao* and *Ang Thong* were just surveyed once, sites on *Koh Phangan* could be sampled during high and low season, leading to a total number of 14 surveys in the study.

2.2.1. Species census

Fish community of the surveyed reef was analyzed using the Underwater Visual Census Method (UVC) of the Reef Check Program, first described by Brock (1954). All herbivorous fish species (Table A.2.), the total number of carnivorous fishes and all occurring species of sea urchins (Table A.3.) were counted from 0 to 20m and 30 to 50m of each transect line, having 10m space between the transects were no data was collected to ensure independence between the samples. Four cross-lines of 5m length were positioned across each transect line, spaced 10m apart, inducing 2,5m wide area left and right of the transect for data collection. The maximum height above the transect for counting is restricted to 5m in the water column. To minimize disturbance of the fish community, a 5 min waiting period at the beginning of the counts and between the transects was maintained. The fishes were counted while swimming with a standardized swimming speed of 5m per minute along the entire length of each 20m transect, getting a 4 min timed swim per transect. This combined time and area restricted method resulted in a covered area of 600m² per survey (6 transects x 20m length x 5m width).

Sea urchin censi were carried out in the same area on the return path without a time limit. Special care was taken to include also those organisms that were hiding beneath topographic structures or in cavities. Data were recorded directly onto data sheets on underwater paper. Collected data were used to assess community structure of the species for the entire area of the reef.

2.2.2. Exclusion cages

Cages were placed in identical water depth of 5m on dead corals or stones in the reef to ensure that living corals were not threatened by them. To avoid pile-up of the tiles with sediment, cages were positioned in 0,5 to 1m height above the seafloor. Every cage was equipped with 12 tiles made of terracotta, each tile having a size of 2x2,8 cm. Three replicates of closed, semi-closed and open cage designs were deployed in the reef (Fig.2.2.). While the closed cages excluded both the herbivore fishes and sea urchins, the semi-closed ones with an open top were used just to prevent the sea urchins from feeding on the tiles, whereas the fishes could enter the cages from above. The open cages were acting as controls, giving both the fishes and the sea urchins the opportunity to feed on the algae growing on the tiles. Wire of the cages (mesh size 2,5 cm) was cleaned once a week by a steel brush to avoid overgrowth of the cages and consequential lack of light inside, potentially leading to negative effects on growth on the tiles. Biweekly from March to June, one random tile was removed from each cage to analyze algae growth on it. Tiles were collected separately in plastic bags, filled with sea water to ensure survival of the grown species. In the laboratory, tiles were photographed with a high definition camera (Canon 7d with a Canon EF 100mm f/2.8 USM Macro Objective Lens) to permit later specified identification of the grown species and the exact calculation of algae cover on the tiles with a specialized program (Coral Point Count with Excel Extensions V4.0, CPCe, Kohler et al. 2006). Algae cover of the tiles was examined under a binocular before and after rinsing the tiles with deionized water. Tiles were carefully washed by a spray bottle to remove the overlying sediment without affecting the algae cover on it. Afterwards, tiles were positioned upright to drain the remained water. After about 30 seconds of dripping, tile cover was scraped by a keen scalpel and the weight of the achieved material was measured by a special accuracy balance (Sartorius TE612, measuring accuracy 0,01g). After 24 hours of drying the measurement was replicated. Mean values of these dry weights were used to compare algae growth in the different cages. Biodiversity of the grown algae species was visually identified to the lowest possible taxonomic level using available reference literature (Veron, 1986).

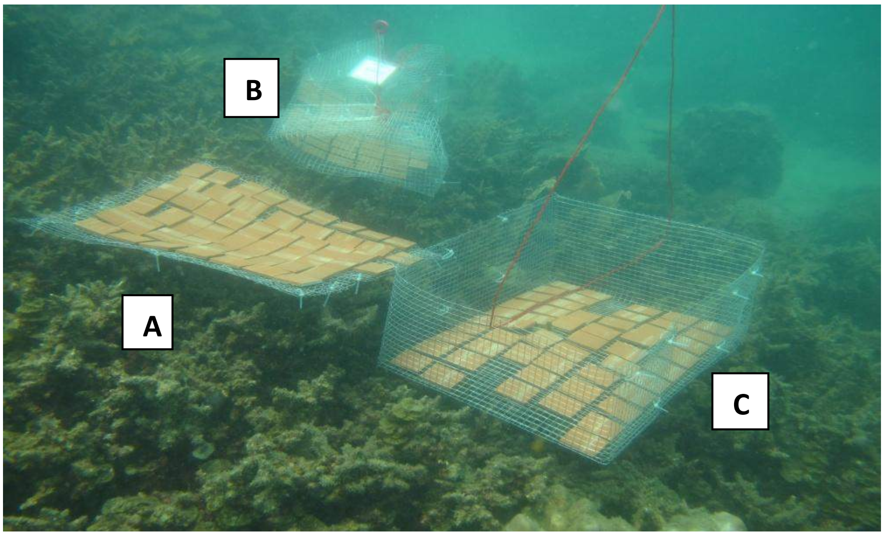

Fig. 2.2.: Exclusion cages deployed in the reef of Mae Haad, P.; A: open (control); B: closed; C: semi-closed; picture taken by the author.

2.2.3. Rugosity measurements

To consider different habitat complexities of the analyzed reefs, correlating with density and diversity of the counted organisms (Carpenter et al. 1981), surface topography of selected parts of the surveyed reefs of *Koh Phangan* was measured using the Chain-and-Tape Method (Risk 1972). For this purpose an iron chain (length 10 m, width 4 cm) was installed in straight line over the substrate, and the distance between the start and the end point of the chain was scaled with a measuring tape. To calculate the rugosity, the measured distance between the end points was divided by the length of the chain. Rugosity-Coefficients near 0 show high reef complexity (McCormick 1994). This measurement was repeated seven times over different areas along the transect lines, representing a proper mean and the standard deviation of rugosity for all study sites.

2.2.4. Fish census at food markets

Once a week, nearby fish markets were visited to record number and species of catched fishes. Thereby, just fishes catched in the study area were considered.

2.2.5. Data analysis

All statistical tests were conducted using Graph Pad Prism 5.0 for Windows. For each survey, number of counted individuals was converted to m^2 and mean and standard error were calculated for each species. The possible relationship between species abundance and tourist density at high and low season was tested using Mann-Whitney-U-test (two-tailed). Changes in species abundance between study sites with different tourist numbers were tested using Kruskal-Wallis-test (one-way ANOVA). Biodiversity of the study sites was compared using Shannon Index H`. To compare growth rates of algae in the different exclusion cages over time, results of algae cover calculations for collected tiles were analyzed using Kruskal-Wallis-test.

3. Results

3.1. Patterns of species richness and abundance

Altogether, herbivorous reef fishes composed 26 % (3902 individuals) of all counted fishes on the study sites (15009 individuals), predominantly made up of *Pomacentridae* (damselfishes), *Siganidae* (rabbitfishes), *Scaridae* (parrotfishes), and *Chaetodontidae* (butterflyfishes). Carnivorous species obtained an average density of 4,95 individuals/m² on the surveyed reefs, while averaged 2,07 herbivorous fishes/m² occurred on the 6 sampling sites. *Pomacentridae* revealed the highest values (1,44 individuals/m²), followed by *Chaetodontidae* (0,24), Scaridae (0,204) and *Siganidae* with 0,15 individuals/m² (Fig.3.1.).

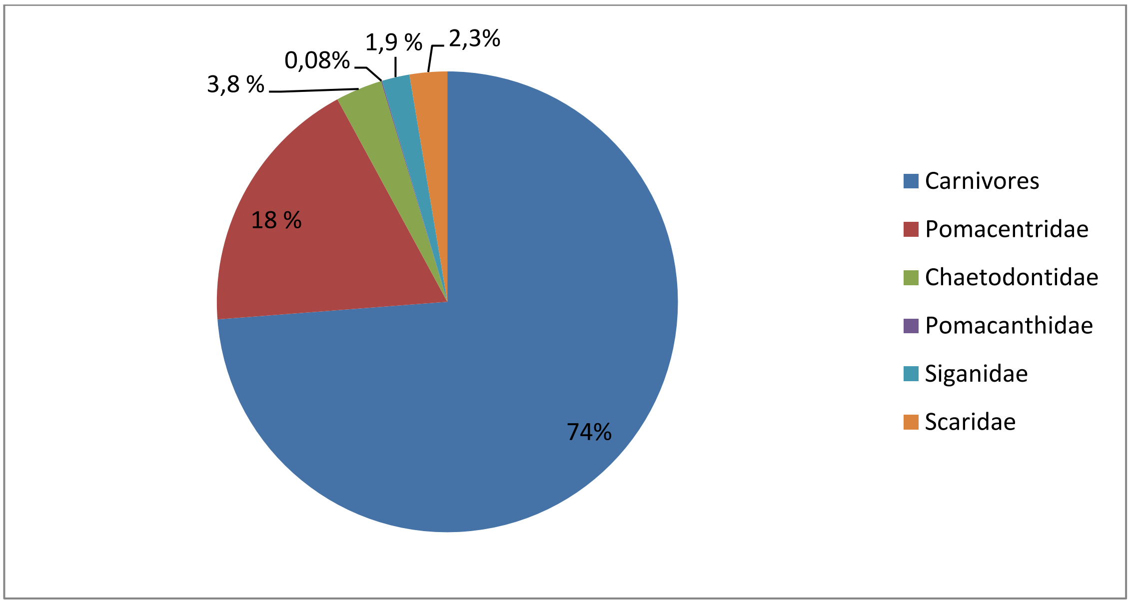

Fig. 3.1.: Composition of fish community on the surveyed coral reefs; percent values demonstrate the proportion of herbivorous fish families and carnivores on the total number of fishes counted at all surveys.

Damselfishes were mainly represented by *Abudefduf bengalensis* (Fig.A.2.6.), *Abudefduf vaigiensis* (Fig.A.2.9.), *Amphiprion perideraion* (Fig.A.2.11.) and *Hemiglyphidodon plagiometopon* (Fig.A.2.14.), with *A. vaigiensis* having the highest frequency of occurrence. Rabbitfishes were dominated by *Siganus puellus* (Fig.A.2.24.), followed by *Siganus javus* (Fig.A.2.23.). The most frequent parrotfishes, *Scarus rivulatus* (Fig.A.2.21.) and *Scarus ghobban* (Fig.A.2.19.), mainly appeared in huge groups together with *S. puellus.* The butterflyfish *Chaetodon octofasciatus* (Fig.A.2.2.) presented the most frequent butterflyfish at all surveys.

Just 2 species of sea urchins occurred on the study sites. The long-spined sea urchin *Diadema setosum* (Family: Diadematidae, Fig.A.3.1.)was most frequent on almost all study sites, showing an averaged abundance of 1,18 individuals per m². *Echinothrix calamaris*

(Fig.A.3.2.), which also belongs to the *Diadematidae*-Family, was recorded in much lower abundances (0,035 individuals/m²).

3.2. Distribution patterns between study sites

3.2.1. Comparison of islands

When all surveys were pooled together, coral reefs of *Ang Thong Marine Park* showed significantly (Kruskal-Wallis-test; P<0,0003) higher fish abundances than the tourist-frequented reefs of Koh Phangan and Koh Tao (Fig.3.2.). The mean number of counted fishes per transect added up to 127 herbivorous individuals and 341 carnivorous individuals in *Ang Thong,* compared to averaged 42 herbivorous and 98 carnivorous individuals on *Koh Tao* and a mean number of 39 herbivorous and 137 carnivorous fishes per transect on *Koh Phangan.*

Countings in the bays of *Koh Phangan* and *Koh Tao* showed no significant differences in herbivorous (Mann-Whitney-U-test, p=0,77) or carnivorous (Mann-Whitney-U-test, p= 0,4) fish species abundance between the islands, although there was a trend of increased amount of fishes on the sites of *Koh Phangan.* Numbers of herbivorous fish species were almost equal on both islands (0,39 ind./m² on *Koh Phangan*, 0,42 individuals/m² on *Koh Tao*), whereas carnivorous fish abundance tended to be higher on *Koh Phangan* (1,38) than on *Koh Tao* (0,98).

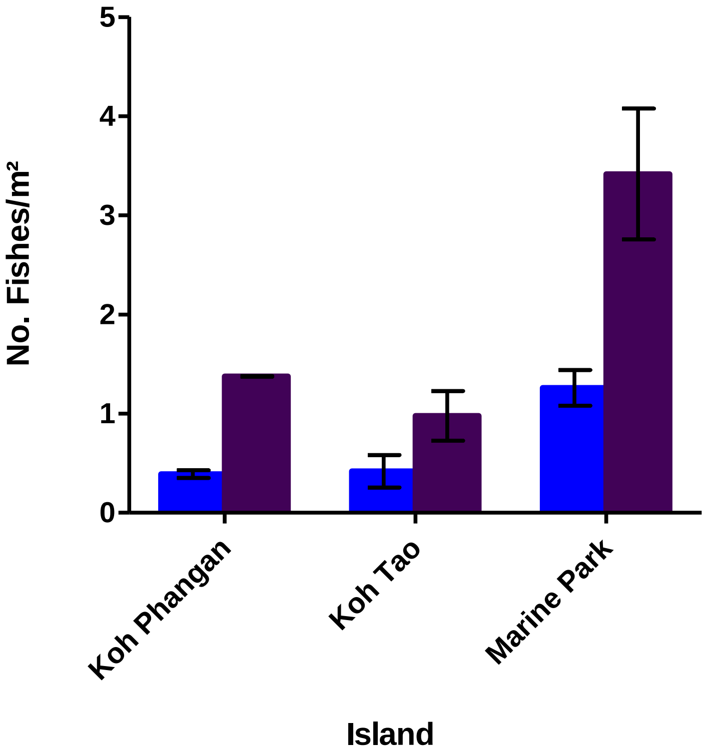

Fig. 3.2.1.: Mean fish abundance on the surveyed islands; bars show average number±SE of herbivorous (blue) and carnivorous (purple) fishes counted on all study sites on the islands.

Mean abundance of *Diadema setosum* and *Echinothrix calamaris* was significantly higher (Kruskal-Wallis-test, p=0,04) in the *Ang Thong Marine Park* than in the bays of *Koh Phangan* or *Koh Tao.* Averaged 1,12 individuals of sea urchins per m² were found in the reef of *Ang Thong,* compared to 0,024 individuals on *Koh Phangan* and 0,069 individuals on *Koh Tao*. Reefs of *Koh Phangan* and *Koh Tao* didn`t show significant differences (Mann-Whitney-U-test, p=0,27).

3.2.2. Comparison of sampling bays

Considerable site-variations in patterns of fish abundance between sampling sites under high and low influence of tourists could be verified (Fig.3.3.). On *Koh Phangan*, the mean number of all fishes per m² (Carnivores and Herbivores) were significantly higher (Mann-Whitney-U-test, p<0,03) in the low-frequented bay of *Haad Khom* (2,10 ind./m²) than in *Haad Yao* (1,6), demonstrating the study site with the highest tourist density on *Koh Phangan.* The medium-influenced bay of *Mae Haad* (P) showed lowest fish abundances (0,96 ind./m²) on the island. Abundances of herbivorous fishes did not differ significantly between the sites of *Koh Phangan* (Kruskal-Wallis-Test, p=0,37). Highest distribution of herbivores was found in *Haad Yao* (0,46 ind./m²), followed by the bay of *Haad Khom* (0,36). Just 0,34 individuals/m² occurred in the bay of *Mae Haad*.

On *Koh Tao*, total fish abundances also varied significantly (Mann-Whitney-U-test, p=0,016) between the high-frequented bay of *Mae Haad* and the barely visited *Mango Bay*. Averaged 1,77 individuals/m² occurred in the reef of *Mango Bay*, whereas just 0,99 fishes/m² were found in *Mae Haad.* Distribution of herbivorous fishes was also significantly higher (Mann-Whitney-U-test, p=0,005) in *Mango Bay* (0,66 ind./m²) than in *Mae Haad* (0,18).

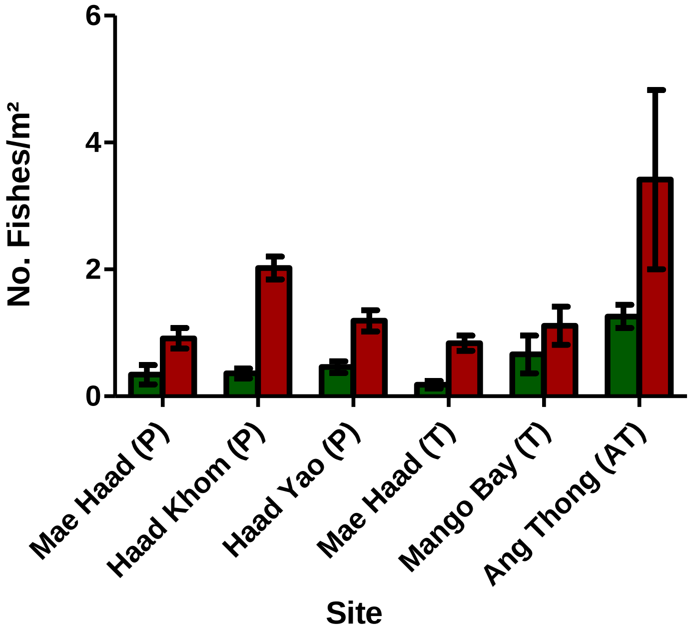

Fig. 3.2.2.: Distribution of carnivorous and herbivorous fishes on the study sites; green (herbivore) and red (carnivore) bars show mean ± SE of all surveys.

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Sea urchin abundance showed different distribution patterns (Fig.3.4.) than fish distribution. There were no significant differences (Kruskal-Wallis-test, p=0,4) between the study sites of *Koh* Phangan, but the peak species number was found in *Haad Yao* (0,032 ind./m²), followed by *Haad Khom* with 0,024 individuals/m². Lowest abundances were counted in the medium-frequented bay of *Mae Haad* (0,016). Countings on *Koh Tao* showed similar distributions. Although there were no significant differences between countings (Mann-Whitney-U-test, p=0,29), numbers of urchins tended to be much higher on the high tourist-influenced bay of *Mae Haad* (0,12 ind./m²) than in the low-frequented *Mango Bay*.

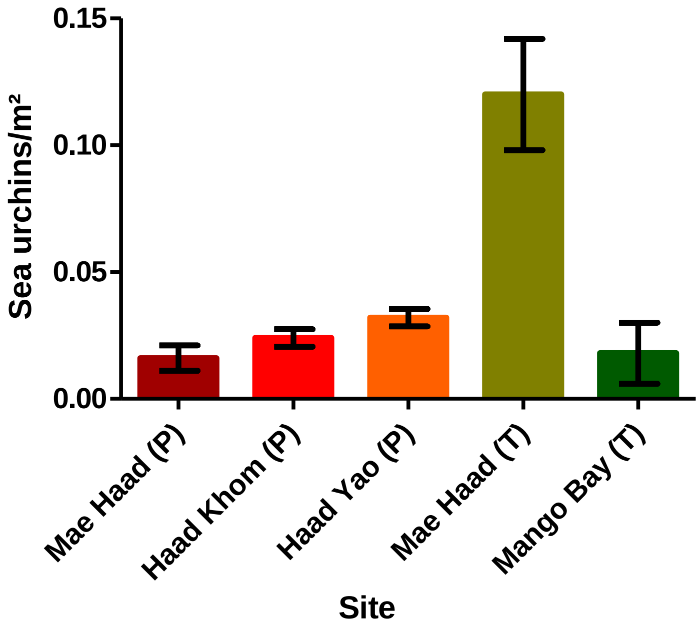

Fig. 3.2.3.: Distribution patterns of sea urchins on all study sites; bars show mean±SE of all surveys.

3.3. Effects of high and low season on species abundance

Surveys at high and low season on the study sites of *Koh Phangan* revealed significant changes in total and herbivorous fish abundance on 2 of 3 sites (Fig.3.5.). Amounts of herbivorous fishes were significantly higher in low season in the reefs of *Mae Haad* (Mann-Whitney-U-test, p=0,0002) and *Haad Khom* (Mann-Whitney-U-test, p=0,04). During high season, averaged 0,21 herbivorous fishes/m² were counted in *Mae Haad*, whereas this number was doubled (0,42 ind./m²) during low season. A mean number of 0,24 individuals/m² occurred in the bay of *Haad Khom* during low season, compared to 0,42 individuals in high season. There weren`t statistical significant changes in herbivore species abundance in *Haad Yao*, but numbers tend to be higher in times of low season (0,51 ind./m²) than high season (0,36). Countings of all occurring fishes (Carnivores and Herbivores) showed similar distribution patterns. Especially in *Haad Khom*, averaged fish abundance was considerably higher (Mann-Whitney-U-test, p=0,03) during low season (2,67 ind./m²) than in times with high tourist densities (0,9). Numbers of fishes almost doubled in the bay of *Haad Yao* in low season (1,92 ind./m²) compared to times of high season (1,08). Just the bay of *Mae Haad* showed almost similar fish distributions in both times.

Statistical analyses showed no significant changes in sea urchin abundance in times of high and low tourist season, but a trend of increased species numbers during times with low tourist densities was observable at all study sites. Whereas species abundance increased just slightly in the bay of *Mae Haad* (0,015 ind./m² at high season, 0,016 at low season), numbers of counted urchins increased conspicuously in *Haad* Khom (0,018 ind./m² in high season, 0,027 in low season) and *Haad Yao* (0,012 ind./m² in high season, 0,042 in low season)with the beginning of low season.

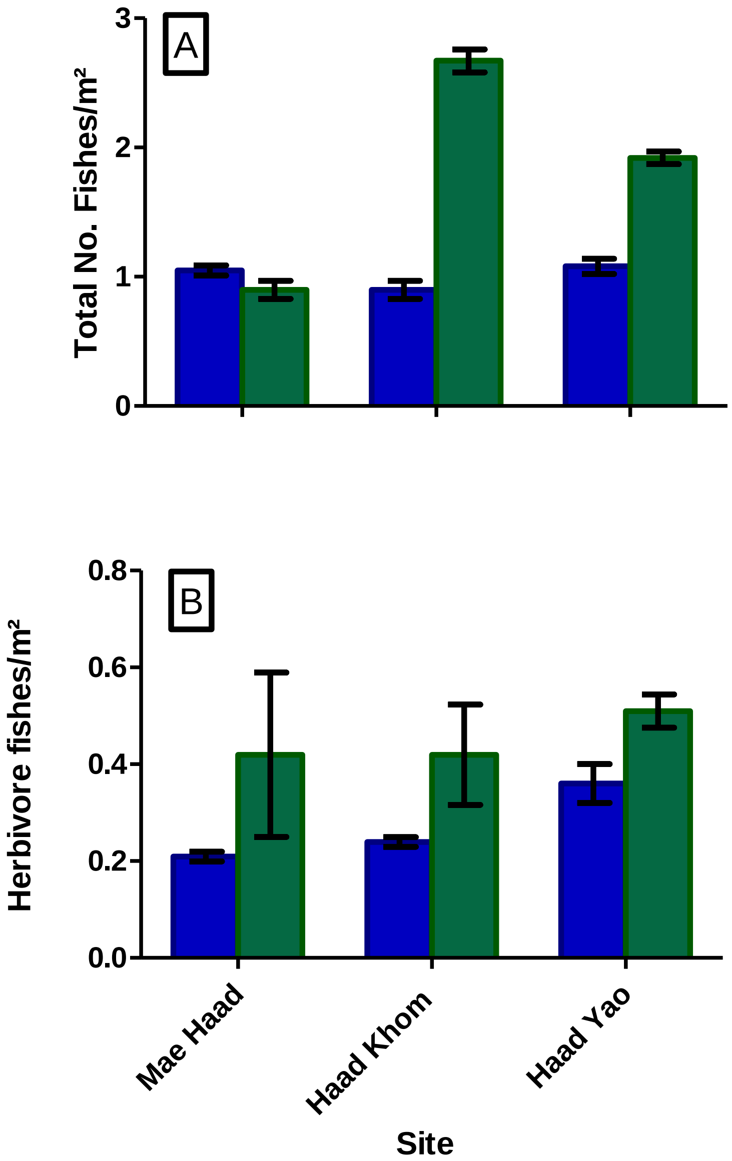

Fig. 3.3.: Abundance of all fishes(A) and herbivorous fish species (B) on study sites of Koh Phangan; bars show mean±SE of all surveys at high (blue) and low (green) season.

3.4. Exclusion cages

As meteorological disturbances destroyed some of the cages and tiles inside, almost no algae growth could be determined in the first weeks of investigation. Therefore, biomass and algae cover on the tiles was just recorded from the third survey week. Sample period was thus reduced to 12 weeks, wherefore it difficult to draw conclusions from the results.

3.4.1. Differences in biomass and species composition between cage configurations

Kruskal-Wallis-test showed no significant differences between algae biomass of closed, semi-closed and open cage configurations (p=0,93), although percentaged algae cover varied widely between the tiles after a certain time (see chapter 3.4.2.). Highest averaged biomass was found in the semi-closed cages (1,965±1,26 g/tile, mean±SD) followed by open designs (1,958±1,26). Closed configurations showed lowest amounts of biomass (1,948±1,27) and percentaged algae cover on the tiles (averaged 18,11±15,09%). Cover on the tiles of semi-closed designs was little lower (33,06±23,18%) than averaged cover of tiles in open cages (34,23±26,99%).

All tiles were covered by 2 groups of algae, turf algae or crustose coralline algae (CCA). Growth of macroalgae was just determined infrequently at the end of the survey period. In the closed cages, turf algae composed averaged 48,13 % of algae cover, while CCA made up 39,38%. Highest growth of turf algae was found in the open cages (58,13%), whereas CCA formed 41,88% of grown algae. Tiles in the semi-closed configurations showed highest cover of CCA (49,38% of algae cover) of all cages and a medium growth of turf algae (50,63%). Analysis of species composition didn`t show significant differences between cages (Kruskal-Wallis-test, p=0,37).

3.4.2. Changes in biomass and species composition over time

After a test duration of 4 weeks, algae growth on the tiles of all cage designs increased just few (Fig.3.4.). Averaged weight of grown algae tend to be a modicum above zero (closed: 0,04±0,01 g/tile; semi-closed: 0,08±0,01 g/tile, open: 0,09±0,02 g/tile), and percetaged cover didn`t exceed 20% (averaged 6% in closed cages, 12% in semi-closed designs, 16% in open cages). First increase in algae cover was established after 8 weeks of survey period. Averaged overall weight of algae increased significantly (Mann-Whitney-U-test, p=0,001, respectively) in all cage designs (closed: 2,67±0,2 g/tile; semi-closed: 2,47±0,3 g/tile; open: 2,44±0,5 g/tile). Averaged percentage cover also changed significantly (Two-way-Anova, p=0,001) for tiles of semi-closed (62±10%) and open (51±8%) cages, whereas algae cover remained constant on tiles of closed cages (19±3%). After a test duration of 10 weeks, percentaged algae cover decreased significantly (Mann-Whitney-U-test, p=0,001) in semi-closed (38±5%) and open (17±4%), which is probably caused by strong winds during that time.

Species composition on tiles didn`t show significant differences during survey period. In closed configurations, turf algae dominated on all analyzed tiles. After 6 weeks, they composed averaged 66% of grown species, which only changed at the end of the test duration. After 12 weeks, CCA started to dominate on the tiles (71%). Tiles in open cages showed similar patterns. Turf algae dominated from survey week 3 (averaged 61%) to week 10 (58%), until CCA prevailed in week 12 (76%). Tiles in semi-closed cages were primarily overgrown by CCA (averaged 68% in survey week 3), but after 6 weeks, turf algae started to dominate cover. In week 12, CCA and turf algae were found on the tiles in equal parts.

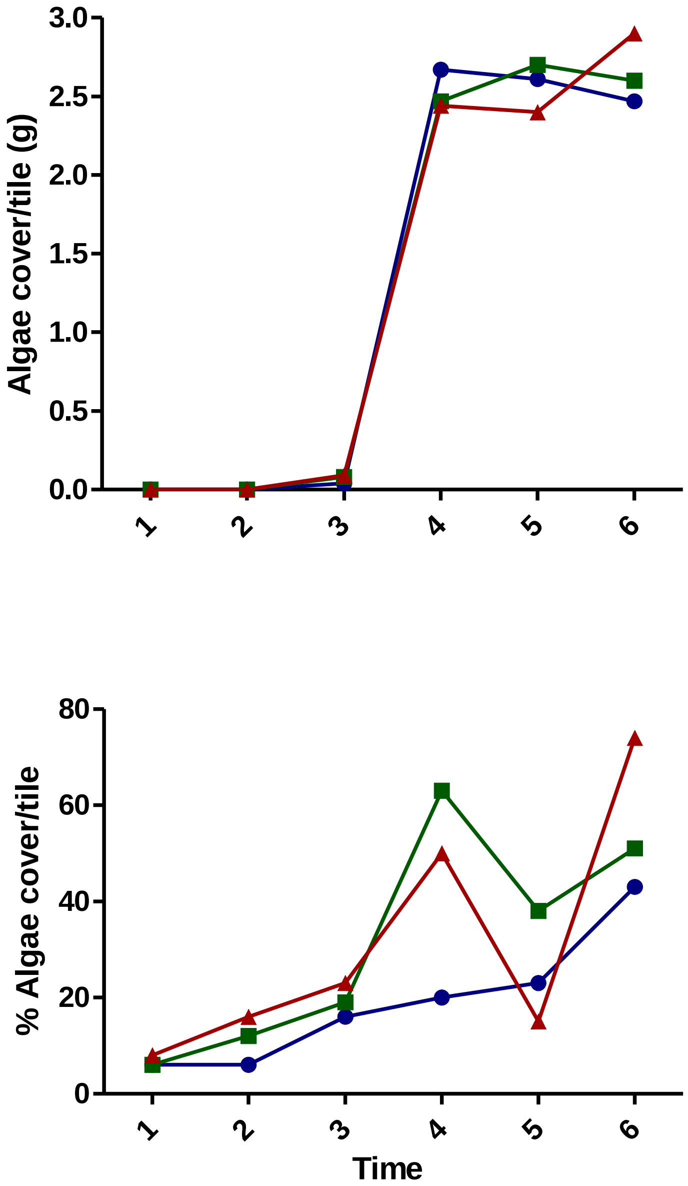

Fig. 3.4.: Averaged algae cover on collected tiles of closed (blue), semi-closed (green) and open (red) cage designs. X-axis shows date of tile removal; 1: after 3 weeks; 2: after 4 weeks; 3: after 6 weeks; 4: after 8 weeks; 5: after 10 weeks; 6: after 12 weeks.

3.5. Biodiversity of Herbivores

Comparison of biodiversity index H`(Shannon-Index, Table 3.5.) showed highest diversity of herbivorous fishes in *Haad Khom* in high season (H`=2,02), followed by *Mae Haad* (P)during high season (H`=1,99) and low season (H`=1,94). Lowest diversity was measured in the sampling sites of *Koh Tao* (1,4 in *Mae Haad*, 1,03 in *Mango Bay*) and in the bay of *Haad Yao* during high season. Countings in *Ang Thong Marine Park* revealed relatively low biodiversity (H`=1,52) compared to tourist-influenced study sites.

As there occurred just 2 species of sea urchins in the sampling bays, biodiversity indices for sea urchins were considerably lower than indices for herbivore fishes. Highest diversity could be established in the bay of *Haad Yao* during high and low season (each with H`=0,69). Bays of *Mae Haad* and the *Ang Thong Marine Park* were almost exclusively populated by individuals of the genus *Diadema setosum* and therefore showed low indices of 0,02 respectively. There wasn`t detectable biodiversity in the bay of *Mae Haad* on *Koh Tao*.

Table 3.5.: Biodiversity indices of herbivorous fishes and sea urchins for all sampling sites and all surveys.

Site	Survey No.	Time	Shannon-Index	
			Fishes	**Sea urchins**
Mae Haad (P)	01	high season	**1,87**	**0,02**
	02	high season	**1,99**	**0**
	03	low season	**1,86**	**0,66**
	04	low season	**1,46**	**0,67**
	05	low season	**1,94**	**0,63**
Haad Khom (P)	01	high season	**2,02**	**0,67**
	02	low season	**1,81**	**0,43**
	03	low season	**1,84**	**0,66**
Haad Yao (P)	01	high season	**0,72**	**0,69**
	02	low season	**1,71**	**0,60**
	03	low season	**1,51**	**0,69**
Mae Haad (T)	-	high season	**1,40**	**0**
Mango Bay (T)	-	high season	**1,03**	**0,64**
Ang Thong Marine Park	-	----	**1,52**	**0,02**

3.6. Rugosity

All 3 measured coral reefs in Koh Phangan showed similar topography of reef surface (Table 3.2.). Most complex surface (value closest to 1) was found in *Mae Haad* (0,648), but differences to values of *Haad Khom* (0,663) and *Haad Yao* (0,657) were low and not significant.

Table 3.6.: Results of rugosity measurements at the sampling sites of Koh Phangan; values of measured distance show mean values of all measurements proceeded at the study site.

Study site	Straight-line distance (m)	Measured distance(m)	Rugosity-Coefficent
Mae Haad	10	6,48	0,648
Haad Khom	10	6,63	0,663
Haad Yao	10	6,57	0,657

To investigate the relationship between rugosity and biodiversity (H`), correlation of these values were tested using the Pearson-Coefficient. Results didn`t show any correlation (r=-0,02,p=0,98).

3.7. Fish census at food markets

A bigger part of sighted fishes (82%) are carnivorous species, mainly of the family *Carangidae* (jacks and pompanos) with 43%, followed by snappers (*Lutjanidae*, 22%) and groupers (*Epinephelidae*, 10%). Herbivorous fishes are mainly represented by *Siganidae* (rabbitfishes, 8%) and *Ephippidae* (batfishes, 8%). However, numbers of catched herbivorous fishes tend to be much higher due to extreme squid fishing on the study sites, but a bigger part of these bycatches is not sold on the markets because of low demand.

4. Discussion

4.1. Species richness and abundance

Generally, fishes of the family *Pomacentridae* were the dominant herbivorous group at almost all study sites (18% of all counted fishes). Species of the families *Siganidae* (rabbitfishes) and *Scaridae* (parrotfishes) were counted in much lower abundances (*Scaridae* 2,3%, *Siganidae* 1,9%) than Pomacentrids, but as they occurred on large, combined feeding schools, total amount of both families was comparable high on some sampling sites. Chaetodontids composed the second largest part of all herbivorous fishes (3,8%). Studies in comparable water depth of Satapoomin (2002) on the Adang-Rawi Islands in the Andaman Sea, Thailand , recorded herbivorous fish abundances predominantly made up of *Pomacentridae* (11,73% of all species), *Chaetodontidae* (4%), *Scaridae* (3,4%) and *Acanthuridae* (2,4%), while carnivorous species composed about 77% of all counted fishes (74% in this study). Surveys of Low and Chou from 1987 to 1992 on 6 reefs around Singapore also showed dominance of Pomacentrids on similar water depth, as well as studies of Reopanichkul (2009) or Randall (1990), who described damselfishes as the most abundant and diverse groups of tropical reefs around the world. This pattern is probably explained by more reasons. Most damselfishes are territorial , like *Amphiprion perideraion* (Hattori 2002) and *Hemiglyphidodon plagiometopon* (Wilson et al. 1997), and don`t leave their territory due to disturbances as fast as mobile species. This aggressive habitat defense by damselfishes can lead to lower abundances of other herbivorous species, as described by Choat and Bellwood (1985), or Jones (2006). Other Pomacentrids such as all *Abudefduf* species occur just in large aggregations in the water column above the reef (Frédérich et al. 2008). Furthermore, damselfishes were not fished in the surveyed area, and the small size of the species degraded inadvertently catches by fishing nets. In contrast, fishing pressure on lower occurring species like Scarids or Siganids was much higher in the region. The assured high amount of chaetodontid species (3,8%) on the study sites could be a poor indicator of coral reef health, as suggested by Reese (1981) and Bell (1984), who argued that high abundances of *Chaetodontidae* would show decreased coral reef health. However, evidence for that thesis is disputable. Other studies in comparable water depth showed dominance (>95%of all herbivorous fishes) of *Acanthuridae* and *Scaridae* in the Red Sea (Bouchon-Navaro et al. 1981, Clark et al. 1968), in the Great Barrier Reef (Russ 1984) and in the Pacific (Galzin 1977). Total number of carnivorous and herbivorous fishes also varied between different studies. Our study recorded an averaged number of 4,95 carnivorous fishes m^{-2} and 2,07 herbivorous fishes m^{-2} on the sampling sites, while Satapoomin (2002) counted averaged 4,42 carnivorous and 1,33 herbivorous fishes m^{-2} in the Andaman Sea, Thailand. Bouchon-Navaro (1981) reported about much lower herbivorous fish abundances (0,15 ind./m^2) in the Red Sea, but don`t specify carnivorous fish amount. However, high fish abundances in our study can be explained by high fish densities in the *Ang Thong Marine Park*, where influence of tourism and fishing activities on fish communities is low.

Considering just censi on *Koh Phangan* and *Koh Tao*, averaged abundances of fishes were much lower on our study sites (1,38 carnivorous fishes/m² and 0,39 herbivorous fishes/m² on *Koh Phangan*, 0,98 carnivorous fishes/m² and 0,42 herbivorous fishes/m² on *Koh Tao*) than abundances counted by Satapoomin in the nearby Andaman Sea . Reopanichkul et al. (2009) measured averaged numbers of 1,57 carnivorous fishes m^{-2} and 0,15 herbivorous fishes m^{-2} in the Surin Marine Park, Thailand, while fish assemblages varied widely between polluted and unpolluted sites.

Studies of Ruengsawang et al. (2000) concerning abundances of the sea urchin *Diadema setosum,* showed multiple higher total numbers of urchins (6,08 ind./m²) on Khang Khao Island, Thailand, than counted on our study sites (1,18 ind./m²). Surveys on the nearby Samet Island, Thailand, by Buaruang et al. (2006) revealed lower population densities of *Diadema setosum* (2,94 ind./m²) as the study of Ruengsawang, but still higher numbers than our study. Benitez-Villalobos (2008) found population densities of *Diadema mexicanum* of averaged 4,56 ind. m^{-2} at Bahias de Huatulco, Western Mexico, which also is a multiple of our census.

Different degrees of pollution by tourist impact, as well as temporal and spatial variations between study sites (Mantyka et al. 2007) and different food availabilities (Williams 1983, Russ 1984) are possible explanations for discrepancies in species abundance and compositions between different studies. Some of these possible explanations are discussed in the next chapters.

4.2. Changes in species abundance by tourist densities

Tourism and related human activities as fishing and marine pollution had significant effects on species richness of nearby coral reefs. As hypothesized, abundances of carnivorous and herbivorous fishes and sea urchins were multiple higher in the protected *Ang Thong Marine Park* than in tourism-influenced sampling bays of *Koh Phangan* and *Koh Tao.* This pattern was also established for the study sites on the islands, where countings on survey sites with low tourist densities showed significantly higher total fish abundances than high frequented sampling bays. Total number of fishes was averaged 1.3 times higher in the low frequented bay of *Koh Phangan* than on the high influenced study sites, whereas the low frequented sampling bay of *Koh Tao* even obtained fish abundance 1.7 times higher than the study site with high tourist densities. Lowest fish distribution was recorded in the most disturbed bays, *Mae Haad* on *Koh Phangan* and *Mae Haad* on *Koh Tao.* Although the former didn`t show highest tourist densities on the island, fishing activities were most frequent here, whereas the latter is most of all survey bays influenced by dive tourism and pollution by wastewater. This supports the conclusion that high tourist densities and related disturbances as overfishing and marine pollution lead to significant shifts in density and diversity of fishes. Several previous studies have obtained similar results. Reopanichkul (2009) found that herbivorous and carnivorous fish abundance declined significantly at polluted sites compared to unpolluted sites in Surin Marine Park, Thailand. Hawkins (1993) reported of significantly lower coral cover in areas visited by snorkelers and scuba divers in Sharm-el-Sheikh, Egypt, which can also lead to decreased species richness (Bell et al. 1984; see chapter 4.4.). Alcala (1988) recorded 1.4 times higher density of fishes in the protected Apo Island Reserve, Philippines, than in similar non-reserve areas, as well as Polunin and Roberts (1993), who found that overall fish biomass in areas with high fishing activities was 2 times lower than in reserves areas (Netherland Antilles and Belize) where fishing is prohibited.

Abundance of herbivorous fishes also varied significantly between the study sites of *Koh Tao,* whereas sampling bays of *Koh Phangan* presented almost similar herbivorous fish distribution on the study sites. However, comparison between high and low season at the study sites of *Koh Phangan* showed significant changes in carnivorous and herbivorous species richness. Number of individuals doubled on 2 of 3 sampling bays during low season. These results also support the hypothesis, that high tourist densities lead to lower fish abundances in nearby coral reefs. Wilson (2006) analyzed 17 independent studies about effects of anthropogenic activities and disturbances on fish abundance and found that species richness of 62% of all fishes declined due to disturbance-induced changes in coral reef community structure. Results of Juhasz (2010) support this conclusion and showed increased coral reef damage at greatly visited study sites of Moorea, French Polynesia. Comparable studies investigating species abundances of coral reefs during high and low tourist season were not found.

Sea urchin abundance tend to be higher on the high influenced study sites of both islands than in low frequented sampling bays. This pattern was also detected by different studies, who found that sea urchin populations increased strongly after different modes of disturbances. Ruengsawang (2000) reported about increased sea urchin abundances after a coral bleaching event on Khang Kao Island, Gulf of Thailand, as disturbances lead to high amounts of valuable food resources due to increased growth of filamentous algae on the death substratum. Results of other studies indicated that increased sea urchin populations are caused by predator reductions and low competitive pressure by herbivorous fishes due to overfishing (Glynn et al. 1979, McClanahan et al. 1994, Watson and Ormond 1994, Hay 1984). As study sites with low fish abundances showed highest amount of sea urchins in our study, absence of fishes is the most supposable reason for our results. High sea urchin abundance in *Ang Thong Marine Park*, however, isn`t attributed to these reasons, but can be explained by natural raised species richness in protected and intact areas and is poised with fish abundances on the study site.

4.3. Biodiversity

Calculations of biodiversity index H` could not demonstrate a correlation between tourist density and biodiversity of herbivorous fishes and sea urchins on the study sites. Although there was a trend of higher diversity on low frequented sampling bays on *Koh Phangan,* countings in *Koh Tao* and *Ang Thong Marine Park* could not corroborate these results. Fish biodiversity in the Marine Park was comparable low, whereas counting on *Koh Tao* showed higher biodiversity in the tourism-influenced bay of *Mae Haad.* Sea urchins were mainly represented by *Diadema setosum* and therefore didn`t show biodiversity on almost all study sites. A correlation between rugosity of reef surface and biodiversity could not be established. These results are contradictory to findings of comparable studies (Risk 1972, Carpenter et al. 1981), who found strong relationships between species richness and structural complexity of coral reefs. However, other studies showed results similar to those in our study. Roberts and Ormond (1987) found that structural complexity of coral reefs on the Saudi Arabian Red sea coast are only weakly correlated with fish species richness. Analysis of Jones (2004) of 4 marine reserves in Kimbe Bay, Papua New Guinea, showed that fish biodiversity declined both in marine reserves and non-protected areas due to reef degradation. Although fish abundances were multiple higher on the *Ang Thong Marine Park* than in the tourism-influenced study sites, our results concerning biodiversity could be an indicator of beginning reef degradation in the Marine Park. Further investigations are required to explain these changes.

4.4. Influence of herbivory on coral reef benthic communities

Independent studies and experiments (Litter et al. 2006, Hughes et al. 2007, Burkepile et al. 2008, Diaz-Pulido et al. 2009) have shown importance of herbivores on coral reef health by reducing algal biomass, which facilitates growth and survivorship of corals (Tanner 1995). Consequently, a decrease in herbivore species richness often results in increased algae growth on coral reefs (Stephenson et al. 1960, Carpenter 1986, Bellwood et al. 2004). To investigate the relationship between herbivore species richness and benthic community composition, identical coral reefs were surveyed simultaneously to this study (see Schwieder (2011) for further information). All occurring algae (mainly turf algae) and corals (16 hard and soft coral families) were recorded in certain intervals along the transect line. Results support findings of other studies, and statistical analysis showed significant correlations between coral cover and herbivore species richness (Pearsons $r = 0{,}88$, $p = 0{,}02$). Especially massive corals as *Poritidae* showed increased abundance on study sites with high abundances of herbivores. *Ang Thong,* the study site with highest herbivore species density (1,27 herbivorous fishes/m^2, 1,12 sea urchins/m^2) showed highest coral cover (averaged 78%) of all study sites. Coversely, highest algae cover (averaged 50%, respectively) was recorded in sampling bays with lowest herbivore abundance (0,18 herbivorous fishes/m^2 and 0,12 sea urchins/m^2 in *Mae Haad, P* ; 0,34 herbivorous fishes/m^2 and 0,016 sea urchins/m^2 in *Mae Haad, T;* Pearsons $r = -0{,}98$, $p = 0{,}0009$).

Our results and findings of comparable studies show that decreasing herbivore species abundance due to disturbances as overfishing can lead to phase shifts from coral-dominated coral reefs to hyperabundances of algae. Experiments by Hughes (2007) in the Great Barrier Reef showed that exclusion of larger herbivorous fishes lead to increased growth of fleshy macroalgae and decreased growth of corals. Burkepile (2008) also reported about reduced algae cover in coral reefs with increased herbivore species richness on Conch Reef, Florida Keys. Wilson (2006) found that increased frequency of anthropogenic disturbances lead to a declined abundances of 62% of fish species, which resulted in >10% decline in coral cover. Decrease in herbivore species abundance appears critical for the health of coral reefs, as intense feeding of algae by diverse herbivores has positive effects on growth, reproduction and survivorship of corals (Green et al. 2009). Coral reef resilience, defined as the ability of reefs to absorb disturbances and rebuild coral-dominated systems (Hughes et al. 2007), is just possible with an intact, coral-dominated benthic community. As resilience of coral reefs in tourism-frequented bays is more and more debilitated by overfishing, pollution and other disturbances, die-offs, coral bleaching and other diseases are prevalent results of this development.

4.5. Exclusion cages

Experiments with cage designs excluding different herbivorous species couldn`t reveal clear answers of herbivory effects on algae growth. As some cages were repeatedly destroyed by severe storms, opportunity of algae growth on the tiles wasn`t comparable for all cage configurations. Different exposure of light on the tiles could also be a possible explanation for received findings, as closed cages, where highest algae growth was expected due to exclusion of all herbivores, showed lowest percentaged algae cover during the survey period. Although cages were cleaned at regular intervals, sporadic overgrowth of wire by algae could not be prevented. Tiles in semi-closed cages, which excluded just sea urchins, showed highest averaged algae biomass and growth of CCA, whereas highest amount of turf algae was recorded for open cages, acting as controls and didn`t exclude any species. Macroalgae were barely found on the tiles. A possible explanation for this pattern could be high abundance of CCA, who are capable of suppressing the growth of some macroalgae, as described by Vermeij (2011). His experiments showed that presence of CCA reduced the growth rate and recruitment success of different species of macroalgae, whereas relative growth rates of macroalgae increased by 54,6% when CCA were absent. Short survey period couldalso be an explanation for absent macroalgae. Comparable studies (Paine et al. 1968, Burkepile 2008, Smith 2006) were conducted over a much longer period, whereas the survey period of this survey could be too short for settlement of macroalgae.

Our results couldn`t show significant changes between different cage configurations. Lowest algae growth was found in tiles of closed cages, followed by semi-closed configurations. Tiles in open cages were most overgrown. Biodiversity of algae didn`t differ significantly between the cages. These results didn`t support the hypothesis that exclusion of all herbivores (closed cages) or partial exclusion (semi-closed) leads to an increase in abundance and biodiversity of algae. These findings are not conform with results of other studies. Hughes (2007) reported about dramatic explosions of macroalgae abundance after exclusion of large herbivorous fishes in areas of the Great Barrier Reef. Algal biomass was 9 to 20 times higher in cages who exclude herbivorous fishes than in partial cages or open plots. Carpenter (1990) investigated benthic community composition after mass mortality of the sea urchin *Diadema antillarum* in the reef of St.Croix, U.S. Virgin Islands, and found significant increases in algal abundance from 22% to 439% across reef zones. Several other studies (Jayewardene 2009, Lewis 1986, Thacker et al. 2008) also showed that exclusion of herbivorous fishes results in higher biomass of macroalgae in experimental plots. In this study, significant changes of algal abundance could just be established over time, but not between cage configurations. Increased algae cover on tiles was detected after 8 weeks for all cage designs. Highest algae cover, mainly cover of CCA, was found in semi-closed cages, which could lead to the assumption that sea urchin grazing differs from herbivorous fish grazing. This hypothesis was tested by McClanahan (1997) in reefs of Kenya, and results corroborated the assumption. In reefs where sea urchins dominated grazing, experimental plates showed little change in algal abundance and were mainly overgrown by turf algae. Plates in areas dominated by fish grazers showed greater algal diversity and higher abundance of crustose coralline algae and fleshy algae than coral reefs dominated by sea urchins. Summarized, McClanahan found out that sea urchins maintain levels of algae cover below that of herbivorous fishes. On later studies (2002), McClanahan showed that reduced abundances of fishes can lead to dominance of fleshy algae and to higher abundance of turf algae. These findings could be an explanation for highest algal abundances in semi-closed cages, where grazing by sea urchins was prohibited. However, studies of McClanahan, as well as finding of other studies (Litter et al. 2006) observed that abundance and biodiversity of algae isn`t just controlled by herbivory, but depends also on intensity of pollution, sedimentation and nutrient levels. The “Relative Dominance Model” established by Litter (2006) demonstrated that increased nutrient input stimulate harmful fleshy algal blooms and inhibit the growth of reef-building corals. Crustose coralline algae dominated just under conditions of minimal competition, and dominance correlated closely with increased sea urchin population under elevated nutrients. Enhanced sedimentation and pollution on reefs can promote dominance of turf and green algae (McClanahan 2002). As our study site is strongly influenced by tourism and related disturbances as pollution and sedimentation, these factors could also influence algae growth in exclusion cages. Especially dominance of turf algae on almost all investigated tiles could be explained by pollution of the reefs.

5. Conclusion

Tourism, especially marine-based, is an important factor for Thailand`s economy and will furthermore arise in the next years. Intact reefs and their amazing dive sites are prior reasons for many tourists to visit the country. This study demonstated, that tourism-induced disturbances, especially overfishing and pollution by wastewater, lead to a gradual decline in reef quality. Parts of reefs around the study sites were furthermore obviously destroyed by blasts of reefs to facilitate access for fishing and dive boats to the coast (personal observations). These factors and related reef degradation doesn`t have only harmful aftermath to reef ecosystems, but can also have negative socio-economic consequences due to a decline in tourist numbers. Sustainable resource management, as well as improved wastewater management and considerate dive tourism are possible improvements to ensure coral reef health and related ecosystem services. Governance systems have to implement flexible restrictions to protect fish species before-not after-stocks collapse, but coeval ensure income of local fisheries. Vulnerable dive sites has to be protected by strict regulations to allow reefs to regenerate, and the understanding of the importance of a healthy coral reef has to be provide in the population. Degradation of coral reefs can just be prohibited by an effective combination of sustainable management, public support and political will.

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List of Illustrations – Weblinks:

Cover image:
http://u.jimdo.com/www32/o/s22e2f689d5ae0fa3/emotion/crop/header.jpg?t=1308075484

Fig.A.2.1.:
http://www.fishbase.org/Summary/speciesSummary.php?ID=5564&genusname=Chaetodon&speciesname=lineolatus&AT=Chaetodon+lineolatus&lang=German

Fig.A.2.2.:
http://www.fishbase.org/Summary/speciesSummary.php?ID=5570&genusname=Chaetodon&speciesname=octofasciatus&AT=Chaetodon+octofasciatus&lang=German

Fig.A.2.3.:
http://www.fishbase.org/Summary/speciesSummary.php?ID=6666&genusname=Chaetodon&speciesname=wiebeli&AT=Chaetodon+wiebeli&lang=German

Fig.A.2.4.:
http://www.fishbase.org/Summary/speciesSummary.php?ID=5737&genusname=Platax&speciesname=orbicularis&AT=Platax+orbicularis&lang=German

Fig.A.2.5.:
http://www.fishbase.org/Summary/speciesSummary.php?ID=5739&genusname=Platax&speciesname=teira&AT=Platax+teira&lang=German

Fig.A.2.6.:
http://www.fishbase.org/Summary/speciesSummary.php?ID=6517&genusname=Abudefduf&speciesname=bengalensis&AT=Abudefduf+bengalensis&lang=German

Fig.A.2.7.:
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Fig.A.2.8.:
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Fig.A.2.9.:
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Fig.A.2.10.:
http://www.fishbase.org/Summary/speciesSummary.php?ID=5477&genusname=Amblyglyphidodon&speciesname=curacao&AT=Amblyglyphidodon+curacao&lang=German

Fig.A.2.11.:
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Fig.A.2.12.:
http://www.fishbase.org/Summary/speciesSummary.php?ID=5697&genusname=Chrysiptera&speciesname=brownriggii&AT=Chrysiptera+brownriggii&lang=German

Fig.A.2.13.:
http://www.fishbase.org/photos/PicturesSummary.php?StartRow=2&ID=5112&what=species&TotRec=12

Fig.A.2.14.:
http://www.fishbase.org/Summary/speciesSummary.php?ID=5487&genusname=Hemiglyphidodon&speciesname=plagiometopon&AT=Hemiglyphidodon+plagiometopon&lang=German

Fig.A.2.15.:
http://www.fishbase.org/Summary/speciesSummary.php?ID=5707&genusname=Neoglyphidodon&speciesname=melas&AT=Neoglyphidodon+melas&lang=German

Fig.A.2.16.:
http://www.fishbase.org/Summary/speciesSummary.php?ID=5708&genusname=Neoglyphidodon&speciesname=nigroris&AT=Neoglyphidodon+nigroris&lang=German

Fig.A.2.17.:
http://www.fishbase.org/photos/PicturesSummary.php?ID=7902&what=species

Fig.A.2.18.:
http://www.fishbase.org/Summary/speciesSummary.php?ID=6564&genusname=Pomacanthus&speciesname=sexstriatus&AT=Pomacanthus+sexstriatus&lang=German

Fig.A.2.19.:
http://www.fishbase.org/photos/PicturesSummary.php?StartRow=2&ID=5548&what=species&TotRec=21

Fig.A.2.20.:
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Fig.A.2.21.:
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Fig.A.2.22.:
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Fig.A.2.23.:
http://www.fishbase.org/photos/PicturesSummary.php?StartRow=4&ID=4618&what=species&TotRec=8

Fig.A.2.24.:
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Fig.A.3.1.:
http://aquaportal.bg/site/gallery/60.jpg

Fig.A.3.2.:
http://www.acquaportal.it/_ARCHIVIO/ARTICOLI/Ricci/Echinothrix-calamaris.jpg

7. Appendix

Table A.1.: Herbivorous fish species of all sampling sites.

Family	Species	Functional group	Feeding habit (Herbivory)
Chaetodontidae	Chaetodon lineolatus	Grazer	facultative
	Chaetodon octofasciatus	Grazer	facultative
	Chaetodon wiebeli	Grazer	facultative
Ephippidae	Platax orbicularis	Browser	facultative
	Platax teira	Browser	facultative
Pomacentridae	Abudefduf bengalensis	Browser	facultative
	Abudefduf notatus	Browser	facultative
	Abudefduf sexfasciatus	Browser	facultative
	Abudefduf vaigiensis	Browser	facultative
	Amblyglyphidodon curacao	Browser	facultative
	Amphiprion perideraion	Browser	facultative
	Chrysiptera brownriggii	Browser	facultative
	Dascyllus trimaculatus	Browser	facultative
	Hemiglyphidodon plagiometopon	Browser	obligatory
	Neoglyphidodon melas	Browser	facultative
	Neoglyphidodon nigroris	Browser	facultative
	Pomacanthus annularis	Browser	facultative
	Pomacanthus sexstriatus	Browser	facultative
Scaridae	Scarus ghobban	Scraper	obligatory
	Scarus prasiognathos	Scraper	obligatory
	Scarus rivulatus	Scraper	obligatory

Siganidae	Siganus guttatus	Grazer	obligatory
	Siganus javus	Grazer	obligatory
	Siganus puellus	Grazer	facultative

Table A.2.: Images of classified fishes (Source: www.fishbase.org).

- **Chaetodontidae (Butterflyfishes)**

Fig A.2.1.: *Chaetodon lineolatus* (Lined butterflyfish; Photo by Randall, J.E.)

Fig.A.2.2.: *Chaetodon octofasciatus* (Eightbanded butterflyfish; Photo by Randall, J.E.)

Fig.A.2.3.: *Chaetodon wiebeli* (Hongkong butterflyfish; Photo by Randall, J.E.)

- **Ephippidae (Spadefishes, Batfishes)**

Fig.A.2.4.: *Platax orbicularis* (Orbicular batfish; Photo by Randall, J.E.)

Fig.A.2.5.: *Platax teira* (Longfin batfish; Photo by Randall, J.E.)

- **Pomacanthidae (Angelfishes)**

Fig.A.2.6.: *Abudefduf bengalensis* (Bengal sergeant; Photo by Randall, J.E.)

Fig.A.2.7.: *Abudefduf notatus* (Yellowtail sergeant; Photo by Randall, J.E.)

Fig.A.2.8.: *Abudefduf sexfasciatus* (Scissortail sergeant ; Photo by Randall, J.E.)

Fig.A.2.9.: *Abudefduf vaigiensis* (Indo-Pacific sergeant ; Photo by Randall, J.E.)

Fig.A.2.10.: *Amblyglyphidodon curacao* (Staghorn damselfish; Photo by Adams, M.J.)

Fig.A.2.11.: *Amphiprion perideraion* (Pink anemonefish; Photo by Randall, J.E.)

Fig.A.2.12.: *Chrysiptera brownriggii* (Surge damselfish; Photo by Randall, J.E.)

Fig.A.2.13.: Dascyllus trimaculatus (Threespot dascyllus; Photo by Randall, J.E.)

Fig.A.2.14.: ***Hemiglyphidodon plagiometopon*** **(Lagoon damselfish; Photo by Randall, J.E.)**

Fig.A.2.15.: ***Neoglyphidodon melas*** **(Bowtie damselfish; Photo by Field, R.)**

Fig.A.2.16.: ***Neoglyphidodon nigroris*** **(Black-and-gold chromis; Photo by Randall, J.E.)**

A.2.17.: ***Pomacanthus annularis*** **(Bluering angelfish; Photo by Randall, J.E.)**

Fig.A.2.18.: ***Pomacanthus sexstriatus*** **(sixbanded angelfish; Photo by Cook, D.C.)**

- **Scaridae (Parrotfishes)**

Fig.A.2.19.: *Scarus ghobban* (Blue-barred parrotfish; Photo by Randall, J.E.)

Fig.A.2.20.: *Scarus prasiognathos* (Singapore parrotfish; Photo by Randall, J.E.)

Fig.A.2.21.: *Scarus rivulatus* (Rivulated parrotfish; Photo by Randall, J.E.)

- **Siganidae (Rabbitfishes)**

Fig.A.2.22.: Siganus guttatus (Goldlined spinefoot; Photo by Honeycutt, C.)

Fig.A.2.23.: *Siganus javus* (Streaked spinefoot; Photo by Shao, K.T.)

Fig.A.2.24.: *Siganus puellus* (Masked spinefoot; Photo by Randall, J.E.)

Table A.3.: Occurring sea urchins.

Fig.A.3.1.: Diadema setosum (Long-spined sea urchin; Source: Hristo Hristov, Aquasaur)

Fig.A.3.2.: Echinothrix calamaris (Banded long-spine urchin; Source: Roberto Sozzani)