Coral Reef Investigations in Abu Dhabi and Eastern Qatar

Final Report

January 2005 - December 2007

DOLPHIN ENERGY دولفين للطاقة

Project Sponsor:

DOLPHIN ENERGY دولفين للطاقة

Project Manager:

Emirates Wildlife Society EWS

WWF

Implementation Agencies:

Environment Agency - ABU DHABI هيئة البيئة - ابوظبي

RESEARCH • DEVELOPMENT • PROTECTION

Designed by Nick Crawley

Executive Summary:

These are the final findings of the 3 year project *Coral Reef Investigations in Abu Dhabi and Eastern Qatar* covering the period 01 January 2005 to 31 December 2007. The project objectives were to record and map coral reefs between Abu-Dhabi and Eastern Qatar; assess the condition and potential for recovery of degraded systems and build capacity of national researchers in Abu-Dhabi and Qatar. The overall goal was to develop a conservation management plan for coral habitats under study.

In its completion, the project has undertaken large and fine scale mapping of coral in the study area using satellite imagery, ground verification, accuracy reports, fieldwork around Abu-Dhabi and eastern Qatar, training (theoretical and practical) of scientific personnel at the Supreme Council for the Environment and Natural Resources (SCENR) and the Environmental Agency Abu-Dhabi (EAD), identification of project champions among the trainees, completion of a coral reef monitoring training manual, production of a conservation master plan endorsed by all the project partners and completed the final edition of the Coral Reef Documentary.

Work completed reveals and confirms that although overall coral biodiversity remains depressed in the region, it is clear that, given protection, reefs will recover from the damage suffered during past stress/temperature anomalies of 1996, 1998 and 2002- in what was likely the strongest disturbance spanning a century. Nevertheless, their active reproduction indicates they remain in good heath and are beginning to regenerate.

The Arabian Gulf reefs are very much alive; and growing; particularly in the coral hotspots of Halul (Qatar) and Ras Ghanda (Abu-Dhabi) discovered to be prime areas of coral biodiversity. Furthermore, the project highlighted that the offshore islands and banks of Abu-Dhabi and eastern Qatar harbor some of the most extensive and biologically important coral reef resources of the southern Arabian Gulf.

Even though the Arabian Gulf's corals are unique and seem to endure extremely harsh conditions when compared to corals in other parts of the world, scientists are increasingly concerned that regional coastal development is accelerating coral die-off. The coral reef management plan put in place presents legislation and policy required to achieve their preservation

The overall project progress is more than satisfactory, with 100% of the area mapped; coral recovery potential for the equivalent area assessed, more than 100% of the field trips undertaken, local trainees selected and trained; coral management plan endorsed and first ever documentary on coral reefs of the southeastern Arabian gulf completed.

PROJECT HIGHLIGHTS FOR THIS PERIOD:

- Mapping and inventory conducted of all the coral reef and associated habitats throughout the 86,400 km^2 region study area within joint Qatari/UAE maritime waters.
- All Landsat, Ikonos and Quickbird images acquired and stitched into a continuous mosaic. High resolution (30m) geo-referenced satellite map were used.
- Large scale mapping and development of several baseline products completed
- Fine-scale mapping of Bu Tinah shoal and the area between Ras Hanjurah and Ras Ghanada as well as Halul completed.
- GIS network including habitat classification system done.
- An identification list of coral species in the southeastern Arabian Gulf has been finalized and a list of scientific literature relevant to coral reef studies in the Arabian Gulf compiled.
- Types, structure and dynamics of the coral species in the southeastern Arabian Gulf studied and described.
- Detailed site assessment: over 1800 dives & visual inspections
- Nineteen sites have been evaluated as suitable sites for permanent monitoring stations in key locations in the Arabian Gulf. Surviving coral at all sites were found to be in a healthy state and no diseases were observed.
- Twelve permanent coral monitoring stations were installed Abu Dhabi - Eight stations have been installed at Al Hiel, Bu Tinah (x 2), Makaseb, Saadiyat, Ras Ghanada and Yasat (x2). One of the Yasat stations is a partial station, consisting of the settlement plate rack only.

- Qatar - Four stations were installed at Halt Dalma, Halul (x 2) and Fasht Al-Ghabi. Halt Dalma is a partial station, consisting of the settlement plate rack only
- More than 2000 ground truthing points were surveyed.
- Twelve coral monitoring stations are now active.
- A monitoring station log has been developed to track 2005-2007 activities and to plan for future years.
- A training manual with four technical and instructional chapters has been completed. An interactive coral identification program has been created to supplement the training manual.
- Software provided to SCENR and EAD
- Analytical coral assessment software customized for the Gulf and provided to EAD/SCENR
- Documentary film production for the first film documenting the corals of the south-eastern Arabian Gulf completed.
- Classroom and field training for selected researchers from SCENR (Qatar) and EAD (UAE) was conducted in Abu Dhabi, Qatar and Florida. This included extensive field work and interaction with marine environmental agencies in the USA.
- 30 UAE and Qatari nationals trained, including students.
- A trainee is pursuing a masters degree related to this project.
- Expert in-country training for 20 personnel and overseas training for four nationals.
- EAD and SCENR gained leadership qualities in development of a comprehensive coral reef management strategy.

Key findings:

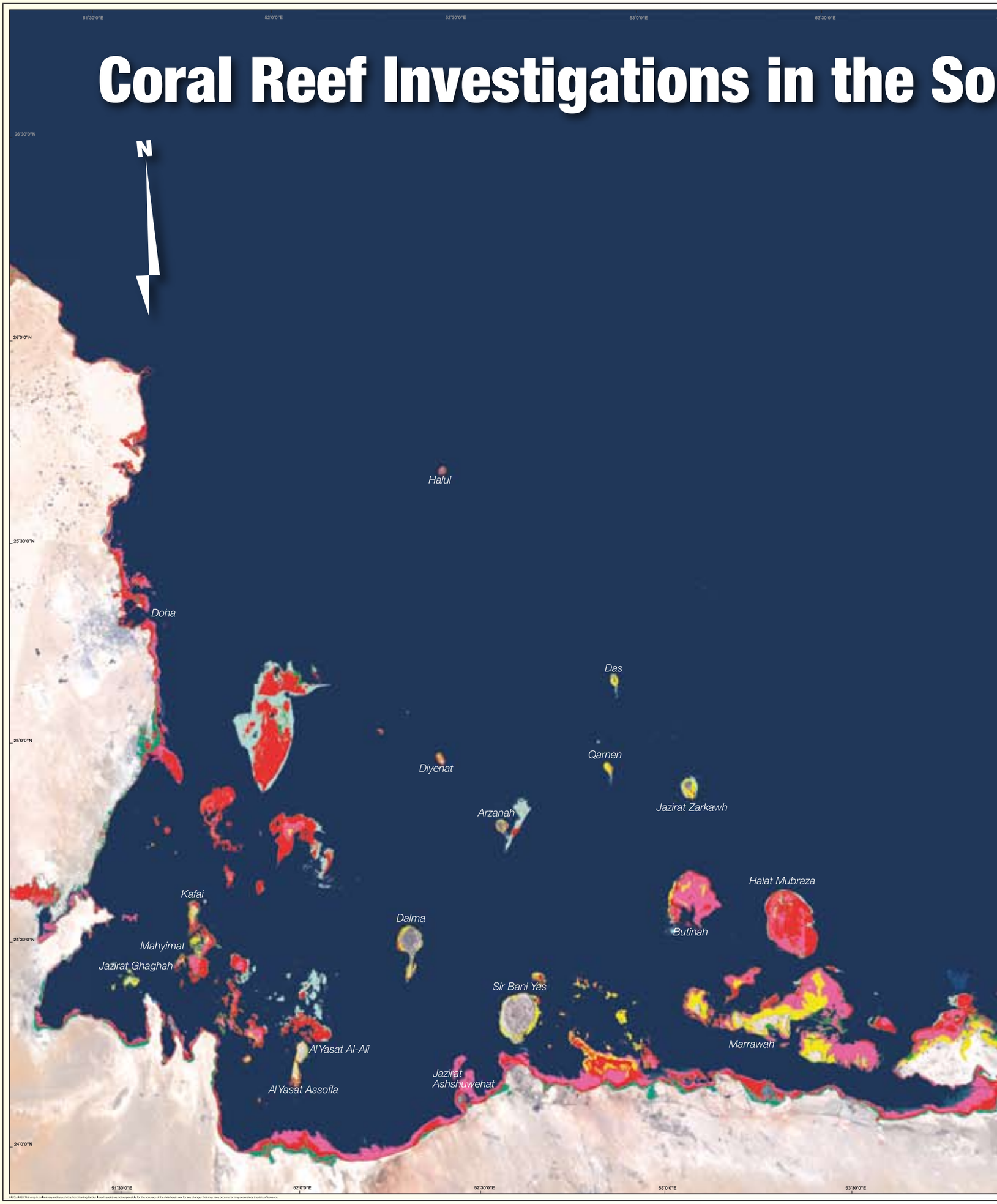
- Overall coral biodiversity still depressed and coral coverage at record low levels
- Clear signs of the coral system's resilience
- Reefs show very active signs of regeneration
- So far, no extinctions have been identified
- Fertile upstream seeding population and active spread of sexual propagules throughout the region
- No evidence for asexual increase in coral populations yet; colonies are still juvenile
- Active recruitment and reproduction indicates that the remaining corals are in good health. Thus, there is hope for a full recovery of the coral systems, provided protection and management measures are enforced.

SCIENTIFIC FINDINGS FOR THIS PERIOD:

- Coral reefs of varying density were found to be present on all the islands and offshore banks investigated in the southeastern Arabian Gulf. Corals have also been found located beyond reef complex associated islands.
- The largest and most continuous coral areas on the maps occur around Halul Island (Qatar) and Ras Ghanada (Abu Dhabi). Yasat and Dalma Islands (Abu Dhabi) also record good coral growth and high coral cover. Coral growth at Yasat occurs along a relatively deep and narrow fringe that is not as clearly visible on Landsat-based maps as are the coral areas around Halul and Ras Ghanada.
- Thermal disturbances of 1996, 1998 and 2002 gravely restricted areas covered by live corals. The satisfactory health of corals has been ascertained. Regeneration is variable between sites. Sites such as Ras Ghanada, Saadiyat and Halul are undergoing vigorous recovery.
- Despite being impacted by stress events and the limited area covered by live corals, some of the most extensive and biologically important coral reef resources of the southeastern Arabian Gulf occur in offshore islands and banks of Abu Dhabi Emirate and Qatar.
- Dinah Island was observed to have the widest distribution of corals - despite the lower density of its corals compared to the other islands.
- The corals of Jernein Islands are in a very early phase of regeneration.
- The observed corals bear clear evidence of a fertile upstream seeding population and active spread of sexual propagules throughout the region.
- There is no evidence for asexual increase in coral populations yet, largely because the colonies are still too small (asexual propagation is a frequent occurrence in

large size Acropora)

- Of a total coral fauna of 36 species prior to past thermal disturbances, at least half are again firmly established within the region. It appears that while Acropora diversity is still depressed (i.e., only three of six previously known species were found), no major shifts in species presence have occurred overall. The major change is a shift away from Acropora dominance.
- Temperature profiles from four sites for the timeframe Sep, 2005 through Oct-Nov, 2006 indicating a mean of 28.2°C, with a minimum of 16.2°C on January 31, 2006 and a maximum of 36.2°C on August 23, 2006, signify that the annual profiles for all sites are very similar - an indication that the sea water temperature is spatially constant throughout the shallow (<6m) regions of the southeastern Arabian Gulf.
- A two-year temperature profile from Yasat for the timeframe of Sep, 2005 through Aug, 2007 indicated the area experienced 22 consecutive days of water temperatures below 20°C in winter 2006 (Jan 18 - Feb 8) compared to 77 consecutive days in winter 2007 (Dec 18, 2006 - Mar 4, 2007).
- Reef slope data indicated that the seafloor is nearly horizontal at most of the monitoring station locations, with a mean slope of 2.8°. Saadiyat has the lowest slope of 0.8°. Makaseb has the greatest slope of 7.5°.
- Rugosity values ranged from 1.2 - 1.8, indicating varying degrees of reef contour complexity between the sites.
- Sea urchin densities ranged from 0.0-10.5 individuals per m^2 during 2006 and 2007. Crown-of-thorns starfish were not observed at any of the monitoring station sites.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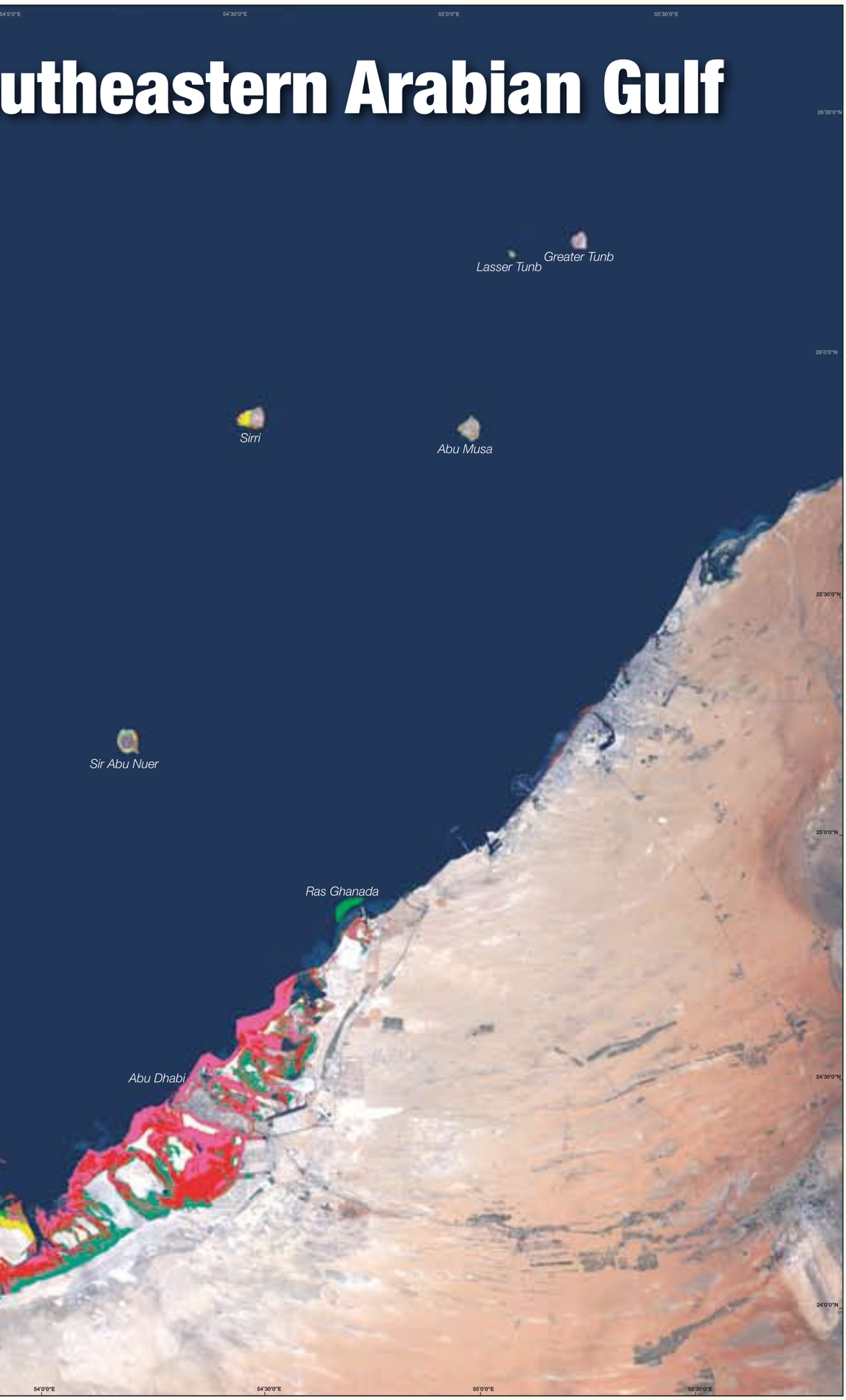

Legend:

Sand		Unconsolidated carbonate sand.
Dense live coral		Dense coral colonies on hardground, typically consisting of *Siderastrea savignyana, Acropora clathrata, Porites lutea, P. harrisoni* intermingled with *Favia spp*. And *Platygyra spp.*
Coral reef under recovery		Sparse to dense recovering colonies of *Acropora clatharta* and *A. downigi*
Mixed rubble assemblage		Predominately unconsolidated to consolidated rubble on hardground.
Mixed seagrass and algal assemblage		Mainly *Halodule uninervis* with occasional *H. ovalis* often associated with a macro-algal community consisting of *Rhizoclonium tortusum*,
Nearshore mixed algal community and terrestrial vegetation		Nearshore sand dominated by marco-algal community.
Unresolved deep		Typically substrate at a depth too great to classify clearly without ambiguity. Typically the assemblage consists of unconsolidated sand.

Note: Discovered depth from 0 to 6m

About the Project:

The main purpose of this three year project is to study the distribution, diversity, abundance, composition and health of the coral reefs and associated habitats in selected areas of the coastal and marine waters of the Emirate of Abu Dhabi and Eastern Qatar. In addition to the direct scientific research and study, the project will include media awareness campaigns and specialist training of UAE and Qatari scientists. The overall goal of the project is to utilize the collated information to develop a conservation and management plan for the Southern Arabian Gulf coral ecosystems.

Project Managers:

Emirates Wildlife Society EWS

WWF

Implementation Agencies:

Environment Agency Abu Dhabi

Technical Advisor:

NCRI

Project Sponsor:

DOLPHIN ENERGY دولفين للطاقة

Coral Reef Investigations in the Southeastern Arabian Gulf

January 2005 - December 2007

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LIST OF ABBREVIATIONS:

EWS-WWF
Emirates Wildlife Society in association with World Wide Fund for Nature - UAE Project Office

EAD
Environment Agency- Abu Dhabi formally known as Environmental Research and Wildlife Development Agency Abu Dhabi (ERWDA), UAE

NCRI
National Coral Reefs Institute Florida, USA

SCENR
Supreme Council for the Environment and Natural Reserves Doha, Qatar

1. Introduction

1.1 Project Background

Coral Reefs are among the planet's richest habitats both in terms of biodiversity as well as the ecological services they provide. They are also among the most vulnerable to disturbance- both natural and anthropogenic. The health of coral systems has progressively declined throughout the tropical and subtropical world; and the Arabian Gulf reefs are no exception.

In the UAE and Qatar, coral reefs along with associated mangroves and sea grass habitats, play important ecological, economic, recreational and cultural roles. Unfortunately, these critical habitats are degrading rapidly; with severe temperatures and coastal developments being prime causes. Additional anthropogenic pressures contribute to reef degradation.

There is evidence that the recovery of degraded corals may be dependent on reduction of human-induced disturbance to these habitats. Such reduction can only be realized through the adoption of sound conservation and management measures. To implement sustainable development strategies, information on the coral habitat is vital. Many reef habitats of Abu Dhabi and Qatar, however, remain uncharted because they have not yet been systematically mapped and evaluated.

Dolphin Energy Ltd. (Dolphin), in association with the World Wide Fund for Nature (WWF) and its UAE partner, the Emirates Wildlife Society (EWS), is sponsoring a three-year project to assist in the Conservation of Coral Reef Habitats in the Arabian Gulf. The project is referred to as Coral Reef Investigations in Abu Dhabi and Eastern Qatar. The project study area is 86,400 km^2 within joint Qatari/UAE maritime waters.

The main purpose of this three-year project is to study the distribution, diversity, abundance, composition and health of the coral reefs and associated habitats in selected areas of the coastal and marine waters of the Emirate of Abu Dhabi and Eastern Qatar. In addition to the direct scientific research and study, the project includes media awareness campaigns and specialist training of UAE and Qatari scientists. The overall goal of the project is to utilise the collated information to develop a conservation and management plan for the southern Arabian Gulf coral ecosystems.

This is the final project report, and covers the period 01 January 2005 to 31 December 2007. The report presents a synopsis of the main project activities, technical issues, key findings, and a summation of the trainee development programme.

Supplemental reports on the site data (slope, rugosity, sea urchin and crown-of-thorns starfish presence, and temperature), training manual, Arabian Gulf coral identification presentations, management plan and support documents have been finalized and provided to both the Environment Agency-Abu-Dhabi (EAD) and Supreme Council for the Environment and Natural Reserves (SCENR).

The followings are the project partners and their role gratefully acknowledged:
DOLPHIN ENERGY-Project sponsor, business and interface coordination
NCRI - Technical experts, scientific and software support
EWS-WWF - Project manager
EAD Abu Dhabi - Implementation agency, local knowledge, expertise and resources
SCENR Qatar - Implementation agency local knowledge, expertise and resources

1.2 Objectives

The principal project objectives are:

- Inventorise and map coral reef habitat
- Investigate the diversity and condition of the coral reefs identified
- Assess the status of reef fish and benthic life forms
- Develop capacity of UAE and Qatari research personnel
- Develop conservation and management regime
- Increase conservation awareness amongst stakeholders

1.3 Project Organization

Title	**Coral Reef Investigations in Abu Dhabi and Eastern Qatar**
Duration	**January 2005 - December 2007 (3 years)**
Sponsor	**Dolphin Energy Ltd**
Project Manager	**Emirates Wildlife Society in association with World Wide Fund for Nature(EWS-WWF)**
Governmental Agencies	**Environment Agency- Abu-Dhabi (EAD), United Arab Emirates**
	Supreme Council for the Environment and Natural Reserves (SCENR), Qatar
Technical Advisor	**National Coral Reefs Institute (NCRI), Florida, USA**
Principal Investigator (PI):	**Bernhard Riegl**
Technical Assistant (TI):	**Samuel Purkis**
Budget	**US $ 513,000 over three years**



Training	• 30 UAE and Qatari nationals trained, including students • A trainee is pursuing a masters degree relating to this project • Training manuals for future recruits • Expert in-country training for 20 personnel + overseas training for four nationals • Leadership of EAD & SCENR in development of management strategy
Software & mapping	• Software provided to SCENR and EAD • High resolution (30m) geo-referenced satellite map • GIS network including habitat classification system • Analytical coral assessment software customized for the Gulf and provided to EAD/SCENR
Dives	Detailed site assessment: over 1800 dives & visual inspections
Area	• Map and inventory all the coral reef and associated habitats throughout the 86,400 km region study area within joint Qatari/UAE maritime waters. • Over 2000 ground truthing points

2. Work Completed

Over the last three years, the project conducted a lot of activities and managed to achieve its main objectives, such as satellite mapping, fine scale mapping, classroom and field training coral reef monitoring field missions, drafting and completing the management plan. The project managed over 1800 dives and visual inspection and more than 2000 ground truthing points. The activities included in this report represent the final findings and are described in their particular sections with the individual tasks as outlined in the approved project execution plan.

A more technical and detailed description is offered in the subsequent chapter entitled 'Technical Issues' or in the Appendices.

2.1 Mapping of Coral Reefs and Shoals

The following mapping procedures have been accomplished:

✓ Large scale map of entire marine survey area using Landsat - TM and Aster imagery
✓ Image mosaics covering entire and critical parts of survey area
✓ Images geo-referenced and geo-corrected against groundtruthing and installed on EAD and SCENR computers
✓ Imagery for fine-scale map of marine survey in Bu Tinah shoal and area between Ras Hanjurah and Ras Ghanada in the Emirate of Abu-Dhabi, and Halul in Qatar, obtained in Ikonos and Quickbird imagery and installed on EAD and SCENR computers.

As a follow up to the above, coral reef mapping underwent further refinement in the final stages of the project. In fact, embedded in the large-scale study that relied on moderate resolution Landsat 7 ETM+ satellite, the two sites of particular interest (Bu Tinah and Ras Ghanda) were targeted using the ultra-high resolution Quickbird platform. The nested approach to the study provides a map product at differing scale and facilitates the comparison of the different mapping technologies considered while studying the spatial relationships of the benthic habitats resolved. Furthermore, additional aesthetics work has been conducted on the large scale map by EAD mapping specialists who updated the imagery to now include the palm island- Jebel Ali as well as arabized the map and improved on the map legend.

2.2.1 Summary of Main Achievements

- **Large-scale map of entire marine survey area of Abu-Dhabi Emirate and Eastern Qatar using "Landsat-TM" or "Aster" imagery completed and fine-tuned**

In order to produce the large scale map which indicates the location and densities of coral reefs; Landsat 7 ETM data was sourced and procured from partner governmental organizations, EAD and SCENR as well as independent data providers. This exercise was not only vital for the mapping requirement, but it also presented a positive collaboration, in the context of data-sharing, between the stakeholders and in particular EWS-WWF, NCRI, EAD and SCENR.

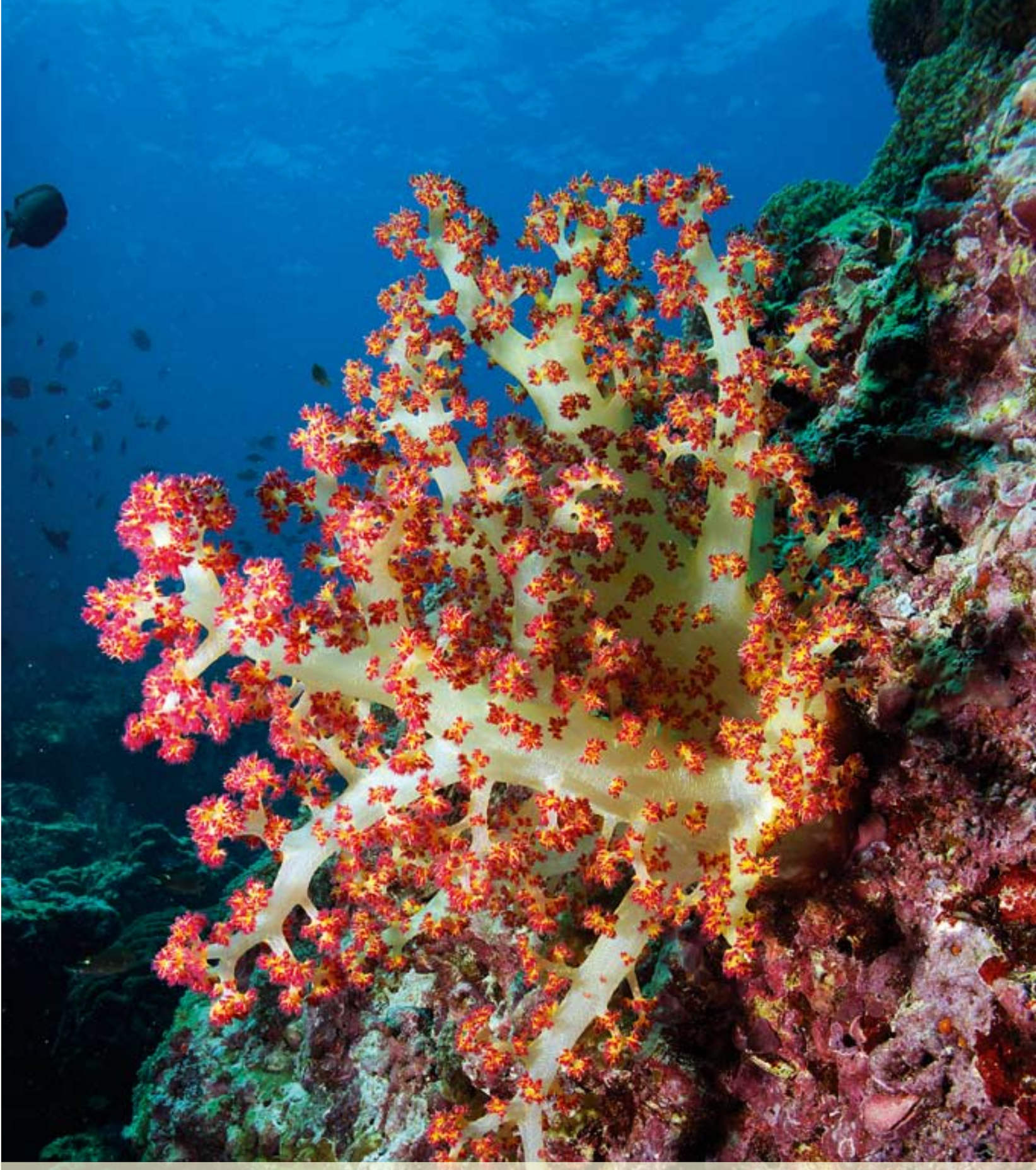
Provision of mapping product with changes as per EAD concerns in particular to image classification of Marawah was undertaken with the active participation of EAD trainees exhibiting further progress in the trainees' competency in image database and software use.

Furthermore, additional work was undertaken by EAD and SCENR to review the large scale map from a user-interface perspective. For example, the map was arabized, the legend was revisited so that the colour categorization would be easier to identify and existing protected areas were assimilated.

- **Several image mosaics that cover both the entire and critical parts of the survey area produced**

Using the data acquired both from EAD and SCENR and purchasing further data from independent data providers several mapping baseline products were created. This included the following products:

- Mapping tiles with only areas of special interest (expert -driven decision after having seen the images).
- Several tiles of the entire study area that can be easily handled by GIS
- A mosaic of the entire study area.



The data for each product was given to SCENR and EAD. Since SCENR and EAD would be the data custodians for the project, any inquiries regarding the data would be handled and disseminated through these agencies.

- **Images geo-referenced and geo-corrected against ground-truthing and datum points- and provided both in hard copy (as color-composite print-outs) as well as part of a geographical information system installed on both EAD and SCENR computers.**

Sample areas of the images (and/or mosaics of images) that were identified as including areas of interest for the present project were rigorously ground-truthed.

Ground-truthing is important to:

- Verify the accuracy of the maps.
- Geo-reference data points that can be used in the future for monitoring purposes.

Ground-truthing took place during several field campaigns at the Eastern coast of Qatar and Abu Dhabi Emirate throughout the projects' duration. In addition, coordinates of all ground-truthed areas were loaded into navigation software that will allow accurate and rapid navigation to the ground-truthing areas.

Ground-truthing information and images were entered into a spreadsheet and stored in a database at EAD and SCENR. Finally, ground-truthing points, coded for information content, were super-positioned onto the maps and accuracy statistics were calculated.

- **Image classification of above stipulated image mosaic depicting different habitat types optimized to outline coral reefs completed.**

A system of algorithm for image classification and/or evaluating of algorithms were produced in collaboration with scientists from EAD and SCENR. A collaborative and participatory approach was used in order to provide an easily useable product, the generation of which can be followed-up within the agencies so that it is easily available within their existing software. For example, based on the classified images, production of a series of geo-tiff files can be imported into any desired GIS system.

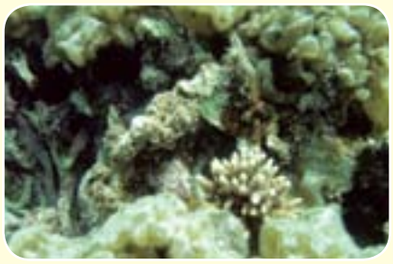
- **Fine scale imagery verified in terms of accuracy of the maps and geo-referenced data points for future monitoring purposes.**

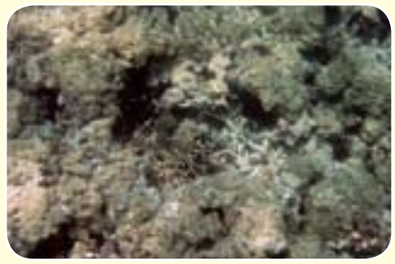
Classification of Bu Tinah, Ras Ghanada and Halul has been completed remotely by scientists at NCRI and submitted to both EAD and SCENR for their independent review. The fine-scale mapping images and classifications received were added to the ArcMap habitat map. Atmospheric correction algorithm and glint removal contributed to progress in fine tuning the detailed mapping for Bu Tinah and Ras Ghanada. Furthermore, shape files describing the fine-scale habitat maps for Taweelah have been provided despite the turbidity in the area, thereby resolving offshore dense coral patches.

- **Statistical evaluation of coral reef field data**

As requested by EAD and SCENR, a data report that outlines how the images were classified together with the accuracy report and statistics (including a compilation of a GIS synoptic report) has been completed and submitted to EAD and SCENR for their review. As there were no comments on the report, it is now considered final.

The report concludes that through evaluation of all the results achieved by the project, Landsat TM imagery can be used to accurately classify coarse level habitats for large scale areas such as the southeastern Arabian Gulf, assuming sufficient ground control data is available. In addition, when small scale areas are considered in isolation (i.e. Bu Tinah Bank), ETM+ imagery returned classifications comparable to those observed with the Quickbird sensor, provided coarse scale assemblages are targeted.





2. 2 Assessment and Monitoring of Coral Reefs

Upon successful completion of the large-scale mapping of coral reefs and shoals, it was important to correctly transfer the information from the large-scale to the fine-scale product in order to assure classification accuracy. The type, health and diversity of coral communities identified in the different scale mapping exercises were verified during the May-June, 2006 field mission. The field mission included the following activities:

- More groundtruthing points were obtained for satellite imagery
- Sites were re-evaluated for setting up permanent monitoring stations
- Coral species lists were developed and included percentages afflicted by diseases, bleaching and predation. No new coral species were recorded, indicating that the 2005 surveys had been exhaustive
- Researchers received on-site training while participating in groundtruthing
- Bu Tinah shoal and the area between Ras Ghanada and Ras Hujarh, for which fine-scale mapping was generated, were resurveyed and their coral reef resources were rapidly assessed
- Photo transects were taken at Ras Ghanada. These were assembled and digitized by researches during subsequent training in Florida (June, 2006)
- Photographs were taken to demonstrate the condition of coral growth
- Data was collected along 10m transects to provide an accurate assessment of space cover by live coral

Field work in the Ras Ghanada area included the study of the coral community and the distribution of other nearby habitats including sea grass meadows (dense and sparse), sand plains, hard grounds and coral patches on hard grounds.

Coral Point Count (CPCe) software and database program was modified and adapted to the Arabian Gulf fauna. Images taken for the groundtruthing database were imported into the CPCe program. Researches can now use this tool to determine area cover, species diversity, colony size distribution and health status.

Additional efforts have been focused on implementing long-term coral monitoring programs in Abu Dhabi and Qatar. Twelve permanent monitoring stations have been installed in key locations in the southeastern Arabian Gulf; including Halt Dalma, Halul (x2) and Fasht Al-Ghabi in Qatar and Al Hiel, Bu Tinah (x2), Makaseb, Saadiyat, Ras Ghanada and Yasat (x2) in the Emirate of Abu Dhabi. Key SCENR and EAD personnel have been trained in installation procedures so that further sites may be added at their discretion.

Baseline data has been collected at the monitoring stations. Key SCENR and EAD personnel have been trained to analyze the data and digital images generated from annual monitoring activities. Such analyses may be used to make spatial comparisons between coral communities in the southeastern Arabian Gulf. In addition, annual data collection from the monitoring stations will allow the respective environmental agencies to monitor temporal changes (i.e., regeneration, growth and mortality of the coral reef community) at each site. Specific action items for the annual monitoring of each station are already in place through 2009.

2.2.1 Summary of Main Achievements

- **A list of coral species in the southeastern Arabian Gulf has been finalized *(Appendix 1)***

Of a total coral fauna of 36 species prior to past thermal disturbances, at least half are again firmly established within the region. A key component of the project was to investigate whether a shift in community structure or species composition had occurred during the severe population restriction following the thermal anomalies of 1996, 1998 and 2002. It appears that while Acropora diversity is still depressed (i.e., only three of six previously known species were found), no major shifts in species presence have occurred overall. The major change is a shift away from Acropora dominance.

Settlement plates

Design of coral monitoring stations

The monitoring station design included three basic components; settlement plate racks, photo transects and temperature recorders.

- ***Settlement plate rack***
  The settlement plate rack resembles a tree with horizontal branches that may be parallel or perpendicular to each other. The plates are small tiles made from materials similar to the reef substrate such as unglazed ceramic or limestone. The plates act as artificial substrate onto which the coral larvae may attach. The establishment of new coral recruits may indicate development, growth or regeneration of a reef.

- ***Photo transects***
  Photo transects allow researchers to monitor the long-term recruitment, growth and mortality of individual corals within a specific area. The transect markers ensure the repeatability of photographs by marking the start and end points of surveys. The monitoring stations in the southeastern Arabian Gulf utilize the "Mercedes star" transect pattern. Ideally, the settlement plate rack serves as the center marker. Three transect markers are cemented into the nearby reef, approximately 12m from the center marker and at 120° angles from each other. Measuring tapes can be run from the center marker to each of the end markers to create the three rays of the star pattern.

  Once the transect markers are in place, digital photographs are taken along each of the three rays. A camera framer is used to ensure that each photograph is taken at the same angle and distance from the reef. This allows for repeatability over time and when multiple photographers are involved.

- ***Temperature recorder***
  Recorders are deployed underwater to log the ambient seawater temperature every hour. These provide detailed daily, seasonal and annual temperature profiles.

Installation of Coral monitoring stations

Nineteen sites have been evaluated as suitable sites for permanent monitoring stations at key locations in the Arabian Gulf. A monitoring station log has been created to track the 2005-2007 field work and the 2008-2009 plans for each location.
(*A narrative of these site visits is provided in Appendix 2*)

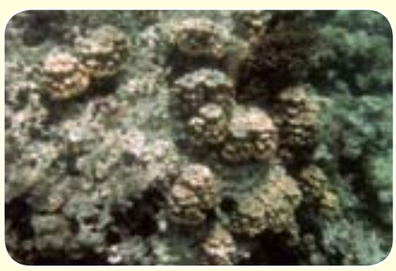
- Twelve permanent coral monitoring stations were installed
  Abu Dhabi - Eight stations have been installed at Al Hiel, Bu Tinah (x2), Makaseb, Saadiyat, Ras Ghanada and Yasat (x2). One of the Yasat stations is a partial station, consisting of the settlement plate rack only.
  Qatar - Four stations were installed at Halt Dalma, Halul (x2) and Fasht Al-Ghabi. Halt Dalma is a partial station, consisting of the settlement plate rack only.

- One site has been temporarily designated as "Status to be Determined" and may be revisited by SCENR.
  An exploratory site at Um Al-Arsan had healthy corals, but strong currents made installation during the 2006 work impossible.

- Six sites have been designated as inactive
  - An exploratory site at Al Ashat (Qatar) was considered for a monitoring station location in 2006. However, the reef structure did not have live colonies and was determined to be unsuitable for a station.

  - An exploratory site at a mooring buoy (Qatar) was considered for a monitoring station location in 2006. Healthy corals were apparent; however, the depth was unsuitable as a training location. SCENR may decide to consider this location for a monitoring station at a future date.

  - An exploratory site at Khor Al Udaid (Qatar) was considered for a monitoring station location in 2006. However, this is an oyster reef cemented by coralline algae, making it unsuitable to monitor corals.



- The settlement plate racks from two sites that were initiated in 2005, Delma (Abu Dhabi) and Shra'aw (Qatar), were found overturned in 2006. The respective sand and solid rock substrates were unsuitable for the installation of long-term monitoring stations.

- The Qafay (Abu Dhabi) site that was initiated in 2005, is in Coast Guard restricted waters and has thus been removed from the active station list.

Installation of the monitoring stations includes hammering the settlement plate racks and transects markers into the substrate and securing them with an underwater epoxy. The epoxy is lightweight and solidifies quickly underwater. Once the epoxy dries, settlement plates are attached to the racks. Temperature recorders are deployed where available. Digital photographs are taken and site benthic data are collected. Data sheets have been developed to record depths for slope calculations, bottom contour distances for rugosity calculations, sea urchin and crown-of-thorns starfish counts and other relevant information.

- Completion of the Conservation Action Plan for Corals in Abu-Dhabi and Eastern Qatar.

A final version of the conservation action plan and assignment of responsibilities was completed in December 2007 with active participation from all the stakeholders.

2.3 Institutional Capacity Building and Dissemination of Results

2.3.1 Summary of Main Achievments

- In 2005, researchers (26 in all) from EAD and SCENR were exposed to a series of classroom lectures introducing them to the relevance of optical remote sensing to the project, coral reef ecology and biodiversity pertaining to the Arabian Gulf and coral reef monitoring
- Twelve marine scientists/researchers selected from EAD and SCENR received intensive training in both the classroom and field. Training was conducted during three field trips in Abu Dhabi and Qatar during 2006.
- The training manual is complete and has been distributed to the project participants.
- Coral Identification training tools have been developed, including an interactive ID program, pictorial ID chart and decision matrix.
- Coral reef Management Plan has been completed
- Participation in the Marine Conservation Forum 2006 took place
- Steering Committee Meetings were convened on a quarterly basis alternating locations between Qatar and Abu-Dhabi
- Excellence in Environmental Projects and Products Award was received in 2006
- Best in Environment Award was secured 2006
- More footage for coral reef documentary under production was acquired
- Increased project awareness among stakeholders was generated
- Training mission to the National Coral Reef Institute, Florida, USA was organised in June 2006
- A jointly prepared scientific paper was submitted for presentation at an international meeting (September 2006, Bremen, Germany) by EAD, SCENR and EWS-WWF
- An outreach environmental awareness programme on the importance of coral reef conservation was implemented at Abu Dhabi Women's College (ADWC)

2.3.2 Presentation and Awards

- Participation in the Marine Conservation Forum held in Abu Dhabi on September 11-14, 2006

The Marine Conservation Forum 2006, held under the patronage of the Ministry of Environment and Water, was the first of its kind to be hosted by the EWS-WWF as a regional conference to discuss the conservation issues of marine turtles and coral reefs. The Forum brought together

government officials, NGO's, scientists, biologists, researchers and academia to discuss the common threats to, and concerns about, these species and to collaborate on conservation-based solutions.

Dr. Bernhard Riegl, Principal Investigator, together with a national team of specialists working on the coral reef project from both Abu-Dhabi and Doha, were key participants at the Forum which devoted the first two days to discussing regional coral reef conservation efforts.

According to the presentations presented by both EAD and SCENR scientists, Halul in Qatar and Ras Ghanada in Abu Dhabi are two areas where the most vigorous coral regeneration is taking place. Yasat and Dalma islands in Abu Dhabi also recorded good coral growth and high coral cover. The coral reef investigations in Abu-Dhabi and Eastern Qatar were cited at the Forum as a model project for the region; a project where the excellent cooperation between governmental agencies and other entities involved was used to ensure that effective conservation measures are in place to protect environmental resources in the Gulf.

- Participation in SPE International HSE Conference in France

A paper on the project will be presented to the Society of Petroleum Engineers (SPE) International Health, Safety and Environment (HSE) Conference in France in April 2008. This conference is considered to be the most important HSE conference for oil and gas producers around the world. The paper describes the background, structure, achievements and strategies adopted to successfully optimize the political, technical and scientific benefits of the project for all stakeholders.

- Excellence in Environmental Projects and Products Award

The Coral Reef Investigations in Abu-Dhabi and Eastern Qatar project received the 2006 Excellence in Environmental Projects and Products Award at the Offshore Arabia conference held in Dubai. Offshore Arabia is organized by the Regional Clean Sea Organization (RECSO) whose members include ADNOC, QP, PDO, Saudi Aramco, BAPCO, Maersk, Dubai Petroleum Company, Kuwait Oil Company, Iranian Offshore Oil Company and Saudi Aramco Texaco.

The award was given to Dolphin Energy for submitting a paper titled, 'Developing a Regional Coral Conservation Strategy - the Dolphin Energy Perspective' for presentation during Offshore Arabia. The paper was prepared by Marcus Chandler (Environmental Manager) for presentation by Marwan Al Kendi (Environmental Engineer).

- Pipeline Magazine Excellence in Energy Awards 2006 - Best in Environment

On behalf of Reflex Publishing, the publisher of Pipeline Magazine, the project Coral Reef Investigations in Abu Dhabi and Eastern Qatar was selected to receive the Excellence in Environment Award at the Excellence in Energy Awards 2006.

All stakeholders receiving the prize at the Pipeline 'Excellence in Energy Awards' Ceremony in Abu-Dhabi, 03 December 2006

3. Technical Findings

3.1 Mapping of Coral Reefs and Shoals

3.1.1 Landsat Imagery

Agreement was reached that the most applicable way of mapping the coral areas of Abu Dhabi and Eastern Qatar is by using Landsat imagery in combination with abundant groundtruthing. An additional factor suggesting production of first a coarser-resolution product was the vastness of the survey area, which would have in any case demanded a down-sampling of high-resolution data in order make the data-volume handleable. The chosen data-baseline, Landsat passive optical satellite imagery, was acquired from in-house databases at EAD. Additional scenes were procured by EWS-WWF. Thus, nearly complete coverage over the entire study area was achieved. Since Landsat data are a widely-used standard data product, all parties agreed that it was indeed the best data- format for the trainees.

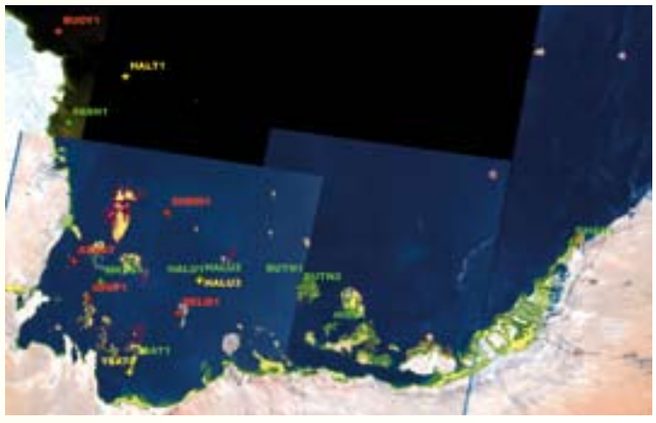
As a first processing step, the data were stitched into one continuous mosaic. Geo-referencing was checked and, in comparison to ground-control points, found to be accurate. No geodetic fiducially points were available, however, when projecting GPS positions onto the maps in real time, and in comparison with strategically chosen points that could be cross-correlated between image and position in the field (i.e. when the observer super-positioned his position in real-time onto the Landsat image and he stood near a house, the Landsat image also showed his position to be near a house), the geo-positioning of the image was found to be accurate. Where accuracy was doubtful, correction was undertaken. Both hardcopies as well as softcopies of the maps were circulated in reports and as printouts that were handed to the project partners for referral. The fused version of the image was installed on the EAD and SCENR databases and handed as a CD to the network managers of both authorities.

The Landsat images used for the mapping were acquired under conditions with different water turbidity and cloud cover which made significant correction, cleaning and masking of the image necessary. Data were processed with full 11-bit radiometric resolution. Sun glint, caused by the reflection of sun rays at high angle of incidence on waves, was removed using a custom-built algorithm. The de-glinted imagery was radio metrically calibrated to retrieve at-sensor radiance It was then further corrected for atmospheric effects using the Fast Line-of-Site Atmospheric Analysis of Spectral Hypercube (FLAASH) software package in ENVI (by Research Systems Inc.). FLAASH incorporates MODTRAN4 radioactive transfer code and in addition to atmospheric absorption and scattering, models and corrects for adjacency effects. FLAASH output is scaled irradiance reflectance that scales to irradiance reflectance in the case of Lambertian surfaces. Prior to classification, deep water, terrestrial and cloud affected areas were masked and omitted from further processing. Classification was conducted iteratively using a k-means algorithm to yield multiple ecologically-relevant classes. To reduce classification noise, the processed map-product was filtered with a median filter constructed using a 3x3 pixel neighborhood. Classes that were clearly erroneous were edited contextually to ensure a realistic representation of benthic character.

For ground-truthing and as accuracy assessment, information was collected at over 2000 points. Groundtruthing information consists of a geo-referenced description of bottom type, which is either obtained by a spot-dive or by the diver looking over the side of the boat using an aqua scope.

Several approaches were employed in the algorithm classifications which include:

- Unsupervised and supervised classification in ENVI and production of a product based on this technology.
- Development of code and a supervised classifier in Matlab and production of a mapping product based on this technology.



3.1.2 Fine tuning of large scale map of marine survey

For consistency of classification, it is important that a particular facies in one portion of the image have a comparable spectral signature to an occurrence of the same substrate type in a different part of the image mosaic. However, the spectral signatures of similar facies in different images are often not

Table of monitoring stations

M. station	Name
ASHAT	AL Ashat
HIEL1	Al Hiel
BUOY1	Buoy
DELM 1	Delma
HALT 1	Halt Delma
HALU2	HALU2
HALU1	HALU1
FASH1	Fasht Al-Garbi
UDAID	hor AL Udaid
MKSB1	Makaseb
QFAY1	Qafay
SHRW1	Ahra'aw
ARSN1	Um Al-Arsan
YSAT1	Yasat Ali
YSAT2	Yasat Asfi
BUTN1	Bu Tinah
BUTN2	Bu Tinah
SDYT1	Saadiyat
GHAN1	Ras Ghanada

congruent due to spectral image artifacts. These artifacts can occur due to the image acquisition process and atmospheric affects and are most pronounced in extensive image mosaics. Because the ETM+ images were not analogous in their spectral signatures, it was necessary to spatially resize the mosaic to 31 smaller image subsets, each representing an area to be mapped. All 31 resized image subsets were derived from offshore areas. It was determined that the offshore features of the southeastern Arabian Gulf should be classified separately from the coastline due to difficultly in matching the spectral signatures of like facies for both areas.

It is not uncommon for classified images to often suffer from a lack of spatial coherence (Speckle or holes in classified areas). In all of the unsupervised and supervised classified images, a Clump Classes Filter was used to clump adjacent similar classified areas together using morphological operators. Low pass filtering could be used to smooth these images, but the class information would be contaminated by adjacent class codes. Clumping classes solves this problem. The selected classes were clumped together by first performing a dilate operation and then an erode operation on the classified image using a kernel of the size of 3x3 pixels. Filtering the classification does improve the spatial coherency; however, as pixels are clumped together, the spatial resolution of the image decreases. Vector formatting for the classified imagery is necessary for exportation into the ArcGIS program which was used to host the final map product. This requires the classification that is produced in a raster format to be converted into vector format, which can then be read into the ArcGIS program. Each of the seven individual categories defined during the classification process were saved to vector format with one class per layer. The resulting vectors were then saved as individual shape files, where each class contains its own shape file. These shape files were then loaded as layers into ArcGIS for the final map output.

3.1.3 Fine Scale Mapping

After discussions with the project team several target areas for fine-scale mapping were identified; two areas in Abu Dhabi and one area in Qatar, which were of high interest to the management agency and the project sponsor alike:

Bu Tinah shoal
Area between Ras Hanjurah and Ras Ghanada
Halul

The project obtained an Ikonos and a Quickbird image of the relevant areas in Abu-Dhabi; while SCENR obtained the imagery through their own resources due to their availability in-house and also because the Halul imagery acquired through the project was of low quality as cloud cover obscured many relevant features.

Identified areas of interest, listed above, were rigorously ground-truthed. For the geo-referencing of the high-resolution images, the same groundtruthing points could be used as for the Landsat-based product. This allowed significant economy in field work and data handling. Ground-truthing was important to verify the accuracy of the maps as well as geo-reference data points for future monitoring purposes.

In a very similar approach as in the production of classification for the Landsat product, a system of algorithms for image classification were produced for the fine scale mapping in collaboration with scientists from EAD and SCENR. For example, based on the classified images, production of a series of geo-tiff files can be imported into any desired GIS system. At present, preliminary classification files exist that will be refined in collaboration with scientists from EAD and SCENR. The preliminary classifications for Bu Tinah and Ras Ghanada, along with the image, were transferred to EAD in early June 2006. Work on Halul was developed in SCENR by Qatari scientists.



3.2 Assessment and Monitoring of Coral Reefs

3.2.1 Assessment

The offshore island and banks of Abu Dhabi emirate harbour some of the most extensive and biologically most important coral reef resources of the entire Arabian Gulf. Rapid assessment, convened in the first quarter of 2005 constituted an important, concentrated mission on assessing the status of Abu Dhabi's and eastern Qatar's coral reef resources in the aftermath of three significant natural stress events i.e. sea-surface temperature anomalies of 1996, 1998 and 2002 that are known to have caused extensive coral mortality. The mission sought to confirm whether indeed regeneration of corals could be observed and, if so, to assess the potential for recovery of degraded reefs.

Methods employed during the mission were rapid assessment and ground-truthing with emphasis on covering as much ground as possible

The corals of Abu Dhabi and Eastern Qatar occur in three bio-geographic settings:

i. Coral reefs consist of a several-meter thick framework consisting of the in-situ (located where they naturally grow), interconnected framework built by corals. Framework reefs can be sub-divided into:

- Fringing reefs
- Stringer reefs and
- Patch reefs

ii. Coral carpets consist of laterally continuous frameworks of coral that do not reach the water surface. These are the most extensive coral ecosystems in the Arabian Gulf.

iii. Non-framework building coral communities are sparse coral assemblages consisting of only a few, widely-spaced corals that generally do not touch or interlock.

Abu Dhabi and eastern Qatar corals grow in one of the most stressful environments for corals anywhere in the world. For corals, temperature variation between winter and summer is extreme, varying up to over 20 degrees C. Thus, on a decadal scale, both upper and lower lethal temperatures are attained relatively frequently.

Several such anomalies have been recorded historically from the area. It is believed that the Arabian Gulf coral communities represent a dynamic system that shrinks and expands in response to mortality events triggered by temperature anomalies. During years of temperature extremes, either all corals or just certain species regularly experience significant mortality, or even mass mortality.

- Summer 1996: The temperature anomaly (locally 2.5 degrees above seasonal average for three months) led to Acropora-specific mortality. This coral species is relatively fast growing and aggressive.

- Summer 1998: The anomaly (also locally 2.5 degrees above seasonal average for four months) led to further mortality among all other species, killing all corals in some areas.

- Summer 2002: Temperature anomaly was milder. It lasted only one month but, nonetheless, stressed the system further and led to bleaching of surviving corals.

- 2002 - 2005: There were no significant temperature anomalies in the Abu Dhabi region. The situation, therefore, lent itself to an assessment of regeneration after the triple stress event.

Sequence of coral development, as derived from ecological time series data and spatial analyses obtained by the PI in the period 1995 to 2003, has been described and illustrated.
So far, no extinctions have been identified. However, overall coral biodiversity still remains depressed and coral coverage of available substratum remains at record low levels. The observed corals on all investigated islands bear clear evidence of a fertile

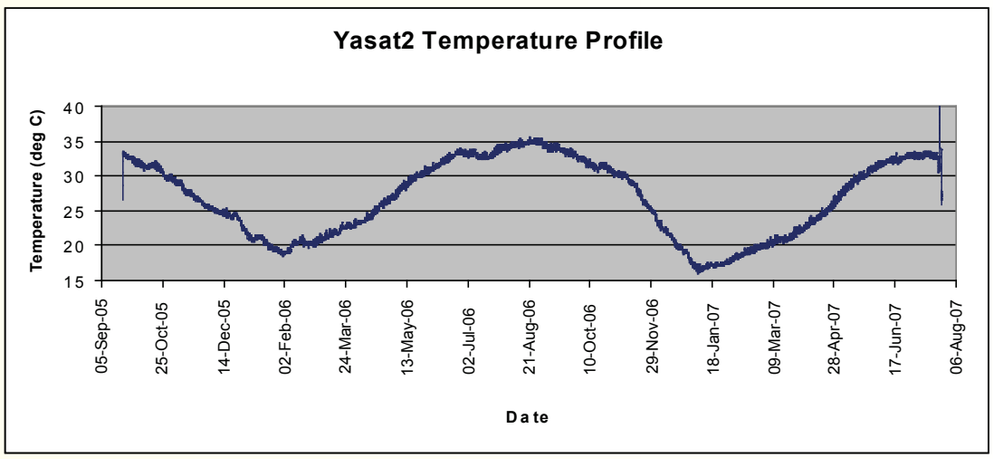
upstream seeding population and active spread of sexual propagules throughout the region. There is no evidence of asexual increase in coral populations yet, largely because the colonies are still too small (asexual propagation is a frequent occurrence in large-size Acropora). The active recruitment and reproduction indicates that remaining corals are in good health, otherwise reproductive failure would have been observed. Thus, there is hope for a full recovery of the coral systems.

The assessment clearly demonstrated that Abu Dhabi and Eastern Qatar coral reefs are not dead and still in need of protection.

3.2.2 Data collection from coral monitoring stations -

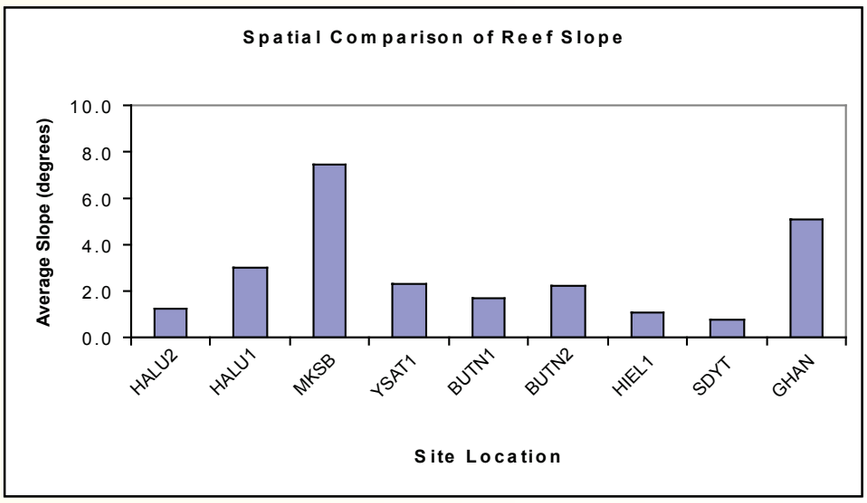
Temperature recorders were retrieved from Yasat1, Makaseb, Delma1 and Shra'aw. These provided temperature profiles from Sep, 2005 through Oct-Nov, 2006, which indicated a mean of 28.2°C, with a minimum of 16.2°C on January 31, 2006 and a maximum of 36.2°C on August 23, 2006. The annual profiles for all sites are very similar, an indication that the sea water temperature is spatially constant throughout the shallow (<6m) regions of the southeastern Arabian Gulf.

- A two-year temperature profile from Yasat for the timeframe of Sep, 2005 through Aug, 2007 showed seasonal variations between the winters of 2005-6 and 2006-7.

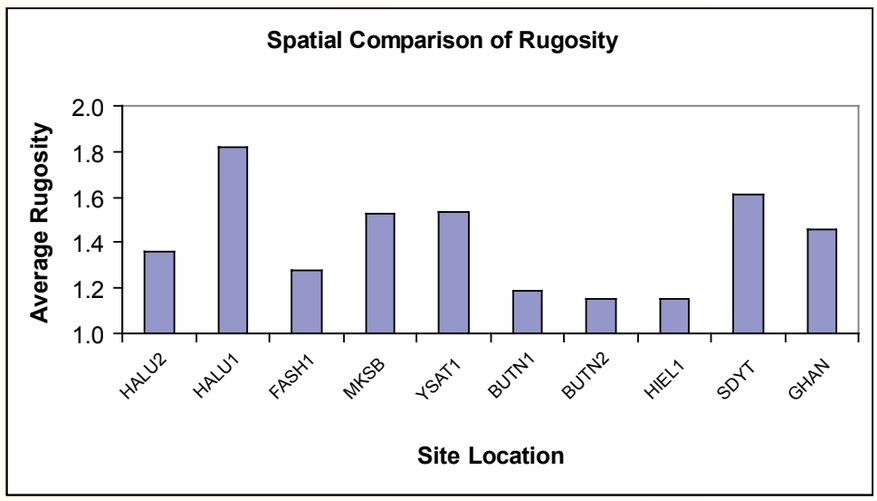


  - Winter cooling from 30°C to 20°C began at nearly the same time both years, but progressed at different rates. Winter cooling began on Nov 5, 2005 and Nov 9, 2006, continuing at rates of 0.13°C/day and 0.22°C/day, respectively. Water temperatures reached 20°C on Jan 18, 2006 and Dec 24, 2006.
  - The area experienced 22 consecutive days of water temperatures below 20°C in winter 2005-6 compared to 77 consecutive days in winter 2006-7.
  - Spring warming from 20°C to 30°C began on Feb 28, 2006 and on Mar 10, 2007 and continued at rates of 0.12°C/day and 0.15°C/day, respectively. Water temperatures reached 30°C on May 21, 2006 and May 16, 2007.

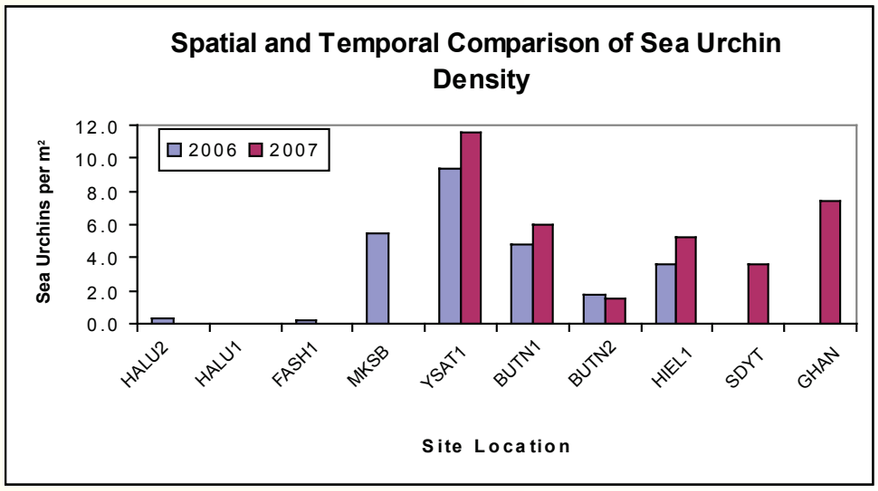
- Depth readings were used to calculate reef slope at the coral monitoring stations. The seafloor is nearly horizontal at most of the monitoring station locations, with a mean slope of 2.8°. Saadiyat has the lowest slope of 0.8°. Makaseb has the greatest slope of 7.5°.



- Contour distances along the transect rays were used to calculate rugosity. Rugosity values ranged from 1.2 - 1.8, indicating varying degrees of reef contour complexity between the sites.

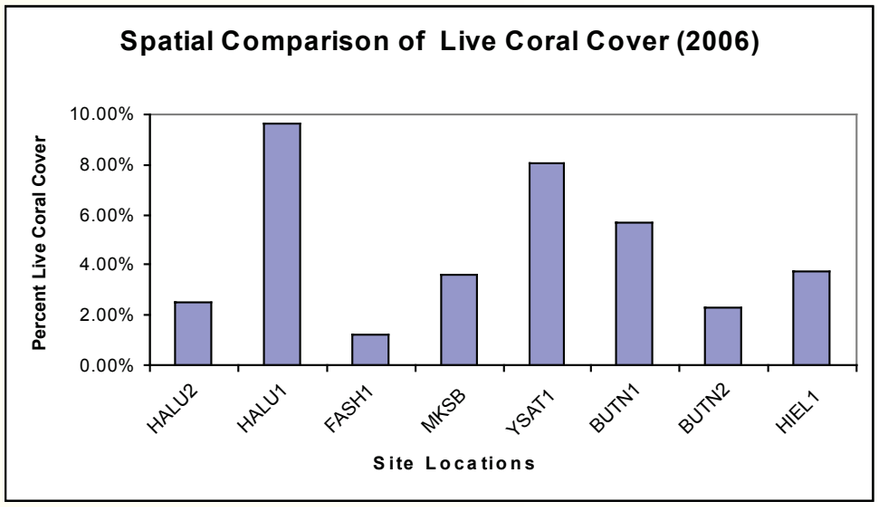


- Sea urchin densities along the transect rays ranged from 0.0-10.5 individuals per m^2 during 2006 and 2007. Crown-of-thorns starfish were not observed at any of the monitoring station sites.



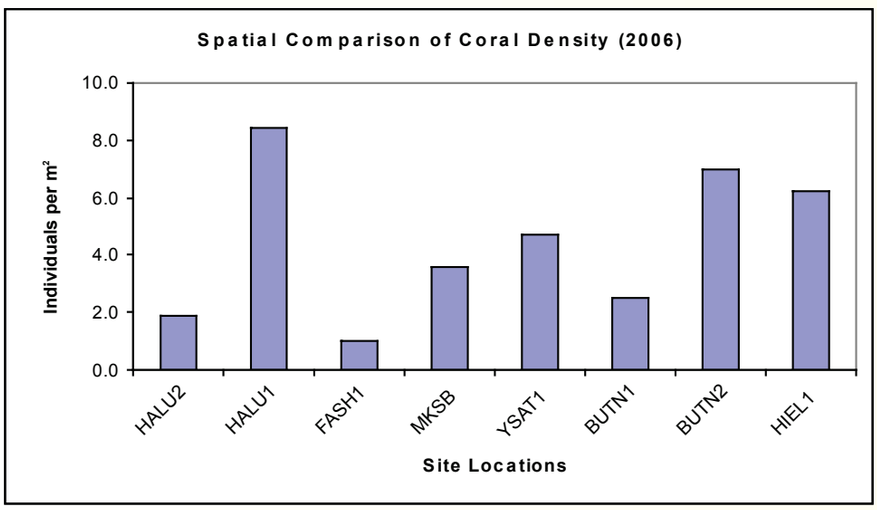
Digital images were taken along the transect rays. Spatial comparisons were made between monitoring station locations after coral identifications and CPC analyses were completed for the 2006 and 2007 images. Future spatial and temporal comparisons will be made by SCENR and EAD as additional data is collected from the monitoring stations.

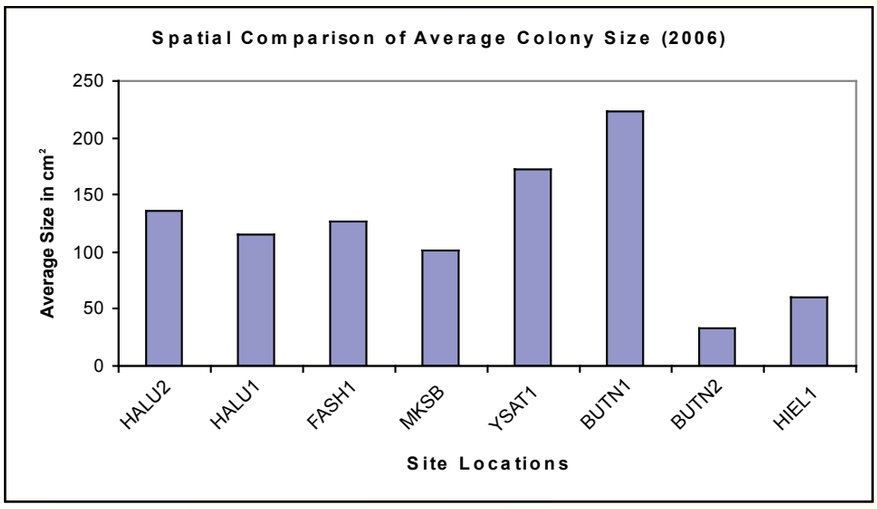
- Live coral cover ranged from 1.3% to 9.7% at Fasht Al-Ghabi and Halul1, respectively in 2006.
- Coral density ranged from 1.0 to 8.4 colonies per m^2 at Fasht Al-Ghabi and Halul1, respectively.
- Average colony size ranged from 33.5 to 223.2 cm^2 at Bu TInah2 and Bu Tinah1, respectively.



- Settlement plates were retrieved in 2006 from Yasat1 and Makaseb after one year underwater. No recruits were observed on the Yasat plates. Coral polyps (<4 mm diameter) had settled onto two of the Makaseb plates.
  Additional settlement plates were retrieved and evaluated in 2007 from both Yasat sites after two years underwater and from Al Hiel and both Bu Tinah sites after one year underwater.

- No signs of bleaching or disease were observed at the monitoring stations in 2006. A few Porites spp. colonies showed signs of Yellow Band Disease at the Ras Ghanada, Saadiyat and Yasat2 monitoring stations in 2007. However, the disease was not widespread. No signs of bleaching were observed at the other monitoring stations during 2007.





4. Coral Reef Management Plan

A report detailing the conservation management framework was prepared jointly by EAD, SCENR, EWS-WWF and NCRI. It presents a synthesis of the scientific studies carried out and highlights areas with prime coral communities with emphasis on those of particular interest. An executive summary of the management plan is included in Appendix 3.

Against a background on coral reefs situation worldwide and in the Arabian Gulf, the framework spells out the legislation and policy required to achieve conservation. A situational assessment of coral reefs in Abu Dhabi and eastern Qatar incorporates not only distribution, diversity and status of coral reefs, associated habitats and species, but also discusses their governance and lists users and stakeholders.

The final section on conservation and management recommends the establishment of protected areas for reefs outside existing protected areas and, at the same time, outlines management measures for reefs already in protected areas. Detailed monitoring scheme and plan are suggested, concluding with priority actions and timeframe.

A closed door workshop was convened in Fort Lauderdale, Florida at the NCRI campus on the 25 to the 30th of June, 2007. The attendees included:

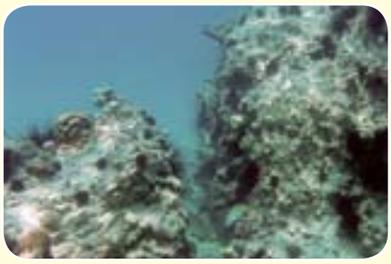
Mohamed Abdel Moati (SCENR)
Ahmad Al Mansoori (SCENR)
Ashraf Al Cibahy (EAD)
Suaad Al Harthi (EAD)
Kristi Foster (NCRI)
Sam Purkis (NCRI)
Wendy Wood (NCRI)
Bernard Reigl (NCRI)
Fred Launay (EWS-WWF)
Razan Al Mubarak (EWS-WWF)

The objective of the workshop was to deliberate on and commence the drafting of the conservation action plan to mange the corals of southeastern Arabian Gulf - one of the main objectives of the project. In addition to its direct relevancy to the project, the workshop was also an invaluable training opportunity for two project trainees, Ahmad Al Mansoori and Suaad Al Harthi, to participate and be exposed to the nature of management plan deliberation and delivery.

Attendees of this workshop also got a chance to engage with coral reef management practitioners in Florida. Meeting and talks were organized for the attendees with David Hilmer from the National Oceanic and Atmospheric Administration (NOAA) a US federal agency focused on the condition of the oceans and the atmosphere, as well as Matt Patterson from the National Park Services in the US which is a body charged with preserving the natural resources in the US. The result of the meetings was the sharing of best management practices and to determine some key lessons to be learnt.

The five day workshop was facilitated by NCRI and EWS-WWF- and resulted in the drafting of the framework for the conservation action plan.

Further work on the plan was provided by all the stakeholders in the ensuing months- with regular communication between the authors taking place. The final draft will be endorsed by the management of EAD and SCENR.



5. Capacity Building

Building the capacity of national marine scientists in conducting coral reef research was a critical component of the project. At every stage, local researchers received hands on training from NCRI experts in both classroom and field in coral reef survey, assessment, data analysis, monitoring, mapping and management planning.

Training of scientific personnel from SCENR, and EAD, continued. Training over the past three years was developed and held to increase level of understanding regarding:

- Scientific diving and operational efficiency and safety
- Biology of Arabian Gulf coral reefs and environmental stressors
- Field operations and data gathering
- Installation and sustaining of coral reef monitoring stations
- handling of remote-sensing data within available software
- Production of GIS and synoptic reports
- Differentiation of man-made and natural impacts

- **Capacity Building within SCENR and EAD**

Commencing in January 2005, the projects' principal investigators: Dr. Bernard Riegl and Dr. Sam Purkis engaged in classroom teaching focusing on the biology, geology and ecology of Arabian Gulf coral reefs, as well as an outline of remote sensing technology.

At the onset teaching relied on power-point presentations, of which a complete set of printouts was provided to all trainees and visitors for reference purposes. Also, a complete set of reprints from the work of Riegl and Purkis, and a list of scientific literature relevant to coral reef studies in the Arabian Gulf were compiled and referenced for the use of the trainees.
The first joint training trip was convened in Abu-Dhabi at the end of January 2005. Its mission: assessment of the trainees' capabilities in boat handling and diving, which were found to be very strong. It was also observed that trainees clearly favored the field component over the classroom component.

In order to maintain high levels of interest among trainees, training provided in April 2005 was almost entirely field-based and regarded the identification of live corals and species. Trainees obtained a hands-on "learning-by-doing" instruction in the use of remote-sensing and geopositioning equipment, as well as coral reef assessment.

In June, 2006, a two-week training mission was undertaken at the National Coral Reef Institute in Florida, USA. The specific goal was to expose selected SCENR and EAD researchers to USA management authorities and their missions, styles of work, institutional set-ups and coral reef monitoring programs. Participants were exposed to a range of activities covering:

- GIS training
- Training in the use of Landsat-based and Quickbird/ Ikonos based mapping products for the management of marine resources
- Hands-on demonstration of boat-based survey techniques

- Meetings with Broward County Resource Management Agency
- Meeting with US National Park Service in Biscayne Bay National Park
- Hands-on training in data management for monitoring

Two representatives from the National Coral Reef Institute, Florida were based in Abu Dhabi in Sept-Dec, 2006 to provide extensive hands-on training related to the installation of coral monitoring stations, identification of Arabian Gulf corals, and the analysis of underwater images and field data. Twelve SCENR and EAD staff participated in the field work during this period.

Installation of each monitoring station required detailed preparations, accurate navigation and advanced underwater techniques. Skills were practiced during simulated beach installations and utilized during the actual underwater installations of the coral monitoring stations. Procedures that have been included in the training manual for future reference by SCENR and EAD include:

- Design and procurement of station materials and equipment
- Photo framer assembly
- Boat navigation to site using GPS
- Installation of settlement plate racks and photo transect markers - beach simulation
- Installation of settlement plate racks and photo transect markers - underwater
- Photography settings and camera maintenance
- U/W photo transects
- U/W data collection (contour distance, depth, sea urchin counts)

- **Bi-national research efforts.**

The first bi-national research expedition was assembled in September 2005, involving staff from NCRI. SCENR and EAD. The objective of this cruise was to be a:

1) Training mission:

- To assure all trainees are comfortable with identifying corals at least to genus level, distinguishing live from dead corals, and estimating coral cover.
- To assure all trainees can comfortably identify likely coral habitat, name correctly the different types of reef framework and non-framework environments and relate these to general environmental setting.

2) Rapid-assessment mission:

- To assess coral cover and regeneration status in the visited sites.
- To evaluate good monitoring sites.
- To deploy settlement plates

3) Ground-truthing mission:

- To use information obtained from the rapid assessment for the ground-truthing of GIS and remote-sensing products.

A second bi-national research expedition was undertaken in 2006; in which participants included researchers from EAD and SCENR as well as NCRI. The research activities included extensive investigations that were conducted in the territorial waters of eastern Qatar.

The goals of the 2006 expedition included:

a) Removal of settlement plates installed during 2005
b) Retrieval and deployment of temperature loggers.
c) Installation of photo transects markers (Mercedes Star).
d) Installation new settlement plates.
e) Computer training which focused on the CPCe program to conduct area analysis of coral cover
f) Identification of diseases and bleaching.
g) Underwater data reporting.
h) Identification of Sea Urchins and Crown-of-Thorns along coral areah

A wet lab aboard the Mukhtabar Al Bihar research vessel in Qatar was converted into a computerized classroom for data analysis following each day's field work. SCENR and EAD personnel learnt to identify the most common Arabian Gulf corals. An interactive training program demonstrated colony and corallite morphologies as visual cues for coral identification. Using these skills, along with a decision matrix from the training manual and a pictorial identification chart, the trainees analyzed digital images using Coral Point Count (CPCe) software. This provided coral surface area cover information for each monitoring station. The trainees also learned to analyze the data collected at each site.

- Downloading Temperature Loggers and Data Processing
- Spatial Comparisons of Slope, Rugosity, Sea Urchin Abundance
- Protocols for Monitoring Station Logs
- Image Coding Protocols
- Image Color Correction
- Coral Area Analysis using Point Count and Excel
- Image Mosaics using PowerPoint
- Coral ID Training Exercise

In 2007, the project's final year, entailed an evaluation of the training and capacity building process by EWS-WWF with NCRI trainers. Training was assessed, documented, and lessons learnt reported to implementation agencies and all stakeholders. Raising the profile of trainees among project stakeholders and also within their respective organizations was taken up.

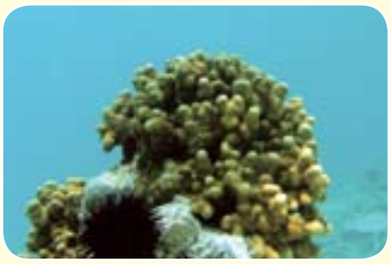
- **Training Manual**

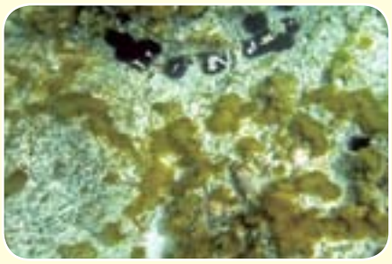
The training manual has been completed and can now be adapted as a separate publication for both internal training and public consumption. The final training manual has incorporated feedback received from SCENR and EAD, and now consists of four chapters associated with coral reef monitoring in the Arabian Gulf. Chapter 1 provides an overview of the existing scientific findings related to the biology of corals in the region. Chapter 2 contains procedures and specifications for the design, installation and use of permanent field monitoring stations. Chapter 3 includes methods to analyze the images and data collected from field monitoring stations. Chapter 4 provides hard coral identification keys that can be utilized in the field and for subsequent image analysis. Each chapter contains several stand-alone sections, allowing the program participants to choose which topics to read.

- **Further training on Coral Reef Identification**

  Various tools have been created to assist SCENR and EAD trainees with the identification of corals of the Southern Arabian Gulf. These include:

  - A pictorial coral identification chart
  - Coral ID Training Tool (PowerPoint presentation) which consisted of an interactive exercise to learn the terminologies of the main 5 colony shapes, 6 corallite shapes and 5 features of branching corals as well as a 'how to identify Arabian Gulf corals' to the genus level





6. Schedule & Cost

The project was completed on schedule and in accordance with the agreed execution plan with completion during the last quarter of 2007.

Total Expenditure for period ending: 31 December 2007	
	[currency is in UAE Dirhams and US Dollars]
Third party fees including cost of contract with NCRI	
	TOTAL: AED 986,841 (USD 268,528/-)
Travel, Meetings & training costs	
	TOTAL: AED 114,268/- (USD 31093/-)
Communications & Fundraising Cost including the cost of the Documentary	
	TOTAL: AED 334,842/- (USD 91,113/-)
Field Running Cost	
	TOTAL: AED 238,487/- (USD 64,523/-)
Capital asset cost	
	TOTAL: AED 113,826/- (USD 30,930/-)
WWF Int'l fees	
	TOTAL: AED 42,207/- (USD 11,203/-)
EWS-WWF Management fees	
	TOTAL: AED 57,369/- (USD 15,610/-)
TOTAL EXPENDITURE:	**DHS. AED 1,887,840/- (USD 513000/-)**
SPONSORSHIP FEEs RECEIVED:	**DHS. AED 1,887,840/- (USD 513000/-)**

6.1 Time planning:

The project time-planning adopted for the project are specified below and highlight NCRI expert inputs.
PI = principal investigator, TA = technical advisor

August and November 2004: Steering Committee - Kick-off meeting

October to December 2004:

- Staff at EAD and SCENR collect and collate all available data on coral reef research and conservation available in the agency.
- Staff at NCRI collect and collate all available data regarding coral reefs in the project area. This will entail a detailed literature search. Commence production of teaching materials.
- Commence mapping work at NCRI (work to commence with Landsat TM imagery acquired from EAD on 16 August 2004)
- Production of preliminary mapping product at NCRI in order to evaluate quality and suitability of existing imagery

January 2005:

- PI in EWS-WWF office. Training (Reef biology, Survey methods), presentation of first stages of preliminary mapping product.

April 2005:

- PI and TA in EWS-WWF office. Field trip to assess the status of coral reefs in wider Abu Dhabi region (assessment of Qatari reefs done by Dr. Riegl previously in August 2004).

July 2005:

- TA work at NCRI to complete product (GIS, remote sensing, spatial analysis).

September 2005:

- PI and TA in EWS-WWF office. Autumn field trip, re-visiting sites from April field-trip plus adding new sites. Training (GIS, remote sensing)

December 2005/January 2006:

- TA and PI work at NCRI to produce training materials and complete product for mapping and assessment, as well as reports.

April/May 2006:

- PI arrives 2 weeks ahead of TA, prepares for spring field trip. Both PI and TA partake in field trip to the project area. After field trip, PI leaves. TA remains on-site and archives information from field trip.

September/October 2006:

- PI arrives 2 weeks ahead of TA, prepares for autumn field trip. Both PI and TA partake in field trip to the project area. After field trip, PI leaves. TA remains on-site and archives information from field trip.

January 2007/February 2007:

- PI and TA work at NCRI to complete reports, training materials, mapping and GIS products.

May/June 2007:

- PI arrives 2 weeks ahead of Purkis, prepares for spring field trip. Both PI and TA partake in field trip to the project area. After field trip, PI leaves. TA remains on-site and archives information from field trip.-
- Coral Reef Conservation Management Plan Drafted

August -December 2007:

- Debriefing meetings. PI and TA handover of all products to EAD and SCENR
- Final Steering Committee convened in Abu-Dhabi

7. Interface Coordination

The project represents an outstanding example of successful trans-boundary collaboration for conservation. The coordination between two government agencies from different nations, a corporate sponsor, local and international nongovernmental organizations and a globally recognised scientific institute presented both a challenge and unique partnering opportunity. The scope and diversity of partners involved further reinforced the challenge facing effective project implementation.

In the end, what emerged was a collaborative effort like no other in the region; the result of a partnership with a singular, shared mission - to conserve coral reefs.

Thorough pre-implementation negotiations led to a realistic, shared execution plan - prepared and approved by all parties. This permitted smooth progress in organization and assignment of project responsibilities and, subsequently, project implementation itself. Over time, project staff members, identified from participant organizations, established a strong and open work ethic.

A steering committee composed of representatives from all partners met every quarter (there were seven meetings in all) to facilitate project management. Apart from meetings, monthly progress reports and bi-annual project reports were circulated to all parties concerned.

Monthly Progress Reports have been regularly issued by EWS-WWF and the final Steering Committee Meeting was held at the Dolphin Headquarters in Abu-Dhabi on 4th of December 2007. The meeting provided an opportunity for a high level review of the project progress as well as a presentation on project deliverables and the opportunity to obtain feedback from all of the partners.

7.1 Project Team members and their attributes

Project Sponsor

Dolphin Energy

- Financial Support
- Business Management
- Interface Coordination
- Facilitate Knowledge Transfer

Technical Experts

NCRI

- Expert Training
- Scientific Knowledge
- Technical & Software Support

Project Manager

EWS-WWF

- Project Management
- Scientific Forum
- International Prestige & Credibility
- Local Prominence

Implementation Agencies

EAD

- Local Knowledge
- Regulatory Expertise
- In - country Resources
- Logistical Support
- Graduate Trainees
- Ultimate Custodian of CCS for Abu Dhabi

SCENR

- Local Knowledge
- Regulatory Expertise
- In- country Resources
- Logistical Support
- Graduate Trainees
- Ultimate Custodian of CCS for Qatar

7.2 Communications

- **Biannual Reports**

The Biannual Reports produced have captured the interest of a wider audience. As a result, the circulation of the reports has increased; and production numbers increased from 70 to 250 copies. Moreover, there have been requests to translate the report into Arabic. It was agreed that this will be done for the final report which would include a compilation of all the reports produced.

- **Production of an Environmental Documentary on Corals of the Arabian Gulf**

There was further progress on the documentary on corals being produced by Ocean World Productions for the project. Following filming during the September 2005 expedition in Qatar, field trip-cum-training sessions in Abu Dhabi (May-June, 2006) as well as the press conference in Abu Dhabi to announce the large-scale coral reef map (June 2006). Additional footage was shot during the field work at Bu Tinah, Dalma and Ras Ghanada. Interviews were shot during November 2007 with key project stakeholders, and the script was approved. The final film edition is expected to be complete by March 2008.

- **Production of presentations and dissemination of results in the scientific community**

A scientific paper was prepared and abstract accepted for presentation at the meeting of the International Society for Reef Studies in Bremen in September 2006. Members of the EWS - WWF project team; EAD and SCENR co authored the presentation. The full paper will be submitted for publication in the conference proceedings or an independent journal.

- **Project Outreach to Abu Dhabi Women's College (ADWC)**

Serving as a platform for dialogue, debate and ultimately creative campaigns the project served as a case study for university students in Abu Dhabi for coral reef protection in the Arabian Gulf. The Higher College of Technology (HCT) women's college in Abu-Dhabi as part of 'Project Eco-challenge,' students were exposed to the complexities of coral reef conservation in the context of the rapid coastal development in the UAE through discussions, field trips and a workshop held on March 22nd, 2006 at the Abu Dhabi Women College (ADWC). The aim was for students to develop environmental campaign strategies as part of their course work. The move marks the beginning of 'Project Eco-challenge,' a joint EWS-WWF and HCT (Higher Colleges of Technology) initiative that promotes community participation through educational institutes. The project also provides work experience opportunities to national students.

- **Dolphin Corporate Video**

Dolphin Energy's Corporate Communications has commissioned and completed a corporate video that focused on this particular project. The video was presented in various conferences and exhibitions; and was an excellent tool to communicate about the results and partnerships forged through this project.

- **Dolphinsight magazine**

Over the past three years, several articles have been published in Dolphininsight magazine, raising the awareness of Dolphin Energy ltd, employees and stakeholders specifically on the roles of the corporate sector in community and environmental work as well as the findings of the project.

- **Dar Al Khair**

Dar Al khair, EWS-WWF quarterly newsletter has featured the findings and project highlights over its duration. The distribution of the newsletter is wide reaching- with recipients being from embassies, business groups, environmental agencies across the UAE as well as universities and research institutions.

- **www.panda.org and www.panda.org/uae**

The project was also featured on both WWF's international and national websites as a project working towards WWF's global priority- marine conservation under the coral reef conservation cluster.

- **Google earth**

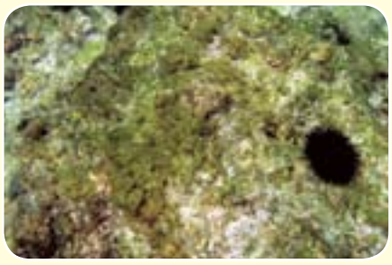
An interesting project application was its featuring on Google earth. WWF has partnered with Google Earth whereby users of Google Earth will be able to learn about the geographical location of selected WWF projects - of which the Coral Reef investigations in Abu-Dhabi and Eastern Qatar is one. Read a description of each and be directed to WWF's global website, www.panda.org, for more information.

- **AME-info**

Additionally, what has given the project a readership boost is it features on the Arabian Environment page on the extensively read AME-info website www.ameinfo.com with over 17 million page views a month (June 2006).

- **Other media**

The project was picked up by journalists in both Qatar and the UAE; with much interest and was covered extensively, Dolphin Energy ltd, has monitored the local media and produced press monitoring portfolios to all the stakeholders.
Moreover, there were three well attended press conferences organized. The first in Abu Dhabi on to launch the project, the second in Doha releasing the findings of the first bi-national expedition and the third on June 4, 2006 to announce the release of the first regional coral reef map of the southeastern Arabian Gulf.



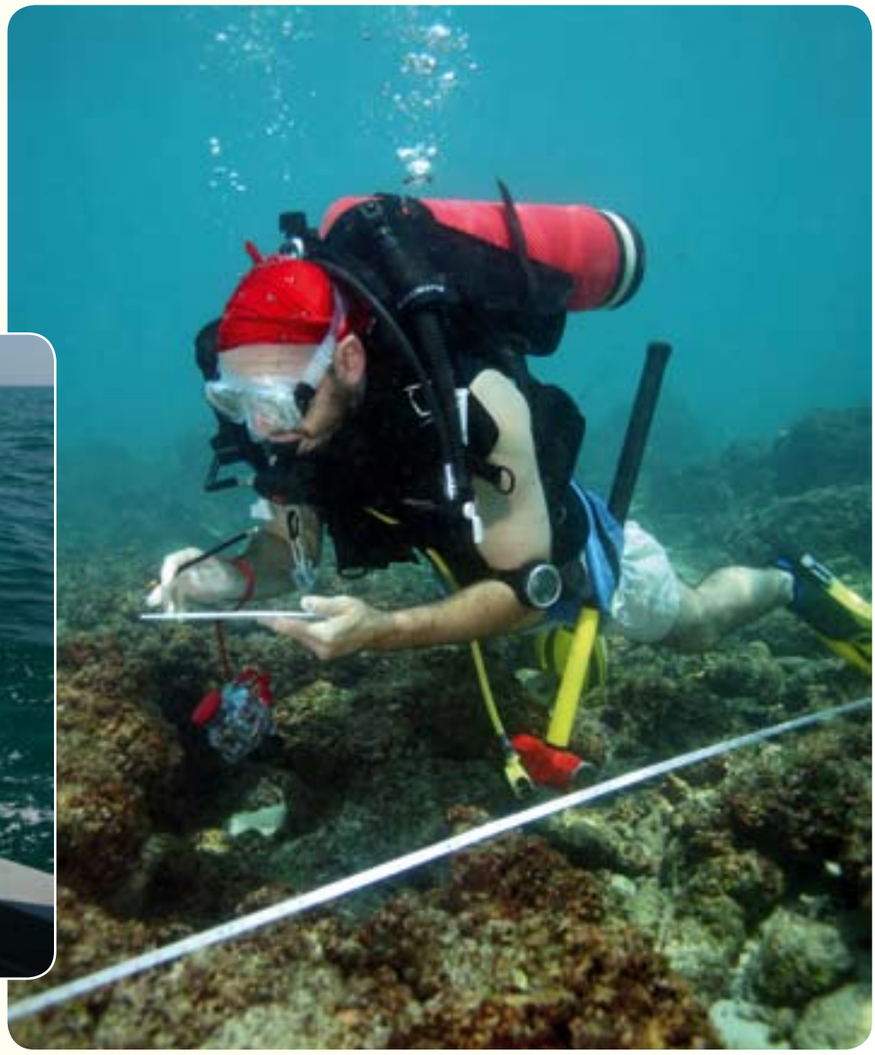
8. HSE Issues

Health, safety and environment issues were of paramount importance to Dolphin Energy and all participating agencies during this project. All project personnel involved in underwater coral habitat investigations possessed minimum diving certificates and an Emergency Response Plan was put in place for all marine activities. It was also made mandatory that project equipment used (boats, diving apparatus and other) met with international safety requirements and complied with all local regulations.

The main purpose of the Emergency Response Plan (ERP)was to detail precise actions to be carried out by the diving staff in the event of an actual emergency, and to provide the necessary level of pre-planning and rescue allocation in preparation of an emergency to include training, exercises, facilities and etc.

The plan covered emergency response by Dolphin, EAD, SCENR and EWS-WWF, responsibilities, on board communications and emergency contacts, safety system and emergency equipment interfaces, evacuation, escape and rescue and emergency response scenarios.

Dolphin has established two emergency management teams, one located in Doha and the other in Abu Dhabi. In the event of an emergency during the project, Emergency Management Teams could be mobilized by calling the respective duty emergency coordinator or Dolphin reception.



9. Lessons Learnt

The following paragraphs highlight some of the lessons learnt and areas that require further attention for future projects.

Why Dolphin Energy, EWS-WWF, NCRI, EAD and SCENR were logical partners:

- The building of a partnership between NCRI, EWS-WWF, EAD and SCENR strengthens all four agencies' position as leading institutions within in their geographic areas as well as globally for coral reef conservation, assessment, monitoring and restoration.
- Dolphin Energy strives to be an environmentally and socially responsible operator within the energy sector and ranks QHSE equally with other business objectives..
- The project's goals fall within NCRI's institutional mission: assessment, monitoring and restoration of coral reefs.
- NCRI, is a leading laboratory for high-latitude reefs science and has long-standing scientific experience in the Arabian Gulf area.
- Significant pre-existing information was injected into the project via the NCRI Monitoring Network and the project findings provided valuable feedback to the worldwide network and the scientific community in general.
- EAD and SCENR are the two leading environment agencies responsible for environmental custodianship and policy enforcement in Abu Dhabi and Qatar and have brought a lot of local knowledge and expertise to the project..
- EAD and SCENR are emerging centers of research and beneficiaries of institutional capacity building and professional development of UAE and Qatari nationals.

This partnership and the willingness from the start to do the project in partnership have certainly proven invaluable. The science, training, capacity-building components as well as methodologies have been shared amongst all the project participants.

Through the project, a cooperative, collaborative "mood", as well as acknowledgement that many things are valuable when shared amongst all the projects participants and have led, directly and indirectly to bi-lateral initiatives outside the scope of project.

The junior staff from SCENR and EAD that have participated in the project have developed a higher interest in the project and in the outcomes because they could see its relevance beyond their own organizations. They could also easily recognize that colleagues in other countries have similar challenges to face.

The science and methodology implemented through this project has been very robust and will produce long-lasting results.

The ownership of the project, its outcomes and consequences, have been rooted in the respective organizations being the implementation agencies, such as EAD and SCENR, but also in the scientific partner, NCRI and the sponsor Dolphin Energy.

The overall goals of the project were to:

- Provide specific and tailor-made monitoring and assessment approaches to the unique environment of Abu Dhabi and Qatar and institutional set-up within EAD and SCENR.
- Use the latest technology and scientific thought as reasonable and appropriate to ensure relevance and sustainability of coral reef management within EAD and SCENR.
- Ensure compatibility and interaction with other international monitoring and assessment initiatives.
- Provide evidence of the relevance and importance of coral reef conservation to the UAE and Qatar public and other stakeholders.
- Build capacity within EAD and SCENR to maintain in-house significant and independent coral reef assessment and monitoring capabilities beyond the three years of the project.

All these goals have been achieved within the established, agreed timeframe and within budget.

An active participation of all the project partners is a key to the success as is the clear understanding and acceptation of each partner of the role and responsibilities of everyone within the project.

The pro-active participation from the sponsor in all aspects of the project was also very valuable as it demonstrated a level of genuine interest, not only for the communication - marketing benefits but for the scientific and conservation outcomes of the project. This is extremely rewarding and encouraging when dealing with conservation and scientific organizations that are always

somewhat suspicious of the real drivers that motivate sponsorships from corporations, and in the context of an organization like EWS- WWF, to demonstrate to their members and supporters,that they are partnering for the right reasons.

The project also demonstrated that collaboration and coordination is not something that comes easily and naturally. Collaboration and coordination requires active efforts and skills, that are built on mutual respect and a shared vision.

Areas for improvement

The estimation on a three years budget, for a project involving several partners and significant coordination, needs to consider an allowance for “unforeseen expenses” or contingencies. Fortunately for this project, Dolphin management had flexibility to cater for justified unforeseen expenses

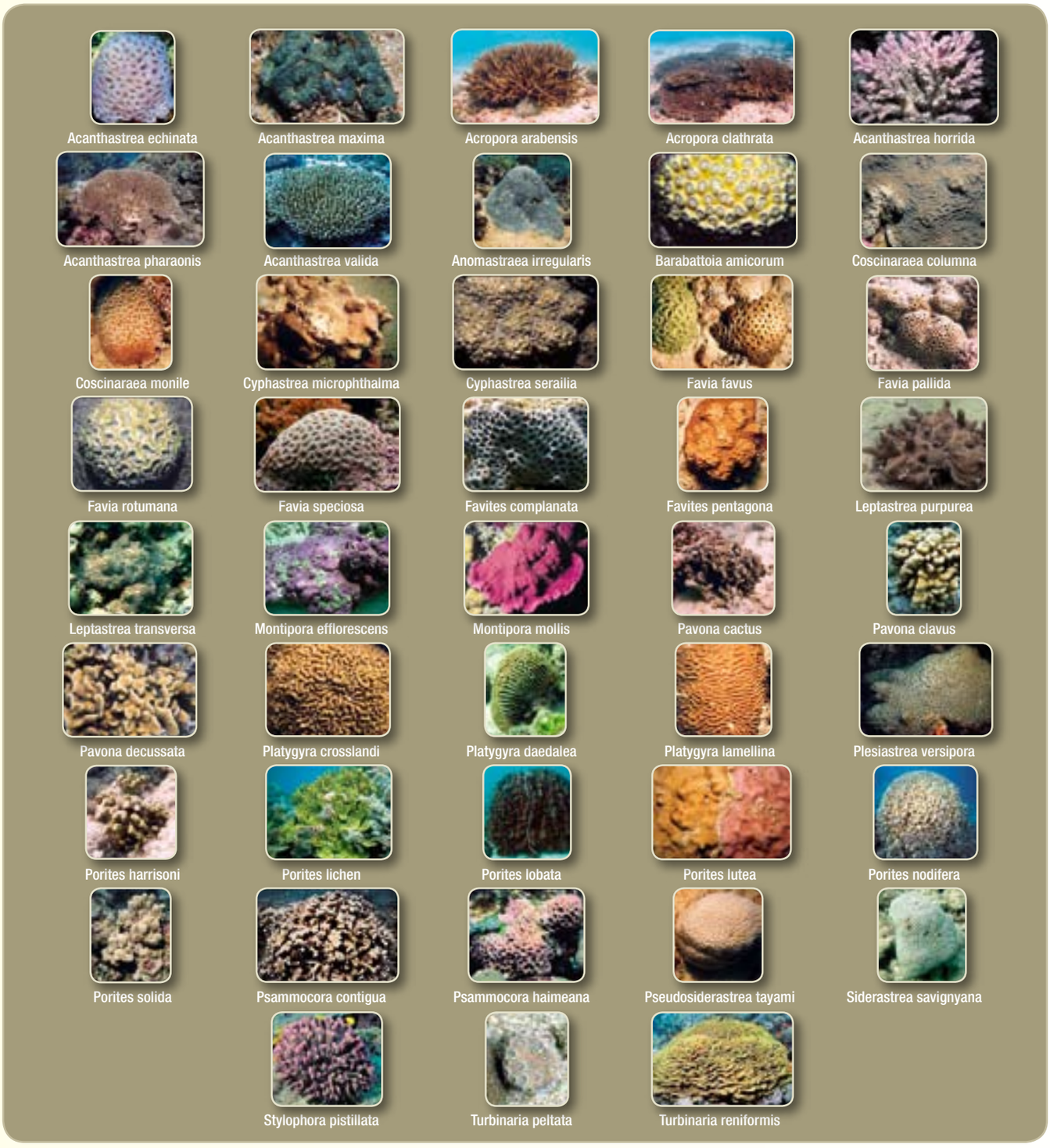
The reporting requirements and schedules should be clearly established and understood by all parties at the onset of the projects through an agreed execution plan, signed and agreed by all partners.

Mechanisms to resolve dispute or timing, scheduling issues should be included.

The integration of the scientific requirements of the projects and the external communication requirements should be conducted early during project planning and form an integral part of the project proposal and execution plan.

Appendices

APPENDIX 1.Coral species in the southeastern Arabian Gulf



APPENDIX 2: A narrative of site visits 2005-2007

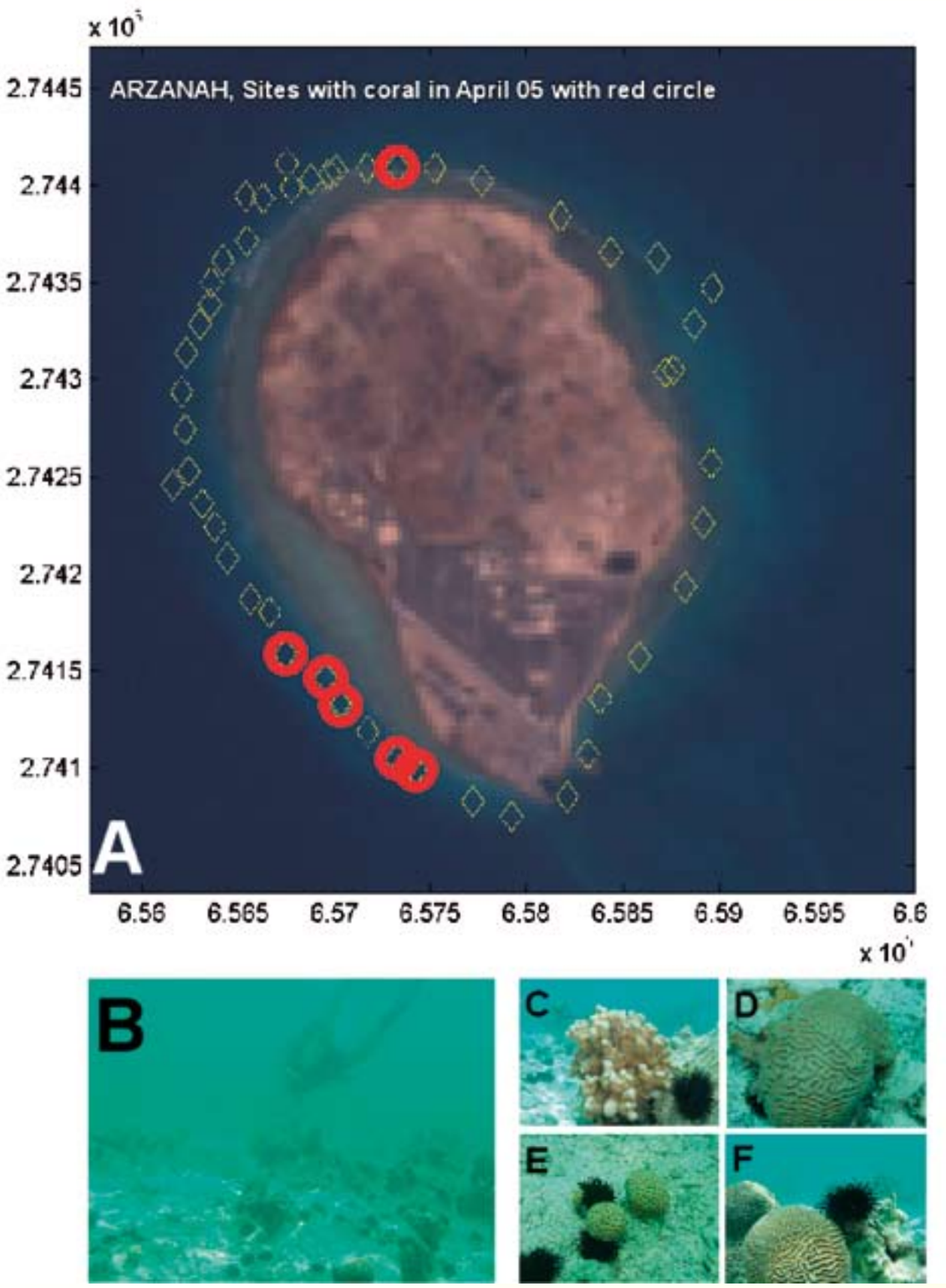
2005 Visits:

ARZANAH ISLAND

Arzanah is a high island with development concentrated on its southern part. Around the islands western part, a small fringing reef is developed.
A total of 51 sites were evaluated, of which 11 showed coral growth. The densest coral growth was found on the western side of the islands. The coral community was clearly in the very early phases or regeneration from serious mortality during the previous thermal stress events. Coral cover was between 1 and a maximum of 5%.
Coral species encountered were:

- *Platygyra daedalea*
- *Platygyra lamellina*
- *Favia pallida*
- *Porites harrisoni*
- *Porites lutea*
- *Cyphastrea microphthalma*
- *Psammocora. sp.*
- *Acropora clathrata (diameter about 40 cm)*

Corals were all of good health and no diseases were observed. The relatively uniform size distribution of corals suggests that all originated from sexually produced gametes of an upstream source.
A possible monitoring site was evaluated at position N 24º46.76104, E 052º33.25565.



Arzanah Coral Sites

(A) Arzanah Island and the evaluation sites. Sites with corals are indicated by red circles. (B) Aspect of the regenerating coral community (C) *Porites harrisoni*. (D) *Platygyra lamellina* (E) *Two colonies of Favia pallida* (F) *Platygyra lamellina*.

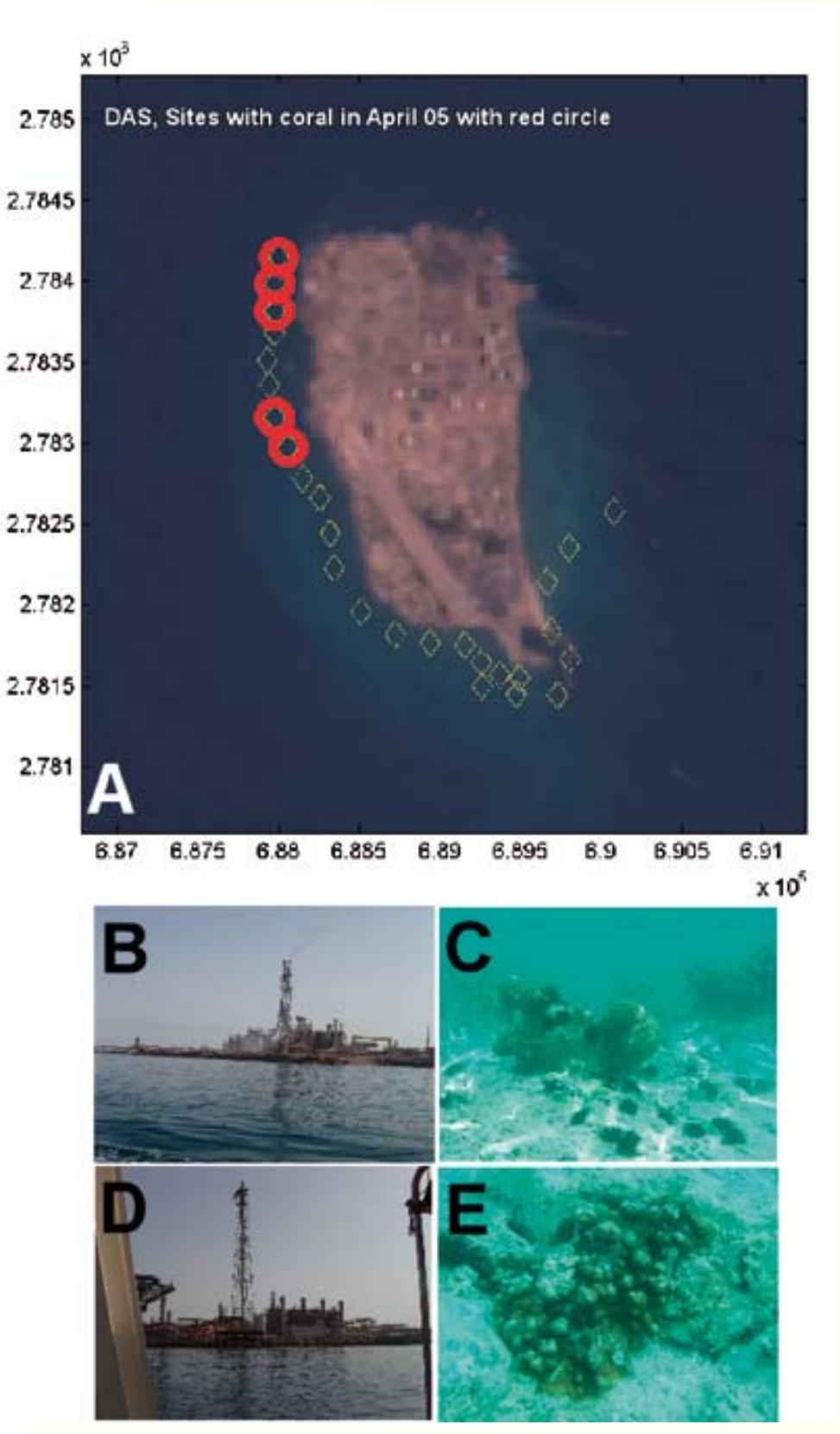
Das Island

Das Island is a high island with heavy development all over and little natural shoreline left. The eastern part of Das is dredged and provides no habitat for corals at all. Surprisingly much of the western area of Das had coral regrowth, despite being immediately adjacent to the industrial installation. There is no reefal structure developed around Das Island, all corals occur in a non-frame building fashion. Due to the significant alteration of the shoreline with extensive dredging and filling, it can no longer be assessed whether Das ever had any framework reefs or not.

A total of 27 sites were evaluated, of which 5 showed coral growths (Figure 6). The coral community was clearly in the very early phases or regeneration and was generally less dense than on other islands. Coral cover was around 1%.
Coral species encountered were:

- *Platygyra lamellina*
- *Favia pallida*
- *Porites harrisoni*

The few observed corals appeared to be of good health and no diseases were observed. The relatively uniform size distribution of corals suggests that all originated from sexually produced gametes of an upstream source. No dives were undertaken since special permission would have needed to be obtained.



Das Coral Sites
A) Das Island and the evaluation sites. Sites with corals are indicated by red circles. (B,D) Aspect of the severely altered shorelinere (C) *Platygyra lamellina* (E) *Porites harrisoni.*

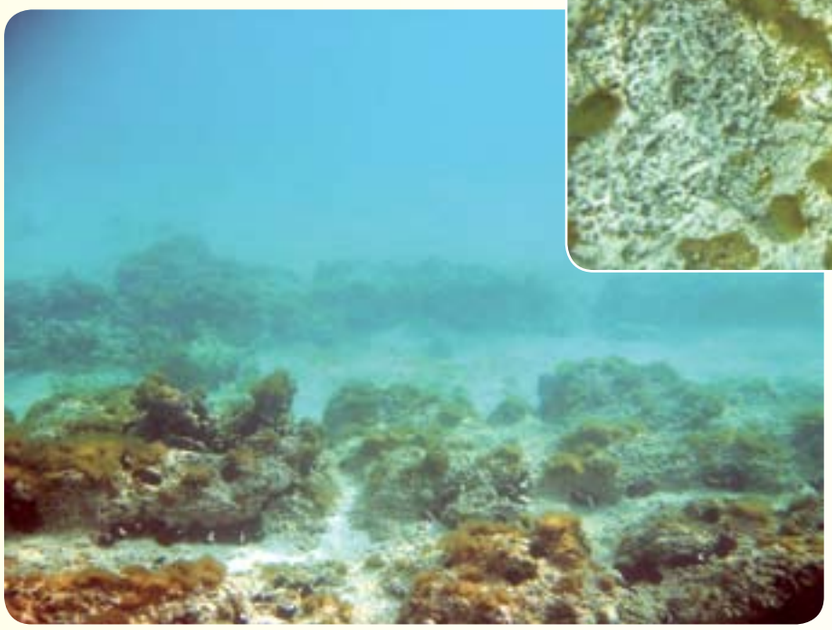
DINAH ISLAND

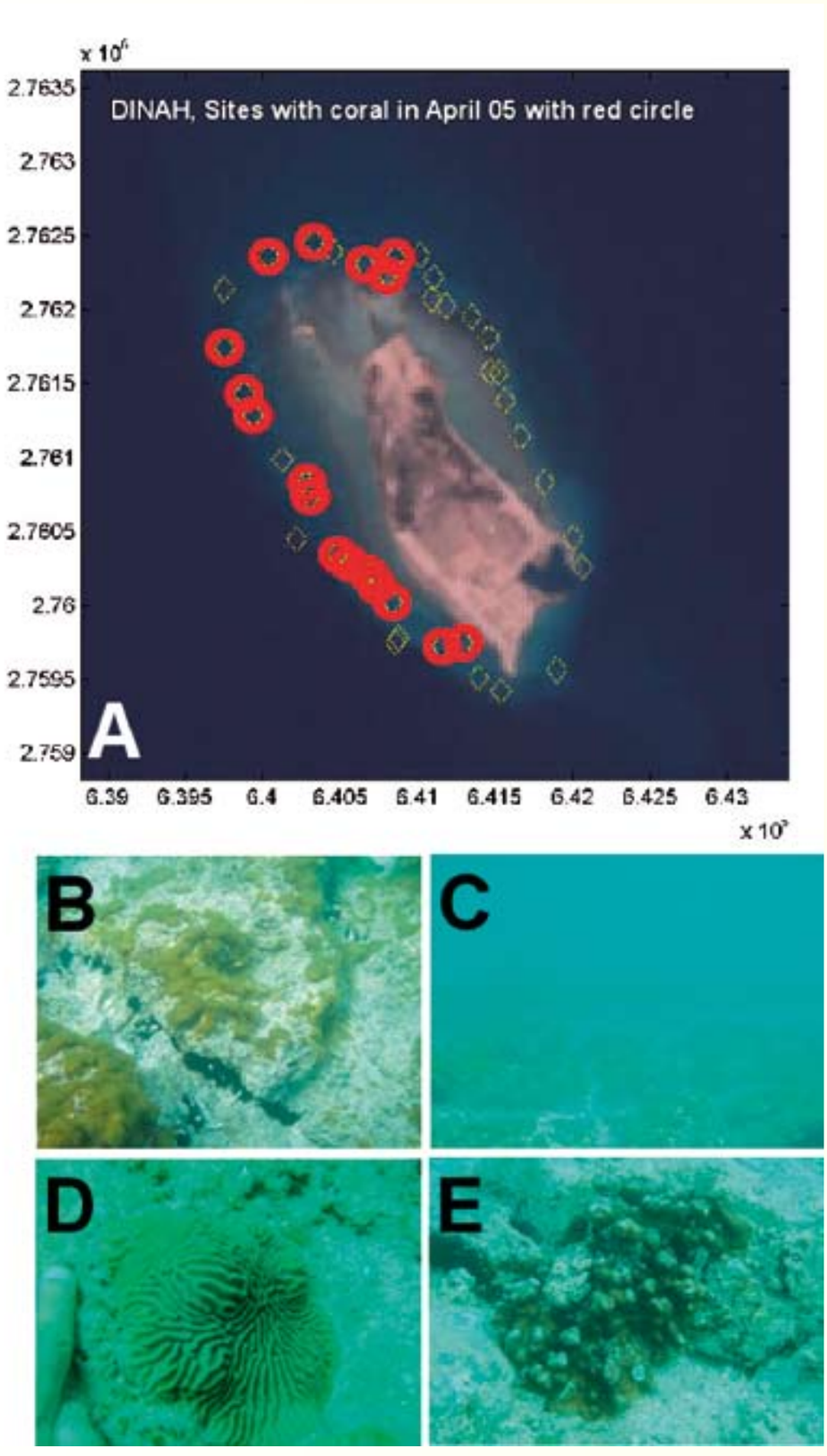
Dinah Island is a low island with relatively little development which is concentrated in the southern part and consists of military installations and a port. The northern section of the island is surrounded by a structure reminiscent of a fringing reef and it is possible that this is indeed made up of coral framework; however verification by drilling would be required. The structure was covered by dense, but patchy brown and green algae but exhibited very little coral growth. Most corals were found on the deeper hard grounds seaward of the fringing structure.

A total of 31 sites were evaluated, of which 17 showed coral growths (Figure 7). The coral community was clearly in the very early phases or regeneration and was generally less dense than on other islands. Coral cover was around 1%. Although Dinah showed the laterally widest distribution of corals around its shoreline (essentially all of the northern section of the island had more or less coral growth), it did not have the densest coral growth of all sites (which was on Arzanah).
Coral species encountered were:

- *Platygyra lamellina*
- *Favia pallida*
- *Porites harrisoni*
- *Porites lutea*

The observed corals appeared to be of good health and no diseases were observed. The relatively uniform size distribution of corals suggests that all originated from sexually produced gametes of an upstream source. No dives were undertaken..





Dinah Coral Sites
(A) Dinah Island and the evaluation sites. Sites with corals are indicated by red circles. (B,C) Aspects of the algae-covered fringing structure (D) *Platygyra lamellina* (E) *Porites harrisoni*

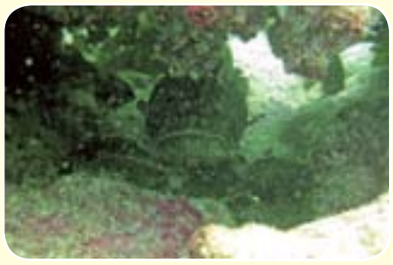
JARNEIN ISLAND

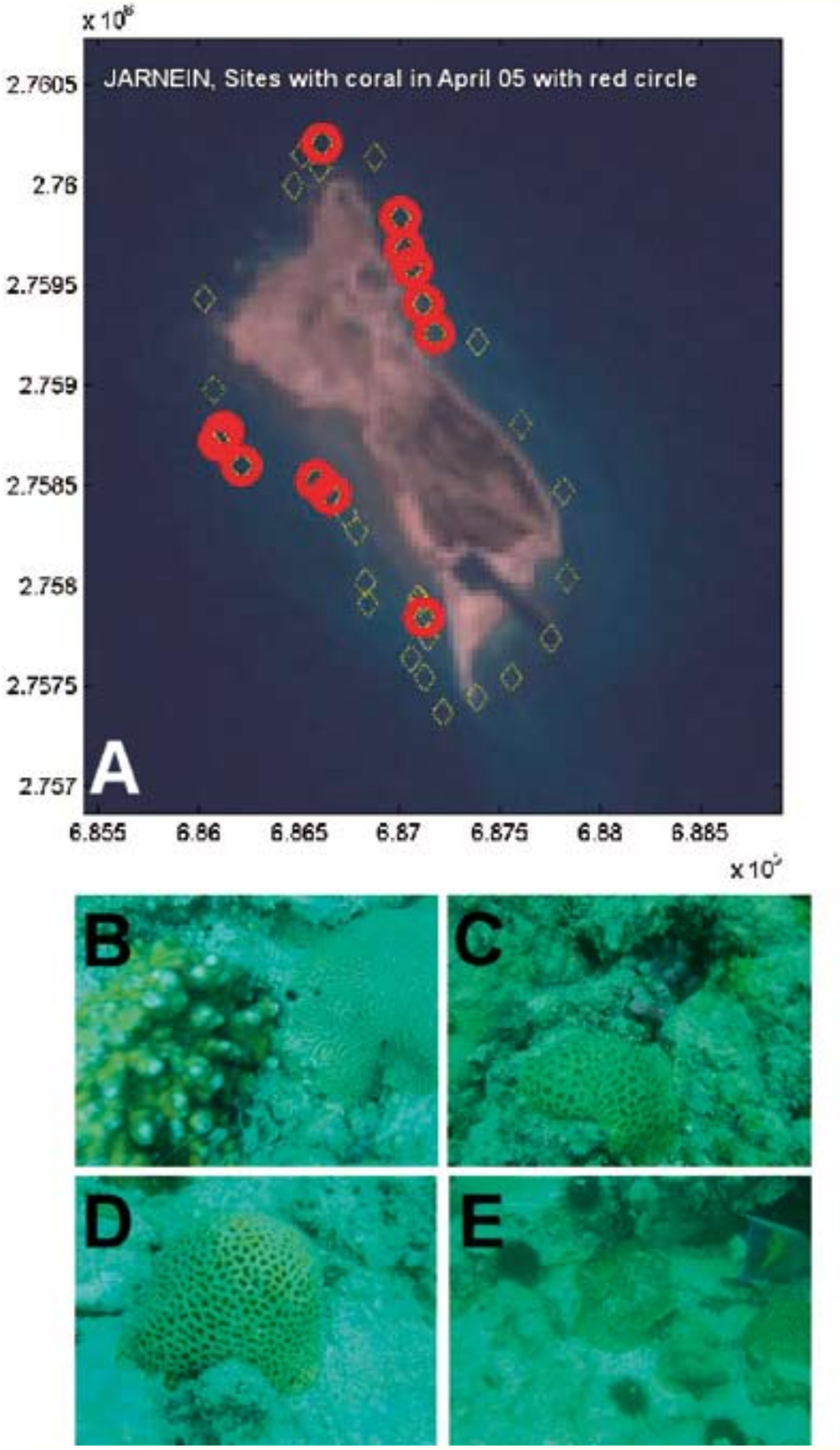
Jarnein Island is a relatively low island with little development which is concentrated in the southern part. The south-eastern section has a structure reminiscent of a fringing reef and it possible that this is indeed made up of coral framework; however verification by drilling would be required. The structure was covered by dense, but patchy brown and green algae but exhibited very little coral growth. Most corals were found on the deeper hard grounds seaward of the fringing structure. The northern shoreline of Jarnein is steeper than in the south, which has a sandy spit. The submarine topography in the north is also steeper than in the south, with sub tidal block-fields but no clear coral frameworks. However, corals are present in most areas.

A total of 31 sites were evaluated, of which 17 showed coral growths (Figure 8). The coral community was clearly in the very early phases or regeneration and was generally less dense than on other islands. Coral cover was between 1 and 5%. Coral species encountered were:

- *Platygyra lamellina*
- *Favia pallida*
- *Cyphastrea microphthalma*
- *Turbinaria reniformis*
- *Pseudosiderastrea tayamai*
- *Plesiastrea versipora*
- *Porites harrisoni*
- *Porites lutea*

The observed corals appeared to be of good health and no diseases were observed. The relatively uniform size distribution of corals suggests that all originated from sexually produced gametes of an upstream source. A dive on a possible monitoring site was undertaken at position N 24º55.98845 E 052º50.61113.





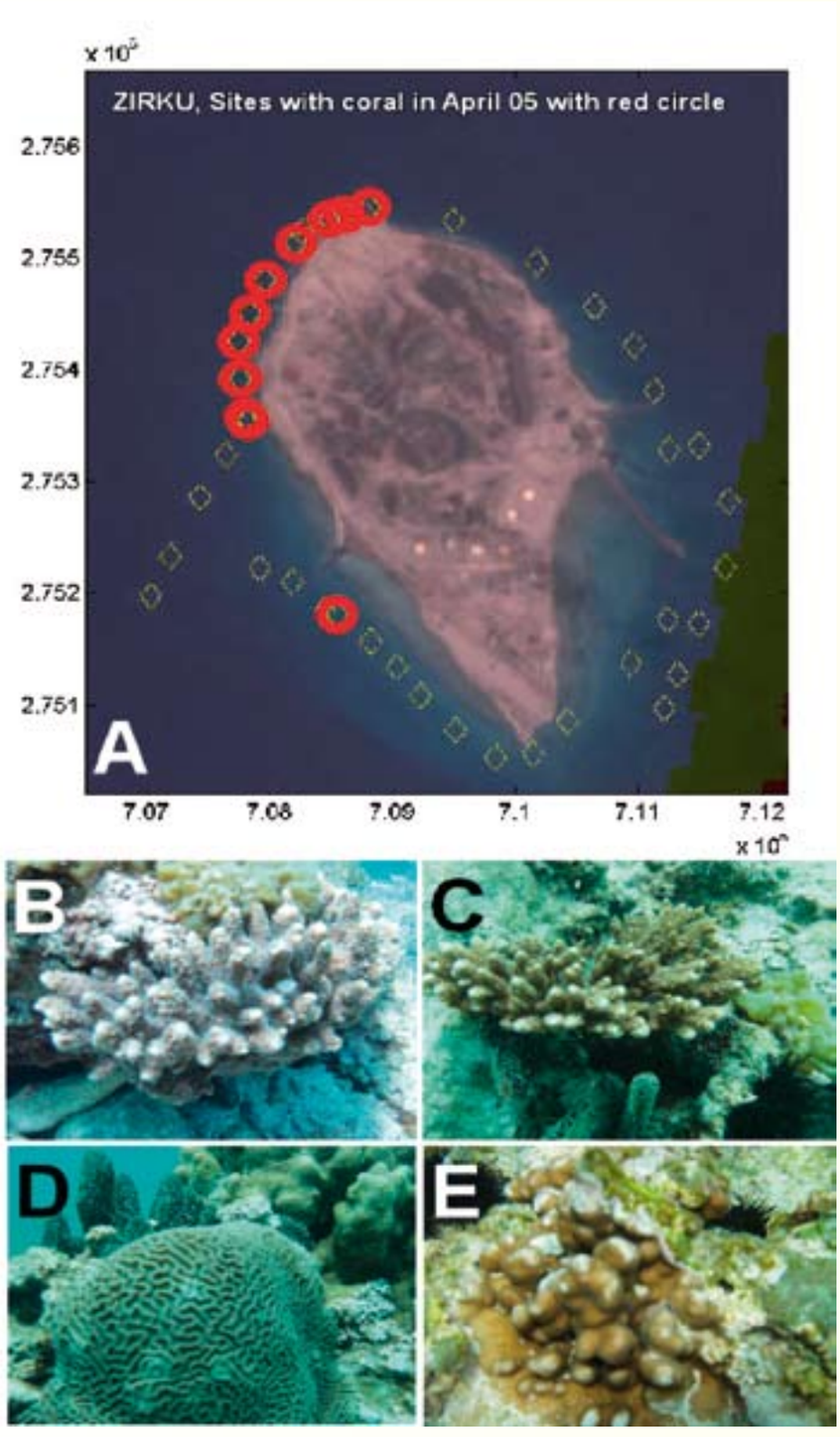
Jernein Coral Sites
(A) Jarnein Island and the evaluation sites. Sites with corals are indicated by red circles. (B) *Porites harrisoni* (B) *Porites harrisoni*. (C) *Favia pallida* (D) *Favia pallida* (E) *Turbinaria reniformis*.

ZIRKU ISLAND

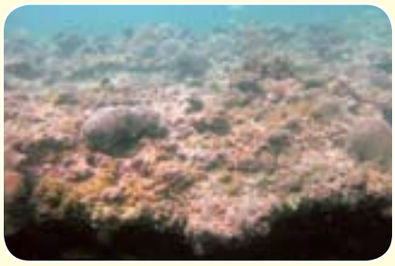
Zirku is a high island with development concentrated on its southern part. Around the islands south-western as well as south-eastern parts, a small fringing reef is developed.
A total of 42 sites were evaluated, of which 11 showed coral growths. The densest coral growth was found on the north-western side of the islands. The coral community was clearly in the very early phases or regeneration from serious mortality during the previous thermal stress events. Coral cover was between 1 and a maximum of 5%.
Coral species encountered were:

- *Platygyra daedalea*
- *Platygyra lamellina*
- *Favia pallida*
- *Porites harrisoni*
- *Porites lutea*
- *Cyphastrea microphthalma*
- *Acropora clathrata (small recruit)*

Corals were all of good health and no diseases were observed. The relatively uniform size distribution of corals suggests that all originated from sexually produced gametes of an upstream source.
A possible monitoring site was evaluated at position N 24º53.01649, E 053º03.46719.



Zirku Coral Sites
(A) Zirku Island and the evaluation sites. Sites with corals are indicated by red circles. (B) *Acropora clathrata* (C) *Platygyra deadalea* (D) *Favia pallida* (E) *Porites harrisoni*

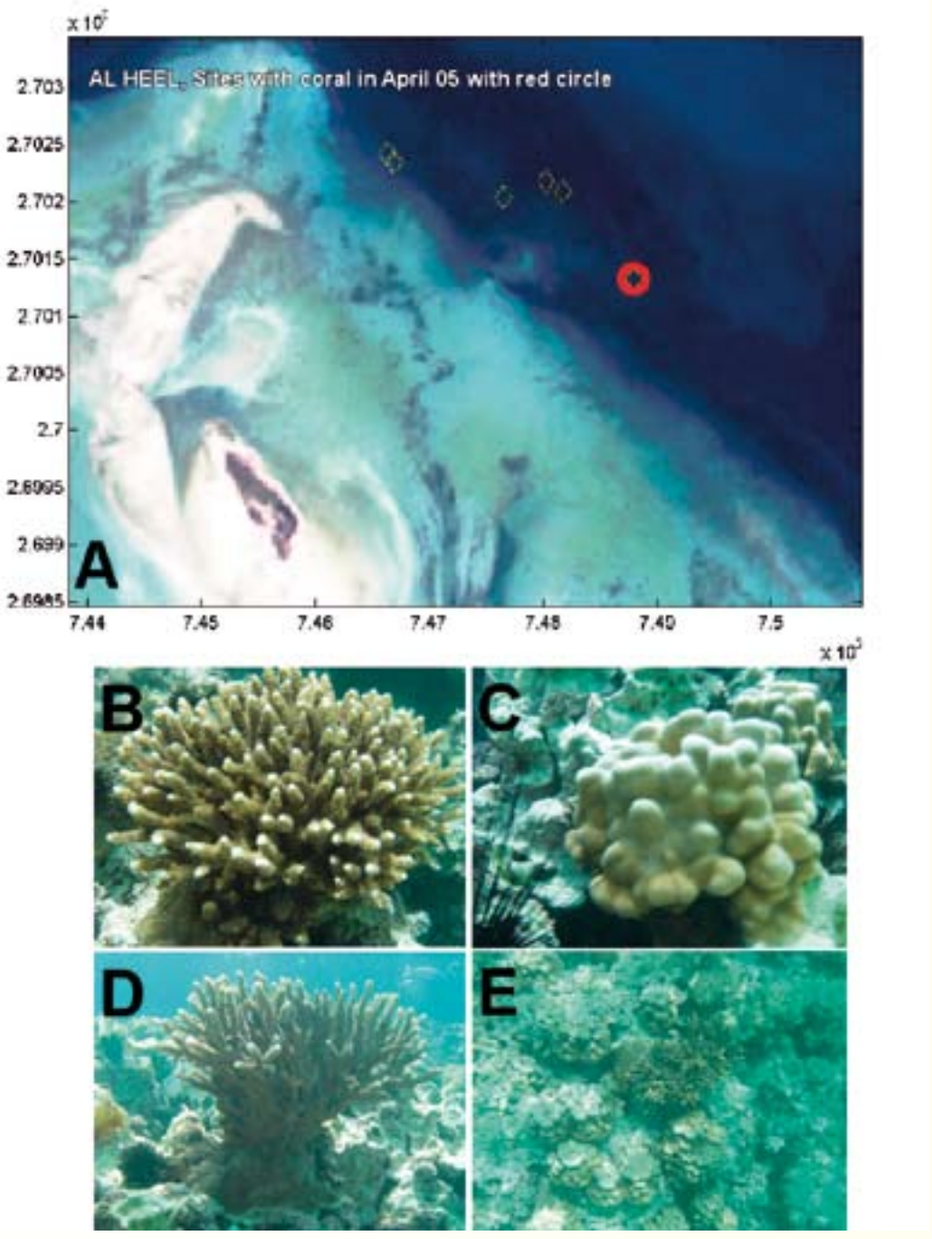




AL HEEL

Al Heel is a small, low island surrounded by a wide shallow bank that is fringed by well developed coral biostromes. There is little development on the island. The island and banks are part of the wide complex of shoals and islands associated with Murrawah Island.
A total of 6 sites were evaluated, all of which were situated within a dense coral biostrome, of which 3 showed coral growth. The coral community showed all the signs of serious mortality suffered during the previous thermal stress events but it was in a further stage of regeneration than all other investigated sites. Coral cover was between 1 and a maximum of 5% and this was the sight with the strongest Acropora recruitment of all sites.
Coral species encountered were:

- *Platygyra daedalea*
- *Platygyra lamellina*
- *Favia pallida*
- *Porites harrisoni*
- *Porites lutea*
- *Cyphastrea microphthalma*
- *Acropora clathrata*
- *Acropora arabensis*

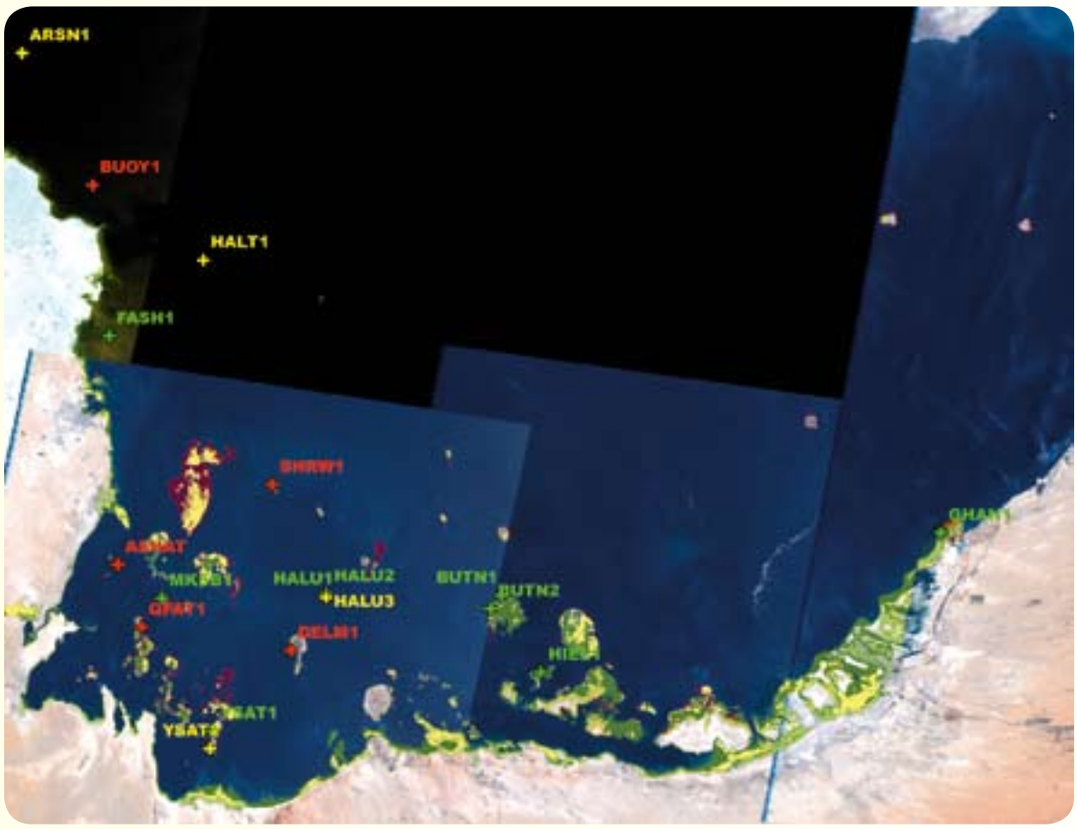
Corals were all of good health and no diseases were observed.
A possible monitoring site was evaluated at position N 24º24'27.68", E 053º27'15.42".



Al Heel Coral Sites
(A) Al Heel and the evaluation sites. Sites with corals are indicated by red circles. (B) *Acropora arabensis* (C) *Porites lutea* (D) *Acropora arabensis* (D) *Acropora clathrata* and *Porites harrisoni*

2006-2007 Site Visits:

Monitoring stations have been installed in key locations in the Arabian Gulf.



Al Ashat (ASHAT)
Inactive Site

November 24, 2006 - Exploratory Dive
- Started exploration at N24 47.063; E51 38.939 and at 2m depth. Towed observer eastward from 2-3m depth. Brief exploratory dive in eastward direction from 5-10m down slope.
- From surface, can see patchy areas that appear to be live coral reefs. However, these are dead colonies covered in filamentous macro algae (which gives the appearance of live coral color).
- Dead colonies include Acropora (rubble) and missives (all 0.5m in diameter or less).
- At 30 ft., sand with some sea grass, amorphous macro algae and sponge.

Al Hiel 1 (HIEL1)
Active Site

August 15, 2007 - Annual Monitoring
- Removed plates on upper right and lower left sides of the rack after one year underwater. Replaced with limestone tiles.
- Tiles 10 and G (lower left) were no longer attached to rack. These were the unglazed ceramic tiles from Qatar. Did not replace.
- Deployed temperature recorder.
- No signs of bleaching or disease.

October 12, 2006 - New Installation
- Installed three transect markers and settlement plate rack with 20 plates. All plates are new. Plates 10 and G are unglazed ceramic control tiles (from Qatar). All other plates are limestone.
- No signs of bleaching or disease.

Buoy 1 (BUOY1)

Inactive Site

November 25, 2006 - Exploratory Dive
- Tied onto buoy at N26 04.005; E51 33.646. Depth was 61 feet.
- Swam quarter circle around buoy. 16m due west, around to 16m due south, and back to buoy.
- Benthic fauna included fire coral, sea whips and small missives (all 0.25m in diameter or less).
- Site is too deep for training location.

Bu Tinah 1 (BUTN1)

Active Site

August 13, 2007 - Annual Monitoring
- Removed plates on upper right and lower left sides of the rack after one year underwater. (Plates 7, 9, and F were not attached to rack.) Replaced with limestone tiles.
- Tiles 11, 12 and H (lower left) were no longer attached to rack. Did not replace.
- Deployed temperature recorder.
- No signs of bleaching or disease.

October 11, 2006 - New Installation
- Installed three transect markers and settlement plate rack with 20 plates. All plates are new. Plates 10 and G are unglazed ceramic control tiles (from Qatar). All other plates are limestone.
- Temperature recorder was NOT deployed.
- No signs of bleaching or disease.

Bu Tinah 2 (BUTN2)

Active Site

August 13, 2007 - Annual Monitoring
- Removed plates on upper right and lower left sides of the rack after one year underwater. (Plates 4, 7, 9, C, and F were not attached to rack.) Replaced with limestone tiles.
- Tiles 2 and A (upper right) were no longer attached to rack. Did not replace.
- Did not deploy temperature recorder.
- A few colonies of Porites had Yellow Band Disease (not widespread). No signs of bleaching.

October 11, 2006 - New Installation
- Installed three transect markers and settlement plate rack with 20 plates. All plates are new. Plates 10 and G are unglazed ceramic control tiles (from Qatar). All other plates are limestone.
- Temperature recorder was NOT deployed.
- No signs of bleaching or disease.



Delma Coral Station (DELM1)

Abandoned Site - No further action required

October 31, 2006 - Annual Monitoring

Returned to site (N24 29.418; E52 17.050) to find station had been completely knocked over. Many of the settlement plates were buried in the sand. Did not try to upright the racks as the sandy substrate would not support the weight of the base and the racks. Could not install new transect markers or rack into sandy substrate. Settlement plates were NOT retrieved. Temperature recorder was retrieved but NOT replaced.

September 21, 2005 - New Installation

- Two settlement plate racks with unglazed ceramic tiles (from Qatar).
- Temperature recorder was deployed.

Fasht Al-Ghabi (FASH1) aka Fasht Al-Hurabi

Active Site

November 26, 2006 - New Installation

- Installed only one transect marker (Ray 2) and settlement plate rack with all new plates. Plates are unglazed ceramic tiles.
- Deployed new temperature recorder attached to settlement plate rack.
- No signs of bleaching or disease.

Halt Dalma (HALT1)

Active Site

November, 2006 - Annual Monitoring

Site was not visited during the research cruise due to a military training exercise in the area.

September 20, 2005 - New Installation

- Installed settlement plate rack only. All plates are unglazed ceramic tiles.
- Temperature recorder was NOT deployed.

Halul 1 (HALU1)

Active Site

November 23, 2006 - New Installation

- Found settlement plate rack from 2005; however, it was knocked over and buried in the sand. Abandoned in place. Took video of toppled rack and new installation.
- Installed three transect markers and settlement plate rack with all new plates. Plates are unglazed ceramic tiles.
- Temperature recorder from 2005 could not be located. Deployed new temperature recorder attached to settlement plate rack.
- No signs of bleaching or disease.

September 19, 2005 - New Installation

- Settlement Plate Rack. All plates are unglazed ceramic tiles (from Qatar).
- Temperature recorder was deployed. Attached to coral ledge behind the settlement plate rack.

Halul 2 (HALU2)

Active Site

November 23, 2006 - New Installation

- Could not find settlement plate rack from 2005 despite pivot search pattern.

- Installed three transect markers and settlement plate rack with all new plates. Plates are unglazed ceramic tiles.
- Temperature recorder was NOT deployed.
- No signs of bleaching or disease.

September 19, 2005 - New Installation
- Settlement Plate Rack. All plates are unglazed ceramic tiles (from Qatar).
- Temperature recorder was NOT deployed.

Khor Al Udaid (UDAID)

Inactive Site

November 21, 2006 - Exploratory Dive
- Explored two sites
- From surface, can see areas that appear to be coral reefs. However, these are actually oyster reefs cemented with coralline algae. No live coral of any sort was found. No dead massive colonies were seen. Thin branched coral fingers, with small diameter immersed polyps, were the only fragments found in the rubble. This indicates that past live coral was monospecific.
- Visibility was ~15m.
- Surrounding substrate included deep silt/mud, as much as 0.5-0.75 meter deep.
- Currents changed rapidly with the tidal exchange.
- This area is not currently suitable for the “Mercedes” star monitoring stations.

Makaseb 1 (MKSB1) aka Mekas

Active Site

July, 2007 - Annual Monitoring

High winds (<20 knots) and subsequent rough seas prevented return to this site for annual monitoring activities.

November 1, 2006 - Completed Installation
- Removed all plates on upper left and lower right after one year underwater. Replaced with limestone tiles except plates 3 and 10 which are unglazed ceramic control tiles (from Qatar).
- Installed three transect markers
- Temperature recorder was retrieved and replaced.
- No signs of bleaching or disease.

September 23, 2005 - New Installation
- Installed settlement plate rack with 11 plates in positions 1, 2, 4, 6, 7, 8, 9, 10, 11, B, D. All plates are unglazed ceramic tiles (from Qatar).
- Temperature recorder was deployed.

Qafay (QFAY1)

Abandoned Site - No further action required

2006

Did not attempt to return to site. Did not request permission. Settlement plates were NOT retrieved.

September 23, 2005 - New Installation
- Installed settlement plate rack with unglazed ceramic tiles (from Qatar).
- Temperature recorder was NOT deployed.
- Coast Guard interrupted installation. Special permission is required to work in these waters.

Ras Ghanada (GHAN1)

Active Site

July 11, 2007 - Completed Installation (by NCRI/EAD)

- Installed all remaining plates. Plate G is unglazed ceramic control tiles (from Qatar). All other new plates are limestone.
- Temperature recorder was deployed.
- Some *Porites* have Yellow Band Disease. No signs of bleaching.

May 20, 2007 - New Installation (by EAD)

- Installed settlement plate rack and three transect markers.
- Installed plates 1, 2, 3, 4, 5, 7, 8, 11 and 12. Plates 7 and 8 are unglazed ceramic control tiles (from Qatar). All other new plates are limestone.
- Found marker tape, but temperature recorder was missing. Did not replace temperature recorder.

May 6, 2006 - Temperature Recorder Only

- Temperature recorder was deployed. It is attached to the coral and marked with a yellow plastic tag.

Saadiyat (SDYT1)

Active Site

July 19, 2007 - New Installation

- Installed settlement plate rack and three transect markers. All new plates are limestone.
- Temperature recorder was deployed.
- Strong surge. High turbidity from nearby dredging.
- Some Porites had Yellow Band Disease. No signs of bleaching.

Shra'aw (SHRW1) aka Sharewa

Abandoned Site - No further action required

November 24, 2006 - Annual Monitoring

Returned to site to find station and cement bag had been completely knocked over. Many of the settlement plates were buried in the sand or covered with ascidians. Did not try to upright the rack. Settlement plates were NOT retrieved. Took video.

Temperature recorder was retrieved but NOT replaced.

This site was not suitable for the "Mercedes" star monitoring station. It was not possible to hammer the markers into the underlying rock nor was it possible to install another settlement plate rack. Existing corals were juveniles (approx 12 inches in diameter max), with no evidence of larger colonies past or present. Coral cover was 2-5%.

A second set of GPS coordinates were provided by Ashraf (N25 03.044; E52 13.350). These were on the other side of the small rock island. Here the coral cover was 5-15% (cover was highest approximately 8 m east of the GPS coordinates). The substrate was similar to the above; thus no attempt was made in install a monitoring station.

September 20, 2005 - New Installation

- Installed settlement plate rack with unglazed ceramic tiles (from Qatar).
- Temperature recorder was deployed.

Um Al-Arsan (ARSN1)

Inactive Site - Recommend Installing Monitoring Station

November 25, 2006 - Exploratory Dive

- This is a known dive site with live coral. Attempted to survey ~200 meters NE of buoy at N26 30.766; E51 17.958 but the strong current pulled marker underwater.
- Attempted to tie off on buoy to survey the surrounding area at N26 30.685; E51 18.039. Could see live coral from surface, but ~2 knot current prevented diver from reaching buoy to make descent. Site aborted due to unsafe conditions.

Yasat Ali (YSAT1)

Active Site

July 23, 2007 - Annual Monitoring

- Removed plates on upper right and lower left sides of the rack after two years underwater. Replaced with limestone tiles except E due to obstruction by the reef.
- Deployed temperature recorder.
- A lot of blue *Porites*. No signs of disease.

October 31, 2006 - Completed Installation

- Removed all plates on upper left and lower right after one year underwater. Replaced with limestone tiles except 3 and 10, which are unglazed ceramic control tiles (from Qatar).
- Installed four photos transect markers. The settlement plate rack is along the edge of reef and therefore could not serve as center for the photo transects.
- Temperature recorder was retrieved but NOT replaced.
- No signs of bleaching or disease.

September 22, 2005 - New Installation

- Settlement Plate Rack with 12 plates in positions 1, 3, 4, 7, 8, 10, 12, A, D, F, H. All plates are unglazed ceramic tiles (from Qatar).
- Temperature recorder was deployed.

Yasat Asfl (YSAT2)

Active Site

July 23, 2007 - Annual Monitoring

Dredging continues in area. Water was turbid. Mild current.

- Retrieved all settlement plates (1, 2, 3, 4, 6, 7, 8, 9, 11, 12, G) after 22 months.
- Replaced tiles in all positions. New tiles are limestone.
- Retrieved temperature recorder. Did NOT deploy temperature recorder.

October 31, 2006 - Annual Monitoring

Returned to site to find nearby dredging. Located settlement plate rack but visibility was less than 2 meters. Was able to confirm that settlement plate is still in place. However, by the time the team geared up, a milky white sediment plume came through and dropped visibility to less than 6 inches. Was not able to relocate the site.
Settlement plates and temperature recorder were NOT retrieved.

September 22, 2005 - New Installation

- Settlement Plate Rack with unglazed ceramic tiles (from Qatar). Temperature recorder was deployed.

Appendix 3: Coral Reefs Conservation and Management Plan-Executive Summary

Sometimes called the “rainforests of the ocean”, coral reefs are among the most diverse and valuable ecosystems on Earth. Coral reefs support more species per unit area than any other marine environment, including about 4,000 species of fish, 800 species of hard corals and hundreds of other species and are thus indeed comparable to the tropical rainforests. It is possible another 1 to 8 million undiscovered species of organisms are living in and around reefs. Especially in the Arabian Gulf region, which is situated in a hyper-arid area with relatively low biodiversity on land, the coral reefs of the region are the biological treasure chest housing most of the region’s biodiversity. In many areas, this biodiversity is considered key to finding new medicines for the 21st century. Many drugs are now being developed from coral reef animals and plants as possible cures for cancer, arthritis, human bacterial infections, viruses and other diseases.

Healthy reefs contribute to local economies in various way through tourism, fishing, bio-prospecting and recreational opportunities. Coral reefs buffer adjacent shorelines from wave action and prevent erosion, property damage and loss of life. Reefs also protect the highly productive wetlands along the coast, as well as ports and harbours and the economies they support. Globally, half a billion people are estimated to live within 100 kilometres of a coral reef and benefit from its production and protection.

Despite protective efforts through legislation, enforcement, and education, reefs are seriously threatened by human activity. Attempts for corrective actions are sometimes confounded by a collective inability to clearly distinguish between natural system variability and anthropogenic effects. Debate on this issue suggests that human activities may be additive or act as an accelerant to natural levels of variability. While there is evidence of increasing abilities to address reef decline, serious threats from a wide variety of sources also continue.

Threats, both natural and anthropogenic, can be categorized in two broad categories: physical and biological. Physical stressors include short-term climatic effects (e.g. periodic storm damage), long-term climate change (e.g. climate change, increasing CO2 in seawater), ship groundings, anchor draggings and development-related activities (e.g. sedimentation/turbidity). Many coral reefs, like those in the Arabian Gulf, are close to major commercial shipping lanes, and the errors of navigation and resultant groundings on reefs by small and large ships are a persistent and increasing problem. Ship groundings and anchor damage destroy coral structures that took hundreds of years to form. Biological considerations encompass maintenance of basic ecological function, eutrophication, over-harvesting of marine resources (commercial and recreational fishing, illegal collection of substrate, tropical collectors), disease, and introduction of exotic species. Interpreting individual and synergistic effects among these factors is hampered by a lack of basic scientific data, especially at the scale of individual reef systems.

There are many good reasons to conserve biodiversity. Abu Dhabi’s and Qatar’s lands and its waters as well as its species (including ourselves) are dependent upon the maintenance of biological diversity. Plants, microorganisms and animals all contribute to the functioning of life on earth. Without biodiversity, life on earth would simply cease to exist. In addition to environmental services biodiversity helps to define our existence - our environment is part of us and we are part of our environment. It provides us:

- Food, fiber and building materials
- Peace, joy and inspiration
- Significant lifestyle, learning and recreational opportunities
- Support for our fishing, pastoral and tourism industries.

Additionally, we have explicit legislative and administrative responsibilities for the protection of biodiversity as well as a moral obligation.

It is therefore logical to conserve coral reefs, as the most diverse marine system of the Emirate of Abu Dhabi and the State of Qatar.

The future of Abu Dhabi and Qatar depend primarily on the health of its petrochemical sector, but increasingly also, if the model of other Emirates is followed, on strong and flourishing tourism, mining (in particular marine sands and aggregates) and fishing industries. An economically strong Emirate is more likely to be able to provide the human and financial resources necessary for effective natural resource management and conservation. The same applies at the regional level. Economically viable regions will be more capable of addressing environmental issues and tackling conservation problems. Thus Abu Dhabi and Qatar are

singularly well poised to undertake meaningful and effective conservation measures for their coral reefs.

Abu Dhabi and Qatar retain the bulk of their native marine environments and much of it is in good to excellent condition, although urgent conservation measures are needed, given the massive development pressure in coastal areas. Abu Dhabi and Qatar have the opportunity to avoid repeating the environmental disasters made elsewhere in the Emirates and to genuinely pursue the twin goals of ecologically sustainable development and biodiversity conservation.
In addition, the scenery, wildlife and beauty of Abu Dhabi and Qatar's marine environment, of which its coral reefs are the crown jewel, have the potential of attracting visitors and thus become self-sustaining with regards to the costs of their conservation.

The WWF has assessed the 1,507 ecoregions and identified the "Global 200" – the most biologically distinct terrestrial, freshwater and marine ecoregions of the planet. The Global 200 include 142 terrestrial, 53 freshwater and 43 marine priority ecoregions for conservation priority in the world.
The Global 200 were selected for their species richness, endemism, higher taxonomic uniqueness, unique ecological or evolutionary phenomena, global rarity of habitats, intactness and representation. Their conservation status of ecoregions was assessed in the tradition of IUCN Red Data Book categories for threatened and endangered species. As per the Global 200 WWF classification, **the Arabian Gulf is included in one of the 43 marine priority ecoregions for conservation: the Arabian Sea**.

The Arabian Gulf is one of the areas that are most severely affected by the loss and degradation of coral reefs and for which, according to recent estimates, 30% of the coral reefs are at a threatened-critical stage and up to 65% of the coral reefs may have been lost already due to natural causes (fluctuation of temperatures, diseases) and anthropogenic stresses (oil pollution, unmanaged coastal development, unregulated commercial and recreational fishing and diving; Wilkinson 2004). The Arabian Sea (including Arabian Gulf) ecoregion is classified as "**Critically Endangered**" and therefore should be the focus of priority conservation actions.

With their national legislation and regional agreements, the UAE and Qatar dispose of the necessary legal framework for an effective protection of their coral reefs.
However, there is an urgent need to implement the integration of the environment and its preservation in the decision making at high local and/or federal levels in the development planning with:

1) Publication and diffusion of Integrated Coastal Management Plan and Coastal Sensitivity Atlas subject to continuous updating
2) Development and implementation of Environment Impact Assessment (EIA) quality regulations,
3) Continued involvement of the local communities in the decision making
4) Improvement of the national and international trans-boundaries collaborations
5) Establishment and management of new potential Marine Protected Areas (MPAs)
6) Prevention of any trade of coral reefs species through the revision of CITES status for coral reef species (UAE) and inclusion in Appendix I (UAE and Qatar)
7) Continued training of MPA staff in environment, public awareness, safety, coral reef and wildlife monitoring and surveys issues.

The most important threats to coral reefs in the project area are:

- Increased turbidity from dredging and filling
- Pollution, dredging, spills, groundings, ballast water, anchoring associated with Maritime/shipping
- Fisheries practices ("*Gargoor*" [wire fish traps], gill nets, overfishing)
- Habitat loss due to development
- Desalination plant pipelines (physical) and effluents (chemical, temp, salinity)
- Other pipelines and effluents (oil, gas, waste water treatment, industrial, cooling water)
- Nutrient levels associated with fertilizing golf courses, grasses near coasts
- Anchoring, groundings, spills, trash from recreational boats
- Use of artificial reefs as replacements to natural reefs

Over the last decades, the Arabian Gulf region has witnessed spectacular economic growth. This has sparked a veritable building boom in the coastal zone for residential, touristic and commercial development. Already in some areas, this has resulted in the near-total loss of its natural coastal zone and the devastation of some the Arabian Gulf's most diverse coral reefs.

Specific threats to the coral reefs of Abu Dhabi include:

- Construction in the coastal zone:
- reefs around Abu Abyad island are subject to dredging and filling
- most reefs around Sir Bani Yas have been infilled
- more than half the reefs of Dalma have been dredged or infilled
- most reefs around Jebel Dhanna have been dredged or infilled
- damage to reefs on Mubarraz has occurred due to construction of petroleum installations
- the unique reefs at Ras Ghanada are threatened by plans for a major port development
- many other less drastic examples exist

The main objective of the Conservation and Management Plan is to *"Conserve and protect the coral reefs and associated ecosystems of Abu Dhabi and Qatar for sustainable use through integrated management research and education".*

From the perspective of conservation of the coral reef communities between Abu Dhabi and Qatar, several aspects have to be considered to be of particular importance in making recommendations for management:

- Achieving representativeness in conservation across the different coral community types in relation to their geographic distributions in Abu Dhabi and Qatar;
- Conserving viable populations, particularly of species with restricted distributions and low abundance;
- Conserving sites of outstanding diversity, coral cover and replenishment potential;
- Minimizing risk of future biodiversity loss in terms of the small extent of some of the individual communities, and their particular susceptibility to both localised and regional disturbances;
- Providing for future research opportunities. These coral communities provide unique opportunities for ecological, biogeographic, evolutionary and environmental - climatological studies;
- Providing for future eco-tourism opportunities.

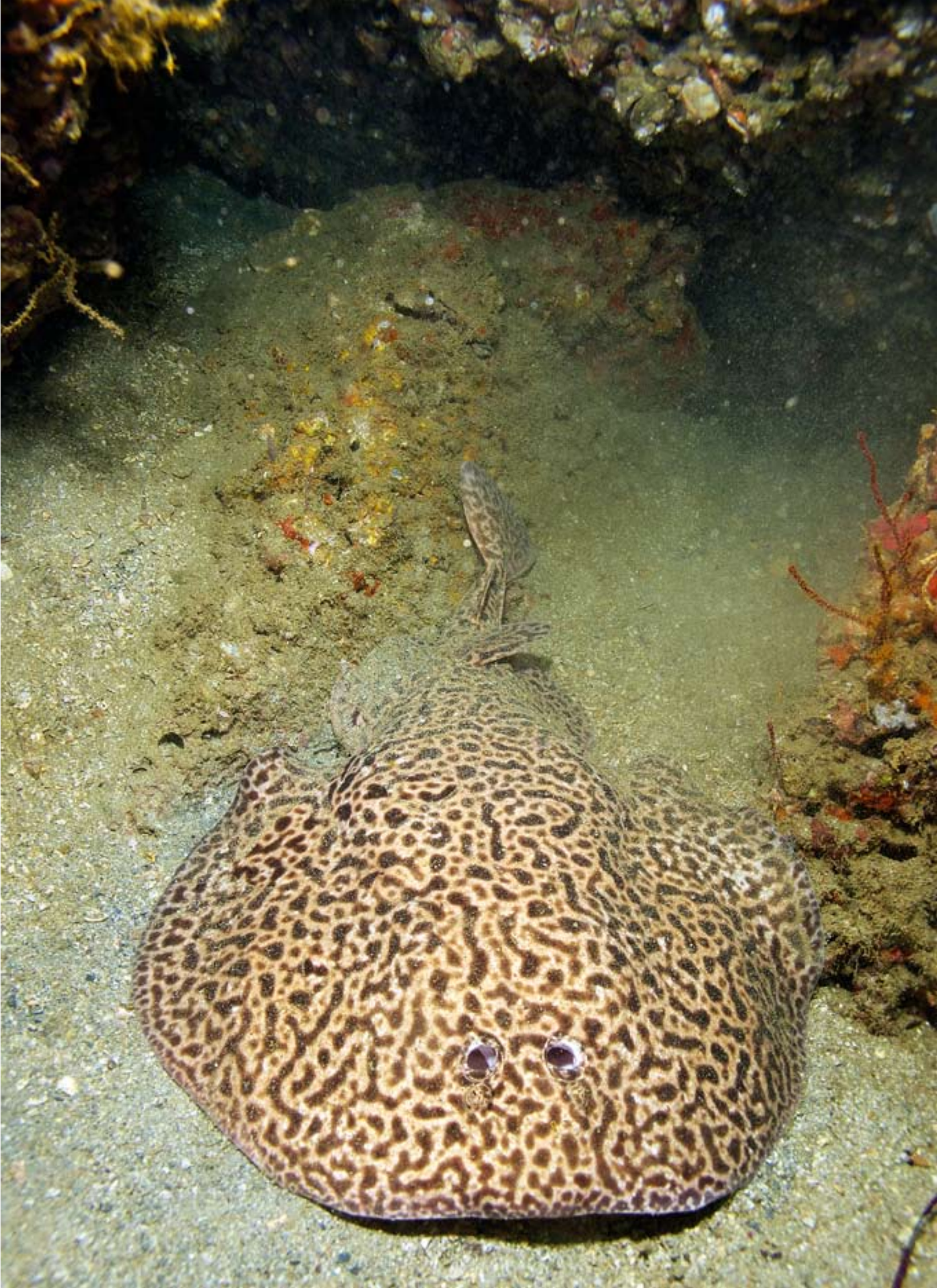
From the perspectives of resistance and resilience in the face of future disturbance, and of maintenance and replenishment of populations, it is considered particularly important to protect sites that:

- Have high replenishment potential;
- Have been unaffected or little affected by recent disturbances;
- Host species with restricted distributions, considered to be uncommon or rare throughout their distribution ranges.

The conservation and management plan has the following main objectives:

1) Execute long term partnerships for monitoring, management and conservation for coral reef sites
2) Incorporate coral reef conservation into national environmental strategies
3) Foster and coordinate local and regional agreements on coral reef issues
4) Build national capacities for coral reef conservation
5) Reduce key threats to Gulf coral reefs and associated reef resources
6) Encourage applied research to support management decisions
7) Periodically monitor coral reef ecosystems
8) Monitor and assess coral reef ecosystems for sustainable use
9) Manage, archive and disseminate data
10) Enhance awareness and education on coral reef conservation

The plan provides an overview of the legal, biological, conservation status of coral reefs in Abu Dhabi Emirate and Qatar and highlights a number of priority areas and actions to be taken by the relevant authorities.



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Emirates Wildlife Society (EWS) is a local (UAE) environmental NGO established in February 2001. EWS works at the federal level and aims to promote the conservation of nature in the UAE. To achieve its goals, EWS has partnered with and works in association with the world's most experienced conservation organization, WWF.

WWF (also known as World Wildlife Fund in the US and Canada) is one of the world's largest and most experienced independent conservation organization, with almost 5 million supporters and a global network active in more than 100 countries.

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature by:
- conserving the world's biological diversity
- ensuring that the use of renewable natural resources is sustainable
- promoting the reduction of pollution and wasteful consumption

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