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# THE RED SEA RANGERS: A CASE STUDY ON USING SPATIAL COLLECTIONS AND REMOTE SENSING TO PROTECT AQUATIC RESOURCES.

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**ABSTRACT:** In 1997 the Nature Conservation Sector (NCS) of the Ministry of Egyptian Environmental Affairs Agency (EEAA), through the Egyptian Environmental Policy Program (EEPP) assisted by the United States Agency for International Development (USAID), formed the Red Sea Rangers. A seminar for the EEPP Program Support Unit (PSU), funded by USAID through the International Resources Group (IRG), focused on training the Rangers to use spatial collections and remote sensing to map and help manage Egypt's Red Sea coastal resources. Spatial collections used included satellite images, ancillary Geographic Information Systems (GIS) data, and Red Sea field observations. Satellite image processing software was used to integrate these resources.

This paper provides a background on the spatial resources and the satellite image processing and interpretation techniques that were used during the training, addresses some of the challenges of communicating technical issues in a multi-cultural environment, and contains a post training land-fill siting study conducted by the Rangers.

**Keywords:** Remote Sensing, Geosenssing, Image Processing, Red Sea, Rangers, Egypt, Education, EEAA, USAID, GIS, Environmental monitoring

**Introduction**

In 1997 the Nature Conservation Sector (NCS) of the Egyptian Environmental Affairs Agency (EEAA), through the Egyptian Environmental Policy Program (EEPP) assisted by the United States Agency for International Development (USAID), formed the Red Sea Rangers. The Ranger program was implemented to protect Egypt's Red Sea coastal resources and Marine Park Protectorates. Between January 24th and 28$^{th}$ 2004 a 5-day, hands-on remote sensing seminar for the EEPP's Program Support Unit (PSU), which is managed by International Resources Group (IRG) with assistance from the United States Agency for International Development (USAID), was provided to 10 Egyptian Red Sea Rangers in Hurghada, Egypt. In order to assist the Rangers in mapping, management and protection of Egypt's Red Sea coastal and marine Resources, the seminar, jointly conducted by instructors from Egypt and the United States (US), used Leica's Imagine© satellite image processing software, to integrate satellite images, available ancillary Geographic Information Systems (GIS) data and Red Sea field observations.

**The Egyptian Red Sea Coast Line**

The Egyptian portion of the Red Sea coastline covers approximately 1500 km. The coral reefs of the Red Sea, and in particular the Egyptian sections, are one of the World's most spectacular recreational diving destinations. Besides a popular tourist destination (Figure 1. Tourism), the Red Sea serves as a major Mid-East shipping route. The whole region has tremendous population growth potential. Impacts to fragile Red Sea marine resources from existing recreational and commercial activities and associated population growth potentially include: increased shoreline development (Figure 2. Shoreline Development); damage to coral reefs from marine recreation, such as boating, fishing, diving, and coral/fish collecting (Figure 3. Marine Recreation); over-fishing; aquatic and terrestrial habitat degradation from over-use and pollution; commercial shipping accidents; and increased need for land-based solid waste disposal sites.

**Figure 1. Tourism**

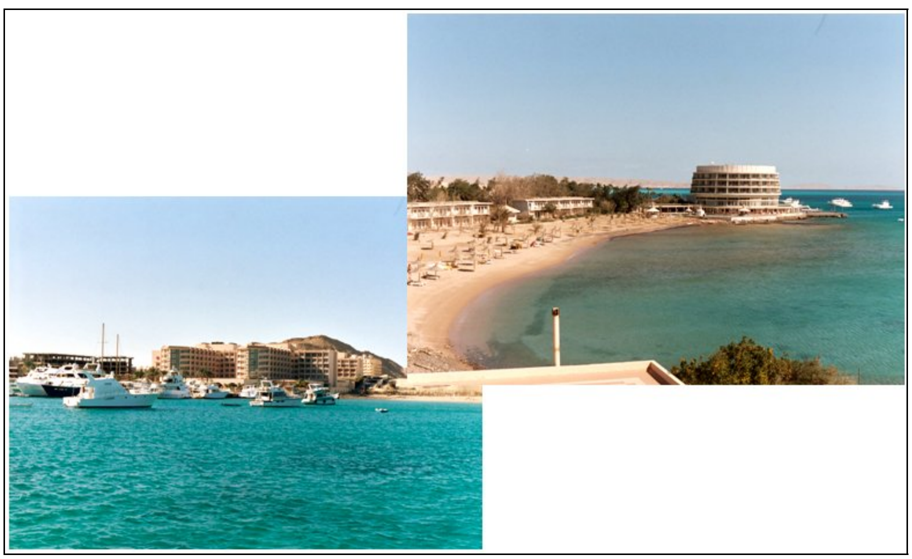

**Figure 2. Shoreline Development**

**Figure 3. Marine Recreation**

**The Red Sea Rangers**

There are approximately 40 Red Sea Rangers. The Ranger's assignments in addition to covering aquatic based resources include the surrounding coastal habitat and EEAA Park Protectorates. Daily Ranger tasks vary from maintaining environmental compliance of tourist industry diving boats, environmental education for tourists, and enforcing environmental regulations on fishing, boating and collecting of marine species, to ground surveying marine and coastal resources, and using GIS, GPS, and remote sensing for mapping. Figure 4. Red Sea Rangers at Work contains images of the rangers performing their duties.

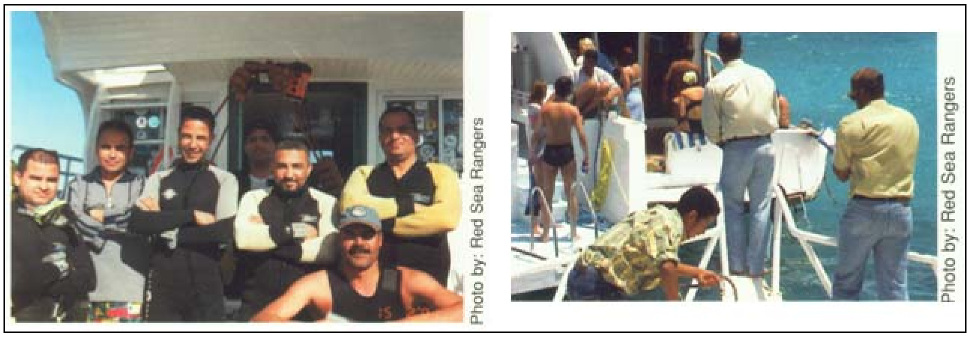


**Figure 4. Red Sea Rangers at Work**

Ten of the 40 rangers are directly involved in daily mapping activities. Using GIS, GPS, and remote sensing technologies the Ranges collect spatial data on coastal resources, monitor environmental changes, attempt to predict the spatial extent of impacts from commercial accidents, and locate future coastal infrastructure facilities. Through the EEAA and USAID many educational materials have been developed for the Ranger's public education program. Figure 5. Red Sea Ranger Mapping Program is an example of the material developed for the Ranger's mapping program.

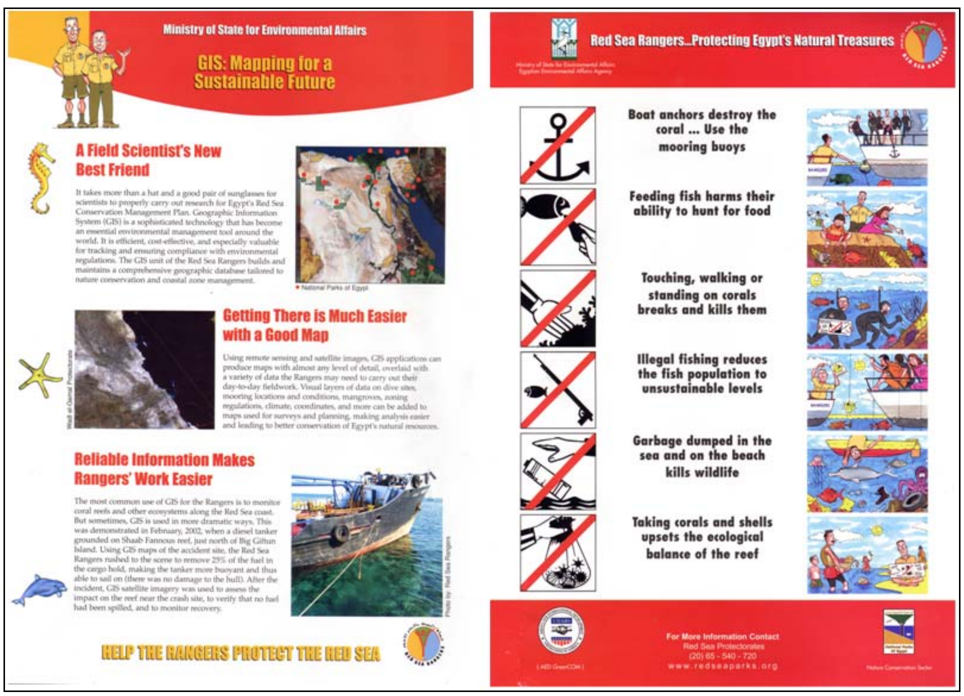


**Figure 5. Red Sea Ranger Mapping Program**

## COURSE LOCATION AND OUTLINE

The 5-day course was conducted in Hurghada, Egypt. Hurghada is located on the Red Sea southeast of Cairo, Egypt and northeast of Aswan, Egypt (Figure 6. Course Location).

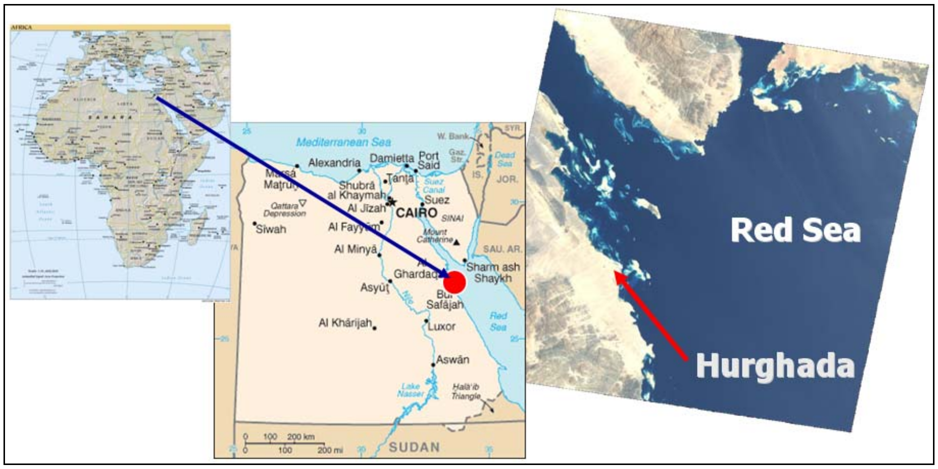


**Figure 6. Course Location**

The following is an itinerary of the course's daily activities.

*Remote Sensing and Geographic Information Systems for Coastal Resource Management*
*A Short Course Developed for Program Support Unit*
*Hurghada, Egypt*
*24-28 January 2004*

***Day 1***

Introduction and examples of remote sensing applications for environmental assessment and management
Elements of electromagnetic spectrum, principles of remote sensing and multi-spectral scanners
Principals and methodology of image enhancements
Laboratory exercise: image enhancement using ERDAS Imagine

***Day 2***

Introduction to image classification
Image classification methodology
Change detection
Laboratory exercise: change detection using ERDAS Imagine

***Day 3***

Applications of Remote Sensing and GIS to coastal zone management
Theory and application of hand-held spectrophotometer
Laboratory Exercise: image classification using ERDAS Imagine

***Day 4***

Field trip to Red Sea seagrass and coral reefs to demonstrate theory and application of using hand-held spectrophotometer in marine biology
Laboratory Exercise: field data processing and application of field data to enhance image classification

***Day 5***

Field trip to North Hurghada Mountains to demonstrate theory and application of using hand-held spectrophotometer in Geology
Laboratory Exercise: field data processing and application of field data to enhance image classification

## REMOTE SENSING AND GIS BACKGROUND

Both GIS and remote sensing are used to create computer data models of the real world and can be used separately or integrated for enhanced analysis. GIS and remote sensing are widely used by academic researchers, private companies, governmental entities, and many non-governmental organizations such as USAID, UN, UNESCO, FAO and others.

Remote sensing typically involves interpreting remotely sensed data, such as satellite images or multi-spectral digital aerial photographs, to inventory, measure, and investigate the world's resources. Remote sensing has many uses, such as measuring and monitoring natural resources, geologic and natural phenomenon, natural disasters, and anthropogenic environmental effects, as well as simply mapping geographic features. Remotely sensed image data is typically represented by rows and columns of square grid cells or pixels, each of which contains a single digital number recorded from a platform of sensors. Each senor on the platform records a portion of the electromagnetic spectrum, which is referred to as a band. Interpretation of imagery can be either visual or computer aided.

Geographic Information Systems are systems of computer hardware, software, data and people used to create, store, display, manipulate, overlay, analyze, and map geographic features and their descriptions or attributes. GIS typically uses vector data. Depending upon the collection scale or generalized nature of the information, vector data represents geographic features by points, lines, or polygons. Points are used to represent a single location with no area. Lines are used to represent linear features, which also do not have area. And lastly, polygons are used to represent homogenous areas, or areas with similar attributes. Examples of locations represented by points might include ATM's, post boxes, or gelatarias.  Lines might be used to represent street centerlines and above or below ground utilities.  Some examples of polygons might include buildings, administrative boundaries, soils, or land use.

Researchers must remember that the people who create data and use GIS and remote sensing are influenced by their personal experiences and biases and have multiple purposes for creating, interpreting and using the data.

**The Classroom**
Nine Rangers participated in the weeklong training session (Figure 7. The First Day). Days 1 through 3 were devoted to theoretical aspects of remote sensing and related applied laboratory exercises.  Days 4 and 5 were devoted to acquiring field measurements for comparison to remotely sensed image data.

**Figure 7. The First Day**

**Day 1**
Remote sensing theory, principles, image enhancement theory, applications and exercises.

In general, remote sensing devices such as satellites contain a platform of sensors, which are sensitive to, and record reflectance values from objects on the earth's surface (Figure 8. Remote Sensing Theory).  The reflectance values, or digital numbers, recorded are measurements of radiant energies of the electromagnetic spectrum.  The spectrum is typically divided into radio, microwave, infrared, visible, ultraviolet, x-ray, and gamma-ray radiation.  Most satellites only detect a small portion of the spectrum.  The electromagnetic spectrum detection range of the sensor platform is referred to as the sensor's spectral resolution. Spectral resolutions can vary widely between satellites. The range of spectral resolution and the purpose of the research influence the remotely sensed data sets chosen.

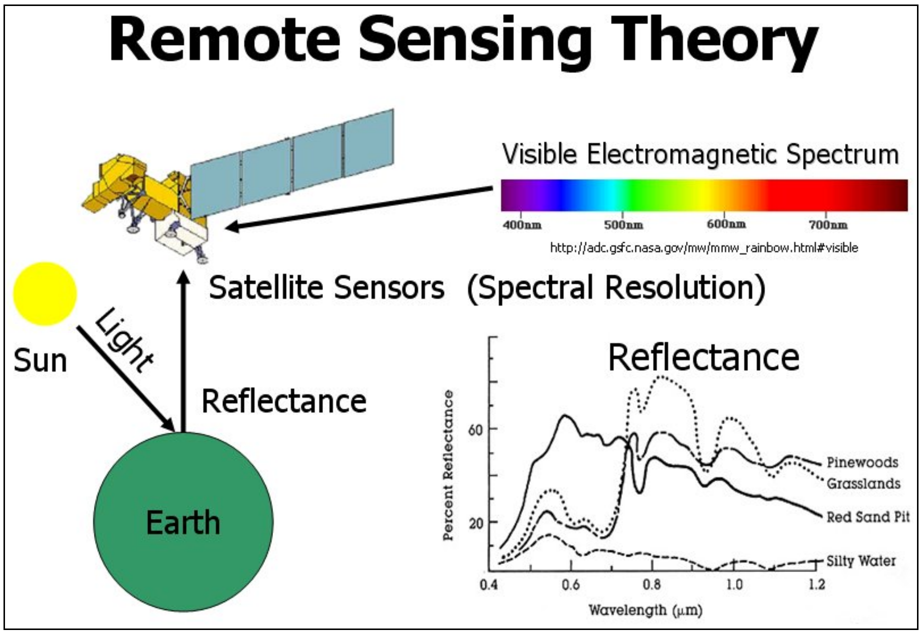


**Figure 8. Remote Sensing Theory**

Another factor influencing satellite choice is the sensors spatial resolution. Remotely sensed image data are typically represented by rows and columns of square grid cells or pixels, each of which contains a single digital number recorded from a platform of electromagnetic sensors. The Spatial resolution refers to the ground size of the pixel, or grid cell. Cell size influences the size of the ground object the sensor is able to resolve, which can affect the digital number recorded. For example, if a satellite sensor's spatial resolution is a 30-meter by 30-meter cell size, the digital number measured for objects larger than the cell size are probably a good measure of the object. If objects are smaller than the cell size, numerous objects are measured, each contributing varying reflectance values to the digital number. Figure 9. Satellite Image Data illustrates the spectral/spatial resolution elements of remotely sensed data. Some popular satellite remote sensing platforms are: Landsat, SPOT, Aster, IRS-C, AVHRR, Goes-East/West, IKONOS, IRS, Terra – ASTER, SeaWiFS

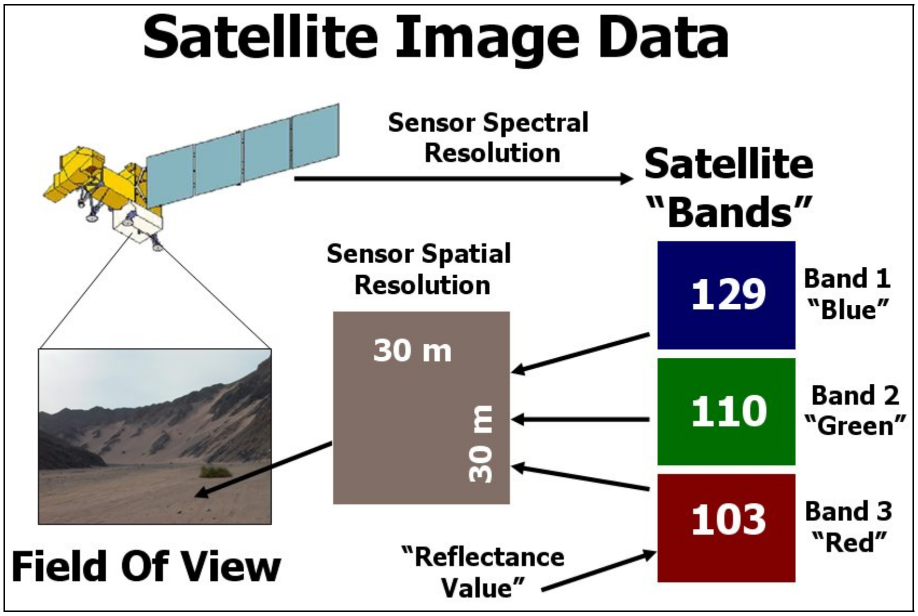

**Figure 9. Satellite Image Data**

Remote sensing and remotely sensed images are highly technical. Additional information on the topics can be found at the US's National Aeronautic and Space Agency Remote Sensing Tutorial found here: http://rst.gsfc.nasa.gov/start.html. Detailed information about remote sensing satellites and their sensors can be found in the "Guide to Land Imaging Satellites" http://www.asprs.org/news/satellites/ by William E. Stoney. Additional information resources are available in the Information Sources section of this paper.

**Days 2 and 3**
Image classification introduction and methodology, change detection, applications of Remote Sensing and GIS to coastal zone management, hand-held spectroradiometer theory, and laboratory exercises.

Classification of remotely sensed data is a 2-part process. The parts are commonly referred to as Preprocessing and Post-processing. Preprocessing involves corrections applied to the recorded image data related to atmospheric conditions such as sun angle, clouds, haze, radiometric calibrations due to satellite sensor variations over time and Geometric correction to transform data from Space Oblique Mercator, a satellite coordinate system, to a "real world" coordinate system, such as UTM.

Post-processing involves the actual classification process, either "unsupervised" or "supervised", which assigns cells new values, or classes. The classes often represent some observed feature on the earth, for instance a marsh, mangrove, or shallow water. Simply stated, in an "unsupervised" classification method the computer assigns classes based on the statistical relationship of a cell's digital number to the range of the entire image's digital numbers. In a "supervised" classification process the researcher uses ancillary data collected from GIS, hard copy maps, photo interpretation, or ground-truthing (ground visits to identifiable places in the image) to guide the computer in assigning classes based on statistical relationships. Ancillary data from ground-truthing can also be augmented with the use of a hand-held spectroradiometer (Figure 10. Ground Truth Spectroradiometer), which measures the percentage reflectance in relationship to the wavelength, or portion of the electromagnetic spectrum that was reflected. Comparisons can then be made between the satellite recorded reflectance values and reflectance values on the ground. Lastly, for either "unsupervised" or "supervised" classification processes ground-truthing is also used to verify the accuracy of the final classified image.


**Figure 10. Ground Truth Spectroradiometer**

A classified image is the result of the process. Figure 11. Image Classification illustrates a reef area around Hurghada classified into 3 classes, green for land, light blue-green for shallow water and light blue for deeper water. The laboratory exercises used Leica's ERDAS Imagine© and personal PCs to perform the classification exercises.

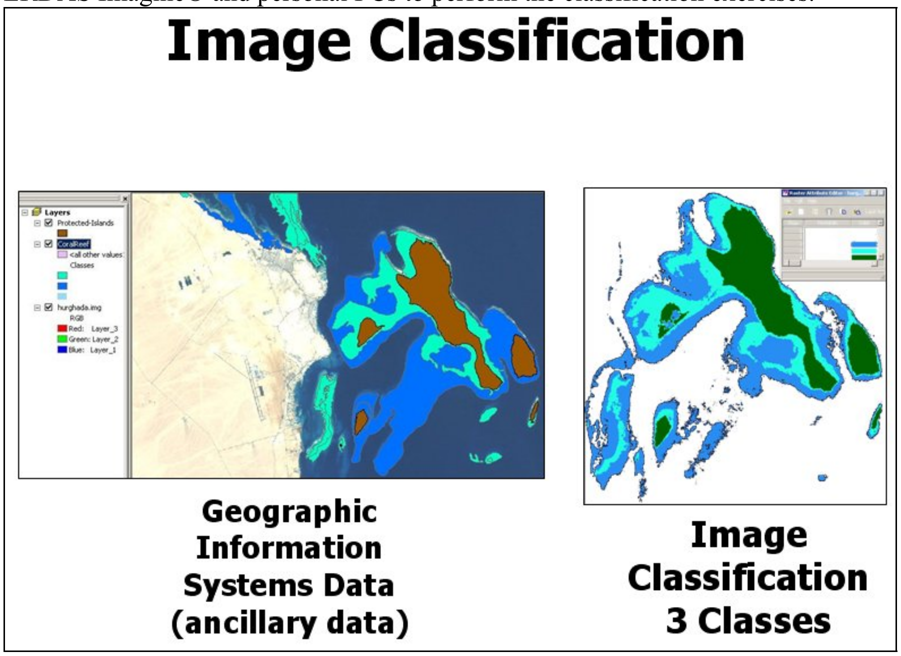


**Figure 11. Image Classification**

Another way to quickly interpret remotely sensed data is through image display and enhancement. Through the use of a computer monitor a series of 3 sensor "bands" (see Figure 9. Satellite Image Data) can be displayed in various combinations (Figure 12. Image Display and Enhancement). Switching the order of the displayed bands can enhance the ability to interpret the image.

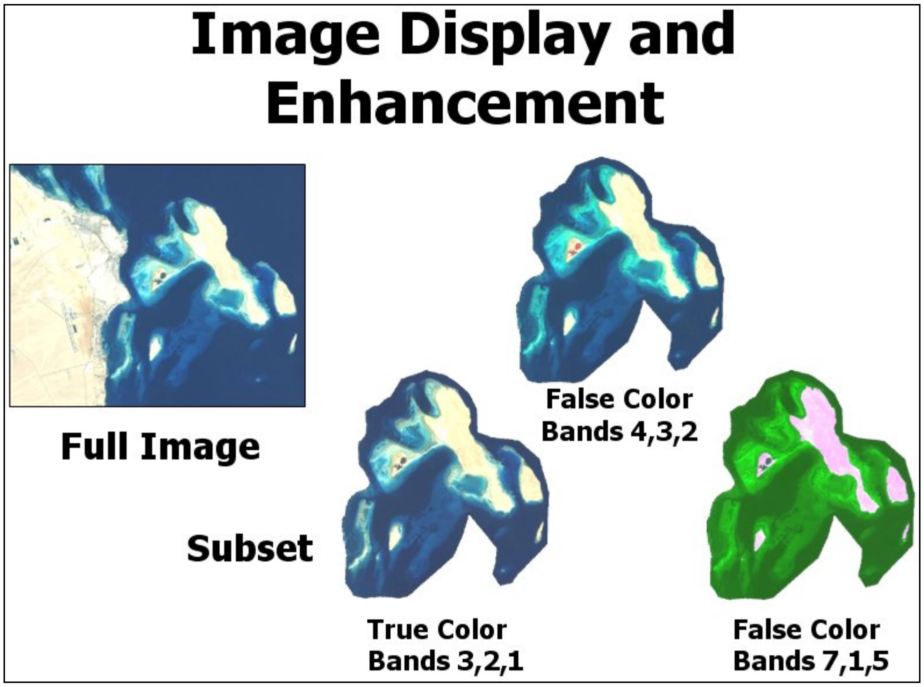


**Figure 12. Image Display and Enhancement**

**DAYS 4 AND 5**
**DEMONSTRATE THEORY AND APPLICATION OF USING HAND-HELD SPECTRORADIOMETER IN MARINE BIOLOGY AND GEOLOGY, DATA PROCESSING AND LABORATORY EXERCISES TO APPLY FIELD DATA IN ORDER TO ENHANCE IMAGE CLASSIFICATION.**

A hand-held spectroradiometer made by Analytical Spectral Devices, Inc (http://www.asdi.com/products-spectroradiometers.asp) was used to collect spectral data samples from various locations on the Red Sea and in the Hurghada mountains study areas. A GPS and laptop computer were used to record the position and descriptive data for each location. Several field activities were performed on each trip. The activities included: Mission Planning to identify site specific study areas, Equipment Checks to calibrate the equipment, and Data Collection of reflectance values. Figures 13 through 17 illustrate the Red Sea field activities, example study areas and simulated examples of data collected. Figures 18 through 22 illustrate the activities and examples for the Hurghada Mountains trip. Lastly, the group picture in Figure 23. The Last Day concluded a successful course.


**Figure 13. Red Sea Mission Planning**

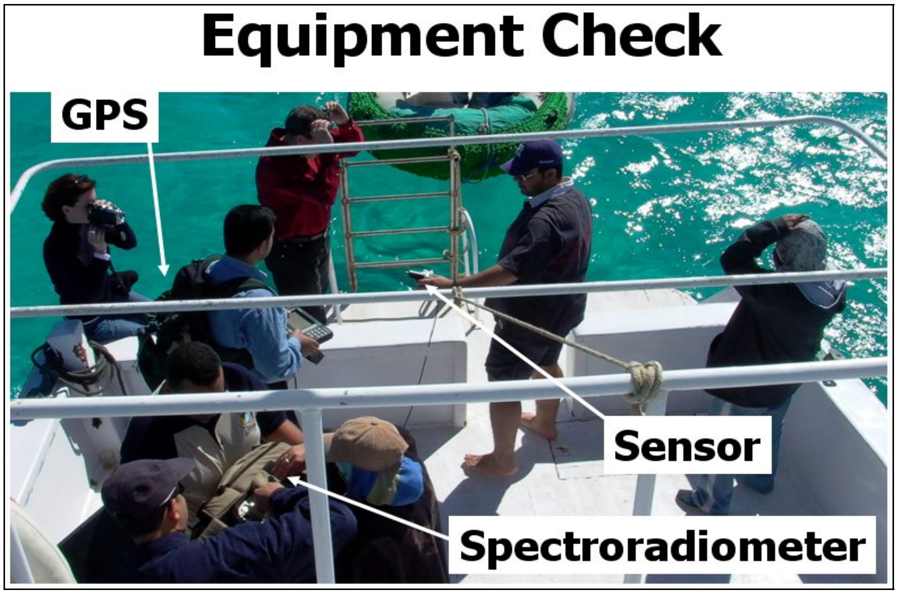


**Figure 14. Red Sea Equipment Check**

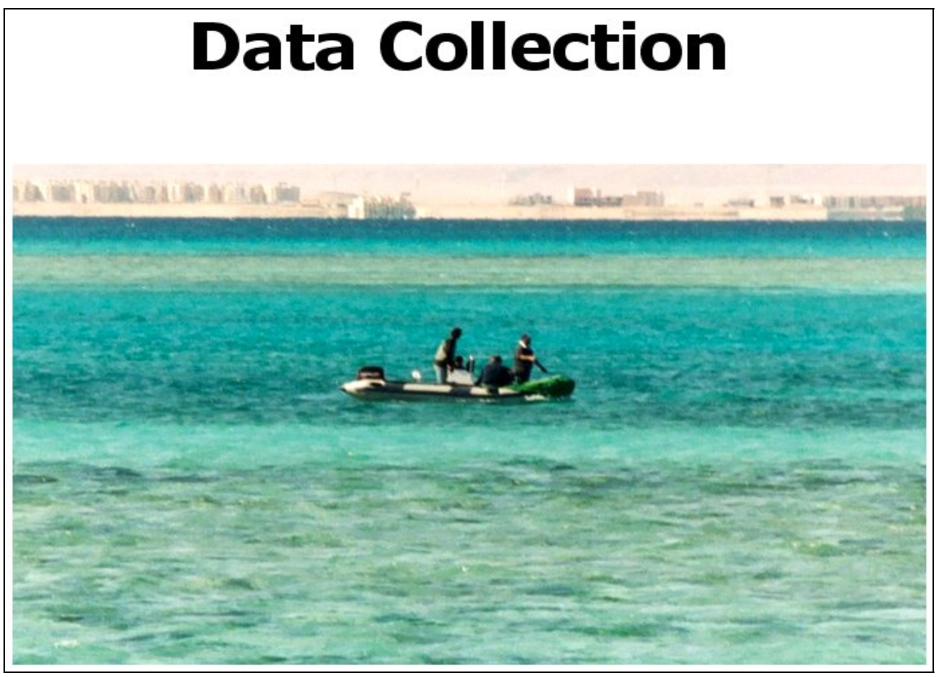


**Figure 15. Red Sea Data Collection**

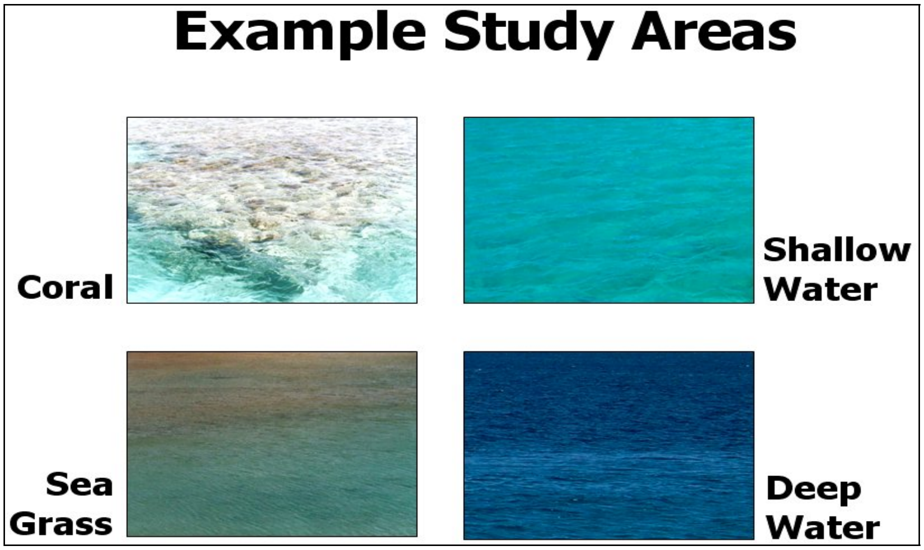


**Figure 16. Red Sea Example Study Areas**

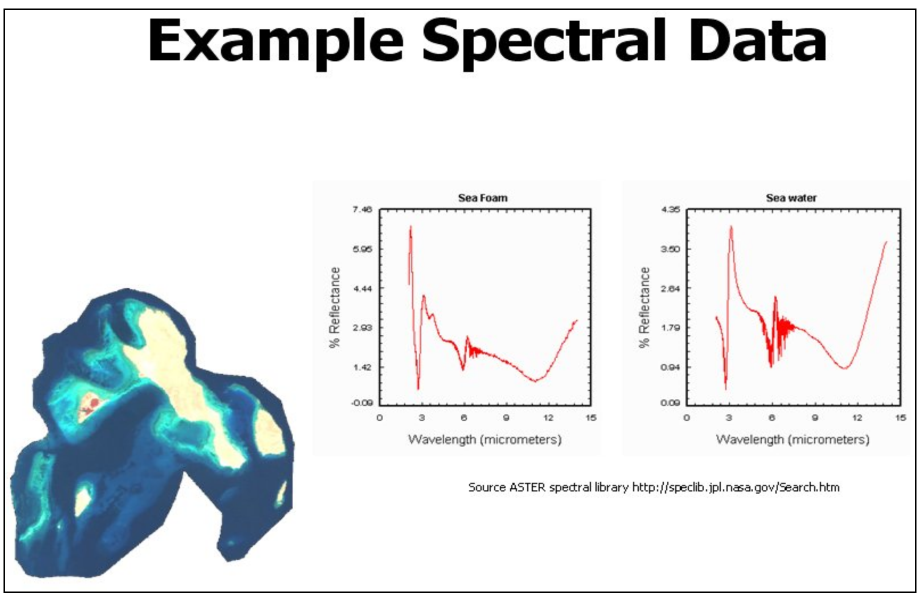


**Figure 17. Red Sea Simulated Spectral Data**


**Figure 18. Hurghada Mountains Mission Planning**

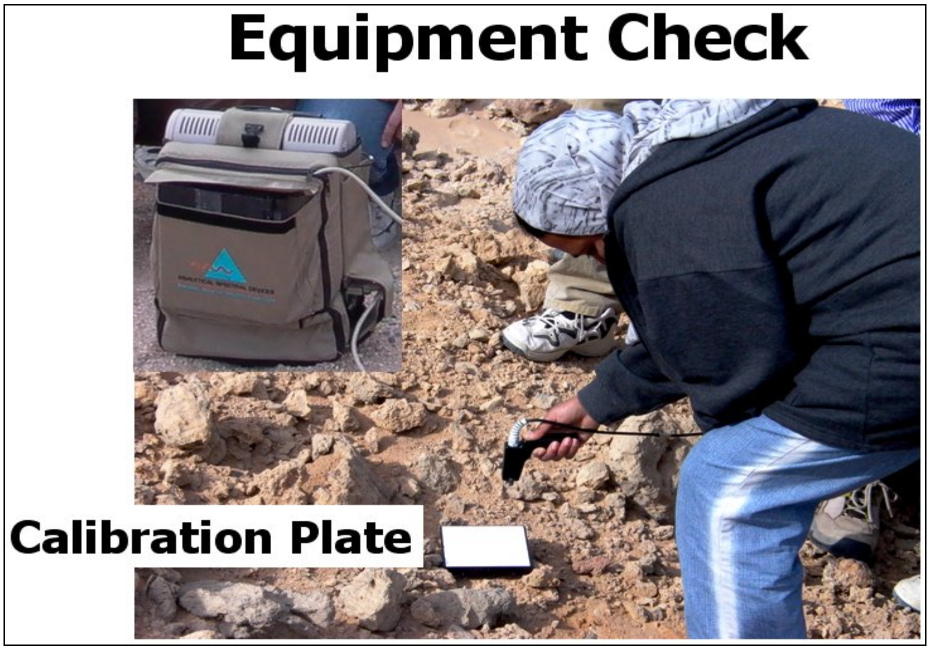


**Figure 19. Hurghada Mountains Equipment Check**

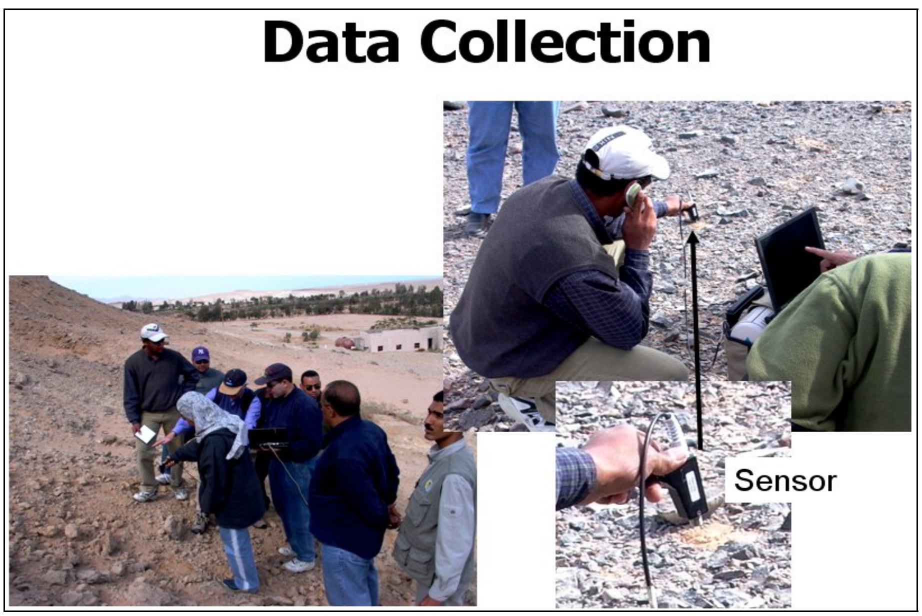


**Figure 20. Hurghada Mountains Data Collection**


**Figure 21. Hurghada Mountains Example Study Areas**

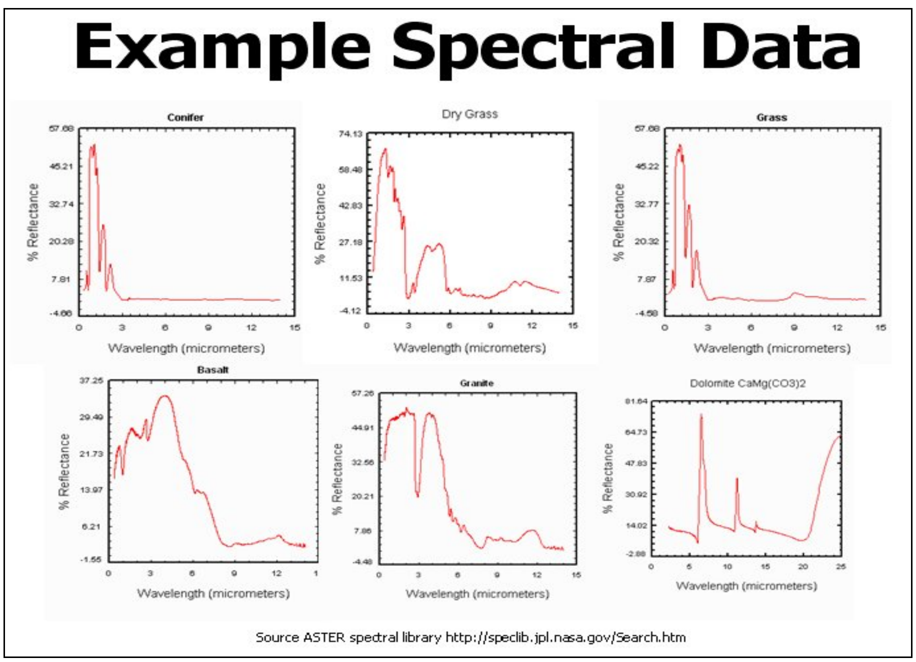


**Figure 22. Hurghada Mountains Simulated Spectral Data**


**Figure 23. The Last Day**

**APPLIED POST TRAINING LANDFILL SITING STUDY**

The siting study, "Using Remote Sensing and GIS Techniques for Landfill Site Selection, Red Sea, Egypt," a white paper by Dr. Hesham Abd-El Monsef, presents a study area which extends from Sharm EL Fuqayra down to the boundary of Wadi El Gemal National Park The park is along the Egyptian Red Sea coast (Figure 24. Landfill Siting Study Area) and encompasses a great diversity of habitats in a uniquely compact setting, representing a complete terrestrial / marine ecosystem characteristic of the Red Sea coast. The area includes a significant proportion of the mangrove resources and many important threaten species. Basement rocks dominate the study area and provide many economic building materials. Sedimentary sequences of the coastal area also include large amounts of gypsum, anhydrite, sand and gravel.

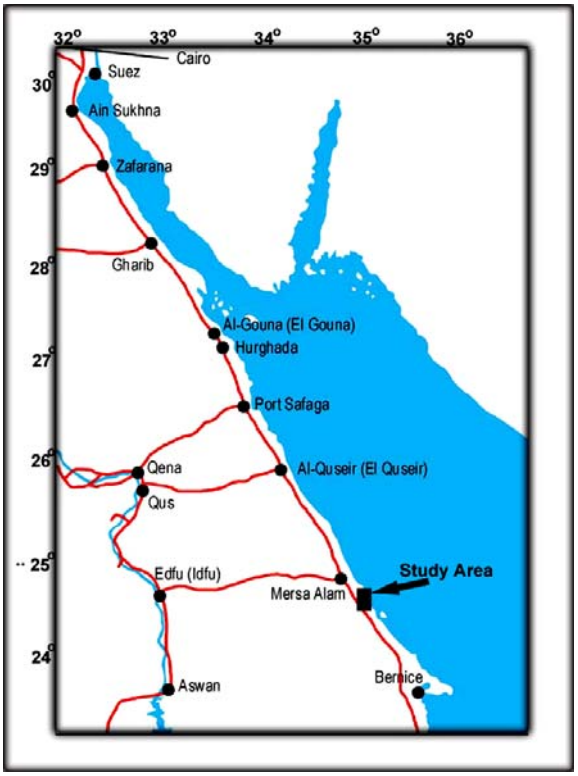


**Figure 24. Landfill Siting Study Area**

The tourism activities and infrastructure are growing rapidly in the area. This will lead to an increase of existing and future solid waste. To prevent environmental impacts Solid Waste management is needed.

This study aims to identify suitable site for solid waste landfill through screening-level process that used remotes sensing and GIS techniques. GIS model have been developed to implement the landfill site selection criteria. The criteria used in the model were distance from the coast, protectorates, and roads, as well as specified slope, drainage, and soils. GIS model were based on data interpreted from ASTER and QuickBird satellite images, field survey using sub-meter differential GPS and previous published data. The sites selected for detailed studies are shown in Figure 25. GIS Criteria and Selected Sites.

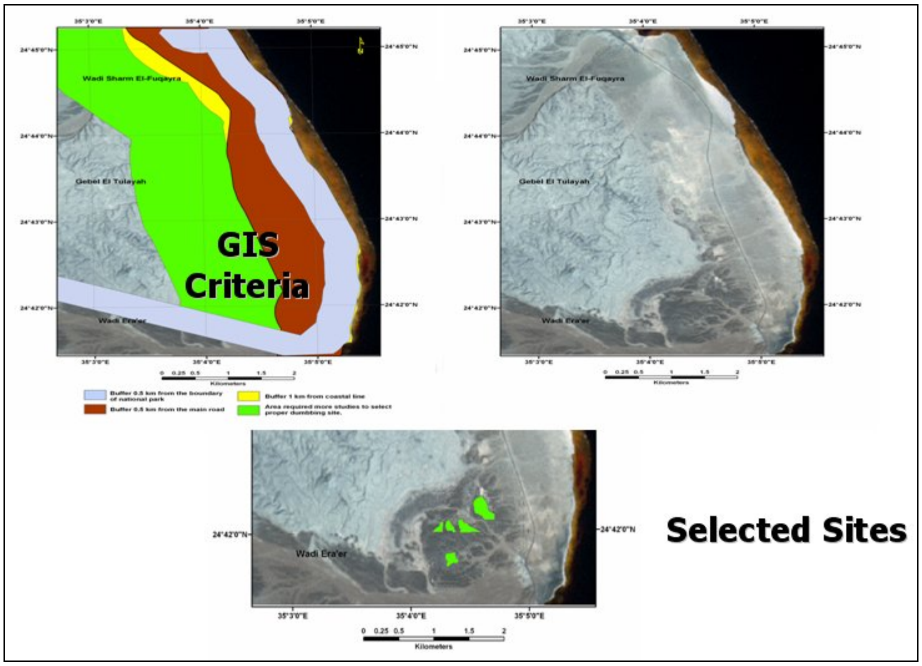


**Figure 25. GIS Criteria and Selected Sites**

**INFORMATION AND DATA SOURCES**

Many remote sensing information sources are available. A few freely available satellite image and GIS data sources are also available. Some of the electronically available resources are presented here and were available as of December 1, 2005.

Articles

Holden, Heather, Chris Derksen and Ellsworth LeDrew. 2000. “Coral reef ecosystem change detection based on spatial Autocorrelation of multispectral satellite data” http://www.gisdevelopment.net/aars/acrs/2000/ts3/cost006.shtml GIS Development, Proceedings Asian Conference on Remote Sensing.

David Palandro, Serge Andréfouët, Frank E. Muller-Karger, Phillip Dustan, Chuanmin Hu, and Pamela Hallock. 2003. “Detection of changes in coral reef communities using Landsat-5 TM and Landsat-7 ETM+ data” http://pubs.nrc-cnrc.gc.ca/cjrs/m02-095.html Canadian Journal of Remote Sensing.

Center for International Earth Science Information Network (CIESIN) Socioeconomic Data Applications Center “An Annotated Guide to Earth Remote Sensing Data and Information Resources for Social Science Applications” http://sedac.ciesin.columbia.edu/remote/

Electromagnetic spectrum
http://observe.arc.nasa.gov/nasa/education/reference/emspec/emspectrum.html
http://imagers.gsfc.nasa.gov/ems/visible.html
http://adc.gsfc.nasa.gov/mw/mmw_rainbow.html#visible
http://adc.gsfc.nasa.gov/mw/mmw_EM.html

Institute for Marine Remote Sensing (IMaRS) - University of South Florida
http://imars.marine.usf.edu/
Institute for Marine Remote Sensing Millennium Coral Reef Mapping Project
http://imars.marine.usf.edu/corals/index.html
IMaRS Authors & References
http://imars.marine.usf.edu/corals/ar.html
IMARS data
http://imars.marine.usf.edu/corals/maps/mes_reefs.html

Land Cover Analysis General FAQs: What is a Pixel
http://www.csc.noaa.gov/crs/lca/faq_gen.html#WPWM

Landsat applications
http://landsat.gsfc.nasa.gov/images/Landsat_Applications.html

Landsat archive of coral reefs
http://oceancolor.gsfc.nasa.gov/cgi/landsat.pl

Landsat 7 Science Data Users Handbook
http://ltpwww.gsfc.nasa.gov/IAS/handbook/handbook_htmls/chapter6/chapter6.html

Millennium Coral Reefs Landsat Archive
http://oceancolor.gsfc.nasa.gov/cgi/landsat.pl?sub=main_page&path=174&row=41&x=-934&y=2421&n=0&t=IMaRS

NOAA's Coral Reef Health and Monitoring Program
http://www.coral.noaa.gov/

Ocean colors explained
http://disc.gsfc.nasa.gov/oceancolor/index.shtml
Ocean Color Research
http://oceancolor.gsfc.nasa.gov/SeaWiFS/LINKS.html

Planetary Coral Reef Foundation
http://www.pcrf.org/remotesensing.html

ReefBase
http://www.reefbase.org/
ReefBase Internet Map
http://www.reefbase.org/dataphotos/dat_gis.asp

Remote Sensing Data and Information
http://rsd.gsfc.nasa.gov/rsd/RemoteSensing.html

Remote sensing and satellite image information
http://landsat.gsfc.nasa.gov/education/compositor/

Remote Sensing of Coral Reefs
http://oceancolor.gsfc.nasa.gov/SeaWiFS/reefs/
http://oceancolor.gsfc.nasa.gov/cgi/reefs.pl
http://eol.jsc.nasa.gov/reefs/

Remote Sensing of Coral Reefs Overview of Integrated Collaborations, Projects and Products
http://eol.jsc.nasa.gov/Reefs/Reefs.pdf

Remote sensing tutorial NASA
http://www.fas.org/irp/imint/docs/rst/Front/tofc.html

Spectroradiometer
http://www.asdi.com/products-spectroradiometers.asp

UNEP World Conservation Monitoring Centre "World Atlas of Coral Reefs"
http://www.unep-wcmc.org/marine/coralatlas/introduction.htm