Assessment of the status of Kalawy Bay's fringing reef, Safaga, Egypt

by Reef Check Germany e.V.

with support from Magic Life GmbH & Co KG
Magic Life Club Kalawy Imperial
Magic Divers

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Summary

Tourism in coral reef areas is a great source of income for many countries. Yet, in many areas, both human and natural disturbances are degrading the coral reefs. Reefs have adapted to natural disturbances, which have been common over evolutionary time (Connell et al. 1997). By contrast, human activities are relatively new disturbances. Coral reef areas subject to chronic disturbances have been found to recover in only a few cases compared to natural disturbances (Connell et al. 1997). Poorly planned tourism development, but also the tourists themselves, such as snorkelers and SCUBA divers, may have negative impacts on coral reefs and organisms dependent on them.

Reef Check Germany e.V. was commissioned by Magic Life Kalawy to do a study on the health status of their house reef at Kalawy Bay, and to give recommendations for sustainable use. The survey was carried out in March 2008, shortly after the opening of the hotel. The study will serve as a baseline for future monitoring to establish possible biological effects from diving and snorkeling activities. Data were collected on the house reef of Magic Life Kalawy Imperial, which are frequented daily by the dive centre Magic Divers. Data were collected using an extended Reef Check survey method, a more detailed survey of selected reef fishes, invertebrates and corals, representing environmental indicators of local importance for coral reef health. A detailed survey of coral damage and the fish, coral and mollusc diversity was also included.

The extended Reef Check survey showed that the most abundant indicator fish was butterfly fish, followed by parrotfish. Unfortunately no large groupers were observed and only one giant moray was counted. Both sites and all depths were similar in composition and abundance of the invertebrate indicators. Long-spined sea urchins, giant clams and trochus shells were the only indicators present at all sites. The amount of trash under water was very low and only a few corals with damage were observed. Some coral predation by *Drupella* spp. and *Corallophila* spp. was recorded. Apart from the damage and predation, the coral population was healthy as no coral diseases were observed within the surveyed area. The percentage cover of live hard coral at Kalawy Bay was 32.5 %. The live soft coral cover was 13.9 %. The percentage cover of recently killed coral was low with an average of 0.7%. Branching Acropora was the most abundant hard coral type, while soft corals of the family Xeniidae were most abundant.

Overall there were no exceeding deviant results compared to Reef Check data over the last years for this region. The reef is in a healthy and normal condition and features the same diversity as other fringing reefs of the surrounding area (e.g. Safaga and El Quseir).

A total of 9536 fishes were counted for the extended survey, belonging to 93 species from 63 genera and 23 families. The majority of fish belonged to the families Pomacentridae (Damselfishes) and Serranidae (Groupers, Soapfish & Anthiases). The reef area north of the entry (ML-B) was around double as rich concerning fish compared to the area of ML-A. The most abundant fish was the lyretail anthias (*Pseudanthias squamipinnis*) with 34.7%, followed by the half-and-half chromis (*Chromis dimidiata*) with 20.8% and miry's demoiselle (*Neopomacentrus miryae*) with 8.4% of the total number of fishes. Most fish species belonged to the family of the wrasses (Labridae; 18 species), of the damselfishes (Pomacentridae; 12 species) and of the butterfly fishes (Chaetodontidae; 8 species).

Furthermore, a total of 39 mollusc species were recorded, 7 bivalve species and 32 snail species. The most abundant bivalve was the coral scallop (*Pedum spondyloideum*) with an average of 17.3 individuals per 100 $m^{2.}$ The most abundant snail was the purple coral snail (*Coralliophila violacea*) with an average abundance of 3.0 individuals/100 m^2.

129 species of reef-building corals were identified, most belonging to the family Faviidae with 28 species, followed by Acroporidae with 18 species. The results of the extended protocol show that the corals of the survey were primarily of the branching type with the predominant genus Acropora.

The results of our studies show that the fish, coral and invertebrate populations in Kalawy Bay are not affected by diving activities. We have to consider that the diving activities on the reef started only two months before the beginning of this study. It is important that future long term monitoring be carried out so that possible changes in community structure can be detected. The coral reefs are overall in a good condition; only the construction of the jetty had consequences. The symptoms of different coral colonies should be observed and documented in the future. Proper management of tourist activities, regular clean-ups and an annual control by the Reef Check method are suggested which is of importance for the long-term healthy condition of Kalawy Bay's coral reef.

1. Goals

From the 3rd to 14th of March 2008 the Reef Check team of the Red Sea Environmental Centre in Dahab conducted a study 30km south of Safaga, at the house reef of *Club Magic Life Kalawy Imperial*. The goals of this study were:

- assess the health status of fringing reef along Kalawy Bay
    - based on an extended Reef Check survey
    - including biodiversity of the coral, fish and mollusc population
    - in consideration of possible effects of human activities (mainly diving and snorkeling) on the reef community
- set a baseline for future continuous monitoring
- establish long-term monitoring stations
- train the dive staff in the Reef Check methodology
- inform the management of our findings and make recommendations

Coral reef survey data from this project will be sent to the Reef Check headquarters where it is used for regular reports on the health of reefs at the global and regional scale. These reports are also available at the Reef Check website. At the countrywide scale, Reef Check Egypt will use the results to describe the conditions of reefs in the Red Sea. The data will be housed in the Reef Check database. Over time, as repeat surveys are conducted, data will be used as an early warning detection for large intensity changes. At the local scale, results will be used to describe the health of the reef, which will assist resource managers to manage tourist activities in Kalawy Bay.

2. Introduction

Coral reefs are among the most biologically diverse ecosystems. They are highly productive and species rich, important for coastal defence by acting as natural barriers against waves, and still may contain important compounds applicable for medicinal products. The aesthetic and commercial value of coral reefs may also represent a great source of income by recreation and tourism.

Coral reefs have been characterised as “highly sensitive ecosystems” (Hughes 2002). Coral reefs subject to stress may have slower growth rates, lower reproductive output, increased susceptibility to disease, and differences in patterns of distribution and abundance of some species (Brown & Howard 1985). The world’s coral reefs are being degraded by both natural and human disturbances (Bellwood et al. 2004; Connell et al. 1997; Pandolfi et al. 2003). There is still debate as to the causes of diseases such as black band and white band diseases and predator outbreaks (e.g. *Acanthaster planci* starfish or the coral-eating snail Drupella), which may have serious impacts on coral reefs. Anthropogenic (man-made) disturbances include overharvesting, pollution, coastal development which may lead to sedimentation, and improper waste management. Degradation of coral reefs by tourism is also of concern (Barker & Roberts 2004; Rodgers et al. 2003; Salm 1986). Activities such as snorkeling (Allison 1996; Plathong et al. 2000; Rogers et al. 1988), reef walking (Hawkins & Roberts 1993; Liddle & Kay 1987; Ormond et al. 1997; Rodgers et al. 2003; Woodland & Hooper 1977) and SCUBA diving (Hawkins & Roberts 1992b) have been shown to have a negative impact on coral reefs . Snorkelers and swimmers may unintentionally damage corals by bumping into them or grabbing onto them for support. They may intentionally collect organisms for souvenirs. Novice divers with poor buoyancy control may break corals and stir up sediment which may stress corals (Hawkins & Roberts 1992a). Corals subject to repeated damage would have to allocate energy to tissue repair, and would have less energy left for growth and reproduction (Liddle & Kay 1987; Meesters et al. 1994; Ward 1995; Zakai et al. 2000). Rodgers et al. (2003) found that growth rates were reduced following trampling, and that very few trampling events can inflict damage to corals. In some coastal areas of Egypt (e.g. Hurghada), tourist development has been proceeding without an active management plan (El-Gamily et al. 2001; Jameson et al. 1999). Construction projects to meet the demands of increasing tourism have led to an alteration of the coastal zone and degradation of the mainland fringing reefs caused by fillings on the reef flat, dredging activities followed by sedimentation (El-Gamily et al. 2001; Hawkins & Roberts 1994; Jameson et al. 1999), and constructions blocking littoral currents (Frihy et al. 2004). Given the degree of these impacts, effective management of popular dive- and snorkeling sites is of importance for sustainable tourism.

The Egyptian Environmental Affairs Agency (EEAA) is responsible for conservation and management of coral reefs in the Egyptian Red Sea. In the past decades action has been taken to try to reduce further damage to local coral reefs. Management includes establishment of protected areas, administered by the EEAA's Department of Protectorates, which also ensures compliance with user regulations. To prevent further anchor damage on the coral reefs at popular diving and snorkeling sites, Hurghada Environmental Protection and Conservation Association (HEPCA), with participation from the Protectorates Division of EEAA installed over 250 mooring buoys in the Hurghada and Safaga area in the late 1990's (Jameson et al. 1999). This number has risen to more than 1000 installed moorings in the northern Red Sea. This seems to have decreased anchor damage, which was one of the major impacts from dive- and snorkeling tourism in Egypt.

Many divers say that they are more satisfied with the diving experience when they are informed about the local marine life. Barker & Roberts (2004) found that intervention by a dive guide reduces damaging contacts with the reef and Medio et al. (1997) found that a thorough environmental briefing of divers before a dive reduces contact with the substrate. Snorkelers, swimmers and divers might not be aware of the damage they are causing when touching, trampling on or kicking corals or other reef organisms. Some studies have found that diving sites with damaged corals may lose their attractiveness (Hawkins & Roberts 1992a). In order to keep the coral reefs and associated fauna and flora healthy, it is important to find a balance between recreation and conservation.

Reef Check Germany e.V. was commissioned by Magic Life Kalawy Imperial and their incorporated dive centre Magic Divers to do a study on the health status of their house reef at Kalawy Bay, and to give recommendations for sustainable use. Club Magic Life Kalawy Imperial is located approximately 30 km south of Safaga on the Red Sea Riviera of the Egyptian mainland. The club has around 117,000 m² of premises with a main building and 13 smaller buildings with a guest capacity of 533 rooms. The club opened for guests on the 1st of January 2008. The dive centre, Magic Divers, has a capacity of 100 dive guests for dive courses and guided dives. In addition to the house reef, Magic Divers also utilize six dive sites by zodiac, six dive sites by bus transfer and ten dive sites by boat from Safaga. The house reef is accessible via a 250 m long and 2.5 m wide jetty. The jetty ranges from the coast to the end of the reef flat and was finished in December 2007. It provides a large platform and a lifting device for handling their 3 zodiacs.

3. Methods

3.1. Survey sites

Data was collected on the house reef of Magic Life Kalawy Imperial located 30 km south of Safaga at the northern Red Sea coast (see Figure 1). The study sites were located next to the jetty (which is also used as an entry point by divers) along the fringing reef, between North 26°30'30.98" / East 34° 4'21.44" and North 26°30'40.63" / East 34° 4'18.53".

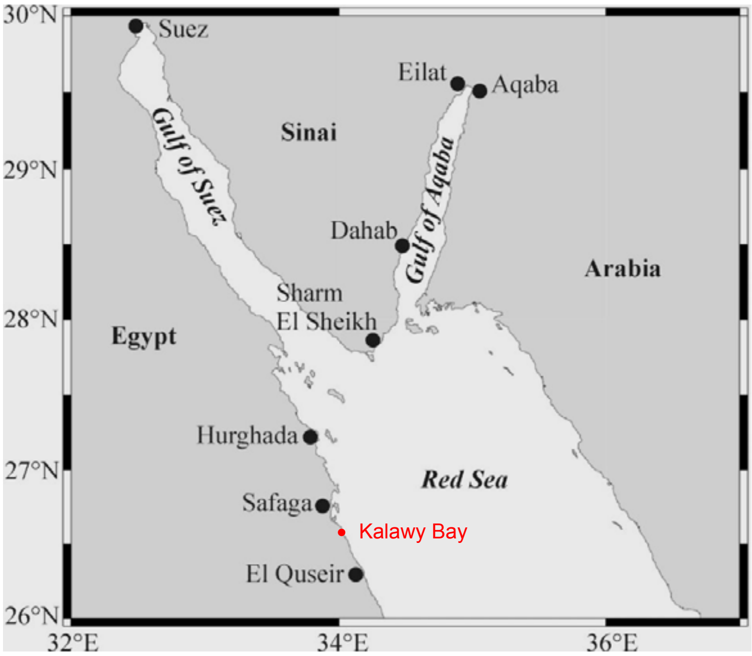

Figure 1: Kalawy Bay lies 30 km south of Safaga, in the northern Red Sea.

The survey sites were chosen based on frequency of use and were used daily by Magic Divers. The house reef is divided into two dive sites (north and south). Two sites further away are dived on by boat (drift dive back to the jetty). For this study two sites were chosen, one north (ML-B) and one south (ML-A) of the jetty (Figure 3). The area right next to the entry point was, due to its steep walls, not suited for a Reef Check survey. The entry point is located in the northern part of the small bay. The underwater topography of the two chosen reef slope areas was similar, the northern side being slightly less steep and less structured than the southern part.

Figure 2: Kalawy Bay (lagoon) and the house reef of Magic Life Kalawy. The hotel was still under construction when this image was taken.

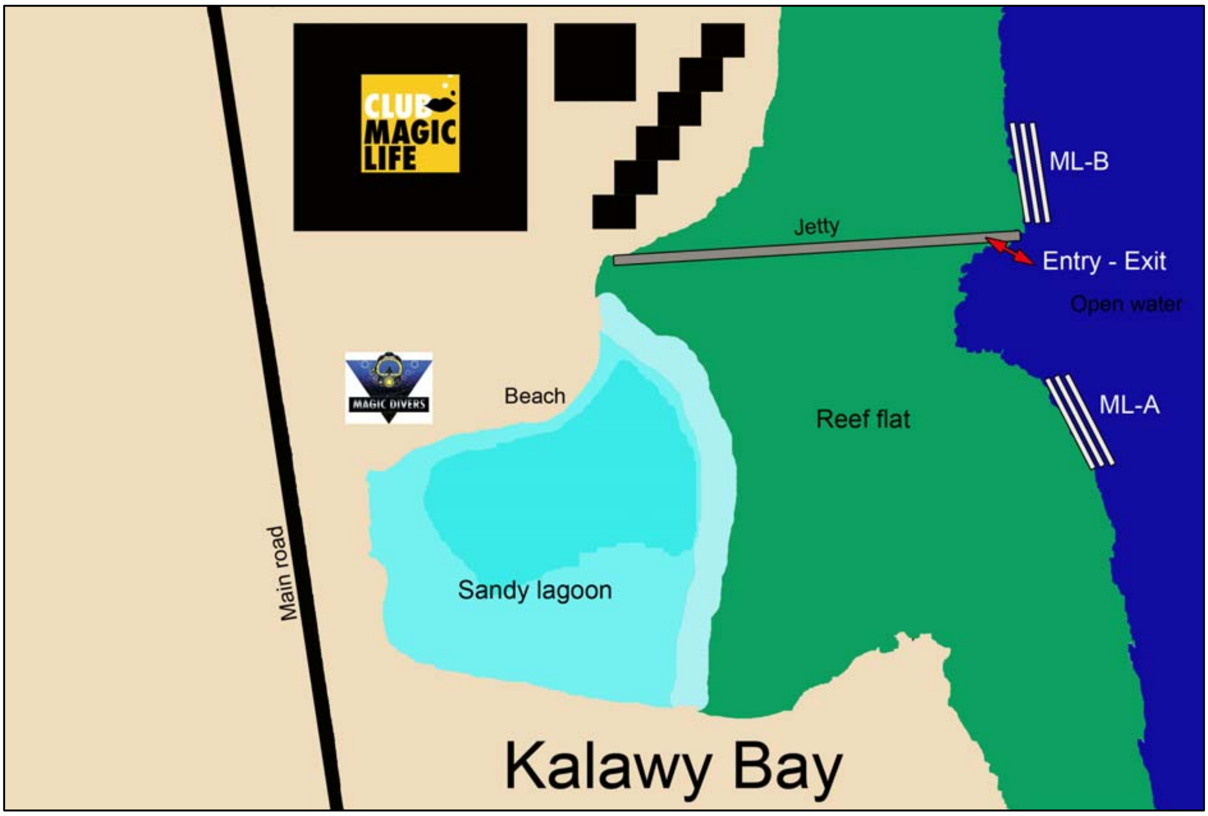

Figure 3: Map of Kalawy Bay showing the lagoon, the house reef of Magic Life Kalawy, the jetty and the study sites ML-A and ML-B.

The lagoon of Magic Live Kalawy is mainly used by swimmers (Figure 2 and Figure 3), but also for snorkeling, windsurfing, kayaking and scuba diving. The lagoon consists of very fine sediment that can be easily kicked up and causes a natural turbidity of the water. The lagoon is mostly shallow, the water level at low tide being between 150 and 120 cm. In the north-eastern part there is a deeper pool (the deepest part of the lagoon) which is marked and used by the diving centre for courses.

3.2. Methods of sampling

3.2.1. Reef Check method

This project was based on Reef Check, a well-tested standardized methodology to characterize reef condition. The Reef Check survey methodology was developed by a group of marine scientists led by Dr. Gregor Hodgson (Reef Check Foundation) in 1996. It then underwent extensive peer review and has been continuously updated and improved through the annual publication of the Reef Check Survey Manual (Hodgson et al. 2006, www.reefcheck.org). The methodology has been developed with the intention to create a scientifically rigorous, but also easily understandable survey that can be carried out by non-scientists as well. The Reef Check survey focuses on the abundance of particular coral reef organisms that best reflect the condition of the ecosystem and that are easily recognizable to non-specialists. Table 1 shows the fish indicators, Table 2 the invertebrate indicators, and Table 3 the substrate categories for the Red Sea region. Images of indicator taxa are given in the appendix.

The selection of the Reef Check organisms was made based on their economic and ecological value, their sensitivity to human impacts (over-fishing/harvesting, aquarium trade), and ease of identification. Sixteen global and eight regional indicator organisms serve as specific measures of human impacts on coral reefs. Some Reef Check indicators are on the species level while others are on a higher taxonomic level.

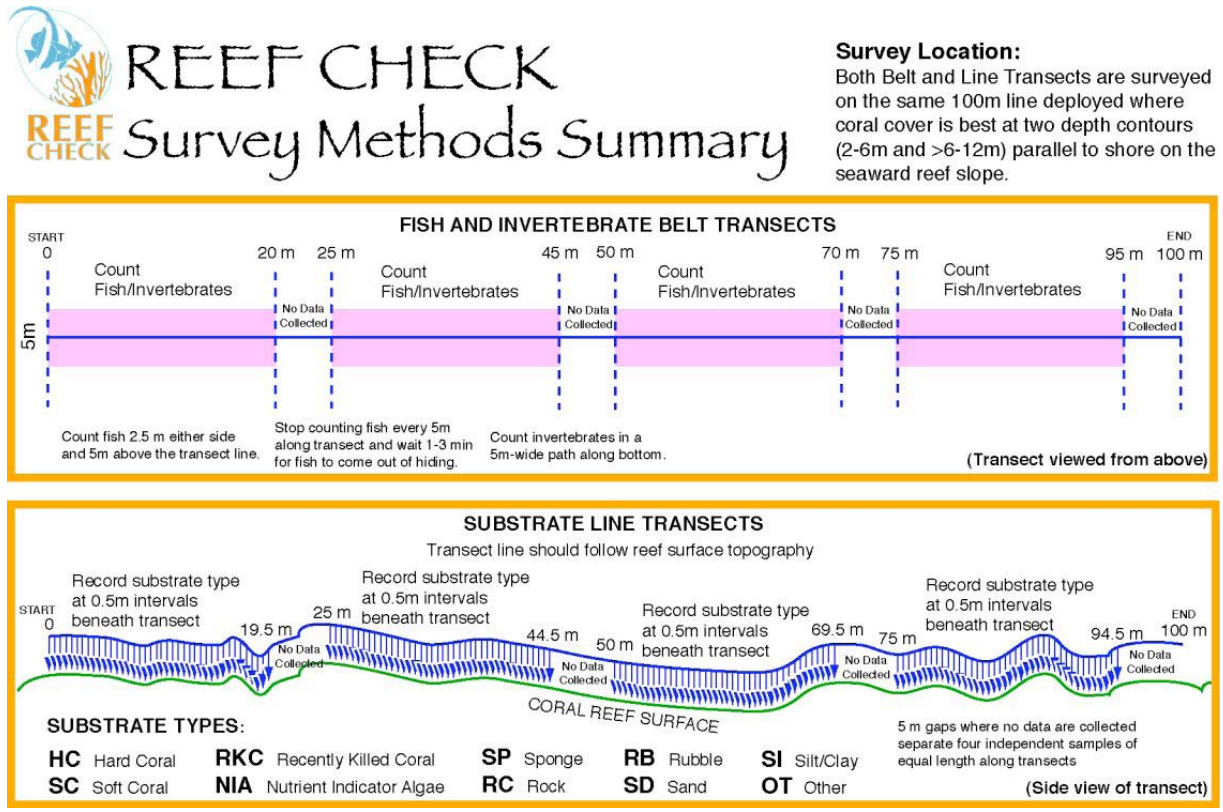

Figure 4: Summary of the Reef Check Survey Method

The Reef Check survey begins with a site survey to determine the extent of the reef and the overall coverage of various substrates and live/dead coral. The actual Reef Check survey (Figure 4) is comprised of four 20 m transects surveyed at each of two depths, shallow (2-6 m) and mid-reef (6-12 m). Each 20 m transect is sampled for 1) indicator fish species typically targeted by fishermen, aquarium collectors and others, 2) indicator invertebrate species typically targeted as food, curios, or aquarium specimens, 3) reef substrate type including live coral, recently killed coral, nutrient indicator algae, and other substrate types, and 4) any signs of damage or diseases, including broken corals, bleaching, trash, fishing nets and lines etc.

Table 1: Reef Check fish indicators for the Red Sea.* also counted off-transect. (Hodgson et al. 2006, www.reefcheck.org)

Common name	**Scientific name**	**Indicator of**
Butterflyfish	Chaetodontidae	aquarium trade (and overfishing)
Sweetlips	Haemulidae	overfishing
Broomtail wrasse	*Cheilinus lunulatus*	overfishing
Humphead wrasse*	*Cheilinus undulatus*	overfishing and live fish trade
Grouper > 30 cm	Serranidae	overfishing and live fish trade
Parrotfish > 20 cm	Scaridae	overfishing, producer of coral sand
Bumphead parrotfish	*Bolbometopon muricatum*	overfishing, producer of coral sand
Snapper	Lutjanidae	overfishing
Moray eels	Muraenidae	overfishing

Table 2: Reef Check's invertebrate indicators for the Red Sea (Hodgson et al. 2006, www.reefcheck.org).

Common name	**Scientific name**	**Indicator of**
Lobster	*Panulirus* ssp.	overfishing
Banded coral shrimp	*Stenopus hispidus*	aquarium trade
Long-spined urchins	*Diadema spp., Echinotrix spp.*	overfishing
Pencil urchin	*Heterocentrotus mammilatus*	curio trade
Collector urchin	*Tripneustes* spp.	overfishing
Crown-of-thorns starfish	*Acanthaster planci*	population outbreaks
Giant clam	*Tridacna* spp.	overfishing, aquarium / curio trade
Triton	*Charonia* spp.	curio trade
Trochus shells	*Tectus* spp. & *Trochus* spp.	curio trade
Sea cucumber	Holothuroidea	overfishing

The sampled fish transects are 5 m wide (2.5 m left and right of the line) and 5 m high, and invertebrate and damage transects are 5 m wide, whereas the substrate transect is sampled at 0.5 m intervals (point intercept method). The substrate type along the transect tape is recorded every 50 cm with the help of a small metal nut to avoid biases. The substrate types are defined in Table 3. Additionally, a site description records over thirty measures of environmental conditions and expert ratings of human impacts (Hodgson et al., 2006).

Table 3: Reef Check's worldwide standardized 10 categories for substrate types (Hodgson et al. 2006, www.reefcheck.org).

Hard coral (HC)	Includes besides Scleractinia also fire coral (*Millepora*), blue coral (*Heliopora*) and organ pipe coral (*Tubipora*) because these are reef builders.
Soft coral (SC)	Include zoanthids, but not sea anemones (the latter go into "Other").
Recently killed coral (RKC)	Coral that died within the past year. The coral may be standing or broken into pieces, but appears fresh, white with corallite structures still recognizable, only partially overgrown by encrusting algae etc.
Nutrient indicator algae (NIA)	Various blue green algae, *Ulva* and bubble algae to record blooms of algae that might be response to high levels of nutrient input. Algae such as *Sargassum* and *Halimeda* are considered to be part of a healthy reef and are therefore not recorded for this category.
Sponge (SP)	All sponges to discover possible sponge blooms that could be the response to disturbance.
Rock (RC)	Any hard substrate whether it is covered in e.g. turf or encrusting coralline algae, barnacles, oysters etc. and all coral dead for more than one year.
Rubble (RB)	Rocks and coral pieces of the size 0.5 – 15 cm in diameter (if larger, then it is considered rock).
Sand (SD)	Rocks smaller than 0.5 cm in diameter that falls quickly to the bottom when being dropped.
Silt/Clay (Si)	Sediment that remains in suspension if disturbed.
Other (OT)	Any other sessile organisms including sea anemones, tunicates, gorgonians or non-living substrate.

Not all types of reef qualify for a Reef Chef Survey. Drop-offs, depths of more than 12 m or areas with high sand coverage are inappropriate and would cause misleading results since they favour some organisms while others can hardly persist.

The surveyed reef parts should therefore best possible represent the total reef, in terms not only in type and physical conditions, but, for the purpose of this study also dive intensity and usage.

3.2.2. Extended Reef Check method

Data were collected using an extended Reef Check survey method. This extension was developed by scientists at the Red Sea Environmental Centre and was implemented in a successful Reef Monitoring project in Dahab, South Sinai. The aim of the extended protocol is to provide more and better defined data describing the status of coral reef health with respect to anthropogenic and natural impacts in the South Sinai region and

the Northern Red Sea. The more detailed surveys provide a more comprehensive picture of abundance and diversity of selected reef fishes, invertebrates and corals, respectively, representing environmental indicators of local importance for coral reef health.
In addition, to obtain specific data to quantify impact of recreational diving and snorkeling activities, a separate coral damage survey has been designed. This additional survey on actual coral damage provides a comprehensive data set on natural coral damage such as predation by coral-feeders as well as coral breakage and abrasion by natural or human impact. Substrate categories are monitored in an extended survey comprising a diversification of 32 instead of 10 substrates compared with the standard Reef Check procedure. All data obtained can be fully utilized by the Reef Check headquarters by extracting the core data considered in the standard Reef Check protocol.

A surface marker buoy (SMB) was deployed to mark the beginning and end of each transect to obtain Global Positioning System (GPS) data. Permanent markers were deployed together with the dive centre staff for future surveys. A 95 m reel with markers for 20 m segments, fish counts and substrate points was used for the surveys. The width of each 20 m segment was marked with 5 m cross lines. All transect were documented with a 10 mega pixel digital camera and red filter. These overview images were taken perpendicular to the transect, along the transect with the line centred in the middle. The entire 95 m transect (including 5 m spacers) was recorded on 30-40 images. On the 15 m and 10 m transects the complete 5 m width was included in these images. On 5 m depth the width was less due to limited distance above the transect for the observer, but including at least 1.5 m to either side of the transect line on the images.

At each site chosen, Reef Check surveys were carried out at three different depths, 5 m, 10 m and 15 m, gathered from the extended Reef Check protocol (Alter 2006). The 15 m transect was added because this area is, and will most likely be frequently used by divers. The extended Reef Check consisted of these 4 surveys:

(1) *Fish belt transect:* Four 5 m wide (centred on the transect line) by 20 m long segments of 5 m height were sampled for indicator fish species or fish groups. Some indicators were counted off-transect as well (see * in Table 1 and Table 4)

(2) *Invertebrate & trash belt transect:* The same four 5 m wide by 20 m long segments as in the fish belt transect was used. Invertebrate indicators listed in Table 2 and Table 5 were recorded within this belt transect including trash.

(3) *Coral damage belt transect:* All hard corals within the same belt transect as used for the invertebrates were inspected for any damage or disease. Subsequently, they were allocated to 9 different categories according to the type of predation and/or the degree of abrasion or breakage. Definitions are given in Table 6, the categories in Table 7.

(4) *Substrate point intercept line transect:* Points were sampled at 0.5 m intervals along the line to determine the substrate types and coral composition of the reef. The points were allocated to the 32 categories shown in Table 8.

3.2.2.1. Fish survey

Fish were counted after standard Reef Check procedures (Hodgson et al., 2006). The method is a combination of time and area restricted survey. Each 20 m were divided into four 5 m segments. Fish were counted stationary for 1 minute at each 5 m markings, followed by 1 minute slowly swimming over this 5 m segment looking for hidden indicators such as moray eels. 7 additional indicators (Table 4) were added to the standard Reef Check fish indicators for the Red Sea. Three of the additional indicators and one standard indicator are counted off transect as well. These are marked with an asterisk in Table 1 and Table 4. For these indicators, the survey is basically restricted to time and just limited to the reef area.

Table 4: Additional fish indicators counted in the extended Reef Check survey. * are also counted off-transect (Alter 2006).

Common name	Scientific name	Indicator of
Grouper < 30 cm	Serranidae	overfishing and live fish trade
Trevallies*	Carangidae	overfishing/reef fish predation
Steephead parrotfish	*Clorurus gibbus*	Overfishing
Twinspot snapper*	*Lutjanus bohar*	Overfishing
Spangled emperor*	*Lethrinus nebulosus*	overfishing
Bluestreak cleaner wrasse	*Labroides dimidiatus*	key indicator for reef fish diversity
"Farmer fish"	*Stegastes* and *Plectroglyphidodon*	Increases in algal cover

3.2.2.2. Invertebrate and trash survey

All invertebrate indicators were counted within each 20 m by 5 m (100 m²) belt. The additional indicators are given in Table 5. Simultaneously, any trash observed was recorded and divided into four sub-categories:

(1) Fishing nets: Small fragments as well as whole (intact) fishing nets. Fishing nets and lines entangled in corals are included.
(2) Fishing lines: Fishing lines of all sizes or lengths.
(3) Plastic bags: All types of bags (e.g. free floating and bags wrapped around rock or coral colonies).
(4) General: All trash or rubbish which cannot be divided into one of the above categories.

Table 5: Additional invertebrate indicators counted in the extended Reef Check surveys (Alter 2006).

Common name	Scientific name	Indicator of
Slipper lobster	*Scyllarides* spp.	local fishing, overfishing
Three-knobbed conch	*Strombis tricornis*	local fishing, curio trade
Common spider conch	*Lambis truncata sebae*	local fishing, curio trade
Reef octopus	*Octopus cyaneus*	local fishing

3.2.2.3. Coral damage survey

Coral damage was recorded along the same 20 m by 5 m belt transects as used for the invertebrate survey. All reef-building coral colonies within the transects were surveyed for damage, disease, feeding scars or any other impact.

Table 6: Definitions of coral damage for the extended Reef Check survey.

Coral damage	**Definitions**
Breakage:	Coral colonies with overturned parts or branches or detachment of the whole colony (from the substrate). Fragments are spread around the impacted colony in most cases. Parrotfish bites are not included.
Abrasion:	The corals' surface is scrubbed or rasped mostly with hoods of algae covering the damaged areas. The surrounding coral tissue often has a change in colour.
Disease:	The coral shows characteristic disease patterns i.e. concentric black or brown patches.
Predation:	Coral damage caused by parrotfish bites, coral-feeding snails or Crown-Of-Thorn starfishes

All impacted coral colonies were assigned to nine categories. Five of them describe the degree of breakage or abrasion: 0-25%, 25-50%, 50-75%, 75-100% and "detached colony" ("detached colony" means that the colony is completely detached from the substrate but still alive). Definitions of coral damage are given in Table 6. The remaining four categories represent colonies damaged by predation and therefore showing feeding scars. The nine categories of coral damage are summarized in Table 7. Furthermore, all corals were surveyed for coral diseases, if known the disease was registered. At the same time, the type of coral was recorded, differentiating 6 categories including the four major genera of reef-building corals *Pocillopora, Acropora, Stylophora* and *Porites*, the fire coral genus Millepora and "Other".

Table 7: 9 categories of coral damage for the extended Reef Check survey (Alter 2006).

Coral colonies showing predation by	**Coral colonies showing breakage and abrasion**
Drupella spp.	< 25 %
Coralliophilia spp.	25 - 50 %
Acanthaster planci (COTS)	50 - 75 %
Parrotfish bites	75 - 100 %
	Detached colony

The total number of damaged coral colonies of the categories was put in relation to the coral population. A quantification of the branching coral population was done to calculate the ratio of damaged branching corals to branching coral population. This analysis was based on a modification of the Square-transect method (Laxton & Stablum 1974). 4 m² frames (2 m x 2 m, see Figure 5) were cut out of the overview images. The frames were referenced with the 0.5 m markers on the transect line. Within each 20 m transect, five of these 4 m² squares were cut out and analysed. All branching corals of the genus *Acropora*, *Pocillopora* and *Stylophora* with a diameter of more than 3 cm were counted within these squares. Five 4 m² squares per 20 m results in total area of 80 m² out of 400 m² as the sample size. From this 20 % (80 m²) the branching population size of 400 m² was extrapolated.

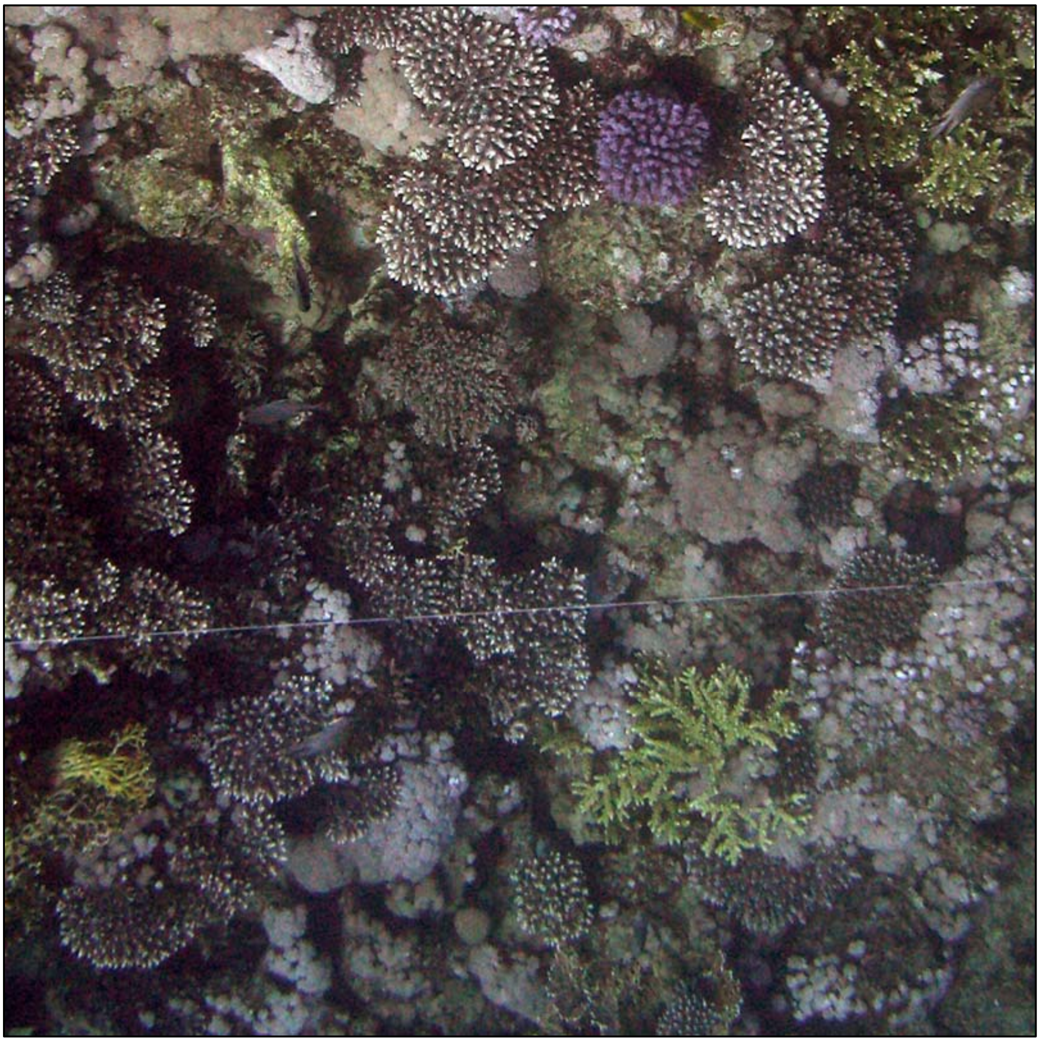

Figure 5: Frame (2 m x 2 m) for the determination of branching coral populations.

The ratio of damaged branching corals to branching coral population was calculated to obtain a perspective of physical damage to corals. Subsequently, the calculated coral damage index was compared to the following definition: “If any transect has a percentage of broken coral colonies greater than or equal to 4%, or the percent cover of coral rubble is greater than or equal to 3%, sites should be subject to further monitoring, assessment and/or restoration” (Jameson et al. 1999).

3.2.2.4. Substrate survey

The substrate transect was sampled with the point intercept method at 0.5 m intervals. With this method the substrate type under the transect line was determined at points every 50 cm resulting in 40 points per 20 m. To avoid biases a plumb line was used. A diversification of 32 substrate categories was implemented in this extended Reef Check survey. The substrate types are defined in

Table 8. The increase of categories is mainly due to the division of Hard Coral (HC) into 13 hard coral categories.

Table 8: Definitions of the 32 substrate categories of the extended Reef Check survey, Alter (2006) modified according to English et al. (1994).

Acropora Branching (AB)	Bushy-, cushion or tree-like formations of staghorn corals, including growth-form or branching types arborescent, corymbose, caespito-corymbose and caespitose. Common species are *Acropora variolosa, Acropora secale* and *Acropora acuminata.*
Acropora Digitate (AD)	Acropora colonies with thick upright branches on a solid base. The growth-form for this category is digitate. Common species are *Acropora humilis, Acropora gemmifera* and *Acropora digitifera.*
Acropora Tabulate (AT)	The growth-form of staghorn corals building plate- or table-like colonies is called tabulate. Common species of this category are *Acropora hyacinthus, Acropora subulata* and *Acropora pharaonis.*
Porites Massive (PM)	Large, massive, more or less rounded colonies of pore corals *Porites* spp. Common species are *Porites lutea* and *Porites lobata.*
Porites Columnar (PC)	Large, columnar colonies of pore corals *Porites* spp. Common species are *Porites harrisoni* and *Porites nodifera.*
Coral Branching (CB)	Colonies are primarily composed of branches of any sort (except for branched colonies of *Acropora* ssp.). Common species belonging to this category are *Pocillopora damicornis, Pocillopora verrucosa* and *Stylophora pistillata.*
Coral Encrusting (CE)	Colonies which are thin and adhere to the substrate so that their shape is given by the shape of the substrate. Common species belonging to this category are *Montipora* spp., *Pavona varians* and *Echinopora hirsutissima.*

Coral Foliose (CF)	Colonies which have leaf-like fronds or which consist of thin sheets which are not encrusting. Common species belonging to this category are *Mycedium* spp., *Oxypora* spp. and *Echinophyllia* spp.
Coral Massive (CM)	Colonies which are broadly similar in all dimensions and are mostly solid. Common species belonging to this category are *Favia favus, Favia laxa* and *Favites vasta.*
Coral Sub-massive (CS)	Colonies which are indeterminate, a mixture of several growth-forms or which have a nodular surface but are otherwise similar to massive, rounded colonies. Common species belonging to this category are *Favia stelligera, Echinopora gemmacea* and *Favites pentagona.*
Mushroom corals (CMR)	All types of typical mushroom corals. All free-living rounded to elongate species are included in this category. Foliose species of *Podabacia* spp. are not included.
Coral Millepora (CME)	All species of fire corals belong to this category. Abundant species are *Millepora dichotoma* and *Millepora platyphylla.*
Coral Tubipora (CTU)	This category is for the organ pipe coral *Tubipora musica.*
Soft Coral (SC)	This category includes all soft corals and species of the Alcyoniina Group (Fabricius & Alderslade 2000), except the soft corals of the family Xeniidae, which are a separate category (see below: SCX).
Soft Coral Xeniids (SCX)	All species of the soft coral family Xeniidae belong to this category. Species of this family can in most cases easily be distinguished from other types of soft corals. They are mostly whitish and their tentacles look feathery due to rows of pinnules on both sides. In addition, the polyps of some Xeniidae species are pulsating. Furthermore, species of Xenia are the most abundant soft corals in the northern Red Sea (Fabricius & Alderslade 2000).
Zoanthids (ZO)	Zoanthids are small colonial sea anemones easily recognised by their tentacles' arrangement organised in two rows. The polyps are usually joined together by a tissue called coenenchyme.
Macro Algae (MA)	Macro algae are larger (canopy height usually >10mm) erect algae with rather complex anatomical forms. Although macro algae are often more resistant to physical and biological disturbances than corallines and turfs, grazing by certain herbivores and high wave action can be inhibiting their growth. High macro algal biomass can interfere with coral recruitment and reduce coral survival.
Algal assemblage (AA):	This category includes a mix of different algae species, which attain a bigger size than turf algae but are smaller than macro algae. *Codium* sp. is composed of fuzzy rounded pencil-thick branches in round clumps. They are found on shallow reefs.
Coralline Algae (CA)	Coralline algae are calcified, often encrusting algae usually pink to dark burgundy in colour. They play two important roles in the coral reef community: first of all by contributing calcium carbonate to the reef structure and secondly by possibly facilitating settlement of coral recruits.

Turf Algae (TA)	Turf algae are a multi-specific assemblage of diminutive, often filamentous algae that attain a canopy height of only 1 to 10 mm. These micro-algal species have a high diversity, although only 30 to 50 species commonly occur at one time. There is a high turnover of individual turf algal species seasonally and only a few species are able to persist or remain abundant throughout the year. They are often able to recover rapidly after being partially consumed by herbivores. Turfs are capable of trapping surrounding/circumfluent sediment and are also capable of killing corals by gradual encroachment.
Fleshy Algae (FA)	Slimy and/or fleshy algae of various species spread in some reef areas and possibly affecting corals.
Recently Killed Coral (RKC)	Coral colonies or parts of them are freshly white or greenish by a film of algae but with white corallite structures which are still recognizable. Thus, colonies or parts of colonies were killed recently (in the past few weeks or month, < 6 months).
Dead Coral (DC)	Dead coral colonies where growth forms, corallite walls and openings are still recognizable but otherwise all smaller structures are eroded. The colonies mostly appear grey and have been dead for more than 6 month.
Dead Coral with Algae (DCA)	Similar to dead coral but colonies are covered with thick, mostly fleshy algae. A layer of microscopic turf algae is normally on most substrate and does not fall into this category.
Other (OT)	Ascidians, anemones, gorgonians etc.
Rock (RCK)	Any hard substrate whether it is covered in e.g. turf or encrusting coralline algae, barnacles, oysters etc. would be placed in this category; any hard substrate larger than 15 cm.
Rubble (RB)	Unconsolidated coral fragments between 0.5 and 15 cm diameter.
Sand (SD)	In the water, sand falls quickly to the bottom after being dropped; smaller than 0.5 cm.
Silt (Si)	Sediment that remains in suspension if disturbed. Note that these are practical definitions not geotechnical. Often, silt is present on top of other indicators such as rock. In these instances, silt is recorded if the silt layer is thicker than 1 mm or covers the underlying substrate such that you cannot observe the colour of what is underneath.
Water (Wa)	Fissures deeper than 50 cm.

3.2.3. Diversity and abundance

The surveys of the extended Reef Check protocol were the first surveys conducted for each transect. On the second dive, each transect was surveyed for diversity and community assemblages of fish, molluscs and corals.

3.2.3.1. Fish survey

A visual census survey of the fish community, as described in English et al. (1994) was integrated in this study. The same Reef Check transects of 80 m length in total (4 times 20 m), 5 m width and 5 m height were surveyed for fishes at three different depths (5 m, 10 m and 15 m). All non-cryptic and day-active species were identified and recorded. Thus, the results and conclusions are restricted to these species and don't claim to be complete regarding absolute fish diversity (Brock 1982). The duration for the count of each transect was 60 minutes.

Abundance

Fish abundance was described as follows:

Absolute abundance (AA): Total number of a fish species in the population.

Relative abundance (RA):

$$RA = \frac{\text{average abundance of species i from each depth and site}}{\text{average abundance of all species from each depth and site}} \text{ x } 100$$

Frequency of appearance (FA):

$$FA = \frac{\text{number of transects in which species i was present}}{\text{total number of all transects}} \text{ x } 100$$

AA is the total number of individuals of one particular species. RA reflects the percentage of each species compared to the total abundance of all fishes. FA shows the percentage on how many transects the species was present.

For readers convenience abundance of fishes was also expressed in abundance related to transect area:

Abundance: Individuals per 100 m²

Indices

The Shannon-Wiener diversity index and species richness was calculated and incorporated to compare fish communities among sites and depths:

Shannon-Wiener -Index H': $H' = -\sum_{i=1}^{S} (Pi - \ln Pi)$

n_i = the number of individuals within species i (i=1,2,3, ….)

N = the number of individuals present in the entire sample.

$P_i = n_i / N$ = relative abundance

Species Richness [S] = the number of species present in a sample

3.2.3.2. Mollusc survey

A visual census survey on common mollusc species (Phylum Mollusca) was conducted within the Reef Check survey. All non-cryptic, day-active and non-minute mollusc species were identified and counted. This census was restricted to these species and does not claim to be complete.

Abundance and diversity indices were analysed as described for the fish census survey (see 3.2.3.1.)

3.2.3.3. Coral survey

Diversity of hermatypic corals was assessed qualitatively for the Reef Check transects by using the visual survey method (Kenchington 1978). All hermatypic coral species were identified and recorded per 400 m² (4 x 100 m²) belt transect. The duration for the inspection of each transect was 50-60 minutes. Within the substrate survey (see 3.2.2.4.) hermatypic corals were identified to genus and species level to assess abundance and dominance of common coral species.

From all data, Shannon-Wiener diversity index and species richness were calculated to compare coral diversity and community assemblage among sites and depths.

Shannon-Wiener -Index H' (as cited in Loya 1976): $H' = -\sum_{i=1}^{S} (Pi - \ln Pi)$

n_i = the number of colonies within species i (i=1,2,3, ….)

N = the number of colonies present in the entire sample.

$P_i = n_i / N$ = relative abundance

The diversity index (H') converges to zero if all colonies belong to one species and reaches its peak H'max if all species have a similar amount of colonies (Müller 1984).

Evenness or equitability (as cited in Stirling & Wilsey $J' = \frac{H'}{\ln(S)}$ 2001):

H' = Shannon-Wiener – Index

S = Species Richness

This index typically is on a scale ranging from near 0, which indicates low evenness or high single-species dominance, to 1, which indicates equal abundance of all species or maximum evenness.

Dominance (Scheer 1978): $D = \frac{ci}{C} x100$

c_i = coverage of species i (i=1,2,3, …)

C = total coverage of all species

3.2.4. Further observations

Observations and a brief census survey were done. For this, the entire area of Magic Life Kalawy which is used for aquatic recreational activities like SCUBA diving, snorkeling or kayaking was inspected visually. This area included back reef area, reef flat and fore reef area. An investigation of the lagoon area and the area around and below the new built jetty was carried out.

3.2.4.1. Jetty area

Areas under and around the jetty, especially in the vicinity of the platform, were inspected and documented more closely.

3.2.4.2. Lagoon

Within the lagoon fish and invertebrate fauna was counted and documented. Furthermore, abundance and size distribution of the upside-down jellyfish *Cassiopeia andromeda* were determined. For abundance five counts of a frame of 5 m x 5 m (25 m^2), which were done randomly inside the lagoon, were used. The size of 34 different individuals was measured by a standard folding rule.

3.2.5. Statistics

For all transect data, an ANOSIM (analysis of similarities) significance test and a hierarchical cluster analysis were performed. Cluster analysis was based on similarities with group average as cluster mode. Data was transformed with log (X+1). The statistical analysis was prepared by using PRIMER-5 software (Primer-E 2000).

Cluster analysis serves to find natural groupings of samples such that samples within a group are more similar to each other, generally, than samples in different groups. Hierarchical clustering with group average linking, based on sample similarities or dissimilarities such as Bray-Curtis, is appropriate for delineating groups of sites with distinct community structure.

These methods take a similarity matrix as their starting point and successively fuse the samples into groups and the groups into larger clusters, starting with the highest mutual similarities then gradually lowering the similarity level at which groups are formed. The process ends with a single cluster containing all samples. The result is a tree diagram or a dendrogram, with the x axis representing the full set of samples and the y axis defining a similarity level at which two samples or groups are considered to have fused.

ANOSIM significance test compares similarities of species compositions between the samples and can give evidence for differences. A two-way crossed layout of ANOSIM was performed with the transformed data. Two terms are important in an ANOSIM significance test: p (significance level) and Global R. Global R indicates the degree of similarity between the tested groups with values between –1 and 1. If all replicates within sites are more similar to each other than any replicate from different sites, the value of R is 1. Values close to zero indicate that the similarity between sites is very high, showing a low difference between them (Clarke & Warwick 1994).

4. Results

4.1. Extended Reef Check surveys

The following results for the fish, invertebrate and substrate surveys are restricted to the 5 m and 10 m transects to make the data comparable to all Reef Check data from the Red Sea of the past 10 years. The results containing all transects are listed in the appendix. All comparisons are related to all Reef Check data from the past 10 years (Leliwa 2007).

4.1.1. Fish survey

Most abundant of the RC fish indicators were butterfly fish (Chaetodontidae) with an average abundance of 12.6 individuals per 100m² (see Table 9). A similar average value was recorded for butterfly fish in a study at the El Quadim Bay close to El Quseir (Heiss et al. 2005), the abundance values lie clearly above the average value of 8.1 for this region (region 2, years 2002-2006 from Leliwa 2007). Parrotfish (Scaridae) was the second most abundant with 4.9 individuals per 100m², which is 1.8 individuals higher than the average for the northern Red Sea.

Table 9: Total number and mean abundance per 100 m² and standard deviation (SD) of fish indicators pooled for the 5 m and 10 m transects. *Additional indicators are marked with an asterisk.

Indicator	Total	Mean	SD
Parrotfish >20cm (Scaridae)	79	4,9	3,0
Steephead parrot (*Clorurus gibbus*)*	0	0,0	0,0
Broomtail wrasse (*Cheilinus lunulatus*)	11	0,7	0,5
Humphead wrasse (*Cheilinus undulatus*)	0	0,0	0,0
Trevallies (Carangidae)*	0	0,0	0,0
Snapper (Lutjanidae)	5	0,3	1,3
Twinspot Snapper (*Lutjanus bohar*)*	2	0,1	0,3
Spangled emperor (*Lethrinus nebulosus*)*	1	0,1	0,3
Butterflyfish (Chaetodontidae)	201	12,6	5,2
Sweetlips (Haemulidae)	0	0,0	0,0
Grouper < 30 cm (Epinephilinae)*	8	0,5	1,0
Grouper > 30 cm (Epinephilinae)	1	0,1	0,3
Bluestreak cleaner wrasse (*Labroides dimidiatus*)*	61	3,8	2,4
"Farmer fish" (*Stegastes* spp. & *Plectroglyphidodon* spp.)*	8	0,5	1,0
Moray eels (Muraenidae)	0	0,0	0,0

Three indicators had one individual in total over all transects: A humphead wrasse (*Cheilinus undulatus*), a grouper (Epinephelinae) with an estimated size of 40 cm, and a giant moray eel (*Gymnothorax javanicus*). The abundance of broomtail wrasse (*Cheilinus lunulatus*) was about twice as high as the average for this region, whereas the abundance of sweetlips (Haemulidae) and snappers (Lutjanidae) was significantly lower compared to the average values of the years 2002-2006.

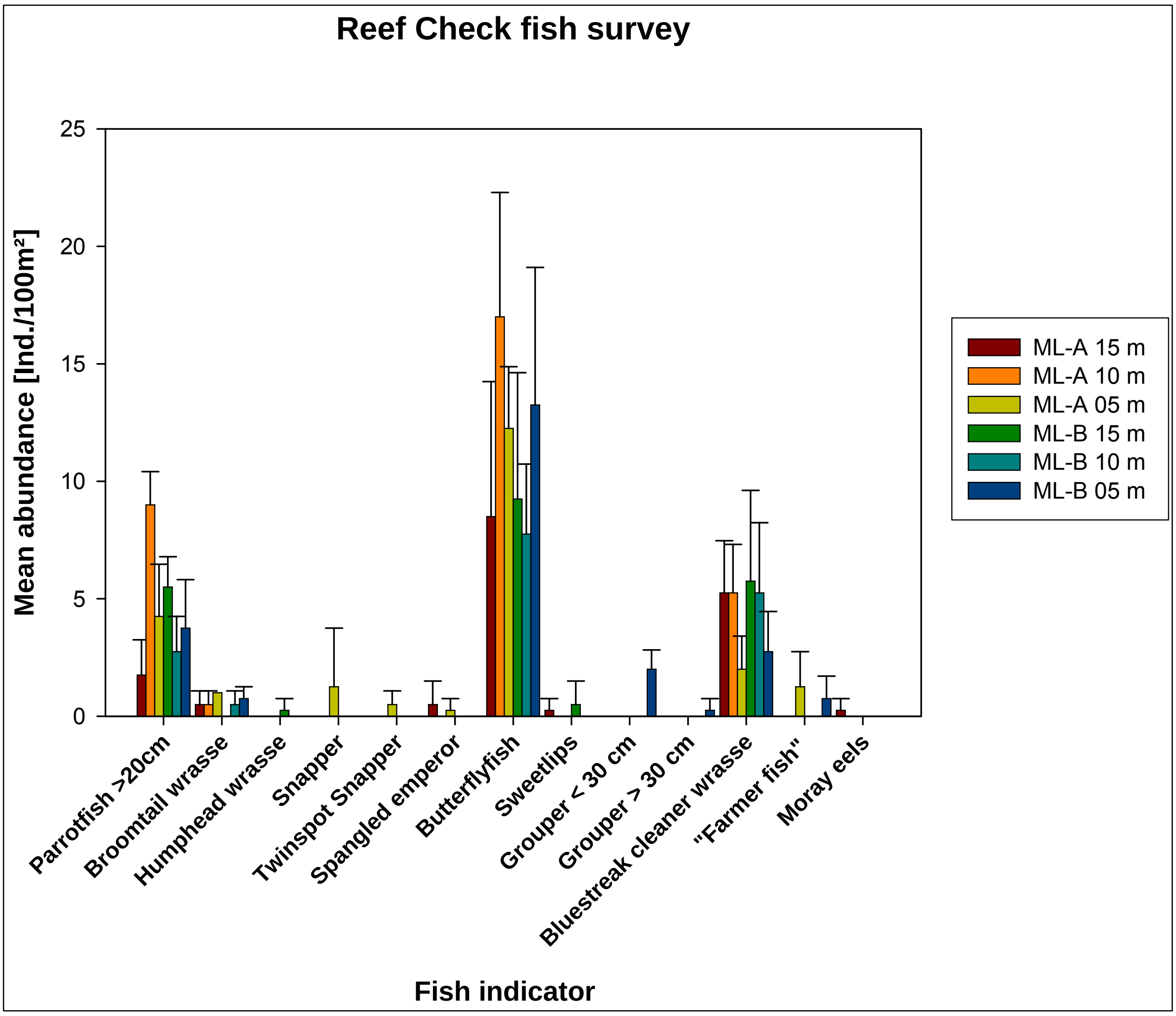

Figure 6: Results for fish indicators of Kalawy Reef. Grouped by transect.

Just a few “farmer fish” were counted, those were situated in the shallow 5 m transect. They seem not to have any significant increasing effect on algal cover as no algae was detected in the substrate analysis. The bluestreak cleaner wrasse (*Labroides dimidiatus*) showed a mean abundance of 3.8, which is almost double the abundance in the Dahab area (Alter, unpublished data).

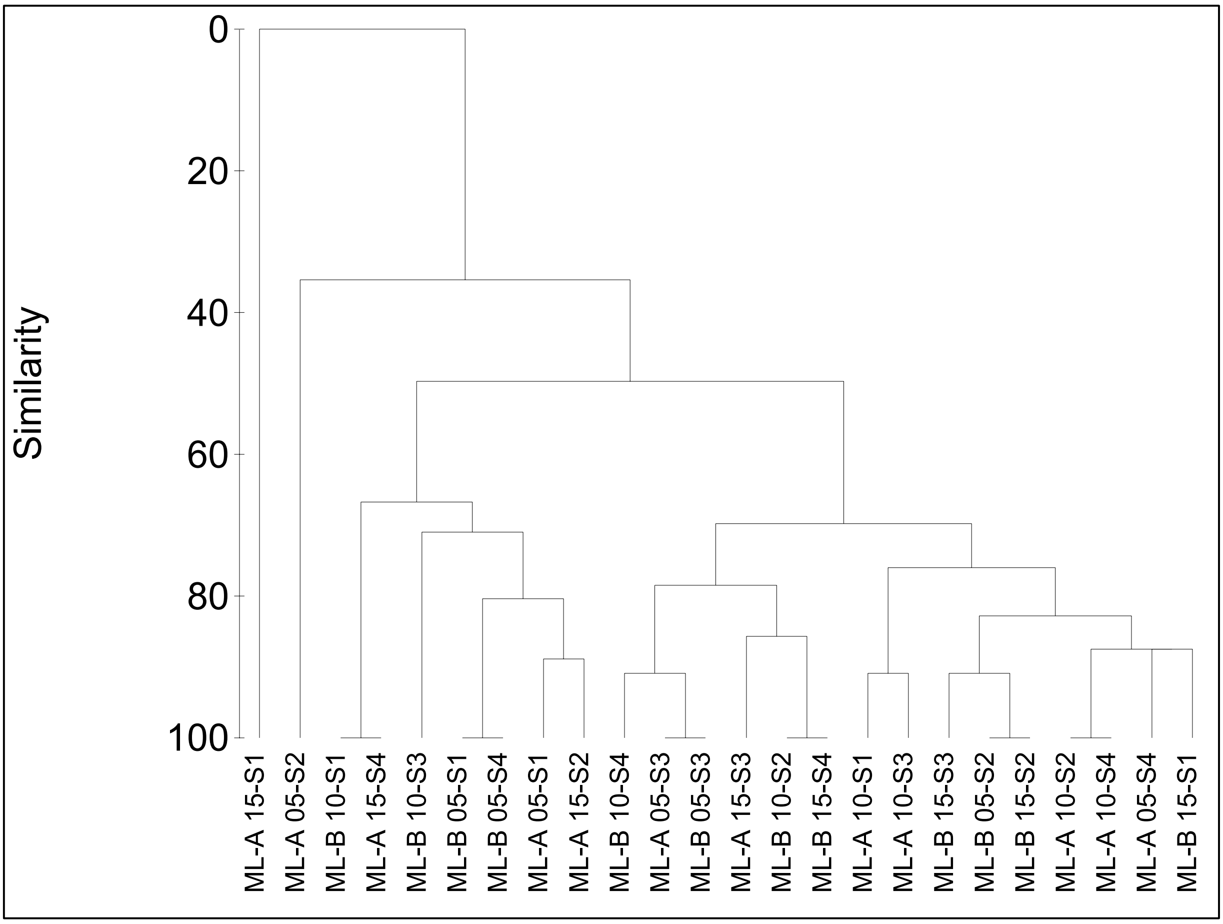

Figure 7: Results of the cluster analysis for fish indicators.

Table 10: ANOSIM significance test for Bray-Curtis-Similarity for the composition of fish indicators among transects (*0,05≥p≥0,01, **0,01>p≥0,001, ***p<0,001).

	transects
Global *R*	0,201
P	0,011
significance level	*

The cluster analysis of the fish indicators shows two main groups (Figure 7). These groups are very heterogeneous and show no clearly defined pattern. The ANOSIM-test demonstrates the similarity within the transects, yet it does not indicate significant differences concerning depths or sites.

4.1.2. Invertebrate and trash survey

All six surveyed transects were similar in composition and abundance of the invertebrate indicators. Long-spined sea urchins, giant clams and trochus shells were the only indicators present at all sites. The bioeroding long-spined sea urchins had an average of 4.8 individuals per 100m^2, which is higher than the average for this region (3.1 individuals). Numbers were higher on the 5 m transects than on the 10 m transects.

Table 11: Pooled total number, mean abundance per 100 m² plus standard deviation (SD) of invertebrate indicators for 5 m and 10 m transects. *Additional indicators are marked with an asterisk.

Indicator	Total	Mean	SD
Lobster (*Panulirus* spp.)	0	0,0	0,0
Slipper Lobster (*Scyllarides* spp.)*	0	0,0	0,0
Banded coral shrimp (*Stenopus hispidus*)	1	0,1	0,3
Long-spined urchins (*Diadem* spp. & *Echinotrix* spp.)	85	5,3	4,3
Pencil urchin (*Heterocentrotus mammillatus*)	7	0,4	1,0
Collector urchin (*Tripneustes gratilla*)	0	0,0	0,0
Sea cucumber (Holothuroidea)	0	0,0	0,0
Crown-of-thorns (*Acanthaster planci*)	0	0,0	0,0
Giant clam (*Tridacna* spp.)	112	7,0	5,1
Triton (*Charonia tritonis*)	0	0,0	0,0
Three-knobbed conch (*Strombis tricornis*)*	0	0,0	0,0
Common spider conch (*Lambis truncata sebae*)*	0	0,0	0,0
Trochus shells (*Tectus dentatus* & *Trochus maculatus*)	9	0,6	0,9
Reef octopus (*Octopus cyaneus*)*	0	0,0	0,0

No collector urchin was observed in any transect. Pencil urchins had an average abundance of 0.3 individuals per 100m^2. Only one banded coral shrimp was recorded and no lobsters or slipper lobsters, but these organisms are nocturnal and tend to hide in cracks and crevices during the day, which makes it easy to impossible to find them, depending on the complexity of the reef structure. Since the Reef Check protocol requires that all surveys are carried out by daylight, i.e. between 8 and 17 h, this error for nocturnal species is systematic and comparisons to other Reef Check sites are possible.

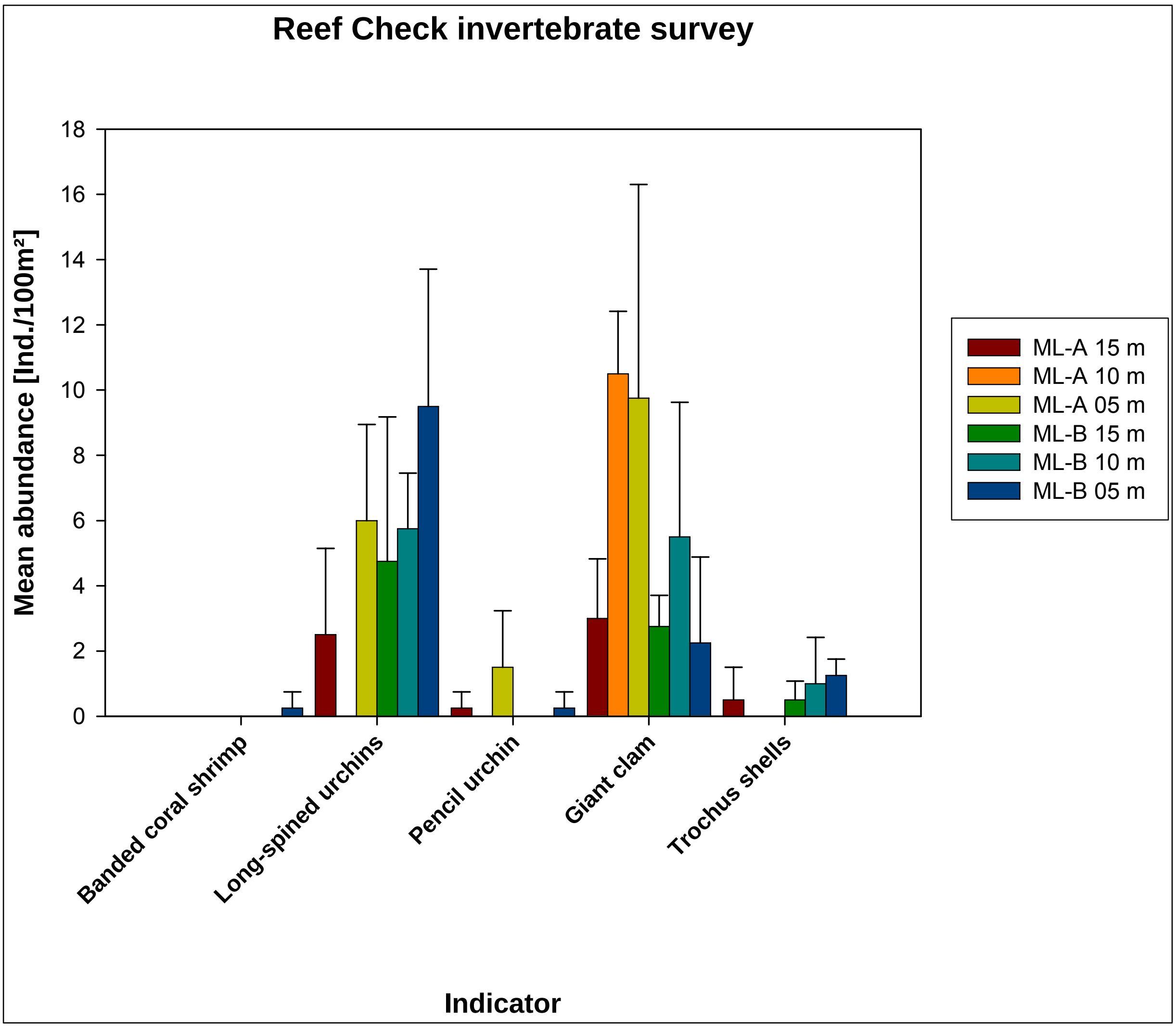

Figure 8: Results of the invertebrate surveys as mean abundance [Ind./100 m²] plus standard deviation. Indicators with 0 individuals are not shown.

Neither conches nor triton shells were found at any transect. Conches prefer sandy reef areas and reef flat / back reef areas. Thus, this indicator was irrelevant for the investigated sites. The numbers of pencil urchins were lower compared to the average for the Red Sea. Abundance of giant clams was also lower with 7.0 compared to 16.0 individuals per 100 m^2 for the region, but higher than the 5.6 recorded for a reef area around El Quadim Bay (Heiss et al. 2005). Most giant clam sizes were between 10-20 cm and only a few larger than 30 cm. Neither crown-of-thorns starfishes themselves nor signs of their predation on corals were observed. Abundance values for invertebrate indicators are summarized in Table 11. A comparison between the transects is shown in

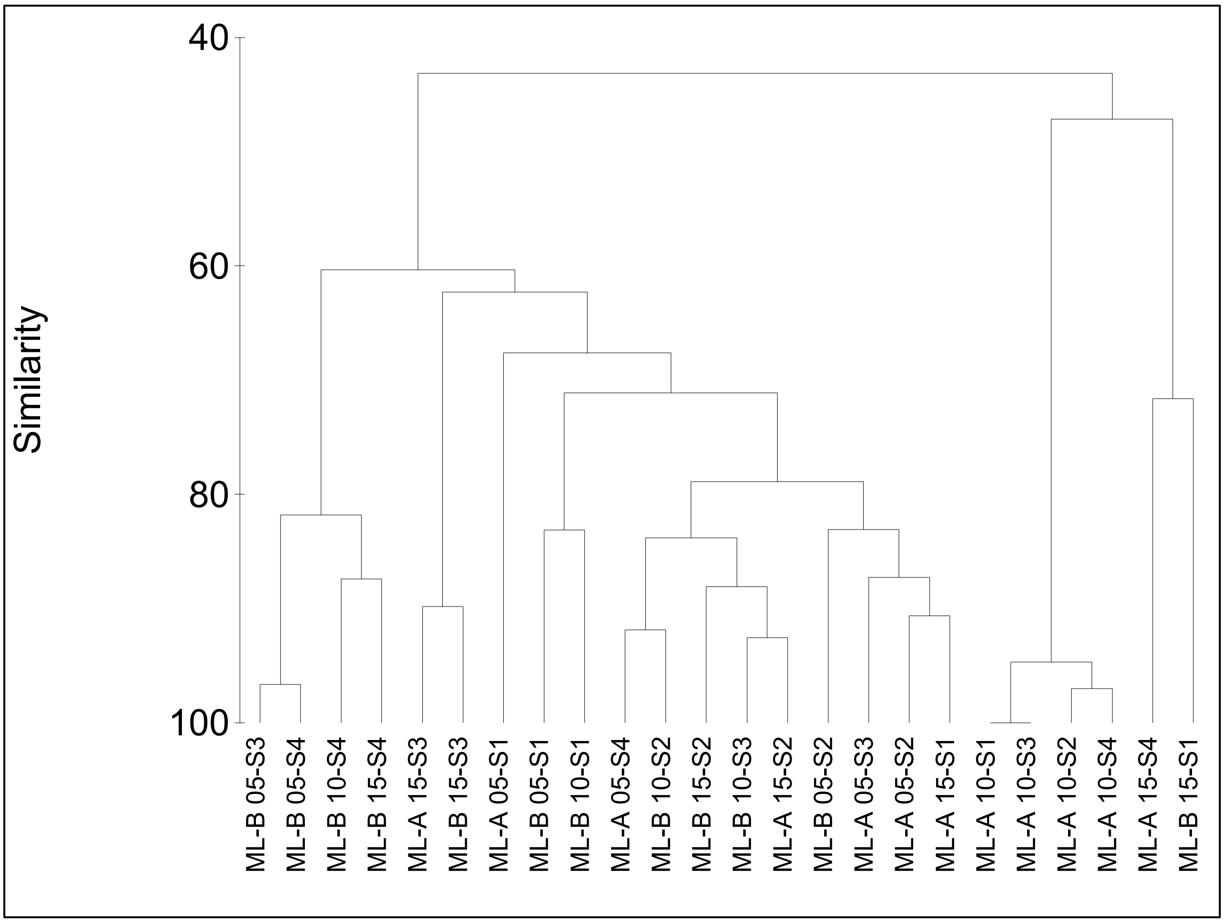

Figure 9: Results of the cluster analysis for invertebrate indicators.

Figure 8.

Table 12: ANOSIM significance test for Bray-Curtis-Similarity for the composition of invertebrate indicators with respect to depths and survey sites (*0,05≥p≥0,01, **0,01>p≥0,001, ***p<0,001).

	Gebiet	Tiefe
Global *R*	0,265	0,166
P	0,002	0.015
significance level	**	*

The cluster analysis of the invertebrates shows two main groups (Figure 9). The small group (on the right hand side) includes all similar replicates from 10 m depth in ML-A. Also integrated in this group are the replicates of the 15 m transects, which are closest to the entry point. The large group (on the left hand side) depicts several subcategories. The left one is confined to survey site ML-B and the very right one to survey site ML-A. The ANOSIM significance test confirms significant differences in the composition of invertebrate indicators with regard to depths and survey sites.

Trash

The amount of trash under water was very low. In most transects absolutely no trash was found. Just two plastic bags and two old wires stuck in the reef. The house reef had been cleaned up by the dive centre staff few months prior to this study.

4.1.3. Coral damage survey

Coral damage was low at all transects. Just a few colonies with breakages were found; damage was mostly below 25% of a colony. Further, a few overturned ("detached") colonies with still living areas were recorded. In total, 52 coral colonies showed different stages of natural damage compared to 144 colonies with damage from predation. In contrast to the extrapolated population of branching corals, the damage ranked at percentages from 0.29 % to 0.66 % for coral damage (see Table 13). The range is far below the coral damage index of 4 % by Jameson et al. (1999). The difference between these values seems to reflect the fact that this reef area has not been used for diving activities before 2008.

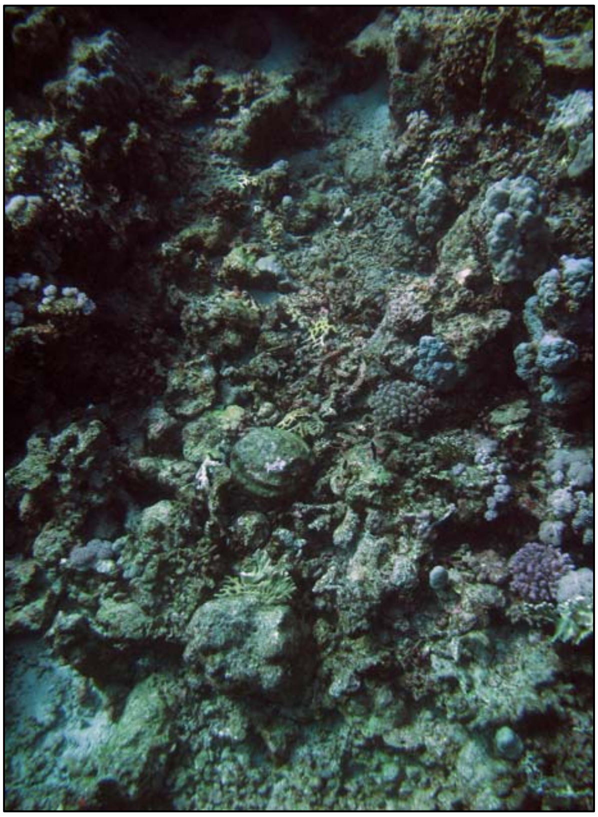

Figure 10: Reef slope section with much coral rubble close to start points of transects at site ML-A

Hence, a correlation of this damage to diving activities surely cannot be excluded, but natural physical damage seems to be more likely. Wave energy seems to be quite high in that area. Further, we observed certain cross-sections with high coral rubble and broken corals just few meters wide dragging down the reef slope (see Figure 10 and Table 13). The most affected genus was *Acropora* spp., but this genus was the most common and dominant genus as well (compare 4.2.3.).

Table 13: Pooled coral damage data for all transects. *Millepora was not counted as branching corals.

	Type	Total	Mean	SD
Coral colonies per 80 m²	*Acropora* spp.	887	37,0	14,7
	Pocillopora spp.	666	27,8	18,4
	Stylophora spp.	55	2,3	2,6
	Seriatopora spp.	1	0,0	0,2
	Millepora spp.*	215	9,0	6,8
Breakage - damaged colonies	< 25 %	33	1,4	1,4
	25 - 50 %	6	0,3	0,7
	50 - 75 %	1	0,0	0,2
	75 - 100 %	2	0,1	0,3
	Detached colony	10	0,4	0,7
Kind of damaged colonies	*Acropora* spp.	26	1,1	1,2
	Pocillopora spp.	10	0,4	0,6
	Stylophora spp.	3	0,1	0,4
	Seriatopora spp.	0	0,0	0,0
	Millepora spp.	12	0,5	0,9
	Porites spp.	0	0,0	0,0
	Other	0	0,0	0,0
Predation (impacted colonies)	*Drupella* spp.	116	4,8	3,7
	Coralliophila spp.	12	0,5	1,2
	Acanthaster planci	0	0,0	0,0
	Parrotfish	16	0,7	1,0
Kind of impacted colonies (Predation)	*Acropora* spp.	87	3,6	2,3
	Pocillopora spp.	22	0,9	1,6
	Stylophora spp.	4	0,2	0,4
	Seriatopora spp.	0	0,0	0,0
	Millepora spp.	0	0,0	0,0
	Porites spp.	27	1,1	1,8
	Other	2	0,1	0,4

Predation by the corallivorous gastropod *Drupella* spp. was prevailing with a total number of 116 colonies affected, on average 4.8 per 100 m². This coral-eating snail feeds exclusively on branching corals. Colonies infested by the second coral-eating snail, *Corallophila* spp., were just scarcely found. This snail feeds exclusively on pore corals *Porites* spp. where 12 sparsely populated colonies were found (see Table 13 and Table 14). The percentage of branching corals affected by coral-feeders was low and ranged from 0.64 % to 1.84 %.

Apart from the damage and predation, the coral population was healthy as no coral diseases were observed within the surveyed area.

Table 14: Results of the coral damage surveys pooled for depths and sites.

Site / Depth	A	B	15 m	10 m	5 m
Coral Damage - Branching coral	0,63%	0,36%	0,47%	0,50%	0,51%
Coral Predation - Branching corals	1,43%	1,50%	1,98%	0,72%	1,71%
Predation & Damage	2,06%	1,87%	2,45%	1,22%	2,21%
Rubble (RB)	6,25%	6,67%	10,32%	7,19%	1,88%
Mean Damage (0-5)	1,8	2,6	2,0	2,6	1,9
Coral Damage (No. of colonies)	32	20	10	19	23
Coral Predation (No. of colonies)	75	69	54	25	65
Branching Coral Population, extrapolated (No. of colonies)	1278	1403	878	1435	1710

4.1.4. Substrate

The live hard coral cover (HC) of the fringing reef along Kalawy Bay ranged from 17.5 % to 45.0 % (on 20 m transects), with an average of 32.5 %. The live soft coral cover (SC) found was between 2.5 % and 27.5 %, with an average of 13.9 %. The average cover of total live corals (HC+SC) was 46.4 %. Almost the same percentage (47.3 %) was found for the category rock consisting of old reef carbonate. The fraction of recently killed corals (RKC) was low with an average of 0.7 %. Sponges and “Other” were not common with 0.3% each (see Figure 11). A summary of mean percentages and standard deviations for all 10 Reef Check categories are given in Table 15.

The corresponding results for the extended Reef Check categories are represented in Table 14. Results of the category Rock (RC) differs in the extended protocol compared to the standard protocol in that coralline algae (CA) and dead corals (DC) are separate, while counted as rock (RC) in the standard protocol.

Furthermore, the results show that the algal cover was altogether very low. Individual areas with recognizable turf algae were assessed (Table 16).

Table 15: Results of the substrate surveys with standard RC categories. Pooled data for 5 m and 10 m transects.

Category	Mean	SD	Min	Max
HC	32,5%	8,2%	17,50%	45,00%
RKC	1,1%	1,6%	0,00%	5,00%
SC	13,9%	8,5%	2,50%	27,50%
NIA	0,0%	0,0%	0,00%	0,00%
SP	0,0%	0,0%	0,00%	0,00%
RC	47,3%	6,5%	37,50%	60,00%
RB	4,5%	4,8%	0,00%	15,00%
SD	0,2%	0,6%	0,00%	2,50%
SI	0,0%	0,0%	0,00%	0,00%
OT	0,3%	1,3%	0,0%	5,0%

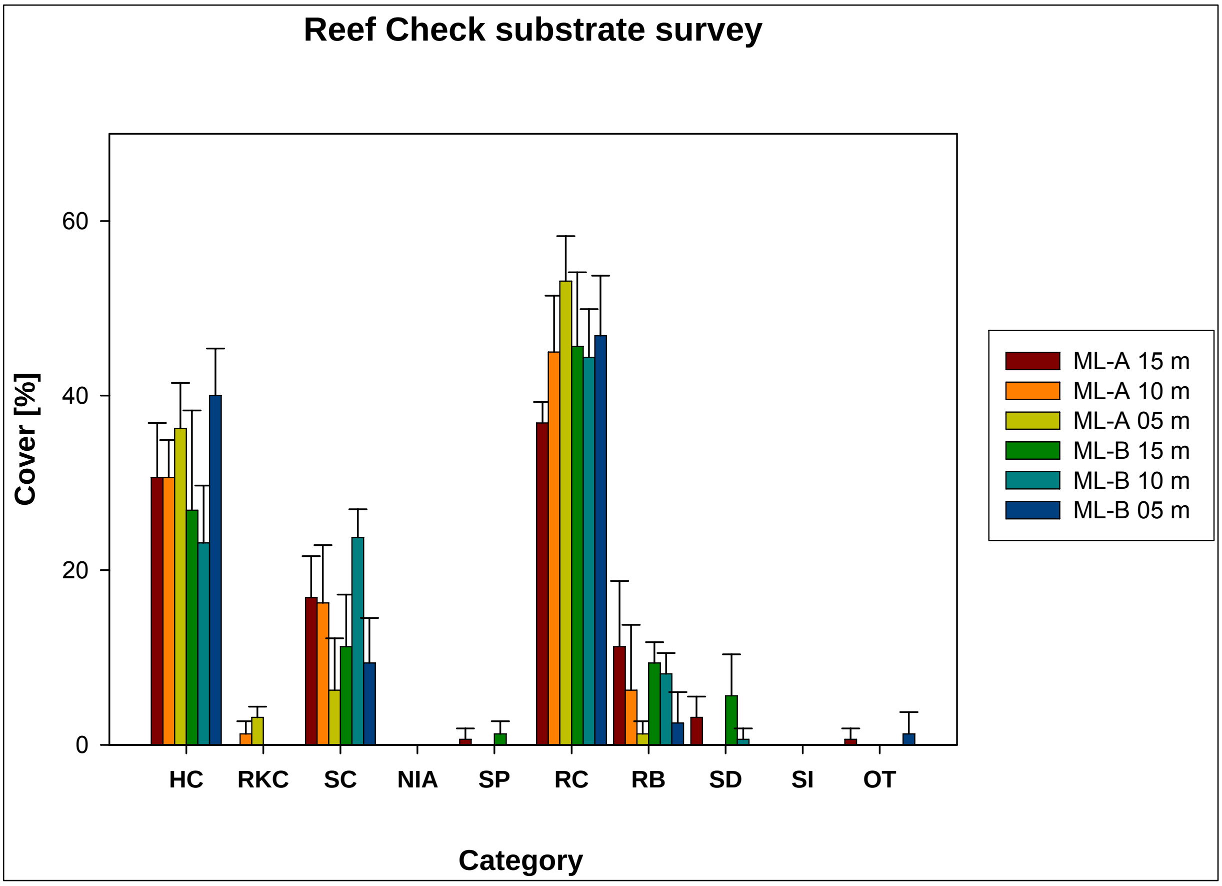

Figure 11: Percentage of standard RC categories for all transects.

Table 16: Results of the substrate surveys with extended RC categories. Pooled data for 5 m and 10 m transects.

Category	Mean	SD	Min	Max
AB	12,7%	6,4%	2,5%	25,0%
AD	1,1%	2,0%	0,0%	7,5%
AT	1,6%	2,9%	0,0%	10,0%
PM	3,9%	3,4%	0,0%	12,5%
PC	0,3%	1,3%	0,0%	5,0%
CB	6,6%	5,3%	0,0%	15,0%
CE	1,1%	1,6%	0,0%	5,0%
CF	0,0%	0,0%	0,0%	0,0%
CM	0,6%	1,4%	0,0%	5,0%
CS	1,1%	1,8%	0,0%	5,0%
CMR	0,0%	0,0%	0,0%	0,0%
CME	3,6%	3,0%	0,0%	7,5%
CTU	0,0%	0,0%	0,0%	0,0%
SC	3,4%	5,1%	0,0%	15,0%
SCX	10,5%	10,3%	0,0%	27,5%
SP	0,0%	0,0%	0,0%	0,0%
ZO	0,0%	0,0%	0,0%	0,0%
OT	0,3%	1,3%	0,0%	5,0%
AA	0,0%	0,0%	0,0%	0,0%
CA	0,5%	1,0%	0,0%	2,5%
HA	0,0%	0,0%	0,0%	0,0%
MA	0,0%	0,0%	0,0%	0,0%
FA	0,5%	1,4%	0,0%	5,0%
TA	1,4%	2,2%	0,0%	7,5%
DC	0,3%	0,9%	0,0%	2,5%
DCA	0,0%	0,0%	0,0%	0,0%
RKC	1,1%	1,6%	0,0%	5,0%
SD	0,2%	0,6%	0,0%	2,5%
RB	4,5%	4,8%	0,0%	15,0%
Si	0,0%	0,0%	0,0%	0,0%
Wa	0,2%	0,6%	0,0%	2,5%
RC	44,5%	7,4%	30,0%	57,5%

Acropora corals (AB) contributed the most to live coral cover with 12.7 % and soft corals of the family Xeniidae (SCX) with 10.5 % on average (Table 16). The results of the extended protocol show that the corals of the surveyed fringing reef area of Kalawy were primarily of the branching type. The branching corals had a total of 21.9% cover, 15.3%

being *Acropora* spp. corals. The sometimes dominating coral genus *Porites* spp. was comparably rare with 4.2 %. All other hermatypic corals added up to 6.4 %.

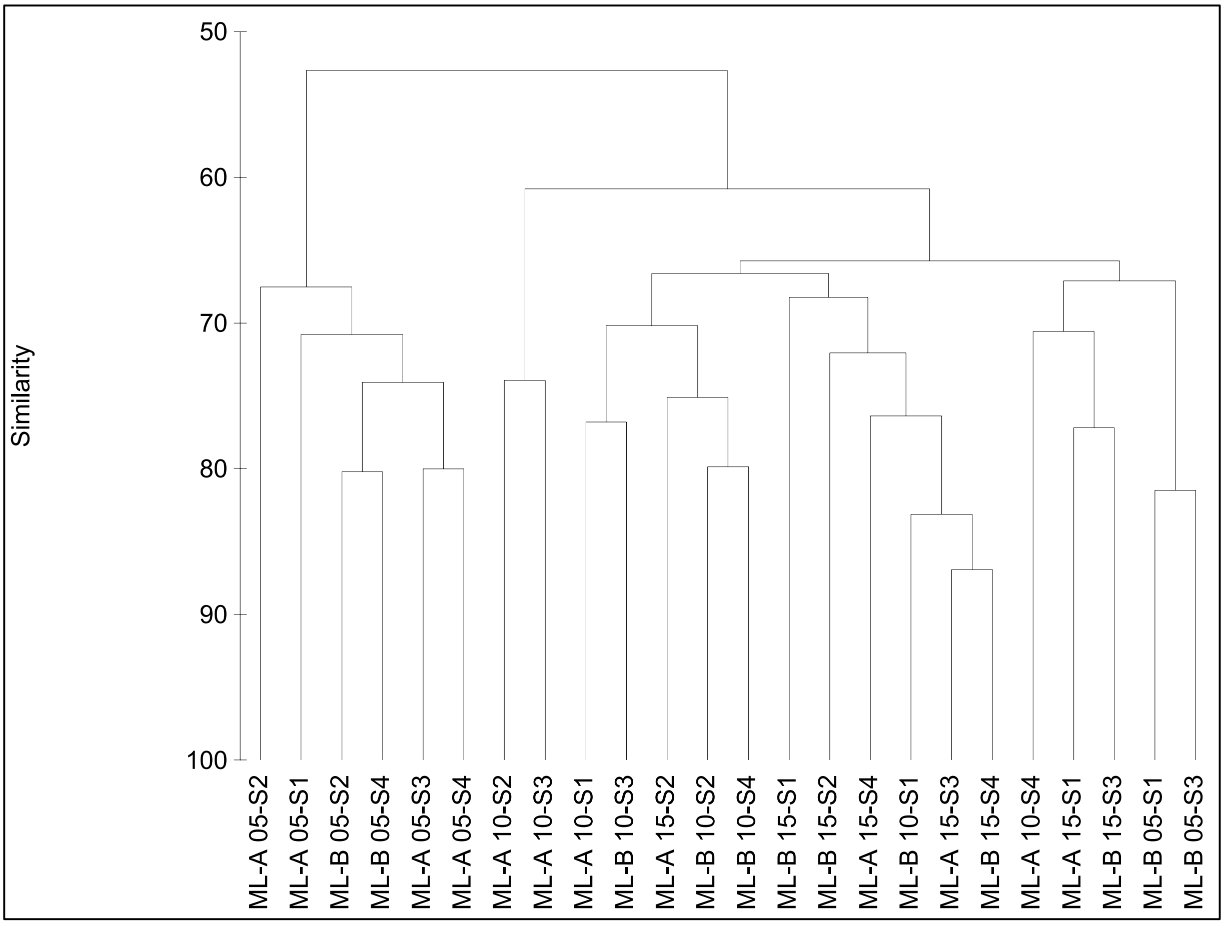

Figure 12: Results of the cluster analysis for the substrate survey.

Table 17: ANOSIM significance test for the Bray-Curtis-Similarity for the composition of transects for substrate cover (extended categories, $0,05 \geq p \geq 0,01$, $^{**}0,01 > p \geq 0,001$, $^{***}p < 0,001$).

	Transekte	Tiefe
Global *R*	0,554	0,595
P	0,001	0.001
significance level	**	**

The cluster analysis for the extended substrate categories resulted in 2 main groups (Figure 13). The first main group (left) includes six out of eight 5 m replicates (20 m each), The second main group (right) with its subcategories reveals no distinguished grouping. The ANOSIM significance test for the Bray-Curtis-Similarity allocates significant discrepancies for the depths but nor for the survey sites.

4.2. Diversity and abundance

4.2.1. Fish survey

A total of 9536 fishes were counted, consisting of 93 species of 63 genera and 23 families. The majority of fish belonged to the families Pomacentridae (Damselfishes, 46.5%) and Serranidae (Groupers, Soapfish & Anthiases, 35.1 %). For the latter just the subfamily Anthiinae (Anthiases) supplied 34.7 %. Other abundant families were the Labridae (Wrasses) with 4.1 % and Acanthuridae (Surgeonfishes) with 3.4 %.

Table 18: Total, absolute and relative abundance of 6 most abundant fish species of Kalawy Reef.

	Abundance				
Species	**Total**	**Mean**	**SD**	**absolute [Ind./m²]**	**relative [%]**
Pseudanthias squamipinnis	3310	551,67	342,78	1,38	34,7
Chromis dimidiata	1983	330,50	264,27	0,83	20,8
Neopomacentrus miryae	803	133,83	188,37	0,33	8,4
Amblyglyphidodon indicus	490	81,67	64,14	0,20	5,1
Chromis viridis	340	56,67	60,30	0,14	3,6
Pomacentrus sulfureus	284	47,33	34,83	0,12	3,0

The by far most abundant species was *Pseudanthias squamipinnis* (Lyretail anthias, Plate 1, page 77) with 34.7 %, followed by *Chromis dimidiata* (Half-and-half chromis) with 20.8%, *Neopomacentrus miryae* (Miry's demoiselle) with 8.4%, *Amblyglyphidodon indicus* (Pale damselfish) with 5,1% and *Chromis viridis* (Blue-green chromis) with 3,6%. The six most abundant fish species are shown in Table 15. The complete list is given in Table 36 in the appendix

The distribution of fish numbers between the sites ML-A and ML-B differed strongly. ML-B showed almost double the number of individuals (6346) compared to ML-A (3190) for pooled data. On the 15 m and 10 m transects the numbers were even more than double between the sites. Corresponding to depth most fish were counted on 10 m. The ML-B 10 m showed the highest fish abundance of all transects.

Table 19: Fish diversity of Kalawy Reef.

	Species		Individuals		Genera	
Family	**total**	**in percent**	**total**	**in percent**	**total**	**in percent**
Labridae	18	19,4%	389	4,1%	15	23,8%
Pomacentridae	12	12,9%	4429	46,4%	7	11,1%
Chaetodontidae	8	8,6%	192	2,0%	2	3,2%
Acanthuridae	7	7,5%	324	3,4%	4	6,3%
Scaridae	7	7,5%	66	0,7%	5	7,9%
Serranidae	6	6,5%	3344	35,1%	4	6,3%
All families (total)	93		9536		63	

Most of the 93 species recorded for the Kalawy sites were Labridae (Wrasses; 19.4%, 18 species), Pomacentridae (Damselfishes; 12.9 %, 12 species), Chaetodontidae (Butterflyfishes 8.6 %, 8 species), Acanthuridae (Surgeonfishes; 7.5 %, 7 species), Scaridae (Parrotfishes; 7.5 %, 7 species) and Serranidae (Grouper; 6.5 %, 6 species). A short summary of fish diversity is given in Table 19. Comparative values concerning the fish diversity of other coral reefs in the Red Sea are provided in Table 21. By means of Species Richness [S], the pooled number of species from sites ML-A (76 species) and ML-B (75 species) was similar.

Table 20: Diversity indices for fish assemblages of Kalawy Reef.

Site / depth	**A**	**B**	**15 m**	**10 m**	**5 m**
Individuals	3190	6346	3265	3608	2663
Species Richness [S]	76	75	66	68	65
Shannon-Wiener Index H'	2,48	2,03	2,25	2,29	2,23
Eveness E = H'/lnS	0,64	0,52	0,57	0,58	0,58

Common species in terms of frequency of appearance (FA=100, appearance in all 6 transects) were *Acanthurus nigrofuscus* (Dusky surgeon), *Ctenochaetus striatus* (Lined bristletooth), *Zebrasoma desjadinii* (Sailfin tang), *Zebrasoma xanthurum* (Yellowfin tang), *Chaetodon austriacus* (Polyp butterflyfish), *Chaetodon paucifasciatus* (Redback butterflyfish), *Heniochus intermedius* (Red Sea bannerfish), *Paracirrhites forsteri* (Freckled hawkfish), *Labroides dimidiatus* (Bluestreak cleaner wrasse), *Thalassoma rueppellii* (Klunzinger's wrasse), *Centropyge multispinis* (Dusky angelfish), *Amblyglyphidodon indicus* (Pale damselfish), *Chromis dimidiata* (Half-and-half chromis), *Pomacentrus sulfureus* (Sulphur damsel), *Pseudochromis fridmani* (Orchid dottyback), *Priacanthus hamrur* (Crescent-tail bigeye), *Pseudanthias squamipinnis* (Lyretail anthias) and *Rhinecanthus assasi* (Picasso triggerfish).

Table 21: Comparison of fish diversity of Kalawy reef with diversity of other coral reefs in the Red Sea. Contributions of fish families to the total diversity in percent. To increase the comparability, data from the 15 m transects is not included. 1this study, 2Kochzius (2007), 3Zajonz et al. unpublished data, 4Schraut (1995)

place	Labridae	Pomacentridae	Chaetodontidae	Scaridae	Acanthuridae	Serranidae
Kalawy[1]	19,8	10,5	9,3	8,1	7,0	7,0
El Quadim Bay[2]	17,5	9,7	5,2	5,2	5,8	9,1
Dahab[3]	13,7	11,9	5,4	3,6	5,4	7,7
Sharm El Sheikh[4]	14,8	10,2	5,1	4,0	4,5	6,3

In contrast, 31 species were just encountered on either one of the sites. At site ML-A, 16 individual species appeared and 15 at site ML-B. Within the transects the species richness had a range from 42 to 56 with a total abundance range from 976 to 2632 individuals. The Shannon-Wiener diversity index (ln basis) ranged from 1.98 to 2.58. A summary of diversity indices is listed in Table 20. In spite of the big discrepancies in abundance between ML-A and ML-B no significant differences between survey sites or depths were found.

Table 22: Comparison of the Relative Abundances of the most common species of Kalawy reef with different coral reefs in the Red Sea. To increase comparability, data from the 15 m transects is not included. 1this study, 2Kochzius (2007), 3Khalaf & Kochzius (2002).* Data not available.

Art	Kalawy[1]	El Quadim Bay[2]	Marine Science Station[2] (Jordan)
Pseudanthias squamipinnis	30,6	32,5	24,1
Chromis dimidiata	25,6	44,9	5,6
Neopomacentrus miryae	6,2	*	6,2
Amblyglyphidodon indicus	4,5	*	0,5
Chromis viridis	4,5	3,6	1,6

4.2.2. Mollusc diversity

A total of 39 mollusc species was found within the sites ML-A and ML-B. This number can be divided into 7 different bivalves and 32 gastropod species. In this section the most common species found within the surveyed transects will be presented. A summary of mollusc diversity for several taxonomic groups is given in Table 23.

Table 23: Summary of mollusc diversity and total abundance at Kalawy.

Taxonomic group	Species	Percent	Individuals	Percent
BIVALVIA	7	18,0%	685	63%
GASTROPODA	32	82%	402	37%
CEPHALASPIDEA	2	5.1%	4	0,4%
NUDIBRANCHIA	8	20,5%	12	1,1%
ARCHAEOGASTROPODA	3	7,7%	35	3,2%
MESOGASTROPODA	9	23,1%	134	12,3%
NEOGASTROPODA	10	25,6%	217	20%
TOTAL	**39**		**1087**	

Within the bivalve shells the coral scallop (*Pedum* spondyloideum, Plate 2, page 79) had the highest abundance with an average of 17.3 individuals per 100 m². The abundance ranged between 29.8 individuals per 100m² at 10 m depth and 2.3 individuals per 100 m² at 5 m depth. Most coral scallops were counted at 10 m depth. The results show dissimilarity in abundance between sites ML-A and ML-B. The coral scallop was much more abundant at site ML-B (Table 24).

Table 24: Abundance of bivalve shells sorted by transects.

Abundance - sorted [Individuals/100 m²]							
BIVALVIA	**A5**	**A10**	**A15**	**B5**	**B10**	**B15**	**TOTAL**
Pedum spondyloideum	2,3	18,0	16,3	13,0	29,8	24,8	17,3
Tridacna spp.	9,8	10,5	3,0	2,3	5,5	2,8	5,6
Streptopinna saccata	4,8	1,3	2,3	3,5	2,5	1,5	2,6
Pteria aegyptiaca	1,3	1,0	0,0	3,0	3,3	0,3	1,5

The Giant clams (*Tridacna* spp.) showed the opposite pattern and were more than twice as abundant at site ML-A than ML-B. The average abundance of *Tridacna* spp. was 5.6 individuals per 100m². The highest abundance was on the 10 m transects at both sites.

The Coral pen shell (*Streptopinna saccata*) had an average of 2.6 individuals/100 m², while the Red Sea wing oyster (*Pteria aegyptica*) had an average of 1.5 individuals/100 m². The abundance did not vary greatly at different depths. Within transect A15 no individual of *Pteria aegyptica* was counted. The average abundance of bivalve shells for all transects is shown in Table 24.

Table 25: Abundance of gastropods at Kalawy Reef.

	Abundance - sorted [Individuals/100 m²]						
GASTROPODA	**A5**	**A10**	**A15**	**B5**	**B10**	**B15**	**TOTAL**
Coralliophila violacea	5,3	1,5	4,0	2,8	3,8	1,3	3,0
Drupa ricinus	6,0	0,5	2,0	3,8	3,0	0,8	2,7
Vermetus adansoni	2,8	1,0	3,0	1,5	6,5	1,0	2,6
Drupella cornus	3,3	1,0	3,0	2,0	2,8	1,5	2,3
Latrius turritus	1,0	1,0	2,0	3,0	1,8	2,5	1,9
Serpulorbis imbricatus	1,3	0,8	1,0	1,3	1,5	0,3	1,0

The gastropod Purple coral snail (*Coralliophila violacea*) had the highest average abundance with 3.0 individuals/100m². The abundance ranged between 5.3 individuals/100 m² at 5 m depth and 1.3 individuals/100 m² at 15 m depth. *Coralliophila violacea* was more abundant at site ML-A than at ML-B. Hence, distribution pattern was variable between sites. The highest abundance at site ML-A was at 5 m and 15 m, while at site ML-B it was at 10 m. At site ML-A the abundance seems to be correlated with cover of its prey coral *Porites* spp. However, at site ML-B no pattern was detectable.

The Prickly drupe (*Drupa ricinus*) was the second most abundant species with 2.8 individuals/100 m². The distribution pattern was very variable with a tendency of increasing numbers towards shallow depths. The largest number of Prickly drupes was found at 5 m with 6 individuals/100 m².

The Adanson's Worm shell (*Vermetus adansoni*) had an average abundance of 2.6 individuals/100 m², while the Horn drupe (*Drupella cornus*) had an average abundance of 2.3 individuals/100 m². *Vermetus adansoni* showed a great variation in abundance within transects ranging from 1 individual/100m² to 6.5 ind./100 m².

Latrius turritus had an average abundance of 1.9 individuals/100 m² while the Scaled Worm shell (*Serpulorbis imbricatus*) had an average abundance of 1 individual/100 m². The average abundance of gastropod shells for all transects is shown in Table 25.

Table 26: Abundance of gastropods at Kalawy Reef. Average abundances for survey sites and depths in individuals/100 m^2

Species	ML-A	ML-B	15 m	10 m	5 m
Pedum spondyloideum	12,2	22,5	7,6	23,9	20,5
Tridacna squamosa	7,8	3,5	6,0	8,0	2,9
Streptopinna saccata	2,8	2,5	4,1	1,9	1,9
Pteria aegyptiaca	0,8	2,2	2,1	2,1	0,1
Coralliophila violacea	3,6	2,6	4,0	2,6	2,6
Drupa ricinus	2,8	2,5	4,9	1,8	1,4
Vermetus adansoni	2,3	3,0	2,1	3,8	2,0
Drupella cornus	2,4	2,1	2,6	1,9	2,3
Latrius turritus	1,3	2,4	2,0	1,4	2,3
Serpulorbis imbricatus	1,0	1,0	1,3	1,1	0,6

The cluster analysis on the composition of the mollusc population (Figure 13) shows the following order: One group consists of the deep sites (15 m transects) and one of the 5 m and 10 m transects. Within the latter ML-A and ML-B are grouped, with ML-B showing the highest similarity. Thus, the cluster analysis provides evidence for a clear distinction of the mollusc population among depths and survey sites. The result of the ANOSIM test could not be used for a statement.

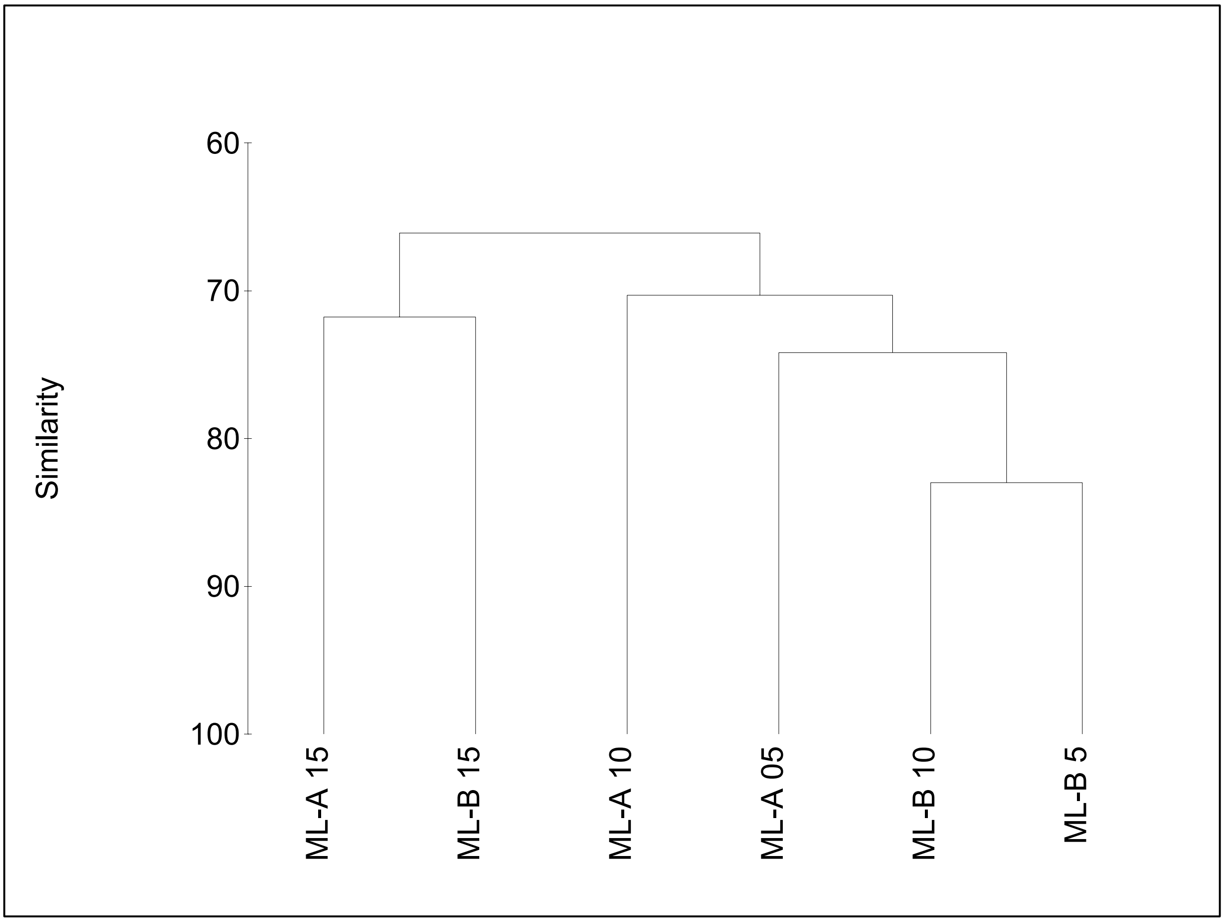

Figure 13: Results of the cluster analysis for the composition of mollusc fauna.

4.2.3. Coral survey

Within the study sites (2400 m²) a total of 129 species of reef-building corals were identified. The majority was stony corals with 125 species (Class: Anthozoa, Order Scleractinia). Most of these species belonged to the family Faviidae (29.5 %, 38 species) followed by the Acroporidae (21.7 %, 28 species) and the Poritidae (9.3 %, 12 species). The 4 remaining species, considered as reef-building corals, were 3 species of fire corals (Class: Hydrozoa, Order: Leptolida) and the organ pipe coral *Tubipora musica* (Class: Anthozoa, Order: Alcyonacea).

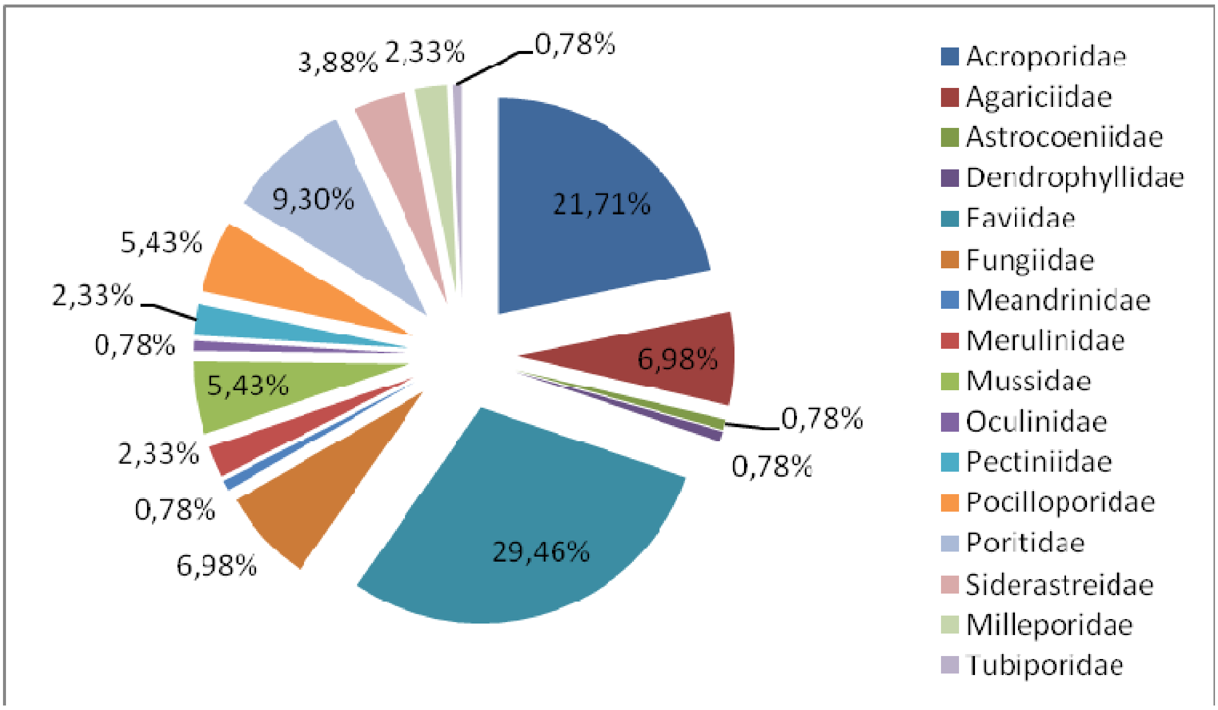

Figure 14: Diversity of hermatypic corals of Kalawy fringing reef, 129 species sorted by families.

The Species Richness [S] of reef-building corals per transect (400 m²) varied between 70 and 85 species with an average of 77.5. The highest number of species was found at site ML-A on the 15 m transect. On both sites the diversity increased with depth showing its highest values on the 15 m transects and lowest on the 5 m transects. Site ML-A showed a greater coral diversity on 15 m and 10 m than site ML-B. A total of 25 species were recorded within all 6 transects (FA= frequency of appearance=100), including the common staghorn coral species *Acropora eurystoma, Acropora secale, Acropora valida* and *Acropora variolosa*. Additionally, 18 species with appearance inside just one transect were found (FA= 16.7). 25 species were recorded within only two transects (FA= 33.3). For instance, *Acropora gemmifera* and *Acropora hyacinthus,* two shallow-water species, were only encountered within the 5 m transects. On the contrary, the faviid coral *Favia laxa* was found at 15 m and 10 m, but not inside the 5 m transects of both sites. The brain coral *Platygyra daedalea* was the only species found throughout site ML-A, but was not recorded at site ML-B. The diversity of hermatypic corals sorted by families is summarised in Figure 14. A complete species list sorted by families is provided in the appendix in Table 38 on page 74.

Table 27: Coral cover of common coral groups for all transects.

	Coral cover [%]					
	ML-A 15m	**ML-A 10m**	**ML-A 05m**	**ML-B 15m**	**ML-B 10m**	**ML-B 05m**
Hard corals (HC) Total	**30,6**	**31,3**	**36,9**	**26,9**	**23,1**	**40,0**
Acropora spp.	13,8	19,4	16,9	8,1	10,0	15,6
Montipora spp.	3,1	0,6	0,0	4,4	1,9	1,3
Pocillopora spp.	3,1	0,6	8,8	3,8	5,6	10,0
Stylophora spp.	0,0	0,0	0,0	0,6	0,0	0,0
Porites spp.	6,3	2,5	5,0	3,8	3,1	6,3
Millepora spp.	1,3	3,8	4,4	0,6	0,0	6,3
Faviidae	2,5	3,1	0,0	4,4	1,9	0,0
Hard corals (HC) Other	0,6	1,3	1,9	1,3	0,6	0,6
Soft corals (SC) Total	**16,9**	**16,3**	**6,3**	**11,3**	**23,8**	**9,4**
Xeniidae	15,0	13,8	0,0	9,4	23,8	3,8
Sinularia spp.	0,6	2,5	6,3	0,0	0,0	5,0
Rhytisma spp.	0,0	0,0	0,0	1,3	0,0	0,6
Klyxum spp.	0,0	0,0	0,0	0,0	0,0	0,0
Lithophyton spp.	0,6	0,0	0,0	0,0	0,0	0,0
Soft corals (SC) Other	0,6	0,0	0,0	0,6	0,0	0,0

Table 28: Diversity indices of hermatypic corals resulting from the point-intercept method.

Site	**ML-A 15m**	**ML-A 10m**	**ML-A 05m**	**ML-B 15m**	**ML-B 10m**	**ML-B 05m**
Points (n=)	48	50	59	41	37	64
Cover [%]	30,6	31,3	36,9	26,9	23,1	40,0
Species Richness [S]	17	17	16	18	12	20
$H' = -\Sigma\ pi\ ln\ pi$	2,18	1,96	2,35	2,21	2,20	2,49
$J' = H'/lnS$	0,77	0,69	0,85	0,77	0,89	0,83

The substrate analysis using the point intercept method showed a Species Richness [S] = 40 species, ranging from 12 to 20 per survey (4 x 20 m, 160 points) with a mean value of 16.5. Minimum and maximum were found at site ML-B, the first at 10 m depth and the second within the 5 m transect. By contrast, Species Richness at site ML-A was similar throughout the depths with 16 to 17 species per transect. Yet at the same time the divergence in the number of sample points between the three transects was higher in ML-B than in ML-A (Table 28).

The Shannon-Wiener diversity index ranged from 1.96 to 2.49. Maxima at each site were on 5 m transects. Thus, Species Richness and Shannon-Wiener index indicate a structure of higher diversity in the shallower area. A summary of coral cover, Diversity indices and Species Richness for each transect is listed in Table 28.

The index J' (Evenness) showed values between 0.69 and 0.89 within the transects (4 x 20 m) with the maximum in ML-B 10 m and minimum in ML-A 10 m. The high value at ML-B 10 m indicates equal abundances and reflects the low Species Richness. The contributions of coral genera or groups shown in Table 27 reflect this difference. However, it has to be considered that soft corals were not included here. At ML-B 10 m only the family Xeniidae, which had the highest cover within soft corals, was recorded. The remaining transects also included other soft coral genera like *Sinularia* spp. or *Rhytisma* spp. Within the 5 m transects the contribution of Xeniidae was low to non-existent. Instead, *Sinularia* spp. appeared more frequently at this depth (Table 27).
Montipora spp. showed highest degree of coverage within 15 m transects, compared to *Pocillopora* spp., which contributed considerably to coral cover inside the 5 m transects. *Porites* spp. was represented within all transects but showed no dominance like it does in some reef areas. The family Faviidae was present with a substantial cover at 15 m and 10 m, while it was not detected with the point intercept method inside the 5 m transect. *Millepora* spp. had a high coverage only within the shallow transects. No relevant contributions to coral cover of the remaining hard corals were detected (Table 27).

Dominance

On species level the analysis resulted in following picture. Pooled over all transects the highest mean dominance was shown by *Acropora valida* (Plate 3, page 81) with 14.4 %, followed by *Pocillopora verrucosa* with 12 %, *Acropora variolosa* with 11.7 % and *Acropora secale* with 10.2 %. *Acropora valida* was the most dominant species within the 15 m transects and on transect ML-B 10 m. *Pocillopora verrucosa* was the most dominant species inside the 5 m transects while *Acropora secale* was the second most abundant here at both sites. *Acropora variolosa* showed a clear dominance inside the ML-A 10 m transect (Table 29). The dominant species of each transect are illustrated in Figure 15.

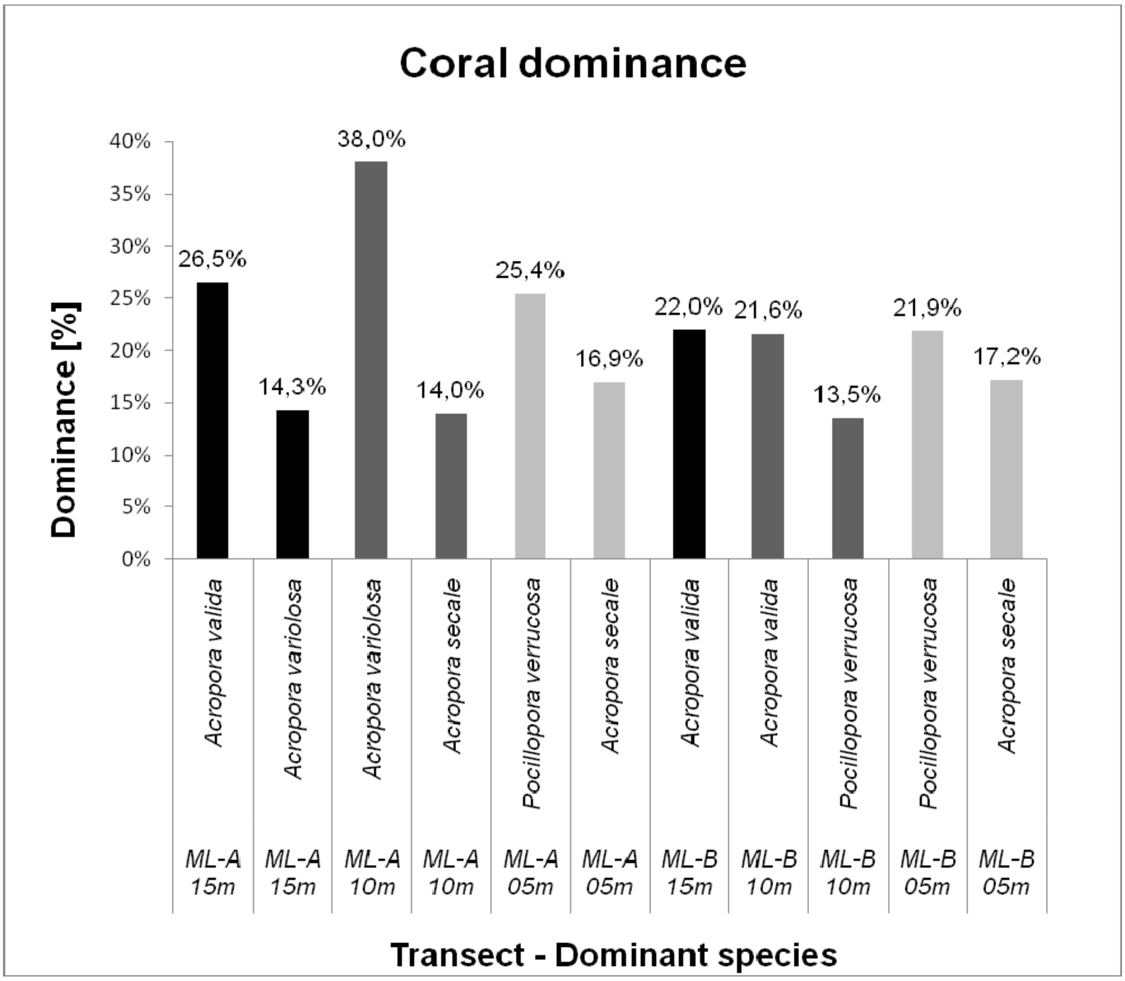

Figure 15: Dominant species and their dominance (in %) within surveyed transects.

Pooled for depths, the 15 m transects were dominated by *Acropora valida*, the 10 m transects by *Acropora variolosa* and the 5 m transects by *Pocillopora verrucosa* (Table 30). *Acropora secale* contributed considerably at 10 m and 5 m, with highest values for 5 m.

Table 29: Dominance of the 6 most abundant hard coral species of Kalawy Reef, listed by transects.

Species	ML-A 15m	ML-A 10m	ML-A 05m	ML-B 15m	ML-B 10m	ML-B 05m	Mean
Acropora valida	26,5%	8,0%	6,8%	22,0%	21,6%	1,6%	14,4%
Pocillopora verrucosa	4,1%	2,0%	25,4%	4,9%	13,5%	21,9%	12,0%
Acropora variolosa	14,3%	38,0%	1,7%	4,9%	8,1%	3,1%	11,7%
Acropora secale	0,0%	14,0%	16,9%	2,4%	10,8%	17,2%	10,2%
Porites nodifera	12,2%	2,0%	5,1%	7,3%	5,4%	7,8%	6,6%
Millepora dichotoma	2,0%	10,0%	8,5%	2,4%	0,0%	12,5%	5,9%

Table 30: Dominance of the 6 most abundant hard coral species of Kalawy Reef, listed by depth and site.

Species	A	B	15 m	10 m	5 m
Acropora valida	13,8%	15,0%	24,2%	14,8%	4,2%
Pocillopora verrucosa	10,5%	13,4%	4,5%	7,8%	23,6%
Acropora variolosa	18,0%	5,4%	9,6%	23,1%	2,4%
Acropora secale	10,3%	10,1%	1,2%	12,4%	17,1%
Porites nodifera	6,4%	6,8%	9,8%	3,7%	6,4%
Millepora dichotoma	6,8%	5,0%	2,2%	5,0%	10,5%

In summary, the surveyed reef sites were clearly dominated by branching corals. These consist primarily of three species of Staghorn corals (genus Acropora) and *Pocillopora verrucosa*. The predominant growth form was branching; other growth-forms (e.g. columnar or massive) were rather uncommon.

4.3. General observations

4.3.1. Entrance area

The inspection of the area around the entrance point of the jetty of the Magic Life complex yielded some changes of the corals in that area, which can probably be referred to this construction event.

On one hand we recorded a few heavily damaged respectively segregated coral colonies (Figure 16 A). On the other hand some of the corals which grew underneath the jetty platform showed different stages of bleaching (Figure 16 B+C). These were mainly colonies of the common Raspberry coral *Pocillopora verrucosa* (Figure 16 D). In the deeper area off the coast, in one line with the jetty, some big massive or columnar blocks of pore corals *Porites* spp. were found. Some of these also showed different stages of bleaching or dead parts where the white skeleton was clearly visible or that were already slightly overgrown with algae. One colony of the pore coral *Porites lutea* with a diameter of more than one meter had already died off completely.

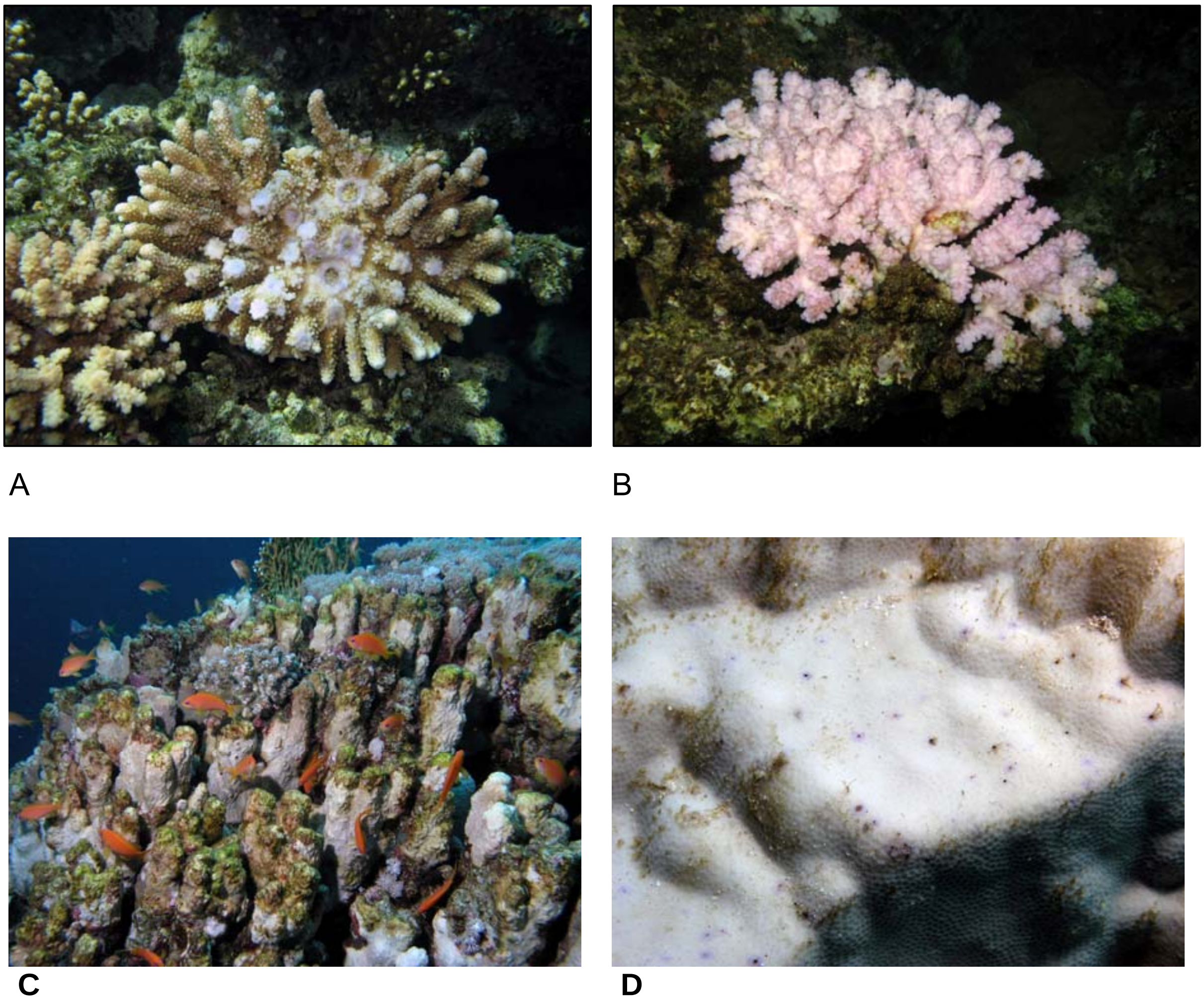

Figure 16: Observed A) coral damage, B) advanced state of coral bleaching, C) and D) died-off parts, partially covered with algae, in the vicinity of the entrance point.

4.3.2. Census surveys and observations at the lagoon

Two coral blocks (Figure 17 A) and an approximately 25 m^2 large area of stones and rocks with diverse fish and invertebrate fauna were found at the centre of the lagoon. A large number of upside-down jellyfish (*Cassiopea andromeda*, Figure 17 B) was found in most of the lagoon. The turbidity of the water makes it difficult for swimmers and others to spot the jellyfish. This species lives its adult stadium upside-down and most of the time rests motionless on the bottom. In its typical upside-down position the jellyfish exposes its zooxanthellae (symbiontic, unicellular algae) to the sunlight giving it the characteristic name upside-down jellyfish. The sting of *Cassiopea* may cause symptoms like pain and skin rash. Upon large-scale contact it can even cause dizziness, headache, vomiting and blackouts. If these symptoms occur, the victims should directly leave the water and the nematocysts have to be removed. Medical care is advisable.

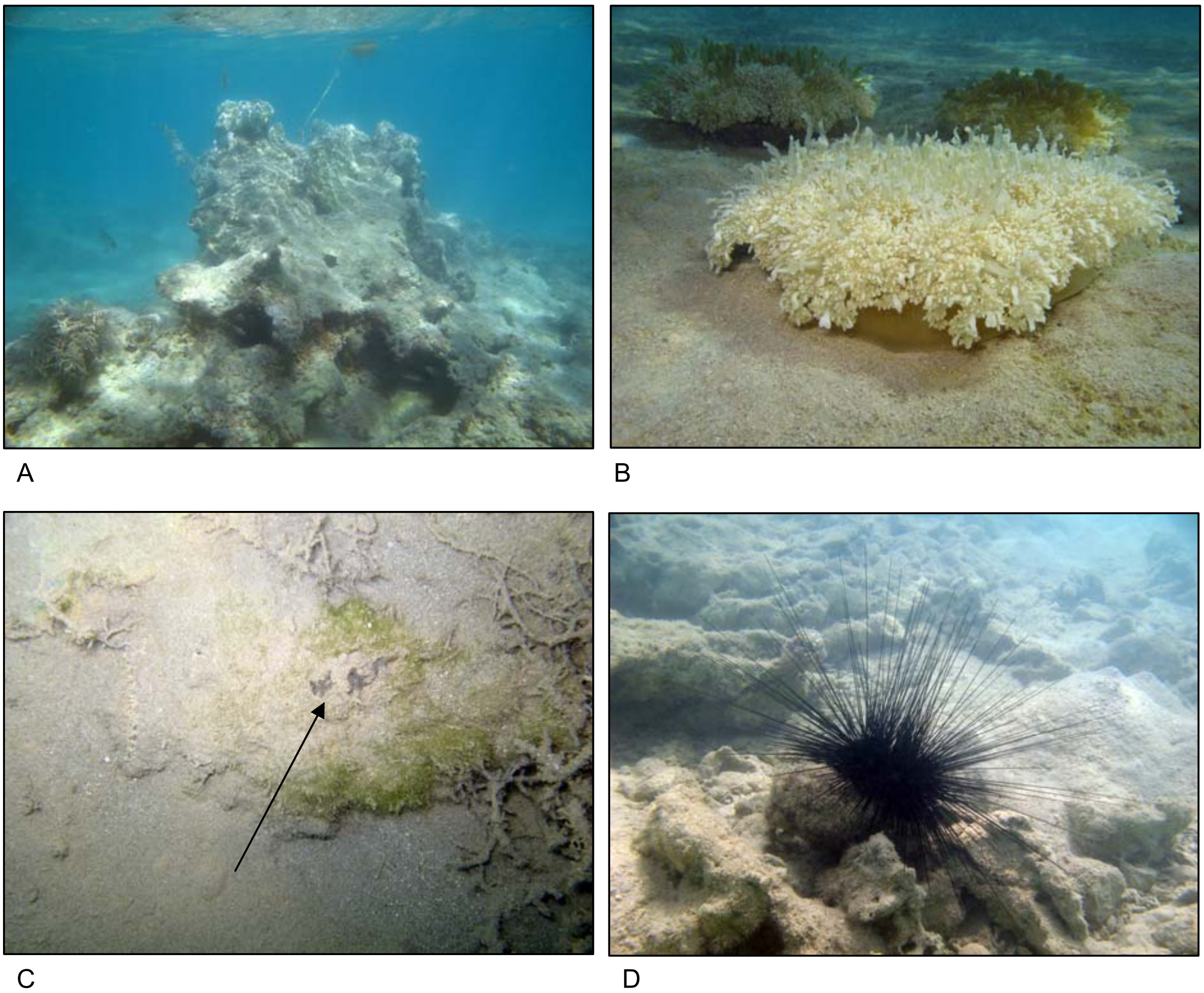

Figure 17: A) Coral block inside the lagoon. B) 3 upside-down jellyfish (*Cassiopea andromeda*) inside Kalawy lagoon. C) Stonefish (*Synanceia verrucosa*), who digged itself in. Arrow= Poisonous dorsal fin rays. D) 3 long-spined urchins (*Diadema paucispinum*) in the area with solid sediment (coral rubble).

As mentioned, upside-down jellyfish were found all over the lagoon, yet the abundance in the shallow parts was much lower than in deeper areas. The results of a quantitative analysis of the central area (excluding the shallow part) showed an abundance of 0.59 individuals per square meter (see Figure 18); this means about one jellyfish per two square meters. The maximum found was 1.28 upside-down jellyfish per square meter (32 jellyfish in 25 m²), the minimum 0.16 (3 jellyfish in 25 m²). The analysis of the size gave results ranging between 8 cm and 25 cm, with an average size of 18.76 cm (see Figure 19).

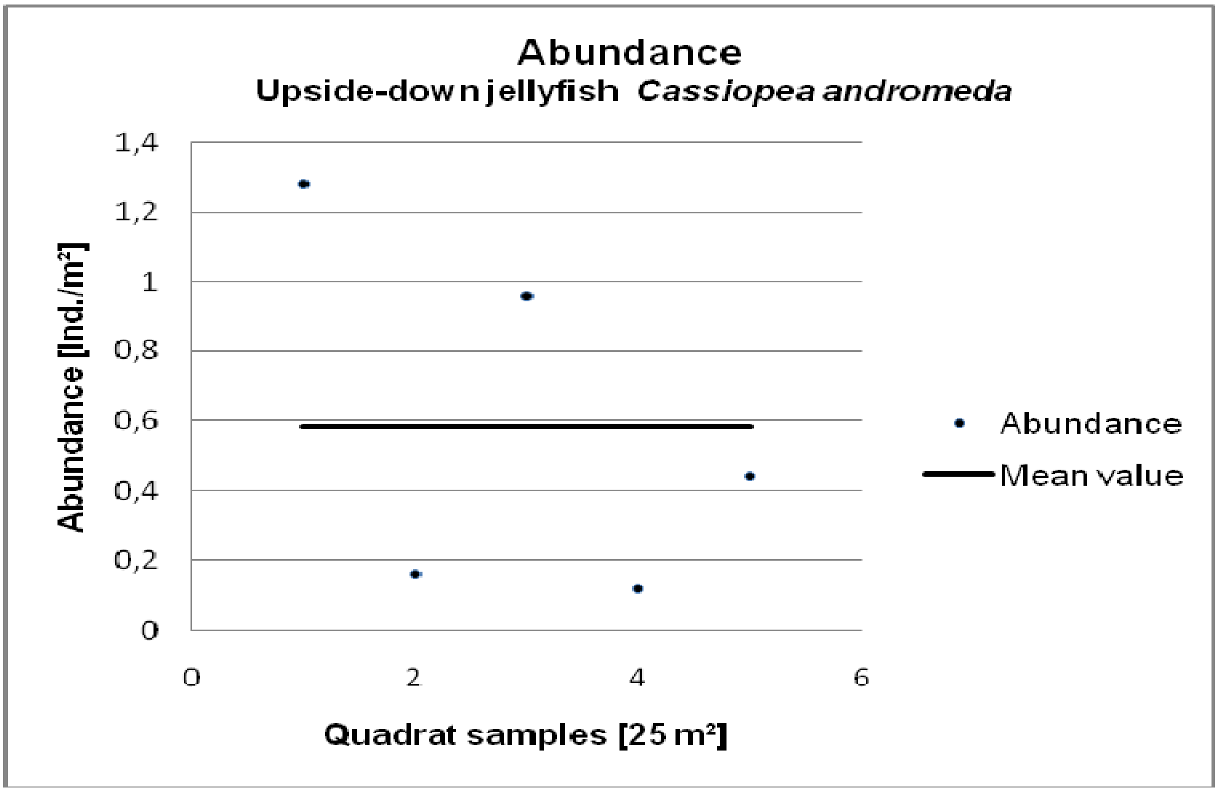

Figure 18: Abundance of the upside-down jellyfish (*Cassiopea andromeda*) in the Kalawy Lagoon. Frame = 5m x 5 m = 25 m², 5 counts.

Next to a great number of upside-down jellyfish, other potentially dangerous animals were found in the lagoon. These include stonefishes (*Synanceia verrucosa*, Figure 17 C) and long-spined urchins (*Diadema paucispinum*, Figure 17 D), both of which pose a potential threat to people.

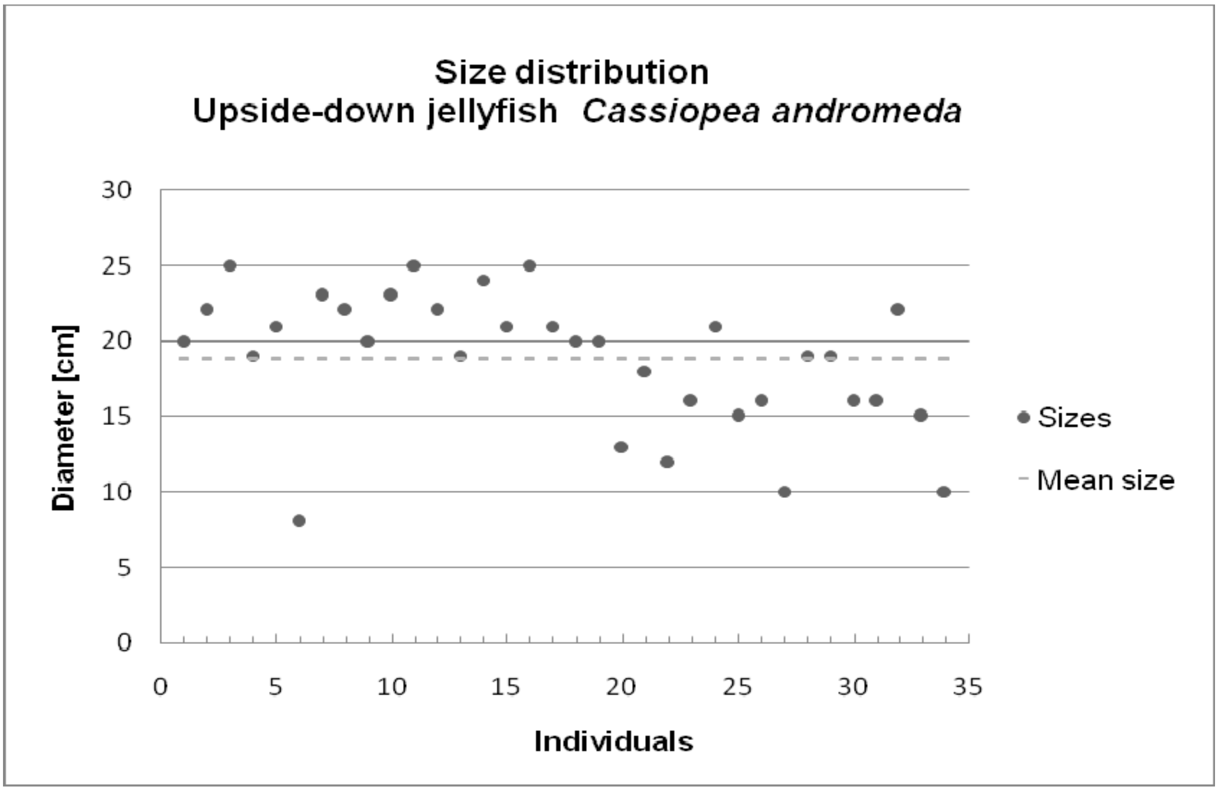

Figure 19: Size distribution of the Upside-down Jellyfish in the Kalawy lagoon. Diameter [cm] rund up on cm, sample n=34 jellyfish

In the area around the two coral blocks 22 fish species were identified and altogether 208 fish were counted. The majority of these were common silver-biddys (*Gerres oyena*) with an estimated 120 individuals. The second most abundant species was the pharao cardinalfish (*Apogon pharaonis*). It usually kept close to the blocks or to long-spined urchins. The results of the fish census survey are shown in Table 31.

Table 31: Number of counted and identified fish species in Kalawy lagoon.

Scientific name	Common name	Individuals
Gerres oyena	Common silver-biddy	120
Apogon pharaonis	Pharao cardinalfish	23
Neoniphon sammara	Spotfin squirrelfish	11
Gymnothorax griseus	Peppered moray	9
Pterois miles	Devil firefish	8
Istigobius decoratus	Decorated goby	5
Apogon cyanosoma	Yellow-striped cardinalfish	5
Amblygobius albimaculatus	Butterfly goby	3
Sebatapistes strongia	Barchin scorpionfish	3
Chaetodon auriga	Threadfin butterflyfish	2
Chaetodon fasciatus	Striped butterflyfish	2
Parupeneus forsskali	Red Sea goatfish	2
Arothron hispidus	Whitespotted puffer	2
Monodactylus argentus	Silver moony	2
Scolopsis ghanam	Arabian spinecheek	2
Synanceia verrucosa	Stonefish	2
Pomacentrus trilineatus	Threeline damsel	2
Canthigaster margaritata	Red Sea toby	1
Canthigaster coronata	Crowned toby	1
Heniochus intermedius	Red Sea bannerfish	1
Ostracion cyanurus	Bluetail trunkfish	1
Dendrochirus brachypterus	Shortfin turkeyfish	1

5. Discussion

5.1. Extended Reef Check

The extended Reef Check survey showed that the most abundant indicator fish was butterfly fish, followed by parrotfish. Unfortunately no large groupers were observed, but one giant moray was counted. Both sites and all depths were similar in composition and abundance of the invertebrate indicators. Long-spined sea urchins, giant clams and trochus shells were the only indicators present at all sites. The amount of trash under water was very low and only a few corals with damage were observed. Some coral predation by *Drupella* spp. and *Corallophila* spp. was recorded. Apart from the damage and predation, the coral population was healthy as no coral diseases were observed within the surveyed area. The percentage cover of live hard coral at Kalawy Bay was 32.5 %. The live soft coral cover was 13.9 %. The percentage cover of recently killed coral was low with an average of 0.7%. Branching Acropora was the most abundant hard coral type, while soft corals of the family Xeniidae were most abundant. Overall there were no exceeding deviant results compared to Reef Check data over the last years for this region.

The house-reef is in a healthy and normal condition and features the same diversity as other fringing reefs of the surrounding area (e.g. Safaga and El Quseir).

5.2. Diversity and abundance

5.2.1. Fish survey

The by far most abundant species in Kalawy Bay was lyretail anthias (Pseudanthias squamipinnis), followed by half-and-half chromis (Chromis dimidiata). In the nearby El-Quadim-Bay, in contrast, Chromis dimidiata shows a clearly higher abundance than Pseudanthias squamipinnis (Kochzius 2007). Pseudanthias squamipinnis is also the most common species in the protectorates of the Marine Biological Station of Aqaba, Jordan (Khalaf & Kochzius 2002b) and in the Sanganeb atoll in Sudan (Krupp et al. 1993). Here C. dimidiate is also the second most abundant species (Table 22).

With regard to the species richness Labridae (wrasses) and Pomacentridae (damselfish) are the predominant fish families of coral reefs in the Red Sea. The wrasses make up for the highest percentage of species in Kalawy, followed by the damselfish. The contingents of wrasses and damselfishes are even higher than in other locations like the El-Quadim-Bay (Kochzius 2007) or Sharm-El-Sheikh (Schraut 1995). Also the values for Chaetodontodae (butterfly fish), Acanthuridae (surgeonfish) and Scaridae (parrotfish) were slightly higher. The percentage of Serranidae is very similar to the values for Sharm-El-Sheikh (Schraut 1995), but lower than those for El-Quadim-Bay (Kochzius 2007). This high abundance indicates a prosperous reef regarding fish diversity and richness (Bshary 2003).
The abundance of fish in the surveyed area was higher north of the entrance than south of it. Concerning the depth the opposite pattern was observed, with the lowest (ML-A) and highest (ML-B) abundances at a depth of 10 m. Due to the small sample size at each depth and site, statistically based conclusions on abundances could not be determined.

5.2.2. Mollusc survey

Altogether 39 mollusc species, consisting of 9 bivalve and 32 gastropod species, were presented in this study. The number of species is certainly not complete, since many gastropod species are diminutive and/or cryptic. For their identification it would be necessary to take out individuals and have them analyzed by experts. The results of the cluster analysis show a relation between mollusc populations and depths and survey sites. The sites at depths of 5 m and 10 m are very similar to one another and seem to hold their own community structure. The same seems to apply to the transects at 15 m. Not enough data was collected to support these trends with scientifically significant results, yet this was also not the primary aim of this study.

5.2.3. Coral survey

129 species of hermatypic corals are growing along the reef slope of Kalawy lagoon, 125 of which are stony corals. The reef slope is mainly dominated by branching corals of the genera *Acropora* and *Pocillopora*. Data on species numbers for stony corals species

varies between 128 (Abou Zaid 2000) and 220 (Sheppard & Sheppard 1991) for the northern Red Sea. The results of the current Reef Check study are consistent with the results of Abou Zaid (2000), although in these studies only a defined area of the reef was surveyed. It is likely that not all species were recorded, since some species are restricted to certain depths or sites which were not examined here. A comparable study (Heiss et al. 2005) found 144 species of stony corals for El-Quadim-Bay near El Quseir, Egypt. A fraction of these species was found within the bay's protected areas. Furthermore, all reef areas down to a depth of 40 m were surveyed. The species growing in these zones are most likely present in Kalawy as well, yet these areas were not analysed. A comparison to other studies, which were also restricted to certain sites and depths, resulted in a different image. Riegl & Velimirov (1991) found 96 hard coral species (92 stony corals) for the region around Hurghada, and Loya & Slobodkin (1971) found 97 species (95 stony corals) for Eilat in the Gulf of Aqaba. These studies were based on the line-intercept-transect method and are not directly comparable. The point-intercept method, which was used for the present study, is not capable of determining species richness. It was rather used for an assessment of dominant species. It can be stated with certainty that the majority of hermatypic corals of the northern Red Sea can also be found in Kalawy.

5.3. General observations

5.3.1. Jetty area

It is understandable that construction activities that come along with tourism affect nature in some way. The construction of the jetty for divers and snorkelers is reasonable in that probably most impact on the reef occurs during entrance and exit. The changes in physical properties, especially by means of light and current, that took place due to the construction of the jetty and close by wave-breakers, can be observed on the impacted coral fauna. The currently observed and described symptoms should by all means be continuously monitored and documented.

5.3.2. Lagoon

Different animal and plant species inhabit the lagoon. Especially upside-down jellyfish are highly abundant and quite large in the lagoon. The sizes of the measured individuals were almost all considerably larger than maximum size given in the common reef guides (Lieske & Myers, Debelius). Coloration of tentacles of the upside-down jellyfish seems fairly variable. The two most abundant fish species in the lagoon did not appear at the reef. For some observed juvenile fish the lagoon seems to serve as nursery ground. Most of the juveniles were butterfly fish, but also a blackspotted rubberlip (*Plectorhinchus gaterinus*) used the rubble area in the central part of the lagoon for protection. There were some more species like Silver moony (*Monodactylus argenteus*), which only have been seen in the lagoon. These characteristics, the fine silt sediment and the topography indicate a high similarity to the local mangrove stocks.

5.3.2.1 Recommendations concerning the lagoon

We advise to put information boards along the beach. Like the pool rules, there should be rules for the use of the lagoon (for example: use shoes, don't touch anything, stay within the marked area, etc.). These information boards should also provide information about potentially dangerous animals and about other biological aspects of the lagoon. For potential incidents there should be an emergency plan prepared.

A marked snorkeling area would also increase safety. The area could be limited with an artificial barrier, locking up the potentially dangerous animals. This area could also be used to move the Upside-down jellyfish out of the very shallow swimming area. A natural barrier could at the same time be an artificial substrate for corals and other animals, therefore increasing the attractiveness of the snorkeling area.

During this study the team observed several hotel guests walking over the reef table. This reef walking destroys the reef and the guests risk harming themselves on the sharp and stinging coral. Therefore walking over the reef table without any previous information or guidance should be forbidden. Information boards could provide this information and a marked path to the other side of the lagoon should be installed. Clearly marked areas for snorkelers will reduce the impact on the reef. An information system according to the actual weather situation and about high and low tide is necessary and will increase safety. In addition, a Reef Guard could provide more information about the lagoon and the reef. A Reef Guard could guide tours and check for violations of the rules to protect the environment and therefore ensure the health status of Kalawy bay.

5.4. Conclusion and recommendations

A key to success for a sustainable and effective preservation of a house-reef also lies in an adequate education of diving instructors and dive guides of a diving centre. They act as a multiplier and convey their knowledge and skills to the recreational divers. It has been proven that a detailed dive briefing, in which also ecology, the dangers for coral reefs and baselines for a responsible behaviour underwater are conveyed, can significantly reduce the damage at the reef (Barker & Roberts 2004). Scuba divers tend to act like their diving instructors. This is a good opportunity for the diving instructors to act as examples for environment-friendly diving. It should be considered that every diving instructor and dive guide obtains an ecological education. Furthermore, briefings with instructions for an environment-friendly behaviour should be standardized. Such a briefing should also be addressed to snorkelers who rent their equipment at the diving centre.

Diving courses are usually carried out in marked areas of the lagoon or at the swimming pool. There is no explicitly marked section for courses at the house-reef. There should be agreements among diving instructors concerning which places the practices for the diving courses should take place. These areas should be clearly marked. Any practice of skills during the courses should be demonstrated at the lagoon or swimming pool. Thus, the sedimentation on the corals is minimized at the house-reef. With a clearly defined area for courses at the house-reef the impact through damaging contact by inexperienced divers can be reduced to a minimum.

The results of this study show that the populations of fish, corals, and molluscs are rich. The Kalawy house-reef is in a good general condition and exhibits only few examples of coral breakage. Very little trash was found. As mentioned a clean up was performed by the dive centre staff two months prior to the study. This is exemplary and we want to encourage the dive centre staff to proceed with regular clean up events and take care of their house reef. Thereby the diving guests learn to respect the underwater world, and through this the amount of future trash is reduced. Trash removal is the main benefit a reef area can get from being used as a dive site.

A measurable impact by scuba divers and snorkelers was not found. Here it must be accounted for that the house-reef has been used as a diving site for only two months. Since then more than 1,000 dives took place (an estimated 500 dives per month).

The observed impact on different coral colonies close to the entrance at the jetty should be continuously monitored and documented. To keep the Kalawy house-reef in a good condition for the future a well elaborated and planned use should be of priority. Clean-ups should take place on a regular basis as well as a yearly control with the Reef Check method. We want to encourage the use of adjacent reef areas with regard to the recommended Carrying Capacity (Hawkins & Roberts 1994) of 5,000-6,000 dives per year and per reef section. The amount of divers should be registered and limited at the different dive sites, especially if there are particular attractions (like the young White-tip Reef shark) to see. Thus it could be avoided that certain rare animals feel disturbed and leave the place.

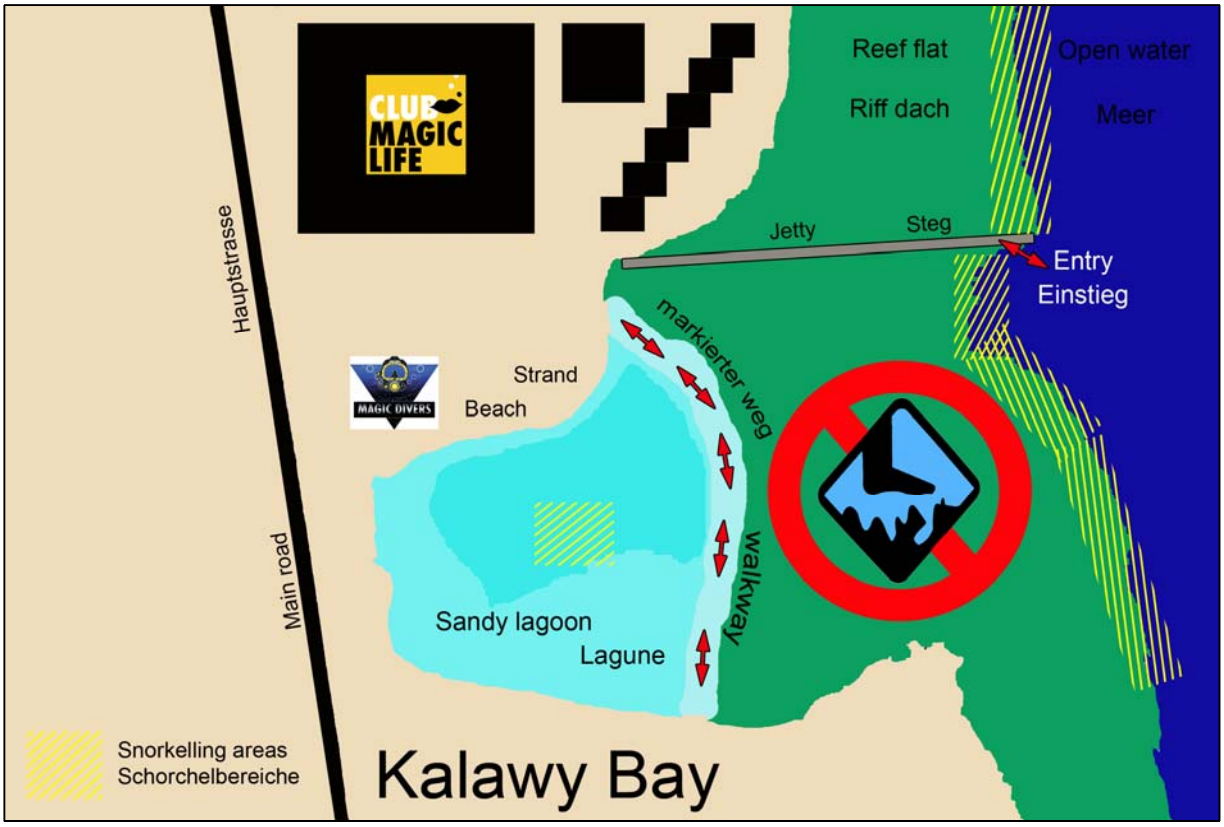

Figure 20: Suggestion for the declaration of different areas and rules (displayed snorkeling areas, “keep off the reef flat”-area, and marked walkway)

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7. Appendix

7.1. Tables

Table 32: Total number and mean abundance per 100 m² and standard deviation (SD) of fish indicators pooled for the 5 m, 10 m and 15 m transects. *Additional indicators are marked with an asterisk.

Indicator	**Total**	**Mean**	**SD**
Parrotfish >20cm (Scaridae)	108	4,5	2,8
Steephead parrot (*Clorurus gibbus*)*	0	0,0	0,0
Broomtail wrasse (*Cheilinus lunulatus*)	13	0,5	0,5
Humphead wrasse (*Cheilinus undulatus*)	1	0,0	0,2
Trevallies (Carangidae)*	0	0,0	0,0
Snapper (Lutjanidae)	5	0,2	1,0
Twinspot Snapper (*Lutjanus bohar*)*	2	0,1	0,3
Spangled emperor (*Lethrinus nebulosus*)*	3	0,1	0,4
Butterflyfish (Chaetodontidae)	272	11,3	5,4
Sweetlips (Haemulidae)	3	0,1	0,4
Grouper < 30 cm (Epinephilinae)*	8	0,3	0,8
Grouper > 30 cm (Epinephilinae)	1	0,042	0,2
Bluestreak cleaner wrasse (*Labroides dimidiatus*)*	105	4,4	2,7
"Farmer fish" (*Stegastes* spp. & *Plectroglyphidodon* spp.)*	8	0,3	0,8
Moray eels (Muraenidae)	1	0,0	0,2

Table 33: Pooled total number, mean abundance per 100 m² plus standard deviation (SD) of invertebrate indicators for 5 m, 10 m and 15 m transects. *Additional indicators are marked with an asterisk.

Indicator	**Total**	**Mean**	**SD**
Lobster (*Panulirus* spp.)	0	0,0	0,0
Slipper Lobster (*Scyllarides* spp.)*	0	0,0	0,0
Banded coral shrimp (*Stenopus hispidus*)	1	0,0	0,2
Long-spined urchins (*Diadem* spp. & *Echinotrix* spp.)	114	4,8	4,1
Pencil urchin (*Heterocentrotus mammillatus*)	8	0,3	0,9
Collector urchin (*Tripneustes gratilla*)	0	0,0	0,0
Sea cucumber (Holothuroidea)	0	0,0	0,0
Crown-of-thorns (*Acanthaster planci*)	0	0,0	0,0
Giant clam (*Tridacna* spp.)	135	5,6	4,6
Triton (*Charonia tritonis*)	0	0,0	0,0
Three-knobbed conch (*Strombis tricornis*)*	0	0,0	0,0
Common spider conch (*Lambis truncata sebae*)*	0	0,0	0,0
Trochus shells (*Tectus dentatus* & *Trochus maculatus*)	13	0,5	0,8
Reef octopus (*Octopus cyaneus*)*	0	0,0	0,0

Table 34: Results of the substrate surveys with standard RC categories. Pooled data for 5 m, 10 m and 15 m transects.

Category	Mean	SD	Min	Max
HC	31,3%	8,4%	10,0%	45,0%
RKC	0,7%	1,4%	0,0%	5,0%
SC	14,0%	7,6%	2,5%	27,5%
NIA	0,0%	0,0%	0,0%	0,0%
SP	0,3%	0,8%	0,0%	2,5%
RC	45,3%	7,3%	35,0%	60,0%
RB	6,5%	5,6%	0,0%	20,0%
SD	1,6%	2,9%	0,0%	12,5%
SI	0,0%	0,0%	0,0%	0,0%
OT	0,3%	1,1%	0,0%	5,0%

Table 35: Results of the substrate surveys with extended RC categories. Pooled data for 5 m, 10 m and 15 m transects.

Category	Mean	SD	Category	Mean	SD
AB	12,1%	6,1%	ZO	0,1%	0,5%
AD	0,7%	1,7%	OT	0,3%	1,1%
AT	1,0%	2,4%	AA	0,0%	0,0%
PM	3,5%	3,4%	CA	0,6%	1,1%
PC	0,9%	1,9%	HA	0,0%	0,0%
CB	5,6%	4,6%	MA	0,0%	0,0%
CE	2,1%	3,0%	FA	0,3%	1,1%
CF	0,0%	0,0%	TA	1,5%	2,1%
CM	1,1%	2,3%	DC	0,2%	0,7%
CS	1,0%	1,6%	DCA	0,0%	0,0%
CMR	0,3%	0,8%	RKC	0,7%	1,4%
CME	2,7%	2,9%	SD	1,6%	2,9%
CTU	0,0%	0,0%	RB	6,5%	5,6%
SC	2,8%	4,3%	Si	0,0%	0,0%
SCX	11,0%	9,2%	Wa	0,1%	0,5%
SP	0,3%	0,8%	RC	42,6%	8,3%

Table 36: Results of the fish census surveys in Kalawy, Safaga, Egypt. Data are sorted by Abundance and given as total abundance with mean values and standard deviation (SD) per transect (400 m²), relative abundance and abundance as individuals per 100 m².

				Abundance	
Species	**Total**	**Mean**	**SD**	**relative [%]**	**[Ind./ 100 m²]**
Pseudanthias squamipinnis	3310	551,67	342,78	34,7	138
Chromis dimidiata	1983	330,50	264,27	20,8	83
Neopomacentrus miryae	803	133,83	188,37	8,4	33
Amblyglyphidodon indicus	490	81,67	64,14	5,1	20
Chromis viridis	340	56,67	60,30	3,6	14
Pomacentrus sulfureus	284	47,33	34,83	3,0	12
Pomacentrus trichourus	250	41,67	41,63	2,6	10
Abudefduf vaigensis	240	40,00	74,57	2,5	10
Caesio suevica	177	29,50	31,54	1,9	7

	Abundance				
Species	**Total**	**Mean**	**SD**	**relative [%]**	**[Ind./ 100 m²]**
Pseudochromis fridmani	150	25,00	21,98	1,6	6
Zebrasoma desjadinii	140	23,33	23,90	1,5	6
Paracheilinus octotaenia	93	15,50	17,06	1,0	4
Labroides dimidiatus	83	13,83	10,36	0,9	3
Myripristis murdjan	81	13,50	25,01	0,8	3
Caesio striata	80	13,33	32,66	0,8	3
Thalassoma rueppellii	80	13,33	12,01	0,8	3
Ctenochaetus striatus	72	12,00	5,06	0,8	3
Neoniphon sammara	65	10,83	13,82	0,7	3
Chaetodon austriacus	56	9,33	4,97	0,6	2
Priacanthus hamrur	53	8,83	8,61	0,6	2
Chaetodon fasciatus	41	6,83	7,36	0,4	2
Chaetodon paucifasciatus	41	6,83	5,15	0,4	2
Paracirrhites forsteri	40	6,67	3,88	0,4	2
Zebrasoma xanthurum	39	6,50	2,43	0,4	2
Centropyge multispinis	36	6,00	3,22	0,4	2
Acanthurus nigrofuscus	34	5,67	8,57	0,4	1
Gomphosus caeruleus	31	5,17	2,79	0,3	1
Heniochus intermedius	29	4,83	1,83	0,3	1
Siganus luridus	26	4,33	5,09	0,3	1
Acanthurus sohal	20	3,33	5,32	0,2	1
Chromis flavaxilla	19	3,17	7,76	0,2	1
Calotomus viridescens	19	3,17	4,45	0,2	1
Bodianus anthioides	17	2,83	3,19	0,2	1
Scarus niger	16	2,67	1,86	0,2	1
Cephalopholis argus	16	2,67	1,86	0,2	1
Naso hexacanthus	14	2,33	5,72	0,1	1
Pygoplites diacanthus	13	2,17	1,47	0,1	1
Oxycheilinus digramma	11	1,83	1,17	0,1	0
Hipposcarus harid	11	1,83	1,72	0,1	0
Chaetodon semilarvatus	10	1,67	1,86	0,1	0
Anampses twistii	10	1,67	2,66	0,1	0
Pseudocheilinus hexataenia	10	1,67	4,08	0,1	0
Chaetodon auriga	9	1,50	0,84	0,1	0
Bodianus diana	9	1,50	2,74	0,1	0
Plectroglyphidodon lacrymatus	9	1,50	2,07	0,1	0
Cephalopholis miniata	9	1,50	1,38	0,1	0
Halichoeres hortulanus	8	1,33	1,21	0,1	0
Chlorurus sordidus	8	1,33	1,21	0,1	0
Scarus ferrugineus	8	1,33	1,37	0,1	0
Cheilinus lunulatus	7	1,17	1,17	0,1	0
Larabicus quadrilineatus	7	1,17	2,40	0,1	0
Parupeneus forsskali	7	1,40	1,14	0,1	0
Coris aygula	6	1,00	0,89	0,1	0
Lutjanus bohar	6	1,00	1,67	0,1	0
Grammistes sexlineatus	6	1,00	1,55	0,1	0
Rhinecanthus assasi	6	1,00	0,00	0,1	0
Naso elegans	5	0,83	2,04	0,1	0

			Abundance		
Species	**Total**	**Mean**	**SD**	**relative [%]**	**[Ind./ 100 m²]**
Pseudodax mollucanus	5	0,83	2,04	0,1	0
Pseudocheilinus evanides	5	0,83	2,04	0,1	0
Pseudodax moluccanus	5	0,83	1,17	0,1	0
Dascyllus trimaculatus	5	0,83	2,04	0,1	0
Pterois miles	5	0,83	0,98	0,1	0
Cirripectes castaneus	4	0,67	0,82	0,0	0
Caranx ignobilis	4	0,67	0,82	0,0	0
Chaetodon trifascialis	4	0,67	1,63	0,0	0
Lutjanus ehrenbergi	4	0,67	1,63	0,0	0
Macolor niger	4	0,67	1,03	0,0	0
Sufflamen albicaudatus	4	0,67	1,63	0,0	0
Pomacanthus imperator	3	0,50	1,22	0,0	0
Amblyglyphidodon flavilatus	3	0,50	1,22	0,0	0
Dascyllus marginatus	3	0,50	1,22	0,0	0
Pterois radiata	3	0,50	0,55	0,0	0
Ostracion cyanurus	3	0,50	0,55	0,0	0
Arothron diadematus	3	0,50	0,55	0,0	0
Sargocentron caudimaculatum	2	0,33	0,82	0,0	0
Chaetodon melannotus	2	0,33	0,82	0,0	0
Cetoscarus bicolor	2	0,33	0,52	0,0	0
Chlorurus gibbus	2	0,33	0,82	0,0	0
Cephalopholis hemistiktos	2	0,33	0,52	0,0	0
Ostracion cubicus	2	0,33	0,82	0,0	0
Arothron hispidus	2	0,33	0,82	0,0	0
Gymnothorax undulatus	1	0,17	0,41	0,0	0
Ecsenius dentex	1	0,17	0,41	0,0	0
Ecsenius gravieri	1	0,17	0,41	0,0	0
Plagiotremus rhinorhynchus	1	0,17	0,41	0,0	0
Plagiotremus townsendi	1	0,17	0,41	0,0	0
Cheilinus undulatus	1	0,17	0,41	0,0	0
Epibulus insidiator	1	0,17	0,41	0,0	0
Lethrinus borbonicus	1	0,17	0,41	0,0	0
Parupeneus cyclostomus	1	0,17	0,41	0,0	0
Pomacanthus maculosus	1	0,17	0,41	0,0	0
Plectropomus areolatus	1	0,17	0,41	0,0	0
Fistularia commersonii	1	0,17	0,41	0,0	0

Table 37: Fish diversity of Kalawy, Safaga, Egypt. Number of species and genera (total and in percent) for recorded fish families, as well as abundance (total number of individuals), abundance per 100 m² (100 m²) and relative abundance (RA).

Family	species	percent	genera	percent	ind.	percent	100 m²	RA
Labridae	18	19,35%	15	23,81%	389	4,08%	16,2	0,04
Pomacentridae	12	12,90%	7	11,11%	4429	46,45%	184,5	0,46
Chaetodontidae	8	8,60%	2	3,17%	192	2,01%	8,0	0,02
Acanthuridae	7	7,53%	4	6,35%	324	3,40%	13,5	0,03
Scaridae	7	7,53%	5	7,94%	66	0,69%	2,8	0,01
Serranidae	6	6,45%	4	6,35%	3344	35,07%	139,3	0,35
Blenniidae	5	5,38%	3	4,76%	8	0,08%	0,3	0,00
Pomacanthidae	4	4,30%	3	4,76%	53	0,56%	2,2	0,01
Holocentridae	3	3,23%	3	4,76%	148	1,55%	6,2	0,02
Lutjanidae	3	3,23%	2	3,17%	14	0,15%	0,6	0,00
Caesionidae	2	2,15%	1	1,59%	257	2,70%	10,7	0,03
Mullidae	2	2,15%	1	1,59%	8	0,08%	0,3	0,00
Scorpaenidae	2	2,15%	1	1,59%	8	0,08%	0,3	0,00
Balistidae	2	2,15%	2	3,17%	10	0,10%	0,4	0,00
Ostraciidae	2	2,15%	1	1,59%	5	0,05%	0,2	0,00
Tetraodontidae	2	2,15%	1	1,59%	5	0,05%	0,2	0,00
Muraenidae	1	1,08%	1	1,59%	1	0,01%	0,0	0,00
Carangidae	1	1,08%	1	1,59%	4	0,04%	0,2	0,00
Cirrhitidae	1	1,08%	1	1,59%	40	0,42%	1,7	0,00
Lethrinidae	1	1,08%	1	1,59%	1	0,01%	0,0	0,00
Pseudochromidae	1	1,08%	1	1,59%	150	1,57%	6,3	0,02
Priacanthidae	1	1,08%	1	1,59%	53	0,56%	2,2	0,01
Siganidae	1	1,08%	1	1,59%	26	0,27%	1,1	0,00
Fistulariidae	1	1,08%	1	1,59%	1	0,01%	0,0	0,00
Diversität	**93**	**species**	**63**	**genera**	**9536**	**fish**		

Table 38: Coral diversity: List of identified reef-building coral species in survey area in Kalawy, Safaga, Egypt. Species are grouped by coral families. All families belong to stony corals (Order: Scleractinia) except the ones marked with (*).

Hermatypic corals of Kalawy Reef		
Acroporidae	**Faviidae**	**Meandrinidae**
Acropora acuminata	*Cyphastrea chalcidicum*	*Gyrosmilia interrupta*
Acropora digitifera	*Cyphastrea hexasepta*	**Merulinidae**
Acropora eurystoma	*Cyphastrea microphthalma*	*Hydnophora exesa*
Acropora gemmifera	*Cyphastrea serailia*	*Hydnophora microconos*
Acropora hyacinthus	*Echinopora forskaliana*	*Merulina scheeri*
Acropora pharaonis	*Echinopora fruticulosa*	**Mussidae**
Acropora samoensis	*Echinopora gemmacea*	*Acanthastrea echinata*
Acropora secale	*Echinopora hirsutissima*	*Acanthastrea faviaformis*
Acropora selago	*Echinopora lamellosa*	*Blastomussa merleti*
Acropora squarrosa	*Favia danae*	*Blastomussa wellsi*
Acropora subulata	*Favia favus*	*Lobophyllia hataii*
Acropora valida	*Favia helianthoides*	*Lobophyllia hemprichii*
Acropora variolosa	*Favia laxa*	*Symphyllia erythraea*
Astreopora gracilis	*Favia matthai*	**Oculinidae**
Astreopora listeri	*Favia speciosa*	*Galaxea fascicularis*
Astreopora myriophthalma	*Favia pallida*	**Pectiniidae**
Montipora aequituberculata	*Favia rotumana*	*Echinophyllia aspera*
Montipora cocosensis	*Favia stelligera*	*Oxypora glabra*
Montipora cryptus	*Favia veroni*	*Oxypora lacera*
Montipora efflorescens	*Favites halicora*	**Pocilloporidae**
Montipora floweri	*Favites paraflexuosa*	*Pocillopora damicornis*
Montipora hemispherica	*Favites pentagona*	*Pocillopora eydouxi*
Montipora informis	*Favites spinosa*	*Pocillopora veruccosa*
Montipora meandrina	*Favites vasta*	*Seriatopora hystrix*
Montipora spumosa	*Goniastrea edwardsi*	*Stylophora danae*
Montipora stilosa	*Goniastrea pectinata*	*Stylophora pistillata*
Montipora tuberculosa	*Goniastrea peresi*	*Stylophora subseriata*
Montipora verrucosa	*Leptastrea bottae*	**Poritidae**
Agariciidae	*Leptastrea pruinosa*	*Alveopora daedalea*
Leptoseris incrustans	*Leptastrea purpurea*	*Alveopora viridis*
Leptoseris mycetoseroides	*Leptastrea transversa*	*Goniopora burgosi*
Leptoseris scabra	*Montastrea curtas*	*Goniopora columna*
Leptoseris yabei	*Leptoria phrygia*	*Gonioporal lobata*
Gardineroseris planulata	*Platygyra acuta*	*Porites columnaris*
Pachyseris speciosa	*Platygyra crosslandi*	*Porites harrisoni*
Pavona bipartita	*Platygyra daedalea*	*Porites lobata*
Pavona explanulata	*Platygyra lamellina*	*Porites lutea*
Pavona maldivensis	*Plesiastrea versipora*	*Porites nodifera*
Pavona varians	**Fungiidae**	*Porites rus*
Astrocoeniidae	*Ctenactis crassa*	*Porites solida*
Stylocoeniella guentheri	*Ctenactisechinata*	**Siderastreidae**
Dendrophylliidae	*Fungia fungites*	*Coscinerea columna*
Turbinaria reniformis	*Fungia granulosa*	*Coscinarea monile*
	Fungia horrida	*Psammocora haimeana*
	Fungia repanda	*Psammocora profundacella*
Milleporidae	*Fungia scruposa*	*Psammocora superficialis*
Millepora dichotoma	*Fungie scutaria*	
Millepora exesa	*Podabacia sinai*	**Tubiporidae**
Millepora platyphylla		*Tubipora musica*

Table 39: Flora and fauna of Kalawy Bay's lagoon, Safaga, Egypt. Identified species of the brief inspection.

Scientific name	Common name
Mollusca	**Molluscs**
Cerithum sp.	Horn shell
Strombus gibberulus	Fighting conch
Strombus tricornis	Three-knobbed conch
Vasum turbinellus	Common pacific vase seashell
Echinodermata	**Echinoderms**
Diadema paucispinum	Common long-spined urchin
Crustacea	**Crustaceans**
Lissocarcinus sp	Swimming crab
Pagurus hirtimanus	White-eye hermit crab
Osteichthyes	**Bony fishes**
Amblygobius albimaculatus	Butterfly goby
Apogon cyanosoma	Yellow-striped cardinalfish
Apogon pharaonis	Pharao cardinalfish
Arothron hispidus	Whitespotted puffer
Canthigaster coronata	Crowned toby
Canthigaster margaritata	Red Sea toby
Chaetodon auriga	Threadfin butterflyfish
Chaetodon fasciatus	Striped butterflyfish
Dendrochirus brachypterus	Shortfin turkeyfish
Gerres oyena	Common silver-biddy
Gymnothorax griseus	Peppered moray
Heniochus intermedius	Red Sea bannerfish
Istigobius decoratus	Decorated goby
Monodactylus argenteus	Silver moony
Myrichthys colubrinus	Harlequin snake eel
Neoniphon sammara	Spotfin squirrelfish
Ostracion cyanurus	Bluetail trunkfish
Parupeneus forsskali	Red Sea goatfish
Plectorhinchus gaterinus	Blackspotted rubberlip
Pomacentrus trilineatus	Threeline damsel
Pterois miles	Devil firefish
Scolopsis ghanam	Arabian spinecheek
Sebastapistes strongia	Barchin scorpionfish
Synanceia verrucosa	Stonefish
Spermatophyta	**Seed plants**
Cymodocea serrulata	Clump seagrass
Halodule uninervis	Ribbon seagrass

Table 40: Fish census of 2 central blocks in Kalawy Bay's lagoon, Safaga, Egypt.

Scientific name	Common name	Individuals
Gerres oyena	Common silver-biddy	120
Apogon pharaonis	Pharao cardinalfish	23
Neoniphon sammara	Spotfin squirrelfish	11
Gymnothorax griseus	Peppered moray	9
Pterois miles	Devil firefish	8
Istigobius decoratus	Decorated goby	5
Apogon cyanosoma	Yellow-striped cardinalfish	5
Amblygobius albimaculatus	Butterfly goby	3
Sebatapistes strongia	Barchin scorpionfish	3
Chaetodon auriga	Threadfin butterflyfish	2
Chaetodon fasciatus	Striped butterflyfish	2
Parupeneus forsskali	Red Sea goatfish	2
Arothron hispidus	Whitespotted puffer	2
Monodactylus argentus	Silver moony	2
Scolopsis ghanam	Arabian spinecheek	2
Synanceia verrucosa	Stonefish	2
Pomacentrus trilineatus	Threeline damsel	2
Canthigaster margaritata	Red Sea toby	1
Canthigaster coronata	Crowned toby	1
Heniochus intermedius	Red Sea bannerfish	1
Ostracion cyanurus	Bluetail trunkfish	1
Dendrochirus brachypterus	Shortfin turkeyfish	1

7.2. Plates

Plate 1: Abundant fish species of Kalawy.

Lyretail-Anthias
Pseudanthias squamipinnis (male)

Lyretail-Anthias
Pseudanthias squamipinnis (female)

Half-and-half-Chromis
Chromis dimidiata

Miry's Demoiselle
Neopomacentrus miryae

Bluegreen Chromis
Chromis viridis

Pale damselfish
Amblyglyphidodon indicus

Indo-pacific Sergeant
Abudefduf vaigensis

Reticulated damsel
Pomacentrus trichourus

Sailfin tang
Zebrasoma desjadinii

Lined bristlethooth
Ctenochaetus striatus

Orchid dottyback
Pseudochromis fridmani

Bluestreak cleaner wrasse
Labroides dimidiatus


Klunzinger's wrasse
Thalassoma rueppellii


Red Sea eightline flasher
Paracheilinus octotaenia


Striated fusilier
Caesio striata


Red Sea fusilier*Caesio suevica*

Plate 2: Abundant mollusc species of Kalawy.


Coral pen shell
Streptopinna saccata


Giant clam
Tridacna spp.

Purple coral snail
Coralliophila violacea

Prickly drupe
Drupa ricinus

Adanson's worm shell
Vermetus adansoni

Horn drupe
Drupella cornus

Latirus turritus

Coral scalop
Pedum spondyloideum

Plate 3: Abundant coral species of Kalawy

Acropora valida

Acropora valida

Acropora variolosa

Acropora variolosa

Acropora secale

Acropora secale

Acropora samoensis

Acropora eurystoma