FINAL REPORT

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ASSESSING THE AMOUNT OF CORAL GROWTH IN HIGH RECREATIONAL USE AREAS OF KANEOHE BAY: A CASE STUDY USING REMOTE SENSING ON REEFS NEAR COCONUT ISLAND

By:
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ABSTRACT

The objective of this project was to assess the coral health in areas around Coconut Island by comparing a high use recreation area versus a low use area as a means of measuring the impacts of human activity on the reef system. My plan to accomplish this project was to use multi-spectral imagery gathered from an airplane of the area surrounding Coconut island. This data was collected by TerraSystems Inc. (TSI) as part of a much larger survey of the coral health in all of Kaneohe Bay headed by Marlin Atkinson and Mr. Eric Hochberg of the School of Ocean and Earth Science Technology (SOEST) at the University of Hawaii. This comprehensive survey of Kaneohe Bay by SOEST is part of an ongoing project to determine the methodology of using remote sensing, in particular spectral imagery, to map coral reefs worldwide from satellites. Kaneohe Bay is being used as a test site of this technology. My project represents an offshoot of this comprehensive project by SOEST. The results of this project indicate little coral growth near the eco-tourist site. However, at this time there is no distinct correlation between the lack of coral and the tourists. Further studies need to be done in order to find out if the tourists are impacting the coral reef. In addition, the results show that spectral imagery will be an important tool for mapping and understanding coral reef health in high recreational use areas.

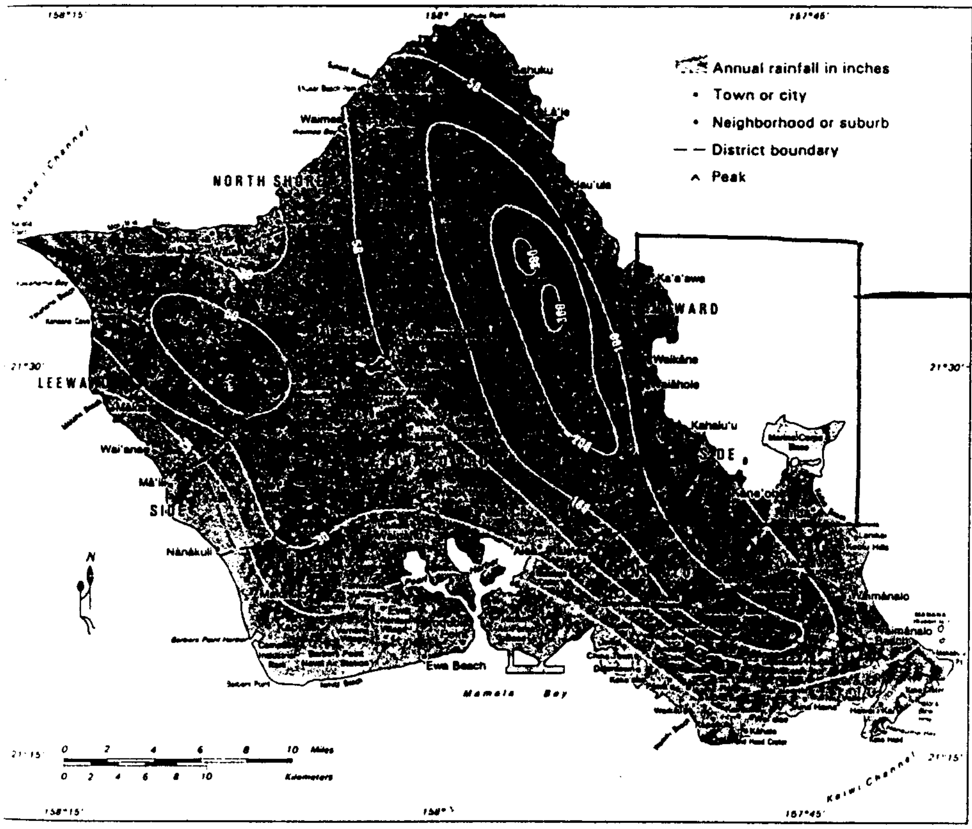
INTRODUCTION

KANEOHE BAY

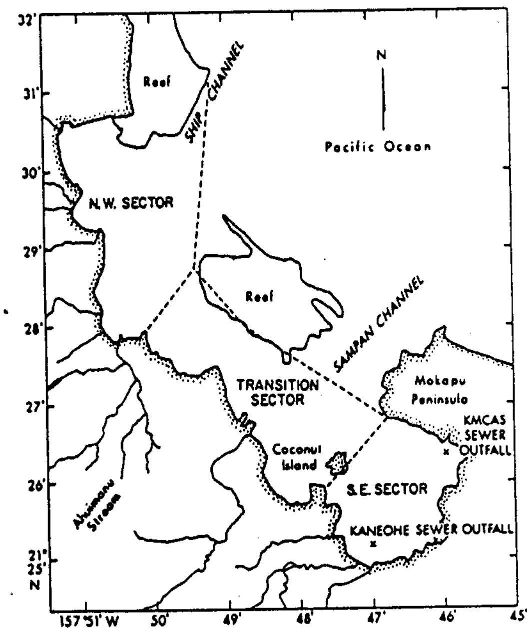
Kaneohe Bay is located on the windward side of the island of Oahu (Fig. 1). The bay is protected by a barrier reef which has created a sheltered environment where corals grow and flourish (Laws, 1993). The corals play an

Figure 1

Oahu



Kaneohe Bay



Kaneohe Bay and environs.

Sources:

Oahu Map: Morgan 1996

Kaneohe Bay Map: Laws 1993

important part in the survival of the ecosystem that has evolved in the bay. They supply food and shelter for the organisms, such as fish and invertebrates, and help to maintain the ecology within the bay.

In the past, Kaneohe Bay had sewage pumped into the southeast sector of the bay. This led to the degradation of much of the coral in the affected area. The discharge lasted for about thirty years, ending in 1978. The discharge was ended because of the effects to the corals and since then the coral has been growing back (Laws, 1993).

Researchers at SOEST want to study how low earth orbit satellites can be used for monitoring coral reefs world wide. This proposed system, which is being tested in concept using Kaneohe Bay, could be used to map coral destruction and health, as well as monitoring the recovery of the coral. This technology could also be used to identify areas for recreational use, or to assess the status of boat channels, in addition to serving as a worldwide model for future projects regarding multi-spectral imagery of corals. Eric Hochberg (graduate student, SOEST) will be using the entire multi-spectral data set to create an entire map of the reefs in Kaneohe Bay. This map will show areas of coral, sand, algae, and deep water. The goal is to show that this technology can be transferred to satellite remote sensing (Hochberg and Atkinson, in prep.).

For my project I wanted to study the difference in the amount of coral growth between an area with high human use and an area with little use. I decided to use the area around and near Coconut Island (Fig. 2), in the southeast sector of the bay, for my study area. This was an ideal location because the coral surrounding Coconut Island is protected and has very little exposure to human contact and destruction. However, one of the patch reefs near the island, known as Checker Reef, gets heavy use because it is used as an eco-

Figure 2

Photo of Coconut Island in Kaneohe Bay

tourism site. Tourists are brought to the reef to enjoy snorkeling, jet skiing, and wind surfing. This project proposes to assess how much damage is being done by the tourists to the coral in the Checker Reef area.

REMOTE SENSING

Remote sensing is very useful for obtaining knowledge of the characteristics in a certain area. In general, remote sensing uses electromagnetic radiation sensors to record images of the environment which can be interpreted to yield useful information of an area. Remote sensing provides information by measuring the intensity of the electromagnetic radiation being reflected or emitted from the earth's surface. Measures of the electromagnetic radiation, as a function of wavelength, give information concerning the shape, topography, and composition of the ground (Curran, 1985). The information gained can be put to use in all areas concerning environmental sciences.

One area where the application of remote sensing is beneficial is in the management of our natural resources. For example, it has been used in forestry to monitor the effects of logging. Also, geologists can use remote sensing to survey the surface features of an area to find places conducive to mining (Warner, et al., 1996). Furthermore, remote sensing can also be beneficial in monitoring agricultural land and vegetation cover (Drury, 1990).

Remote sensing is commonly accomplished through the use of satellites or airplanes. However, other means can be used such as a boat. For this project I will be analyzing data collected from an airplane using multi-spectral imagery. Multi-spectral imagery uses specific wavelengths to take digital images of the earth. The information is obtained by reading how strong the reflectance of each band is. This gives the information needed to analyze the spatial area examined and its composition (Drury, 1990).

Data collected from planes must be gathered very systematically. To do this, the area examined is divided into evenly spaced parallel lines, known as 'flight paths' (Fig. 3) . The plane follows each flight path while the multi spectral scanner takes pictures periodically to cover the entire area (Gradie, pers. comm.).

PROCEDURES

INFORMATION GATHERING ON REMOTE SENSING

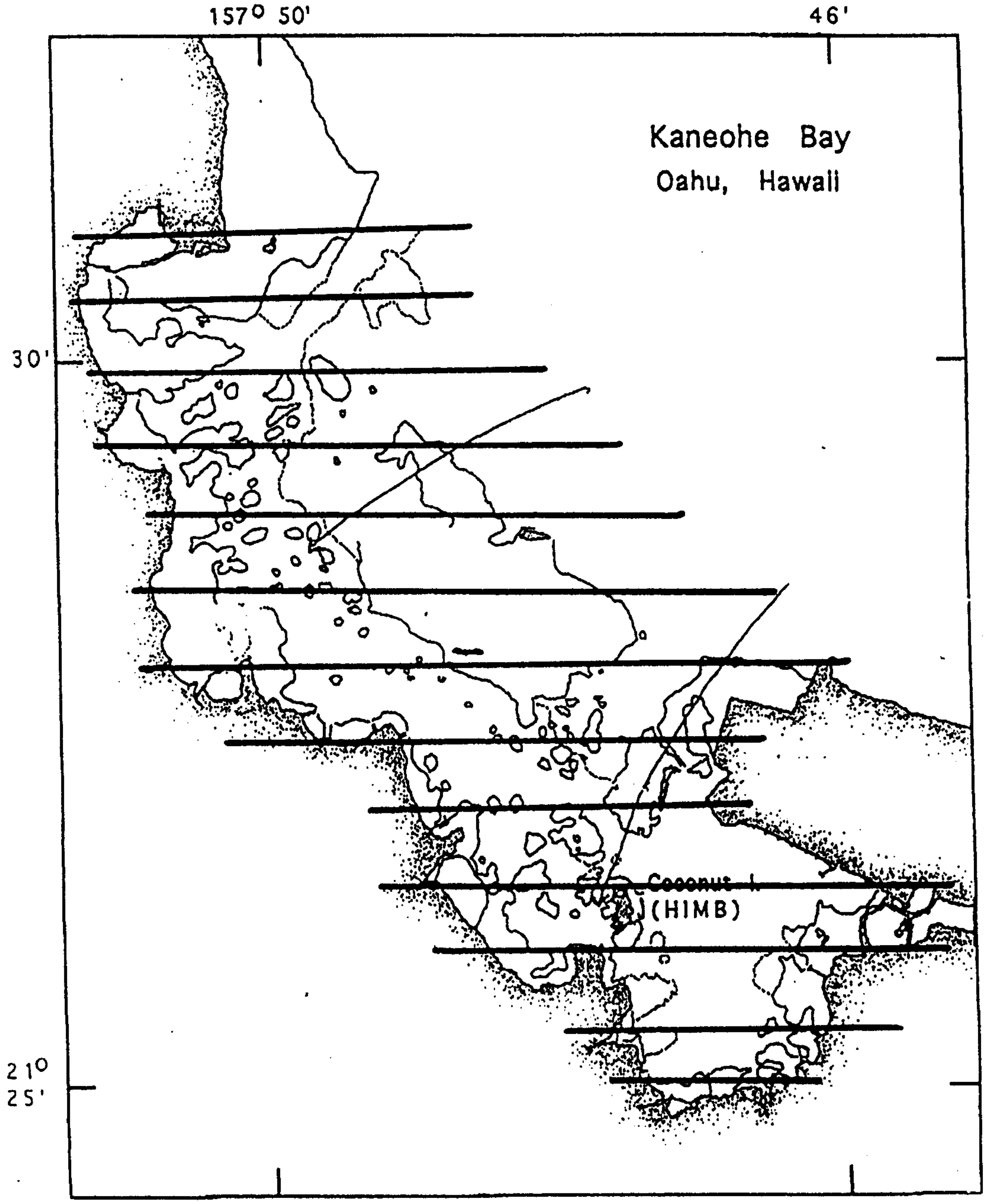
I reviewed literature at Hamilton Library on remote sensing and its applications. I found several useful books: Small Format Aerial Photography (Warner, et al., 1996), Principles of Remote Sensing (Curran, 1985), and A Guide to Remote Sensing (Drury, 1985). This has helped to familiarize me with remote sensing and its uses.

In addition, I have also used the internet as an information source. The SOEST program has a web site entitled 'Virtually Hawaii' which can be located at: http:\\www.soest.hawaii.edu/. This contains many remotely sensed images of Hawaii along with a tutorial about remote sensing which has also been very helpful in gaining a foundation of knowledge about remote sensing.

In addition, I have found some information concerning previous work using remote sensing for coral reefs. One study in the Dominican Republic used Landsat data from a satellite to distinguish between coral, seagrass, and sandy areas. This project was partly successful in that some areas were able to be mapped while others were not. Specifically, it was easy to distinguish sand from coral and seagrass but not the seagrass from coral. The reason for this is because the seagrass and coral reflect similar amounts of specific wavelengths

Figure 3

Flight Paths over Kaneohe Bay: October 1996



Note: Dark horizontal lines represent flight paths taken by TSI.

Source: TSI

whereas sand does not. Sand has a higher reflectance and had a significantly greater mean Landsat digital count than did seagrass or coral, making it easier to distinguish. One problem with this project was that because the data was from a satellite, the pixel size used was very large at 812 m2 (Luczkovich et al 1993). This could present problems because within such a large area there are many small patches made up of varying bottom types. A pixel in such an area would not give a clear indication of a specific bottom type.

Another study was done on Heron Reef, located within the Great Barrier Reef Marine Park, to see how well remote sensing could be used to determine differences in coral reef zones. Fourteen reef zone groups were used. These zones varied according to depth and/or bottom type and ranged from open water to breaking waves and from corals to sand (Ahmad and Neil 1994). This study was quite successful and shows that coral density gradients and distribution patterns can be found using remote sensing.

Damage to coral reef areas from direct human contact often occurs. A study done of the reef-flats at Sharm-el-Sheikh (a popular diving and tourist area on the Egyptian Red Sea), shows that damage to the coral has occurred from divers and tourists. The results indicate that there is significantly more coral damage, more rubble and bare rock, and smaller coral colonies in heavily trampled areas than in less trampled areas (Hawkins 1993).

Although damages to coral reefs from direct human contact are evident there did not seem to be any data showing an attempt to use remote sensing to specifically measure that damage.

I also contacted and met with Eric Hochberg who is currently doing work in Kaneohe Bay using remote sensing. This project is being done by the SOEST department at UH with Dean Barry Raleigh and Marlin Atkinson in charge.

Mr. Hochberg introduced me to his project which involves creating an entire map of Kaneohe Bay and its reefs through the use of remote sensing. He helped to explain the concept of using band ratios to discern different materials on the reef. Mr. Hochberg's work has formed the basis of my project because he has been able to identify which multi-spectral bands are most useful in the mapping of a reef. Four bands were selected by Mr. Hochberg based upon hyperspectral imagery, acquired by SETS Technology Inc., of a small portion of the reef system which Eric previously studied. This information was used by TSI to gather the relevant data of Kaneohe Bay.

MULTI SPECTRAL DATA GATHERING OF KANEOHE BAY

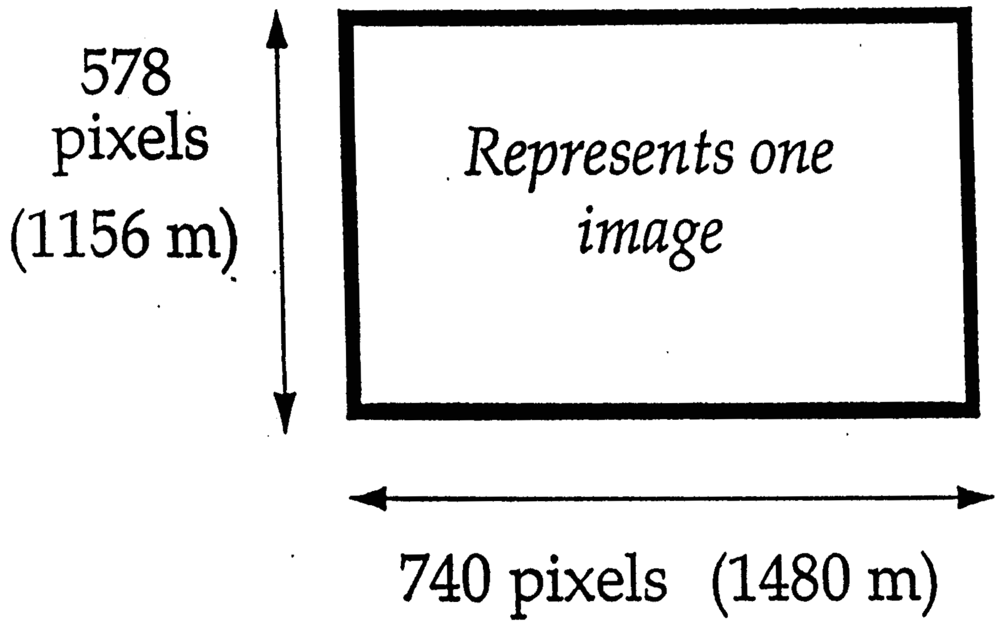
Data has been gathered by TSI using aerial multi-spectral imagery. Four narrow bands at 488nm, 550nm, 570nm, and 701nm were used to do this. As mentioned earlier, these bands were chosen by Mr. Hochberg after careful study of previous hyperspectral data gathered of the area.

TSI took 263 images of Kaneohe Bay on October 5, 1996. The plane flew at 10,000 feet and used fourteen different flight paths to cover the bay. As the plane flew along, an image was taken every 7 seconds. Each image is made up of tiny squares known as pixels which, for this data, are two square meters. Each image is 578 pixels by 740 pixels (Figure 4).

CORRECTING DATA

During the data collection process there are several artifacts which arise that need to be adjusted before data can be analyzed. These artifacts come about from a variety of reasons including inadvertent electrical interference and image misalignment. Image misalignment arises due to the movement of the plane or because the lenses of the camera are not in the same place when the

Figure 4



- one pixel is 2 square meters

image is taken (Gradie, pers. comm.).

Electrical interference can induce a regular pattern of spots on an image. This interference is known as 'noise' and should be removed for the best interpretation of the image. Removing the 'noise' is known as 'noise reduction' using a process called Fourier Transforms (Gradie, pers. comm.). This process is complex and difficult to understand. Although 'noise' is not always a problem, I was introduced to this concept in order to understand its effects.

An artifact normally encountered is a condition known as 'offset'. This arises due to the movement of the plane which creates spatial differences between the separate bands. Luckily, this can be easily corrected on the computer through a simple but tedious process known as 'offsetting' (Gradie, pers. comm.).

Another artifact which must be addressed on all images arises from the spatial misalignment of the camera system and its lenses. This occurs because the four lenses used are not aimed at exactly the same point on the ground when the image is taken. To correct this problem the images must be 'co-registered' together. This process uses one band as the base image and rotates, stretches, and translates the other three bands to match the spatial orientation of the base image (Gradie, pers. comm.). This creates a nice clear image. This work was done on the ENVI (Environment for Visualizing Images) program. ENVI is the program used at TSI to read, analyze and process remotely sensed data. It also allows maps to be made from the images.

SELECTION OF SITE

There were two different areas that I chose as possibilities to study for this project. One area was the southeast end of Kaneohe Bay where the

Kaneohe Yacht Club is located and the other was the area around Coconut Island.

The area near Kaneohe Yacht Club is interesting because of the amount of use and human contact this section of the bay gets. There are many boats going in and out of the yacht club at all times and homes line the shoreline which increases human interaction with the bay. In addition, this end of the bay is where the old sewage outfall was. I feel it would be interesting to assess how much coral there currently is in the area. However, the images taken in this area had some cloud cover which could make the process of analyzing the data more difficult. For this reason I did not choose this area to study.

Coconut Island is also an interesting area with high usage. Many boats travel around and to the island. In addition, a reefs near the island named Checker Reef is used for eco-tourism purposes. Boats from Heeia Kea boat harbor bring tourists to the reef to enjoy the waters of Kaneohe Bay. They are allowed to snorkel, wind surf, and jet ski. I thought it would be interesting to see if there are any effects to the reefs in the area due to the interaction of the tourists. The images collected near Coconut Island were very clear and therefore I chose this area to study rather than Kaneohe Yacht Club. The project area is shown on the following page (Fig. 5) with Coconut Island, Checker Reef, and the recreation area.

MOSAICING THE IMAGES

In order to get a large area to study, several images must be 'mosaiced' together. This is done by overlapping the edges of two images to align them according to landmarks on both the images (Figure 6). This is possible because when the images are taken from the airplane the flight paths overlap one anoth-

Figure 5

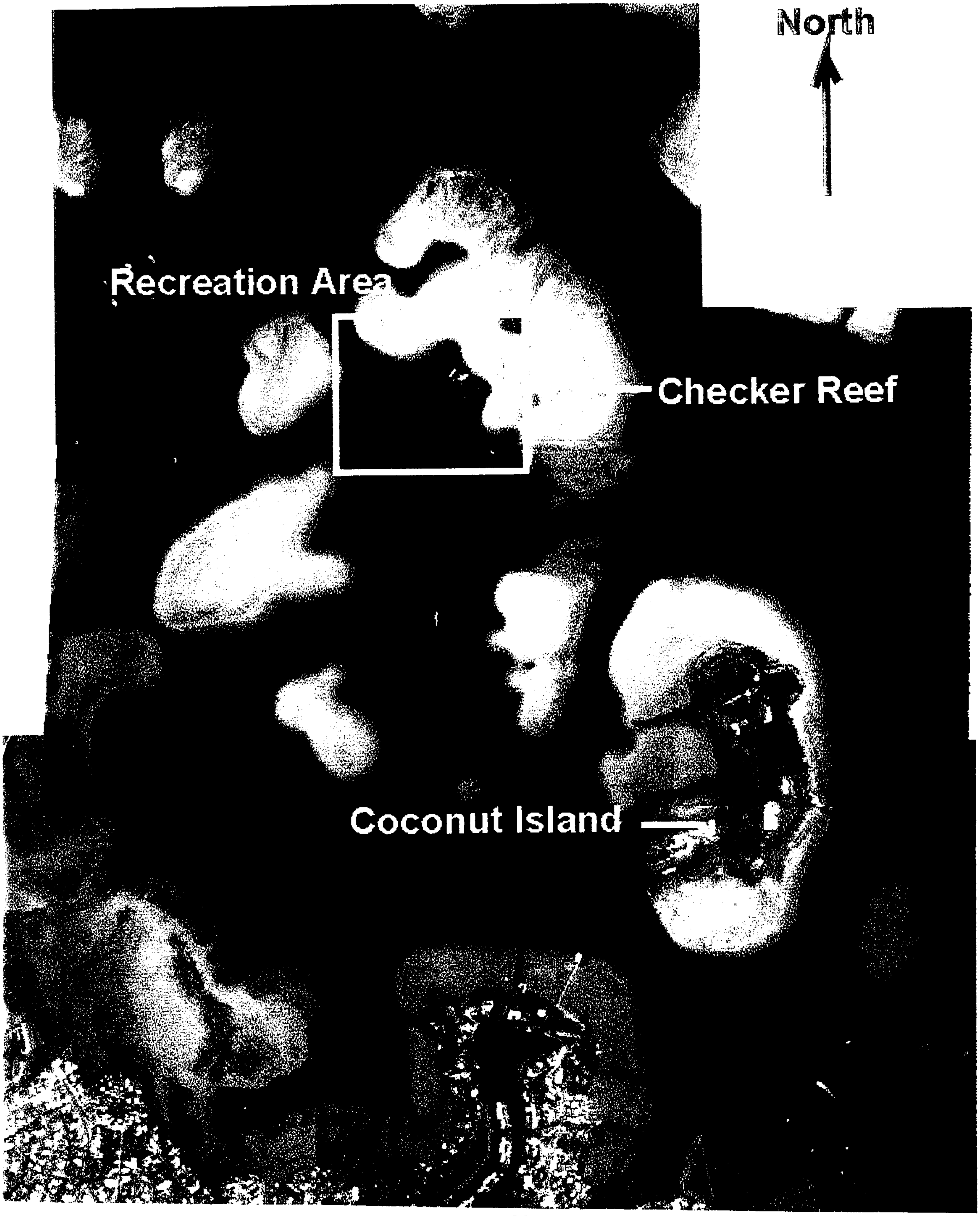
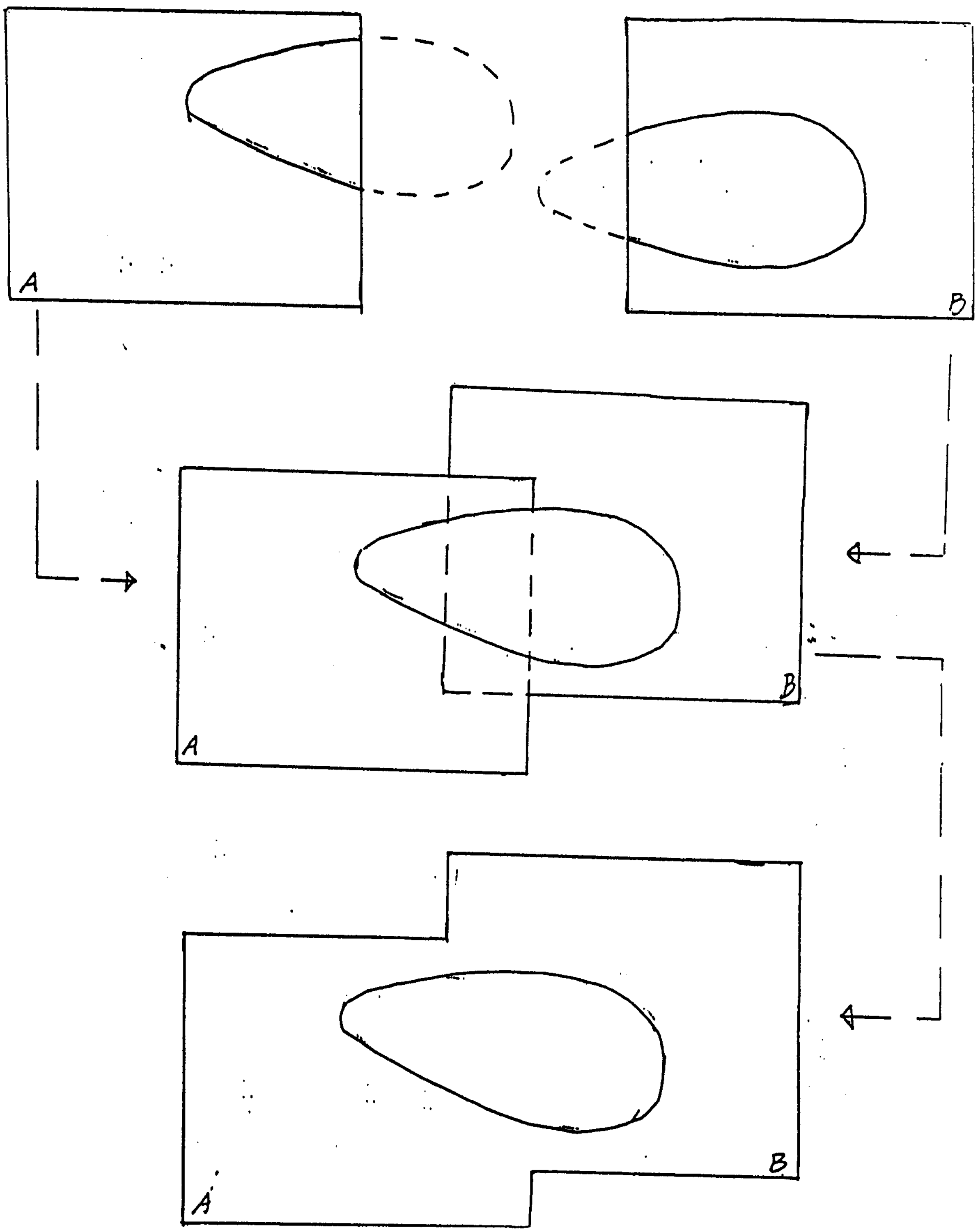


Figure 6
<u>Mosaicing Images</u>



Note: -Representation of mosaicing two images together
-Oval shape represents an island

er slightly to insure that all points on the ground are covered (Gradie, pers. comm.).

Five images have been mosaiced together to create the clear picture of the entire Coconut Island area and its surroundings (Fig. 5).

GEOREFERENCING THE IMAGE

'Georeferencing' is the process whereby the area to be analyzed serves as an overlay to a digitized map. This is done by selecting the same points on the image as on the map to match with one another. This creates latitudinal and longitudinal degrees on the observed area. Thus, the image is 'georeferenced'. This allows for accurate identification of locations in the area. In order to do this, a map has to be selected and digitally scanned before it can be used (Gradie, pers. comm.).

ANALYZING THE DATA

To analyze the data for this project, band ratios were used. Band ratios allow differences in composition of materials to be seen more readily. They are created by dividing one band with another.

RESULTS

TSI was successful in collecting data needed for the SOEST project. This data covered the entire area of Kaneohe Bay using 263 images. My project entails the study of only one of these images, centered near Coconut Island. Prior to the analysis, corrections were made to the data as needed. These corrections included co-registration, offsetting, and georeferencing (discussed in the procedures section).

A small study section in the area where the tourists are on Checker Reef was chosen to be analyzed along with an area on the reef around Coconut Island (Fig. 7). It was simpler to do the analysis in this manner. Reasons for this are explained in the 'discussion' portion of the paper.

The analyzed sample area of Coconut Island (Fig. 8) consists of four colors. Each color represents a difference in spectral characteristics or a difference in material. The meaning of each color is as follows: yellow represents sand, green represents algae, red represents living coral, and blue represents deep water (water below approximately 5 m). The area which extends approximately to the 150 m mark in each direction is Coconut Island. The analysis indicates that the island is a combination of these colors. This area should be disregarded. The pertinent area is the perimeter of the reef (the area which meets the deep water). These preliminary results indicate a high amount of coral growth along the perimeter. There is also some sand and a lot of algae.

The analyzed sample of the Checker Reef recreation area (Fig. 9) consists of the same colors representing the same materials as the Coconut Island sample: yellow represents sand, green represents algae, red represents living coral, and blue represents deep water (below approximately 5 m). The areas in the deep water, which show up as mostly coral and some sand, are actually the boats and floaters from the tourist operations. These areas should be disregarded as they are not accurate. However, the pertinent area is the perimeter of the reef (the area which meets the deep water). According to the results there is little coral growth directly in front of the tourist area. This area consists mainly of sand and algae. However, there is some coral growth off to the sides.

Figure 7

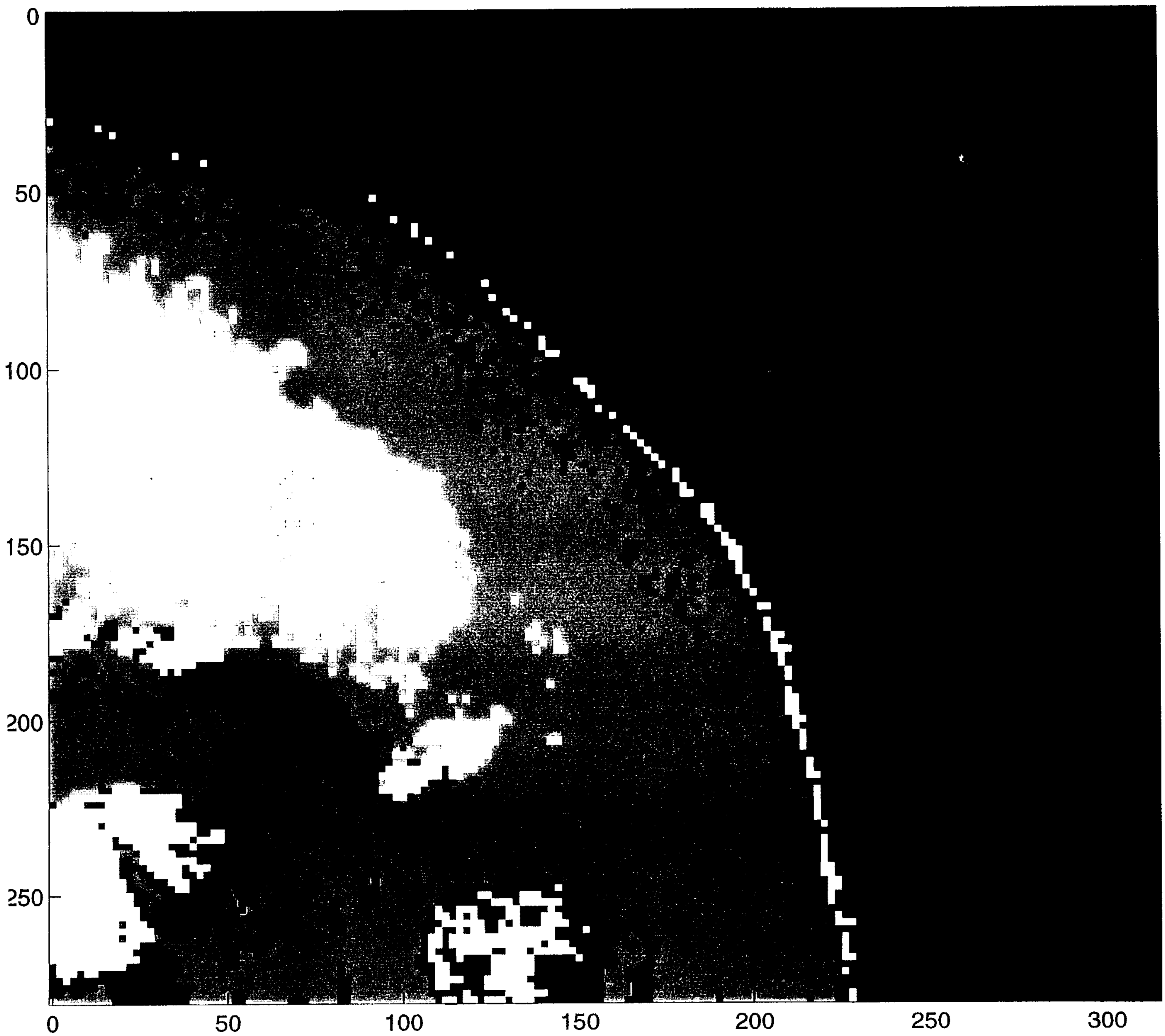
k11ap_s.jpg

CHECKER REEF SAMPL' ARE

COCONUT ISLAND SAMPLE AREA

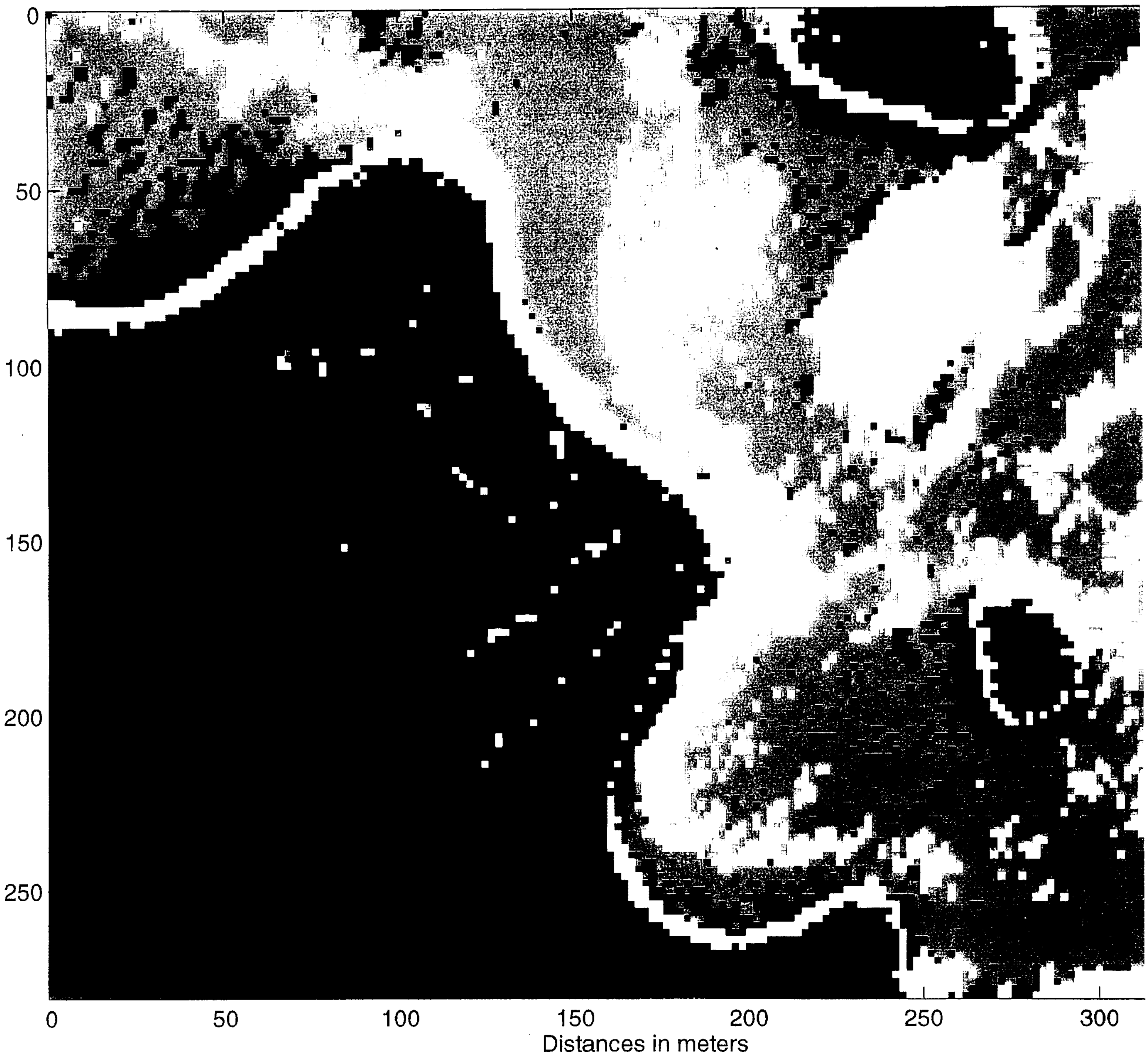
-Shows the approximate areas sampled from checker reef and coconut island.

Figure 8
Coconut Island Sample Area



Blue- Deep Water
Green- Algae
Yellow- Sand
Red- Living Coral

Figure 9
Checker Reef Sample Area



<u>Blue</u>- Deep Water
<u>Green</u> - Algae
<u>Yellow</u>- Sand
<u>Red</u>- Live Coral

DISCUSSION

Unfortunately, up to this point, data analysis has not been completely successful. This is because the algorithms, which Eric Hochberg developed from a previous study, didn't work very well with the new data gathered. However, Mr. Hochberg and Professor Atkinson will most likely be able to complete their project of mapping Kaneohe Bay once they have been able to make corrections needed for the algorithms.

The previous study done by Mr. Hochberg used hyperspectral remote sensing to survey a small area of Kaneohe Bay prior to the project with TSI. Hyperspectral remote sensing is not limited to a few bands but encompasses all wavelengths. With this data Mr. Hochberg was able to choose four bands (488nm, 550nm, 570nm, 701nm) to simplify his project with TSI. He then developed an algorithm for the area using the four bands to discern between different materials on the reef. He was able to distinguish areas of coral, algae, and sand or rubble. However, this algorithm has not been as successful in discerning materials using the new data gathered by TSI for all of Kaneohe Bay.

Due to the problems with the algorithms, small study areas were chosen instead of studying the entire area. Mr. Hochberg was able to analyze these data samples using his algorithms to come up with the two diagrams shown of the areas. However, it must be remembered that these data sets are preliminary and should be tested again after the algorithms have been perfected to insure their accuracy.

Although the findings indicate that there is little coral growth in the study area of Checker Reef, it cannot be assumed this is specifically due to the effects of the tourists. In order to accurately assess this, one would have to know the amount of coral which existed on Checker Reef prior to the eco-tourism. Had there been remotely sensed data of the area prior to the eco-tourism, this could be assessed. The area on Checker Reef may have always been sand and was chosen as an eco-tourism location because of this.

As mentioned in the results, both areas sampled contain items which are above water. The Checker Reef area contains what are believed to be boats and buoys and the Coconut Island sample has a portion of the island in it. These areas above water show up as combinations of different materials and should be disregarded. However, it can be assumed that the area on the outer portions of the reefs is generally accurate.

There simply was not enough time to accomplish all that I hoped to do for this project. Interpreting the data will be quite simple once the correct algorithms are calculated. In addition, more research is needed in studying the area in order to truly assess the amount of damage done and what the damage stems from.

In the future this data can be used for other projects. For example, if new remotely sensed data are collected at a later date, it can be compared to the data collected in this project to look at differences in coral growth. The effects of eco-tourists on an area can then be more accurately assessed.

Such data would be useful in eco-tourism management of the reefs. It would help in determining a sustainable amount of people for an area over a specific amount of time. This could keep the coral in the area healthy, assuming that there is some damage done to the area which could be linked to the activities of the tourists.

In the end, this project was ultimately about learning what remote sensing is rather than coming up with a specific conclusion about the eco-tourism effects to the reef. I foresaw that such a project would need more time and research but felt it would be interesting to attempt. It was beneficial to learn what remote sensing is, how it is used, and how it can be applied. This is knowledge which will be useful in the future and applies to a wide variety of environmental fields.

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