The influence of water quality and stress effects on coral reefs on the basis of nutrient indicator algae cover of different dive sites around Koh tao, Thailand

Lena Franke

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Content

Abstract

The regional economies and ecosystems of Koh tao, Thailand depend largely on the health of coral reefs, which are declining in many areas around the island due to human activities both on land and in the sea. Without these coral reef ecosystems, much of the tourism on Koh Tao would cease and could lead to a collapse of Koh Tao's thriving economy. This research aims to identify trends in numbers of nutrient indicator algae and it's correlations with grazers to be able to detect possible changes in numbers over time. Furthermore, water quality has been tested and stress effects per dive site have been assessed and rated to be able to detect possible trends in reef health and the most influencing factors on reef ecology.

To achieve this ecological monitoring methods were applied by using belt transects to count the numbers of certain indicator species. To measure the nutrient indicator algae cover quadrant samples were taken along the same line transects that were used for the ecological monitoring. Water samples were analysed using general water testing procedures and stress effects per dive site were assessed by using zoning maps.

The results found during this small research project lead to the conclusion that waste water pollution and in one area sedimentation are the most influencing factors on algae growth around Koh tao and therefore also coral reef health.

The short-term prognosis for coral reef health around Koh tao is grim if tourism keeps increasing without the adjustment of economic management approaches for conservational purposes and coral reefs might only be saved by losing their attractiveness and economic value and thereby reducing tourism to a minimum only to regenerate again over long term.

1.Introduction

The island of Koh tao, situated in the gulf of Thailand is currently facing a number of problems that have big impacts on the island's reefs. Waste water pollution, sedimentation, over extraction/-use, deforestation and runoff have been causing a steep decline in the reef's biodiversity over the last few years (Scott 2008). Key causes of coral reef decline have been the over-development of the coastal area and the over-use of coral reef resources (Wilkinson 1999). A surge in land development is leading to clearance of important coastal ecosystems. Unregulated construction, such as hotels, has increased sedimentation in the waters and is destroying reefs as light levels in the water column are reduced and reefs are smothered. Untreated sewage and run-off have caused nutrient loading into coral reef waters, leading to algal blooms and eutrophication. Over fishing and -use have decimated coral reef fish populations and their habitats.

Damage to the reefs has been caused by the increase in tourism itself, through direct damage by careless tourists and through the unregulated construction and the irresponsible operation of tourist related facilities. Mass tourism poses a threat to reefs and to the income that coral reefs provide to the local population (Cesar *et al*.2003). The major influences considered above are seen as diminishing circles of impact spreading away from centres of human population (e.g. the predictive maps in Bryant *et al.* 1998). These changes were damaging coral reefs and the threats were increasing proportionally with both population and economic growth (Wilkinson 1999).

On Koh Tao, many human activities have a direct and observable negative effect on reef health. Few waste water treatment systems exist or are functioning properly , most grey water flows directly into the environment, and sewage is held in septic tanks that are poorly built and rarely emptied. The water from showers, sinks, washing machines flows directly out of many resorts, homes, and restaurants into small surface ditches that lead to waterways or the sea. This causes an increase in nutrient and pollutant concentrations in the island bays, where it creates a competitive advantage for algae over corals, making rebound from bleaching events almost impossible in some areas. Development and deforestation releases tons of sediment into the coastal waters during rain events. This leads to reduced light availability for photosynthesis, causes further stress to corals for removal, and in some cases can bury reefs completely (Castro 2007 & Wilkinson 1999). Slow regrowth due to nutrition can be found in Chalok Ban Kao and areas such as Tanote Bay have experienced very noticeable increases in sedimentation over the last few years due to the lack of erosion control (Scott 2008). Nutrients, especially nitrogen, iron and phosphorus play a major role in controlling primary production thus also algae growth. Primary production can become nutrient limited even with enough light available. Over much of the ocean the limiting nutrient is nitrogen. Oceanographers are becoming concerned that nitrogen input to the open ocean is increasing.

Human activities release large amounts of nitrogen compounds which are transported by the atmosphere and deposited into the ocean. This could enhance primary production , maybe even improve fisheries, but could also disrupt food webs or cause widespread Eutrophication (Castro 2007 & Huber 2007). Marine algae can be an indicator for a change in nutrient levels in the water and by assessing the percentages present over time a trend may be detected.

This study aims to investigate the nutrient distribution in the water, the population of grazers and the nutrient indicator algae cover at different study sites. A change over time might be detected over the last few years as the tourism and population on Koh Tao have been increasing. Identifying threats from land that might affect biodiversity and specifically the coverage of algae along the transect lines that might threaten the coral reefs is thus one of the main subjects of investigation within the scope of this paper. Moreover identifying any correlations between the monitored indicator species, algae and other factors that are involved is the other main goal of this research.

The main research questions are:

- What are the different stress effects per assessed dive site?
    - ➢ How big, on a scale of 0-5 is the possible influence of each of the stress effects on each of the assessed dive sites?
- What trend in time can be seen when the data from the years 2006-2009 is compared to each other for water quality as well as for the algae percentage cover.
- What is the correlation between the factors algae percentage cover and number of grazers?

To be able to answer these questions, a correlation was tested between algae percentage cover and number of grazers at four dive sites. Additionally a water sample of each study site has been taken, analysed and compared to previous water testing results of these sites. Different stress effects on these sites will also be taken into account by rating them on a scale of development from 0-5. The stress effect factors that will be rated are waste water pollution, sedimentation, over extraction/-use, deforestation, runoff and population-/village size. Data on the number of grazers, water quality and algae percentage cover of the last three years, namely 2006-2008 will be used to determine a possible trend over time.

The results will allow an insight into the current degree of influence and threat from the mainland and other human disturbances.

Data will be gathered using the same methods and exact same locations as have been used for the data from the previous years to make the research more viable. Species and algae will be monitored by using belt transects and all data will be processed in the statistical computer program SPSS to determine any correlations.

In the chapters below the methods and study sites will be described in detail followed by the results of the findings and a discussion of the results and research. Subsequently a conclusion will be drawn on which the recommendations for future management will be based.

2. Ecological monitoring and NIA estimations

Four of the most popular dive sites around Koh tao, namely Chalok baan kao bay, Ao leuk bay, Tanote bay and Hin Wong bay have been investigated for key indicator species, nutrient indicator algae cover and water quality using the Ecological Monitoring method, hereafter referred to as "EMP". All these dive sites are situated in the east and south of the island and will be described in more detail below.

Fig. 1: Dive site overview (by google.com)

The maps underneath show the dive site's composition and the location of the two transect lines per study site.

2.1 Study sites

Chalok baan Kao is situated in the south of the island in front of Chalok baan kao village and is a reef that is in stages of regrowth. The bottom is mostly coral rubble, but many young branching and other hard corals will be seen. There may be large numbers of Sea Urchins on the deeper of the two transect lines in the research area (9-11m), hereafter referred to as deep line. Generally, there are not many fish on the shallower of the two transect lines (5-10m), hereafter referred to as shallow line. The starting point is a fixed point from where the transect line begins and is usually an underwater landmark such as a big massive coral or a sunk concrete block. The starting point of the deep line can be hard to find from the surface, and often you may need to descend in order to locate it (Scott 2008).

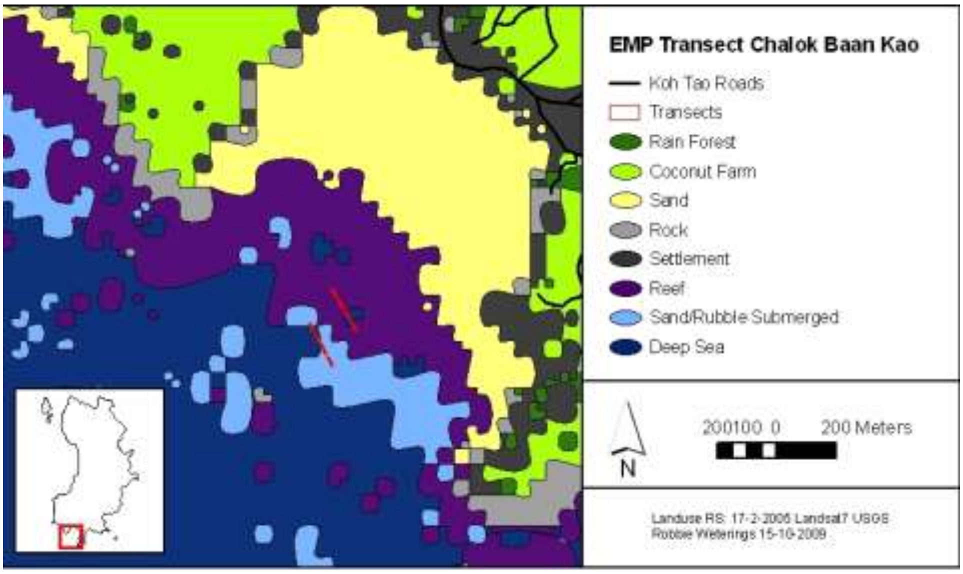

Fig. 2:Landuse map of Chalok baan kao (by Robbie Weterings)

Ao leuk is a scattered reef on sandy bottom, high biodiversity, but relatively low coverage. The deep line can be found just off of the southern buoy near the beach. The shallow line is a little harder to find, but can easily be found after locating the deep line. Usually there are not many fish on the deep line, and sedimentation in the last year seems to be affecting coral health (Scott 2008).

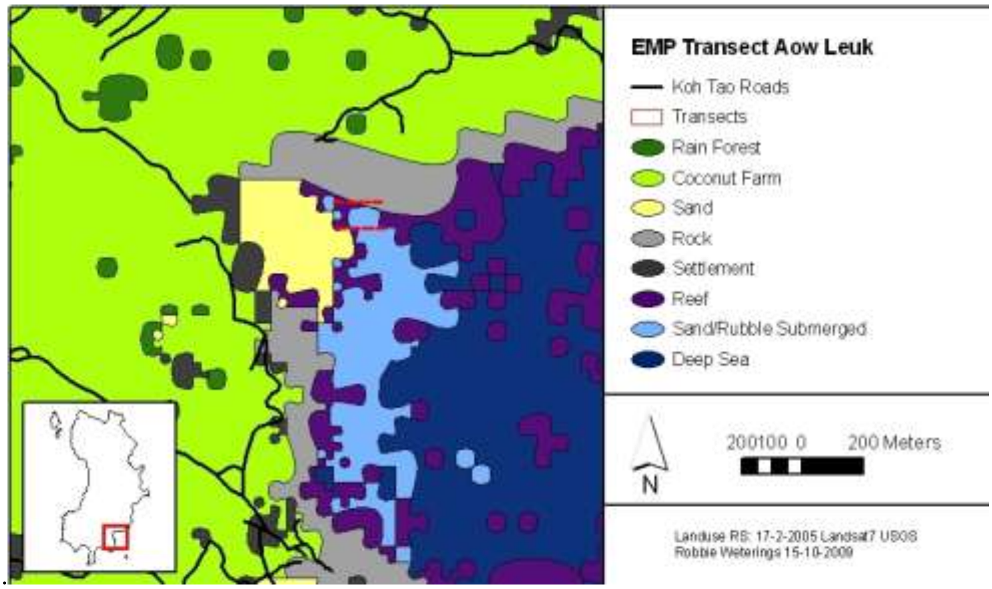

Fig. 3: Land use map of Ao leuk (by Robbie Weterings)

Tanote bay was historically one of the most biodiverse and interesting bays around Koh tao. Since late 2006 this areas has been receiving very high sedimentation rates due to the construction of a reservoir above the bay. There are still some corals present, but mostly the substrate is covered in silt (Scott 2008).

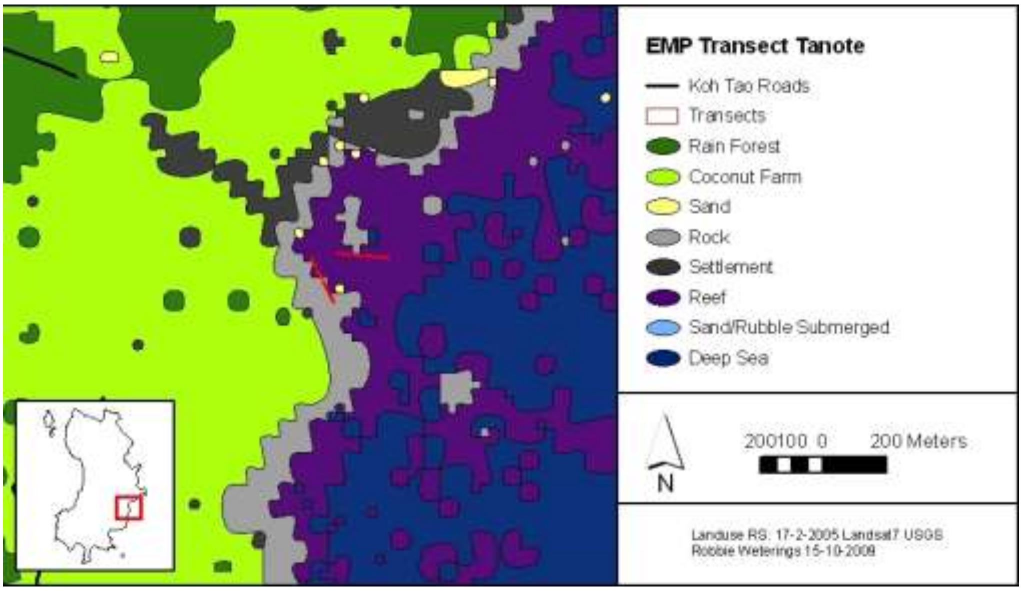

Fig. 4: Land use map of Tanote (by Robbie Weterings)

Hin Wong bay has got almost 100% branching coral coverage on the shallow line and very good massive coral coverage on the deep line. The deep buoy can be found right next to the rock sticking out of the water at the end of the tie -line, from where the shallow line can be found (Scott 2008).

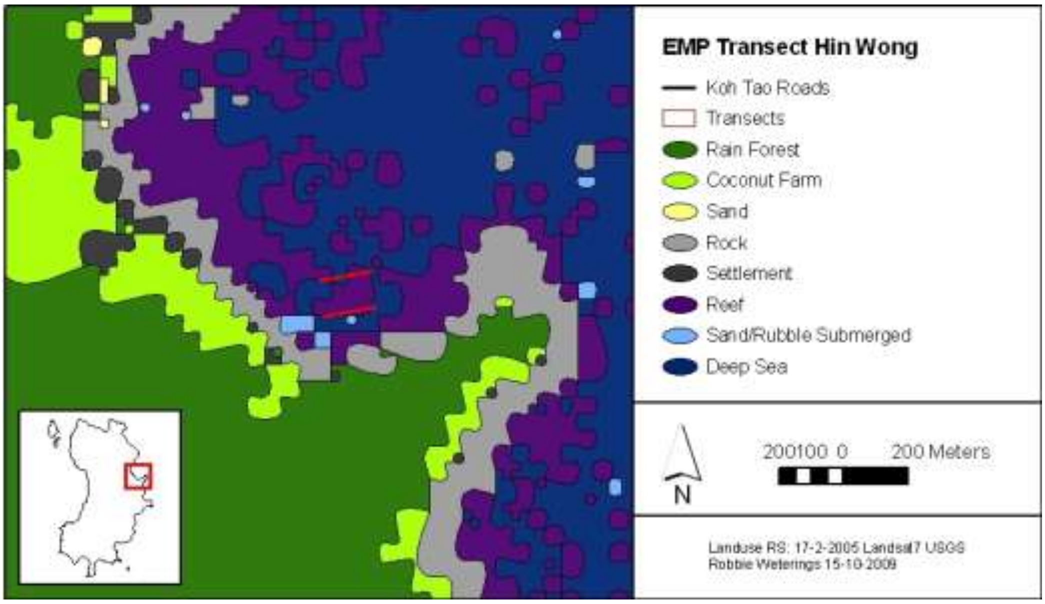

Fig.5: Land use map of Hin Wong (by Robbie Weterings)

2.2 Monitoring ecological indicator species

The species studied involved parrotfish, marbled, orange spiked, black and other sea cucumbers, giant clams and sea urchins all of which are indicator species chosen for observation due to their specific functions within coral reefs or their responsiveness to certain threats (Scott 2008). These particular species for this study have also been chosen due to the fact that they all to some extent feed on algae or filter the water.

Furthermore, the nutrient indicator algae percentage cover has been estimated per transect line and a water sample has been tested for each dive site.

The monitoring of the ecological indicator species was done by swimming along 100 meter long transect lines. After every 20 metres a 5 meter long section is left blank, meaning data is not being collected (see fig:6). For the fish a zickzack swimming motion is maintained throughout the EMP (Ecological monitoring) always maintaining a distance no larger than the own body length plus fins.

Fig.6: Belt transect method

For the invertebrate EMP the same procedure is applied but the surveyor does not have to keep swimming the whole time but should take time to look underneath rocks and corals etc. to look for the invertebrates.

The transects are fixed and the starting and end point are found by using a compass following the same coordinates every time. Ideally two people are doing this. After the measuring tape has been fixed to the starting point with a knot or by weighing it down with a piece of rock or dead coral, one should swim in the front with the compass to find the ending point of the transects. At the same time the other is following closely laying out the measuring line as close to the substrate as possible with the metric side facing upwards.

For each dive site two transects have been created, one more shallow (5-10m) and the other a little deeper (9-11m). The exact locations of the transects can be seen on the maps above (see fig.2-5)

The equipment needed to conduct the EMP is a compass, a plastic slate and pencil plus a 100 meter measuring tape (or two times 50m).

2.3 Algae cover and water testing

To be able to estimate the percentages of algae cover this method had to be slightly adjusted to the different purposes. Following the same transect lines, this time no section was left blank but measurements have been taken every 10 metres rather than consistently along the 100 meter line.

Using a 1m² quadrant subdivided into 25 sub quadrants with rope for each of which the different nutrient indicator algae percentages were written down. The starting point is at 0 metres at the right side of the line. After 10 metres the same will be done on the left side after 20 m on the right side again and so on. One side of the quadrant should be touching the measuring line. If the quadrant cannot be laid down it should be leaned against the rock or corals as carefully as possible as though not to damage any corals but should still touch the line with one side. If the line however happens to be free above the ground the quadrant will have to be laid on the bottom where it would be touching the line if it were lying on the substrate. While estimating, the surveyor should hover above the middle of the quadrant maintaining a slightly "head down" position to avoid touching any marine life with the fins or stirring up sediment (see photo below). A total of 10 quadrants should be measured this way if the air supply allows it.

Additional equipment used were the 1m² quadrant with 2 weights attached on one end and an empty water bottle. The slate should be prepared by drawing the 10 quadrants and sub quadrants on the slate prior to the dive so they only need to be filled in. Enough space should be allowed for each of the sub quadrants as there might be more than one type of algae per sub quadrant which need to be written down into the same sub quadrant using their abbreviations (see next page).

Photo: Estimating algae percentage cover (by Chad Scott)

Moreover, a water sample has been taken at 5 metres depth from each of the study sites and later been analysed for the amount of phosphorus, nitrogen, and the turbidity. For these tests a Colorimeter machine, Sample cells, Reagents, deionized water (or drinking water) and a soft cloth have been used.

For measuring turbidity a sample cell with deionized water is placed in the colorimeter and “zeroed”. Subsequently a cell with the water sample is placed in the colorimeter after shaking it, then the value for turbidity for the sample can be read from the colorimeter machine.

For the reagent tests two sample cells are filled with 10 mL of the water sample. One cell is the ‘prepared sample’ with the nitrogen (NitraVer 5) or phosphorus (PhosVer 3) reagent dissolved inside it, the other is a ‘blank cell’ with deionized water for zeroing the colorimeter prior to each test. For more details see appendix II.

The type of algae measured were *Caulerpa serrulata, Halimeda capiosa, Halimeda macroloba, Valonia ventricosa, Actinotrichia fragilis* up to 6cm, *Actinotrichia cfragilis* up to 25 m (Blackburn 1989), *Padina gymnospora, Turbinaria sp.,* Unidentified filamentous blue-green algae, Unidentified red algae, Unidentified brown-green algae
The abbreviations used during the survey were as follows:

Caulerpa serrulata:	CS
Halimeda capiosa:	HC
Halimeda macroloba:	HM

Valonia ventricosa, Sailor's eyeball: SE

Actinotrichia fragilis up to 6cm Spikeweed small: Sps

Actinotrichia fragilis up to 25 m Spikeweed large: Spb

Padina gymnospora Funnelweed: FW

*Turbinaria sp.*Turbinweed: TW

Unidentified filamentous blue-green algae : F

Unidentified red algae *phylum Rhodophyta* sp : R

Unidentified brown-green algae Brown semi rigid but slippery macro algae: L

Unidentified red algae *phylum Rhodophyta* sp: R

Unidentified brown-green algae Brown semi rigid but slippery macro algae: L

All of these types of algae are nutrient indicator algae, hereafter referred to as NIA which are an indicator of high nutrient levels in the water (eutrophication).

2.4 Stress effects

The scores for the stress effects were evaluated by using zoning maps (See appendix 1) of the island on which could be seen which areas are used for what actions and also by interviewing locals.

Subsequently the previously gathered data has been entered into the statistical computer program SPSS where the following tests have been used to discover any correlations between the variables.

K-S test for normal distribution

Spearman and Pearson correlation analysis

Linear regression estimation analysis

3. Results

This chapter presents the results relevant to answering the research questions beginning with stress effects and water quality results, algae percentage cover per study site, followed by trends in time and the found correlations.

3.1 Stress effects and water quality

Scores:

0 = no effect/impact on ecosystem 1 = light effect/impact on ecosystem 2 = light to medium effect/impact on ecosystem

3 = medium effect/impact on ecosystem 4 = medium to strong effect/impact on ecosystem

5 = very strong effect/impact on ecosystem

These scores have been evaluated with the help of zoning maps and personal rating and thus have a speculative rather than a scientific character.

Dive site	Hin Wong	Tanote	Ao leuk	Chalok
Waste water	2	2	3	5
Sedimentation	2	5	3	3
Over extraction/-use	4	3	4	5
Deforestation	2	5	2	1
Runoff	2	5	2	5
Pop.-/Village size	1	3	1	5
Turbidity FTU **2008**	/	3,3	4,16	/
Phosphate mg/l **2008**	/	0,5	0,14	/
Nitrate mg/l **2008**	/	0,95	0,96	/
Turbidity FTU **2009**	0	0	0	2,5
Phosphate mg/l **2009**	0,13	0,17	3,22	5,38
Nitrate mg/l **2009**	0,8	0,7	0,67	0,8

Table 1: Stress effect scores and water quality results

As can be seen in the table above Chalok is the area that is most affected by influences from land. It achieves the highest possible score (5) for four of the six stress effect factors. However, Tanote scores almost as high for the total score and the influences from land are therefore similarly heavy at this site. Hin wong and Ao leuk both score high for over extraction/-use.

As for the water quality results it is hard to find ideal values since the nutrient concentrations are dependent on seasonal changes, upwelling and other factors of influence. However, it can be said that the phosphate value for Chalok is noticeably higher than at the other sites. The amount of nitrate measured was lowest in Ao leuk.

Concentrations of nitrate have gone down slightly in Ao leuk and Tanote since 2008 whereas phosphate concentrations in Ao leuk have increased noticeably in 2009. The phosphate content in Tanote bay on the other hand has gone down since 2008 (see table 1).

Turbidity is also highest in Chalok in 2009. In Ao leuk and Tanote it has gone down considerably since the previous year (see table 1).

This table suggests that high stress factor scores are linked to high nutrient levels, especially the stress factors waste water, deforestation and runoff seem to aid higher nutrient levels to develop.

3.2 Algae percentage cover

In this chapter the total algae cover of each of the assessed dive sites will be discussed.

	Total algae cover %	Phosphate mg/l	Nitrate mg/l
Chalok shallow	20,5	5,38	0,8
Chalok deep	6,88	,,	,,
Hin wong shallow	7,8	0,31	0,8
Hin wong deep	4,32	,,	,,
Tanote shallow	11	0,17	0,7
Tanote deep	10,02	,,	,,
Ao leuk shallow	18,68	3,22	0,67
Ao leuk deep	6,2	,,	,,

Table 2: Total algae cover

Table 2 above shows that the 3 of 4 sites with higher nutrient levels and/or stress factors also have a higher general algae coverage.The table furthermore shows that Chalok shallow has got the highest algae cover (20,5%) followed by Ao leuk shallow, Tanote shallow, Tanote deep, Hin wong shallow, Chalok deep, Ao leuk deep and Hin Wong deep as the site with least algae coverage (4,32 %). It is also noticeable that for each site taken separately the deep transects show noticeably less algae cover than the shallow lines (see table 2).

3.2.1 Chalok transect

This table shows the percentages of the different types of algae found on this transect.

	Chalok Shallow	Chalok Deep
Total F	52 %	97 %
Total R	23 %	2,3 %
Total L	22,6 %	0 %
Total TW	6 %	0 %
Total FW	0%	0 %
Total NIA cover	**20,5 %**	**6,88 %**

Table 3: Algae cover Chalok

The algae cover here is the highest of all assessed sites with a high percentage of filamentous algae.

3.2.2 Hin Wong transect

This table shows the percentages of the different types of algae found on this transect.

	Shallow	Deep
Total F	72,3 %	51,38%
Total R	27,6 %	48,6 %
Total L	0 %	0 %
Total TW	0 %	0 %
Total FW	0%	0 %
Total NIA cover	**7,8 %**	**4,32 %**

Table 4: Algae cover Hin wong

This site has the lowest total algae cover and also the lowest diversity of algae types although the Tanote transect has a very low algae species diversity as well.

3.2.3 Tanote transect

This table shows the percentages of the different types of algae found on this transect.

	Shallow	Deep
Total F	96,3 %	19,3 %
Total R	3,4 %	80,6 %
Total L	0 %	0 %
Total TW	0,22 %	0 %
Total FW	0%	0 %
Total NIA cover	**11 %**	**10,02 %**

Table 5: Algae cover Tanote

On the Tanote transect a low diversity of algae species has been found of which most species found on the shallow line were filamentous but most species on the deep line were unidentified red algae.

3.2.4 Ao leuk transect

This table shows the percentages of the different types of algae found on this transect.

	Shallow	Deep
Total F	86,8 %	54,5 %
Total R	13 %	43,8 %
Total L	0 %	1,6 %
Total TW	0 %	0 %
Total FW	0,1 %	0 %
Total NIA cover	**18,68 %**	**6,2 %**

Table 6: Algae cover Ao leuk

The most common algal species found on this transect are again unidentified red algae and filamentous blue-green algae with over 80 percent filamentous on the shallow line but only 54,5 % on the deep and 43% red algae on the deep line.

The total algae cover is highest in Chalok and the human population size here is also the largest of all 4 sites (see table 3). Tanote on the other hand scores high on the Sedimentation factor. The lowest total amount of algae however has been monitored on the Hin Wong transect.

3.3 Trends in time

For the deep transect lines of Hin Wong, Ao leuk and Chalok, algae cover is higher this year than it has been in the previous years since 2006 (see fig.12-14).

To better understand the following graphs it should be said for clarification that the values on the x-axis represent the years per location, the last two digits are the years in which the measurements have been taken, the first digit is merely the number assigned for the particular study site (e.g. 606 stands for Ao leuk deep in 2006)

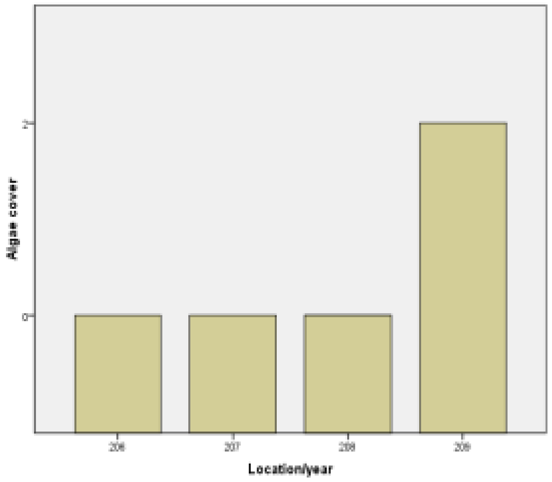

Fig.12: Hin Wong deep in the years 2006-09

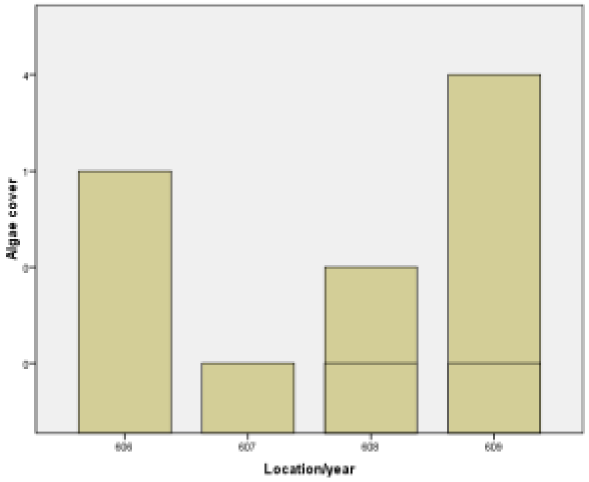

Fig.13: Ao leuk deep in years 2006-09

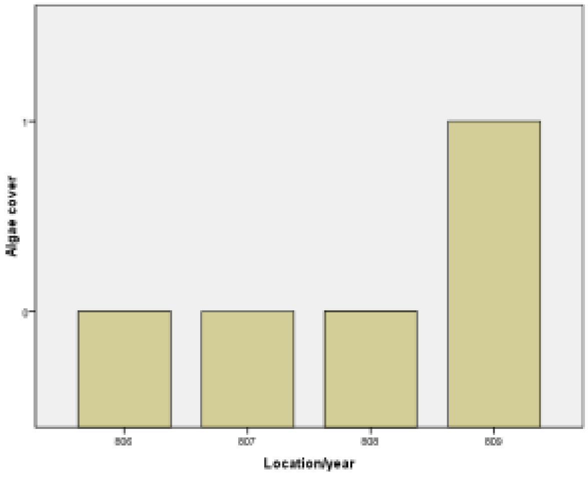

Fig.14: Chalok deep in years 2006-09

At the shallow transect in Hin wong the highest algae cover has been measured in 2008 and has gone down noticeably in 2009. The same goes for the shallow line in Ao leuk where the decrease in algae is even more significant (see fig.15 and 16).

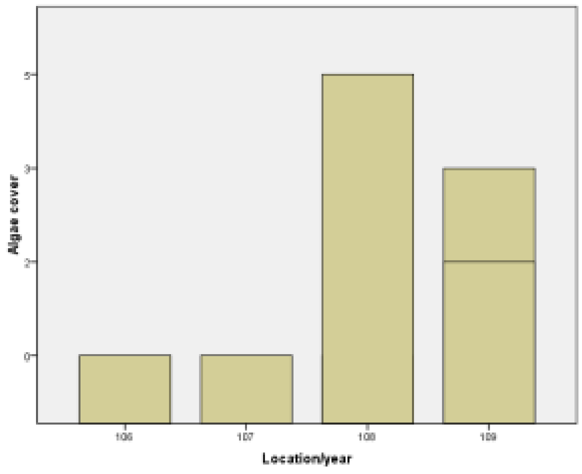

Fig.15: Hinwong shallow in years 2006-09

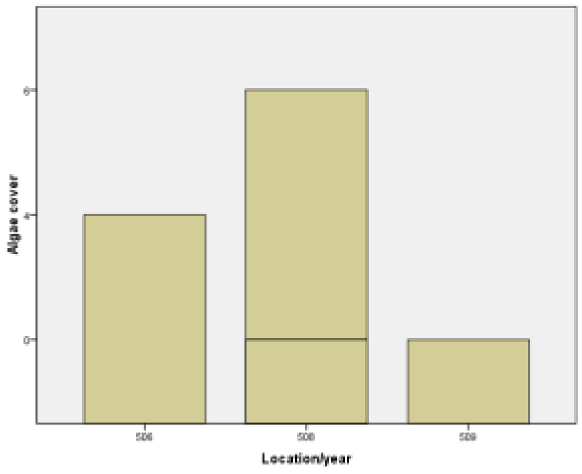

Fig.16: Ao leuk shallow in years 2006/08/09

At the deep line in Tanote and the shallow line in Chalok year 2006 was the one with the highest amount of algae measured (see fig.17 and 18).

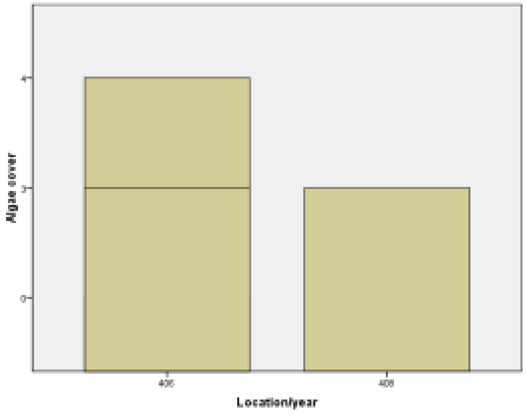

Fig.17: Tanote deep in years 2006/08

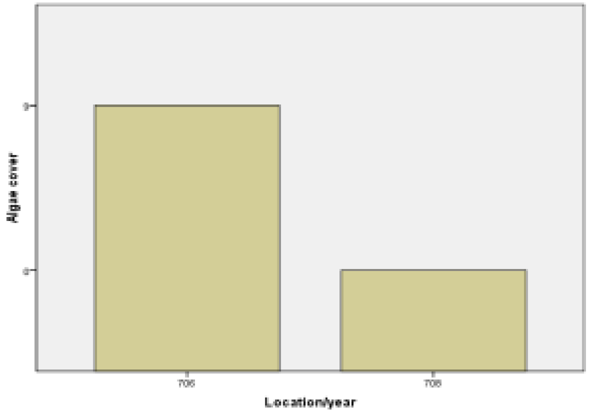

Fig.18: Chalok shallow in years 2006/08

For three of the 8 transect lines all of which are deep transects the year 2009 has been the one with most algae cover whereas for two of the shallow transects 2008 has been the year with most algae measured. The shallow line in Tanote is the only transect for which 2006 was the year with the highest amount of algae measured.

3.4 Correlations

The following results have been found trying to answer the question of correlations between grazers and algae. All of these factors have been related to one another without applying any knowledge about their ecologies, thus without being based on antecedent hypotheses.

The correlation matrix showed that algae cover has a positive effect on the number of giant clams (Spearman = 0.312, p = 0.028).

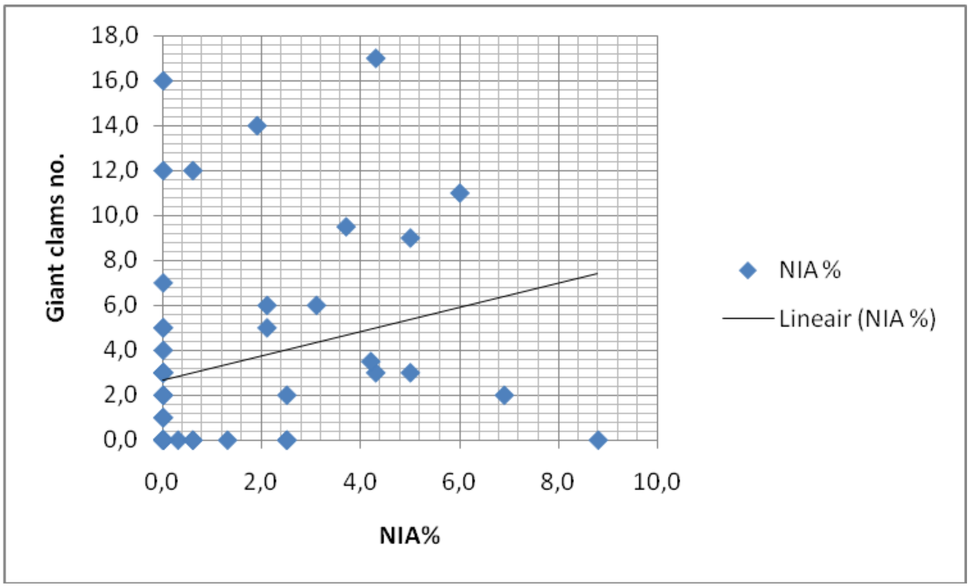

Fig.7: Correlation between NIA and number of giant clams

The number of large parrot fish is positively correlated to the number of small parrot fish (Spearman 0,429, p= 0,002)

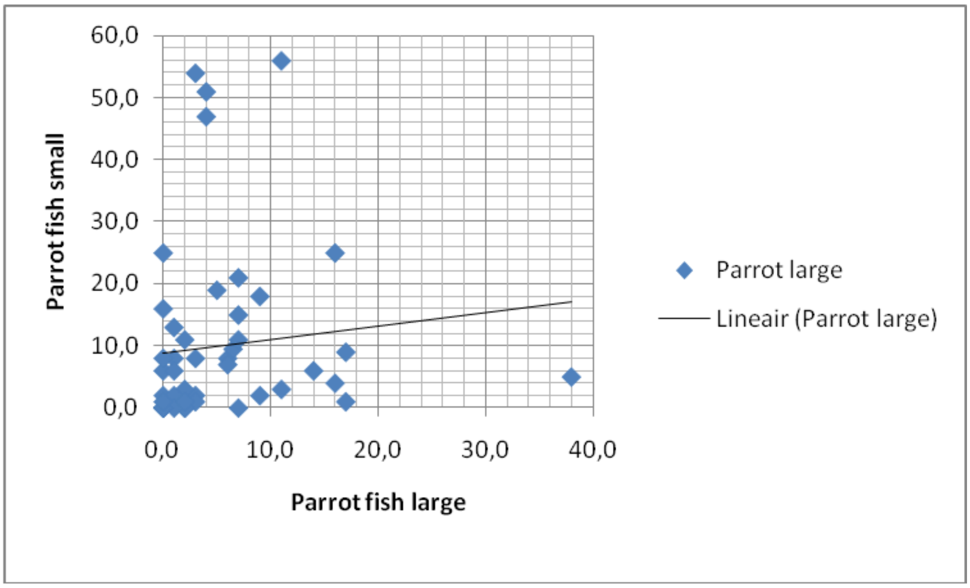

Fig8.: Correlation between large parrot fish and small parrot fish

The number of large parrot fish has got a positive correlation to the number of giant clams (Pearson 0,429, p= 0,002)

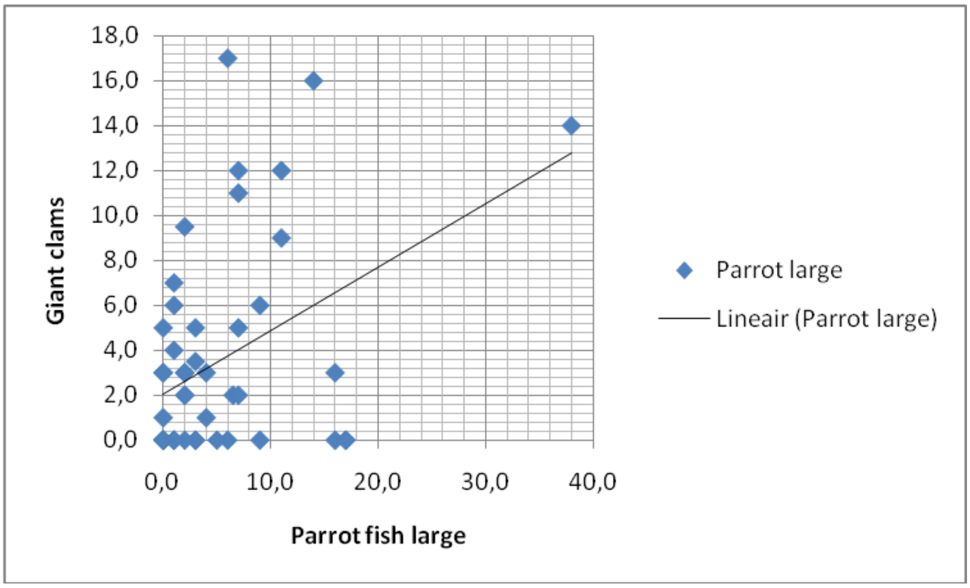

Fig.9: Correlation between large parrot fish and giant clams

The number of orange spiked sea cucumbers is positively correlated to the number of other sea cucumbers (Spearman 0,457, p=0,001)

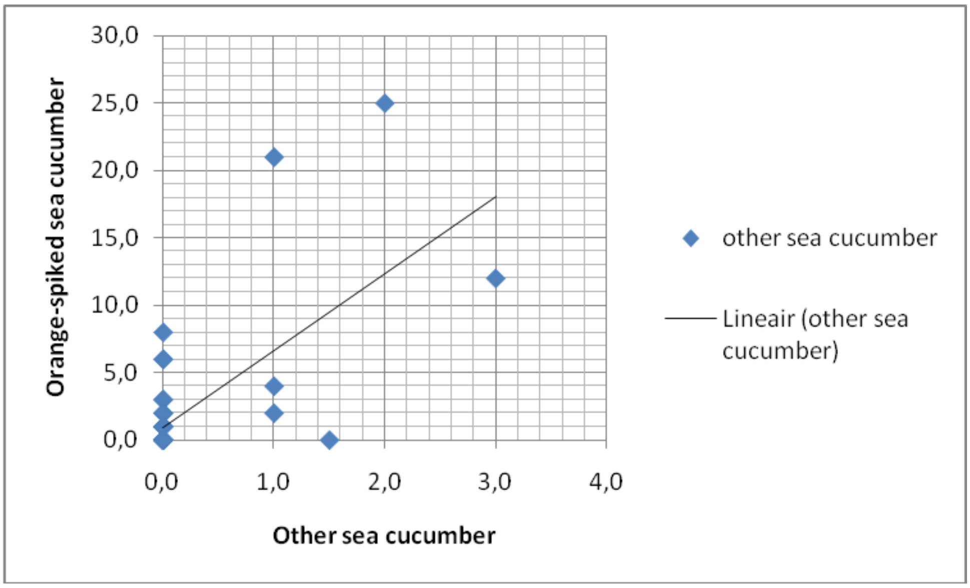

Fig.10: Correlation between other sea cucumbers and orange spiked sea cucumbers

There is a positive correlation between the number of giant clams and the number of black sea cucumbers (Spearman 0,271, p=0,057). However this correlation matrix shows borderline values concerning the significance of this correlation and will therefore not be included in the drawing of conclusions.

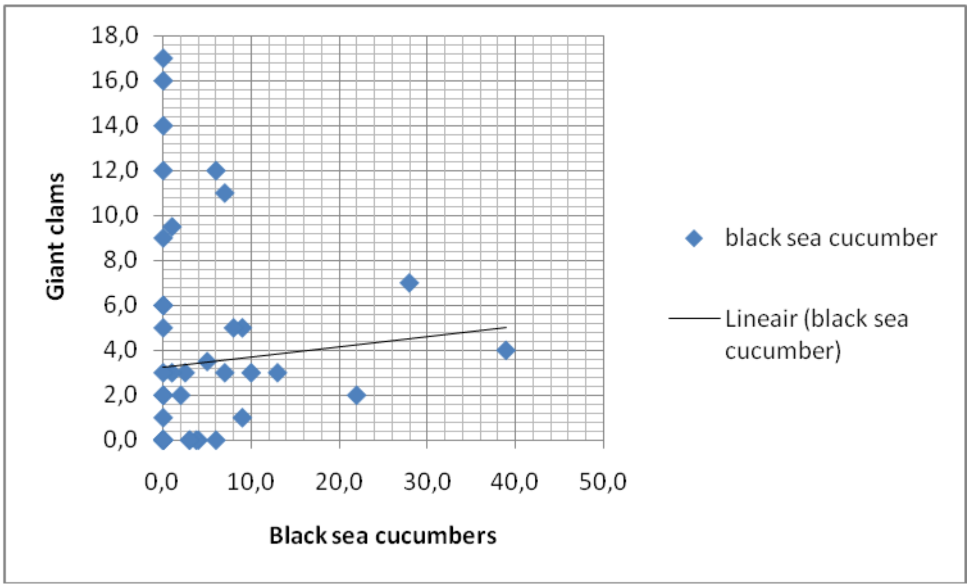

Fig.11: Correlation between black sea cucumbers and giant clams

4 Discussion

Stress effects

The stress factors sedimentation and Eutrophication (waste water) have the most influence on the marine ecosystem. And all other stress factors mentioned in this report eventually result in sedimentation and Eutrophication. A surplus of nutrients would result in an increase in algae cover, whereas an overload of sediment would result in turbid water and eventually in a decrease of algae cover, due to less sunlight being able to penetrate, depending on how long this turbid condition lasts.

The high scores for sedimentation, runoff and deforestation at the Tanote site are a result of the installation of a reservoir at the top of a mountain situated above the bay (see appendix 1). Hin wong and Ao leuk both score high for over extraction/-use presumably because of the unusually high number of divers and snorkelers that visit the sites every day.

Algae cover and water quality & Trends in time

The results for the separate dive sites have shown that deep transects show noticeably less algae cover than the shallow lines. This can simply be explained by the lower amount of light that is able to penetrate at a greater depth which regulates the rate of photosynthesis that algae needs to survive. Another factor would be the closer proximity to shore of the shallow lines where the exposure to nutrient rich waste water is greater (Wayne 1989).
As for the different types of algae the filamentous blue-green algae seems to grow better in shallower water and is in competition with other algae, especially red in deeper water which suggests that it depends on a lot of sunlight for photosynthesis but also because of the closer proximity to shores and thus exposure to higher concentrations of waste water that carries a lot of nutrients. In deeper water it is less capable to out compete other types of algae. The fact that the total algae cover is highest in Chalok leads to the assumption that the waste water

concentration there is also higher than on the other sites. The fact that the human population size here is also the largest of all 4 sites supports this assumption (see table 2 and 3). Wilkinson also stated that organic and inorganic pollution favours the growth of planktonic and large benthic algae (Wilkinson 1999).

Tanote on the other hand scores high on the Sedimentation factor which could be a reason for the relatively low amount of total algae cover since algae more frequently grow on firm attachment points such as rocks or dead coral than on sand or shingle (Lewis 1964). It would be useful to compare algae cover to coral cover for future researches purposes.

For Tanote the highest amount of algae measured was 2006 which was previous to the sedimentation caused by the build of the reservoir above the bay. Algae growth decreased due to the increased stress factor of sedimentation in this area.

The three deep transects, namely Hin wong, Ao leuk and Chalok for which 2009 is the year with most algae growth have been exposed to more waste water every year due to an increase in land development near these study areas which favours algae growth. The strong fluctuations in the nutrient levels of the water is likely to be caused by the low and high holiday seasons but also rainy seasons that the island is subjected to.

Correlations

The found correlation between NIA cover and number of giant clams might be explained by the fact that both occur where enough nutrients are present. Giant Clams use a siphon to draw in water to filter and consume passing plankton. Giant clams are excellent bio-filters, which mean they filter nutrients out of the water for their own use and this is how they take in nourishment. However, Giant clams usually occur in very clear waters whereas high concentrations of marine algae tend to occur in turbid waters as well which is why this correlation is not representative since it cannot be underplayed by scientific findings.

There is also no particular reason why the numbers of large parrot fish and small parrot fish should influence one another. Individuals of all sizes share the same habitat and have the same diet. There’s no indication as to why they should compete with one another. The same applies for the other groups of apparently correlating species, namely giant clams and large parrot fish, orange-spiked sea cucumbers and other sea cucumbers and finally giant clams and black sea cucumbers although all of these are different species and therefore do not share the same diet and feeding behaviour unlike small and large parrot fish.

Furthermore, the tests have shown a negative correlation between nutrient indicator algae and the amount of sponges (Spearman -0,219, p= 0,044) although this correlation is not a strong one. The algae found during this survey was mainly found on hard surfaces and most marine sponges share the habitat of quiet, clear waters, because sediment stirred up by waves or currents would block their pores, making it difficult for them to feed and breathe (Krautter 1998). The greatest numbers of sponges are usually found on firm surfaces such as rocks (Weaver *et al* 2007) so habitat competition might be a possibility. However, the significance here is very low and therefore it is questionable whether this result should be taken into account during the examination of influencing factors.

The found correlations did not meet the expectations that NIA % cover is correlated to the number of the different marine grazers.

All of these correlations have been tested without applying any knowledge about the organisms’ ecologies thus without being based on antecedent hypotheses. Therefore, these correlations have a low significance.

5 Conclusion

The increasing rate of direct anthropogenic damage will cause further degradation to the major coral reef areas of Koh tao, Thailand if management of waste water, diving etc. does not change in favour of reef conservation while tourism still increases. The following results support this assumption.

The area of Chalok shows the highest amount of algae and high scores of stress factors in 4 of the 6 categories which concludes that the nutrient richness of the water supports algae growth and a decrease in coral reefs in this area.

All of the trends in algae cover can be explained by the stress effects previous to or following these peaks in algae growth (see discussion). Stress factors per study site can be reviewed in the chapter results.

As for the water quality results the comparison between different years shows strong fluctuations in the nutrient levels which is likely caused by the holiday seasons but also rainy seasons that the island is subjected to (Casabianca *et al. 1997)*. However, it can be concluded that Chalok is exposed to the highest level of waste water with the highest nutrient contents of all sites followed by Ao leuk, Tanote bay and finally Hin wong as the least polluted site of the four.

The correlations that were found suggest that the numbers of a few species influence one another on the assessed dive sites (see results) which can however not be supported scientifically. Therefore, the main influence on algae growth found during this research is waste water pollution and sedimentation.

6 Recommendations

To be able to extend this research it will be necessary to further monitor the marine areas around Koh tao to detect changes and fluctuations in time and to be able to determine protected areas and species, thereby also considering correlations between species. Further data of nutrient contents, algae cover, different substrate cover and number of nutrient indicator organisms will be needed for further research in this area, also to get correlations with a higher significance. To be able to get a better overview over the coral reef health it is advisable to include measurements of coral density, coral health, stages of bleaching and coral damage of the big groups of corals into further researches in this area.

Adjusting the management of certain areas especially looking at waste water treatment by further creating awareness of the economical necessity of these marine areas for the local people would be essential for this cause. Promoting and raising funds for better sewage systems for further or existing development might help changing views around the locals. A solution for the over-use of some areas might be to assess a fixed number of divers and snorkelers for heavily used dive sites per day during the high season as well as a time schedule for when dive schools are allowed on which dive sites although this would be hard to realize since there are just too many dive businesses on Koh tao.

Furthermore, more detailed testing of the correlations between the factors substrates, algae, composition of ocean floor, time of year, fishing and further disturbances will help to better understand the influencing factors within the coral reef areas around Koh tao.

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Appendix

I Zoning map

Zoning map (by Save Koh tao)

II Colorimeter manual

II Colorimeter manual

General Guide:

Wearing gloves and mask to avoid direct contact with reagent.
When using reagent, try to remove all the powder from the foil pouch by tapping repeatedly.
Rinse sample cells with water sample before use.
Rinse the cells with deionized water immediately after use (if not available, use drinking water instead).
Don't use detergent to clean glassware.

Equipments:

Colorimeter machine
Sample cells
Reagents
Deionized water (if not available, use drinking water instead)
Soft cloth

Reagent Blank Correction (p. 49)

Purpose: To subtract the color absorbed when running the test with deionized water instead of sample.

Warning: Don't use Reagent Blank Correction feature if the procedure uses a reagent blank for zeroing. In this manual, use Reagent Blank Correction feature in **Nitrate** and **Phosphorus** tests only.

Procedure:

Run the test using deionized water (if not available, use drinking water instead) with each new lot of reagent.
Press **READ** to obtain the blank value. Jot down this blank value in a piece of paper.
Press **SETUP**, scroll to **BLANK**, press **ENTER**. The display will show **BLANK?**.
Enter the blank value that you have jotted down.
Press **ENTER**.
The display will show 0.00 mg/L (resolution and unit vary) and the sample cell icon will be displayed.

To disable the Reagent Blank Correction feature: Press **SETUP**, scroll to **BLANK**, press **ENTER** twice. The sample cell icon will disappear from the display.

Nitrate, Mid Range (p. 305 – 307)

Pretest:

For most accurate result, perform the Reagent Blank Correction first. Make sure that sample cell icon appears on the display.
Fill two sample cells with 10 mL of sample each. Label one cell as 'prepared sample', another as 'blank cell'.
Prepare one **NitraVer 5 Nitrate Reagent Powder Pillow**.

Procedure:

Press **PRGM**. The display will show **PRGM ?**.
Press **5 4 ENTER**. The display will show **mg/L, NO3-N** and the **ZERO** icon.
Empty **NitraVer 5 Nitrate Reagent Powder Pillow** into prepared sample cell. Cap the cell.
Press **TIMER** then **ENTER**. A one-minute reaction period will begin. Shake the sample vigorously until the timer beeps.
After the timer beeps, the display will show **5:00 TIMER 2**. Press **ENTER**. A five-minute reaction period will begin.
After the timer beeps, wipe off any liquid or fingerprints. Place blank cell into the cell holder, tightly cover with instrument cap.
Press **ZERO**. The cursor will move to the right, then the display will show **0.0 mg/L NO3-N**. (If Reagent Blank Correction is on, the display may flash "limit".)
Place prepared sample into the cell holder, tightly cover with instrument cap.

Press **READ**. The displayed result will be in **mg/L NO3-N** or **NO3**.
Jot down the result in data sheet.

Nitrogen, Ammonia (p. 339 – 340)

Pretest:

Make sure that Reagent Blank Correction feature is disable. You should not see sample cell icon on the display.
Fill a sample cell with deionized water (if not available, use drinking water instead). Label it as 'blank cell'.
Fill the second sample cell with 5 mL of the sample. (Note: The official manual will require you to fill 10 mL, just ignore it.) Label it as 'prepared sample'.
Prepare two **Ammonia Salicylate Reagent Powder Pillow**.
Prepare two **Ammonia Cyanurate Reagent Powder Pillow**.

Procedure:

Press **PRGM**. The display will show **PRGM ?**.
Press **6 4 ENTER**. The display will show **mg/L, NH3-N** and the **ZERO** icon.
Empty one **Ammonia Salicylate Reagent Powder Pillow** into each cell. Cap both cells and shake to dissolve.
Press **TIMER** then **ENTER**. A three-minute reaction period will begin.
After the timer beeps, empty one **Ammonia Cyanurate Reagent Powder Pillow** into each cell. Cap both cells and shake to dissolve.
The display will show **15:00 TIMER 2**. Press **ENTER**. A 15-minute reaction period will begin.
After the timer beeps, place the blank cell into the cell holder, tightly cover with instrument cap.
Press **ZERO**. The cursor will move to the right and the display will show **0.00 mg/L NH3-N**.
Place prepared sample into the cell holder, tightly cover with instrument cap.
Press **READ**. The displayed result will be in **mg/L**.

Phosphorus, Reactive (p. 483 – 484)

Pretest:

For most accurate result, perform the Reagent Blank Correction first. Make sure that sample cell icon appears on the display.
Fill two sample cells with 10 mL of sample each. Label one cell as 'prepared sample', another as 'blank cell'.
Prepare one **PhosVer 3 Phosphate Powder Pillow**.

Procedure:

Press **PRGM**. The display will show **PRGM ?**.
Press **7 9 ENTER**. The display will show **mg/L, PO4** and the **ZERO** icon.
Empty **PhosVer 3 Phosphate Powder Pillow** into prepared sample cell. Shake for 15 seconds.
Press **TIMER** then **ENTER**. A two-minute reaction period will begin. While waiting for this two-minute reaction period to finish, you can test the blank cell by putting it into the cell holder and tightly cover with instrument cap. Press **EXIT** then **ZERO**. The display will show **0.00 mg/L PO4**. (If Reagent Blank Correction feature is on, the display may flash "limit".)
After the timer beeps, place the prepared sample into cell holder, tightly cover with instrument cap.
Press **READ**. The displayed result will be in **mg/L phosphate (PO43-)**.