CORAL REEFS ASSESSMENT

AN ASSESSMENT OF CORAL REEFS IN AMBON, INDONESIA

By

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ABSTRACT

Increasing human activity and population pressure on coastal marine resources, especially coral reefs, in Ambon have caused significant stresses on coral communities requiring careful management. A suitable environmental management strategy for this complex ecosystem, however, must be based on an accurate assessment of the state of these resources, natural variability, and the impact of human activities. Consequently, baseline research is needed to describe reef areas and to provide data about environmental changes.

One control site (Tanjung Setan) and three affected sites (Hila, Wayame and Wailiha) on Ambon were observed to assess the condition of the reefs. Coral cover, coral growth rate, species richness and environmental parameters such as suspended particulate matter (SPM), resuspended sediment, salinity, temperature, dissolved nutrients (NO_3 and PO_4), $\delta^{15}N$, and water clarity were measured to assess reef condition and to determine the possible causes of reef degradation.

Average coral cover in the control site (Tanjung Setan) is higher (64%) than that in affected sites: Hila (27%), Wayame (36%) and Wailiha (11%). Also, the greatest number of species was found in Tanjung Setan (101 spp.) followed by Hila (66 spp.), Wayame (62 spp.) and Wailiha (43 spp.).

Coral growth rates show different trends from coral cover and number of species. Corals in Tanjung Setan have higher growth rate (1.61 cm/year) than those in Hila (1.45 cm/year) and Wayame (1.31 cm/year), but corals in Wailiha show almost the same growth rate (1.57 cm/year) with that in Tanjung Setan. The surprisingly rapid growth rates at Wailiha are probably caused by high nutrient availability and rapid growth of corals to keep pace with high sedimentation rates.

The $\delta^{15}N$ content of coral tissue was analyzed at each site to trace the sewage (nutrients) loading from the land. Relatively high ratio of $\delta^{15}N$ found in Wailiha and Wayame indicated sewage (nutrients) inputs to the reefs in these areas. In addition, limited lignin testing on corals from Wailiha showed positive results, indicating that the plywood factory adjacent to the reef influences the corals there.

High SPM and resuspended sediment values, high dissolved nutrients and $\delta^{15}N$ content, and turbid water in Wayame and Wailiha indicated that these reefs are under siltation and sewage (eutrophication) stress. Hila mainly suffered from physical disturbance such as fish blasting and coral collecting, suggested by bomb craters and coral fragments. Conversely, no significant evidence of human impact was found in the control site (Tanjung Setan), where SPM, resuspended sediment, dissolved nutrients, and $\delta^{15}N$ values are all low, and water clarity is very high.

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CHAPTER I

INTRODUCTION

I. 1. The Importance of Coral Reefs

Coral reefs are one of the most biologically complex and diverse marine ecosystem on earth (Hallock et al, 1993). They are unique among high-diversity and high-productivity marine communities, distinguished by their ability to thrive in clear, oligotrophic waters devoid of high levels of nutrients (Newell, 1972; Richmond, 1993).

The relationship between reef-building corals and their symbiotic unicellular algae (zooxanthellae) is central to the existence of coral reef communities. Zooxanthellae photosynthesize using the metabolic wastes of the corals, thereby producing food for themselves, their coral hosts and even for other members of the reef communities.

The importance of modern coral reefs are evidenced by various natural and economical values they have. They produce and protect land, support fisheries and tourism, and provide opportunities for education and research (Richmond, 1993; Tomascik, 1993). Furthermore, they have cultural value for islander and tropical coastal communities.

Not only modern reef but fossil reefs also have economic importance. Fossil reefs of different builders and ages are associated with mineral deposits and petroleum reserves. For example, the northern edge of Presqui'Ile Barrier reef at Pine Point, on the southern shore of the Great Slave Lake , Northwest Territories, Canada and upper Middle Triassic reefs in the Eastern Alps from Switzerland to Austria have lead-zinc deposits (Cortes, 1981).

The Silurian reefs of Great Lakes area, the Devonian reefs of Western Canada and the Cretaceous and Tertiary reef complexes of Middle East are associated with petroleum reserves (Cortes, 1985).

I. 2. Ecological Controls on Coral Reefs

I. 2. 1. Salinity

Scleractinian are relatively stenohaline organisms with death resulting when salinity drops below 27‰ or increase above 40 ‰ (Kinsman, 1964; Fagerstorm, 1983). This is why the great majority of reefs are found in normal marine water (34-36 ‰), whereas there are no reefs in fresh water and most low diversity reefs occur in brackish water (Fagerstrom, 1983). However, the generally accepted relationship between salinity and coral reef distribution is indirect rather than experimental.

On the contrary, some experimental studies of the effect of salinity on corals showed that some species (i.e. *Porites sp*) grow in salinity exceed normal tolerance ranging from lower limit 17.5 to 28 ‰ and higher limit of 38.5 to 52.5 ‰ (Goodbody, 1961; Kinsman, 1964; Muthiga and Szmant, 1987). The survival of coral in this abnormal salinity depends on the degree of abnormality and the time that they are subject to abnormal salinity (Fagerstrom, 1983).

According to Muthiga and Szmant (1987), detrimental effects of salinity on hermatypic corals can occur due to physiological stress on the coral animal or the algal symbionts that disrupted their symbiotic relationship.

I. 2. 2. Temperature

Water temperature is an important control and reef corals are most abundant in the range of 25 to 29°C (Kinsman, 1964). Although reef corals as a group are generally considered to be stenothermic, the ambient temperature for the same coral species can differ quite distinctly in different geographic areas where the same species of coral occurs (Coles and Jockiel, 1977). Furthermore, in certain circumstances coral can withstand limited exposure to very low (16-17°C) or high (36°C) temperature.

Low temperature is a distinct limiting factor in corals' distribution (Clausen and Roth, 1975) since in 18°C and below, reef building corals generally are affected adversely and compete unsuccessfully for space with other benthic organisms (Glynn and D'Croz, 1990). High temperature, however, may only occasionally be limiting in the present day ocean except where there is rapidly fluctuating temperature.

The first apparent symptom of temperature stress on reef corals is the disturbance of the symbiotic association between animal tissue and endosymbiont zooxanthellae (Coles and Jockiel, 1977) and the initial response of stressed corals is partial to total-colony bleaching (Glynn and Steward, 1973; Coles and Jockiel, 1978). In addition, Lesser (1990) showed that increases in temperature significantly reduce the total number of zooxanthellae per polyp.

Recently, numerous cases of coral bleaching and death of corals due to temperature stress especially triggered by El Nino, were evidenced throughout the Pacific and Caribbean (Lasker et al., 1984; Glynn, 1984; Glynn and D'Croz, 1990).

I. 2. 3. Light

The dependence of coral reefs on light is mainly associated with the photosynthesis process by endolithic algae zooxanthellae. Consequently, light as a physical factor only effects the structure of coral communities in the upper shallow and in the deep zone of the reef (Sorokin, 1993; Shick, 1995).

In the shallow water, however, the excess of light could inhibit photosynthesis in endosymbiotic zooxanthellae and reduce the calcification process (Siebeck, 1981; Jockiel and York, 1982). Therefore, corals might be expected to have developed defenses against it. The coenosarc of corals contains pigment and Mycosporine-like amino acids (MAAs) that believed to have protective action against ultra violet radiation (Sorokin, 1993).

Conversely, in the deep zones of reefs, the deficiency of light influence species composition of coral communities in the biotopes where illumination drops to 3-5% and inhibits distribution of hermatypic corals in deeper zones (Sorokin, 1993). However, many ahermatypic and hermatypic corals that are adapted to low illumination occur in this zone.

The effect of light on coral growth has been reported of by Kawaguti, 1931 Goreau, 1959, 1961; Yonge, 1968; and Yap et. al., 1993. The results of observations by Goreau clearly show that there is a significant increase in the calcification rate on exposure of the coral to light. The differences in light and dark experiment were not caused by a decrease in the pH of the water of dark experiment.

I. 2. 4. Dissolved Nutrients

Coral and zooxanthellae need dissolved nutrients element for growth, maintenance and reproduction. In particular for zooxanthellae, the most important of these elements are Nitrogen (as NO_2^{-2}, NO_3^{-1}, NH_4^{-1} and dissolved organic Nitrogen) and Phosphorus (as PO_4^{-3}, dissolved organic phosphate and other forms)(Fargerstrom,1983). However, Nitrogen and Phosphorus are available in least supply in coral reef environment and therefore are potential limiting factors for coral reef distribution (D'Elia and Wiebe, 1990).

Interestingly, coral reefs flourish in seas of low nutrient content. Also, they have very high gross productivity, with high biomass, but very low net primary productivity which then leads to the assumption that there is a relationship between reef productivity and nutrient availability (Smith et. al. , 1986). The obvious implication of this is that nutrient cycling and conservation play an important role in sustaining high gross productivity (D'Elia and Wiebe, 1990).

The sources of nutrients to coral reefs depend on reef geography and physiography. Nutrients supply for the open ocean and atoll reef comes from nutrients advected in sea water, regenerated from long-term nutrients accumulations in sediment reserves, whereas reefs near high island receive supplies of nutrients from terrigenous sources such as runoff or groundwater inputs (D'Elia and Wiebe, 1990).

D'Elia (1988) describes that the major sources and sinks of nutrients in coral reef environments are advection, upwelling and endo-upwelling, migrations of large organisms, seabirds' dropping, groundwater, precipitation, runoff, burial, resuspension, and diffusion.

I. 3. Previous Works

Ambon Island has been visited by scientists since 16th century. The first biological observation was conducted by George Edward Rumpf (also known as Rumphius) who stayed in Ambon in 1653. Between the 17th and 18th century, Alfred Russel Wallace and Tydeman (with *H. M. Siboga*) were investigated the reef and the terrestrial environment around Ambon and Mollucas (Randall and Eldredge, 1983).

The observations around Ambon and Mollucas were more extensive since *Snellius* expedition (since 1920) and *Rhumphius* expedition (1970) began. Since that time, reports have been published in various journals based on the results of these expeditions. However, most of the observations mentioned above emphasized the general characteristics of the marine environment in Mollucas and only a little specifically focused their works on coral reefs around Ambon island.

Randall and Eldredge (1983), Best et al (1989), Boekschoten et al (1989) and Sukarno (1989) are some of the workers that investigated the coral reef ecosystem around Mollucas, but only Randall and Eldredge specifically focused their work on coral reef in Ambon and some small islands adjacent to Ambon island.

In an attempt to determine the degree of degradation of reefs around Ambon Island, we tried to obtain previous quantitative data to compare with our recently-collected data. Because of the differences in methods used and location, however, it was difficult to make accurate comparison, and to draw conclusions from those comparisons. Moreover, previous workers usually did not specify their exact research sites.

I. 4. Description of research site.

I. 4. 1. General Description

As one of the richest reef region in the world, Eastern Indonesia is of crucial importance for development of tropical marine biology especially in coral reef due to its diversity, complexity and variety of distribution pattern. However, many coastal region and off shore reef in this area are now threatened in several ways. Ambon Island, for instance, used to have a very beautiful, rich and healthy coral reef but in time, with growing human population, exploitation become more intensive and the methods used in some cases were very destructive, that resulting in serious damage in reefs around the island.

Alfred Russel Wallace who was among the early naturalists visited the Mollucas and spent some time at Ambon during December 1857, October 1859, and February 1860 wrote of Ambon Bay:

> ". . . the clearness of the water afforded me one of the most astonishing and beautiful sights I have ever beheld. The bottom was absolutely hidden by continuous series of corals, sponges, actiniae, and other marine productions, of magnificent dimensions, varied forms, and brilliant colors."

He further added:

> "For once, the reality exceeded the most glowing accounts I had ever read of the wonders of a coral sea. There is perhaps no spot in the world richer in marine productions, corals, shells and fishes, than the harbor of Amboyna." (Randall and Eldredge, 1983).

I. 4. 2. Physical Setting

Ambon Island is located at south-west Ceram in Mollucas islands (figure I.1.). The Island lies along the northern border of the Banda Sea. It is divided into a Northern part (Leihitu) and a Southern part (Leitimur) with Ambon Bay in between and separating the two. Ambon bay is divided into an outer bay and inner bay, separated by a distinct shallow sill.

Hila and Tanjung Setan are located on the North coast, which has quite steep shores with narrow reefs . Tanjung Setan is situated approximately 10 km from Hila, uninhibited and there is no road there. The easiest way to reach Tanjung Setan is by boat that took about 25-30 minutes to get there. The Marine Field Station of Pattimura University located in Hila, about 1 km from the small Hila village.

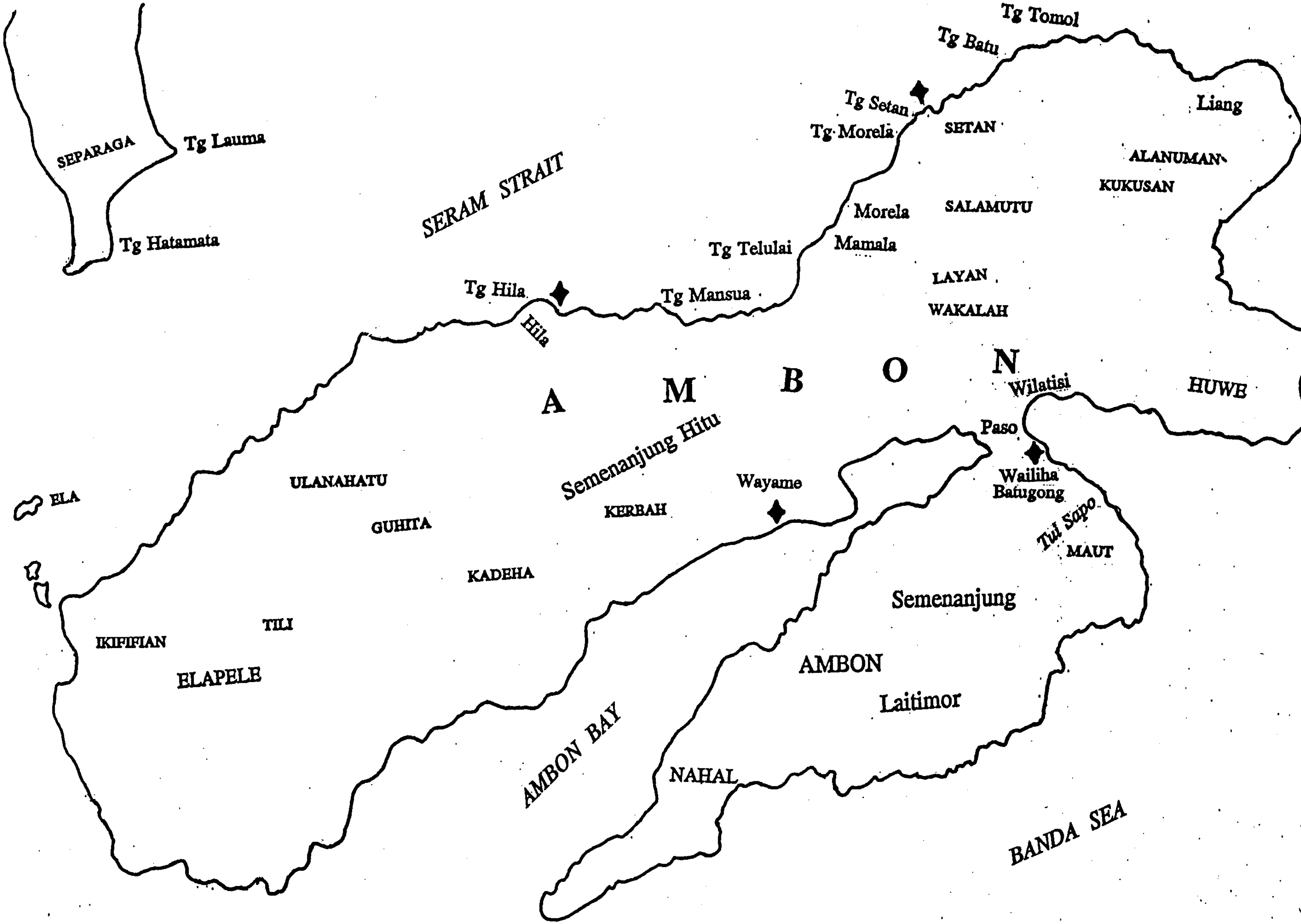
Wayame is located in the outer part of Ambon Bay which is oriented Southwest-Northeast. Population in Wayame escalated recently due to the expansion of Ambon city and because it is close to Pattimura University. In addition, The Government Oil Company has built a new fuel container and transit bridge only approximately 100 m. from the reef that I observed.

Wailiha is situated in Baguala bay about 15 km west of Ambon City. The population around Wailiha also increased very fast recently because there is a plywood factory built there.

Therefore, Tanjung Setan is considered as undisturbed or control area whereas Hila, Wayame and Wailiha are considered as affected reefs.

Figure 1-1. Map of Ambon Island

♦ = Research Sites


Tg Tomol
Tg Batu
Tg Setan
Tg Morela
SETAN
Liang
ALANUMAN
KUKUSAN
SEPARAGA
Tg Lauma
Tg Hatamata
SERAM STRAIT
Morela
SALAMUTU
Mamala
Tg Telulai
LAYAN
WAKALAH
Tg Hila
Tg Mansua
Hila
A M B O N
Wilatisi
HUWE
Paso
Semenanjung Hitu
Wailiha
Batugong
Wayame
ULANAHATU
ELA
GUHITA
KERBAH
Tul Sapo
MAUT
KADEHA
Semenanjung
TILI
IKIFIFIAN
ELAPELE
AMBON
Laitimor
AMBON BAY
NAHAL
BANDA SEA

I. 4. 3. Climate and Oceanography

The climate in Ambon is monsoonal, with the wettest months between May and August and the driest months between December and March. Rainfall ranges from 110 mm in dry season to as much as 634 mm in wet season. The coolest months are between July and September with daily maximum temperature ranging between 27 and 29°C, whereas the warmest months are January and February with temperature ranging from 29 to 35°C. Humidity is high, ranging from 75-85% in dry months and 85-95% in wet months.

Tides in Ambon are semidiurnal ranging from 220 to 230 cm. During the southeast monsoon, high salinity water (34.20-34.50 ‰) enters the Banda sea and the surface temperature decrease below 27°C whereas during northeast monsoon the surface temperature increases to 30°C.

Generally, the sea is calm during the Northeast monsoon (December to March), however storms usually appear in December. The Southeast monsoon begins in May and reaches peak in August indicated by rough condition in southern coast. It then decreases in October.

Upwelling occurs during July, August and September brings about an exchange of the deeper water of the inner bay. Between April and August, the outer bay thermocline rises and cooler water flows into the inner bay.

I. 5. Scope and Objectives

In many parts of the world coral reefs are being eroded by siltation from poor land management, nutrient enrichment from sewage, other form of pollution, destructive fishing practice and intensive use by tourism (Hallock et al., 1993;Richmond, 1993). However, the dimensions of these impacts are largely undetermined and undocumented. Due to this problem, a suitable assessing and monitoring program is required to detect any degeneration and to facilitate the development of effective management plans to ensure the future viability of this ecosystem (Perkins, 1985; Cornforth, 1994; Kenchington and Bleakley, 1994; Hutching et al, 1994; Huber, 1994; Mumby et al, 1995),

The objectives of this work are:

1. to assess the condition of coral reefs around Ambon Island by comparing the condition of the reefs that affected directly and indirectly by human activity, with the reef that considered non-affected or healthy.
2. to determine the possible causes of reef degradation
3. to provide baseline data that are needed to develop a better system in coral reef management in Indonesia.

This research was conducted in the reefs around Ambon Island in June until August, 1994 and May to August, 1995.

CHAPTER II

METHODOLOGY

I. 1. Site Selection.

We wished to compare the condition of reefs that are thought to be healthy and unaffected by human activities to those which are considered unhealthy and anthropologically degraded. We selected one site to be used as an experimental control and three sites that were presumed to be "affected".

Tanjung Setan was chosen as the control site because the land adjacent to the reef is uninhabited and is situated far from rivers, villages and Ambon City. The vegetation in the area is also quite dense, thereby limiting terrestrial influence. This coral reef, therefore, was expected to be healthy and undisturbed.

Hila, also located on the north coast of Ambon Island, is considered influenced by human activities because the reef is located close to a densely-populated village. This reef appeared to typify to narrow reefs on the north coast. Another factor in the selection of Hila was its accessibility - the marine field station of Pattimura University is situated here.

Wayame and Wailiha were selected as potentially-affected site because they are close to very dense populated areas. Wayame located in Ambon bay, which directly receives untreated sewage from Ambon city. Wailiha is situated in Baguala bay, adjacent to plywood factory. The appearance of these reefs suggested stressful growing condition.

We had planned to select sites on the South coast to represent the reefs in that area; They proved to be impossible to access, however, because of rough ocean conditions.

II. 2. Coral Community Assessment

To assess coral communities, the line intercept transect (Life Form method) was used. In this method, the community is characterized using lifeform categories which provide a morphological description of the reef community (fig. 2-1.). All lifeform categories were coded following that described by English et. al., 1994 (table 2-1.).

At each site, we measured 8 transects at 3 and 10 meters depth. Each transect was 25 meters long, which resulted in 400 m total length of transect at each site. The transects were lain over the corals, parallel to the coast line or reef crest following the depth contour. In order to place the transects in a consistent depth, the diver have to refer to a depth gauge when stretching the transects.

The coral colonies passed over by the transect line were measured in centimeter and the data were recorded on the data sheet using water-proof paper. The data were processed using Life Form program (write in dBase III+) developed by the Indonesian Institute of science.

The advantages of this method is that it is reliable and efficient for obtaining quantitative percent cover of not only coral but also other associates living in the reef ecosystem. This method requires relatively simple equipment.

Table 2-1. Lifeform Categories and Codes (after English, 1994).

Categories		CODE	NOTES/REMARKS
Hard Coral:			
Dead Coral		DC	Recently dead, white to dirty white
Dead Coral with Algae		DCA	This coral is standing, but not longer white
Acropora	Branching	ACB	At least 2° branching, e.g. *Acropora palmata, A. formosa.*
	Encrusting	ACE	Usually the base-plate of immature Acropora forms, e.g. *A. palifera* and *A. cuneata.*
	Submassive	ACS	Robust with knob or wedge-like form e.g. *A. palifera*
	Digitate	ACD	No 2° branching, typically includes *A.humilis, A.digitifera, A. gemmifera*
	Tabulate	ACT	Horizontal flattened plates e.g. *A. hyacinthus*
Non-Acropora	Branching	CB	At least 2° branching e.g. Seriatopora hystrix
	Encrusting	CE	Major portion attached to substratum as alaminar plate e.g. *Porites vaughani, Montipora undata*
	Foliose	CF	Coral attached at one more points, leaf-like appearance e.g. *Merulina ampliata, Montipora aequituberculata*
	Massive	CM	Solid boulder or mound e.g. *Platygyra daedalea*
	Submassive	CS	Tend to form small collumns, knobs, or *wedges e.g. Porites lichen, Psammocora digitata*
	Mushroom	CMR	Solitary, free-living corals of the Fungia
	Millepora	CME	Fire coral
	Heliopora	CHL	Blue coral

Table 2-1 (continued)

CATEGORIES		CODE	NOTES/REMARKS
Other Fauna:			
Soft Coral		SC	Soft bodied corals
Sponges		SP	
Zoanthids		ZO	Examples are Platythoa, protopalythoa
Others		OT	Ascidians, anemones, gorgonians, giant clams, etc.
Algae	Algal Assemblages	AA	Consist of more than one species
	Coralline Algae	CA	
	Halimeda	HA	
	Macroalgae	MA	Weedy/fleshy browns, reds, etc.
	Turf Algae	TA	Lush filamentous algae, often found inside damselfish territories
Abiotic	Sand	S	
	Rubble	R	
	Silt	SI	
	Water	WA	Fissures deeper than50 cm
	Rock	RCK	
Other		DDD	Missing data

Figure 2-1. Examples of lifeform categories.

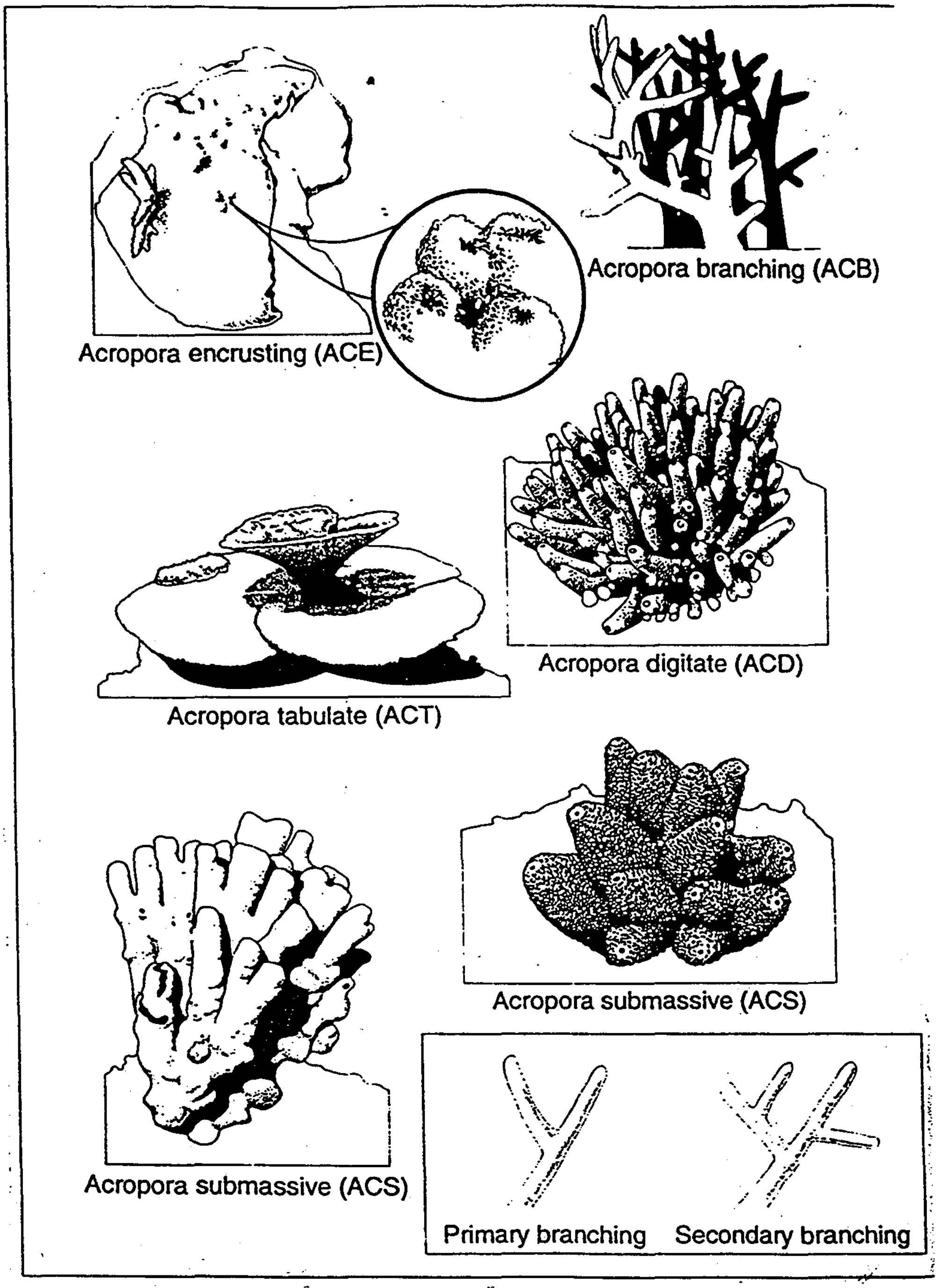
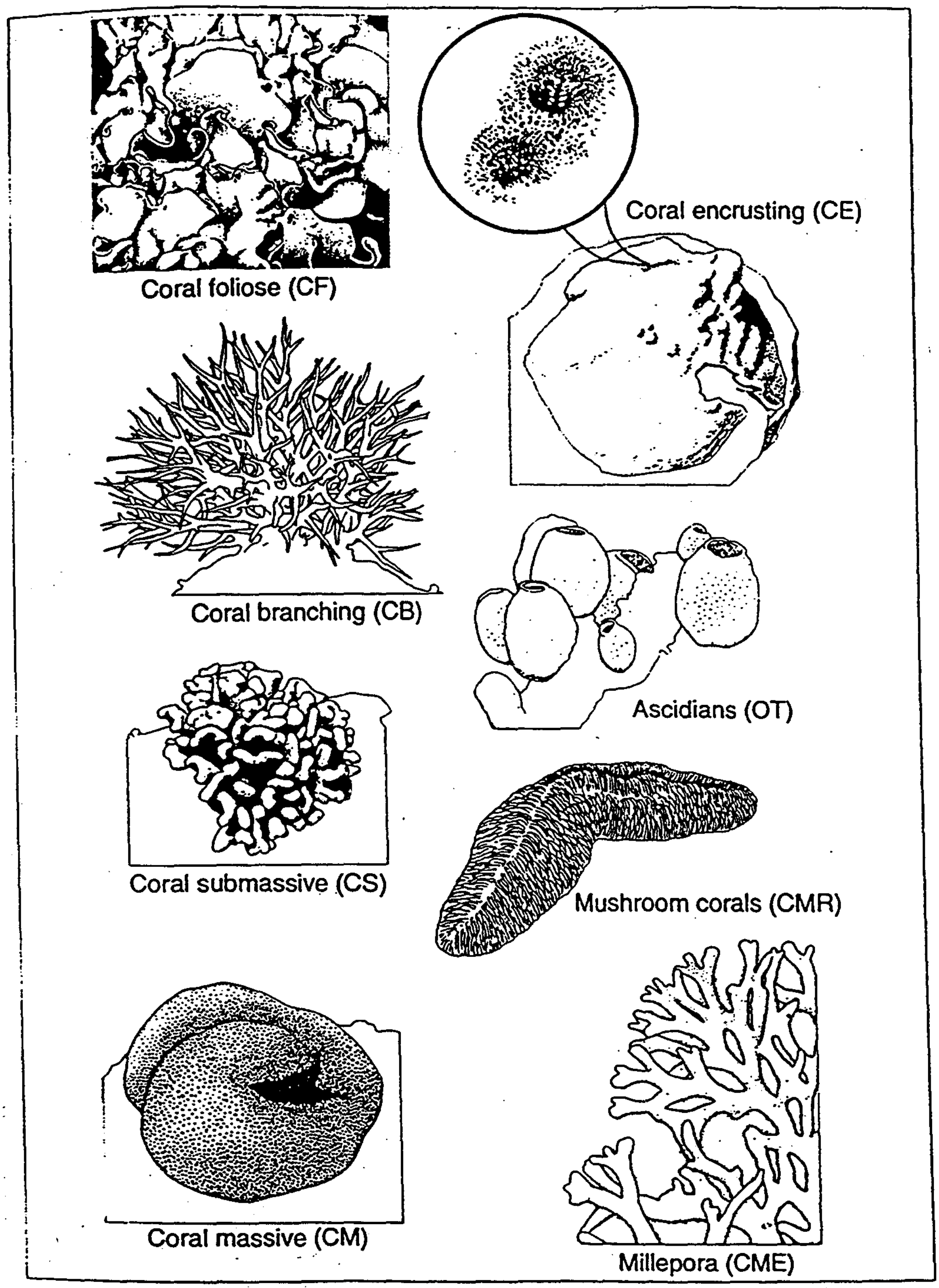


Figure 2-1. Examples of lifeform categories (continued).



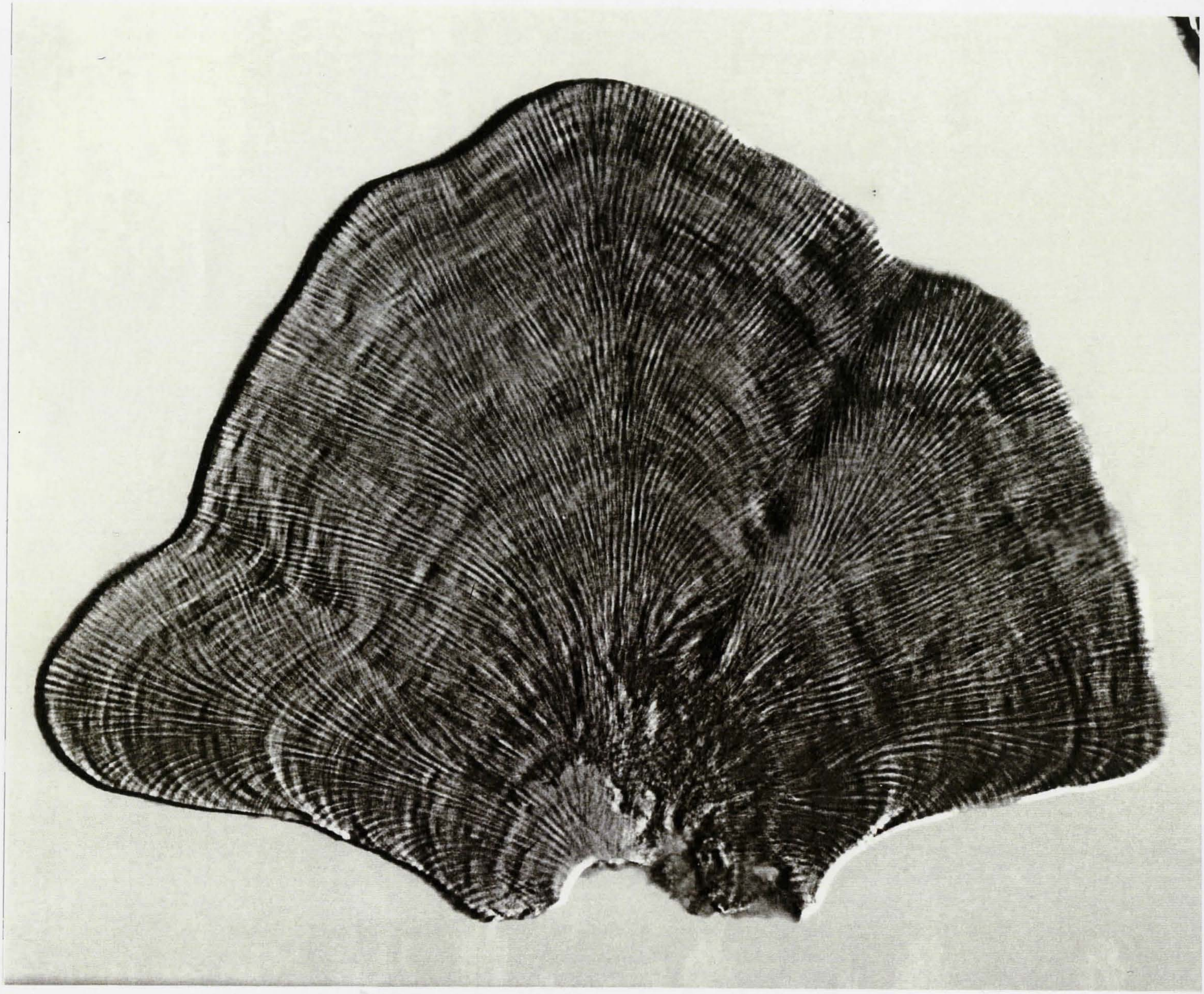
Furthermore, the lifeform categories used allow the collection of useful information by person with limited experience in the identification of coral reef benthic communities (English et. al., 1994; Risk et. al., 1993). The use of this method, including comparison with other method to assess benthic community were discussed further by Loya, 1978; Marsh et. al., 1984; de Vantier, 1986; Harger, 1986; Hatcher and Robertson, 1989; Loya, 1992).

II. 3. Growth rates

Massive coral skeletons show annual variations in density that appear as paired, sub-annual bands of high and low density in X-radiograph (Taylor et al., 1992). These bands have been recognized to be of importance both as a retrospective means of analyzing coral growth and as a possible source of proxy environmental information. The need to monitor and identify changes in threatened reef environment and to understand past and possible future climatic variation has increased its importance (Barnes and Lough, 1992).

To determine the growth rate, a minimum 6 colonies of *Porites lobata* were collected from about 3 meters depth from each site, rinsed with fresh water and air dried. Before removal from the substratum, the tops of all coral heads were marked with a diving knife to make it easier to find the growth axes. Each head was sawn down follow the growth axes, to make a slab about 1 cm thick . The slabs were then x-rayed and the annual density band that appear in the X-ray negative as a series of alternating light and dark band were measured to determine the growth rate (fig. 2-2.). The data obtained from this measurement are the linear accretion of the corals.

Figure 2-2. X-Ray Positive of Massive Coral *Porites lobata*



II. 4. Coral Diversity

To observe coral diversity, 3 to 8 transects of 10 meters long were made at each site, in areas where corals are most abundant. The procedure used to measure the transect were similar to that used to assess coral community, where each coral species passed over by transect line was recorded. In each transect, the number of species were counted and space occupied by colonies were measured. Samples of unidentified species were collected and brought back to the field station and reidentified using Veron (1993). These samples then labeled, soaked with bleach for 1 day, rinsed and air dried before being stored in the field station as a reference collection.

II. 5. Suspended Particulate Matter

Suspended particulate matter (SPM), was determined by filtering 1 liter of water sample through milipore filter. These filters had earlier been soaked in slightly acidic water, rinsed with distilled water, dried and weighed. Water samples were taken at 10 to 30 cm from the sea surface using plastic containers. The filtering was conducted in the field using vacuum hand-pump. These filters were then dried in the oven at 60°C overnight and reweighed. The difference in weight of filter constitutes the SPM load. The sampling was conducted every week in all sites.

II. 6. Resuspension of Sediment

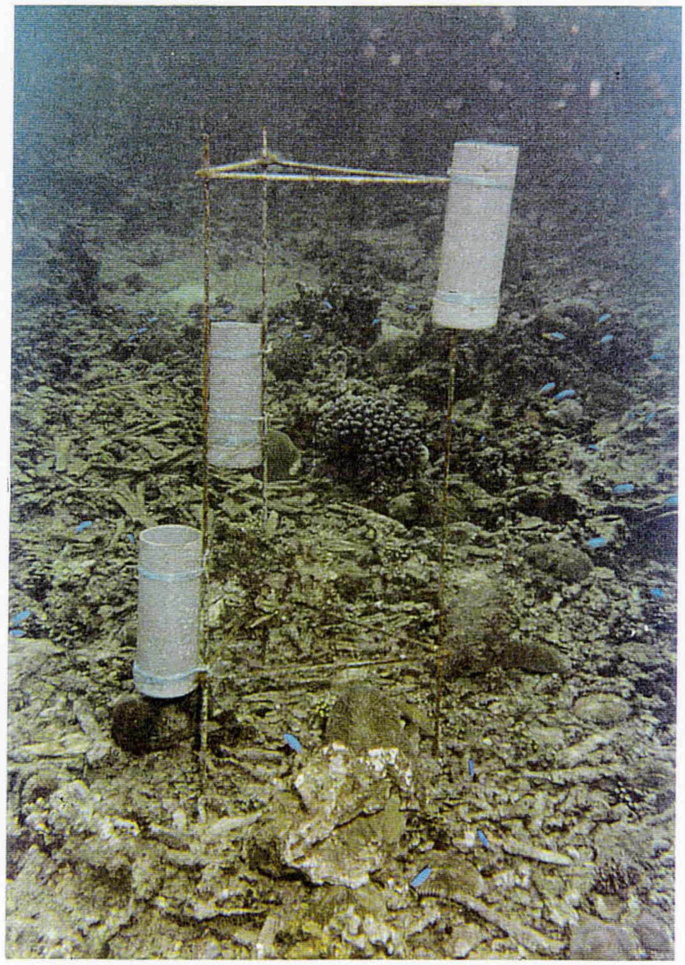
To determine sediment resuspension, three sediment traps were placed at each site ranging from 3 to 5 meter depth. In sites where ocean condition was rough, the sediment traps were placed in a deeper water to prevent waves from tilting the traps. In addition, some rocks were tied in the bottom of the traps. Methods to measure resuspension sediment rate were discussed further by Bloesch (1994) and Kozerki (1994).

The sediment trap comprises a metal tripod frame and three tubes made from PVC attached on it at different distances from the bottom. The construction has a prism shape similar to that used by Cortes and Risk (1985), with 1 m height (fig. 2-3.). The opening of the tube is 47.76 cm^2 and the height is 22.5 cm (9 inch). The ratio of opening diameter and high is 1:3 following that described by Gardner (1980) as the best ratio. According to Gardner, the ratios exceeding 3 will result in overtrapping of vertical flux. The tubes or cylinders were attached to the metal frame by plastic rope with the openings located at 25, 50 and 75 cm. respectively from the substrate.

Every week, sediment retained in each sediment trap was removed, filtered through prewashed and preweighed milipore filter and washed with distilled water to remove salt. The filters were then dried at 80°C overnight and reweighed. The difference in weigh is the amount of vertical flux of sediment trapped in the sediment trap.

Usually after being immersed for about a week under water, filamentous algae would grow on the sediment trap and the tripod frame was corroded. Therefore, each sediment trap, both the cylinder and the tripod frame, were cleaned up before being placed again in the previous location.

Figure 2-3. Sediment Trap



II. 7. Sediment Trapped in Corals Skeleton

Coral species have different capabilities and mechanisms of clearing themselves of sediment particles (Rogers, 1990). However, even though corals exhibit both active and passive removal of sediment particles, excessive sedimentation will result in trapped sediment in their skeleton as they grow (Hubbard and Pocock, 1972; Hubbard, 1975; Laser, 1980). Therefore, coral skeletons contain historical record of sedimentation events and this can also be used as a possible environmental index (Cortes and Risk, 1985).

To determine the amount of terrigenous materials trapped in coral skeletons, about 5 blocks were cut from coral skeleton which were as free from boring as possible. The blocks were taken from outer parts of the skeleton, which was estimated as representing skeleton that grew approximately in the last five years. The samples were immersed in 50% Hydrogen Peroxide for 24 hours to dissolve trapped organic materials then dried in an oven at approximately 100°C . After that, approximately 50 grams of samples were treated with 10 % diluted HCL to dissolved the $CaCO_3$. HCL was added gradually until the carbonate was completely dissolved. Once there was no bubbling evident, the sample were filtered through prewashed and preweighed milipore filters (Whatman milipore filter). After filtering, the filters were again dried, and weigh. The difference in weight is the amount of terrigenous materials trapped in the corals.

II. 8. Bottom Sediment

Samples of bottom sediment were taken randomly around the reef by hand. These samples then rinsed by adding fresh water gradually to remove the salt and dried in the oven at 60-80°C overnight. To determine the amount of acid insoluble material, 50 grams of sample were treated with 10% diluted HCL to dissolved the $CaCO_3$ content. After the activity stopped (which was indicated by no more bubbling), the samples then filtered, dried and reweighed. The difference in weight is the amount of acid insoluble materials.

II. 9. Water Quality and Nutrients Analyses

II. 9. 1. Salinity and Temperature

Salinity and temperature were measured each week using a T-S bridge. This equipment provided with a probe and 100 m long cable which allowed us to measure salinity and temperature at different depths. In this observation, temperature and salinity were measured at the surface, 3 m and 10 m depths considering that in this depth corals are most abundant.

II. 9. 2. Water Clarity

Water clarity was measured at each site using Secchi disc. In an attempt to measure water clarity within the same light intensity, measurements were conducted approximately at the same time in the afternoon.

II. 9. 3. NO_3 and PO_4

From each site, sea water was sampled using a plastic container and stored in a thermos provided with an ice pack for cooling the samples to reduce micro organisms activities. These samples were then brought to the laboratory to analyze dissolved nitrogen (NO_3) and phosphate (PO_4) content following Parsons et. al. (1984).

II. 10. δN15 Analysis

Nitrogen isotopes (the ratio of $^{15}N/^{14}N$) has been used as a tracer of fluxes in natural and disturbed environments (especially by sewage), based on assumption that isotopic signatures can be related to the source. Furthermore, the terrestrial and marine systems have distinct signatures, suggesting any terrestrial contributions to the marine environment would be distinguishable.

To determine δN15, approximately 8 pieces of *Porites lobata* were collected from each site in the same depth (2-3 m.). These samples then dried in the oven at 60-80°C for one or two days then brought back to Canada.

All samples then cut again to remove excess skeletal material. Thin slices of outer part of coral head that consist mostly of coral tissue then soaked in 10 % HCL to remove the remain skeleton. After the skeleton was completely dissolved, the samples were filtered through fine nylon mesh, rinsed with distilled water and centrifuged to remove excess water. Samples were then freeze-dried to ensure preservation.

The freeze-dried samples were loaded into precombusted 6 mm diameter pyrex tubing together with cupric oxide (CuO), placed under vacuum and combusted at 550°C for 2 hours. The resulting N_2 gas then purified before injection into the VG SIRA mass spectrometer.

II. 11. Data Analyses

Data from line intercept transect (lifeform method) were calculate by using small computer program (LF-Coral) released by Indonesian Science Institute.

Statistical analyses were established by applying Mann-Whitney test to compare parameters between sites (Zar, 1974). All statistical analyses were completed by using computer software package Minitab ver. 9.

CHAPTER III

RESULTS

III. 1. Coral Community Assessment

The result of coral community assessment using the line intercept (lifeform) method comprises not only the coverage of life scleractinia but also abiotic factors and other associates that live in the reef environment. By 'coral cover', I mean the percentage of live hard corals recorded along a transect line. In this method, hard corals are divided into the *Acropora* group, which consists of hard corals (Scleractinian) from the genus *Acropora*, and the non-*Acropora* group, which consists of hard corals other than the genus *Acropora*. The average hard coral cover at each site is shown in figure (3-1) and the results of line intercept (lifeform) transects at all sites and depth are shown in figure (3-2) and (3-3). Line intercept data from each transect are presented in appendix A.

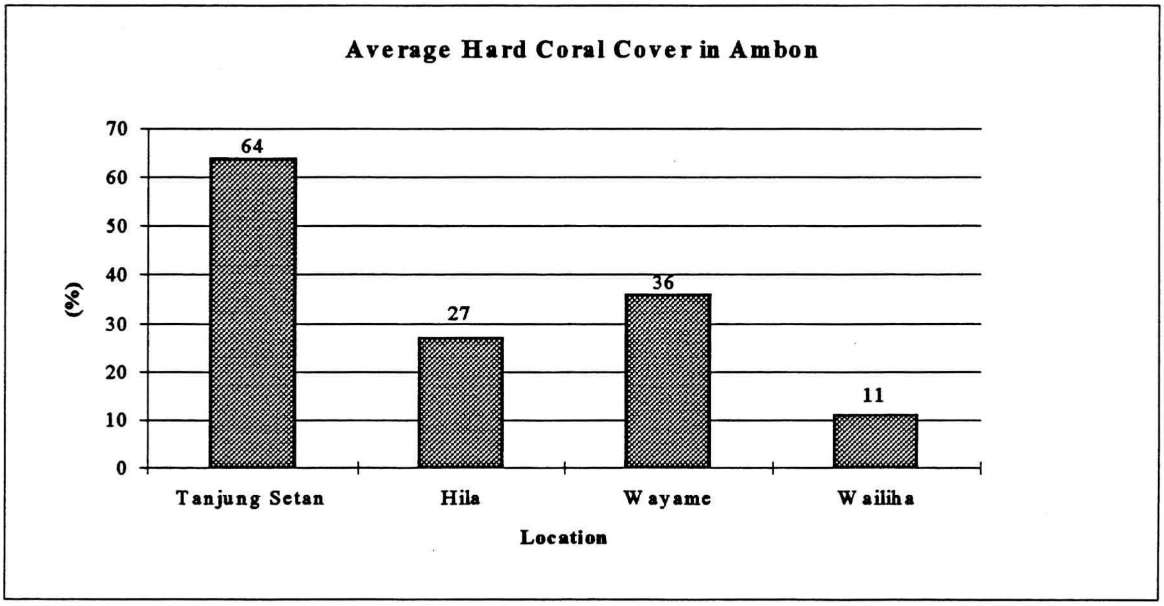
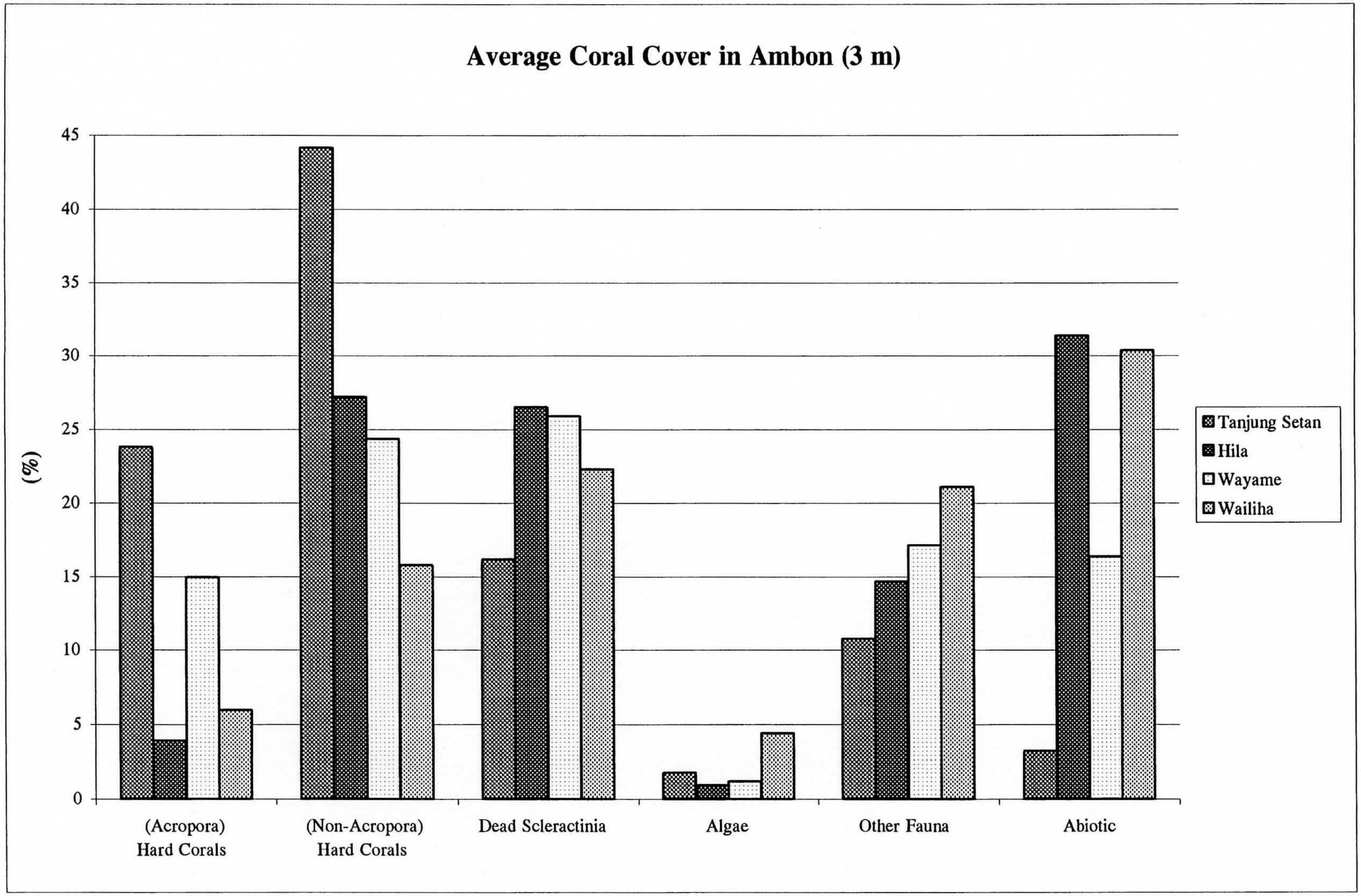
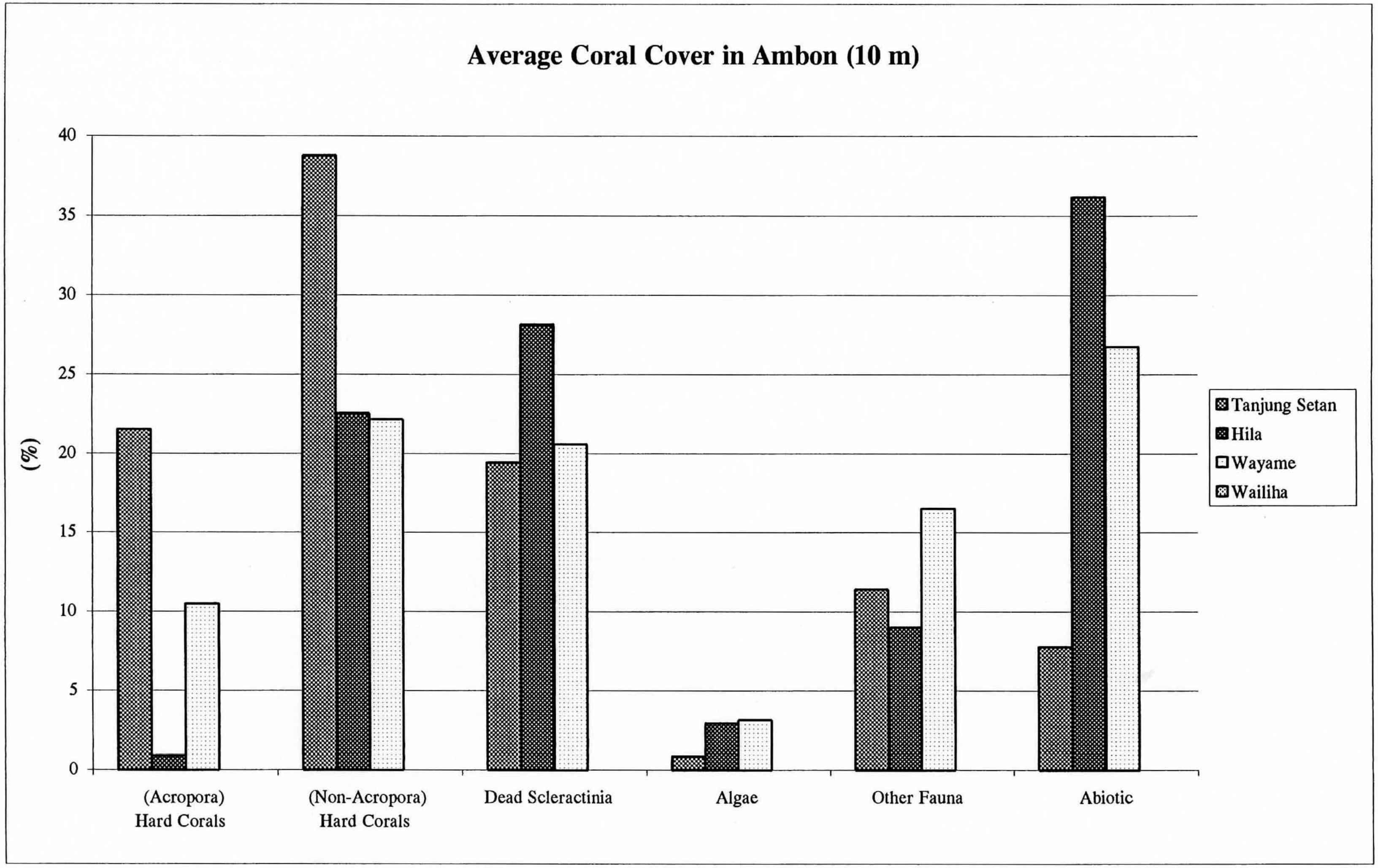


Figure 3-1. Average hard coral cover in Ambon


Average Coral Cover in Ambon (3 m)
(%)
45
40
35
30
25
20
15
10
5
0
(Acropora) Hard Corals
(Non-Acropora) Hard Corals
Dead Scleractinia
Algae
Other Fauna
Abiotic
Tanjung Setan
Hila
Wayame
Wailiha


Average Coral Cover in Ambon (10 m)
(%)
40
35
30
25
20
15
10
5
0
(Acropora) Hard Corals
(Non-Acropora) Hard Corals
Dead Scleractinia
Algae
Other Fauna
Abiotic
Tanjung Setan
Hila
Wayame
Wailiha

The average percent coral cover at Tanjung Setan (64 %) is significantly higher (Mann-Whitney U, all $n1_{-3}$=16, n_4=8, 392≥W≥264, P<0.05) than that at Hila (27 %), Wayame (36 %) and Wailiha (11 %). Interestingly, the percent coral cover at Wayame, located close to Ambon City, is higher than that at Hila, located on the North coast. Statistically, coral cover at Tanjung Setan is highest, Wayame is next, and Hila and Wailiha could not be distinguished.

Since transects were made at 3 and 10 m depth, I could compare the coral cover between different depths. The results showed that coral cover at 3 m depth was always significantly higher than that at 10 m depth, at all sites. At 10 meters depth at Wailiha, the substrate is covered mostly by fine sediment and we found no corals at all. The maximum vertical distribution of corals in this area is approximately 6 m. Consequently, no transects were made at 10 m in this area.

The reef in this area clearly shows the characteristics of reefs under siltation stress. Rough ocean conditions cause bottom sediment mixing, resulting in very low visibility. Frequently, a diver could not see his hand in a distance of approximately 50 cm. On the contrary, the reef at control site (Tanjung Setan) looks very healthy and coral could still be found up to 45 m depth. The reef at Wayame also shows the appearance of some stress, which is expectable because this reef is located adjacent to Ambon harbor and directly faces Ambon city. Surprisingly, corals could still be found at 25 m depth.

The coverage of non-*Acropora* corals is higher than that of *Acropora* corals at all depths and sites (fig. 3-2, 3-3). The differences are statistically significant at all sites (Mann-Whitney U, all $n=8$, $100 \geq W \geq 86$, $P<0.05$).

III. 2. Coral Diversity

Total number of species at 3 and 10 m depth, number of species found only at 3 m and 10 m depth, number of species occurring at both depths and the percentage species shared between depth, total number of species at each sites, and total percentage species shared are given in table 3-2. The complete list of species found in each site is given in appendix B.

Table 3-4. Number of species and percentage species shared between depth and sites

Site	Depth	Transect length	Total spp.	10 m only	3 m only	Both	% shared	Total spp.	Total shared
T. Setan	10 m	70	72	33		39	54		
	3 m	50	68		29	39	57	**101**	39
Wayame	10 m	35	44	24		20	45		
	3 m	35	38		18	20	53	**62**	32
Hila	10 m	85	45	25		20	44		
	3 m	85	41		21	20	49	**66**	30
Wailiha	10 m	N/A	N/A	N/A	N/A	N/A	N/A		
	3 m	65	43		43	N/A	N/A	**43**	N/A

Contrary to the finding that percent coral cover is higher in 3 m depth, the total number of species at 10 m depth is always higher than at 3 m depth at all sites (except for that at Wailiha, where 10 m transects were not made). The highest total number of species is found at the control site (Tanjung Setan) followed by Hila, Wayame and Wailiha respectively. Given the fact that the coral cover at Wailiha is very low and reef condition is unquestionably poor, it is very surprising that the total number of species found at 3 m depths in Wailiha is higher than that at Hila and Wayame. Number of species at Hila is also higher than that at Wayame, even though the coverage of coral at this area is significantly lower than that at Wayame. The increment of species number along the transect line can be seen in figure 3-4.

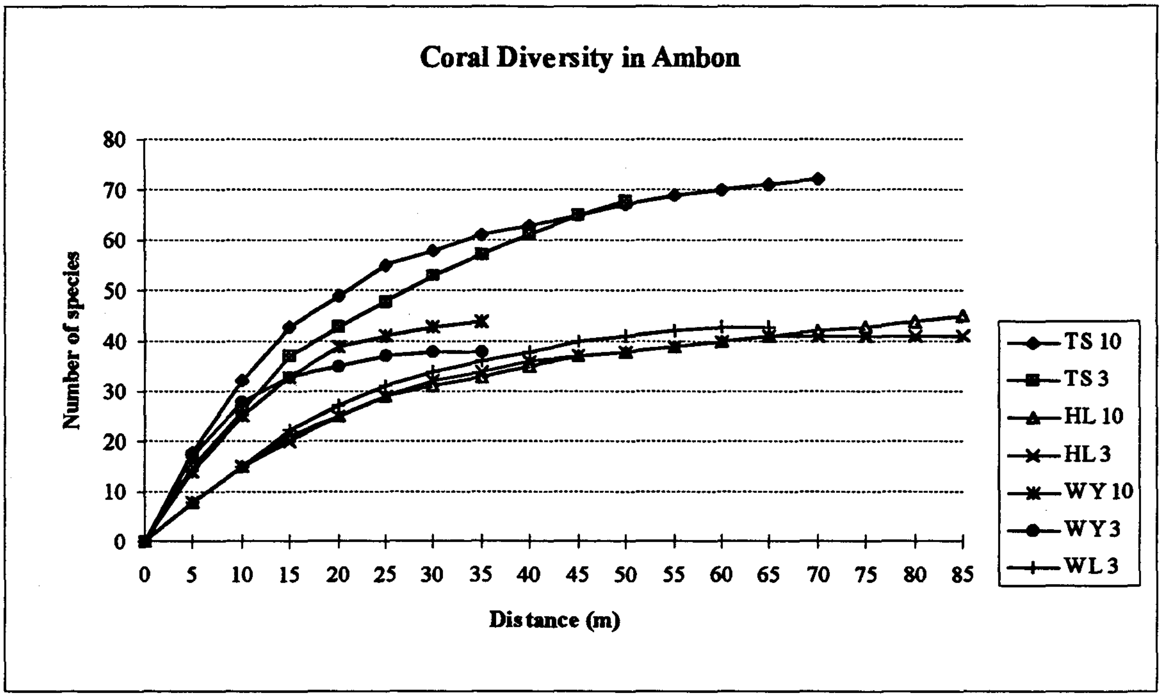


Figure 3-4.

III. 3. Growth rates

The growth rates of corals were attained by measuring a pair of adjacent dense and less dense band in x-ray negative. From samples that have clear density band, the growth rates can be traced over the past 10 years, whereas from samples that have unclear density band, the growth rates can only be traced back up to approximately 5 years. The result of average growth rate of corals in Ambon per year shown in figure 3-5, which shows that growth rate of corals tends to fluctuate at all sites. There are no clear trends of growth rates.

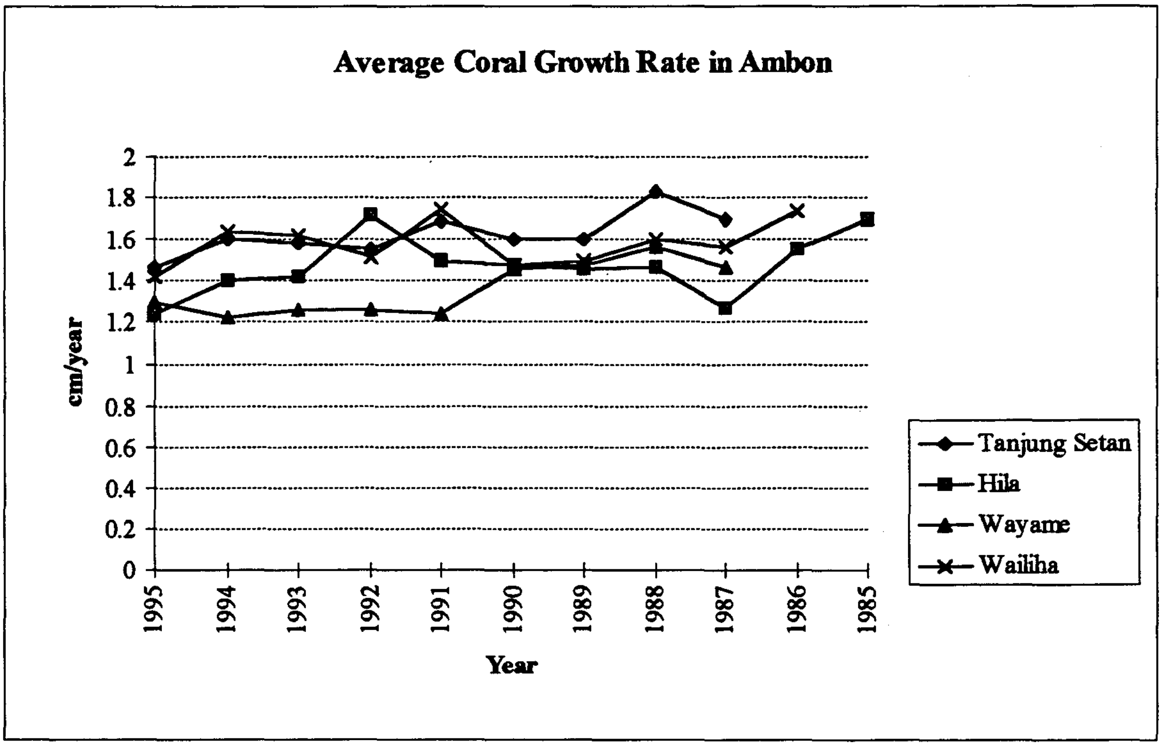


Figure 3-5

By comparing the average growth rates of corals between sites we can see that the growth rates of corals at Tanjung Setan is the highest (1.61 ± 0.1 cm $year^{-1}$) followed by Wailiha (1.57 ± 0.06 cm $year^{-1}$), Hila (1.45 ± 0.17 cm $year^{-1}$) and Wayame (1.31 ± 0.17cm $year^{-1}$) respectively. Interestingly, the growth rate of corals at Wailiha, which is the affected site with very bad environmental conditions is almost as high as that at control site. The average coral growth rates per site are shown in figure (3-6).

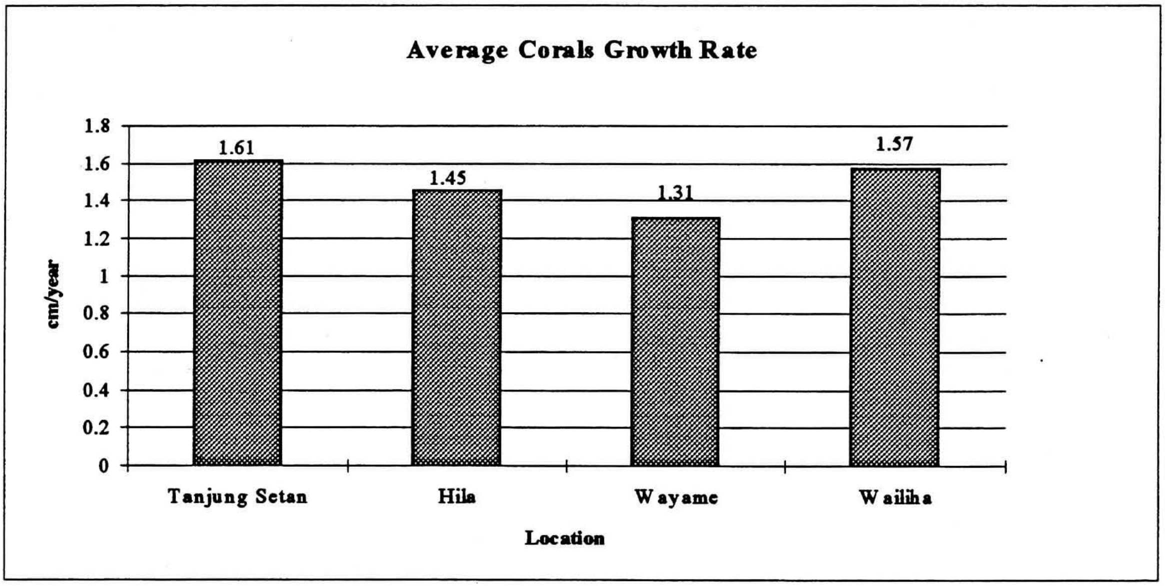


Figure 3-6

The average growth rate of coral at Tanjung Setan is significantly higher than at Wayame (Mann-Whitney U, n1=6, n_2=5, W=50, P< 0.05) but not significantly higher than at Wailiha and Hila. The growth rate of coral at Wailiha is also significantly higher than at Wayame (Mann-Whitney U, n_1 and n_2 = 5, W=40, P<0.05) but not significantly higher than at Hila. Growth rates data from each site are presented in appendix C.

III. 4. Suspended Particulate Matter (SPM)

The content of suspended particulate matter was measured weekly at all sites. The average SPM value is presented in figure 3-7, and SPM values can be seen in appendix D. The highest SPM values were found at Wailiha (15.3 mg L^{-1}), followed by Wayame (11.2 mg L^{-1}), Hila (4.9 mg L^{-1}) and Tanjung Setan (4.5 mg L^{-1}). Wailiha and Wayame are closer to Ambon City, therefore they are the most influenced by city expansion. Forest cutting to provide new housing due to increase of population is suspected as the main cause of high sediment loading in both areas. Furthermore, there is a small river closed to both areas that have inlet only several hundreds' meters from these reefs.

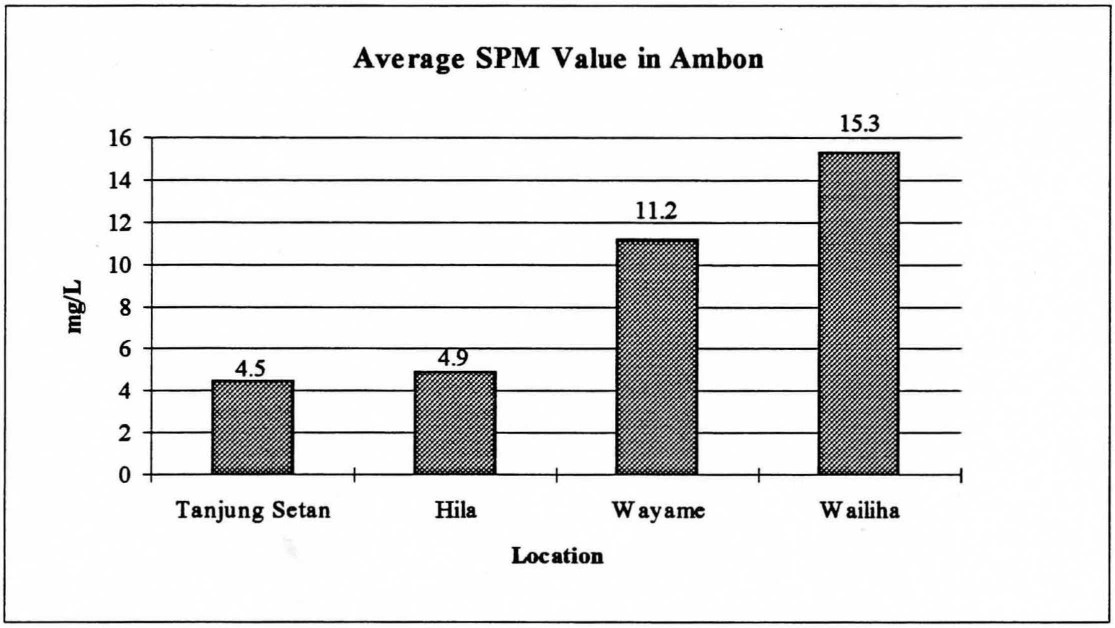
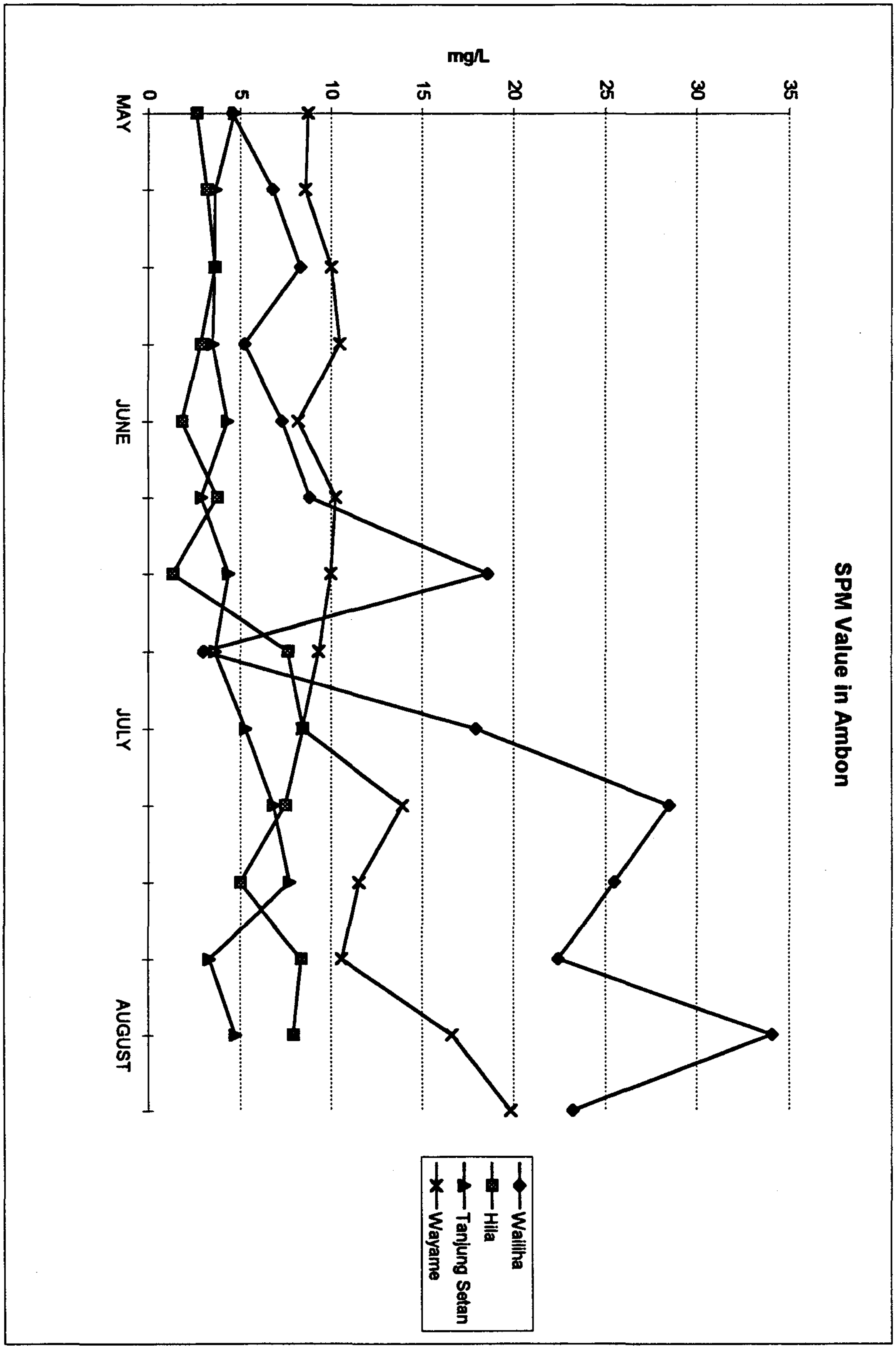


Figure 3-7


SPM Value in Ambon
mg/L
0
5
10
15
20
25
30
35
MAY
JUNE
JULY
AUGUST
Wailiha
Hila
Tanjung Setan
Wayame

The fluctuation of SPM content in sea water is shown in figure 3-8. At all sites, the SPM values tend to increase in rainy season (begun in June). The clearest trend of increasing SPM value in wet season is found at Wailiha and Wayame, due to heavy rains that brought large amount of sediment to the sea through adjacent rivers. Especially at Wailiha, the big difference of resuspended sediment value between seasons not only happened because of heavy rain but also due to big waves that remix the fine sediment in the bottom and bring it to the surface. However, the increase of SPM value at Tanjung Setan and Hila is almost indistinguishable because these reefs are remote from river and the substrate at these reefs are mainly covered by dead corals and coarse carbonate sediment.

Statistical analyses of SPM data shows that SPM value at Wailiha is significantly higher than that of other sites (Mann-Whitney U, n_1=14, n_2 and n_3=13, $264 \geq W \geq 255$, $P<0.05$) but indistinguishable from that at Wayame. The SPM value at Wayame also higher than that at Tanjung Setan and Hila (Mann-Whitney U, n_1=14, n_2 and n_3=13, $287 \geq W \geq 284$, $P<0.05$), and the different between SPM value between Tanjung Setan and Hila is undetectable.

III. 5. Resuspension of Sediment

The value of resuspended sediment presented is the vertical flux of sediment that is captured by sediment traps placed at the reefs area (figure 3-9). The highest average value of resuspended sediment is found at Wailiha (2.56 mg cm^{-1} day^{-1}) followed by Wayame (0.42 mg cm^{-1} day^{-1}), Hila (0.17 mg cm^{-1} day^{-1}) and Tanjung Setan (0.06 mg cm^{-1} day^{-1}).

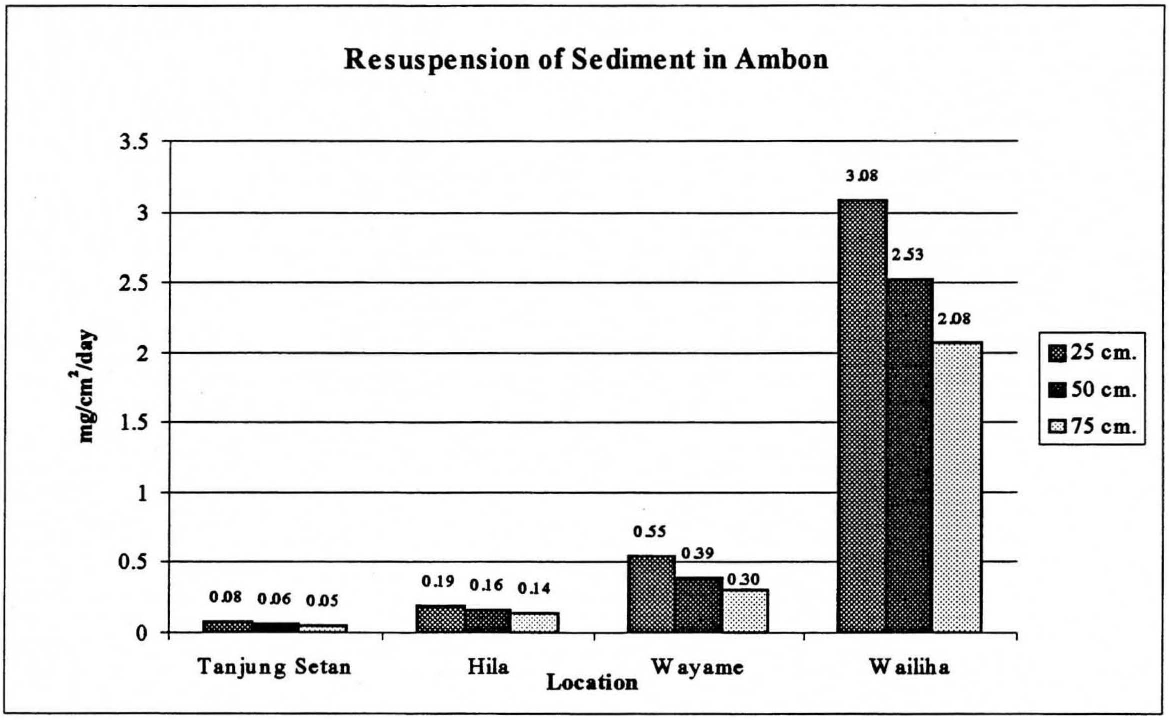


Figure 3-9

The value of resuspended sediment at Wailiha is significantly higher (Mann-Whitney U, n_1 and n_2=14, n_3 and n_4=13, $286 \geq W \geq 247$, $P<0.05$) than at other sites at all distance from the bottom (25, 50, and 75 cm). Similarly, the resuspended sediment value measured at Wayame also higher than at Tanjung Setan and Hila

Table 3-1. Resuspended sediment value in Ambon

	Date	T. SETAN	Date	HILA	Date	WAYAME	Date	WAILIHA
25 cm	14/5/1995	0.07	20/5/95	0.08	12/5/95	0.44	11/5/95	0.12
50 cm		0.06		0.06		0.26		0.09
75 cm		0.05		0.06		0.20		0.08
25 cm	21/5/95	0.05	27/5/95	0.08	19/5/95	0.33	18/5/95	0.17
50 cm		0.05		0.07		0.22		0.15
75 cm		0.04		0.05		0.20		0.14
25 cm	28/5/95	0.07	3/6/95	0.40	26/5/95	0.41	25/5/95	0.13
50 cm		0.06		0.39		0.23		0.11
75 cm		0.05		0.36		0.17		0.07
25 cm	4/6/95	0.09	10/6/199	0.08	2/6/95	0.48	1/6/95	0.54
50 cm		0.08		0.06		0.22		0.28
75 cm		0.07		0.06		0.16		0.26
25 cm	11/6/95	0.07	17/6/95	0.08	9/6/95	0.49	8/6/95	0.55
50 cm		0.05		0.07		0.36		0.68
75 cm		0.06		0.05		0.36		0.50
25 cm	18/6/95	0.09	24/6/95	0.06	16/6/95	0.48	15/6/95	0.76
50 cm		0.05		0.06		0.12		0.63
75 cm		0.05		0.02		0.10		0.56
25 cm	25/6/95	0.08	1/7/95	0.06	23/6/95	0.31	22/6/95	2.04
50 cm		0.06		0.07		0.28		1.56
75 cm		0.05		0.01		0.26		1.24
25 cm	2/7/95	0.07	8/7/95	0.16	30/6/95	0.46	29/6/95	1.99
50 cm		0.06		0.15		0.42		1.24
75 cm		0.05		0.13		0.33		0.90
25 cm	9/7/95	0.05	15/7/95	0.41	7/7/95	0.31	6/7/95	2.40
50 cm		0.05		0.21		0.28		1.01
75 cm		0.04		0.25		0.26		0.72
25 cm	16/7/95	0.08	22/7/95	0.33	14/7/95	0.86	13/7/95	4.58
50 cm		0.07		0.29		0.75		3.42
75 cm		0.06		0.22		0.49		2.20
25 cm	23/7/97	0.11	29/7/95	0.19	21/7/95	0.58	20/7/95	6.95
50 cm		0.10		0.16		0.42		6.08
75 cm		0.09		0.14		0.33		4.75
25 cm	30/7/95	0.07	5/8/95	0.40	28/7/95	0.68	27/7/95	7.30
50 cm		0.05		0.39		0.45		6.11
75 cm		0.06		0.36		0.44		5.32
25 cm	6/8/95	0.10	12/8/95	0.18	4/8/95	1.09	3/8/95	7.11
50 cm		0.07		0.15		0.88		6.44
75 cm		0.05		0.14		0.42		5.46
25 cm					11/8/95	0.77	10/8/95	8.48
50 cm						0.61		7.56
75 cm						0.52		6.86

(Mann-Whitney U, n_1=14, n_3 and n_4=13, 287≥W≥262, P,0.05). Furthermore, the value at Hila is significantly higher than at Tanjung Setan (Mann-Whitney U, n_1 and n_2=13, W=219, P<0.05).

The sediment trapped in sediment traps at different distance from the bottom also shows some differences. At all sites, the value of resuspended sediment trapped at 25 cm was higher than at 50 and 75 cm. The biggest differences were found at Wailiha and Wayame, whereas there is only a small difference at Tanjung Setan and Hila. The resuspended sediment values at all sites are presented in table (3-1).

Even though there are big differences in resuspended sediment at different distances from the bottom at Wailiha, statistical tests cannot detect the differences, due to high variance in samples caused by the big difference of values between dry and wet season. The same problem also happened with the data from Hila. However, the result showed that at Tanjung Setan and Wayame, the value of Resuspended sediment at 25 cm is always higher than that at 75 cm (Mann-Whitney U, n_1=14, n_2=13, 268≥W≥242, P<0.05) and 50 cm (Mann-Whitney U, n_1=14, n_2=13, 251≥W≥216, P<0.05), but there is no difference detected between values at 50 and 75 cm.

Similar to SPM values, the values of resuspended sediment also tend to increase in the wet season, particularly at Wailiha and Wayame. At Wailiha, the very high resuspended sediment value is mainly caused by mixing of sediment by big waves in wet season.

III. 6. Sediment Trapped in Corals Skeleton

Terrigenous material trapped in coral skeleton has been known as an indicator of siltation stress in coral reefs since as they grow, corals will trap some of the sediment in their skeleton. The average amount of sediment trapped in coral skeleton at all sites can be seen in figure 3-10. The percentage of terrigenous material trapped in coral skeleton found at Wailiha (0.47 %) is significantly higher than that at Wayame (0.19 %), Hila (0.05 %) and Tanjung Setan (0.01 %). These values correspond with values of SPM and resuspended sediment showing that the high value of trapped sediment found in area With high value of SPM and resuspended sediment. However, the sediment trapped in coral skeletons at Tanjung Setan is almost undetectable, due to low sediment loading in this area.

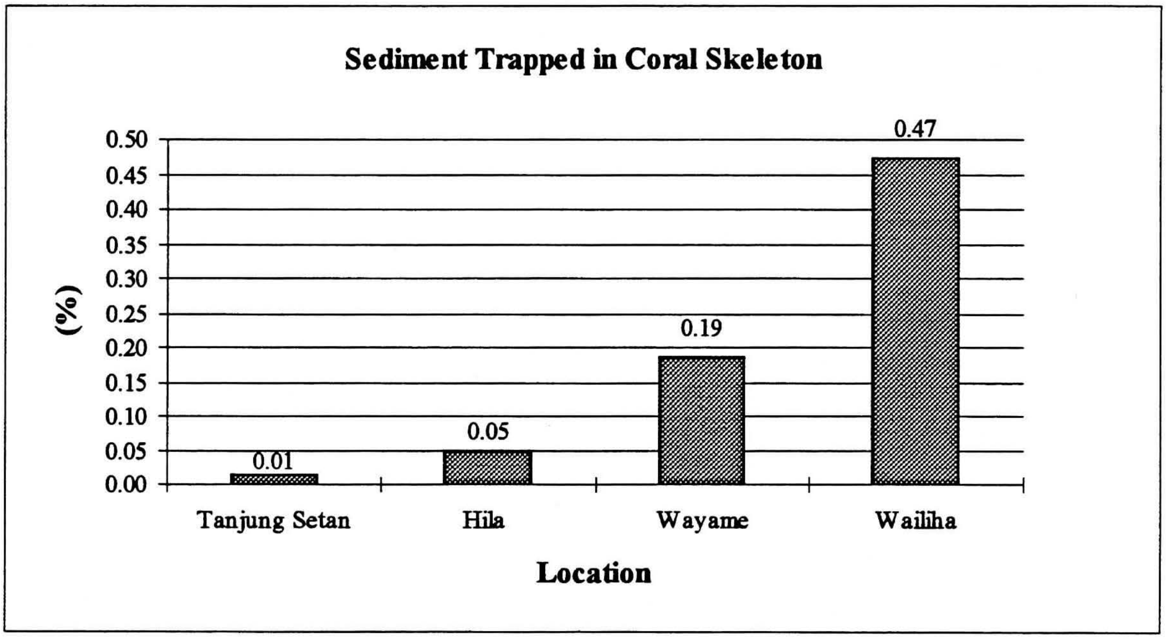


Figure 3-10

III. 7. Bottom Sediment

The comparison of percentage of acid insoluble material in bottom sediment between sites presented in figure 3-11. The highest value found in Wailiha (46.9 %) which also has the highest value of SPM and resuspended sediment. This value is almost as high as that found at Cahuita reef by Cortes and Risk (1985). The lowest value found at control site (Tanjung Setan) which has substrate that mostly covered by dead scleractinian and coarse shell and coral fragments. High values of acid insoluble material are also found at Wayame, with substrate similar to Wailiha.

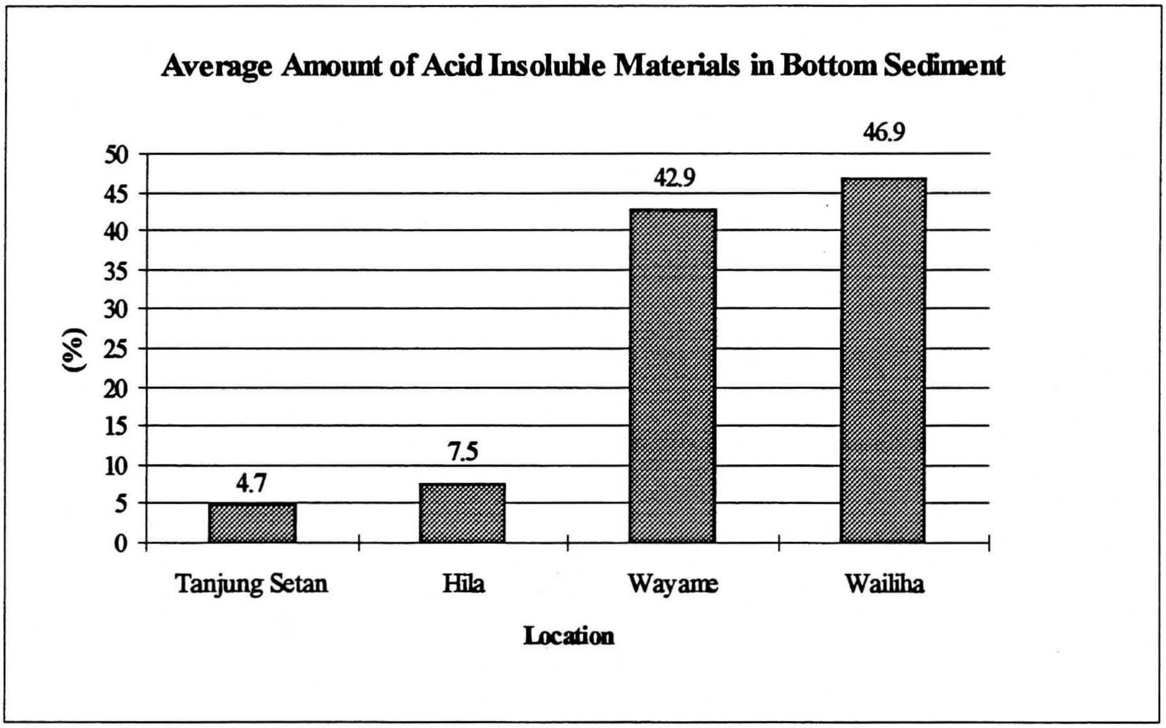


Figure 3-11

The value of acid insoluble material in bottom sediments at Wailiha is significantly higher than other sites (Mann-Whitney U, all $n = 5$, $57 \geq W \geq 52$, $P<0.05$). The data from Wayame are also significantly higher than at Hila and Tanjung Setan (Mann-Whitney U, all $n = 5$, $W=57$, $P<0.05$). The lowest value was found in sediment from Tanjung Setan (control site) that also has the lowest value of SPM content and resuspended sediment.

III. 8. Water Quality and Nutrients Analyses

To determine the environmental condition, some environmental parameters such as salinity, temperature, nutrients (P and N) and water clarity were measured at all sites. Phosphate and Nitrate have been shown to be limiting factor of coral reef growth and distribution. The mean NO_3 and PO_4 content in sea water at all sites is presented in figure 3-12.

The NO_3 content at Wayame (1.46μM L^{-1})is significantly higher (Mann-Whitney U, all $n=8$, $85 \geq W \geq 84.5$, $P<0.05$) than that at Hila and Tanjung Setan, but not significantly higher than at Wailiha. The high NO_3 content at Wayame is expectable since this area receives untreated sewage input from Ambon city and surrounding village. NO_3 content fluctuates from time to time and reach the maximum value in wet season when heavy tropical rain wash out the sewage from land and bring it to the sea. The fluctuation of NO_3 content is presented in appendix E.

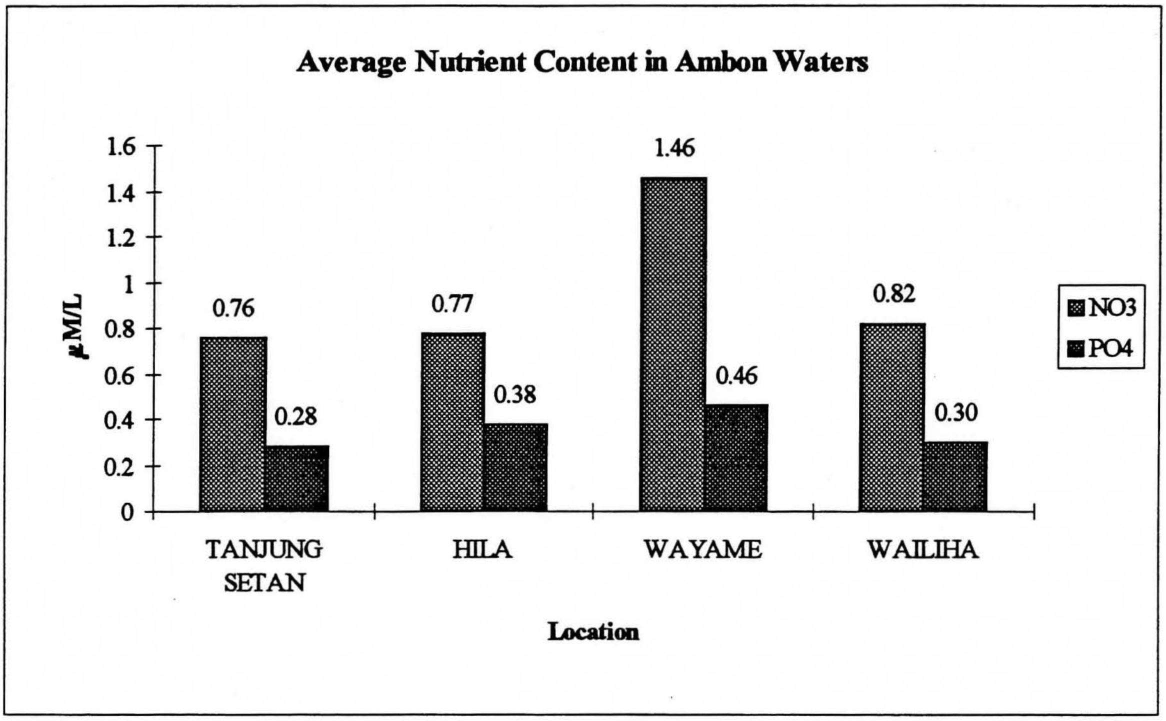


Figure 3-12

Similar to NO_3, PO_4 contents in sea water were also found higher at Wayame compare to that at other sites. However, these differences cannot be detected by statistical test except of the difference between Wayame and Tanjung Setan (Mann-Whitney U, n_1 and n_2=8, W=88.5, $P<0.05$). Moreover, The PO_4 values also tend to increase in wet season. The fluctuation of PO_4 values is given in appendix E.

Salinity (fig. 3-13) and temperature (fig. 3-14) in coral reef environment around Ambon also fluctuate from time to time and tend to decrease in wet season. However, the range of their variance still within optimal range for corals to flourish. The Average salinity range from 32.6 to 34.1 ‰ and the average of temperature range from 24.5 to 28.2 °C.

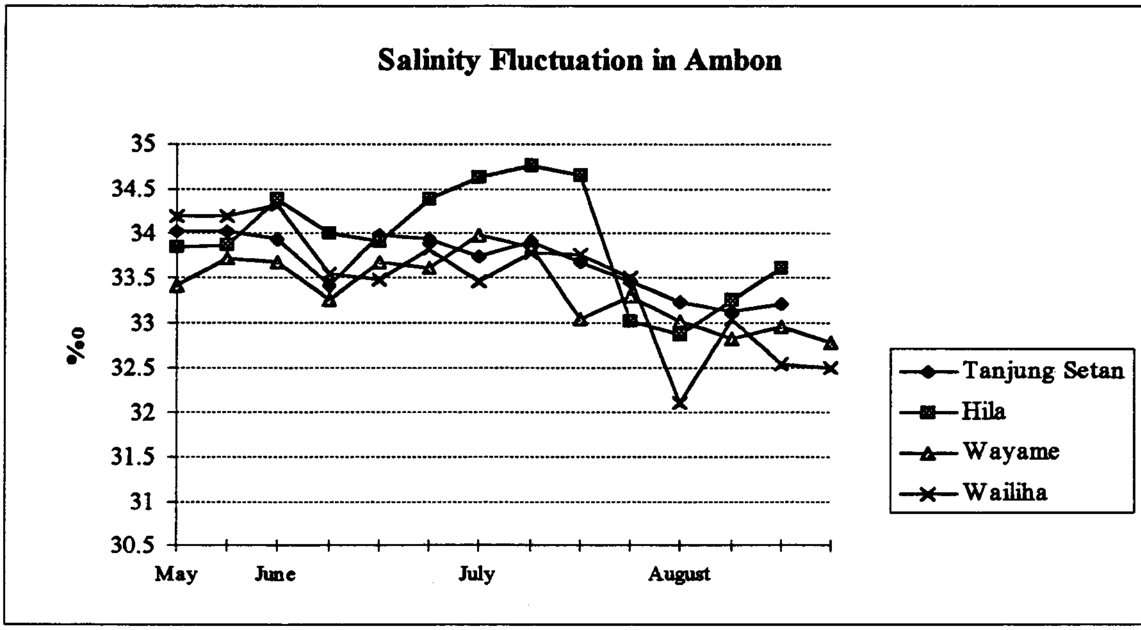


Figure 3-13

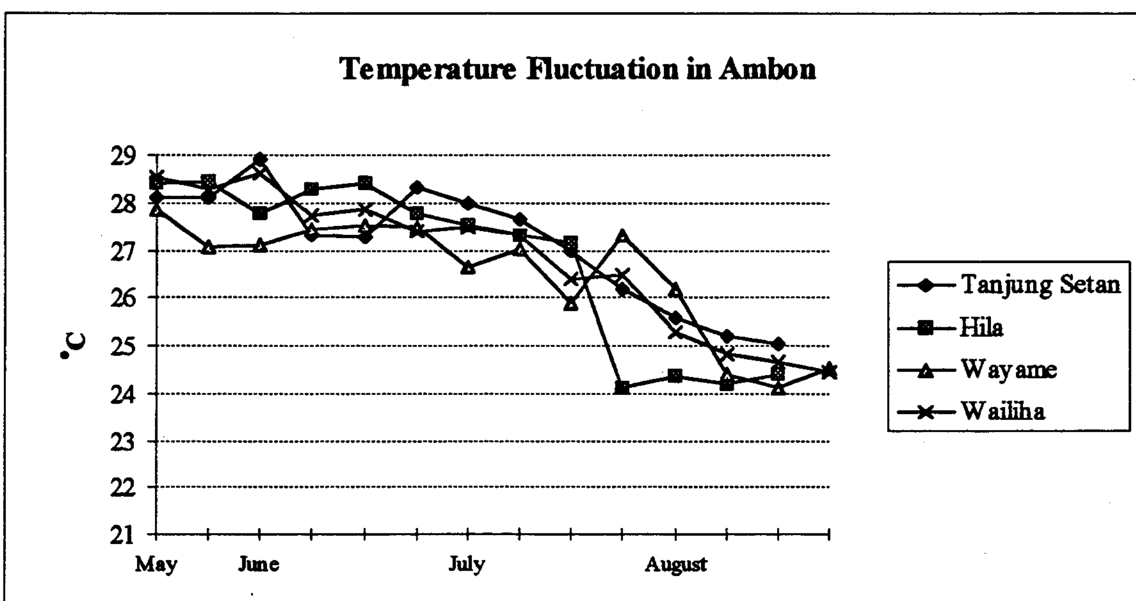


Figure 3-14

Water clarity that we measured at all sites using secchi disk showed that sea water at Tanjung Setan and Hila is remarkable clear, since the secchi disk could still be seen at approximately 21 m. Conversely, water clarity at Wailiha is very poor and reaches the minimum range of 2 m in wet season (fig. 3-15).

The range of water clarity clearly decreases in the wet season at all sites especially at Wayame and Wailiha that receive more suspended particulate and experience rough seas. Water clarity at Hila and Tanjung Setan only slightly changes in wet season.

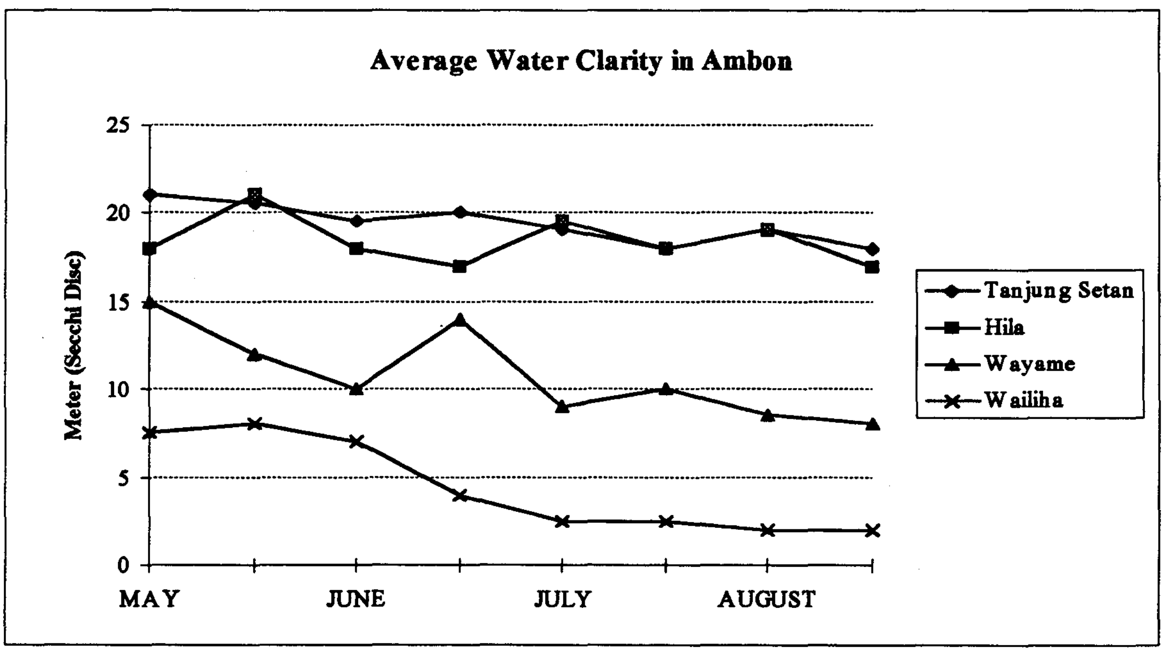


Figure 3-15

III. 9. δN15 Analysis

Terrestrial and marine ecosystems have different values of $\delta^{15}N$, suggesting any terrestrial contributions to the marine environment could be determined. This assumption allowed the use of $\delta^{15}N$ ratio as a tracer of sewage contamination in coral reef environment. This ratio usually expressed in values of per mille (‰) relative to the standard atmospheric Nitrogen:

$$\delta^{15}N = (((^{15}N/^{14}N)_{sample} / (^{15}N/^{14}N)_{standard})-1)*1000$$

(Rundel et. al., 1989; Knowles and Blackburn, 1992).

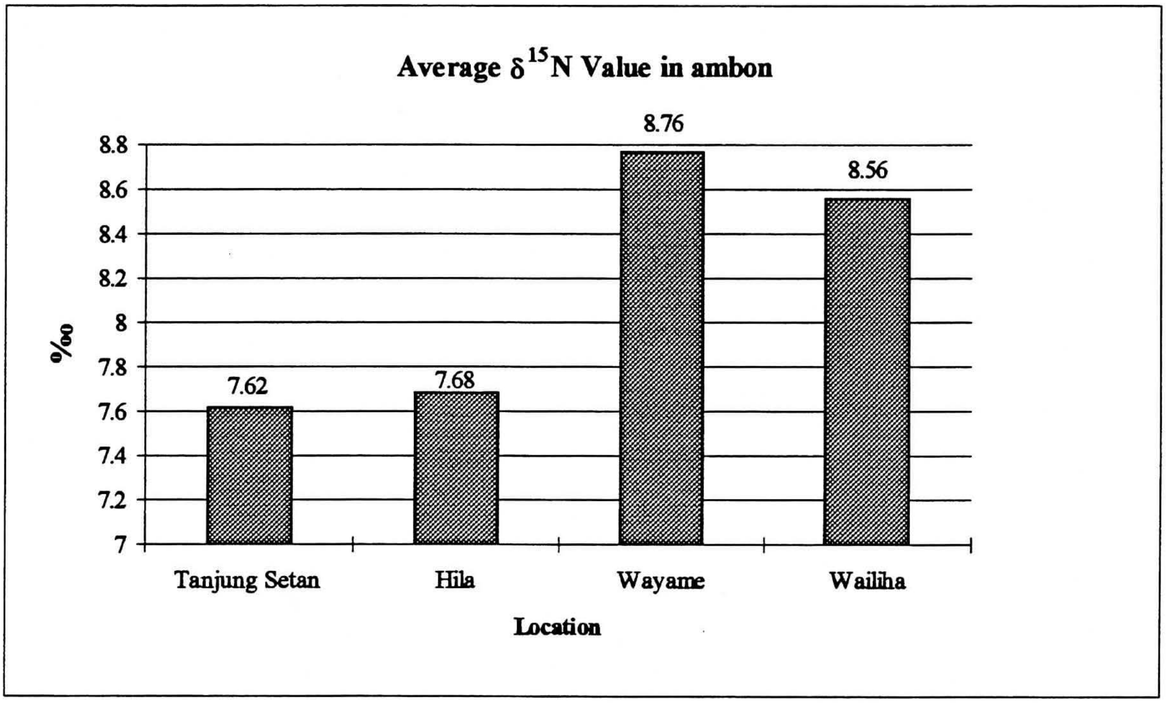


Figure 3-16

The average natural abundance of $\delta^{15}N$ in air is a constant 0.366 ‰, therefore it is used as the standard for Nitrogen analyses, while mean natural abundance of ^{15}N in marine ecosystem is 7.2 ± 2.6 ‰.

The result of $\delta^{15}N$ analysis (Figure 3-16) showed that the ratio of $\delta^{15}N$ in coral tissue at Wayame that located at Ambon bay is significantly higher than at Hila and Tanjung Setan (Mann-Whitney U, n1 and n2=9, n3= 6 $106 \geq W \geq 88$, $P<0.05$) but not significantly higher than at Wailiha. The lowest value of $\delta^{15}N$ found at control site (Tanjung Setan) that has least influence of human activity since this area is uninhabited.

CHAPTER IV

DISCUSSION

IV. 1. Coral Community

Increasing human activity and population pressure on coastal marine resources, especially coral reefs, have caused significant changes in coral community structure that require careful management. Some of the effects that have been found associated with changes in coral reef ecosystems around the world are: increase of turbidity and siltation, abnormal inputs of nutrients and organic matter, pollution from toxic chemicals and oil, thermal loading, alteration to freshwater runoff, changes in water circulation and wave exposure, direct physical damage and breakage, and the selective removal of organisms or components producing population imbalances and possibly interfering with nutrient cycling (Chappel, 1980; Munro and Willson, 1985; Craik et. al., 1990; Grigg, 1990; Gomez, 1994; Goldman, 1994).

An attempt to develop a suitable environmental management strategy for this complex ecosystem, however, must be based on the current state of these resources, their natural variability, and the impact of human activities. Consequently, baseline research is needed to describe reef areas and to provide data about environmental changes (Lang et. al., 1993; Zann, 1994).

The result of coral community assessment in reefs around Ambon clearly showed that the reefs in this area are under stress. This is suggested by low coverage of live scleractinian (fig. 3-2, 3-3) and number of species (table 3-4) found in affected sites (Hila, Wayame and Wailiha). These stresses could be caused by natural or human induced phenomena, or combinations of both. Nonetheless, environmental factors analyses indicated that in this case, the stresses to these reefs are likely to be caused by human activities. On the contrary, coral reefs at the control site (Tanjung Setan), unlikely to be influenced by humans, show remarkably high live scleractinian coverage and number of species.

Comparison with other reefs in Indonesia confirms that Tanjung Setan is a healthy and unaffected reef. The average percent live coral cover at Tanjung Setan (64%) is lower than average live coral cover found by Jompa (1996) at Kapoposan (76.8%), South Sulawesi, but Total number of species at Tanjung Setan (101 spp.) is higher than that at Kapoposan (80 spp.).

The environmental factors measured have a strong relation with coral cover and number of species. In control sites, good environmental conditions allow coral to flourish at both 3 and 10 m depth, and corals can still be found at 45 m depth. In this area, water is crystal-clear, sediment and nutrient input are low, salinity and temperature are in the optimal range for coral to grow, and human impact is low. Local fishermen and a small number of divers sometimes visit control site, but no significant evidence of reef destruction was found. In general, the reef in this area is still healthy and rich with marine organisms.

Similar to Tanjung Setan, environmental factors measured in Hila also stay in the optimal range for coral to flourish, but in this area significant human impact was found. Along the reef, especially at shallow depth, bomb craters, broken branching corals and massive corals turned upside-down were discovered. All the facts clearly showed evidence of physical destruction.

Mechanical destruction in this area mainly comprises fish blasting, coral collecting and anchor damage. According to information gathered from local fisher, and people from the Hila village, however, even though it is illegal, there was an extensive fish blasting activity around this area, but it stopped a few years ago when the government built a police station in the neighbor village.

More damage is now caused by coral collecting. All the foundations of the houses in the village were built using massive coral skeletons. When the tide is low, people from the village go to the reef and collect both live and dead massive corals, load them on bamboo 'rakit' and drag them to the shore. In doing so, they damage the corals by walking and dragging through them.

The observations mentioned above can explain the damage of coral reef in shallow depth, but still cannot explain low coral cover and species abundance in the deeper zone. Corals in this area were found growing on unstable substrate, consisting mostly of boulders and sand. Consequently, the corals in shallow depth are easily destroyed by big waves and corals in the deeper end would have low recruitment rate. However, there is no enough evidence to prove this assumption.

The other reefs observed were Wayame and Wailiha. Contrary to the control site, reefs in these areas display attributes of reefs under siltation and sewage stress. Low coral cover and number of species, especially in Wailiha, indicate the occurrence of stress in these areas. High values of SPM, resuspended sediment, terrigenous materials in coral skeleton and acid insoluble materials distinctively exhibit the occurrence of siltation stress, while high nutrients and $\delta^{15}N$ content as well as the occurrence of other associates such as sponges and algae, are a sign of high nutrients supplied from the land.

Rogers (1990), outlines the effects of heavy sedimentation on coral reefs as fewer coral species, less live coral, lower coral growth rates, greater abundance of branching forms, reduced coral recruitment, decreased calcification, decreased net productivity of corals, and slower rates of reef accretion. Furthermore, excessive sedimentation can adversely affect the structure and function of the coral reef ecosystem by altering both physical and biological processes.

Most of the effects mentioned are found in Wayame and Wailiha. Excessive sedimentation in these areas causes reduced light availability for photosynthesis and limited coral distribution vertically, smothered coral, and lowered coral recruitment all of which results in low coral cover and species richness. High SPM and resuspended sediment produce turbid water that restricts coral distribution to approximately 20 m at Wayame and approximately 6 m at Wailiha.

The highest value of SPM, resuspended sediment, terrigenous materials in coral skeleton and acid insoluble material that we found at Wailiha is higher than that found by Cortes and Risk at an affected site in Costa Rica and by Jompa at an affected site in South Sulawesi, accordingly, coral cover at Wailiha is lower than both sites. On the other hand, number of species at Wailiha (43 spp.) exceeded the number of species found at Costa Rica (18 spp.) and South Sulawesi (39 spp.). The possible answer to this phenomenon is low intraspecific coral competition for spaces due to low coral cover (Rinkevich and Loya, 1982; Hidaka and Yamazato, 1984; Thomason and Brown, 1986; Chadwick, 1988).

Interestingly, Best et. al. (1989) only found 15 species in their observation on coral reefs around Ambon Island during The Snellius-II expedition. The big difference in species number found by Best in reefs around Ambon is probably due to the difference in site selection. Some of the sites observed by Best are close to the sites observed in this study but not exactly the same spot.

IV. 2. Growth rate

One of the important basic to the study coral reef ecosystem or their component with respect to the geological record is the understanding of coral growth rates, growth forms, and longevity. Coral grows very slowly. The average linear growth rate under normal condition is about 10-15 mm/year. Light, clear water, sufficient water movement, and relatively stable temperature have been recognized as important factors for reef and coral growth(Yonge, 1963; Glynn, 1973; Buddemeier and Kinzie III, 1976; Davies, 1983).

Interestingly, coral skeletons have been known to record indications of significant ecological events or condition during the life of the coral. More recently, scientists have attempted to find records of environmental events in the chemistry, isotopic content, and structure of skeletons (Buddemeier et. al., 1974; Shepard et. al., 1975; Boto and Isdale, 1985; Constanz, 1986; Risk et. al., 1987). For example, Carriquiry et. al. (1989) traced the 1982-1983 El Nino warming event in Eastern Pacific by measuring the stable oxygen isotope ratios ($\delta^{18}O$) recorded in massive *Porite lobata* skeletons.

The relationship between the skeletal record and the environment is mainly determined by the mechanism of calcification or coral growth and its environmental controls (Highsmith, 1979). This mechanism—especially in hermatypic corals— has been proved by Goreau (1959 and 1961) to be related to symbiosis between corals and their intracellular algae, zooxanthellae. The results of his study revealed that the calcification rate of reefs was significantly lowered by the exclusion of light. He further concluded that the effect of light on reef coral growth is in part mediated through the zooxanthellae.

Measurements of coral growth rates have been attempted in many different ways, such as direct measurement, calcification flux, change in water chemistry and radioisotope uptake. Other methods well applicable for massive corals have been annual fluorescent bands and density bands (Isdale, 1984; Patzold, 1984; Knutson et al., 1991; Barnes and Lough, 1993; van Veghel and Bosscher, 1995). The last method has attracted many scientists because these bands have been recognized to be of importance both as a retrospective means of analyzing coral growth and as a possible source of proxy environmental information.

The result of coral growth rates measurement using x-radiograph clearly shows growth rate-environmental correlation. Growth rates of corals at the control site (Tanjung Setan) are the highest (1.61 cm/year), which is as expected since this area has optimal environmental conditions. Likewise, corals in Hila also grow fast (1.45 cm/year) because environmental condition in this area are almost as good as condition at Tanjung Setan.

On the other hand, corals in Wayame have the lowest growth rate (1.31 cm/year) due to the effect of siltation and sewage stress. High sediment loading in this area results in low water clarity, thereby cutting down light available for photosynthesis. Since coral and associated zooxanthellae depend on light for rapid deposition of calcium carbonate, high turbidity can reduce coral growth rates (Aller, 1974; Peters, 1985; Bak et. al., 1995).

Moreover, sediment which settles on coral colonies can also result in a decrease in growth rate because of the diversion of energy to the removal of these particles. However, it is not always clear what triggers specific growth responses on corals and coral growth does not appear to be a simple indicator of excessive sedimentation (Dodge et al., 1974; Dodge,1977; Chalker, 1981; Dodge, 1984; Hubbard, 1987).

High nutrient loading also have significant effects on coral growth. Even though the corals tend to respond positively to the increase of nutrients, growth rates will decrease at certain maximum concentrations presumably as a result of smothering, reduced light and reduced photosynthetic capabilities of the coral (Tomascik and Sanders, 1985; Atkinson et. al., 1995; Kendall et.al., 1983; Rogers, 1983).

Interestingly, corals in Wailiha show reverse performance from those phenomena mentioned above. Despite poor environmental condition associated with high sedimentation rate and nutrients concentration, corals in Wailiha surprisingly show high growth rates.

High growth rates of corals in this area are more likely to be related to eutrophication, since corals can absorb nutrients directly across their tissue and use them autotrophically to increase their growth rates. Another possible explanation for this anomaly is that corals may grow more rapidly to keep up with high sedimentation rates that can bury them (Kinsey and Davies, 1979; Edinger, 1991; Montaggiori, 1993; Atkinson, 1995). Furthermore, Tomascik and sander (1987) suggested that SPM up to certain maximum concentration may play a role as an energy sources for increasing coral growth.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

V. 1. Conclusions

- Coral reefs are a very complex ecosystem built mainly by scleractinian corals that can only flourish within specific environmental condition. Moreover, this ecosystem can only survive narrow range of environmental variation. Consequently, any disturbance to the environmental balance could cause degradation to this fragile ecosystem.
- Steady increase in human activity and population pressure on coastal marine resources, especially coral reefs, in Ambon have caused significant changes in coral community structure that are cause for concern over current reef management practices.
- Low live coral cover and number of species at Hila mainly caused by physical/mechanical destruction (coral collecting and fish blasting), while that in Wayame and Wailiha are caused by excessive sedimentation and sewage (eutrophycation) that result in restriction of coral distribution to the shallower area due to decrease light availability, and decrease coral recruitment. Conversely, low human impact in control site (Tanjung Setan) is exhibited by high coral cover and number of species, crystal-clear water, and low nutrient content in surrounding water.
- Coral growth rates were highest at control site that supported by good environmental condition. However it tended to be higher at more eutrophic reefs such as wailiha, but slower at a certain maximum critical nutrient value like in Wayame. The processes that control the growth of coral are still poorly understood.

V. 2. Recommendations

- Coral reefs around Ambon will come under increasing threat due to steady increase of human activity and population pressure. Therefore, political will and institutional capacity to implement the legislation is needed especially for marine environment.
- Urgent action is required by local government to implement and enforce the management of coral reefs since protection of environment appear to be depend on national agenda that usually not appropriate regionally.
- More inrterdiscipline long-term observations, regarding coral reef assessment and monitoring are needed to provide accurate information to develop a suitable management strategy.
- Education and training in disciplines related to coastal management especially regarding coral reef management must be conducted intensively to overcome the lack of trained personnel.
- Local people must be provided with information about the importance of coral reef ecosystems in order to encourage and to build a resposibility to protect this ecosystem.
- For the foreseeable future, this region will continue to need support in terms of finance, resources and expertise in order to establish and staff sustainable management regimes for marine and coastal resource management and for protected areas as components of those regimes.
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Appendix A. The result of line intercept (life-form) method

CORAL COVER IN TANJUNG SETAN

Transect	Depth	Hard Corals (Acropora)	Hard Corals (Non-Acropora)	Dead Scleractinia	Algae	Other Fauna	Abiotic
1	3 m.	22.8	35.9	19.0	0.0	19.9	2.4
2	3 m.	26.7	51.2	14.3	0.8	7.0	0.0
3	3 m.	24.8	49.2	18.0	0.0	4.3	3.6
4	3 m.	18.5	57.3	13.2	0.6	9.3	1.0
5	3 m.	15.7	35.3	32.0	0.0	9.9	7.1
6	3 m.	20.4	52.1	19.4	3.8	4.1	0.1
7	3 m.	24.6	58.1	3.6	1.3	6.0	6.4
8	3 m.	37.1	14.3	9.9	7.6	25.9	5.1
9	10 m.	19.4	31.2	5.4	3.2	34.4	6.3
10	10 m.	33.0	57.1	0.0	0.0	7.8	2.2
11	10 m.	24.5	32.4	26.6	0.0	3.6	12.9
12	10 m.	22.5	52.5	16.3	0.6	7.2	1.2
13	10 m.	18.8	45.6	17.5	0.4	6.2	11.5
14	10 m.	12.2	33.8	17.1	0.0	16.7	20.2
15	10 m.	18.3	31.2	37.2	2.3	5.5	4.0
16	10 m.	23.7	26.6	35.4	0.4	9.9	4.0

CORAL COVER IN HILA

Transect	Depth	Hard Corals (Acropora)	Hard Corals (Non-Acropora)	Dead Scleractinia	Algae	Other Fauna	Abiotic
1	3 m.	9.0	9.5	22.5	0.0	10.0	49.0
2	3 m.	2.7	28.5	38.2	0.0	18.9	11.6
3	3 m.	2.0	18.7	27.8	1.0	10.2	40.4
4	3 m.	4.2	39.0	21.1	3.1	12.6	18.8
5	3 m.	3.4	37.9	32.1	0.0	43.5	22.1
6	3 m.	9.1	10.8	28.6	0.0	1.4	50.2
7	3 m.	0.9	30.4	12.6	0.0	9.7	46.4
8	3 m.	0.1	43.3	29.4	3.4	11.0	12.8
9	10 m.	1.8	23.8	39.2	0.0	6.4	28.8
10	10 m.	1.0	15.0	12.6	0.0	3.9	67.6
11	10 m.	0.0	15.6	43.4	23.4	3.7	13.8
12	10 m.	1.4	24.1	22.7	0.0	2.9	48.8
13	10 m.	1.8	25.1	39.2	0.0	6.4	27.6
14	10 m.	1.4	25.8	23.8	0.0	8.0	39.1
15	10 m.	0.0	33.8	31.5	0.0	20.8	13.9
16	10 m.	0.0	17.2	12.8	0.1	20.0	49.8

CORAL COVER IN WAYAME

Transect	Depth	Hard Corals (Acropora)	Hard Corals (Non-Acropora)	Dead Scleractinia	Algae	Other Fauna	Abiotic
1	3 m.	14.2	17.9	38.9	0.9	12.4	15.7
2	3 m.	19.5	19.1	29.4	1.4	17.1	13.6
3	3 m.	3.5	21.4	28.6	0.2	24.6	21.7
4	3 m.	26.7	23.4	5.4	3.7	34.4	6.3
5	3 m.	18.8	39.0	13.3	0.2	4.2	24.5
6	3 m.	17.2	41.0	12.4	3.3	10.9	15.3
7	3 m.	15.1	11.6	49.5	0.0	8.5	15.3
8	3 m.	4.6	21.5	30.0	0.0	25.0	18.8
9	10 m.	16.7	26.4	27.8	3.7	13.9	11.5
10	10 m.	12.0	20.5	25.7	0.0	7.6	32.9
11	10 m.	17.5	19.4	25.8	0.0	10.7	25.6
12	10 m.	5.5	18.0	28.1	0.0	16.1	32.4
13	10 m.	8.0	15.8	0.0	19.1	39.1	18.1
14	10 m.	16.0	27.2	16.3	0.0	13.3	27.2
15	10 m.	7.0	25.9	18.0	2.2	5.2	41.8
16	10 m.	1.4	24.3	23.0	0.2	26.4	24.6

CORAL COVER IN WAILIHA

Transect	Depth	Hard Corals (Acropora)	Hard Corals (Non-Acropora)	Dead Scleractinia	Algae	Other Fauna	Abiotic
1	3 m.	1.8	23.4	19.8	5.7	23.8	25.5
2	3 m.	11.3	10.6	8.7	0.3	23.0	46.1
3	3 m.	11.0	9.6	22.3	2.3	8.4	46.7
4	3 m.	10.8	13.7	15.2	0.5	14.6	45.2
5	3 m.	3.4	18.5	31.3	0.0	24.0	22.8
6	3 m.	0.0	20.1	39.8	0.2	8.6	31.3
7	3 m.	3.0	16.8	30.9	2.0	32.2	15.1
8	3 m.	6.6	13.4	10.6	24.4	34.2	10.8

Appendix B. List of coral species in Ambon.

Coral sppecies in Tanjung Setan

Acanthastrea hilli
Acropora (duplicate)
Acropora (duplicate)
Acropora (duplicate)
Acropora (duplicate)
Acropora ?selago grp.
Acropora cf. granulosa
Acropora cf. hyacinthus grp
Acropora cf. longicyathus
Acropora humilis
Acropora humilis grp (dup)
Acropora humilis grp (dup)
Acropora humilis grp (dup.)
Acropora hyachintus
Acropora hyacinthus grp.
Acropora loripes
Acropora loripes grp.
Acropora loripes grp.
Acropora nasuta grp.
Acropora selagos grp.
Acropora selagos grp.
Acropora sp. (dup)
Acropora sp. (duplicate)
Australogyra zelli
Cyphastrea microphthalma
Cyphastrea microphthalma
Echinophillia aspera
Euphyllia ancora
Favia matthaii
Favia sp. cf. favus
Favia speciosa
Favites
Favites abdita
Favites abdita
Favites chinensis
Favites complanata
Favites complanata
Favites complanata
Favites flexuosa
Fungia cf. danai
Fungia cf. danai
Fungia sp.
Fungia sp.
Fungia sp.
Fungia sp. 2
Galaxea astreata (columnar)
Galaxea astreata (platy)
Goniastera edwardsi
Goniastrea reniformis
Goniopora djiboutiensis
Hydnophora excesa
Hydnophora microconos
Hydnophora pilosa
Hydnophora pilosa
Leptastrea transversa
Leptastrea transversa
Leptoria phrygia
Leptoseris explanata
Leptoseris explanata
Montastrea annuligera
Montastrea annuligera
Montastrea curta
Montipora
Montipora
Montipora cf. capricornis
Montipora cf. danae
Montipora cf. millepora
Montipora cf. mollis
Montipora cf. peltiformis
Montipora cf. verrucosa
Montipora digitata
Montipora sp.
Montipora sp.
Montipora sp.

Montipora sp. 1
Montipora sp. 2
Oulastrai crispata
Oulophyllia bennettae
Oxypera lacea
Oxypora glabra
Oxypora lacera
Oxypora lacera
Oxypora lacera
Pavona clavus
Pavona decussata
Pavona explanulata
Pavona varians
Pectinia lactuca
Physogyra lichtensteini
Platygyra daedalea
Platygyra pini
Platygyra pini
Platygyra pini
Platygyra verweyi
Porites annae
Porites cf. nigrescens
Porites cylindrica
Porites cylindrica
Porites lobata
Porites sp. 2
Psammocora digitata
Seriatopora caliendrum
Stylophora pistillata
Stylophora pystillata
Tubastrea
Tubastrea coccinea
Tubastrea coccinia
Tubastrea micrantha
Tubastrea micrantha
Tubastrea micrantha,
Tubipora frondens
Turbinaria frondens
Turbinaria frondens
Turbinaria frondens
Turbinaria mesenterina
Turbinaria mesenterina

Coral species in Wayame

Acropora cf. longicyathus
Acropora cf. longicyathus
Acropora cf. pulchra
Acropora cf. pulchra
Acropora cf. pulchra
Acropora cf. pulchra
Acropora humils grp.
Acropora nasuta grp.
Acropora, ACC
Alveopora gigas
Echinophyllia echinoporoides
Echinopora lamellosa
Euphyllia glabrescens
Favia lizardensis
Favites abdita
Favites o/grn by Millepora
Fungia cf. repanda
Fungia cf. repanda
Fungia moluccensis
Fungia sp.
Fungia sp.
Fungia sp.
Gardineroseris planulata
Goniastrea aspera
Goniastrea pectinata
Goniopora djiboutiensis
Heliofungia actiniformis
Hydnophora excesa
Lobophyllia hemprichii
Lobophyllia hemprichii
Merulina scabricula
Montipora cf. danae
Montipora cf. efflorescens
Montipora cf. hispida
Montipora cf. millepora
Montipora digitata
Montipora digitata
Mycedium elephantotus
Oxypora lacera
Oxypora lacera
Oxypora lacera
Pachyseris rugosa
Pavona cf. miniata
Pavona explanulata
Pectinia lactuca
Physogyra lichtensteini
Platygyra lamellina
Platygyra sinensis
Platygyra sinensis
Platygyra sinensis
Plesiastrea versipora
Pocillopora damicornis
Pocillopora, Stylophora
Polyphyllia talpina
Porites cf. lutea
Porites lichen
Psammocora profundicella
Seriatopora hystrix
Seriatopora hystrix
Stylophora pistillata
Stylophora pistillata
Stylophora pistillata
Stylophora pistillata
Stylophora pistillata
Symphyllia recta

Coral species in Hila

Acanthastrea hilli
Acrhelia horrescens
Acrhelia horrescens
Acropora cf. robusta grp
Acropora cf. robusta grp
Acropora humilis grp.
Acropora humilis grp.
Acropora palifera
Euphyllia ancora
Favites flexuosa
Favites pentagona
Fungia cf. moluccensis
Fungia echinata
Fungia fungites
Fungia simplex
Fungia sp 2
Fungia sp.
Fungia sp.
Fungia sp. 1
Fungia sp. 2
Fungia sp. 3
Herpolitha limax
Hydnophora rigida
Hydophora excesa
Leptastrea transversa
Montipora digitata
Montipora sp.
Montipora sp.
Montipora sp.
Oxypora lacera
Oxypora lacera (broken)
Pachyseris rugosa
Pachyseris speciosa
Pavona cactus
Pavona clavus
Pavona decussata
Pavona miniata
Platygyra sinensis
Plesiastrea versipora
Porites cf. lichen
Porites cylindrica
Porites sp.
Sandalolitha robusta
Stylophora pistillata
Tubastrea cf. diaphana
Turbinaria cf. frondens
Turbinaria mesenterina
Turbinaria reniformis

Coral species in Wailiha

Acropora cf. divaricata
Acropora cf. microphthalma
Acropora cf. secale
Acropora granulosa
Acropora horrida
Acropora pulchra
Acropora robusta grp.
Acrpora loripes grp.
Alveopora tizardi
Cyphastrea microphthalma
Echinopora gemmacea
Echinopora lamellosa
Echinopora mammiformis
Favia laxa
Favia matthai
Favia pallida
Fungia cf. F. valida
Goniastrea edwardsi
Goniastrea edwardsi
Goniastrea pectinata
Goniastrea retiformis
Merulina ampliata
Millepora
Millipora on Pavona plates
Montipora cf. hispida
Montipora cf. millepora
Montipora cf. millepora
Montipora sp.
Oulophyllia bennettae
Oulophyllia crispa
Platygyra pini
Platygyra sinensis
Platygyra sinensis
Plesiastrea versipora
Pocillopora damicornis
Porites annae
Porites lobata
Psammocora superficialis
Symphyllia recta
Turbinaria peltata

Appendix C. Growth rate Data

Tanjung Setan

	1	2	3	4	5	6	Average	STD
1995	1.2	1.5	1.7	1.1	1.3	2	**1.47**	0.34
1994	1.2	1.6	1.5	1.6	1.8	1.9	**1.60**	0.24
1993	1.5	1.8	1.4	1.4	1.9	1.5	**1.58**	0.21
1992	1.7	1.7	1.4	1.5	1.8	1.2	**1.55**	0.23
1991	1.5	1.9	1.4	1.8	1.7	1.8	**1.68**	0.19
1990	1.5			1.9		1.4	**1.60**	0.26
1989	1.6			1.4		1.8	**1.60**	0.20
1988	1.9			1.7		1.9	**1.83**	0.12
1987	1.8			1.5		1.8	**1.70**	0.17
1986								
1985							Average	
Average	**1.54**	**1.70**	**1.48**	**1.54**	**1.70**	**1.70**	**1.61**	

Hila

	1	2	3	4	5	Average	STD
1995	1.2	1.5	0.8	1.2	1.5	**1.24**	0.29
1994	1.6	1.6	0.6	1.5	1.7	**1.40**	0.45
1993	1.1	1.9	1	1.7	1.4	**1.42**	0.38
1992	1.6	1.8	1.9	1.7	1.6	**1.72**	0.13
1991	1	1.8	1.6	1.6	1.5	**1.50**	0.30
1990	1.5	1.4	1.4	1.5	1.6	**1.48**	0.08
1989	1.2	1.5	1.4	1.5	1.7	**1.46**	0.18
1988		1.6	0.9		1.9	**1.47**	0.51
1987		1.4	1		1.4	**1.27**	0.23
1986		1.4	1.7			**1.55**	0.21
1985						Average	
Average	**1.31**	**1.59**	**1.23**	**1.53**	**1.59**	**1.45**	

Wayame

	1	2	3	4	5	Average	STD
1995	1.2	0.9	1.6	1.5	1.3	**1.30**	0.27
1994	1.5	0.9	1.1	1	1.6	**1.22**	0.31
1993	1.5	1.1	0.7	1.6	1.4	**1.26**	0.36
1992	1.6	1.5	0.6	1.1	1.5	**1.26**	0.42
1991	1.6	1.3	0.9	1.2	1.2	**1.24**	0.25
1990	1.4	1.5	1.1	1.6	1.7	**1.46**	0.23
1989	1.7		1.5	1.6	1.1	**1.48**	0.26
1988	1.5		1.7	1.5		**1.57**	0.12
1987	1.6		1.4	1.4		**1.47**	0.12
1986							
1985						Average	
Average	**1.50**	**1.20**	**1.07**	**1.37**	**1.40**	**1.31**	

Wailiha

	1	2	3	4	5	Average	STD
1995	1.6	1.4	1.2	1.3	1.6	**1.42**	0.18
1994	1.7	1.5	1.4	1.7	1.9	**1.64**	0.19
1993	1.6	1.5	1.4	1.9	1.7	**1.62**	0.19
1992	1.5	1.7	1.6	1.4	1.4	**1.52**	0.13
1991	2.1	1.5	2	1.5	1.6	**1.74**	0.29
1990	1.7		1.2	1.5	1.5	**1.48**	0.21
1989	1.5		1.5	1.7	1.3	**1.50**	0.16
1988	1.6		1.9	1.3		**1.60**	0.30
1987	1.5		1.4	1.8		**1.57**	0.21
1986	1.9		1.8	1.5		**1.73**	0.21
1985						Average	
Average	**1.67**	**1.52**	**1.54**	**1.56**	**1.57**	**1.57**	

Appendix D. AverageSPM Value in Ambon

	Tanjung Setan	Hila	Wayame	Wailiha
MAY	4.67	2.61	8.71	4.58
	3.63	3.18	8.56	6.78
	3.60	3.62	9.99	8.30
	3.49	2.86	10.46	5.24
JUNE	4.32	1.83	8.18	7.32
	2.89	3.74	10.23	8.78
	4.33	1.30	9.96	18.59
	3.61	7.60	9.30	2.99
JULY	5.28	8.42	8.38	17.93
	6.80	7.44	13.88	28.49
	7.69	4.99	11.50	25.47
	3.33	8.34	10.56	22.42
AUGUST	4.72	7.90	16.62	34.07
			19.83	23.20
AVERAGE	4.49	4.91	11.15	15.30
STD	1.40	2.66	3.40	10.21

APPENDIX E. NUTRIENTS FLUCTUATION IN AMBON WATERS