OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

RESTRICTED

21652

DP/ID/SER.A/1768
14 August 1996
ORIGINAL: ENGLISH

ECOTOXICOLOGY AND MARINE ECOLOGY STUDIES IN POST-WAR KUWAIT

atp. tables map illus

DP/KUW/92/003

KUWAIT

Technical report: Findings and recommendations*

Prepared for the Government of the State of Kuwait
by the United Nations Industrial Development Organization
acting as executing agency for the United Nations Development Programme

Based on the work of P.L. Harrison, Expert on Marine Ecology

Backstopping Officer: Yong-Hwa Kim
Chemical Industries Branch

United Nations Industrial Development Organization
Vienna

---

* This document has not been edited

V.96-85399

CONTENTS

ABSTRACT

This report summarizes the main results, conclusions and recommendations from the UNDP/ UNIDO Coral Reef Ecology Project in Kuwait (DP/KUW/92/003/11-04) during February to December 1995. The purpose of the project is to assist the Kuwait Institute for Scientific Research (KISR) to set up long-term research studies on the ecology of Kuwait's coral reefs. The project aims to investigate the structural and functional characteristics of these reefs with particular reference to natural and anthropogenic stressors. The project has been successful, with the main aims having been achieved and significant advances made on most aspects of the project within the scheduled 11 month assignment period.

The project has provided new information on the status of Kuwait's coral reef communities, including quantitative baseline data against which past and future changes in these communities can be assessed. At present, most of the major coral reef sites examined appear to be in a healthy condition, with some sites having high coral cover. Coral cover varies within and among reefs, with the southern offshore reefs having the best developed coral communities, and northern inshore reefs having lower coral cover. Coral community structure at the major reef sites appears to be similar to that recorded by earlier workers.

Approximately 34 scleractinian coral species have been recorded from Kuwait, and a few additional species may also be present. This relatively low coral species richness probably results from natural environmental stressors acting to limit the number and type of corals able to survive the extremes of temperature and elevated salinity in the northern Arabian Gulf. Records from temperature recording data loggers deployed at Qaru reef showed that sea temperature reached a maximum of 33.9°C during August 1995, which is the highest temperature recorded on coral reefs in Kuwait.

This project has resulted in the first records of coral reproduction in Kuwait. Despite the harsh environmental conditions, local corals are capable of successful reproduction. The corals investigated exhibited an extended spawning period, with two species of *Acropora* branching corals spawning around the full moon period in May, the brain coral *Platygyra daedalea* spawning after the full moon in June, and other species probably spawning in July and August. Larvae from *Acropora* spp. were successfully reared through to settlement and metamorphosis into juvenile coral polyps. Some larvae were able to survive for more than one month, and one *Acropora arabensis* larva was observed to settle at four weeks of age. The extended longevity of these larvae indicates that there is considerable potential for long-distance dispersal of coral larvae within the Arabian Gulf, hence

reefs are likely to be biologically interconnected. An experiment on the effect of different salinity treatments on fertilization rates in *Acropora clathrata* gametes indicates that the high salinity around Kuwait's coral reefs probably does not inhibit fertilization in corals, whereas substantial lowering of salinity reduces or blocks fertilization.

An experiment examining the effects of Kuwait crude oil on the settlement rates of *Acropora arabensis* coral larvae, showed that relatively low concentrations of oil significantly reduces (0. 1-0.3 ppm) or blocks (1.0 ppm) larval settlement. This implies that oil pollution has the potential to disrupt the critically important larval settlement processes which are responsible for the maintenance and renewal of coral communities. Studies on coral growth, gametogenesis, heavy metal contaminants and maintenance of adult corals in aquaria were also initiated during this project. Logistical and funding problems prevented studies on the effects of natural and pollutant stressors on adult corals, and recommendations to improve the efficiency of future projects are made.

The project results and publicity have raised scientific and public awareness of Kuwait's coral reefs, and highlighted the need for their careful management. The major problems facing these reefs at present are, anchor damage to corals, over-fishing, and litter. It is recommended that a single authority be empowered to manage and protect these unique coral reef ecosystems. Priorities for management include installation of mooring buoys around the reefs, public education about the importance and sensitivity of these reefs and the need for their sustainable and wise use, protection of sensitive reef sites, regulations to control fishing and other collection activities, and prevention of littering on these reefs. It is recommended that MAD, KISR staff in conjunction with international expertise continue studies on: coral reef communities; temperature and salinity monitoring; coral gametogenesis, spawning patterns, larval longevity and dispersal; coral growth; and effects of natural and pollution stressors on larval and adult corals. Consideration should also be given to additional projects, including utilizing remote sensing techniques to examine long-term changes in Kuwait's coral reefs, analysis of reef fish populations and fishing pressure, coral coring to reveal long-term climatic and stress history, and preparation of detailed management plans for the protection and wise use of Kuwait's unique sub-tropical coral reef ecosystems.

I. INTRODUCTION

This report, prepared by Dr Peter Harrison, UNIDO Expert in Marine Ecology, presents a summary of the main activities, results, conclusions and recommendations arising from an 11 month mission to Kuwait for the UNDP/ UNIDO Coral Reef Ecology Project in Kuwait (DP/KUW/92/003/11-04), during February to December, 1995. The purpose of this project is to assist the Kuwait Institute for Scientific Research (KISR) to set up long-term research studies on the ecology of Kuwait's coral reefs. The project aims to investigate the structural and functional characteristics of these reefs with particular reference to natural and anthropogenic stressors. The project consists of three phases: Phase 1 - Ecological aspects; Phase 2 - Ecotoxicology of corals; Phase 3 - Data analysis and integration.

A. Project Background

Kuwait has a number of important coral reef ecosystems within its territorial waters. These coral reefs have significant ecological and economic values, and provide essential habitats for many hundreds of species, including some species of commercial importance. In addition, these reefs have important amenity values for recreational fishing, boating and scuba diving. Kuwait's coral reefs are also of great scientific interest because they occur in an extreme environment, beyond the normal limits for coral survival and reef growth (Downing, 1985; Sheppard and Wells, 1988).

The destruction of oil wells, oil processing facilities and shipping during the occupation of Kuwait in 1991 resulted in approximately 10.8 million barrels of oil being released into the Arabian Gulf between January and June 1991, which represents the largest single oil spill in history (Saenger, 1994). The potential impacts of these massive oil slicks focused international attention on the fate of Kuwait's marine environment and its coral reefs.

Following the liberation of Kuwait, the task of rebuilding the country's industrial and research infrastructure began. A series of collaborative projects with the UNDP and UN agencies were established to assist the Government of Kuwait in assessing and overcoming major environmental problems resulting from the invasion of Kuwait and the Gulf War. The UNDP

requested UNIDO to assist the Kuwait Institute for Scientific Research (KISR) to plan studies for monitoring chemical pollutants and the effect of petroleum hydrocarbons upon the ecology of the marine environment. A one month mission by Professor Peter Saenger in 1993 to assess the marine environmental research programs within KISR, highlighted the need for strengthening of expertise in the coral ecology area. As a result, the Kuwait Coral Reef Ecology Project was established to investigate the structural and functional characteristics of Kuwait's coral reefs with particular reference to natural and anthropogenic stressors.

B. Project Objectives

This project consists of three interrelated phases with the following major objectives, as defined in the job description for this mission (refer to Annex 1):

Phase 1. Ecological Aspects

1. Re-assemble all of the regional transect data compiled by Downing (1985, 1991) and Downing and Roberts (1992) from Kuwait's reefs, re-survey these reefs using identical techniques and the line-intercept method, then survey all 13 coral communities of Kuwait. Compare coral species composition and coverage for all reefs, pre-and post-war differences where data are available, and differences between offshore, nearshore and inshore reefs.

2. Investigate the reproductive status, fecundity, spawning period, and gametogenesis of a range of coral species.

3. Initiate coral growth rate studies by staining coral skeletons with Alizarin Red, and re-measuring them at yearly intervals.

4. Sample selected species of corals from all sites to determine heavy metal levels in their tissues.

Phase 2: Ecotoxicology of corals

5. Once reproductive gametes and larvae are available, set up experiments to determine the effects of different salinities, temperature, light intensities, and a range of pollutants on coral larval development and survival.

6. Commence trials to maintain mature corals in aquaria under ambient conditions for subsequent investigations of factors limiting growth and survival, and ecotoxicological responses to a range of pollutants.

Phase 3: Data Analysis and Integration

7. Integrate data from Phases 1 and 2 to identify factors limiting coral communities, predict responses to natural and human-induced stressors, and develop management plans for reefs of high conservation value.

Other duties

8. Identify equipment and training needs required for the project.

9. Submit interim progress reports, prepare an evaluation report, and submit a final report giving the findings and recommendations.

C. Project Outcomes

The project has been successful, with the main aims having been achieved and significant advances made with respect to the specific project objectives. Additional work during the assignment has resulted in the spawning patterns for ecologically important coral species being determined, KISR funding being obtained for a research proposal for this project, the establishment of new research laboratories, and publications and media reports about the project. Details of the progress towards each objective are provided in section II below. Some objectives were slightly modified for logistical reasons, as outlined in the Project Performance Evaluation Report, and below.

II. SUMMARY OF ACTIVITIES, RESULTS AND CONCLUSIONS

A. Situation at the outset of this mission

The detailed project objectives, as defined in the job description for this mission (refer to Annex 1), were ambitious considering that this mission had an effective working period of less than 10 months. Accordingly, arrangements were made with the Mariculture and Fisheries Department (MFD), KISR for the purchase or provision of some essential equipment prior to arriving in Kuwait in February 1995. It was assumed that basic laboratory equipment and funding for the research component of the project were available at KISR.

Upon arrival in Kuwait, it became apparent that KISR had no specific budget for this project, and I was requested to prepare a detailed research proposal for KISR to expedite funding. The project was to be based at MFD, where new laboratory facilities and offices were being completed but were not yet available. Temporary office accommodation was provided at MFD, together with access to a new 32' research vessel, and underwater video and computer equipment. However, with the removal of KISR equipment during the occupation of Kuwait, and subsequent budget constraints, other laboratory equipment or facilities were not readily available for this project. Urgent orders were placed for essential equipment and supplies, as there was likely to be a delay of up to 3 months for delivery of items. Three excellent professionals from MFD were assigned to work on this project: Shaker Alhazeem (90% time allocation), Adel Alsaffar (20% time allocation) and Iman Al-Sabah (40% time allocation, from April-June).

The first 8-10 weeks of the assignment were devoted to preparing the research proposal for KISR (refer to Annex 2), contacting suppliers and organising many quotes and orders for equipment, 'running in' the motors for the new vessel during sea trials, and establishing the research programme with counterparts. Additional delays in establishing the project were experienced due to restricted working hours and access to facilities during the holy month of Ramadan in February, and a five week delay in clearing airfreight which contained personal research equipment brought from Australia for use during this project.

1. Subsequent progress

Field work began in April following completion of the research vessel trials and service. Access to the newly completed MFD office and laboratory buildings in April allowed new research laboratories for this project to be established. The new Coral Reef Ecology laboratory is fully operational, with substantial new equipment including microscopes, lights, micropipettes, precision balance, diving safety equipment, data loggers for recording seawater parameters, seawater heaters, aquaria, and many other laboratory items (refer to Appendix in the KISR Proposal, 2). A second laboratory was established to analyse the underwater video footage of the coral reef communities and footage of coral spawning, using Hi-8 video equipment and a high resolution monitor. Various outdoor flow-through aquaria were established to maintain corals and raise coral larvae, and three wet laboratories were used to study and record coral spawning behaviour, and for larval settlement experiments.

The research proposal prepared for KISR was reviewed at a Technical Review Meeting in June, approved in September, and the project budget account allocated in November 1995. KISR funding of 31,000 KD was approved for this project. This funding is equivalent to US$105,085.00 (calculated from the 1995 UN operational exchange rate of 0.295).

2. Recommendations

The logistical and funding problems encountered during the earlier stages of this project delayed the research programme and reduced productivity. Therefore, for future collaborative projects of this type where a new research programme is to be established, it is recommended that the expert assigned to the project be contracted for a short period prior to the main mission, to assess the facilities available, and the funding, equipment, number of personnel, and the time period required to complete the project. This assessment could be done by a preliminary mission to Kuwait, or in some cases by detailed correspondence. The main mission should then proceed when the necessary funding, equipment, and other support from the counterpart organisation are available.

B. Phase 1: Ecological Aspects

1. Coral reef surveys

1.1 Summary of previous studies

Some detailed data are available on the coral communities at the three main offshore island reefs from Kuwait (Kubbar, Qaru and Umm Al Maradem) from previous transect surveys by N. Downing and co-workers (Downing, 1985, 1989, 1991, 1992; Downing and Roberts, 1992, 1993). In addition, some quantitative survey data and qualitative observations of the coral communities at some other Kuwait reefs are available (op. cit., Fadlallah *et al.*, 1993; Hodgson and Carpenter, 1995). The combined survey data show that the coral communities, live coral cover and coral species richness vary considerably at different areas of each reef, and among different reefs from Kuwait.

The most extensive data are given in Downing (1989) who surveyed a total of ninety six 50 metre transects along 24 main transect lines at the three main offshore island reef sites (Kubbar, Qaru and Umm Al Maradem). At some sites, repeated surveys were done between 1982 and 1987 (Downing, 1989). The repeated survey data show that the coral communities at most deeper reef sites have remained fairly stable through time, whereas the shallower water reef flat communities at some sites have suffered significant periodic mortality resulting from natural perturbations and stress in 1982-83 and 1984-85. Downing (1991, 1992) re-surveyed a few sites at the three offshore island reefs in July 1991, six months after the Gulf War oil spill, and found no evidence of stress or mortality from oil pollution. Subsequent surveys during May 1992 (Fadlallah *et al.*, 1993) and November-December 1992 (Downing and Roberts, 1992, 1993), indicated that significant recent coral mortality and stress had occurred on some reef flat sites. The timing of the observations of coral stress indicated that the unusually low sea temperatures during the winter of 1991-92 may have been the cause of the coral stress and mortality, however, potential long-term effects from the oil spill could not be ruled out (Fadlallah *et al.*, 1993). Saenger (1994) noted that there were no statistically significant differences in the number of coral species or families recorded at oiled versus non-oiled reefs and inshore versus offshore reefs in Kuwait following the Gulf War.

1. 2 Preliminary reef surveys and modifications to the survey design

Preliminary surveys of the major reefs in Kuwait for this project began in April 1995, with a view to repeating the earlier surveys of Downing (1985, 1991) and Downing and Roberts (1992) as outlined in the project objectives. However, a number of logistical difficulties with re-locating the same sites, and problems with the design of the earlier surveys became apparent. Details of these problems and suggested modifications to the survey design were given in a previous interim report, and are summarised here.

The major difficulty with repeating the line transect surveys by Downing (1985, 1991) and Downing and Roberts (1992) is that it is not possible to accurately relocate the previous study sites because; the study sites were not marked, the main reefs are more than 1 km in extent, details of the transect bearing are given for some sites, but some sites are described only in general terms (Downing, 1991; Downing and Roberts, 1992). More complete location details are given for some sites in Downing (1989), where relocation of the survey sites was achieved through the use of a highly accurate Mini-Ranger position fixer which allowed sites to be repositioned to within 1 metre. However this expensive equipment was removed in the invasion and has not been replaced. Given the large variability of the coral communities over scales of a few metres, it is likely that the repeated surveys might be done in different reef environments within the same general area, making any comparisons of community data difficult. Thus site relocation error is a problem for repeated coral reef surveys in the absence of position fixing equipment.

Another significant problem with repeating the previous surveys is that they were based on a single fixed transect at most sites. Statistically meaningful comparisons of communities over time require a replicated survey design to adequately quantify community structure and variability (e.g. Hurlbert, 1984). Replicated surveys at each site overcome the requirement for accurately relocating the exact same transect path within each community. In addition, the previous surveys were concentrated in the deeper reef slope zones, whereas the major changes that have been observed on Kuwait's coral reefs have been mortality events and damage to the shallow water reef flat communities. As it is likely that future impacts from natural stress events and human-

induced damage and pollution will be greatest on the reef flat and upper reef slope zones, surveys in these areas are essential.

Given these problems, and the extensive time periods required for manually recording underwater line transects, it was not logistically feasible or particularly useful to repeat exactly the previous survey methods. Instead, the survey design for this project was changed to overcome these problems, and to take advantage of recent improvements in sampling design and survey techniques. Pilot studies were done at Kubbar reef and Qaru reef in April using replicated 50m underwater video transects to quantify the status of the benthic communities (Table 1). The results showed that the video technique is ideally suited to surveys of Kuwait's reefs. Video surveys provide robust quantitative data, a permanent video record of the sites, and are more time-efficient than convential underwater transect survey methods. Video surveys are now used as the standard method for coral reef community surveys at many reef areas around the world (e.g. Carleton and Done, 1995; Harriott *et al.*, 1995; Harrison *et al.*, 1995 a,b).

At each reef studied, an initial survey was made to assess the areas of greatest coral cover in the shallower reef zones, and visual comparisons made with the coral community habitat maps provided in Downing *et al.* (1989). Survey sites were then selected and prioritised, and at each site seven 50 m transect lines were recorded using a high resolution underwater video camera. Where possible, the quantitative surveys were done in the same reef areas surveyed previously by Downing and co-workers, to facilitate comparisons with the earlier data. Additional qualitative surveys were done at other sites around the reefs to record the coral species present, and the nature of the coral and other benthic communities.

Progress on the reef surveys after April was restricted due to intensive work on coral reproduction and laboratory experiments (see sections 2.0 below). It had been planned that the main reef surveys would be done in September and October 1995. However, progress was slowed by illness among the research team which prevented safe diving during September, many periods of strong winds and rough seas during October-November which precluded safe travel to the reefs, a reduction in personnel available to work on the surveys and transect data, and problems with the engines on the research vessel which required servicing following breakdowns at sea. As the main coral reefs are located 45-95 km away from MFD harbour, travel to offshore reefs and

the video surveys can only be done during periods of good weather. These time constraints will need to be taken into account when future surveys are planned.

1.3 Results of the reef surveys

Surveys have been done at four main coral reefs in Kuwait: Kubbar, Qaru, Umm Al Maradem and Qit'at Urayfijan (Fig. 1). Additional visual surveys have been done at smaller patch reefs to the north of Kubbar and Qaru reefs, and at two coastal sites at Messilah Beach and in the MFD harbour (Fig 1). Quantitative video surveys have been done at Kubbar (5 sites), Qaru (6 sites) and Umm Al Maradem (2 sites), representing a total of 95 transects at 13 sites with 4,750 metres of transect footage. The majority of transects have been analysed (refer to Tables in Annex 3), and the remaining sites will be analysed by MFD staff. The results of these quantitative surveys and visual habitat assessments of other reef areas are summarised below.

At present, the coral reef benthic communities at the reefs studied during this project appear to be in a generally healthy condition. There is little evidence of recent stress or coral mortality at these reefs, although dead coral colonies from previous mortality episodes contribute substantially to the reef substratum. Coral cover and species richness vary greatly around each reef, and among different reefs. The southern offshore reefs tend to have the best developed coral communities, with some sites at Qaru reef having very high coral cover (Fig. 2). The reef flat zones with high coral cover are dominated by massive *Porites*, and in some areas by branching *Acropora*, with a range of faviid brain corals and other taxa present (Tables 1-3). Many reef flat areas are comprised of mainly dead coral, with large areas of sand and sporadic living coral colonies (Table 4). The upper reef slope zones are dominated by very large *Porites lutea* colonies, some of which are many metres in diameter and are likely to be hundreds of years old. A relatively diverse coral community extends from the upper reef slope zone down to the reef base, with the deeper areas dominated by faviid brain corals and other taxa. Coral cover tends to be lower on the northern inshore reefs, with a reduced abundance of *Acropora* branching corals and some other coral taxa.

Very little macroalgae, soft coral or other encrusting benthic invertebrates are present on the reefs examined. This is an unusual feature of Kuwait's coral reefs, because other sub-tropical reefs typically have substantial cover of macroalgae, soft corals and other invertebrates which

potentially compete with reef corals (e.g. Harriott *et al.*, 1994, 1995; Harrison *et al.*, 1995 a,b). Sea urchins, particularly *Echinometra mathaei*, are extremely abundant on these reefs, and their grazing activities probably have a major influence on the benthic communities. Grazing by urchins may prevent the establishment of macroalgae, and is likely to limit recruitment of soft corals, reef corals and many other invertebrates on reefs with high urchin densities. These urchins are also known to be important bio-eroders, and contribute significantly to destruction of dead coral skeletons (Downing and El-Zahr, 1987).

The southern offshore reef around Qaru island, has the best developed coral communities observed in Kuwait, with site 3 having a mean live coral cover of 81% (Table 2). Live coral cover at other sites ranged from 32-67% (Tables 1,3,4). These values compare favourably with results from recent surveys of many reef sites from the Great Barrier Reef, Australia, where mean live coral cover ranged from 12 - 52% (Oliver *et al.*, 1995). The coral community at Qaru reef is dominated by branching and plate *Acropora* colonies at sites 1,3 and 4, with massive *Porites* colonies dominating site 5 and at many other reef flat areas (Tables 1-4). Sea urchins are very abundant in areas with substantial cover of dead coral and contribute 4.1% mean cover at site 1 (Table 1) and up to 17% cover in some transects at site 5 (Table 4).

The most important coral community on the reef flat is at Site 3, approximately 50 metres to the south of the island. This community is dominated by very large plate and branching *Acropora* colonies, some of which are more than 4 metres in diameter. These colonies appear to have been growing undisturbed for decades, and their growth form makes them highly susceptible to anchor damage. Other sites with high *Acropora* cover (sites 1, 2 and 4) are also highly vulnerable to anchor damage, hence much of Qaru reef needs to be protected from anchor damage. Some evidence of anchor damage or breakage of coral colonies due to storm events was evident in the transects at Qaru reef. At site 1, fragmented living coral branches had a mean cover of 1.3%, while dead coral rubble occupied 15% of the transects (Table 1). The problem of anchor damage is a major management issue that will need to be dealt with in the near future to avoid destruction of these fragile coral communities.

The survey sites at Kubbar and Umm Al Maradem reefs encompass a range of coral communities but tend to be dominated by *Porites*, with reduced cover of *Acropora* spp (Tables 5-8). Live coral

cover ranged from 5-59% at Kubbar reef (Tables 5,6), and 27-56% at Umm Al Maradem reef (Tables 7,8). Urchins covered between 7-24% of the transects (Tables 5-8). Both of these reefs are very popular destinations for boating and fishing, and have reduced cover of fragile branching corals and fewer fish present compared with Qaru reef, which is further offshore and less frequently visited. The increased visitation rates and fishing pressure at Kubbar and Umm Al Maradem reefs may have contributed to these differences in the coral fish communities.

The inshore reef at Qit'at Urayfijan and the smaller reefs to the north of Kubbar and Qaru islands have patches of moderate coral cover dominated by *Porites* and brain corals. Despite it's proximity to the major sites of oil release during the Gulf War and potential impacts from industrial effluents from the port facilities, Qit'at Urayfijan supports a moderately diverse coral community. Some large coral colonies are present on the reef flat and reef slope, which clearly survived the 1991 Gulf War oil spill. The coastal sites at Messilah beach and the MFD harbour contain an assemblage of small coral colonies which are potentially up to 8-10 years in age. High sediment levels and cold winter temperatures will limit the development of coral communities in the northern coastal areas of Kuwait, although isolated coral colonies are likely to be found on some subtidal rock platforms.

1.4 Conclusions and recommendations

It is recommended that additional quantitative and visual surveys be done to assess the status of the coral communities at other sites on the reef flat and reef slope of the four main reef systems studied in this project, and at Mudayrah, Taylor Rock, Qit'at Benaya, Getty Reef, Qit'at Bnaider, Twin reef and Naval Base reef (Fig. 1). These surveys should be done by MFD staff utilising the training and methods from this project, with additional assistance for interpretation and statistical analysis from a coral ecologist familiar with the region. When these additional surveys are completed and all the transect data analysed, the combined data will be published in an international refereed journal. Elements of the work will be included in the book 'The Corals and Coral Reef Fishes of Kuwait' being prepared for publication in 1996.

The combined surveys will provide a robust quantitative baseline data set against which previous changes in the reef communities can be compared and future changes monitored. In this context,

it is recommended that the general health of the reef communities at the four main reefs be visually inspected every 3-4 months when temperature data are retrieved from the data loggers at each reef (refer to section B.3). Any sites showing signs of coral stress, recent mortality or physical disturbance should be re-surveyed and monitored to examine the outcome. It is also recommended that the surveys of the main reefs in Kuwait be repeated at intervals of 1-2 years, or after significant perturbations, to monitor long-term changes or stability of these communities. These survey methods and data should also be used to develop a rapid response plan to quantify and monitor impacts and any subsequent mortality or recovery of Kuwait's coral reef communities resulting from natural catastrophes, and human disturbance including pollution events. This plan should be co-ordinated through the EPA, KISR and other appropriate organisations.

When all the current survey data are available, the present status of these coral communities should be compared in detail with data from previous surveys. Allowing for differences in scope and methodology of the various surveys of these coral communities, it is apparent that the present status of the coral communities at the main reef systems in Kuwait is essentially similar to that observed in previous studies (e.g. Downing, 1985, 1989, 1992, Downing and Roberts, 1993; Hodgson and Carpenter, 1995). One noticeable difference is the reduced abundance of the small branching coral *Stylophora pistillata* on the reef flat at Qaru. This coral species was relatively common at this site until at least May 1990 (Hodgson and Carpenter, 1995; K. Carpenter, pers. comm.), but was rarely observed in this study.

Overall, there appear to have been few major changes in the structure and status of these coral communities since the last previous surveys after the Gulf War (Downing, 1992; Downing and Roberts, 1993). Long-term changes in Kuwait's coral reef communities and the coral cays should also be monitored using satellite images from the past ten years. This work should be done in collaboration with Dr Andy Kwarteng, Research Scientist on Remote Sensing, EES, KISR, and the data from this project should be used to ground truth recent satellite images from the main reef sites.

The data from this project also lend support to the conclusions from previous surveys done after the Gulf War, that the massive oil spill during 1991 had only limited impact on Kuwait's coral

reefs (Downing, 1991, 1992; Downing and Roberts, 1992, 1993; Saenger, 1994). This result was unexpected because oil hydrocarbons are known to be toxic to reef corals (e.g. Loya and Rinkevich, 1980; Bak, 1987; Harrison *et al.*, 1990; see also section B.5). This finding raises important questions as to why the massive oil spill had unexpectedly low impacts on reef corals, and highlights the need for further information on the toxicity of Kuwait crude oil to corals (refer to section C.2).

2. Coral species richness

Correct taxonomic identification of scleractinian corals is an essential pre-requisite for understanding the ecology of coral reef communities, and for their management. However, the taxonomy of scleractinian corals is complex, particularly for sub-tropical corals growing near their latitudinal limits. Previous surveys of corals from Kuwait by Downing (1985, 1989) distinguished 28 scleractinian corals from 21 genera. Of these, 17 species were definitively identified (Downing, 1989). Subsequent surveys by Hodgson and Carpenter (1995) recorded 28 hermatypic (reef building) and 6 ahermatypic (non-reef building) scleractinian coral species from Kuwait, including a newly described species, *Acropora arabensis*.

The coral reference collection, photographs and records housed in KISR were almost all destroyed during the invasion and occupation of Kuwait. Therefore, additional coral specimens were collected, photographed and studied during this project to provide a new reference collection of corals at MFD, and to support the ecological studies. Most of the coral species collected and identified have been recorded previously by Downing (1985,1989) or Hodgson and Carpenter (1985). In addition, analysis of the recent coral collection indicates that there are at least three forms of the branching coral *Acropora arabensis* identified by Hodgson and Carpenter (1985). Dr Carden Wallace, the leading authority on the taxonomy and biogeography of the genus *Acropora*, has agreed to examine a range of *Acropora* specimens from Kuwait to confirm their identity. The recently collected corals may also include at least one species of brain coral (Family Faviidae) not recorded by Hodgson and Carpenter (1985). Thus, it seems likely that further detailed taxonomic studies will slightly increase the number of coral species recorded on Kuwait's reefs.

The total of thirty four coral species recorded from Kuwait represents a relatively low species richness, and community diversity is further reduced by the dominance of *Porites compressa*, *Acropora* spp., and a few brain coral species at most reef sites. Compared with the 28 hermatypic coral species identified from Kuwait, 38 hermatypes are known from Saudi-Arabia and Bahrain, while at least 53 species occur in the Gulf of Oman (Hodgson and Carpenter, 1995). Thus, coral diversity in the Arabian Gulf decreases northwards, with increasing distance from the Indian Ocean.

The low coral species richness in Kuwait probably results from natural environmental stressors acting to limit the number and type of corals able to survive the extremes of temperature and elevated salinity in the northern Arabian Gulf region. The extreme environment is likely to result in periods of physiological stress in these essentially stenohaline tropical coral species, hence local populations of coral species surviving near their ecological limits will tend to fluctuate over time in response to extreme climatic events. The reduced abundance of *Stylophora pistillata* at Qaru reef (refer to section B1.4), may represent the outcome of localised stress, as pocilloporids are quite sensitive to environmental changes (P. Harrison, unpubl. obs.). The physiological tolerance limits for temperature and salinity in a range of coral species present in Kuwait could be determined experimentally, in order to predict the consequences of extreme climatic events, and the potential sensitivity of these species to pollutants.

Photographs of living coral species and other reef biota taken during this study have been used in various media reports and publications, and for a poster on Kuwait's coral reefs. In addition, some of these photos and data on coral species will be included in the book 'The Corals and Coral Reef Fishes of Kuwait' being prepared for publication in 1996. It is recommended that the coral reference collection be carefully stored and maintained as a permanent working collection at MFD, with additional specimens housed in museums or in other taxonomic collections overseas.

3. Sea temperature records

Corals and coral reefs are generally restricted to tropical seas experiencing moderate sea temperatures above 18°C, and normal oceanic salinity around 35 parts per thousand. By comparison, the northern Arabian Gulf represents an extreme environment for corals and may

limit reef development. Downing (1985) found that sea temperature and salinity vary on a seasonal basis, and recorded sea temperature ranging from 13.2°C to 31.5°C, and salinity ranging from 38.6 to 42.4 ppt on Kuwait's coral reefs. Hodgson and Carpenter (1995) noted that temperatures in shallow water range between 11.5 to 33.4°C in Kuwait, and elsewhere in the Gulf temperatures up to 35.1°C, and salinity up to 70 ppt have been recorded (Coles, 1988; Coles and Fadlallah, 1991).

In order to quantify seasonal extremes and changes in sea temperature, continuous temperature recording data loggers were deployed on the reef flat and reef slope at Qaru reef, and in the MFD Harbour during July 1995. The results have shown that corals and other biota at Qaru reef are subjected to extremely high temperatures above 32°C for considerable periods of time during the summer season (Fig. 3). The highest sea temperature recorded was 33.9°C during August, coinciding with a maximum air temperature recorded in Kuwait above 52°C. This maximum temperature represents a substantial increase in the known thermal tolerance for reef biota in Kuwait. As expected, the reef flat site at Qaru reef was generally warmer and experienced greater fluctuations in temperature than the reef slope site at 5 m depth (Fig 3). The more extreme reef flat environment may limit the distribution of some corals such as *Turbinaria* and *Pavona* species to deeper reef zones.

It is recommended that staff from MFD deploy additional data loggers on the reef flat and reef slope at Kubbar, Umm Al Maradem and Qit'at Urayfijan reefs during December 1995, and that the data from these reefs and Qaru reef be retrieved every 3-4 months in future. Continuous monitoring of temperature on these reefs will allow long-term temperature records and periodic extremes to be documented for these reefs. The data will provide essential information for observing and predicting stress responses of the coral communities to temperature extremes, and for correlating coral gametogenic and spawning patterns with changes in sea temperature. If sufficient funds are available in future, it is recommended that combined temperature and salinity data loggers be deployed on these reefs, in order to monitor both of these important natural environmental parameters likely to affect coral reef communities.

4. Coral reproduction studies

4.1 Coral reproductive ecology

The processes of reproduction, larval development and recruitment of scleractinian reef corals are essential for the initiation, maintenance and renewal of coral reef communities (reviewed by Harrison and Wallace, 1990). Therefore, in order to understand the ecology of coral reefs and predict the likely impacts of disturbance, it is necessary to understand the mode and timing of coral reproduction, and the tolerance of reproductive processes to stress. The recent renaissance in coral reproductive studies has greatly increased understanding of coral reproductive patterns (reviewed in Fadlallah, 1983; Harrison and Wallace, 1990; Richmond and Hunter, 1990). On the Great Barrier Reef, Australia, and in some other coral reef regions, many different species of corals participate in synchronised multi-specific mass spawning events on a few predictable nights each year (Harrison *et al.*, 1984; Willis *et al.*, 1985; Babcock *et al.*, 1986; Harrison and Wallace, 1990; Harrison, 1993). In contrast, in the Red Sea and some areas of the Caribbean, the ecologically dominant coral species have separate spawning periods (e.g. Shlesinger and Loya, 1985; Szmant, 1986).

4.2 Results and conclusions

The hostile environmental conditions in the Arabian Gulf raised questions as to whether local corals would be capable of sexual reproduction, and if so, what the pattern of reproduction within and among species would be. There had been no previous studies of coral reproduction in corals from Kuwait. Developing gametes were found in some coral species during reef surveys in April 1995, so subsequent field and laboratory work focused on coral reproduction studies. During May, more than 100 colonies of the plate and branching coral species *Acropora clathrata* and *Acropora arabensis* at Qaru reef were mapped and tagged to allow repeated sampling and monitoring of known colonies to determine the spawning period. In addition, portions of many colonies were carefully transported back to aquaria at MFD for observations of coral spawning, and for access to spawned gametes and larvae.

Spawning of *Acropora* colonies in aquaria and in the field began a few nights prior to the full moon period in May, with more extensive spawning activity during the week after the full moon. These are the first records of coral reproduction occurring in Kuwait. The spawning behaviour was typical of *Acropora* species (Fig. 4), however, the pattern of spawning was much less synchronous both within colonies and in populations than has been recorded from most other locations (Harrison and Wallace, 1990). Fadlallah (in press) recently reported synchronous spawning in the same *Acropora* coral species from reefs in Saudi Arabia around the full moon periods in April-May. Recent work on the reproduction of subtropical corals from the East coast of Australia has shown an asynchronous pattern of spawning among *Acropora* colonies and species (Harrison, 1993; Wilson, ms submitted), which is similar to that observed in Kuwait.

Many thousands of coral larvae were reared from the spawned *Acropora* gametes, and larvae were able to settle and metamorphose normally. Thus, the *Acropora* spp. in Kuwait are able to reproduce successfully, and therefore potentially contribute to the essential larval settlement and recruitment processes which maintain these northern coral populations. Given the relatively small size and isolation of Kuwait's reefs, the highly buoyant nature of the eggs and developing larvae, and their minimum planktonic development period of 4-6 days, it is likely that the majority of coral larvae are swept away from their natal reefs after spawning occurs. The subsequent patterns of larval dispersal are likely to vary from year to year according to local circulation and wind patterns in the northern Arabian Gulf. The longer these larvae are able to survive and remain competent to settle, the greater chance of their dispersal to other regions. Of particular interest is the fact that some *Acropora* spp. larvae survived for more than a month, and one *Acropora arabensis* larva was still able to settle successfully four weeks after spawning. This suggests that some coral larvae from Kuwait may be transported substantial distances within the Arabian Gulf, and may recruit onto reefs in Saudi Arabia and other southern regions. Thus coral reefs in this region are likely to be biologically interconnected, which has important implications for management of coral reefs on an international rather than national basis.

Additional detailed study on reproductive patterns of other ecologically important species showed that the brain coral *Platygyra daedalea* spawned mainly 4-5 nights after the June full moon. The spawning behaviour was identical to that observed for this species on the Great Barrier Reef (Fig. 5; cf. Willis *et al.*, 1985, and Babcock *et al.*, 1986), and spawning was more synchronous

within and among colonies compared with the pattern of spawning observed in *Acropora* spp. during May. *Platygyra* larvae were reared successfully for a few days after spawning, but most of these larvae died suddenly a few days later preventing further detailed study. Additional studies of coral spawning patterns were completed in July 1995. Dissections of coral samples collected on 22 July indicated that some massive *Porites* colonies had maturing sperm and may have spawned in August, and one *Favia* brain coral colony had immature sperm indicating that spawning probably occurred in late August or September. Thus, this aspect of the project has been more successful than anticipated. The study has been the first to demonstrate that the major reef-building corals of Kuwait are sexually reproductive, and have an extended spawning period from May until at least August.

The coral spawning behaviour was recorded with macro-photographs and on video. These images have been used to highlight the discovery of the coral spawning in various media reports in Kuwait and overseas (refer to section II.E). The results of this study will be published in an international refereed journal. The discovery of coral spawning in Kuwait creates substantial new opportunities for future research, and also provided access to spawned gametes and larvae for stress and toxicity experiments, as outlined in section II.C. Gametogenic samples collected prior to the spawning periods in 1995 provide a means of assessing polyp fecundity among different coral species.

4.3 Recommendations

It is recommended that research on coral spawning patterns continue in future to confirm the spawning patterns observed in 1995, and to document the spawning periods of other coral species in Kuwait. In particular, the mode and timing of reproduction of *Porites* spp. and *Favia* should be studied further. Additional gametogenic samples should be taken from ten tagged colonies of *Acropora arabensis, A.clathrata* and *Platygyra daedalea* at Qaru reef by MFD staff. The samples should be collected during December 1995, and in 1996 during February, April, and just prior to spawning to determine the gametogenic cycles of these species. Further training in polyp dissections and fecundity analysis will be required. The patterns of gamete growth and maturation should be compared with seasonal changes in sea temperature recorded from data loggers. In addition, long-term experiments to determine the effects of temperature on

the cycles of gametogenesis and spawning in two coral species should be set up at MFD. Detailed studies of the rates of larval development and longevity should be done to determine the dispersal potential for coral larvae from Kuwait's reefs. This study could be done in conjunction with oceanographers at MFD.

5. Coral growth studies

The rate at which coral colonies grow is an important factor in reef development. No previous studies of coral growth have been done in Kuwait. More than 40 colonies of *Acropora arabensis, A. clathrata, Porites compressa, P. lutea* and a few brain coral colonies were stained with Alizarin Red S calcium stain during September and October at Qaru reef. The alizarin stain is incorporated into actively growing areas of the coral skeleton, and leaves a permanent stain line which can be used to determine subsequent growth rates.

It is recommended that samples of the stained coral colonies be collected by MFD staff assigned to the project, during April and in September-October 1996. This will allow the growth rate after 6 and 12 months to be determined for the major reef building corals in Kuwait. The data on coral growth rates will be published in a international refereed journal, and the data should be used by management authorities to help predict the likely rate of recovery of coral communities from future mortality events. In addition, it is recommended that the size of some of the larger colonies of each species be accurately measured in order to determine their approximate age. The largest *Porites lutea* colonies observed at Qaru reef were metres in diameter, and are likely to be many hundreds of years old. An additional project for future consideration would be analysis of skeletal cores taken from these large *Porites* colonies using the coring techniques developed by Isdale (1984). Analysis of such cores from other regions have shown that skeletons of massive *Porites* corals provide long-term records of climate, rainfall, and pollution events affecting the reef environment (e.g. Isdale, 1984; Barnes and Lough, 1989; Dodge et al., 1992).

6. Heavy metal levels in corals

Recent work has shown that reef corals are useful bio-indicators for monitoring heavy metal pollutants in reef environments (e.g. Hanna and Muir, 1990; McConchie and Harriott, 1992). There are no data on the levels of heavy metals in corals from Kuwait. It had been proposed to sample selected species of corals from the major reef sites in Kuwait to determine heavy metal levels in their tissues. However, this aspect of the project has not been completed due to delays in funding for this research. This work is now being done in collaboration with Dr. Bou-Olayan from Kuwait University, an analytical chemist specialising in heavy metal analysis. Due to the complexity of the analysis, a pilot study has been initiated to examine heavy metal levels in corals from Qit'at Urayfijan, which is an inshore reef close to a major industrial port, and therefore likely to be exposed to heavy metal pollutants. Samples from *Porites compressa* and the brain coral *Cyphastrea microphthalma* were collected from Qit'at Urayfijan in November 1995, and will be analysed during 1996.

Based on the results of the pilot study, further samples should be collected from the four major reefs in Kuwait to determine heavy metal levels in coral tissues from the same species, in sediment, and in seawater. These sites represent a range of reef environments likely to differ in their ambient concentrations of heavy metal pollutants. Once detailed information on the type and concentrations of heavy metals is available, coral tissues could be used to monitor heavy metal pollution in Kuwait waters.

C. Phase 2: Ecotoxicology of immature and mature corals

1. Ecotoxicology experiments with coral gametes and larvae

Spawned gametes and coral larvae have recently been used to test the toxicity of oil hydrocarbons, dispersants, heavy metals and nutrients on essential sexual reproductive processes (Harrison, 1994, in prep.; Reichelt and Harrison, in prep; Harrison and Ward, in prep). The results indicate that these reproductive phases are very sensitive to toxicants.

1.1 Effects of salinity on fertilization rates in corals

Following the main night of *Acropora* spp. spawning on 17 May, an experiment was done to examine the effects of different seawater salinities on fertilization rates of *Acropora clathrata* gametes. World ocean salinity averages 35 ppt, whereas salinity in the Arabian Gulf is higher, and salinities of 38-42 ppt have been recorded around Kuwait's reefs (Downing, 1985). Spawned eggs and sperm from different colonies were exposed to different salinities, and percentage fertilization rates determined after 4-6 hours. Five replicate vials were used for each pollutant concentration and the control treatments with normal seawater, and the experiment was duplicated using a reciprocal cross-fertilization design (Harrison, 1994).

Normal high rates of fertilization (92-100% mean fertilization) occurred in 39, 36 and 32 ppt salinity; 75-85% fertilization occurred at 27 ppt; and fertilization was blocked at 21 and 18 ppt and below. The results indicate that the high salinity levels around reefs in Kuwait probably do not inhibit fertilization. Not surprisingly, substantial lowering of salinity results in reduced fertilization, however lowered salinity is unlikely to occur around reefs in this region, particularly during the period of coral spawning. The results of this study will be published as a short paper in an international refereed journal.

1.2 Effects of oil hydrocarbons on coral larval settlement

An experiment was done to examine the effects of the water accommodated fractions (WAF) of Kuwait light crude oil on the ability of *Acropora arabensis* coral larvae to settle and metamorphose into juvenile polyps. The oil WAF in seawater was prepared following the methods of Harrison (1994), and a known number of larvae (approximately 50-60) were added to four replicate beakers in five treaments. The treatments were four concentrations of oil WAF and the control treatment containing normal seawater. Each beaker contained 400 mls of treatment solution and natural reef substratum partly encrusted with coralline algae to provide a suitable substratum for larval settlement (see Harrison and Wallace, 1990). The number of coral larvae settling on the reef substratum after 24 hours was recorded and the data are tabulated below.

Percentage settlement of *Acropora arabensis* larvae in four concentrations of Kuwait oil WAF and in seawater controls after 24 hours exposure (4 replicates per treatment). (P.Harrison, S.Alhazeem, A. Alsaffar and I. Al-Sabah, unpubl. data).

Treatment	A	B	C	D	Mean	Std. Dev.
Control	26.4	52.0	54.1	42.2	43.7	12.63
0.01 ppm oil	34.0	52.6	66.0	31.3	46.0	16.37
0.1 ppm oil	0.0	10.2	24.5	11.1	11.5	10.05
0.31 ppm oil	10.7	4.4	0.0	3.0	4.5	4.51
1.0 ppm oil	0.0	0.0	0.0	0.0	0.0	0.0

A relatively high mean rate of settlement (43-46%) occurred in the seawater control and 0.01 ppm oil WAF treatments, whereas settlement was reduced to 11.5% in 0.1 ppm oil. Only 4.5% settlement occurred in 0.3 ppm oil, and settlement was blocked at 1.0 ppm oil WAF. The results clearly show that WAF of Kuwait crude oil inhibits or blocks settlement of coral larvae at relatively low concentrations. This suggests that oil pollution has the potential to disrupt the critically important larval settlement processes which are responsible for the maintenance and renewal of coral communities. This may be important for coral communities at Qaru reef which is subjected to frequent oiling from natural oil seeps within a few kilometres of the reefs, and for coral communities at Qit'at Urayfijan which is situated near major oil loading facilities.

These are the first data on the effects of oil hydrocarbons on the settlement of larvae from broadcast spawning corals, and will be published as a short paper in an international refereed journal. It had been planned to use larvae from the brain coral *Platygyra daedalea* for further experiments on the effects of oil WAF on larval settlement. However, the *Platygyra* larvae died unexpectedly a few days after spawning, hence no further opportunity existed to continue this work during 1995.

The same method of preparation of the oil WAF was used in subsequent studies by F.S.H Abram, UNDP/ UNIDO Expert in ecotoxicology, and the Ecotoxicology Laboratory team from ESD, KISR to examine the acute lethal toxicity of oil WAF to brine shrimp nauplius larvae, and on the inhibition of hatching of brine shrimp eggs exposed to oil WAF. Initial comparisons of the data suggest that coral planula larvae may be more sensitive to oil WAF than brine shrimp larvae,

which are a standard test organism for ecotoxicology work in many laboratories worldwide (F. Abram, pers. comm.).

1.3 Recommendations

The successful salinity and oil pollution experiments clearly demonstrate that toxicity experiments with coral gametes and larvae are feasible, and can provide important new data on the effects of stressors on coral reproductive success. It is therefore recommended that further experiments be done during the main coral spawning period in May-June 1996, to examine the effects of elevated salinity, oil hydrocarbons, and heavy metals (including nickel, vanadium, copper, and lead) on fertilization rates, larval development and settlement of coral larvae. It is also recommended that comparative toxicity studies on coral larvae and brine shrimp be done in future, to compare the relative sensitivity of these organisms to a range of toxicants. The results of these experiments would provide a framework for predicting the impacts of natural and anthropogenic stressors on coral reproduction, and could be used to establish water-quality guidelines for coral reef areas in Kuwait.

2. Trials with adult corals

Trials to maintain adult corals in flow-through aquarium conditions at MFD, KISR were begun in April 1995, and continued throughout 1995. Portions of colonies representing a range of dominant reef-building coral species were collected from three reef sites from April to July 1995, and maintained in various large-capacity holding tanks with flowing seawater and aeration. Corals became slightly stressed in shallow tanks subjected to direct sunlight, and grew and survived best in deeper 5,000 litre capacity tanks which are shaded from direct sunlight. Coral colonies survived and grew well up until September, when many colonies were smothered by excessive algal growth. Nuisance algal growth could be controlled by maintaining corals in indoor laboratory aquaria with artificial lighting. The results of these trials were used to establish appropriate conditions for maintaining adult corals and larvae during the coral spawning periods in May and June 1995. Some of the corals collected for this project were used for an aquarium display of corals from Kuwait during the official opening and inauguration of the newly completed offices at MFD in November 1995.

The trials demonstrate that adult corals of many species, including sensitive *Acropora* branching corals, can be successfully maintained at MFD. Therefore experiments using adult corals are feasible at MFD. It had been planned to initiate pilot studies examining the effects of temperature on growth and suvival of adult corals during this project, however delays in obtaining funding and equipment prevented scheduled work on this aspect. These experiments could be done in future using equipment now available at MFD. In addition, it had been planned to begin experiments on the effects of oil pollutants on adult corals, in collaboration with F.S.H. Abram, UNDP/ UNIDO Expert in ecotoxicology, and Dr Lulwa Ali, ESD, KISR. However, delays in completion of the Ecotoxicology Laboratory building prevented collaborative studies during 1995. It is recommended that experiments on the ecotoxicological responses of adult corals to oil pollutants be initiated when testing of the oil-dosing apparatus, developed by F.S.H Abram for KISR, is completed, and when appropriate expertise in coral biology and oil analysis is available.

D. Phase 3: Data Analysis and Integration

1. Critical factors limiting coral communities in Kuwait

1.1 Natural stressors and limiting factors

Kuwait's coral reef communities exist in an extreme environment which appears to be close to the limits for coral survival and reef development. Periodic natural perturbations exceed the tolerance limits for some corals, and coral mortality occurs. Previous surveys by N. Downing and co-workers have shown that periods of coral stress and mortality have occurred in 1982-83 and 1984-85, with subsequent recruitment and regrowth, and in the winter of 1991-92. In most instances, unusually cold winter sea temperatures coinciding with extreme low tides are implicated in the coral mortality, and shallow water reef flat coral communities are most affected. Thus, cold winter temperatures and periodic exposure to air appear to be the most important natural factors limiting the upward growth and development of coral communities in Kuwait. Other potentially important natural limiting factors for these reefs include: extreme

high sea temperatures and elevated salinity in summer; high sediment levels, particularly on northern, inshore reefs; and grazing pressure by high densities of *Echinometra mathaei* and other sea urchins, which are major bioeroders, and are likely to limit recruitment of corals and other benthic invertebrates and algae. In addition, experimental data from this project show that settlement of larvae of one coral species is inhibited by relatively low levels of oil hydrocarbons in seawater. Therefore, the natural oil seeps which are prevalent around Qaru reef may periodically inhibit settlement of larvae, and could potentially stress adult corals.

1.2 Human-induced disturbances and pollution stressors

The roles of human-induced disturbance and pollution stressors on Kuwait's coral reefs are not easily assessed. Potential problems include physical damage, litter, overfishing, and chemical and biological pollution.

Anchor damage

The most obvious form of physical disturbance observed during this project was anchor damage and breakage of coral colonies. For example, fragmented coral had a mean cover of 1.3% at Qaru reef site 1, and in transect 9 at this site, 3.4% cover was from fragmented *Acropora clathrata* colonies (Table 1). In the absence of evidence for damage by waves or storms, it is apparent that most of the coral breakage observed resulted from anchors dropped onto, and anchor chains dragged over, coral colonies while small boats were anchored on the reef. Branching *Acropora* and *Stylophora* colonies are most susceptible to anchor damage, although broken *Porites* colonies and overturned massive corals were also evident at some sites. One of the large *A. clathrata* plate coral colonies tagged for reproductive studies was fragmented by an anchor.

Nothing is known about the survival of coral fragments on these reefs, however, it is likely that the smaller fragments will suffer significant mortality. Larger pieces of coral that are overturned or become wedged in the reef are more likely to survive and regrow. Although no data are available, it is possible that the reduced abundance of branching corals at Umm Al Maradem and Kubbar reefs may be related to the high visitation rates at these reefs. These are among the most popular and accessible reefs for boating and fishing trips, hence it is possible

that chronic impacts from anchoring of many vessels may have reduced the abundance of fragile coral species.

Litter

Many of the sites at Qaru and Umm Al Madadem reefs had obvious litter scattered over the reef. In some cases, bags, clothing, blankets, and other household refuse were found entangled in corals and were smothering or abrading the living tissues. As well as reducing the visual amenity values of these reefs, the litter could potentially cause mortality to sea turtles and fish. Much of the rubbish observed appears to have been deposited by Coast Guard personnel stationed on Qaru and Umm Al Maradem islands, and on a number of occasions, members of the Coast Guard were observed throwing large plastic bags full of rubbish onto the reef from the jetty at Qaru island. In one incident, a member of the Coast Guard fired a bullet at a floating bag of rubbish within 50 metres of the anchored research vessel while divers were working in the adjacent reef area. The incident was reported to appropriate authorities. Similar incidents of littering were recorded by Downing (1989). In addition, it is likely that some of the litter has been thrown onto the reefs by visitors in small boats. The problem of litter on these reefs is being partly rectified by volunteer divers who are collecting and removing rubbish from the main reef sites. A recent co-ordinated reef clean-up campaign removed a substantial amount of litter from the main reef sites, and further campaigns are planned for the future (M. Horn, Dive Caroline, pers. comm.).

Ordnance

Although military ordnance from the Gulf War have been removed from the coral reef islands, ordnance are present on some areas of the reef at Umm Al Maradem. At site 1, metal casings from exploded anti-aircraft shells were scattered over the reef, and in some instances were being overgrown by corals. At site 2, an unexploded cluster bomb was observed within the transect area, and was reported to the authorities.

Fishing pressure

There are no data available on the impacts of fishing on coral reef-associated fish populations in Kuwait. Downing (1985, 1989, 1992) provided survey data on reef fishes at the main reef sites, however, no recent detailed quantitative data are available for comparison. Local diving groups

have reported a decline in fish diversity and abundance in recent years, coinciding with an increase in spear-fishing activity (M. Horn, Dive Caroline, pers. comm.). Very few fish larger than 20 cm were observed at Umm Al Maradem and Kubbar reefs during reef surveys in 1995, and a decrease in the number of large territorial fish and parrotfish were evident at Qaru reef towards the end of the survey period. The extent to which these observations are related to increased fishing pressure is not known. In addition to line fishing and spearfishing on the coral reefs, traditional gargoor fish traps are frequently deployed around the main reefs to capture fish. In many cases, the surface buoys marking the location of the gargoor are lost, leaving the wire cage unattended but continuing to capture fish which slowly perish (J. Bishop, MFD, pers. comm.). Overfishing may endanger local populations of important fish species, and lead to changes in other components of the reef community. Therefore, the impacts of fishing on coral reef fish populations in Kuwait requires detailed study in future.

Chemical pollution

Apart from the results of the experiment on the effects of oil pollution on settlement of coral larvae, there are no data available on the impacts of chemical pollutants on coral reef biota from Kuwait. The inshore reef sites such as Qit'at Urayfijan which lie closest to major industrial and port facilities at Shu'aibah may receive diluted effluent from local industries and port activities, however, no details about the chemical composition or quantity of effluents are available. Potential problems include heavy metal contaminants, elevated nutrient levels, and oil pollutants. In addition, chronic oil pollution resulting from pumping of bilges and spillages during loading of oil tankers has been reported. At offshore reefs, problems could occur from degradation of munitions and litter such as portable and car batteries observed at some sites. Further detailed studies on water quality and heavy metal contamination of reef biota are needed.

Biological pollution

There is no evidence of introduced species posing a threat to Kuwait's coral reefs, however, the local culture of exotic fish species, and the discharge of ballast water from ships could potentially lead to the introduction of pest species in future.

1.3 Conclusions

At present there is insufficient information available on these problems to assess the impacts of human-induced disturbances and pollutants to Kuwait's coral reefs. Detailed studies of water quality around coral reef systems, and experimental studies of the impacts of coral fragmentation, fishing pressure, and pollutants on adult corals and other reef biota are needed.

2. Management of Kuwait's coral reef ecosystems

Kuwait has a range of unique and important coral reef ecosystems within its territorial waters. Growing public awareness and use of coral reefs will create increasing pressure on these resources in future. Therefore, it is essential that these reefs are managed correctly in a manner promoting sustainable and wise use. Based on the results of this project, and previous research at MFD, the following management issues need to be addressed.

1. Mooring buoys need to be installed at the major reef sites to prevent further anchor damage to corals. Studies will be needed to determine the most important sites for moorings based on the fragility of the coral community and visitation rates. The most sensitive sites observed in this study are the *Acropora* dominated reef flat areas at Qaru reef, which are highly susceptible to anchor damage. The style of mooring and attachment to the reef, and public acceptance of the use of moorings rather than anchoring on the reef, will also need careful consideration. The Kuwait Diving Team, a volunteer diving group, have plans to install moorings at some reef sites in the near future (H. Alsaffar, pers. comm.).

2. Restrictions on fishing, and the banning of spearfishing, need to be implemented for Qaru, Kubbar and Umm Al Maradem reefs to allow reef fish populations to recover. In addition, diving groups should be encouraged to remove abandoned gargoor fish traps in the vicinity of reefs, and restrictions should be placed on the number of gargoor allowed within 500 metres of these reefs.

3. Further litter removal campaigns need to be encouraged to remove the remaining rubbish on the reefs, and on the islands. In addition, it is essential that the Coast Guard personnel stationed on the islands discontinue the practice of throwing refuse onto the reefs. Rubbish bins have

recently been provided on the islands, and the problem of reef littering has been brought to the attention of senior Coast Guard management.

4. A public education campaign is needed to increase understanding of the importance of Kuwait's coral reefs and their sensitivity to damage and pollution. Issues to be highlighted should include the use of moorings to prevent damage to corals, the need for restrictions on fishing on these reefs, the problems caused by littering and refuse, and the need for public participation in the management of Kuwait's coral reefs.

5. A single authority should be designated and empowered to manage Kuwait's coral reefs. International experience has shown that management of protected areas is more difficult where many authorities are involved in the management decisions. The Great Barrier Reef Marine Park Authority in Australia provides a useful model of a single authority managing coral reef environments. The recently announced Environmental Protection Authority in Kuwait could provide an appropriate management authority for the coral reefs in Kuwait, however, the present status of the EPA is uncertain.

6. When an approriate management authority is designated, a detailed management plan should be prepared to promote the sustainable and wise use of Kuwait's coral reefs. The major coral reefs in Kuwait should be protected as Marine National Parks or Marine Protected Areas within an integrated management plan. A multiple use zoning plan, similar to that developed for the Great Barrier Reef Marine Park in Australia (e.g. Kelleher, 1987) should be developed to allow different activities in different areas of reef, while providing high levels of protection for ecologically important sites. The zoning plans should be prepared in conjunction with scientists, current users of the reef resources, the general public and government authorities, and subject to review in future. Consideration should also be given to protecting sensitive nesting sites for endangered species of sea turtles and migratory birds on the offshore sand islands.

These recommendations provide a framework for further work on management issues. A number of these issues have been addressed in meetings with representatives from various government and scientific organisations, diving groups and local educators.

E. Additional Activities

1. Publications and media reports arising from this Project

Information and photographs from this project have been used in various publications and media reports in Kuwait and internationally. Following the discovery of coral spawning in Kuwait corals a press release was prepared for KISR in May. As a result, the story was highlighted in news articles in three local Arabic daily newspapers, and in the KISR monthly magazine. Additional articles and reports about this project have been produced for a 5-minute television program on Kuwait TV-1, a radio interview for a local Arabic radio network, an article written for the KISR monthly magazine, an article for the UNDP magazine 'Making a difference' celebrating the 50th anniversary of the United Nations, an article for the KISR International newsletter and for the Kuwait Digest magazine, and in three newspaper and two radio reports in Australia. A poster using photographs of Kuwait's coral reefs from this project has been printed at KISR (3,000 copies printed).

The coral photographs and community data will be incorporated into a new guide book on 'The Corals and Coral Reef Fishes of of Kuwait' funded by KISR and EPC, to be published in 1996. A major display about the project work was prepared for the inauguration of the new Mariculture and Fisheries Department buildings during November 1995, and included posters, a display of live corals, and video of coral spawning and reef transects (Fig. 6). These publications and news reports have served to increase public and scientific awareness about Kuwait's coral reefs, and have provided good publicity for this UNDP/UNIDO and KISR Project, and the MFD scientists working on this project.

2. Project seminar

A seminar outlining the background to this project, and the aims and scope of the research was presented at the Mariculture and Fisheries Department, KISR, on 26 April 1995. The seminar was attended by many staff from MFD, Mayada Homad from UNDP, and students and staff from the Kuwait University. The seminar stimulated substantial interest in the project.

3. Training of MFD, KISR staff

Training of KISR personnel assigned to this project has included: experimental and ecological survey design, underwater video survey techniques, coral sampling techniques, quantitative community analysis, data logger training, photographic techniques, coral taxonomy, coral reproduction studies, toxicity studies, coral staining for growth studies, coral transplantation, aquarium maintenance, data analysis, scientific report writing skills, seminar presentation skills, and media liaison. The main staff member assigned to this project, Mr Shaker Alhazeem, has applied for a KISR M.Sc. scholarship to continue his training on coral reef ecology at Southern Cross University in Australia. Mr Alhazeem has been accepted into the M.Sc. course at Southern Cross University, and the additional training would greatly benefit future coral reef projects at KISR.

4. Other activities

Collaborative plans for toxicology research were discussed with F.S.H. Abram, UNDP/ UNIDO Expert in ecotoxicology, and Dr Lulwa Ali from ESD, KISR. The use of satellite images of Kuwait's coral reefs to compare the reef survey data from this project, with current and past satellite images, were discussed with Dr Andy Kwarteng, Research Scientist on Remote Sensing, EES, KISR, and a future collaborative project is planned. The results of this project and reef management issues have been discussed during meetings with KISR, the UNDP, representatives from the Kuwait Environmental Protection Council, Dr John Grainger who is preparing a biodiversity strategy for Kuwait, and commercial and private scuba diving groups who use Kuwait's coral reefs. In addition, micro-photographs of brine shrimp were taken for F.S.H. Abram for the Ecotoxicology Laboratory poster displays, and photographs of the opening were taken for MFD staff. It is likely that some of the reef photographs taken during this project will be used to produce a set of stamps from Kuwait, highlighting local coral reefs.

III. SUMMARY OF RECOMMENDATIONS

Specific and detailed recommendations to consolidate and develop the results of this mission are made throughout this report, and a summary of the major recommendations is provided here. It is recommended that:

1. Staff from MFD, KISR associated with this project continue quantitative surveys of the main coral reefs, and other reef systems in Kuwait. In addition, collection of coral gametogenic samples should continue until June 1996, and temperature and other environmental parameters at the main coral reef sites in Kuwait should be continually monitored using data loggers, and the data retrieved at approximately 3 monthly intervals. Two MFD staff need to be allocated to work full-time on these studies until at least June, 1996.

2. The quantitative reef surveys at the main coral reef sites in Kuwait be repeated 1996-97 by MFD, KISR staff in conjunction with international expertise, to determine the efficacy of repeated surveys using video transect techniques; and thereafter, that these surveys be repeated annually or every two years by trained MFD, KISR staff to monitor the health of these reef ecosystems.

3. Management plans for the long term protection of Kuwait's coral reef ecosystems be developed and implemented by a designated authority during 1996, with priority being given to installation of boat moorings to avoid further anchor damage to corals, monitoring of fishing impacts on reef fish populations, and public education programs to raise awarenes of the importance of these reefs and the need for their wise and sustainable use.

4. Further studies on coral spawning patterns, and experiments on the effects of natural and pollution stressors on coral gametes and larvae be undertaken at MFD, KISR during May-June 1996 in conjunction with international expertise, to provide detailed information on coral reproduction and tolerance limits of corals to stressors.

5. A rapid response plan be developed to quantify and monitor impacts and any subsequent mortality or recovery of Kuwait's coral reef communities resulting from natural catastrophes, and

human disturbance including pollution events. This plan could be co-ordinated through the EPA, KISR and appropriate authorities.

6. A project be developed to compare the results of the recent coral community surveys with satellite images, so that remote sensing techniques can provide a long-term view of any broad-scale changes in reef communities. This project could be initiated during 1996 by ESD and MFD, KISR. Additional collaborative studies on the effects of oil pollutants on corals should be undertaken when appropriate expertise in coral biology and oil toxicology is available.

7. Future co-operative projects proceed when funds specifically allocated for the project by KISR are available for immediate use at the start of the project. The level of funding, staffing, and other logistical support required for the project should be determined in conjunction with the Expert prior to the commencement of the main mission. In some instances, this may require a preliminary assignment to assess the requirements for the project.

ACKNOWLEDGEMENTS

The following people and organisations are thanked for their essential support for this project: the United Nations Development Programme, the United Nations Industrial Development Organisation and the Kuwait Institute for Scientific Research provided funding and logistical support for this project; Shaker Alhazeem and Adel Alsaffar provided continuous excellent work and support for all aspects of this project, including substantial research work after-hours and on weekends and public holidays; Iman Al-Sabah assisted with research on oil experiments and corals during April to June; Mayada Homad, UNDP, maintained guidance for the project; Dr Sulaiman Almatar, Dr Nader Al-Awadhi and Dr Al-Attar supported funding though KISR; Alan Lennox, Katta Sudanandam, Mike Hanson, Aws Alghunaim, Walid Alzakri, Katta Tirulapu provided diving and boating support for the extensive field work; Fred Abram provided guidance on the use of dilution series conforming to standard toxicity tests and assisted on some nights of coral spawning.

REFERENCES CITED

Babcock, R.C., Bull, G.D., Harrison, P.L., Heyward, A.J., Oliver, J.K. , Wallace, C.C. and Willis, B.L. (1986). Synchronous spawning of 105 scleractinian coral species on the Great Barrier Reef. **Marine Biology, 90**: 379-394.

Bak, R.P.M. (1987). Effects of chronic oil pollution on a Caribbean coral reef. **Mar. Pollut. Bull. 18**: 534-539.

Barnes, D.J. and Lough, J.M. (1989). The nature of skeletal density banding in scleractinian corals: finebanding and seasonal patterns. **J. Exp. Mar. Biol. Ecol.126**: 119-134.

Carleton, J. and Done, T. (1995). Quantitative video sampling of coral reef benthos: large-scale application. **Coral Reefs 14:** 35-46.

Clarke, K.R. (1993). Non-parametric multivariate analyses of changes in community structure. **Aust. J. Ecol. 18**: 117-143.

Coles, S.L. (1988). Limitations on reef coral development in the Arabian Gulf: temperature or algal competition? **Proc. 6th Int. Coral Reef Symp., Townsville, 1988, 3**: 211-216.

Coles, S.L. and Fadlallah, Y.H. (1991). Reef coral survival and mortality at low temperatures in the Arabian Gulf: new species-specific lower temperature limits. **Coral Reefs 9**: 231-237.

Davies, P.S. (1989). Short-term growth measurements of corals using an accurate buoyant weighing technique. **Mar. Biol. 101**: 389-395.

Dodge, R.E., Szmant, A.M., Garcia, R., Swart, P.K., Forester, A. and Leder, J.J. (1992). Skeletal structural basis of density banding in the reef coral *Montastrea annularis*. **Proc. 7th Int. Coral Reef Symp., Guam, 1992, 1**: 186-195.

Downing, N. (1985). Coral reef communities in an extreme environment: the northwestern Arabian Gulf. **Proc. 5th Int. Coral Reef Congr. Tahiti 6**: 343-348.

Downing, N. (1989). A study of the corals and coral reef fishes of Kuwait. 2. The reef building corals. Kuwait Institute for Scientific Research Final Project Report MB-42, 144 pp.

Downing, N. (1991). A survey of the coral islands of Kubbar, Qaru and Umm Al Maradem, Kuwait, 13-19 July, 1991. **Report to the IUCN and the WWF**, pp 1-12.

Downing, N. (1992). Kuwait's coral reefs: what future after the Gulf War? **Proc. 7th Int. Coral Reef Symp., Guam, 1992, 2**: 959-968.

Downing, N. and El-Zahr, C.R. (1987). Gut evacuation and filling rates in the rock-boring sea urchin, Echinometra mathaei. **Bull. Mar. Sci. 41**: 579-584.

Downing, N. and Roberts, C. (1992). Report presented to Dr. Habashi (EPC Special Representative) on a survey of Kuwait's coral reefs undertaken on 28 November - 2 December 1992. 33 pp.

Downing, N. and Roberts, C. (1993). Has the Gulf War affected coral reefs in the northwestern Gulf? **Mar. Poll. Bull., 27**: 149-156.

Downing, N. Alsaffar, A. and Priest, R. (1989). A study of the corals and coral reef fishes of Kuwait. 4. Charting Kuwait's coral reefs. Kuwait Institute for Scientific Research Final Project Report MB-42, 60 pp.

Fadlallah, Y.H. (1983). Sexual reproduction, development and larval biology in scleractinian corals. A review. **Coral Reefs 2**: 129-150.

Fadlallah, Y.H., Eakin, C.M., Allen, K.W., Estudillo, R.A., Rahim, S.A., Reaka-Kudal, M., and Earle, S.A. (1993). Reef coral distribution and reproduction, community structure and reef health (Qatar, Bahrain, Saudi Arabia and Kuwait). In: Anon, 1993. Final Report of the Scientific Workshop on the results of the R.V. Mt. Mitchell cruise in the ROPME sea area. Vol. 1, Kuwait, 24-28 January 1993. ROPME-IOC-UNEP-NOAA-EPC, pp. 1-27.

Hanna, R.G. and Muir, G.L. (1990). Red Sea corals as biomonitors of trace metal pollution. **Environ. Monit. and Assess. 14**: 211-222.

Harriott, V.J., Smith, S.D.A. and Harrison, P.L. (1993). Distribution patterns of coral communities in the Solitary Islands Marine Reserve, N.S.W. **Mar. Ecol. Progr. Ser. 109**: 67-76.

Harriott, V.J., Harrison, P.L., and Banks, S.A. (1995). The coral communities of Lord Howe Island. **Mar. Freshw. Res.**, 46: 457-465.

Harrison, P.L. (1985). Sexual characteristics of scleractinian corals: systematic and evolutionary implications. **Proc. Fifth Int. Coral Reef Congress, Tahiti, 4**: 337-342.

Harrison, P.L. (1988). Comparative ultrastructure of scleractinian spermatozoa and its evolutionary implications. **Ph.D. Thesis**, James Cook University of North Queensland, Townsville, 282 pp.

Harrison, P.L. (1990). Sperm morphology and fertilization strategies in scleractinian corals. **Advances in Invertebrate Reproduction, Vol. 5**: 299-304. Elsevier Science Publishers, Amsterdam.

Harrison, P.L. (1993). Coral spawning on the Great Barrier Reef. **Search, 24**: 45-48.

Harrison, P.L. (1994). The effects of oil pollutants on fertilization rates in the scleractinian coral *Acropora tenuis*. **Australian Coral Reef Society Annual General Meeting**, Townsville, 1994.

Harrison, P.L., Babcock, R.C., Bull, G.D., Oliver, J.K., Wallace, C.C. and Willis, B.L. (1984). Mass spawning in tropical reef corals. **Science, 223**: 1186-1189.

Harrison, P.L., Collins, J.D., Alexander, C.G and Harrison, B.A. (1990). The effects of fuel oil and dispersant on the tissues of a staghorn coral *Acropora formosa* : a pilot study. **Proc. Second Workshop on the Role of the Scientific Coordinator on Oil Spill Response, HMAS Cerberus, Victoria, 1990**. pp. 51-61.

Harrison, P., Holmes, N., Banks, S. and Harriott, V. (1995a). Conservation values of Flinders Reef and Myora Reef - Moreton Bay Marine Park. Report for the Queensland Department of Environment and Heritage. **Centre for Coastal Management Report**, 44 pp.

Harrison, P., Harriott, V. and Banks, S. (1995b). Status of the marine benthic communities of Lord Howe Island. Report prepared for the Australian Nature Conservation Agency, Canberra, 62 pp.

Harrison, P.L. and Wallace, C.C. (1990). Reproduction, dispersal and recruitment of scleractinian corals. Chapter 7. In: Z. Dubinsky (Editor), **Coral Reef Ecosystems**, Ecosystems of the World Vol. 25. pp. 133-207. Elsevier Science Publishers, Amsterdam.

Hodgson, G. and Carpenter, K. (1995). Scleractinian corals of Kuwait with a description of a new species. **Pacific Science 49**: 227-246.

Hurlbert, S.H. (1984). Pseudoreplication and the design of ecological field experiments. **Ecol. Monogr. 54**: 187-211.

Isdale, P. (1984). Flourescent bands in massive corals record centuries of coastal rainfall. **Nature 310**: 578-579.

Johannes, R.E. (1975). Pollution and degradation of coral reef communities. In, **Tropical Marine Pollution**. Ed. by F.Wood and R.Johannes. Elsevier Oceanography Series, 12, pp. 13-51.

Kellefer, G. (1987). Management of the Great Barrier Reef Marine Park. **Austr. Parks and Recreation 23**: 27-33.

Loya, Y. and Rinkevich, B. (1980). Effects of oil pollution on coral reef communities. **Mar. Ecol. Progr. Ser. 3**: 167-180

Oliver, J., De'ath, G., Done, T., Williams, D., Furnas, M., and P. Moran (1995). Long-term monitoring of the Great Barrier Reef. Status Report Number 1, Australian Institute of Marine Science, 121 pp.

McConcjie, D. and Harriott, V.J. (1992). The partitioning of metals between tissue and skeletal parts of corals: application in pollution monitoring. **Proc. 7th Int. Coral Reef Symp., Guam, 1992, 1**: 97-103.

Richmond, R.H. and Hunter, C.L. (1990). Reproduction and recruitment of corals: comparisons among the Caribbean, the tropical Pacific and the Red Sea. **Mar. Ecol. Progr. Ser. 60**: 185-203.

Saenger, P. (1994). Cleaning up the Arabian Gulf: aftermath of an oil spill. **Search 25**: 19-22.

Sheppard, C.R.C. and Wells, S.M. (1988). Saudi Arabia. In, **Coral Reefs of the World. Indian Ocean, Red Sea and Gulf**. IUCN/UNEP, Nairobi, 2: 271-290.

Shlesinger, Y. and Loya, Y. (1985). Coral community reproductive patterns: Red Sea versus the Great Barrier Reef. **Science, 228**: 1333-1335.

Szmant, A.M. (1986). Reproductive ecology of Caribbean reef corals. **Coral Reefs, 5**: 43-54.

Willis, B.L., Babcock, R.C., Harrison, P.L., Oliver, J.K. and Wallace, C.C. (1985). Patterns in the mass spawning of corals on the Great Barrier Reef from 1981 to 1984. **Proc. Fifth Int. Coral Reef Congress, Tahiti, 4**: 343-348.

Annex 1: Job description

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

JOB DESCRIPTION

DP/KUW/92/003/11-04

POST TITLE: Expert in Marine Ecology

DURATION: 11.0m/m over 1994 and 1995

DATE REQUIRED: ASAP

DUTY STATION: Kuwait City with travel within the country

PURPOSE OF THE PROJECT: The purpose of the project is to assist the Kuwait Institute of Scientific Research (KISR) to set up long term research studies in monitoring movement and accumulation of toxic pollutants, their effect upon the environment, and their breakdown in the environment (soil, air, water) and carry out model systems to eliminate/minimize the toxic effects to humans, animals, crops and aquatic life.

DUTIES: The expert, in association with an ecotoxicology expert, is expected to oversee and co-ordinate a coral reef ecological study to investigate the structural and functional characteristics of Kuwait's coral reefs with particular reference to natural and anthropogenic stressors. The study will be jointly undertaken by the Environmental Sciences Department (ESD) and the Mariculture and Fisheries Department (MFD) of the Kuwait Institute for Scientific Research (KISR). The expert is expected to work with the counterpart to finalize a detailed research plan, and to oversee its implementation. The research plan shall include three phases:

<u>Phase 1: Ecological Aspects</u>

Re-assemble all of the regional transect data compiled by Downing (1985; 1991) and Downing and Roberts (1992). Re-survey each of the pre-existing transect lines initially sampled using the identical techniques. In addition, the reefs initially sampled by Downing should also be surveyed using a line-intercept method - the most widely used standard technique at present. By using both techniques at the original reef surveyed by Downing, an intercalibration of techniques will be possible. Once the intercalibrations

have been achieved, the line intercept method should be used to survey all 13 coral communities of Kuwait.

Data analysis of this phase should enable the comparison of coral species composition and coverage for all reefs and for those reefs which were surveyed pre- and post-war. Such comparisons will also allow any differences between offshore, nearshore and inshore reefs to be quantified. With the development of a GIS capability within KISR, most of these data can be analyzed and presented in map form.

Growth rate experiments should also be set up at these reefs during this phase. Selected colonies should be marked using Alizarin Red staining and re-measured at annular intervals. The analysis of growth rings in coral skeletons may also be appropriate. Radioactive carbon incorporation is also available as a growth measuring technique but given the logistic difficulties and the lack of a scintillation counter, it is preferable to use the simpler techniques.

Investigation of reproductive status and fecundity should also be initiated during this phase. Representative samples from a range of reef corals should be collected at monthly intervals, preserved and stored for later investigation. Appropriate fecundity measures include number of eggs or sperm/polyp as well as total gonad size. In addition, to determine spawning period, monthly samples should also be collected and analyzed by histological examination and polyp dissection for their gonad development state.

Samples of selected species of corals should also be collected from all sites and processed for determining the heavy metal levels in their living tissue. Processing of samples should include separation of living tissue from the skeletons and preparation of acid-digested samples (using nitric acid and hydrogen peroxide) for storage and subsequent analysis. Living corals are particularly useful as "bio-indicator" species (Hanna and Muir, 1990) because of their ease of sampling, low impact on the target population, their generally wide distribution and their sedentary nature. In earlier studies, heavy metals concentrations in the coral skeleton were used (Dodge and Gilbert, 1984; Howard and Brown, 1984; Scott, 1990) but recent work on tissue analyses suggests that where relatively low trace metal levels are anticipated, trace metal concentrations in the living tissue are higher and provide more detailed information (Bell et al., 1989; Glynn et al., 1989; Hanna and Muir, 1990; McConchie and Harriott, in press).

Phase 2: Ecotoxicology of immature and mature corals

A series of experiments should be set up once reproductive material (sperm, ova and fertilized larvae) is available to determine larval development and survival at different

salinities, temperatures and light intensities as well as a range of pollutants (e.g. heavy metals, water-soluble hydrocarbons, elevated nutrients).

Trials should also be commenced to maintain mature corals in aquaria under ambient conditions for subsequent investigations of limiting factors on growth and survival and on their ecotoxicological responses to a range of pollutants.

Phase 3: Data Analysis and Interpretation

Data from both of the earlier phases need to be integrated and possibly modelled. Temporal and spatial comparisons should assist in identifying critical or limiting factors for each of the coral communities, and extrapolation should enable some predictive modelling to quantify responses in relation to natural and man-made stressors.

As these communities are perceived to have a high conservation value, some mitigation management plans should be formulated on the basis of the above findings.

As well, the expert will be expected to identify equipment and training needs required for the project. The expert should submit interim progress reports, prepare an evaluation report and submit his final report giving his findings and recommendations.

QUALIFICATIONS: The marine ecologist should have:

* extensive coral reef research experience, preferably within an international context;

* demonstrable expertise in coral reef composition, dynamics, taxonomy, reproduction and response to stress, particularly with the effects of pollution on fertilization;

* the ability to provide guidance in quantitative sampling for biological baseline data, data collation and analysis;

* a familiarity with productivity measurements for coral systems;

* an ability to work with a multidisciplinary team (ESD & MFD);

* the ability to assist with the collaborative bioassay laboratory;

* provide research leadership and training skills;

* the ability to work without supervision;

* demonstrated skills in co-ordinating international collaborators;
* SCUBA diving certification, preferably at the instructor level;
* the ability to plan, co-ordinate and participate in field studies;
* demonstrable skills in report preparation;
* the ability to provide advice in relation to additional ecological research;
* the ability to provide post-graduate supervision and guidance; and
* a working familiarity with GIS/RS in relation to coral systems.

LANGUAGE: English

BACKGROUND INFORMATION:

Annex 2: Research funding proposal for KISR

PROPOSAL

'The Ecology of Coral Reefs in Kuwait and the Effects of Natural and Pollution Stress on Corals.

Project Leader: **DR PETER L. HARRISON**

UNIDO Expert in Marine Ecology

Mariculture and Fisheries Department
Food Resources Division
Kuwait Institute for Scientific Research
P.O. Box 1638, 22017 Salmiyah
Kuwait

March 1995

Abstract

This proposal outlines the scope, the significance and the funding support needed from the KISR for the Coral Reef Ecology Project within the Mariculture and Fisheries Department, Food Resources Division of the Kuwait Institute for Scientific Research, Kuwait. The Project has been developed jointly by the United Nations Development Programme and the United Nations Industrial Development Organization and KISR. This project aims to investigate the structural and functional characteristics of Kuwait's coral reefs with particular reference to natural and anthropogenic stressors. The project consists of three tasks which will examine ecological aspects of the major reef systems in Kuwait, the ecotoxicology of corals, and limiting factors for these coral communities. The project will also identify reef communities of high conservation value and formulate management plans for protection of these reefs. The project timetable extends for 11 months from February to December 1995. KISR has provided 17,133 KD support during February - June 1995 to establish this project. To enable the project to be completed, additional KISR support is needed for the period July - December 1995, including operating expenses and capital expenses amounting to 5,862 KD, and part-time salary support of 8,640 KD. The UNDP/ UNIDO are providing more than 49,000 KD support for this project.

Contents

Introduction

This document outlines the scope, the significance, and the funding requirements from the KISR for the Coral Reef Ecology Project within the Mariculture and Fisheries Department of the Kuwait Institute for Scientific Research, Kuwait. The Project has been developed by the UNDP/UNIDO and KISR. UNDP/UNIDO are providing salary, logistic, and administrative support for the Project Leader Dr Peter Harrison for 11 months from February to December 1995. The UNDP/UNIDO Project Document and Dr Harrison's Curriculum Vitae are appended. The background to this project and the research plan are detailed below.

Project Background and Significance

Kuwait has a number of regionally significant coral reef ecosystems. These reefs support diverse coral communities which provide essential habitats for many hundreds of species, some of which are of commercial importance for fisheries. The ecological importance of corals is highlighted by the fact that when corals are selectively killed, the majority of other reef species die or emigrate, and the reef ecosystem collapses. Corals are therefore a key element of coral reefs, and their tolerance to disturbance determines the tolerance levels for the whole reef ecosystem (Johannes, 1975).

Despite their great importance, surprisingly little detailed ecological work has been done on Kuwait's coral reefs. Previous research has provided some information on the coral species and community structure of some reefs, and brief comparisons with pre- and post-war data (e.g. Downing, 1985, 1991; Downing and Roberts, 1993; Saenger, 1994).

This project will build on that foundation to establish detailed quantitative information on the current status of the benthic coral reef communities using new video survey techniques (Carleton and Done, 1995). The surveys will provide important baseline data against which future changes in reef communities can be compared. The project will also provide important insights into coral reproductive processes which are essential for maintaining and renewing these coral communities, and will determine the tolerance levels and impacts of stress on corals. This information will be integrated to provide a framework for managing these unique marine ecosystems.

Objectives

This project aims to investigate the structural and functional characteristics of Kuwait's coral reefs with particular reference to natural and anthropogenic stressors. The project has the following major objectives:

1. To survey the major coral reef communities in Kuwait to provide quantitative baseline data on the status of these reefs, against which past and future changes to these communities can be compared.

2. To study patterns of reproduction and growth of selected ecologically important coral species.

3. To determine heavy metal levels in selected corals, and examine the effects of pollutants and natural stressors on reproductive success and adult coral survival.

4. To identify reef communities of high conservation value, and formulate management plans for these reefs.

5. To train KISR personnel in coral reef surveys, coral reproduction and growth, coral toxicology and scientific presentation methods.

Justification and Benefits to Kuwait

Kuwait is fortunate in having a range of coral reef ecosystems within its territorial waters. These coral reefs are of importance because they have significant ecological, social and economic values for Kuwait. Coral reefs provide essential habitats for many hundreds of species, including some species of commercial importance. These reefs also provide important amenity values for recreational fishing and boating trips for Kuwait citizens. Some reefs are also used for scuba diving tours, and it is likely that recreational diving activities on these reefs will increase rapidly in the near future. This project is of direct benefit to Kuwait because it will quantify the current status of these reef communities, and provide guidelines for management of this important resource.

The potential impacts of the massive oil slicks released during the Gulf War has focused international attention on, and interest in, the fate of Kuwait's marine environment, and particularly on its coral reefs. This project is of international significance because it will examine any long-term impacts of the largest oil spill in history on these coral reefs. In addition, the project will determine the impacts of a range of oil and other pollutants on adult corals and coral reproductive success, thereby allowing prediction of the potential impacts of pollution stressors on these and other reefs.

Kuwait's coral reefs are also of great scientific interest because they occur in an extreme environment, beyond the normal limits for coral survival and reef growth (Downing, 1985; Sheppard and Wells, 1988). Hence the opportunity exists for unique scientific studies of coral tolerance to natural stressors in Kuwait.

Thus, this project provides a range of direct and obvious benefits for improved scientific understanding and management of Kuwait's coral reefs. Publication of the results of these studies in international journals, and presentations at conferences will highlight research activities at the KISR within the international scientific community. The project will also provide a framework for future coral reef studies, which would allow the Kuwait Institute for Scientific Research to develop a regional centre of excellence for coral reef ecological studies.

Research Plan

The project consists of three interrelated Tasks, each of which comprises a number of related studies, as outlined below.

Task 1. Ecological Aspects

1. Survey the major coral reef communities in Kuwait using replicated video and line transects to provide quantitative data against which previous survey data and future changes can be compared.

2. Study reproductive patterns of corals including gametogenic processes, fecundity, spawning patterns, fertilization, embryogenesis, larval development and settlement.

3. Examine growth rates of corals.

4. Determine heavy metal levels in corals.

Task 2: Ecotoxicology of corals

1. Conduct experiments to determine the impacts of pollution and natural stressors on fertilization rates and larval development and settlement of corals.

2. Commence experimental trials on the effects of pollutants on mature coral growth and survival.

Task 3: Data Analysis and Integration

1. Integrate data from Tasks 1 and 2 to identify critical or limiting factors for coral communities in Kuwait.

2. Identify reef communities of high conservation value, and formulate management plans to protect them from anthropogenic impacts.

Project Timetable

The timetable required to complete this project during 1995 is outlined below.

February - March: Finalise the project research plan, order equipment, and establish laboratory facilities. Plan collaborative projects with UNIDO and EES counterparts.

April: Initiate Task 1 surveys and growth and reproduction studies, complete the Coral Reef laboratory, initiate temperature monitoring.

May - July: Continue Task 1 reef surveys, determine coral spawning patterns, and complete Task 2 ecotoxicology experiments on gametes and larvae. Analyse data and initiate manuscripts on these studies.

August - September: Complete Task 1 reef surveys. Collect and analyse heavy metal concentrations in coral samples. Stain coral skeletons for growth analysis. Plan Task 2 toxicity experiments.

October: Analyse transect data and prepare manuscript. Complete toxicity experiments and initiate Task 3 review of data and management plans.

November: Finalise data analysis and prepare manuscripts, and complete gametogenic sampling for 1995. Complete Task 3 management plans and prepare final reports. Tripartite review meeting.

December: Finalise project reports. Debriefing at UNDP office. Travel to UNIDO, Vienna for Project debriefing.

Methodology

Task 1: Ecological Aspects

1. Reef surveys

This study will compare the present status of coral reef communities in Kuwait with information from previous work. The available transect data from Downing (1985, 1991) and Downing and Roberts (1992) will be re-assembled and these sites will be re-surveyed using the same transect techniques. These reefs will also be surveyed using the recently developed video transect technique. Video transects are much more efficient than conventional underwater surveys, and are now used as a standard technique for reef community surveys by major marine research organisations (Carleton and Done, 1995). The technique involves recording replicated transect areas on reefs with an underwater video camera, and then replaying the tapes at slow speed on a high resolution video monitor. The organism or benthic category underlying a fixed point on the screen is recorded at intervals throughout the transect to provide quantitative information on the

percentage cover of each benthic category (e.g. Harriott *et al.*, 1993, and in press; Harrison *et al.*, 1995).

The use of both techniques at reefs previously surveyed by Downing and co-workers will allow intercalibration of the techniques, and allow meaningful comparisons between studies. Other important coral communities in Kuwait that have not previously been surveyed will also be studied using video transects. At each site, a pilot study will be done to examine the variability in benthic community structure among 6-8 replicated video transects. The data will then be analysed using power analysis to determine the number of transects required for an appropriate level of power to detect a statistically significant change in the communities (Fairweather, 1991). The surveys will then be repeated using the required number of transects to provide detailed quantitative baseline data on these reef communities.

The data will then be analysed to allow comparison of benthic community structure on inshore and offshore reefs in Kuwait, and for reefs where pre- and post-war survey data is available, long-term community dynamics and impacts of the war will be determined. The data would be available for incorporation into the KISR GIS database. The benthic data will be analysed to determine whether there are any underlying community patterns using the multivariate software package Primer (Plymouth Marine La.) to perform cluster analysis and non-metric Multi-Dimensional Scaling (MDS) ordinations (Clarke, 1993).

As well as providing data on the status of Kuwait's reefs, the surveys will provide information on the species composition of corals at each site. Representative samples of each coral species encountered will be photographed and a sample collected for taxonomic verification. The samples will be used to build up a coral reference collection at MFD for use in future coral reef projects. There is some controversy over the coral species present on Kuwait's coral reefs (cf. Downing, 1985, 1991; Hodgson and Carpenter, in press), and recent fieldwork on this project has shown that there are more species present on these reefs than previous work has indicated. Therefore, it is essential to verify the taxonomic identification of these corals with specialist scleractinian coral taxonomists Dr C. Wallace and Dr J.E.N. Veron who are world leaders in coral taxonomy, working in Townsville, Australia.

The coral photographs could be used to publish a photographic poster depicting corals from Kuwait, and a photographic guide to the corals and reefs of Kuwait. Both publications will significantly highlight research at the KISR, and enhance public understanding of the importance of Kuwait's coral reefs.

Previous work on reefs in Kuwait has indicated that sea temperature and salinity are likely to vary significantly on a seasonal basis, and may represent natural stresses which limit coral reef development (Downing, 1985; Coles and Fadlallah, 1991). In order to quantify temporal changes in these parameters, two data loggers will be installed at the four main reef sites to monitor and record sea temperature. Salinity will be monitored with a portable salinometer during field trips. Seasonal stress and mortality, and reproductive rhythms of corals will be compared with seasonal changes in these parameters.

2. Coral Reproduction

The processes of reproduction, larval development and recruitment of scleractinian reef corals are critically important for the initiation, maintenance and renewal of coral reef communities (reviewed by Harrison and Wallace, 1990). Therefore, in order to understand the ecology of coral reefs and predict the likely impacts of disturbance, it is essential to understand the mode and timing of coral reproduction, and the tolerance of reproductive processes to stress. Much of my research over the past 15 years has been centred on studies of the mass coral spawning phenomenon on the Great Barrier Reef and elsewhere (e.g. Harrison *et al.*, 1984; Willis *et al.*, 1985; Harrison, 1985; Babcock *et al.*, 1986; Harrison and Wallace, 1990; Harrison, 1993). The research plan proposed for this section of the project is based on methods used successfully in previous studies on these topics (refer to CV).

Gametogenic processes will be studied in three ecologically important coral species. Samples will initially be taken from ten tagged colonies of each species at three monthly intervals. When signs of gamete maturation are evident, the colonies and other populations will be monitored more frequently to determine patterns of spawning within and between species. Samples will be fixed in formalin, decalcified, and either dissected or sectioned for histological examination of egg and sperm development. Polyp fecundity will be quantified from samples of corals taken just prior to spawning. Gametogenic cycles will examined in relation to seasonal changes in seawater temperature and salinity records from the data loggers. Based on previous experience and information available on seawater temperature cycles, it is predicted that significant coral spawning activity will occur following full moon periods in May and June this year. These studies will provide the first information on coral reproductive activity on Kuwait's reefs.

When ripe gametes are detected in corals, colonies will be transferred to aquaria to monitor, photograph and yideo spawning behaviour. Spawning periods will be confirmed by examination of tagged colonies on reefs; the presence/absence of gametes in sequential samples indicates that spawning has occurred. Spawned gametes will be collected for studies of their ultrastructural characteristics, for larval rearing, and for toxicity bioassays (refer to Task 2). Samples of freshly spawned gametes will be fixed for electron microscopy using the protocol developed by Harrison (1985, 1988). Following fertilization, embryogenic and larval development will be monitored. Larval settlement will be studied to determine whether larvae are competent to settle, and larvae will be maintained alive for as long as possible to determine their maximum settlement competency period. These data will allow prediction of the likelihood of locally produced larvae settling on nearby reefs, and their potential for long-distance dispersal to other reef systems in the Arabian Gulf.

3. Coral Growth

Coral growth will be investigated by staining 10 colonies of three coral species with Alizarin Red-S calcium stain. Portions of the colonies will be collected after 6 mo and 12 mo to examine growth patterns following staining. These data will provide the first estimates of coral growth on these reefs, and will allow the potential for coral regrowth after damage to be assessed.

4. Heavy Metal Pollutants

Coral samples will be analysed to determine levels of heavy metal contamination. Replicate samples of two coral species will be collected from four inshore and offshore reefs representing a range of potentially polluted and relatively pristine reef systems. Samples will be oven-dried, acid digested, then heavy metal concentrations in the tissues and skeleton will be determined using AA spectroscopy analyses within the Central Analytical Laboratory at KISR. The data will provide new information on the extent of metal pollution on coral reefs in Kuwait, and this project could be developed in future to monitor pollution levels.

Task 2: Ecotoxicology of Corals

This Task of the project consists of a series of related experiments to determine the stress effects and tolerance limits of coral gametes, larvae and adult colonies with respect to a range of natural and pollution stressors. The results will provide important new information on the the effects of stress on corals, and provide a framework for predicting and managing the impacts of natural and anthropogenically induced perturbations on coral reefs in Kuwait. It is anticipated that some of these experiments could be done in conjunction with Fred Abram, another UNIDO expert based at MFD as Project leader for the Ecotoxicology Project. However, it should be noted that these coral experiments are an integral part of this project, and in no way duplicate or conflict with ecotoxicology work planned for other projects at KISR.

1. Bioassays using Coral Gametes and Larvae

Sensitive new bioassay procedures using spawned gametes and coral larvae have recently been developed to test the toxicity of oil hydrocarbons, dispersants, heavy metals and nutrients on critically important coral reproductive processes (Harrison, 1994, in prep.; Reichelt and Harrison, in prep; Harrison and Ward, in prep). The results indicate that these bioassays provide the most sensitive toxicity tests for corals developed to date, and reveal significant inhibition of reproductive success at pollutant concentrations that are orders of magnitude lower than those which adversely affect adult corals. When freshly spawned eggs and sperm are available (refer to Task 1), eggs and sperm from different colonies will be exposed to a range of pollutants at varying concentrations, and percentage fertilization rates determined after 4-6 hours. Five replicate vials will be used for each pollutant concentration and the control treatments with normal seawater. Pollutants to be tested include water accommodated fractions of Kuwait light crude oil, and heavy metals including nickel, vanadium, copper, and lead. Additional experiments will be done to determine the effects of lowered salinity on fertilization rates.

Once developed larvae are available, additional experiments will be done to determine the effects of some of the pollutants listed above on larval survival and their ability to settle and metamorphose successfully. For each pollutant concentration and seawater control treatments, five replicated settlement containers each containing approximately 100 larvae will be used. The number of larvae surviving or settled will be monitored over time for up to 7 days.

2. Bioassays using Adult Corals

Pilot experiments will be commenced to determine the effects of temperature and a range of pollutants on growth, health and survivorship of adult coral colonies. The range of pollutants tested will depend on the amount of logistic support provided for basic flow-through experimental aquarium facilities at the MFD for this Project and the Ecotoxicology Project, and the rapidity with which these laboratories are completed. Given appropriate support, these experiments would include analysis of the effects of elevated temperature, water accommodated fractions of oils, and heavy metals on corals.

Each experiment will consist of a normal seawater control treatment and three treatments with different concentrations of each toxicant ranging from 2 to 200 fold increase over background levels. Ten colonies of one or two coral species would be used in each treatment for appropriate experimental replication, and the behaviour, health, growth, survival and tissue structure would be monitored during the period of exposure and for two weeks afterwards to monitor recovery or mortality. Samples of coral tissues will be taken from each colony before, during and after exposure and fixed for ultrastructural and histological analysis using the methods developed by Harrison *et al.* (1990). In this way any changes in tissue and cell structure can be carefully monitored. Growth of the colonies will be monitored using the buoyant-weight growth method (Davies, 1989) to determine whether the treatments result in altered growth responses.

Task 3: Data Analysis and Integration

The results of the reef surveys, coral reproduction and growth studies in Task 1, and ecotoxicology experiments in Task 2 will be integrated in order to assist in identifying critical or limiting factors for the main coral reef systems in Kuwait. The results will also be used to model and predict the likely responses and potential impacts of natural perturbations and anthropogenic pollution on these coral reef communities.

The results of the reef surveys will also be used to identify reefs that have a high conservation value, and zones that are susceptible to damage. Management plans will be formulated for these reefs in order to mitigate adverse impacts of human origin. Together, these studies will provide an important and strong foundation for future research and management programs on coral reef ecosystems within the Kuwait Institute for Scientific Research. Given appropriate funding, logistic and personnel support, the KISR could become the leading research institute for coral reef research within the Arabian Gulf region.

Organization and Management Plan

Dr Peter Harrison, UNIDO Expert in Marine Ecology is the Project Leader for this project, which extends for 11 months from February to December 1995. Mr Shakher Al-Hazeem will have 90% involvement with this project, and will be Study Leader for two studies, comprising Gametogenic studies of Corals (Task 1), and Coral Growth studies (Task 1). Mr Adel Al-Saffar will have 20% involvement with this project and will be Study Leader for the Coral Reef Water Quality study (Task 1). Ms Iman Al-Sabah will have a 40% involvement with this project and will be mainly involved with laboratory analysis. Dr Harrison will be Task Leader for the remaining studies. In addition, the large scope of the project requires part-time assistance from at least one other professional diver from KISR to ensure that the field work is completed

Related Projects within KISR

This project is related to the following completed project within KISR:

MB-42 Corals and Coral Reef Fishes of Kuwait

In addition, this project is related to two other projects currently underway, or being planned within KISR.

Some aspects of the Task 2 Ecotoxicology of Corals studies could be done in conjunction with work currently being developed with Dr Fred Abram, UNIDO Expert, and Project Leader for the Ecotoxicology Bioassay Laboratory project at KISR. However, it should be noted that the coral experiments in this project are separate from, and complement the work planned for the Ecotoxicology Project.

A collaborative project is also being planned with Dr Andy Kwarteng (EES, KISR) to use the Task 1 Reef Survey data from this project to ground-truth satellite data for some reefs. This will allow long-term changes in reef communities, and potential effects of the Gulf War oil spill to be assessed.

Training Plan

This project will provide extensive training for Mr Shakher Al-Hazeem, Mr Adel Al-Saffar and Ms Iman Al-Sabah through participation in the field and laboratory research. Aspects of the training in Task 1 will include: video and transect survey techniques, benthic data analysis, MDS programming, coral taxonomy, underwater photography, data logger training, coral spawning techniques, coral dissection training, coral growth staining and analysis, and heavy metal analysis. Task 2 training includes toxicity bioassay techniques using spawned gametes, larvae, and adult corals. In addition to these activities, the Project Leader will be providing training in scientific presentations, and writing scientific papers.

Project Outputs

The Coral Reef Ecology Project at the KISR will result in a wide range of new information of great significance to coral reef ecology both within the Arabian Gulf and internationally. The anticipated outputs from these studies include:

1. Survey data on the major coral reef communities in Kuwait and assessment of the status of these reefs.

2. Determination of reproduction and growth patterns of reef corals.

3. Data on heavy metal levels in corals, and effects of pollutants and natural stressors on reproductive success and adult coral survival.

4. Management plans for significant coral reef communities in Kuwait.

5. Extensive training of KISR personnel in coral reef surveys, and coral biology and experimental methods.

6. Major project reports.

7. Scientific papers published in International refereed journals on aspects of coral reef community structure, coral reproductive patterns, larval development and settlement, coral growth, heavy metal levels in corals, and the effects of temperature, salinity and various pollutants on coral reproductive success and adult colony survival.

Additional future outputs from this project

1. The project results should be presented at international coral reef conferences to highlight coral reef research in Kuwait e.g. the Eighth International Coral Reef Symposium to be held in Panama in 1996.

2. A poster depicting the main reef building corals in Kuwait.

3. A book on the corals and reefs of Kuwait.

4. Collaborative links with projects on Satellite imaging of coral reef communities with Dr Andy Kwarteng (EES) and Ecotoxicology with Dr Fred Abram (UNIDO/ EES).

5. Taxonomic reference collection of scleractinian corals from Kuwait.

6. The Coral Reef Project also provides unique opportunities for development and training of KISR personnel and postgraduate students. Many of the individual studies and topics outlined above would provide excellent Master of Science and Doctor of Philosophy research projects. These could be undertaken jointly with the KISR and regional and international University postgraduate training schemes.

Budget

The budget requirements for this project are summarised below in Table 1. The budget represents the minimum support needed from KISR, to ensure the success of this project. The budget summary in Table 1 is divided into items obtained and salary support for this project provided by KISR during the 1994/95 financial year from February to June 1995, and salary and budget support needed during the 1995/96 financial year from July to December 1995. It is imperative that the project budget is progressed rapidly, as any delays will seriously jeopardise this work.

The Coral Reef Project has been substantially supported through the UNDP/UNIDO. UNDP/UNIDO funding for this project during 1995 amounts to more than U.S. $167,000 = 49,000 KD.

Table 1: KISR funding provided from February-June 1995, and support needed for this Project from July-December 1995.

Budget Item	**1994/95**	**1995/96**	**Total**
Salaries	7,200	8,640	15,840
Operating Expenses			
Exp. Lab. Supplies	180	355	535
Publications		400	400
Operating charges	230	520	750
Service charges	60	3,120	3,180
Others		260	260
Contingencies (5%)	-	233	233
Sub-Total	470	4,888	5,358
Capital Expenses			
Exp. Equipment	8,371	785	9,156
Research Facilities	830		830
Others	262	100	362
Contingencies (10%)	-	89	89
Sub-Total	9,463	974	10,437
Total non-salary items	9,933	5,862	15,795
Total Budget	17,133	14,502	31,635

UNDP/UNIDO funding for this project = **49,000 KD**

References cited

Babcock, R.C., Bull, G.D., Harrison, P.L., Heyward, A.J., Oliver, J.K. , Wallace, C.C. and Willis, B.L. (1986). Synchronous spawning of 105 scleractinian coral species on the Great Barrier Reef. **Marine Biology, 90**: 379-394.

Clarke, K.R. (1993). Non-parametric multivariate analyses of changes in community structure. **Aust. J. Ecol. 18**: 117-143.

Coles, S.L. and Fadlallah, Y.H. (1991). Reef coral survival and mortality at low temperatures in the Arabian Gulf: new species-specific lower temperature limits. **Coral Reefs 9**: 231-237.

Davies, P.S. (1989). Short-term growth measurements of corals using an accurate buoyant weighing technique. **Mar. Biol. 101**: 389-395.

Downing, N. (1985). Coral reef communities in an extreme environment: the northwestern Arabian Gulf. **Proc. 5th Int. Coral Reef Congr. Tahiti 6**: 343-348.

Downing, N. (1991). A survey of the coral islands of Kubbar, Qaru and Umm Al Maradem, Kuwait, 13-19 July, 1991. **Report to the IUCN and the WWF**, pp 1-12.

Downing, N. and Roberts, C. (1993). Has the Gulf War affected coral reefs in the northwestern Gulf? **Mar. Poll. Bull., 27**: 149-156.

Harriott, V.J., Harrison, P.L., and Banks, S.A. (1993). The marine benthic communities of Lord Howe Island. **Centre for Coastal Management Report** for the Australian National Parks and Wildlife Service, 64 pp.

Harriott, V.J., Harrison, P.L., and Banks, S.A. (in press). The coral communities of Lord Howe Island. **Aust. J. Mar. Freshw. Res.**.

Harrison, P.L. (1985). Sexual characteristics of scleractinian corals: systematic and evolutionary implications. **Proc. Fifth Int. Coral Reef Congress, Tahiti, 4**: 337-342.

Harrison, P.L. (1988). Comparative ultrastructure of scleractinian spermatozoa and its evolutionary implications. **Ph.D. Thesis**, James Cook University of North Queensland, Townsville, 282 pp.

Harrison, P.L. (1990). Sperm morphology and fertilization strategies in scleractinian corals. **Advances in Invertebrate Reproduction, Vol. 5**: 299-304. Elsevier Science Publishers, Amsterdam.

Harrison, P.L. (1993). Coral spawning on the Great Barrier Reef. **Search, 24**: 45-48.

Harrison, P.L. (1994). The effects of oil pollutants on fertilization rates in the scleractinian coral *Acropora tenuis*. **Australian Coral Reef Society Annual General Meeting**, Townsville, 1994.

Harrison, P.L., Babcock, R.C., Bull, G.D., Oliver, J.K., Wallace, C.C. and Willis, B.L. (1984). Mass spawning in tropical reef corals. **Science, 223**: 1186-1189.

Harrison, P.L., Collins, J.D., Alexander, C.G and Harrison, B.A. (1990). The effects of fuel oil and dispersant on the tissues of a staghorn coral *Acropora formosa* : a pilot study. **Proc. Second Workshop on the Role of the Scientific Coordinator on Oil Spill Response, HMAS Cerberus, Victoria, 1990.** pp. 51-61.

Harrison, P., Holmes, N., Banks, S. and Harriott, V. (1995). Conservation values of Flinders Reef and Myora Reef - Moreton Bay Marine Park. Report for the Queensland Department of Environment and Heritage. **Centre for Coastal Management, SCU**, 44 pp.

Harrison, P.L. and Wallace, C.C. (1990). Reproduction, dispersal and recruitment of scleractinian corals. Chapter 7. In: Z. Dubinsky (Editor), **Coral Reef Ecosystems**, Ecosystems of the World Vol. 25. pp. 133-207. Elsevier Science Publishers, Amsterdam.

Hodgson, G. and Carpenter, K. (in press). Scleractinian corals of Kuwait with a description of a new species. **Pacific Science.**

Johannes, R.E. (1975). Pollution and degradation of coral reef communities. In, **Tropical Marine Pollution**. Ed. by F.Wood and R.Johannes. Elsevier Oceanography Series, 12, pp. 13-51.

Saenger, P. (1994). Cleaning up the Arabian Gulf: aftermath of an oil spill. **Search 25**: 19-22.

Sheppard, C.R.C. and Wells, S.M. (1988). Saudi Arabia. In, **Coral Reefs of the World. Indian Ocean, Red Sea and Gulf.** IUCN/UNEP, Nairobi, 2: 271-290.

Willis, B.L., Babcock, R.C., Harrison, P.L., Oliver, J.K. and Wallace, C.C. (1985). Patterns in the mass spawning of corals on the Great Barrier Reef from 1981 to 1984. **Proc. Fifth Int. Coral Reef Congress, Tahiti, 4**: 343-348.

Appendix 1. Details of Budget items

Note: * indicates that these items have been ordered.

UNDP/UNIDO funding for this project = **49,000 KD**

Funding requirments from KISR

Professional salaries
Salary costs for Mr Al-Hazeem 11 months @ 90% = 9,504
Salary costs for Mr Al-Saffar 11 months @ 20% = 2,112
Salary costs for Ms Al-Sabah 11 months @ 40% = 4,224

Total salary costs for MFD, KISR personnel = **15,840 KD**

Field Surveys
Research vessel equipment. The following equipment is essential for boat travel, safety and survey requirements: *additional fuel drum and fuel lines 102 KD; *anchor system 51 KD; *winch 275 KD; *ladder, horn, pumps, lights, ropes 120 KD; deck cover 175 KD; *scuba tank stand 85 KD; miscellaneous motor and boat equipment 22 KD. Total = 830 KD.

Safety equipment. *First aid kit 37 KD; *portable oxygen resuscitation kit for scuba diving emergency 135 KD; *emergency flares 5 KD. Total = 177 KD.

Boat fuel and oil costs: estimated from present consumption = 280 KD.

Data loggers: *for temperature recording; two at each of 4 sites plus two replacement loggers = 10 @ 96 KD = 960 KD.

Nikonos lens: Nikonos underwater camera close-up extension tube set = 80 KD

Subsistence allowance: for field trip meals. 4 persons x 20 days 150 KD.

Miscellaneous items: *batteries, survey tapes, *coral sampling equipment, plastic tubs for transporting corals, *perspex tags, underwater paper = 185 KD

Laboratory Equipment
Hi-8 video equipment: *Hi-8 video player 550 KD; *S-VHS large screen monitor 390 KD; *tapes, batteries, recharger 156 KD = 1,096.

MDS analysis package: Multi-Dimensional Scaling (MDS) is essential for analysing the reef community data and is being used extensively overseas for such analysis. The program was developed at Plymouth Marine Laboratories, UK and a site licence is approximately 220 KD.

Microscopes: the project requires full-time use of a minimum of two dissecting microscopes and one high power compound microscope. I strongly recommend purchasing Olympus equipment as it is less expensive than the other major manufacturers, has superior optical quality, and is compatible with my personal Olympus camera equipment which I am prepared to use on this project to reduce costs. *SZ30 microscope 300 KD; *SZ40 microscope and phototube 490 KD; *SZ-STU1 universal stand and SZ-STB1 holder 260KD; *two fibre-optic lights essential for analysing live coral gametes and embryos 700 KD; *two micrometer eyepieces 30 KD; *BHS High Power microscope and phototube 1,200KD; *OM camera adapter 100KD; Total = 3,080 KD.

High precision balance: *essential for buoyant weighing corals for growth studies = 730 KD.

Aquaria: *glass aquaria for monitoring corals, rearing larvae and for stress experiments = 480 KD; plastic and fibreglass coral storage and experimental tanks = 65 KD. Total = 545 KD.

Metal halide lights: essential for maintaining corals in indoor tanks during summer. These lights are the only type capable of maintaining corals in a healthy condition for experiments. 10 Aqualine Buschke 10,000 K light units @ 85 KD = 850 KD.

Experimental flow-through chambers: for coral experiments = 420 KD.

Temperature regulators and heating units* for temperature experiments. 10 @ 95 = 950 KD.

Micropipettes: *one 1 ml and two 5 ml precision micropipettes and tips = 225 KD.

Other items

Glassware: *beakers, *pipettes, *graduated cylinders, glass vials for toxicity experiments = 230 KD.

Chemicals:* formalin, *acid, *ethanol, Bouin's fixative, *Alizarin stain, metal reagents = 105 KD.

Plasticware: disposable pipettes, storage vials, bags, beakers = 40 KD.

E.M. fixatives: osmium tetroxide and glutaraldehyde, Analar grade ethanol, Spurr's resin, for fixing and preparing coral tissue samples for thin sections and ultratructural analysis. Total = 80 KD.

Tissue analysis: thin sectioning and ultrastructural analysis charges for SEM and TEM = 200 KD.

Heavy metal analysis: sample analysis charges for heavy metal levels in coral samples = 1,600 KD.

Taxonomic verification: of coral samples. 4 days @ 300 KD = 1,200 KD

Larval rearing: plankton mesh, plastic pots, mooring system, rearing cages, settlement tiles = 80 KD.

Photographic costs: slide and print films for coral and reef photographs, B&W films and prints, developing charges = 320 KD.

Publication costs: costs of preparing and courier charges for manuscripts = 400 KD.

Miscellaneous costs: fax charges, sample postage, Scleractinian taxonomic monographs, dissecting equipment = 260 KD.

Total non-salary budget items (including Contingency costs) = 15,795 KD.

Annex 3: Data tables and figures

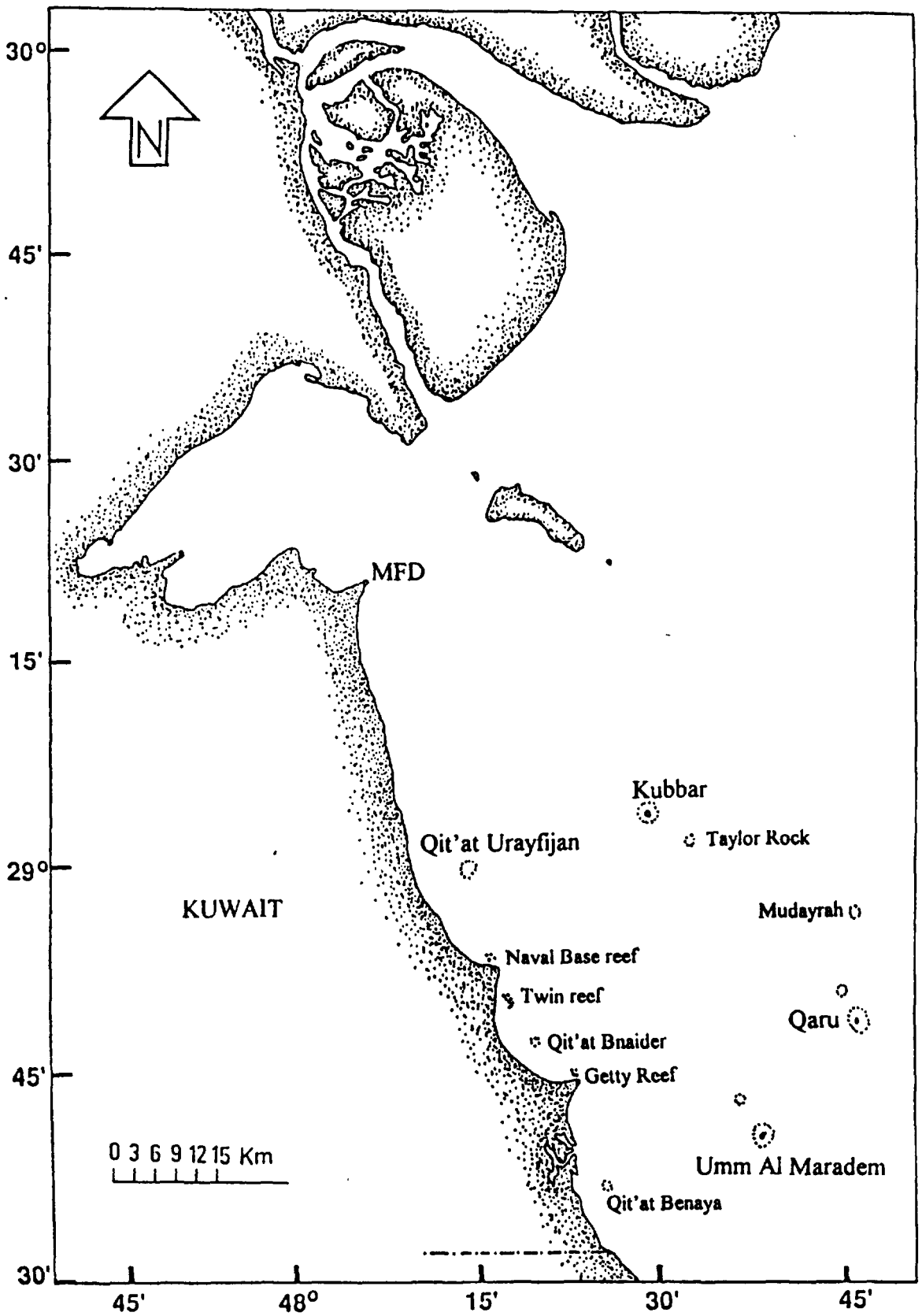


Figure 1. Map showing the location of the main coral reefs in Kuwait

Figure 2. Coral and fish communities at Qaru reef.

Figure 3a. Graph of sea temperature during July- September 1995 at the reef flat site, Qaru reef, Kuwait.

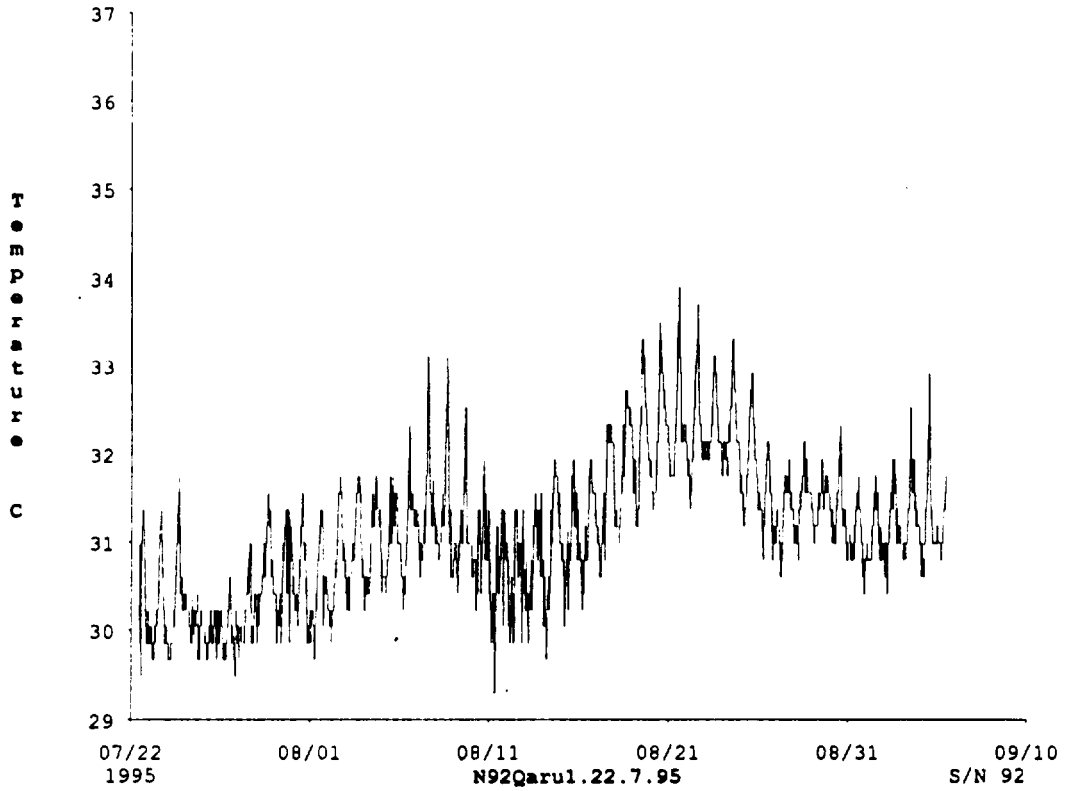
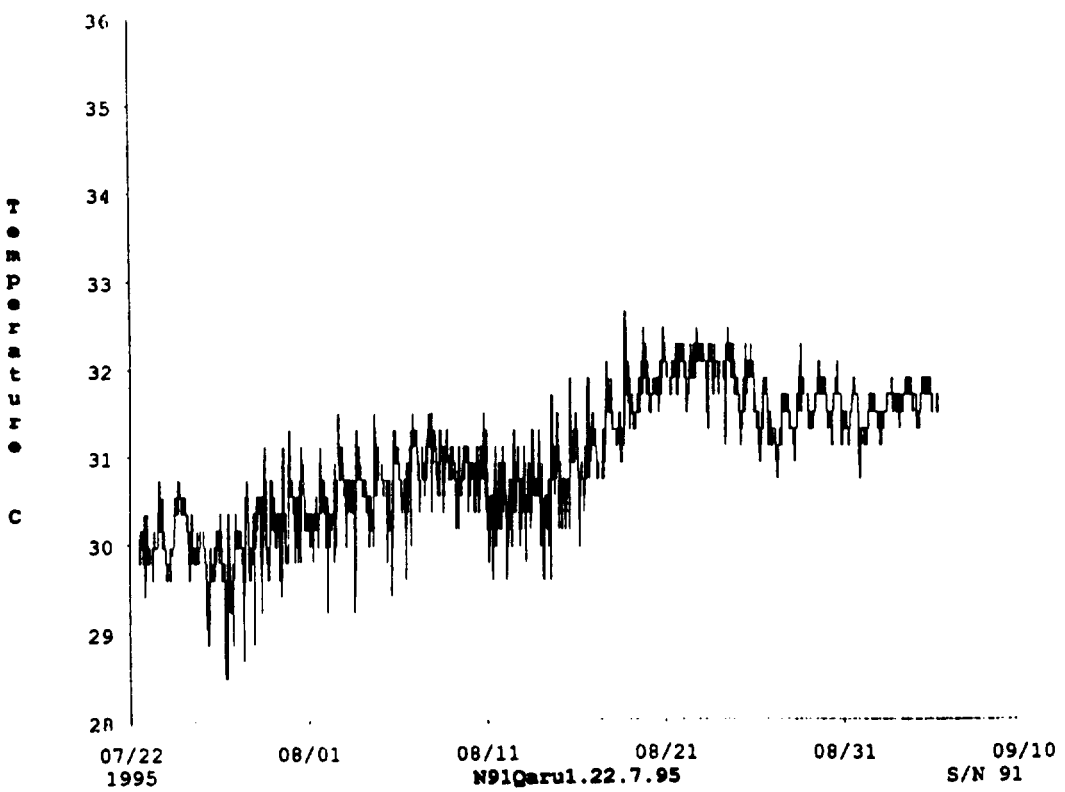


Figure 3b. Graph of sea temperature during July - September 1995 at the reef slope site, Qaru reef, Kuwait.



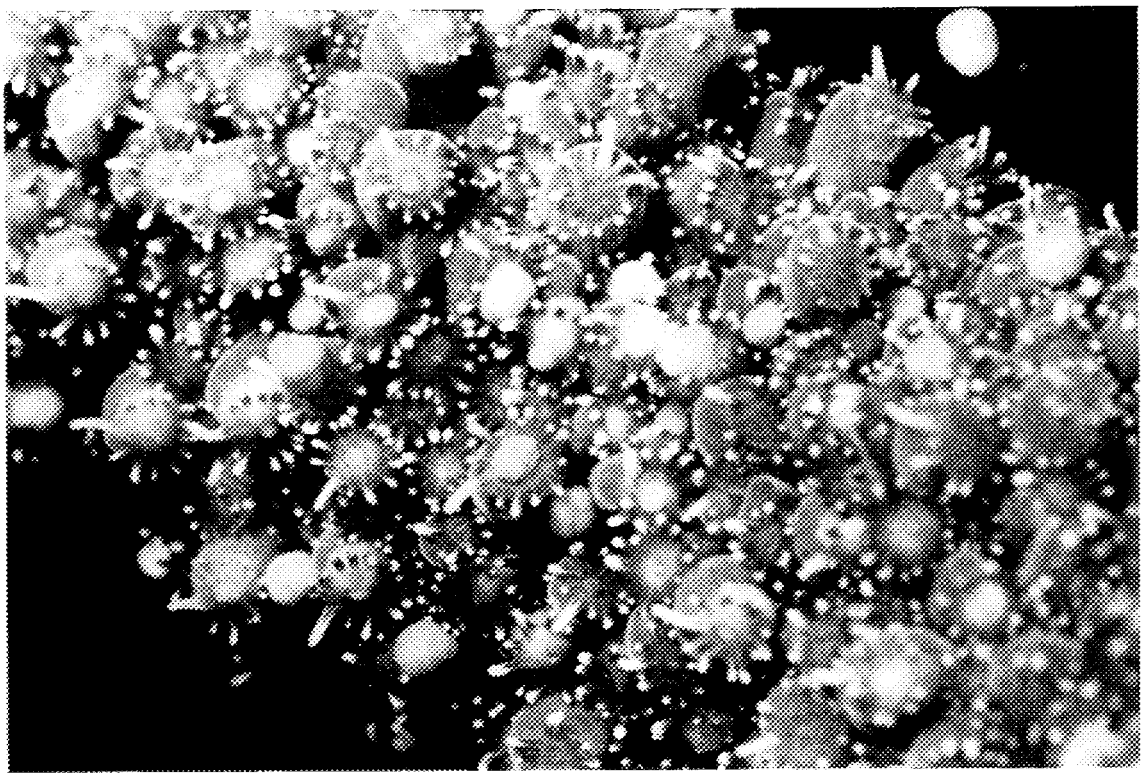


Figure 4. Polyps of *Acropora clathrata* branching coral spawning egg and sperm bundles.

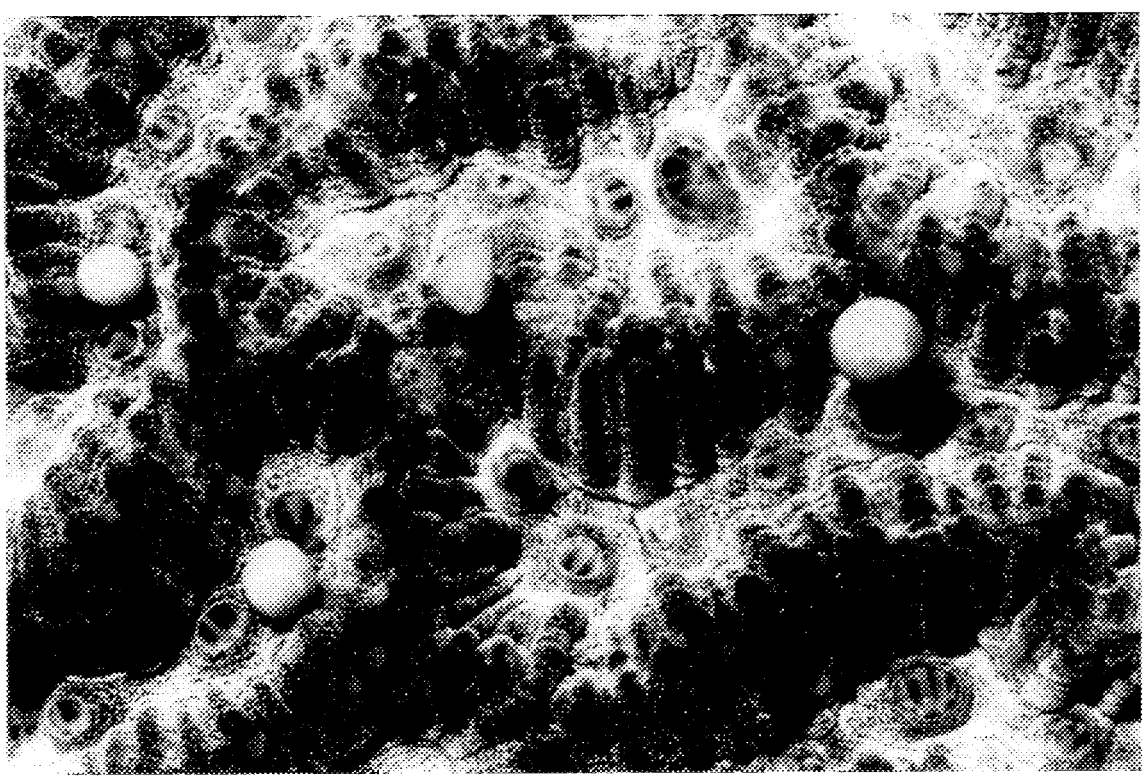


Figure 5. Polyps of the brain coral *Platygyra daedalea* spawning egg and sperm bundles.

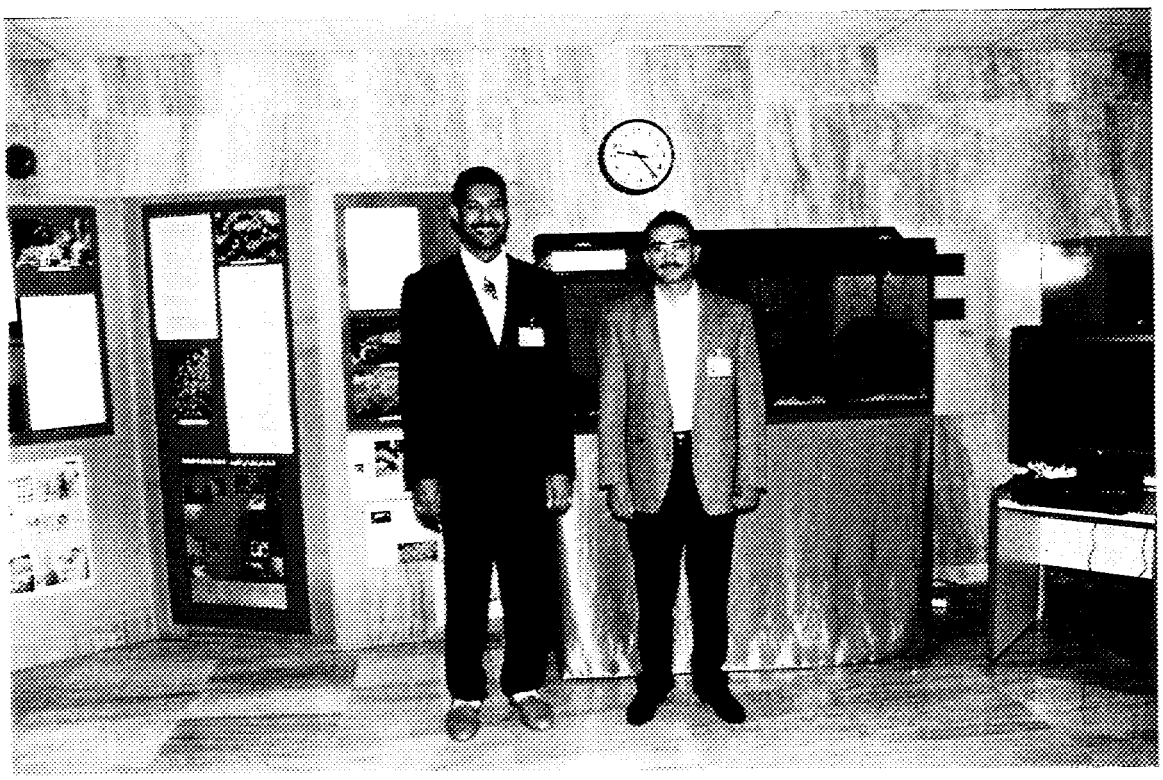


Figure 6. Photograph of Shaker Alhazeem and Adel Alsaffar and the Coral Reef Ecology display at MFD.

Table 1: Summary of % cover of benthic categories in video transects at Qaru Island, Site 1												
Category	Tr 1	Tr 2	Tr 3	Tr 4	Tr 5	Tr 6	Tr 7	Tr 8	Tr 9	Tr 10	Mean cover	Std. dev.
Live coral												
Acropora arabensis	10.5%	6.7%	11.9%	15.0%	16.9%	12.8%	14.4%	7.5%	9.0%	7.6%	11.2%	0.0354
Fragmented *A.arabensis*	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.3%	0.4%	0.3%	0.1%	0.0017
Acropora clathrata	19.7%	12.0%	16.0%	24.0%	16.9%	15.0%	25.7%	26.4%	14.9%	14.9%	18.5%	0.0511
Fragmented *A.clathrata*	0.0%	1.3%	0.6%	1.0%	0.0%	0.8%	1.3%	1.6%	3.4%	1.7%	1.2%	0.0098
Total *Acropora*	30.1%	20.0%	28.8%	39.9%	33.8%	28.5%	41.4%	35.8%	27.6%	24.5%	31.0%	0.0671
Porites compressa	21.3%	22.7%	10.2%	13.4%	9.1%	10.3%	9.7%	22.6%	20.9%	15.7%	15.6%	0.0577
Porites lutea	0.0%	0.0%	0.3%	0.0%	0.0%	1.3%	0.0%	0.0%	4.5%	2.6%	0.9%	0.0153
Total *Porites*	21.3%	22.7%	10.5%	13.4%	9.1%	11.5%	9.7%	22.6%	25.4%	18.4%	16.5%	0.0626
Platygyra	0.8%	1.0%	0.9%	1.3%	0.0%	0.0%	0.0%	0.3%	0.4%	0.6%	0.5%	0.0046
Favia	0.8%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.3%	0.0%	0.0%	0.1%	0.0028
Massive coral (other)	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.6%	0.0%	0.6%	0.2%	0.0026
Other benthos												
Diadema urchin	1.7%	3.3%	0.9%	0.6%	1.4%	2.0%	1.9%	0.3%	1.9%	2.3%	1.6%	0.0088
Echinometra urchin	2.9%	1.3%	2.0%	2.2%	3.7%	4.3%	2.2%	2.2%	1.5%	1.5%	2.4%	0.0097
Pencil urchin	0.0%	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0018
Substratum												
Dead *A.arabensis*	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.3%	0.7%	0.3%	0.3%	0.0056
Dead *A.clathrata*	0.0%	0.7%	4.1%	0.3%	0.0%	0.3%	1.3%	2.2%	1.1%	0.6%	1.0%	0.0126
Dead *Porites*	2.9%	1.3%	0.0%	7.0%	4.1%	3.8%	2.2%	6.9%	5.2%	0.6%	3.4%	0.0247
Dead coral (other)	20.5%	22.7%	32.6%	15.7%	21.3%	26.8%	21.9%	11.0%	18.3%	32.9%	22.4%	0.0692
Rubble	13.8%	20.3%	13.7%	15.3%	21.3%	18.5%	11.9%	14.2%	11.6%	9.3%	15.0%	0.0391
Sand	5.0%	6.7%	4.4%	4.2%	4.7%	4.5%	7.5%	3.1%	6.3%	8.5%	5.5%	0.0168
Total live coral	53.1%	43.7%	40.1%	54.6%	43.6%	40.0%	51.1%	59.7%	53.4%	44.0%	48.3%	0.0688
Total urchins	4.6%	4.7%	3.5%	2.9%	5.1%	6.3%	4.1%	2.5%	3.4%	3.8%	4.1%	0.0111
Total dead coral	23.4%	24.7%	38.4%	23.0%	25.3%	30.8%	25.4%	20.4%	25.4%	34.4%	27.1%	0.0561
Total other substratum	18.8%	27.0%	18.0%	19.5%	26.0%	23.0%	19.4%	17.3%	17.9%	17.8%	20.5%	0.0356

Table 2: Summary of % cover of benthic categories in video transects at Qaru Island, Site 3									
Category	Tr 1	Tr 2	Tr 3	Tr 4	Tr 5	Tr 6	Tr 7	Mean cover	Std. Dev.
Live coral									
Acropora arabensis	28.3	35	40.8	27.1	25.1	35	40.8	33.2	6.44
Fragmented *A.arabensis*	0.2	0	0	0	0	0	0		0.08
Acropora clathrata	51.1	38	30.5	47.4	29.7	38	30.5	37.9	8.58
Fragmented *A.clathrata*	0.5	0	0	0	0.3	0	0	0.1	0.20
Porites compressa	8.1	4	12.2	6.1	11.8	14.7	12.2	9.9	3.87
Porites lutea	0	0	0.5	0	0	0	0.5	0.1	0.24
Platygyra	0	0	0.3	0	0	0	0.3	0.1	0.15
Favia	0	0	0	0.3	0	0	0	0.0	0.11
Cyphastrea	0	0	0	0	0	0	0	0.0	0.00
Other benthos									
Diadema urchin	0	0	0	0	0	0	0		0.00
Echinometra urchin	0.2	1	3.2	3.2	5.5	2.1	3.2	2.6	1.73
Pencil urchin	0	0	0	0	0	0	0	0.0	0.00
Holothurian	0.2	0	0	0	0	0.6	0	0.1	0.23
Substratum									
Dead *A.arabensis*	0.5	0	1.1	0.6	1.4	0	1.1	0.7	0.55
Dead *A.clathrata*	0.7	4	3.2	6.5	3.5	0.6	3.2	3.1	2.02
Dead *Porites*	0	0	0	1.3	0.6	1.2	0	0.4	0.59
Dead coral (other)	0	0	0.3	1.9	0.9	1.5	0.3	0.7	0.75
Rubble	1.7	1	5.3	3.9	15.3	3.3	5.3	5.1	4.78
Sand	8.4	17	2.7	1.6	6.1	3	2.7	5.9	5.43

Table 3: Summary of % cover of benthic categories in video transects at Qaru Island, Site 4												
Category	Tr 1	Tr 2	Tr 3	Tr 4	Tr 5	Tr 6	Tr 7	Mean cover	Std. dev.			
Live coral												
Acropora arabensis	21.1	14	17.8	22	14.4	8.7	20.5	16.9	4.82			
Fragmented *A.arabensis*												
Acropora clathrata	48.2	54.2	50.5	29.1	31.2	35.7	23.7	38.9	38.94			
Fragmented *A.clathrata*	0.7	0	0	0.4	0.3	0	0	0.2	0.20			
Porites compressa	7.6	9.5	5.4	11.2	13.9	15.5	11.1	10.6	10.60			
Porites lutea	0	0	2	0	0.8	0	0.3	0.4	0.44			
Platygyra	0	0.8	0	0.4	0	0.7	0.6	0.4	0.36			
Favia	0	0	0	0.4	0.5	0.4	0	0.2	0.19			
Cyphastrea	0.3	0	0	0	0	0	0	0.0	0.04			
Other benthos												
Diadema urchin												
Echinometra urchin	1	1.1	3.4	3.4	3.9	4	4.1	3.0	2.99			
Pencil urchin												
Substratum												
Dead *A.arabensis*	1.3	0.4	0.3	4.1	0.5	0.4	2.9	1.4	1.41			
Dead *A.clathrata*	6.9	5.3	6.7	14.2	14.2	6.1	12.6	9.4	9.43			
Dead *Porites*	4	2.3	4.7	1.9	3.6	6.9	7.3	4.4	4.39			
Dead coral (other)	0.7	0	2	2.6	5.5	2.9	2.9	2.4	2.37			
Rubble	4	3.4	3.4	2.6	4.7	7.9	5.3	4.5	4.47			
Sand	4.3	3.8	3.7	7.8	6.3	10.8	8.8	6.5	6.50			

Table 4: Summary of % cover of benthic categories in video transects at Qaru Island, Site 5												
Category	Tr 1	Tr 2	Tr 3	Tr 4	Tr 5	Tr 6	Tr 7	Mean cover	Std. dev.			
Live coral												
Acropora arabensis	0	0	0	0	0	0.6	0.6	0.2	0.29			
Fragmented *A.arabensis*	0	0	0	0	0	0	0	0.0	0.00			
Acropora clathrata	0	0	0	1.8	3.2	1.6	0.8	1.1	1.21			
Fragmented *A.clathrata*	0	0	0	0	0	0	0	0.0	0.00			
Porites compressa	35.4	29.3	26.1	35.9	35.1	43.2	46.5	35.9	7.14			
Porites lutea	0	0	0	0	0	0	0	0.0	0.00			
Platygyra	0	0	0.8	0	0	0	0	0.1	0.30			
Leptastrea	0	0	0	0	0	1.3	0	0.2	0.49			
Cyphastrea	0.3	0	0	0	0	0.6	0	0.1	0.24			
Other benthos												
Diadema urchin	0	0	0	0	0	0	0	0.0	0.00			
Echinometra urchin	11.7	16.5	17.6	10.4	8.1	8.2	10.6	11.9	3.78			
Pencil urchin	0	0	0	0	0	0	0	0.0	0.00			
Substratum												
Dead *A.arabensis*	0	0	0	0	0	0	0.3	0.0	0.11			
Dead *A.clathrata*	0	0	0	0	0	0	0.3	0.0	0.11			
Dead *Porites*	20.5	33.3	27.9	42.7	33.4	20.2	21.6	28.5	8.46			
Dead coral (other)	19.3	5.2	18.2	5.3	11.4	18.6	9.2	12.5	6.23			
Rubble	5.1	3.7	6.3	2.1	1.9	0.9	4.5	3.5	1.95			
Sand	8	12.1	2.9	1.8	6.8	4.7	5.6	6.0	3.44			

Table 5: Summary of % cover of benthic categories in video transects at Umm Al Maradem, Site 1												
Category	Tr 1	Tr 2	Mean cover	Std. dev.								
Live coral												
Acropora arabensis	0	0	0.0	0.00								
Fragmented *A.arabensis*	0	0	0.0	0.00								
Acropora clathrata	0	0	0.0	0.00								
Fragmented *A.clathrata*	0	0	0.0	0.00								
Porites compressa	51	55.2	53.1	2.97								
Porites lutea	0	0	0.0	0.00								
Platygyra	0.3	0	0.2	0.21								
Leptastrea	1.1	0.8	1.0	0.21								
Cyphastrea	1.4	0	0.7	0.99								
Massive coral	0	0.8	0.4	0.57								
Other benthos												
Diadema urchin	0	0	0.0	0.00								
Echinometra urchin	9.9	9.3	9.6	0.42								
Pencil urchin	0	0	0.0	0.00								
Substratum												
Dead *A.arabensis*	0	0	0.0	0.00								
Dead *A.clathrata*	0	0	0.0	0.00								
Dead *Porites*	2.7	4	3.4	0.92								
Dead coral (other)	23	17.9	20.5	3.61								
Rubble	4.7	3.2	4.0	1.06								
Sand	6	8.8	7.4	1.98								

Table 6: Summary of % cover of benthic categories in video transects at Umm Al Maradem, Site 2										
Category	Tr 1	Tr 2	Mean cover	Std. dev.						
Live coral										
Acropora arabensis	0.6	0	0.3	0.42						
Fragmented *A.arabensis*	0	0	0.0	0.00						
Acropora clathrata	0.6	0	0.3	0.42						
Fragmented *A.clathrata*	0	0	0.0	0.00						
Porites compressa	30.3	25.6	28.0	3.32						
Porites lutea	0	0	0.0	0.00						
Platygyra	0	0	0.0	0.00						
Leptastrea	0	1.9	1.0	1.34						
Cyphastrea	0	0	0.0	0.00						
Other benthos										
Diadema urchin	0	0	0.0	0.00						
Echinometra urchin	24.3	16.8	20.6	5.30						
Pencil urchin	0	0	0.0	0.00						
Substratum										
Dead *A.arabensis*	0	0	0.0	0.00						
Dead *A.clathrata*	0.3	0	0.2	0.21						
Dead *Porites*	10.3	6.5	8.4	2.69						
Dead coral (other)	24.3	36.2	30.3	8.41						
Rubble	3.7	4.9	4.3	0.85						
Sand	5.7	8.1	6.9	1.70						

Table 7: Summary of % cover of benthic categories in video transects at Kubbar, Site 3										
Category	Tr 1	Tr 2	Mean cover	Std. dev.						
Live coral										
Acropora arabensis	1.6	0.4	1.0	0.85						
Fragmented *A.arabensis*	0	0	0.0	0.00						
Acropora clathrata	0	0	0.0	0.00						
Fragmented *A.clathrata*	0	0	0.0	0.00						
Porites compressa	56.6	54	55.3	1.84						
Porites lutea										
Platygyra	0.4	0.4	0.4	0.00						
Leptastrea	0	0.7	0.4	0.49						
Cyphastrea	1.2	0	0.6	0.85						
Other benthos										
Diadema urchin	0	0.4	0.2	0.28						
Echinometra urchin	7.4	9.9	8.7	1.77						
Pencil urchin	0	0	0.0	0.00						
Zoanthid	0	0.7	0.4	0.49						

Table 8: Summary of % cover of benthic categories in video transects at Kubbar, Site 4				
Category	Tr 1	Tr 2	Mean cover	Std. dev.
Live coral				
Acropora arabensis	0	0	0.0	0.00
Fragmented *A.arabensis*	0	0	0.0	0.00
Acropora clathrata	0	0	0.0	0.00
Fragmented *A.clathrata*	0	0	0.0	0.00
Porites compressa	1.4	16	8.7	10.32
Porites lutea	0	0	0.0	0.00
Platygyra	0.3	0	0.2	0.21
Leptastrea	2.7	0.6	1.7	1.48
Cyphastrea	0	0.3	0.2	0.21
Massive coral	0.3	0	0.2	0.21
Other benthos				
Diadema urchin	0	0	0.0	0.00
Echinometra urchin	14.9	13.2	14.1	1.20
Pencil urchin	0	0	0.0	0.00
Zoanthid	0.7	0.3	0.5	0.28
Substratum				
Dead *A.arabensis*	0	0	0.0	0.00
Dead *A.clathrata*	0	0	0.0	0.00
Dead *Porites*	23.4	12.6	18.0	7.64
Dead coral (other)	36.9	37.5	37.2	0.42
Rubble	0.7	3.4	2.1	1.91
Sand	18.6	16.2	17.4	1.70

Annex 4: Publications from this project

CAMPUS RESEARCH 'Campus Review' Australia
August 31 - September 6, 1995

Kuwait coral relief explained

By SUSANNAH SMITH

THERE'S nothing quite like an ecocatastrophe to get the media hopping with excitement. In fact, the bigger the better.

The Amoco Cadiz oil disaster off the coast of France in 1978 attracted its share of public concern back in the days of blossoming environmental awareness, as did the massive Exxon Valdez spill in Alaska in 1989.

But the destruction wreaked by retreating Iraqi forces in Kuwait in February 1991 was the ecocatastrophe that really whipped the international media into a frenzy of speculation.

Admittedly, there was good reason.

The destruction of more than 730 Kuwait oil wells by the retreating Iraqi forces resulted in an estimated 10.8 million barrels of oil being released into the coastal waters of the Arabian Gulf between January and June 1991.

It was by far the world's largest oil disaster, made worse by the fact that it would take an estimated three and a half years for the small semi-enclosed waterway to churn its water back out to the Indian Ocean.

Long-term disastrous affects to the Saudi Arabian environment, including loss of wildlife and the likely damage to Kuwait's rare coral reefs, were predicted by a colourful variety of environmental experts.

The world was stunned.

But in a surprise ending to the story, one of the major concerns of the catastrophe – the effect on Kuwait's coral reefs – has ended up a far cry from the dire state that most media had forecast.

But the media has forgotten to let the world know.

The media's failure to report what should have been one of the world's most important follow-up stories is a topic that evokes rare anger from world leading coral expert, Dr Peter Harrison.

"The really remarkable thing is that, based on anecdotal evidence, most of the reefs look like they survived the spill virtually unscathed – the ecocatastrophe that everyone was dreading failed to eventuate," Harrison said.

"But what is also interesting is the difficulty that science stories have getting into the media unless they are of the 'bad news' variety.

"When the spill was being described as an ecocatastrophe it was given widespread publicity, but the fact that it hasn't been the disaster everyone thought it would be hasn't been publicised."

A lecturer at the centre for coastal management in the faculty of resource science and management at coastal-based Southern Cross University in Lismore, NSW, Harrison is currently half-way through a 12-month United Nations contract in Kuwait to examine the aftermath of damage to the country's coral reefs.

Harrison is widely known for his role in the team of scientists who discovered the spectacular mass coral spawning on the Great Barrier Reef – a discovery that won the team the Eureka Science Prize in 1992.

His research has been crucial to establishing why Kuwait's reefs have sustained such a mammoth ecological disaster. And closer to home, many of his findings also promise valuable application for Australia's reefs.

The global significance of Kuwait's 13 subtropical platform reefs is that theoretically, they should not exist.

Located a long way from the tropical environment in which most coral reefs – such as Australia's Great Barrier Reef – are typically found, the reefs have somehow managed to survive extremely low temperatures of down to 13 degrees Celsius during winter months.

By comparison, the minimum temperature widely considered to be the limit for coral reef development is 18 degrees Celsius.

Existing in an extreme environment, they are the coldest recorded of any actively growing reef system in the world.

High salinity provides additional stress to the reefs. While world average ocean water has a salinity of 35 parts per 1000, the salinity in the gulf rises as high as 42 parts per 1000.

"Normally, this would put a lot of stress on reef organisms, but Kuwait's reefs have sustained the high salinity levels," Harrison said.

With only around 30 species of coral, compared with around 360 on the Great Barrier Reef and 550 worldwide, Kuwait's reefs are not visually spectacular.

But they certainly hold a unique place in the global environment, and are particularly valuable to Kuwait's largely war-torn and ravaged environment.

In a country where the land mass mostly comprises overgrazed desert and a sprawling metropolis of wealth, the reef systems are the only part of the Kuwait environment that is left in any natural form.

Life after the Arabian Gulf oil spill . . . Dr Peter Harrison breaks down the myth of destruction that surrounds Kuwait's rare coral reef system.

Harrison's research has been crucial to helping scientists understand why, against all odds, the reefs have managed to survive.

"I guess it's been a surprise to just about everybody who's been involved with these studies that they have survived," Harrison said.

Normally when coral comes into contact with oil there are a range of stress responses, brought on by the fact that oil contains a number of highly volatile compounds that are directly toxic to coral tissue.

If the oil is thin, the coral may be able to protect itself by producing a mucus sheath until the oil is carried away. But if the oil is thick, the coral may be killed on impact.

Thick oil also blocks out sunlight, which is crucial for photosynthesis, and smothers the coral by not allowing essential oxygen below the water surface.

Fortunately, the oil released by the retreating Iraqi forces was an extremely light crude oil by world standards, which meant much of it evaporated off the water. In the hot desert environment and beneath high light intensity, many of the hydrocarbon compounds found in oil evaporate very quickly.

Secondly, most of the oil tended to flow along the coastline, bypassing some of Kuwait's most pristine coral reefs.

Thirdly, and most interestingly, it appears that the coral species that make up Kuwait's reefs may have a natural tolerance to oil. This is reflected by the fact that some of the prettiest reefs are located adjacent to natural oil seeps.

"All of these factors combined have confounded everyone's interpretations, and probably saved the environment. There's no other explanation," Harrison said.

While there has been some significant coral death in two of the reefs, Harrison has now attributed this to a winter chilling affect in 1992 when the temperature dropped to just 12 degrees Celsius.

"It appears that natural stress did more damage than the entire oil spill," Harrison said.

One experiment involving oil and larvae has led Harrison to the conclusion that had the oil spills devastated the coral reefs, it would have taken them centuries, if ever, to recover.

"I looked at the effects of oil pollution on the ability of larvae to settle and what we found was that even very low concentration of oil hydrocarbons in the water inhibited coral larvae from settling," he said.

This indicates that the chronic natural levels of oil that have an ongoing existence in the water are probably inhibiting the natural settlement of coral larvae most years. It is therefore only under exceptional circumstances when the oil is forced away by ocean currents or winds, that the larvae are able to settle.

"That makes the existing coral reefs even more rare," he said.

As part of Harrison's contract with the United Nations, he has echoed his success in Australia in recording coral spawning in Kuwait for the first time – an event that attracted intense attention from the Kuwait media.

Harrison's work with spawning led him to some fertilisation experiments looking at the affects of salinity, which provided some interesting answers to why coral in Australia does not successfully spawn during periods of high rainfall.

"What I found was that the high salinity that occurs around the Kuwait reefs does not inhibit fertilisation, but low salinity does block fertilisation. Now, that's not going to be a problem in the gulf where salinity levels are high, but it does explain the fact that in the very first year that we looked at spawning on the Great Barrier Reef we found that everything was killed by an unseasonably early downpour, and the entire reef's output for that year was wiped out," Harrison said.

He has also able to confirm just how tightly cued coral spawning is to a combination of water temperature, moonlight and time after dark.

In Australia, coral spawning occurs four to five nights after full moons in October, November and December. The equivalent time in Kuwait is May and June.

"One of the species in Kuwait spawned on exactly the same night after the full moon, at exactly the same time after sunset, as you would predict it from the Great Barrier Reef, but just six months out of phase," Harrison said.

"I remember just looking at my watch and thinking how amazing it was to be on the other side of the world and these corals were doing exactly the same things in the same lunar phase as Australian corals."

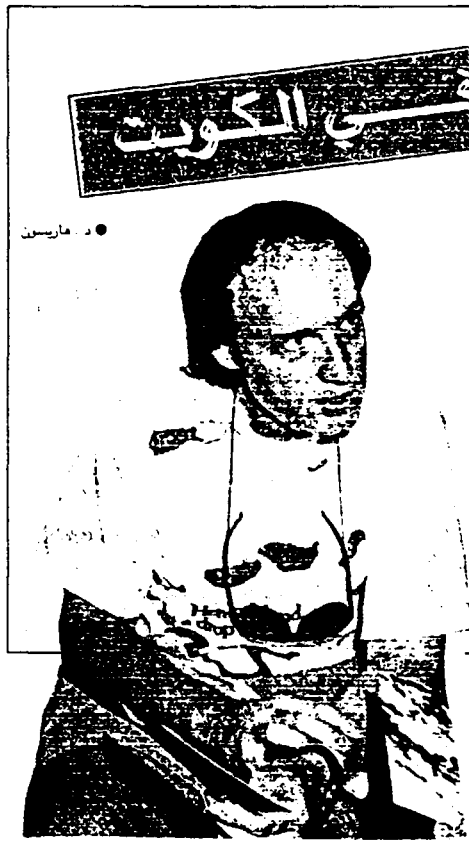
Harrison's contract is jointly funded by the United National Development Program and the United Nations Industrial Development Organisation, in conjunction with the Kuwait Institute of Scientific Research, at a total value of $A160,000.

Harrison will return to Southern Cross University in January 1996.

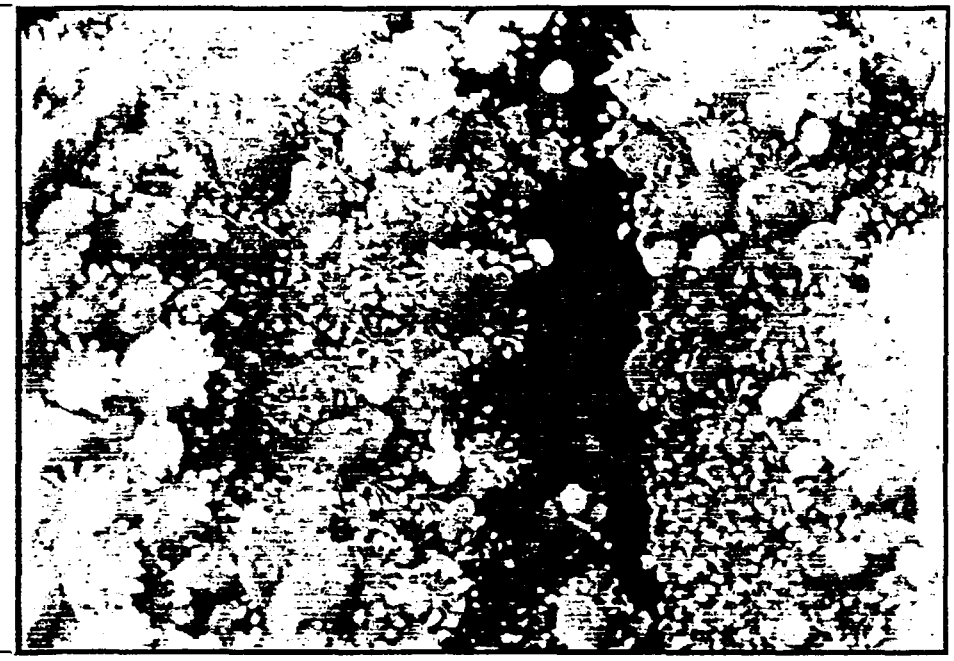
الشعاب المرجانية وطور تكاثرها ونموها

لأول مرة في الكويت

بالوقائع والألوان: عملية تبيُّض المرجان



● د. هاريسون



● الخلايا المرجانية تطفو الى سطح الماء استعدادا للتنفيس

تحقيق: منى فرح

لاول مرة في الكويت، وبالتحديد في الخامس عشر من شهر مايو الجاري، تم رصد وتصوير عملية تبيض للمرجان في احواض زجاجية وتحت ظروف مختبرية في دائرة الزراعة البحرية والثروة السمكية في معهد الكويت للابحاث العلمية. واهمية البحث العلمي انه الخطوة الاولى نحو دراسة تخصصية معمقة للمناطق المرجانية في المياه الاقليمية الكويتية من جهة، ودراسة ومعرفة مقدار نمو وتكاثر المرجان وتوسيع امكانية الاستفادة منه من جهة اخرى. فللمرجان فوائد جمة واهمية كبرى للبيئة البحرية وللانسان على حد سواء. وقد مول مشروع البحث هذا كل من برنامج الامم المتحدة للانماء، ومنظمة الامم المتحدة للانماء الصناعي ومعهد الكويت للابحاث العلمية. قام بعملية الرصد والتصوير فريق مؤلف من باحثين مشاركين في دائرة الزراعة البحرية وهم شاكر الهزيم، ايمان الصباح وعادل الصفار ويرأسه الدكتور بيتر هاريسون من جامعة «ساثرن كروس» في استراليا.

«القبس» التقت فريق العمل في مكان عمله حيث كان الاعضاء يتهيأون للقيام برحلة غوص بالقرب من الجزر المرجانية للحصول على مزيد من المعلومات، وكان هذا اللقاء حول اهمية المشروع واهدافه ونتائجه.

د. هاريسون: ظاهرة غير مألوفة

● الدكتور هاريسون واحد من اعضاء اول فريق المكتشفة لظاهرة التبيض الجماعي المتزامن في شعاب استراليا الكبيرة خلال الاعوام الثمانية الماضية. وقد اجرى ابحاثا تتعلق بتكاثر المرجان في مناطق متعددة من العالم خلال العقد الماضي.

يعتبر د. هاريسون وجود الشعاب المرجانية في المياه الكويتية شيئا غير مألوف لان هذه الشعاب استطاعت ان تتأقلم مع التغيير الكبير في درجة حرارة وملوحة المياه فالشعاب المرجانية عادة ما تنمو في مياه دافئة، ضحلة وصافية ذات ملوحة وحرارة معتدلتين لذلك يتركز تواجدها في سواحل بحار ومحيطات المناطق الاستوائية الضحلة حيث تكون درجة الحرارة معتدلة طوال فصول السنة واشار الى ان تواجد الشعاب المرجانية في الكويت يكثر في ثلاث جزر هي كبر وقاروه وام المرادم وهي جزر تكونت بفعل نمو وتكاثر الشعاب المرجانية، لذا تسمى بالجزر المرجانية.

عملية بيوكيميائية واشكال هندسية

هذا ما يحدث في مختبرات معهد الابحاث العلمية

■ توصيات عملية لحماية الشعاب والجزر في كبر وقاروه

اجراءات صارمة للحماية

ان الشعاب المرجانية في المياه الكويتية تواجه حاليا بعض المشاكل وهذه المشاكل كما يلحظها الصفار هي: تكسير المرجان من قبل المرتادين من حدائة وغواصين الذين يرصون بمراسي القوارب والبحوث على صخور المرجان بغرض تثبيتها مما يؤدي الى دمار كميات كبيرة من المرجان وكذلك يرمون القاذورات. اضافة الى ان بعض الغواصين الذين يستخدمون الهواء المضغوط ينتزعون كميات كبيرة من صخور المرجان لاغراض الزينة ويضيف الصفار: تعتبر الجزر المرجانية في المياه الكويتية حديثة التكوين، وعدم الاهتمام بها قد يؤدي الى تدميرها وبالتالي الى فقدانها. وحمايتها واجب وطني. واشار ان معهد الكويت للابحاث العلمية وبتمويل من ان حماية البيئة ومؤسسة الكويت للتقدم العلمي قد توصيات بشأن حماية الشعاب والجزر في كل من

الاحواض في المعهد، قد تتوصل الى معرفة كيفية تزاوج نوعين مختلفين بواسطة الزراعة ومن ثم اعادتها الى البحر للتكاثر وزيادة عدد انواعها وكمياتها.

وتضيف الصباح ان عملية التكاثر عند الحيوان المرجاني تشبه تلك الخاصة بالانسان. فترة التبيض تستغرق تسعة اشهر. وهذا ما استطعنا معرفته بعد قيامنا بعدة رحلات داخل البحر الى اماكن تواجد المرجان ومتابعة العملية داخل المعهد. بالطبع لم نستطع جمع معلومات وافية عن عملية تكوين البيض داخل الحيوان، ولا نستطيع القول متى بدأت البويضات او الحيوانات المنوية داخل حيوان المرجان ولكن ما نقوم به هو تصنيف انواع المرجان ودراسة امكانية التزاوج بينها.

● كيف جرت خطوات عملية الرصد؟

تجيب الصباح: لدينا نوعان من الاحواض

خطة لـ«زراعة» انواع المرجان: التزاوج شبيه بتزاوج البشر!

● فريق العمل في مختبر الدائرة

بعض نمو وتكاثر الشعاب المرجانية لما تسمى بالجزر المرجانية.

عملية بيوكيميائية واشكال هندسية

يصف د. هاريسون الشعاب المرجانية بانها صخور جيرية تفرزها الملايين من حيوان المرجان. اسطواني الشكل يتراوح حجمه ما بين اجزاء من المليمتر الى عدة سنتيمترات للقطر الواحد. وتتكون بفعل امتصاص حيوانات المرجان لمادة كربونات الكالسيوم الذائبة في ماء البحر ومن ثم تنتج مادة الجير بالتعاون مع خلايا نباتية صغيرة جدا تعيش داخل جسمها. ومادة الجير هذه تترسب في قيعان صلبة مكونة صخورا ذات اشكال هندسية جميلة ومتنوعة الصلابة. ومع مرور الاف السنين تبني هذه الحيوانات ما يعرف بالحواجز او الشعاب المرجانية.

غذاء ودواء للانسان

عن اهمية وجود هذه الشعاب المرجانية يقول د. هاريسون: «بوجودها في الماء تستضيف انواعا كثيرا من الاحياء البحرية كالاسماك والقشريات وانواعا مختلفة من الحشائش والاعشاب البحرية حيث ان الشعاب المرجانية تحميها من الامواج والتيارات البحرية القوية. ومن اهم وظائفها انها تعمل كمصدر طبيعي للامواج فتحمي الارض والمباني الساحلية. اما فوائدها فلا تعد ولا تحصى. فقد كان الانسان القديم يستعين بها في غذائه ودوائه اضافة الى استخدامها في مواد البناء وصناعة المجوهرات. وما يزيد من اهميتها ان الجزر المرجانية تعتبر مناطق سياحية.

● شاكر الهزيم

تكاثر ذاتي للاجنة

● شاكر الهزيم يعتبر تبيض المرجان داخل الاحواض ذا اهمية خاصة لانه تم تحت ظروف بيئية صعبة. ويضيف: «الحيوانات المرجانية في الكويت تتكاثر ذاتيا ونحن في مشروع عملنا استطعنا جمع نوعين من المرجان من جزيرة قاروه، ونقلناها بعناية الى احواض دائرة الزراعة البحرية تحت ظروف مختبرية محكمة.. وبعد ثمانية ايام من الملاحظة والعناية شوهدت عملية التبيض وذلك بخروج المرجان للبيوض والحيوانات المنوية على شكل حبيبات كروية تتخلل الماء الى ان تصل الى السطح يبدأ بعدها البيض بالتفتت والانكسار، وكانت نسبة التلقيح عالية مما ادى الى تكوين الاف من الاجنة التي يتم الان تربيتها وتجربة توطينها في الاحواض. وبعدها سوف يجرى المزيد من التجارب على تاثير الملوثات المختلفة على معدل نمو ونفوق اجنة المرجان».

في كبر وقاروه وام المرادم

مائة نوع من الاسماك

● عادل الصفار حدثنا عن اهمية معرفة انواع المرجان الموجودة في المياه الكويتية وانواع الاسماك التي تعيش عليها. وقال ان دراسة الشعاب المرجانية في الكويت وطور تكاثرها وتاثير الملوثات عليها ليست المشروع الاول لدائرة الزراعة البحرية والثروة السمكية قبل عشر سنوات اي بين عامي ٨٤ و ٨٩، انجزت الدائرة دراسة حول انواع الاسماك التي تعيش على الشعاب المرجانية. وتبين ان هناك حوالي ٣٢ نوعا من المرجان في مقابل مائة نوع من الاسماك منها التجاري (مثل الهامور والسكبر) ومنها اسماك الزينة. وهذه النسبة غير مقبولة خصوصا عند معرفة عدد انواع المرجان الموجودة في مناطق غير الكويت والتي تقدر بالالاف وتستقطب اضعافها من الاسماك. من هنا كانت اهمية تحديد وتعيين مناطق تواجد الحيوانات المرجانية. ومن خلال التفتيش والرصد حددت جزر القاروه وكبر وام المرادم كاهم مناطق تكثر فيها

● عادل الصفار

الحيوانات المرجانية. كذلك تبين وجود مسطحات مرجانية كانت في طور التكوين لان تصبح جزرا مرجانية مثل ام العيش والديرة.. وعلى طول شواطئ الكويت (من راس السالمية الى الخيران) هناك بقايا لبعض المسطحات المرجانية منتشرة بطرق عشوائية.

تاثير الملوثات

● ولكن اين ذهبت تلك المسطحات المرجانية؟!

يجيب الصفار: ان انتشار الحياة المدنية والمصانع النفطية - مثل الاحمدية والشعيبة - وتلوث مياه البحر بمياه الصرف الصحي والنفايات النفطية وانتشار القانورات كل هذا اثر سلبا على عدم استكمال تكوين المسطحات. فالمصانع والملوثات النفطية تسهم في تغير درجة حرارة المياه من المعتدل الى الحار جدا. وهذا الاختلاف يحدث خللا في التوازن المناخي الذي يعيق بدوره نمو وتكاثر الحيوانات المرجانية.

ويؤدي الى فقدانها. وحمايتها واجب وطني. واشار الى ان معهد الكويت للابحاث العلمية وبتمويل من مجلس حماية البيئة ومؤسسة الكويت للتقدم العلمي قدم توصيات بشان حماية الشعاب والجزر في كل من كبر وقاروه وام المرادم وهي تتلخص باقتراحين:

الاقتراح الاول ينص بالسماح للناس بزيارة تلك الاماكن شرط عدم تدخلهم باي شكل من الاشكال بالكائنات الحيوانية والنباتية الموجودة هناك كما يؤخذ بالاعتبار عند ممارسة عمليات صيد الاسماك بالسنارة البحرية والشباك والقوارير، عدم جمع اي مواد بيولوجية، عدم رمي القانورات. منع رسو القوارب على مناطق الشعاب ومنع مرور السفن التجارية. ويجب ان يكون هناك حظر موسمي على الجزر يستمر من اوائل شهر يونيو (وهو شهر التزاوج) حتى نهاية شهر اكتوبر (شهر التكاثر).

اما الاقتراح الثاني فهو تطبيق حماية شاملة بحيث تصبح الجزر والشعاب المرجانية مناطق محظورة لا يحق لاحد التدخل بها الا للمؤسسات العلمية المختصة.

نحو زراعة المرجان

● الخطوة الثانية من المشروع هي دراسة امكانية زراعة المرجان تمهيدا لتطويره في المستقبل. عن هذا الموضوع قالت ايمان الصباح: المهم في البداية وبعد تحديد اماكن تواجد الحيوانات المرجانية وانواعها، العمل على حمايتها وابعاد الاخطار عنها مثل التدخل العشوائي من قبل الانسان وابعاد العناصر الثقيلة مثل الرصاص والزنك التي تقتل الحيوان المرجاني. ومثلما استطعنا رصد وتصوير عملية التبيض داخل

ولكن ما نقوم به هو تصنيف انواع المرجان ودراسة امكانية التزاوج بينها.

● كيف جرت خطوات عملية الرصد؟

تجيب الصباح: لدينا نوعان من الاحواض احواض كبيرة مملوءة بمياه البحر وهي مخصصة لحضن وزراعة الاسماك لقد وضعنا المرجان فيها في الفترة الاولى بعد تجهيزها تجهيزا كاملا بجميع الظروف المناخية الطبيعية المطابقة لتلك الموجودة في البحر، كالاضاءة الطبيعية وكمية الاوكسجين وغيرها. وقبل موسم التكاثر تنقل الحيوانات المرجانية الى احواض صغيرة حتى لا تضيع البيض بين الاسماك فتاكلها هذه الاخيرة. كنا نقوم بعملية الرصد والتصوير يوميا بعد الغروب ونرى ما اذا كانت الحيوانات في حالة التحضير للتبيض. ومعرفة حالة التحضير ترتكز على مراقبة البيوض وكيف يتغير لونها ويحدث لها انتفاخ. البيضة تنفتح ويصبح لون اطرافها مائلا الى الزهري وبعدها. يخرج البيض من الخلية المرجانية ويطفو على سطح الماء في انتظار التفقيس. كل خلية مرجانية تتضمن عشر بيضات والافا من الحيوانات المنوية. بعد ان تطفو على سطح الماء تنفصل الحيوانات المنوية عن البيض. ويذهب البيض بدوره ليتلقح من حيوان منوي انفصل عن خلية اخرى. واهمية المشروع تكمن في اننا استطعنا تدوين موسم تكاثر المرجان واوقات التبيض التي تبين ان لها علاقة بحرارة الماء وكذلك حالة بدور القمر. وهذا يساعد كثيرا في امكانية تربية المرجان على نطاق واسع واثراء الشعاب المرجانية والحد من تدني انتشارها.

● الشعاب المرجانية كما تبدو تحت الماء

● ● ●

● الخلايا المرجانية - حاملة البيض (تحت الماء)

Kuwait coral study

On a brief visit home during his year-long United Nations consultancy in Kuwait, Dr Peter Harrison called into the University in August.
Peter is a world coral expert and Lecturer in the Centre for Coastal Management in the Faculty of Resource Science and Management.
He and his team of three young scientists are helping the Kuwait Institute for Scientific Research (KISR) develop a strong program for the coral.
The $300,000 project being undertaken is the 'Ecology of Kuwait's coral reefs', how the coral have fared following the oil spill in the 1990-91 Gulf War.
Peter said scientists involved in the studies were surprised that although the oil spill was massive, the coral seem to have survived 'virtually unscathed'.
"There seems to have been very little stress because remarkably a number of things happened," he said.
"The oil flowed more along the coast rather than further out where the coral is, more towards Saudi Arabia, and its reefs mainly survived too.
"Oil is directly toxic to the coral and the lack of light and oxygen smothers the coral.
"But the crude oil left by the retreating Iraqi forces is a very light oil and the high light intensity helped to break down the damaging effects on the coral.
"The ecocatastrophe that everyone was expecting didn't happen."
Another scientifically interesting aspect is that Kuwait's coral reefs should not exist.
"They're subtropical reefs and 18 degrees Celsius is the lowest temperature where coral reef growth can be expected," he said.
"The temperature drops to 13 degrees Celsius in the winter.
"But the corals are 400 to 500 years old and some are massive, as big as a room.
"There are about 30 species on 13 reefs and five of the reefs are reasonably important.
"They're not visually spectacular but the reefs off-shore are very pretty."
Peter said that damage to the coral was more likely to have been the result of the chilling effects of winter than the oil spill and some sites had significant anchor damage and coral breakage.
Peter was a member of the team of scientists which discovered the mass coral spawning on Australia's Great Barrier Reef, which won it the Eureka Science Prize in 1992.
He and his team in Kuwait are the first to have recorded coral spawning in that country.
"The synchronous mass coral spawning is on the same night after full moon and at the same time after dark as in Australia, but six months earlier or later," he said.
"This led us to a fertilisation study and we found that the high salinity ocean water does not inhibit fertilisation but low salinity would, and even very low amounts of oil

built-up coastal strip and the rest desert.

"Oil leaks naturally on to the coral reefs – there are huge wafts of oil – but you still get pretty reefs developed adjacent to it," Peter said.
"We have been able to set up a comparative base using an underwater camera, video recordings and photos to quantify any damage to the coral."
The project is funded by the UN Development Program and KISR.
Peter said it took two to three months to establish equipment for a new laboratory at the beginning of the year.
One scientist working with him, Mr Shaker Alhazeem, is coming to the University next year to do a Masters degree.
Peter has another month in Kuwait and returns to the University in January.

Dr Peter Harrison with a feature story in a Kuwait publication about his work on Kuwait's coral reefs.

Korean researcher

Mr Kwon, Sung-Yong, is the latest visitor to the Faculty of Education, Work and Training under the 'Asian Perspectives on Mathematics Education' project.
He is from Korea National University of Education in Jo Chi Won, Chungbuk Province, and is undertaking data collection and analysis for research projects in comparative curriculum, teaching styles and cognitive construction, under the direction of the Faculty's Dr Garry Bell.
He is also continuing the work begun by Mr Seo, Dong-Yop, of Seoul National University, who was a researcher with the Faculty last year.
The 'Asian Perspectives on Mathematics Education' project has been operative since 1992 and has attracted more than $100,000 in funding from various sources.
Two books and a series of teaching materials have been produced as a result of the project, in Korean, Chinese, Japanese, Indonesian, Thai and Vietnamese, in addition to

[illegible]

The project has involved visits of academics

from Japan, Korea and Indonesia, and has provided an editorial centre for the annual publication *Review of Mathematics Education in Asia and the Pacific.*

Christiana Kim recently moved to the area from Inchon. At St Carthage's School, she is pictured with Mr Kwon, telling the class the story of the traditional hair ribbon which forms part of the Korean national dress.

جة ١٤١٥ هـ ٢٤ مايو ١٩٩٥ العدد ٦٩٢٥ / ١٣٧١ ـ السنة ٣٤
الوطن

نتخابات «البلدي»

رحيل امتحانات ٦ إلى ٨ يونيو

● د. منصور غلوم

ية فتور دول ناء حيله نيو. عقاد نفس لية سراء شمل يعقد يعقد انات

النقل في جميع صفوف النقل للمرحلتين المتوسطة والثانوية يوم السبت المقبل المصادف للسابع والعشرين من الشهر الحالي.

تعرض في فيلم تليفزيوني خلال أيام

د. مطر: رصد عملية تبييض المرجان مختبريا لأول مرة بالكويت

كونا ـ من نوري الأستاذ: نجح معهد الكويت للأبحاث العلمية في رصد وتصوير عملية تبييض للمرجان في احواض زجاجية وتحت ظروف مختبرية لأول مرة في الكويت.

وابلغ مدير دائرة الزراعة البحرية والثروة السمكية الدكتور سليمان مطر وكالة الأنباء الكويتية ان عملية مشاهدة وتصوير عملية التبييض تمت بالدائرة حيث تم جمع نوعين من المرجان من شعاب جزيرة قاروه وتم نقلهما بعناية فائقة وتحت ظروف خاصة الى الأحواض.

واوضح انه بعد ثمانية ايام من الملاحظة والعناية شوهدت عملية التبييض وذلك بافراز المرجان للبيض والحيوانات المنوية على شكل حبيبات كروية تتخلل الماء الى ان تصل الى السطح ويبدأ بعدها البيض بالتفكك والانتشار مشيرا الى ان نسبة التلقيح كانت عالية مما أدى الى تكون الآلاف من الأجنة التي يتم تربيتها وتجربة توطينها في الأحواض لاجراء المزيد من التجارب على تاثير الملوثات المختلفة على معدلات نمو ونفوق اجنة المرجان.

واعتبر الدكتور مطر تبييض المرجان داخل الأحواض عملية ذات اهمية خاصة اذ تم التاكد من ان الشعاب المرجانية في المياه الكويتية والتي تعيش تحت ظروف بيئية صعبة تتكاثر ذاتيا وليس لها علاقة مباشرة بالشعاب الواقعة جنوب المياه الكويتية.

واشار الى امكانية تدوين موسم تكاثر المرجان وأوقات التبييض وعلاقتها بدرجة حرارة ماء البحر وحالة بدور القمر مؤكدا امكانية تربية المرجان على نطاق واسع لاثراء الشعاب الطبيعية والحد من تدني انتشارها الناتج عن عمليات الدمار من قبل الملوثات والمؤثرات الطبيعية والنشاطات البشرية.

واضاف ان الدائرة سوف تقوم برصد موسم تكاثر المرجان الموجود في الجزر الكويتية الأخرى مثل جزيرة ام المرادم وجزيرة كبر.

وقال مدير دائرة الزراعة البحرية لكونا ان عملية رصد تكاثر المرجان تمت تحت اشراف فريق عمل برئاسة الدكتور بيتر هاريسون من جامعة سانرن كروس الاسترالية الذي يراس كذلك مشروع البحث عن الشعاب المرجانية الممول من كل من برنامج الأمم المتحدة للانماء ومنظمة الأمم المتحدة للانماء الصناعي ومعهد الكويت للأبحاث العلمية.

وبين ان الدكتور هاريسون يعتبر احد اعضاء اول الفرق المكتشفة لظاهرة التبييض الجماعي المتزامن في شعاب استراليا الكبيرة خلال الاعوام الثمانية الماضية وقد قام بالأبحاث المتعلقة بتكاثر المرجان في مناطق متعددة وقد قام بالأبحاث المتعلقة بتكاثر المرجان في مناطق متعددة حول العالم خلال العقد الماضي مشيرا الى ان مشروع المعهد الحالي يدرس حالة الشعاب المرجانية في المياه الكويتية وطور تكاثرها وتاثير الملوثات عليها.

واضاف ان فريق البحث المكون من كل من شاكر الهزيم وعادل الصفار وايمان الصباح قام بتصوير عملية التبييض لعرضها على فيلم تلفزيوني خاص عن تكاثر الشعاب المرجانية في المياه الاقليمية الكويتية خلال الأيام القليلة المقبلة.

اختتام الاجتماع التنسيقي لمعاوني العمليات الخليجيين

● اللواء الركن فالح الشطي

اختتمت صباح أمس فعاليات الاجتماع التنسيقي الأول لمعاوني العمليات بدول مجلس التعاون

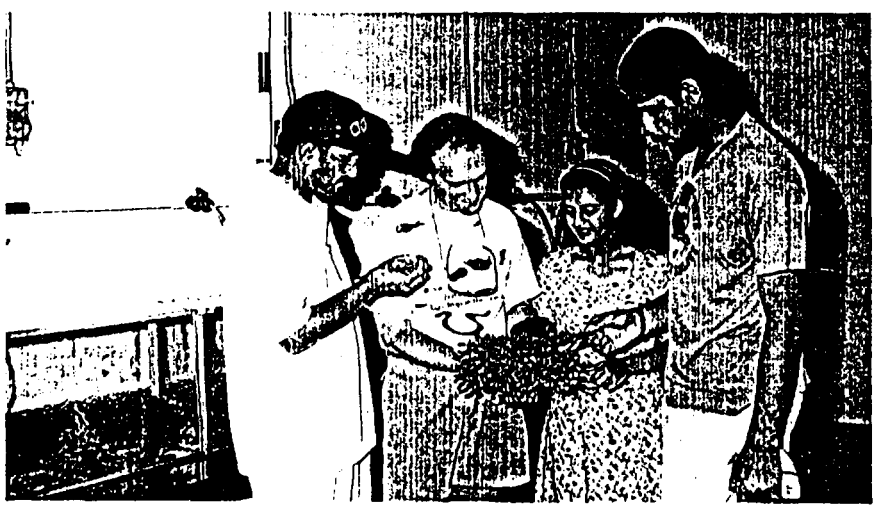
KISR Magazine

محافظ الجهراء زار معهد الأبحاث وتفقد مشروع التخضير

زار محافظ الجهراء الشيخ ابراهيم دعيج الإبراهيم الصباح معهد الكويت للأبحاث العلمية، واستعرض مع المدير العام للمعهد الدكتور عدنان العقيل خطط وبرامج وتوجيهات المعهد في مجالي الزراعة والتخضير. إضافة إلى أهمية المواءمة لدى التخطيط للمشروعات بين المواكبة للمستجدات العلمية والحفاظ على البيئة والتراث الحضاري، وضرورة الاسترشاد بالموروث المعرفي لدى ذوي الخبرة وكبار السن في هذا المجال.

وتفقد المحافظ الصباح مقر مشروع خطة التخضير التي تشمل المنتزهات الصحراوية، المتحف الطبيعي، المناطق المحمية، مدينة الحجاج، منطقة قصر بيان، والحزام الأخضر لمدينة الكويت. كما شملت الزيارة تفقد مختبرات أبحاث الزراعة النسيجية.

المعهد ينجح في تبييض المرجان بأحواض زجاجية



فريق العمل داخل أحد مختبرات المعهد

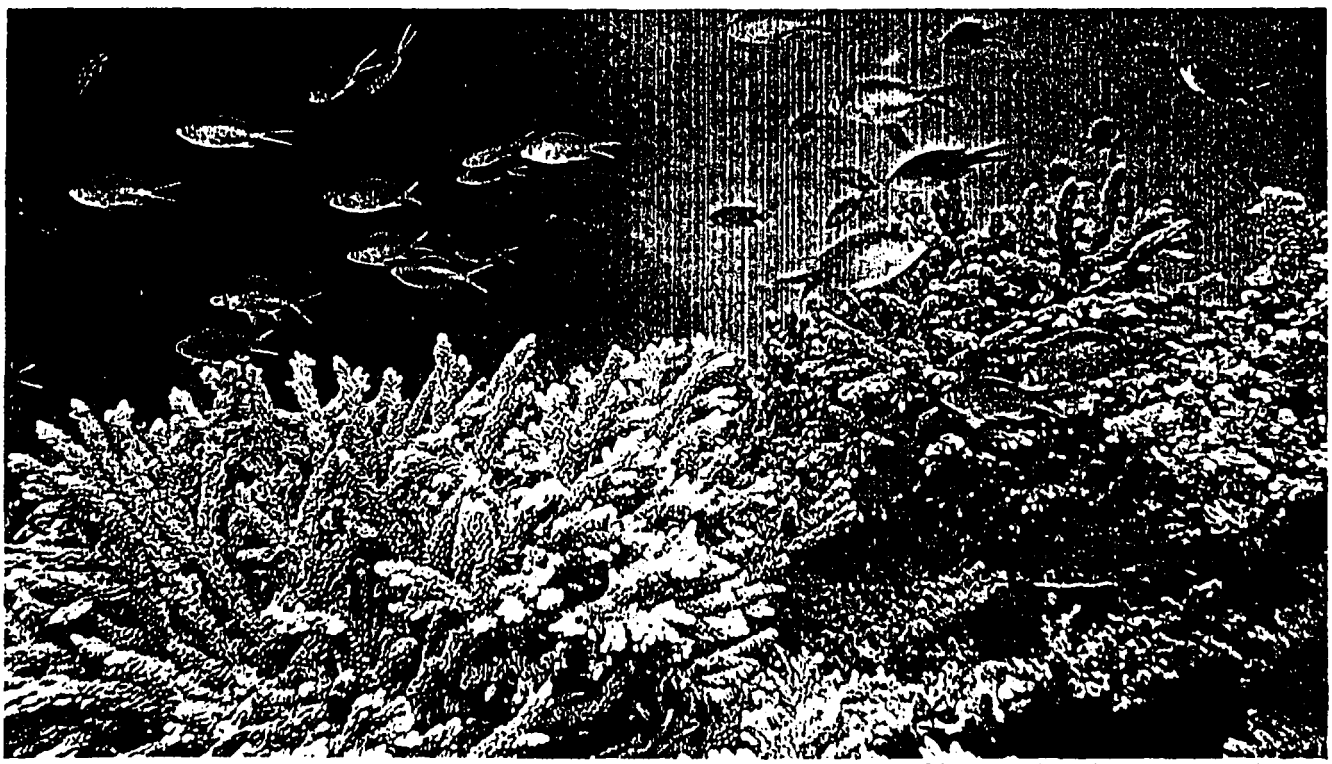
الخلايا المرجانية في طور الإباضة

نجح معهد الكويت للأبحاث العلمية في رصد وتصوير عملية تبييض للمرجان في احواض زجاجية مختبرية لأول مرة في الكويت.

مدير دائرة الزراعة البحرية والثروة السمكية الدكتور سليمان مطر أشار إلى أن عملية مشاهدة وتصوير عملية التبييض تمت بجمع نوعين من المرجان من شعاب جزيرة قاروه ونقلهما بعناية فائقة وتحت ظروف خاصة إلى الأحواض.

وأوضح انه بعد ثمانية ايام من الملاحظة والعناية شوهدت عملية التبييض وذلك بإفراز المرجان للبيض والحيوانات المنوية على شكل حبيبات كروية تتخلل الماء إلى أن تصل إلى السطح. ويبدأ بعدها البيض بالتفكك والانتشار، مشيرا إلى ان نسبة التلقيح كانت عالية مما ادى الى تكون الآلاف من الاجنة التي يتم تربيتها وتجربة توطينها في الاحواض لإجراء المزيد من التجارب على تاثير الملوثات المختلفة على معدلات نمو ونفوق اجنة المرجان.

واعتبر الدكتور مطر تبييض المرجان داخل الاحواض عملية ذات اهمية خاصة، إذ تم التأكد من أن الشعاب المرجانية في المياه الكويتية والتي تعيش تحت ظروف بيئية صعبة، تتكاثر ذاتيا.

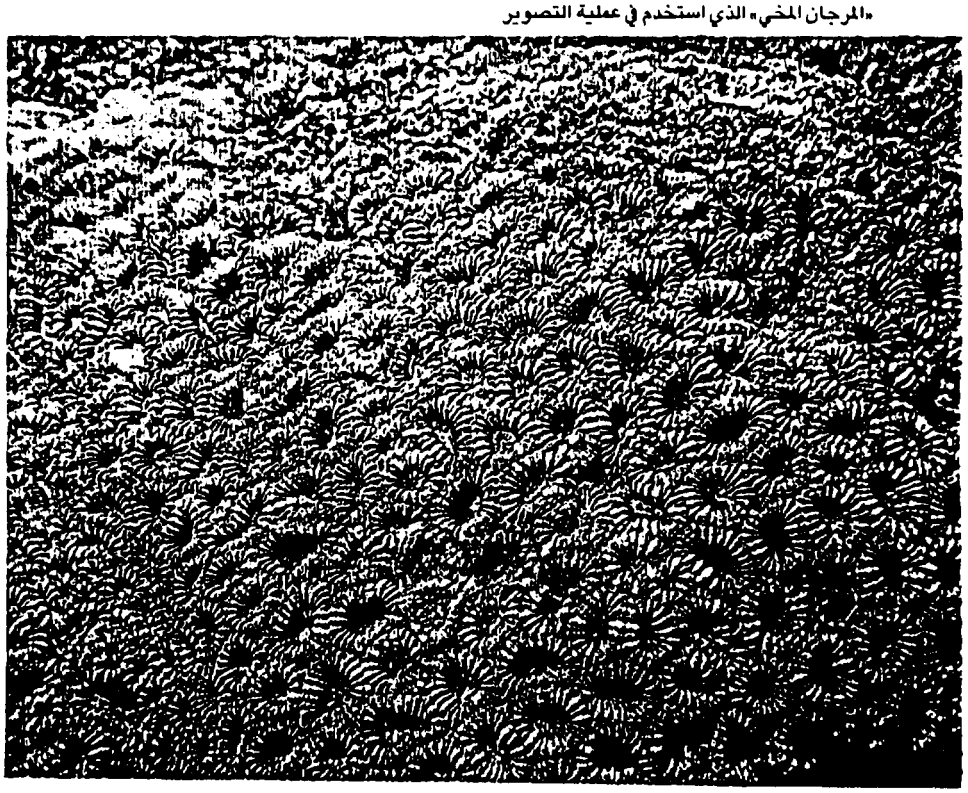


مئات الانواع من الاسماك تعيش في الشعاب المرجانية

الشعاب المرجانية وأطوار تكاثرها ونموها

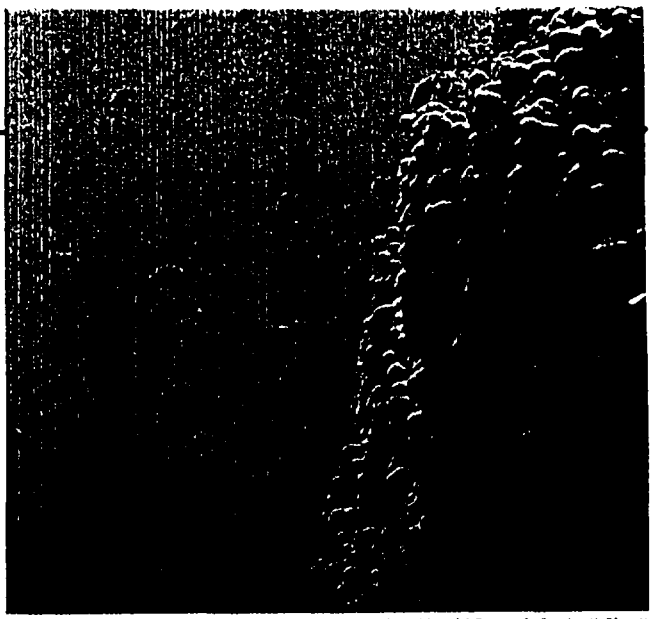
تصوير أول عملية للاباضة في مختبرات المعهد

«المرجان المخي» الذي استخدم في عملية التصوير



لأول مرة في الكويت، وبالتحديد في الخامس عشر من شهر مايو ١٩٩٥، تم رصد وتصوير عملية وضع البيوض المرجانية في احواض زجاجية، وتحت ظروف مناخية - مختبرية، في دائرة الزراعة البحرية والثروة السمكية في معهد الكويت للأبحاث العلمية.

واهمية الحدث العلمي انه الخطوة الاولى نحو دراسة تخصصية معمقة للمناطق المرجانية في المياه الاقليمية الكويتية من جهة، ودراسة ومعرفة مقدار نمو تكاثر المرجان، وتوسيع امكانية الاستفادة منه من جهة اخرى، خصوصا وان دولة الكويت تنعم بانظمة بيئية ذات شعاب مرجانية جميلة ومهمة.



البيئة السليمة ضرورة لنمو المرجان

يرأس مشروع عملية الرصد والتصوير الدكتور بيتر هاريسون من جامعة «ساوثرن كروس يونيفرستي» في استراليا الذي تعاقدت معه منظمة الامم المتحدة للتنمية الصناعية لتدريب وتنسيق عمل فريق باحثين كويتيين من دائرة الزراعة البحرية والثروة السمكية في معهد الكويت للابحاث العلمية. ويتألف الفريق من شاكر الهزيم وعادل الصفار وايمان الصباح.

وساعد تهديد الكارثة البيئية في الخليج العربي في تركيز الاهتمام الدولي على مصير الشعاب المرجانية الكويتية. وفي مواجهة تلوث البيئة البحرية للخليج العربي تعاون معهد الكويت للابحاث العلمية والبرنامج الانمائي للامم المتحدة ومنظمة الامم المتحدة للتنمية الصناعية في وضع مشروع بحثي لدراسة ايكولوجيا الانظمة البيئية الخاصة بالشعاب المرجانية الكويتية، وكان المشروع يرمي الى تحديد الاثار الطبيعية القاسية والاضطرابات التي افتعلها الانسان في حياة المرجان.

تكاثر ذاتي للمرجان

بدأ المشروع في فبراير ١٩٩٥، وحقق البحث انجازات علمية جديدة مهمة. فالحيوانات المرجانية في الكويت تتكاثر ذاتيا، وقد تم جمع نوعين من المرجان ونقلت الى احواض دائرة الزراعة البحرية تحت ظروف مختبرية محكمة. وبعد ثمانية ايام من الملاحظة والعناية، شوهدت عملية الاباضة وذلك بافراز المرجان للبيوض والحيوانات المنوية على شكل حبيبات كروية، تتخلل الماء الى ان تصل الى السطح، يبدأ بعدها البيض بالتفتت والانكسار.

وكانت نسبة التلقيح عالية مما ادى الى تكوين الالاف من الاجنة التي تتم تربيتها وتجربة توطينها في الاحواض.

وتجرى الان عمليات التصوير الفيديوي تحت الماء في المواقع الرئيسية للشعاب المرجانية لتحديد حالة مجموعات الشعاب المرجانية.

وهذه المجموعات تختلف احداها عن الاخرى حول كل حيد صخري وبين مواقع الشعاب، مع تميز مناطق متمتعة بغطاء مرجاني عالي الارتفاع. وثمة مرجان شديد الكثافة في مناطق الشعاب العميقة يبدو انه يرقى الى مئات السنين.. اما النمو الصاعد للمرجان فيقيده الجزر، وثمة دليل على ان بعض مرجان الشعاب المسطحة يموت شتاء، وربما كان السبب هو تضافر الطقس البارد مع تراجع المياه عند الجزر، وهذا الامر يلقي الضوء على الظروف الطبيعية القاسية التي ينبغي على المرجان ان يغلبها. وثمة دليل اخر على ضرر كبير وتدمير قاتل اصابا المرجان بايدي الناس، خصوصا الغواصين منهم الذين يلقون مراسي المراكبُ على مستوطنات المرجان الحي، فيما تعاني بعض المناطق من القمامة الملقاة على الشعاب.

ومن الاهمية بمكان اطلاع الناس على الاضرار اللاحقة بالمرجان، لذا سيكون هدف المرحلة النهائية من هذا المشروع تطوير خطط ادارية ترمي الى التغلب على مثل هذه المشكلة. وسوف يجرى المزيد من التجارب على تاثير الملوثات المختلفة على معدل نمو ونفوق اجنة المرجان في الكويت.

عملية الاباضة

كان الاختراق الاهم في المشروع متمثلا في اكتشاف عملية وضع البيوض المرجانية في الشعاب المرجانية. فقد جرت مراقبة نوعية من مرجان «اكروبورا» المتشعب وهو يبيض في الليل في فترة اكتمال القمر (بدرا) في مايو ١٩٩٥.

وفي خلال عملية وضع البيض تشكلت من البيوض والحيوانات المنوية الصادرة من داخل كل بولب (سليلة مخاطية مرجانية) حزمة تحت فتحة البولب نفسه. ثم كانت الحزمة تخرج من البولب لتصعد وتعوم على سطح المياه حيث تنفصل البيوض والحيوانات المنوية ويحدث التخصيب، وقد بين نمط وضع البيوض في الحوض المائي وفي مائة مستوطنة «اركوبورا» في شعاب جزيرة قاروه ان عملية وضع البيض في كل مستوطنة اقل تزامنا مما يحصل في الجزء الاعظم من مناطق الشعاب المرجانية. ففي الحيد الصخري العظيم (في استراليا) تبيض جميع المستوطنات المرجانية في ليلة او ليلتين، بينما امتدت عملية وضع البيض لدى مرجان «اركوبورا» في جزيرة قاروه لفترة طويلة، وفي الاونة الاخيرة، جرت مراقبة وضع البيض لدى عينات من مرجان Platygyra daedalea الذي جمع من جزيرة قاروه، وتبين انها قسم من اليرقات ذات الحياة الطويلة الى شعاب مرجانية اخرى في الخليج العربي. ويفتح اكتشاف عملية وضع البيض في مياه الكويت الطريق امام عدد كبير من الفرص الجديدة لاجراء بحوث لاحقة في الشعاب المرجانية الكويتية.

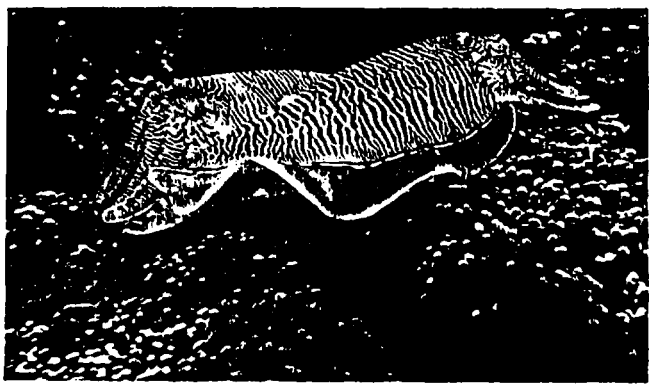
«المرجان الاصبعي» في مرحلة الاباضة

تاثير الملوحة والتلوث النفطي

في خلال مرحلة وضع البيض اجريت تجربتان لاختبار اثار الملوحة والتلوث النفطي في تناسل المرجان. واقام اثنان من الفريق ليلة كاملة لمراقبة اثار ملوحة مختلفة في معدلات تخصيب البيوض بالحيوانات المنوية لمرجان «اركوبورا كلاثراتا». واشارت النتائج الى ان الملوحة البحرية العالية نسبيا الموجودة في شواطىء الكويت لا تمنع التخصيب المرجاني، انما تخفضها الى ما دون التخصيب الحاصل في الملوحة العادية.

وأظهرت تجربة خضعت لها يرقات «اركوبورا ارابنزيس» المرجانية ان المعدلات المتدنية للهيدروكربونات باضت معا ليلتي الرابع والخامس من يونيو بعد مرحلة اكتمال القمر.

وتطورت البيوض المخصبة الى يرقات قابلة للحياة ارتقت الى بوالب (سليلات) مخاطية مرجانية في احواض ادارة الزراعة البحرية والثروة السمكية في منطقة رأس السالمية. وما اثار الاهتمام ان بعض يرقات مرجان «اركوبورا ارابنزيس» بقيت حية لمدة اربعة اسابيع، واليرقة التي صمدت هذه المدة تكون قادرة على البقاء. وهذا ما كان موثقا في السجلات والافلام الاولى للاباضة المرجانية في الكويت، وبينت النتائج ان المستوطنات المرجانية المحلية قادرة على النجاح في التناسل. وفيما تستطيع بعض انواع اليرقات البقاء في الشعاب المحلية لتساعد في الحفاظ على المجموعات المرجانية في مياه الكويت، ينتقل في المياه البحرية تخفض مدة بقاء اليرقات حية او تمنعها من ذلك. وكان لهذا الكشف العلمي مفاعيل تؤثر في بيئة الشعاب المرجانية الكويتية، وكان يبين ان استقرار اليرقات المرجانية في الشعاب يضعف اذا تعرضت لتسرب النفط العادي او لحوادث التسرب النفطي الكبيرة.



«الحبار» في حالة التزاوج

أهمية الشعاب

تشكلت هذه الشعاب عبر الاف السنين بنمو مستوطنات المرجان. ويفرز المرجان الحي هياكل كلسية تشكل البيئة الاساسية للشعاب وتوفر المواطن الاساسية لالاف الكائنات التي تعيش في الشعاب. وبناء على ذلك، يعد المرجان الذي يكون الشعاب عنصرا جوهريا مكونا في النظام البيئي. علاوة على ذلك، تؤمن الشعاب فوائد كبيرة للكويتيين تتمثل في الابحار الترفيهي والصيد والغوص بصفتها مستوطنات لكثير من الكائنات ذات الاهمية التجارية الكبيرة. لكن بمرور الزمن يؤدي ضرب الامواج للشعاب والتأكل الناجم من قوى طبيعية اخرى الى تراكم الرمال وتشكيل المرتفعات الرملية الصغيرة في المياه، مثل جزر «كبر» و«قاروه» و«ام المرادم». وهذه المرتفعات المرجانية تؤمن المواطن الصالحة لتكاثر العضويات والطيور البحرية والسلاحف. وهكذا تكون الشعاب المرجانية عبارة عن انظمة بيئية نشيطة واقعة في توازن دقيق بين نمو المرجان وتطور الشعاب من جهة، والقوى المدمرة المؤدية الى القضاء على المرجان وتأكل الشعاب من جهة اخرى.

وتتمتع الشعاب المرجانية في الكويت باهمية علمية خاصة لانها موجودة في بيئة ذات ظروف مناخية متطرفة تفوق قساوتها نطاق احتمال التطور الطبيعي للشعاب المرجانية. ويعني وجودها في المنطقة الشمالية للخليج العربي انها معرضة لملوحة بحرية مرتفعة نسبيا والى حرارة متطرفة للمياه البحرية. ومن الناحية النظرية، يكون من المستحيل وجود هذه الشعاب لما كانت حرارة مياه البحر تنخفض شتاء الى ما دون ١٣ درجة مئوية، فيما يكون المعدل العادي الطبيعي لحرارة المياه الملائمة لنمو المرجان ١٨ درجة مئوية. غير ان الشعاب المرجانية الكويتية كانت لافتة لجهة قدرتها على البقاء حية بالتغلب على قساوة الطبيعة.

وربما كان الأشد لفتا هو قدرة الشعاب المرجانية على البقاء حية برغم اكبر تسرب نفطي معروف في التاريخ، ارتكبته عن سابق تصور وتصميم قوات الغزو العراقي ابان حرب تحرير الكويت عام ١٩٩١.

خطوات مستقبلية

ويتضمن العمل اللاحق على هذا المشروع اجراء دراسات مفصلة لجماعات الشعاب المرجانية في جميع ارجاء المنطقة الكويتية لتوفير فهم مفصل للوضع الراهن لهذه الشعاب وكشف معدلات نمو المرجان وتحليل مقادير التلوث بالمعادن الثقيلة الذائبة واثار العوامل الطبيعية القاسية والتلوث النفطي في نمو المرجان البالغ وقدرته على البقاء حيا.

وستجمع المعلومات الجديدة من اجل تحديد طبائع الجماعات المرجانية ذات القيمة العالية من أجل المحافظة عليها.

PROJECTS

OIL LAKES UPDATE

On June 6, a delegation representing both KISR and the Arab Oil Company visited the site of the project on the rehabilitation of oil lakes The project is being carried out jointly by KISR and the Japanese Energy Center.

The oil lakes were formed as a result of the setting afire of Kuwaiti oil wells by Iraqi troops as they pulled out of Kuwait. The lakes are a major threat to the environment because of the toxic components of the oil as well as the possibility of the existence of mines and explosives in them.

The project, which was a formally agreed upon last year, is aimed at applying different technologies to treat the severely polluted oil lake bottoms.

The visit coincided with the completion of the first year of the project in which one hectare of oil lake bottom was treated in cooperation with KOC, which allocated the one hectare from oil lake no. 102 in the Burgan oil field. The site was also cleared of mines in cooperation with the Ministry of Defense. More than 3000 m^3 of oil sludge was removed for treatment; the oil was extracted by thermal/chemical methods developed by KISR scientists in cooperation with the Shimidzu Engineering Company in Japan.

Other studies were also carried out on the degree of oil pollution seepage to the various lower soil layers. More than 7000 m^3 of polluted soil was removed to biotreatment methods developed by KISR scientists using bacteria capable of degrading oil. These methods will be extensively assessed in cooperation with the Japanese Obayashi Company.

The duration of this project is three years, and it is the largest environmental project being conducted in the Middle East in cooperation with the Japanese Energy Center. The importance of this project lies in its execution under the very harsh desert conditions. The results of the project will be presented to the concerned authorities as environmental plans and recommendations.

The delegation met with the work team and viewed the ongoing work. They also witnessed the work accomplished in the first stage of the project and were given an explanation of the work to be done in the next stage. At the end of the visit, the delegation expressed their satisfaction with the work and wished the team success in the next stage of

An Oil Lake Burning

REPRODUCTION OF CORALS

Branching coral spawning egg and sperm bundles. Photo by Dr. Peter Harrison

A research team at KISR has successfully observed and documented the reproduction of reef corals for the first time in Kuwait.

The research forms part of the Coral Reef Ecology Project at the Mariculture and Fisheries Department. The project is studying the ecology of Kuwait's coral reef ecosystems, coral reproduction and the effects of pollutants on corals. The research team consists of Dr. Peter Harrison from Southern Cross University in Australia, who is the Project Leader and is supported by the United Nations Development Programme and the United Nations Industrial Development Organization, and Mr. Shaker Alhazeem and Mr. Adel Al-Saffar from KISR.

After weeks of intensive research, many colonies of two species of branching corals collected from Qaru Island were observed spawning at night around the full moon period in May 1995, and brain coral colonies were observed spawning following the full moon in June. During the spawning process, eggs and sperm from each coral polyp are gathered together into a small bundle and released from the coral polyps synchronously. The bundles float to the sea surface where they break apart and fertilization then occurs.

Following spawning, many thousands of coral larvae were raised in tanks at the Mariculture and Fisheries Department, and larvae were able to settle and metamocphose into juvenile coral polyps. Experiments on the larvae showed that very low levels of oil hydrocarbons inhibit coral larval settlement.

These are the first records of coral reproduction in Kuwait, and show that despite the extreme environmental conditions in the northern Arabian Gulf, the coral communities in Kuwait are healthy and capable of successful reproduction.

he yield was even higher. I bought
and was able to repay my loan
:er the harvest. Next, I decided to
: offseason and asked the project
me build a water trough, for which I
ight a machine for making biscuits,
ed for special village events. Assisting
n became very efficient producers.
the surplus at the local market for
ofit.
and returned the third year, he was
ruct our house and improve the
s to our savings. My children took
le and biscuit production while their
naterials in bulk from the big mar-
ates our production there while the
ur produce to the village market.
respected in the village; women
heir affairs. Childbirth is a problem.
I an old birth attendant who was not

PROJECT:
Environmental Support to Kuwait Institute of Scientific Research

OBJECTIVE:
To strengthen the capacity of the Environment Division of the Kuwait Institute of Scientific Research to monitor and assess the effects and movements of toxic chemical pollutants resulting from the Gulf War.

qualified. Women, especially young girls, suffered from contamination and complications when giving birth. With project assistance, I volunteered to train as a midwife, was registered in a formal course and became certified after four months.

Today I am happy. We are working successfully, earning enough money, and my husband is staying with us. There is now something to look forward to."

Shaker Al-Hazeem, ecologist, Kuwait

"...CORALS ARE STILL SUCCESSFULLY REPRODUCING..."

"In spite of extreme climate and marine oil pollution, Kuwait is blessed with important and beautiful coral reef ecosystems. These reefs have been formed over many thousands of years from the growth of coral colonies — dynamic ecosystems delicately balanced between natural forces that encourage growth and environmental disturbances that lead to coral death and reef erosion.

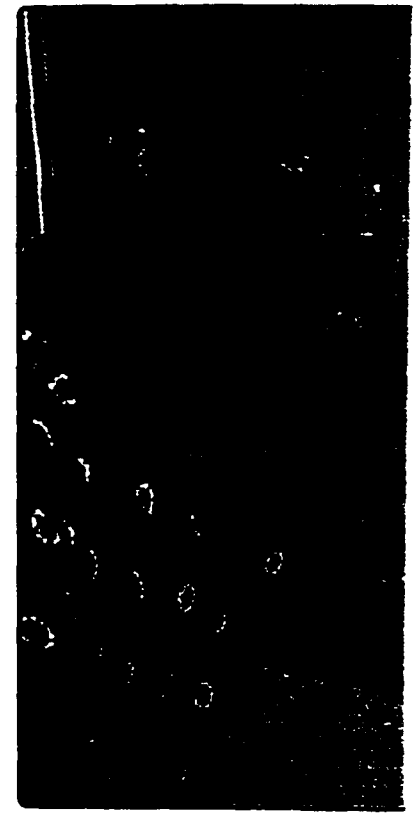
In 1993, the Kuwait Institute for Scientific Research and UNDP began to study Kuwait's coral reefs and the effects of natural stress and human induced disturbances on coral communities. A preliminary survey conducted to determine in which areas outside marine ecology expertise was most critically required recommended that a coral reef ecological study be jointly undertaken to investigate the structural and

functional characteristics of Kuwait's coral reefs.

A consultant conducted underwater video surveys of the major reef sites in order to quantify the status of the coral reef communities. In general, these communities appeared to be in healthy condition and some reefs had high coral cover. However, we saw evidence of significant coral damage and death caused by people dropping anchors onto living coral colonies. Some sites were littered with rubbish that had been dropped onto the reef. This sight opened our minds to the importance of public education in highlighting the damage these activities cause to reef environments. We vowed to continue our efforts to inform people about the importance of these reefs for the survival of fish and shrimp resources.

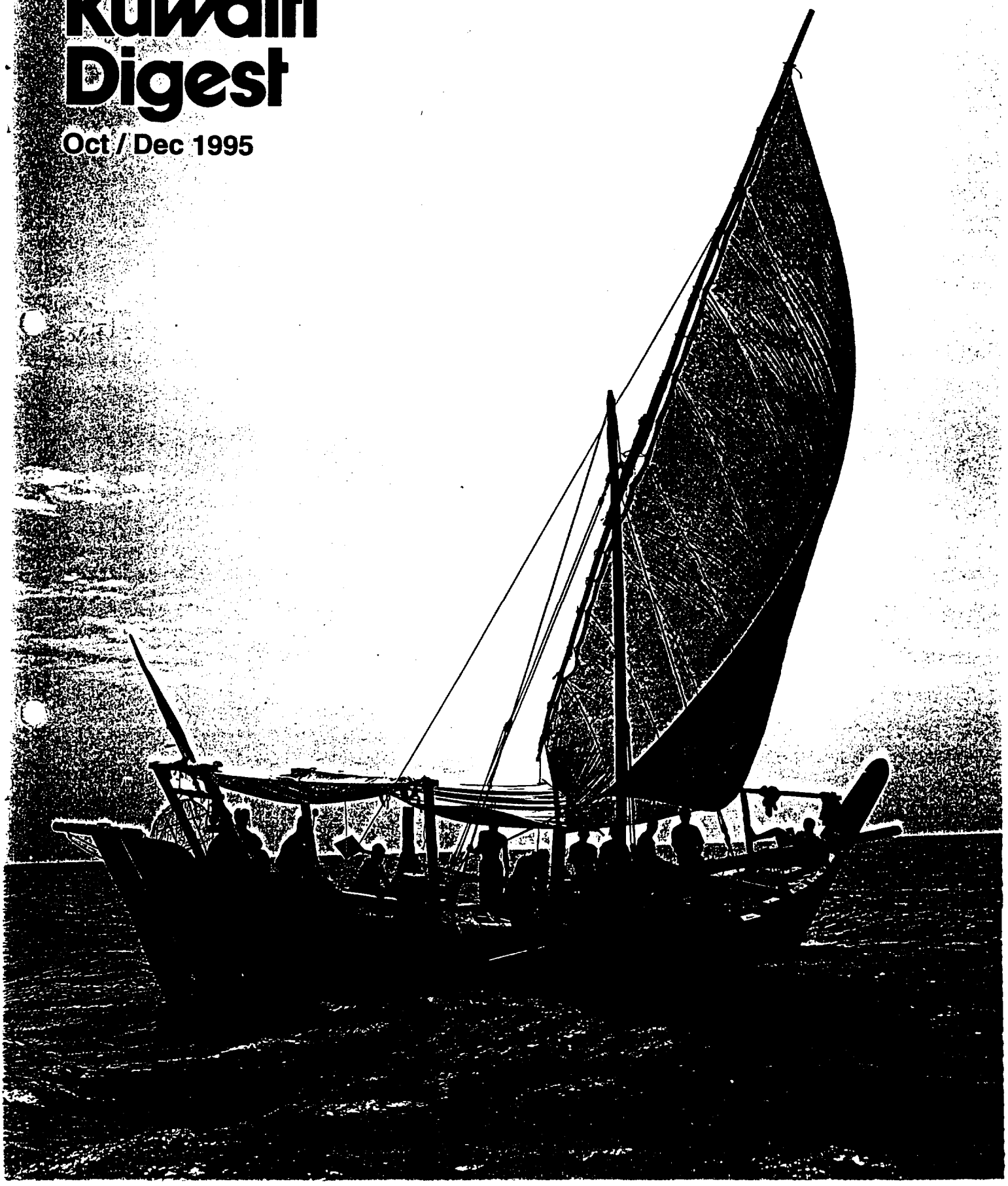
After weeks of intense research, we made our first discovery of coral reef spawning in Kuwait. Two species collected from Qaru Island spawned in aquaria, providing the first evidence that corals are still successfully reproducing on Kuwait's reefs. This was a significant breakthrough.

We hope that, by the end of this project, we will be able to develop management guidelines for protecting Kuwait's unique subtropical coral reefs. Thanks to the project's success, the Institute's management has come to realize the importance of the coral reefs. Consequently my postgraduate studies in Coral Reef Ecology at Lismore University, Australia, have been approved."

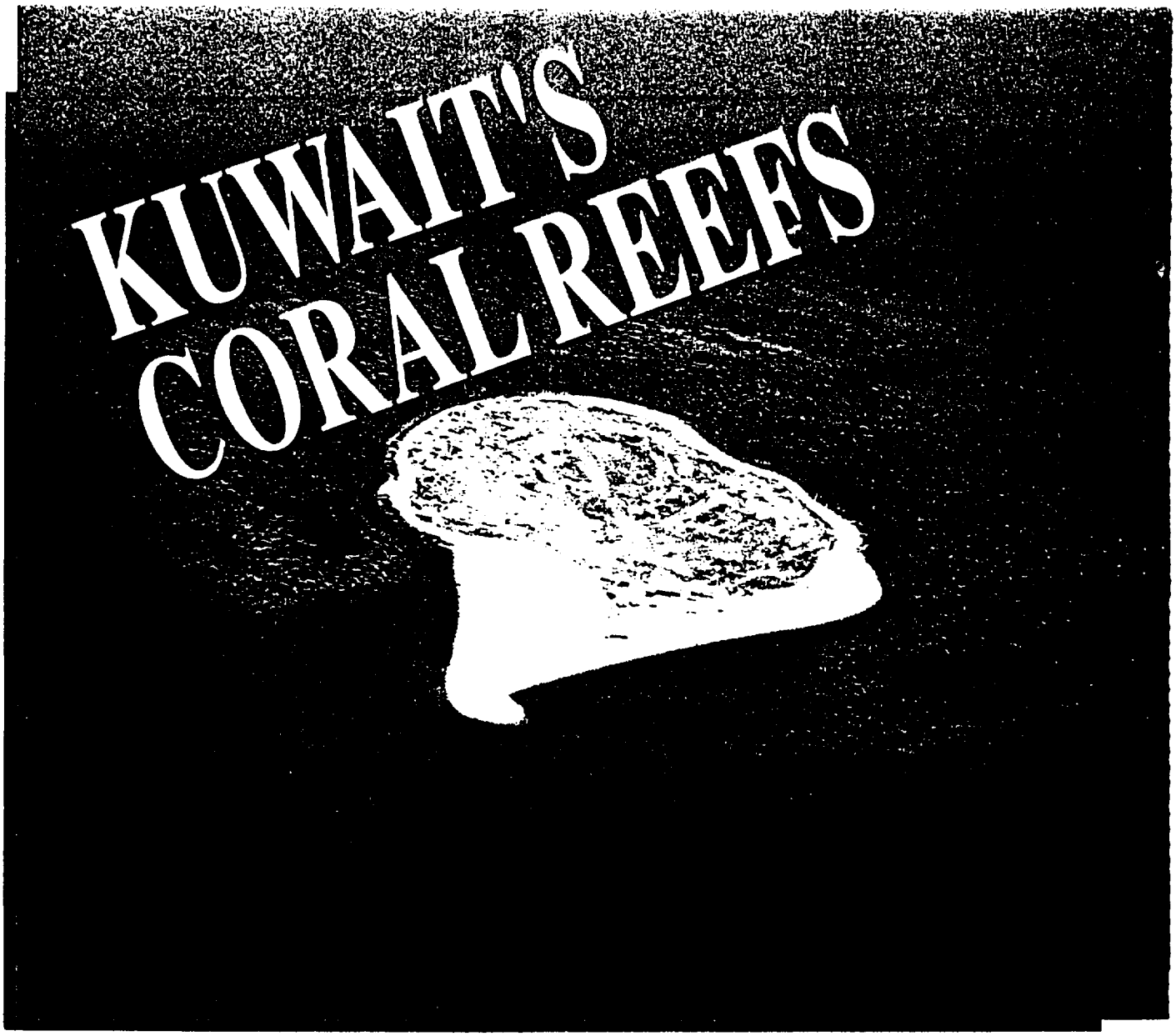


The Kuwaiti Digest

Oct / Dec 1995



KUWAIT'S CORAL REEFS



The coral reef of Qaru as seen from the air

One of nature's most spectacular creations, five living coral reefs just off Kuwait's Arabian Sea coast are the subject of an ongoing study project sponsored by the United Nations and undertaken by the Kuwait Institute for Scientific Research Mariculture and Fisheries Department.

As Kuwait's coral reefs and the ecosystems are unique in the world and are perhaps the most northern, they have come under increasing strain during the last decade, as a result of overuse, the Gulf War, which caused the largest oil spill in history oil and other forms of man-made pollution.

In addition to the oil spill, the water temperature in the Gulf Region was lowered by 4 degrees as black smoke from burning oil wells blotted out the sun's rays to more than 50 percent of the northern Arabian Sea.

What has taken thousands of years to develop, despite the harsh conditions of high salinity levels, extreme heat in the summer, tidal erosion, and cool winter temperatures, Kuwait's coral reefs have survived and flourished until now.

Theoretically, and in fact, Kuwait's five reefs At Kubbar, Qaru, Umm Al-Maradem, Qit'at Uraifjan and Mudayrah should not exist. They do however, even exposed to winter sea temperatures occasionally falling to 13 degrees, when most of the world's coral reefs cannot survive below 18 degrees.

Additionally, the coral reefs support habitats for hundreds of species of marine life, including commercially viable species of fish. When the coral dies, the fish which are sustained by the living reefs move to more fertile feeding and breeding grounds.

Despite the reefs' significance to the marine environment and ecosystems, surprisingly little detailed scientific study has been undertaken on Kuwait's coral reefs.

Mr. Shaker Al-Hazeem

"(Overuse has) disturbed the balance between the reefs' ability to sustain itself and people's pastimes"

Nature's artwork. One of a species of fish co-dependent on Kuwait's Coral reefs

The threat of am ecological catastrophe in the Arabian Gulf after the liberation of Kuwait in 1991 helped focus international attention on the fate of Kuwait's coral reefs.

Qaru, for example, was heavily damaged during an exchange of heavy weapons fire as the allied navies and air forces expelled Iraqi occupiers by force.

Adel Al-Saffar, Shaker Al-Hazeem and Ms. Iman Al-Sabah are research associates at KISR and have shared their scientific research responsibilities with Project Leader Dr. Peter Harrison, recognized as one of foremost world authorities on coral habitat and spawning.

Their aim is to investigate the ecology of the Kuwait's coral reef system with a particular focus on the effects of both natural and man-made stress on the coral communities.

One of the outcomes of the study, developed by the United Nations Development Programme and the United Nations Industrial Development Organization, and implemented by KISR, will be to find solutions to the preservation of the delicate ecosystems before man and time destroy the reefs.

One of the reefs supports the last breeding ground in the region for the green sea turtle.

tury or more of coral growth. While the coral surrounding the reefs in Kuwait are fairly hardy, compared to other world reefs, they grow at a rate of about one-half centimeter per year. In comparison, hardier varieties of coral in other parts of the world grow in the 5 millimeter to 25mm range per year.

While one of the Kuwait Institute for Scientific Research's primary goals is to educate the public, and especially recreational visitors to the five reefs, the current research project aims to discover how science can assist in regenerating the coral, and ultimately, develop a management plan which could include recommendations to the Kuwait Government to try and overcome the problems.

For example, there are no protected wildlife sanctuaries for endangered marine species in Kuwait's coastal waters, especially for sea turtles and resident and migratory birds.

"We were very fortunate indeed to have such a distinguished scientist like Dr. Harrison working with us"

Mr. Adel Al-Saffar

"We really have a terrible situation developing," said Mr. Al-Saffar. "The proliferation of sport divers and recreational fishermen operating without rules or regard to the protection of their environment have disturbed the balance between the reefs' ability to sustain itself and people's pastimes."

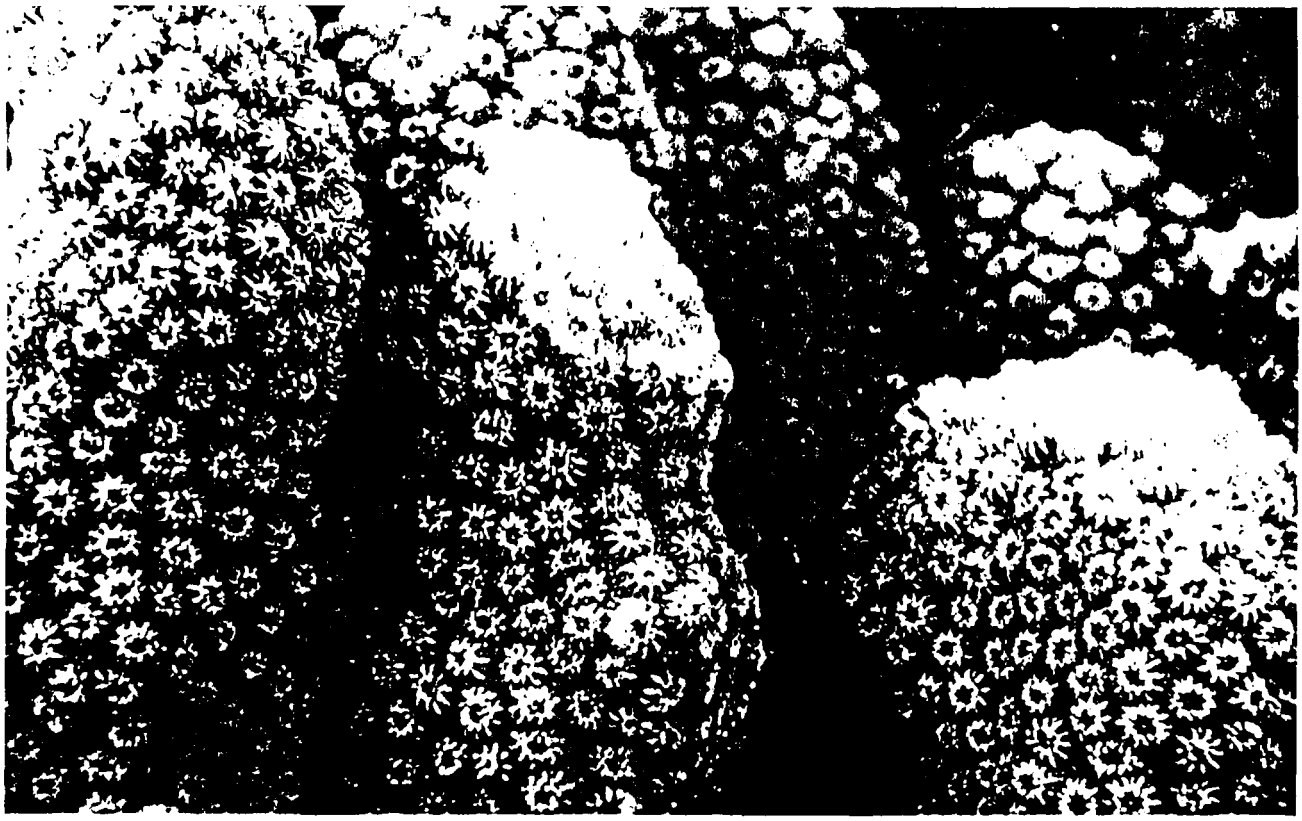
During the last two years, sport diving has grown exponentially, especially among young Kuwaitis. While most are certified and have some understanding of the sensitivity of the undersea environment, for every one qualified diver, there are approximately four to five divers who are un-qualified.

Cabin cruisers and sport fishing boats, when they drop anchor on a reef, inadvertently kill off a half cen-

One of the project's most significant discoveries to date is the identification of spawning times and periods of two species of Kuwait coral, unique in that their spawning periods differ greatly from coral in other world regions.

During the spawning process, eggs and sperm from within each coral polyp are slowly formed into a small bundle beneath each polyp mouth. The bundle is then released from the polyp - around the full moon cycle - and floats to the surface where the egg and the sperm separate, and cross fertilization occurs.

The project team captured the spawning process of several species of Acropora corals in May and colonies of the brain coral species Platygyra daedalea in June



Acropora Coral on the reefs

from the Qaru reef, on film, and duplicated the event in their Kuwait City laboratories.

"We were very fortunate indeed to have such a distinguished scientist like Dr. Harrison working with us," Mr. Al-Saffar said. "Dr. Harrison was the first to discover mass spawning in coral."

Mr. Al-Saffar said the importance of duplicating the spawning process in aquaria was profound. Techniques to transplant the living, growing coral in the laboratory to the reefs could someday be attempted as a means of environmental stewardship.

They were the first records and photographs of coral spawning in Kuwait. The results of the research showed that local coral colonies were capable of successful reproduction, even in an artificial environment, and opened up a wide range of new opportunities for future research on indigenous coral.

"When we started with our coral surveys in cooperation with Kuwait University in 1983 and early 1984 we had zero information on Kuwait's coral reefs," he said.

"From that initial Coral Reef Project, we discovered where the reefs were, identified some 30 varieties of coral living in our waters and catalogued some 120 different species of fish supported by the coral."

Additional scientific research material was provided by the United States research vessel Mount Mitchell in 1992. Its purpose was to survey and analyze data on the damage to the marine environment in the Arabian Gulf region in the after of the Gulf War. Mr. Al-Hazeem was Kuwait's representative for the Kuwait portion of the survey.

Compared to coral reefs in other oceans, Kuwait's reef are minute, the scientists said, but not any less important to the survival of the marine ecosystem in this region as a whole.

"Our reefs are interesting because of the environmental effect, they are the most northern reefs in the world living in high salinity and variable temperature waters," Mr, Al-Saffar said.

The salt content of the Arabian Gulf waters has been measured at 40 parts per thousand compared with 35 parts salt per thousand of waters in other oceans. The

"Theoretically, Kuwait's five reefs should not exist"

Some of the reef coral which spawned in KISR's lab

salt content, the scientists said precluded the survival of hundreds of other coral species found in other regions.

"The focus of our initial study was should we, or should we not protect the reefs," said Mr. Al-Saffar. "We came to the conclusion that we should, and we resumed our study of the reefs this year."

One of the key discoveries resulting from experiments earlier this year focused on the effects of oil coming in contact with coral larvae.

The study showed that even low levels of oil hydrocarbons in seawater reduce, or even block the settlement of larvae on the reefs. The findings have important ramifications, not only because there is natural hydrocarbon seepage in the area, but the reefs may be susceptible to oil pollution accidents in the future.

"So far, we have finished the protection side of our research, particularly the effects of salinity and oil pollution on the coral larvae," said Mr. Al-Hazeem. "The other component in our research is the educational side of the environmental equation."

"So far, we have finished the protection side of our research. The other component ... is the educational side of the environmental equation"

"We have been fairly successful in our attempts to convey our message to the media that coral is a living organism, an animal that we are morally bound to protect and watch over. We are now only beginning to understand what coral is and its benefit to Kuwait," Mr. Al-Hazeem said.

The next step in the public information campaign, he said, is to convey what damages have been wrought by man and what steps can be taken to ensure the coral reefs' survival.

"This is the wealth of Kuwait we are talking about," said Mr. Al-Hazeem. "There is nothing more beautiful for sport divers and tourists to see than a thriving, colorful coral reef."

Both scientists said that the balance of nature had been disturbed and that if steps are not taken immediately to restore that balance, life on the reefs would perish.

Additional research will be conducted later year on all five coral reefs to develop a detailed understanding of the current status of the reefs, their growth rates, the amount of contaminants in the coral, and effects of oil pollution on the growth of adult coral.

UNIDO's Substantive Comment on the final report of Dr. P. L. Harrison

The expert showed great earnestness to implement each item specified in the job description and to report as such.

His achievement through the field work and laboratory set-up with the research staff of KISR was very substantial for capacity building of Kuwait in ecotoxicological assessment of chemical stressors on coral community even under various constraints such as lack of proper equipment, difficult weather and climatic conditions, shortage of funds, insufficient basic data, and shortage of manpower. He succeeded in surveying the present coral community, measuring growth rate, reproductive status, and fecundity, studying in the laboratory on fertility, and data interpretation. A few items, such as analysis of heavy metals and effect on mature corals, were initiated although not completed. One of the remarkable achievements in his work is the observation of reproduction of corals in the sea of Kuwait and the identification of the effects of crude oil on settlement of coral larvae.

However, his initiative and pioneering work in the area of marine ecotoxicology in Kuwait needs follow-up research and training for completion of the major goal of the project which is to monitor the effects of chemical pollutants released during the War and to strengthen the capability of KISR to monitor the pollutants. The ecological work of the expert concluded that any effect from oil spills that occurred during the war were not obvious, while ecotoxicological experiments revealed some clues indicating adverse effects of crude oil at a critical reproduction stage of the coral life cycle. Other exposure factors such as presence of other pollutants and the actual or estimated concentration of the crude oil - which will definitely complicate the interpretation of adverse effect on coral - have not been taken into consideration. Cooperation among biologists, chemists and chemical engineers together with further assistance of consultants will conclude the remaining issues of this nature after the completion of the first phase of the project.

Subsequent work and capacity building on search for cause-effect of oil pollution on the coral population of Kuwait will greatly enhance the capability of managing other toxic chemicals to be environmentally sustainable in the country and will enable Kuwait to play a leading role in ecotoxicology/environmental monitoring of petroleum and related chemicals thus preserving its natural resources and biodiversity from chemical hazards generally in the Arab region.

It should also be noted that based on the expressions of the author and the discussions he had in UNIDO, it is very desirable that more exhibitions are held in the area to educate the public so that the feeling of ownership of the coral reefs is cultivated especially among the school-going children.