社会開発調査部報告書

No. 51

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

NATIONAL COMMISSION FOR WILDLIFE CONSERVATION AND DEVELOPMENT (NCWCD), KINGDOM OF SAUDI ARABIA

# THE STUDY ON COASTAL / MARINE HABITAT AND BIOLOGICAL INVENTORIES IN THE NORTHERN PART OF THE RED SEA COAST IN THE KINGDOM OF SAUDI ARABIA

## FINAL REPORT

## EXECUTIVE SUMMARY

MARCH 2000



JAPAN WILDLIFE RESEARCH CENTER

SHIN-NIPPON METEOROLOGICAL & OCEANOGRAPHICAL CONSULTANT CO., LTD.

S S S
J R
00-045

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

NATIONAL COMMISSION FOR WILDLIFE CONSERVATION AND DEVELOPMENT (NCWCD), KINGDOM OF SAUDI ARABIA

# THE STUDY ON COASTAL / MARINE HABITAT AND BIOLOGICAL INVENTORIES IN THE NORTHERN PART OF THE RED SEA COAST IN THE KINGDOM OF SAUDI ARABIA

## FINAL REPORT

## EXECUTIVE SUMMARY

MARCH 2000

JAPAN WILDLIFE RESEARCH CENTER

SHIN-NIPPON METEOROLOGICAL & OCEANOGRAPHICAL CONSULTANT CO., LTD.


Foreign Currency Exchange Rates Applied in the Study.

| Currency | Exchange Rate (/J.Yen) |
|---|---|
| Saudi Arabian Riyal (SR) | 36.01 |

(Average rate from May 1989 to March 1999)

Note : Following numerical notation is adopted in the Report.

Decimal marker : ". " (period)

Digit separator : ", " (comma)

# THE STUDY ON COASTAL / MARINE HABITAT AND BIOLOGICAL INVENTORIES IN THE NORTHERN PART OF THE RED SEA COAST IN THE KINGDOM OF SAUDI ARABIA

March 2000

Mr. Kimio Fujita

President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit to you the final report entitled "The Study on Coastal / Marine Habitat and Biological Inventories in the Northern Part of the Red Sea Coast in the Kingdom of Saudi Arabia". This report has been prepared by the Study Team in accordance with the contracts signed on 12 December 1997, 11 May 1998 and 21 May 1999 between the Japan International Cooperation Agency and the Joint Study Team of Japan Wildlife Research Center and Shin-Nippon Meteorological & Oceanographical Consultant Co., Ltd.

This report examines the current status of the biological environment and the social environment of the northern part of the Red Sea coast of Saudi Arabia, and also examines the detailed status of the identified Model Area. Based on the examined data, it identifies the important biological habitats and presents the critical areas for the conservation of the biodiversity in a form of maps, and also suggests an action plan to conserve the biodiversity of the Study Area.

The report consists of the Summary, Main Text, Appendices, Biological Inventory (CD-ROM), Habitat Maps of the Study Area, Habitat Maps of the Model Area and Geographical Information System / Database (CD-ROM).

All members of the Study Team would like to express grateful acknowledgement to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Environment Agency and Embassy of Japan in Saudi Arabia, and also to officials and individuals of the Kingdom of Saudi Arabia for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the Study will contribute to the conservation of biodiversity of the northern part of the Red Sea coast of Saudi Arabia and that friendly relations of both countries to promoted further by this occasion.

Yours faithfully,

松島 昇

Noboru Matsushima
Team Leader

# PREFACE

In response to a request from the Government of the Kingdom of Saudi Arabia, the Government of Japan decided to conduct the Study on Coastal / Marine Habitat and Biological Inventories in the Northern Part of the Red Sea Coast in the Kingdom of Saudi Arabia and entrusted the study to the Japan International Cooperation Agency.

JICA selected and dispatched a study team headed by Dr. Noboru Matsushima of Japan Wildlife Research Center and composed of Japan Wildlife Research Center and Shin-Nippon Meteorological & Oceanographical Consultant Co., Ltd. to the Kingdom of Saudi Arabia, five times between December 1997 to February 2000. In addition, JICA set up an advisory committee headed by Mr. Daizaburo Kuroda, Environment Agency Japan, between December 1997 to February 2000, which examined the Study from specialist and technical points of view.

The team held discussions with the officials concerned of the Government of the Kingdom of Saudi Arabia, and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of friendly relationship between two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of the Kingdom of Saudi Arabia for their close cooperation extended to the study.

March 2000

Kimio Fujita
President
Japan International Cooperation Agency

# CONCLUSIONS AND RECOMMENDATIONS

Biodiversity and habitats of the central – northern Red Sea coast of Saudi Arabia were assessed in 1998-99 by the JICA-NCWCD Study Team. Taxonomic, distributional and community structural data were compiled for corals, other benthos, fishes, turtles and marine mammals, algae and seagrasses, birds and coastal vegetation. This information was used in ground-truthing detailed habitat maps prepared from a dedicated aerial photo survey of the study region. Human uses of the study region were assessed from socio-economic surveys and interviews. Comprehensive reference collections of the biota of the region were compiled. All of the above information was input to a dedicated GIS database, designed to facilitate effective conservation management of the region.

Results of the Study indicate that the central – northern Red Sea coast of Saudi Arabia has high local, regional and global significance for conservation management planning. The area supports coastal and marine habitats of generally high ecological integrity, hosting endemic and undescribed species and species listed as globally threatened or endangered. The area also provides sustenance to local and regional human populations in the form of fisheries.

A summary map ranking different areas (15 mins. latitude x 15 mins. longitude) of the study region in terms of their overall conservation and management importance was prepared. The assessment was based on the detailed habitat maps, and incorporated the diversity of habitat types, area and cover of corals, area of seagrasses, algae, mangroves and tidal flats, the number of fishing boats and industrial plants present. The rankings should facilitate development of comprehensive regional marine resource and

management policies, including establishment of a series of Marine Protected Areas in the region.

Five ranks were used, in increasing order of conservation importance:

- Ranks 3-5 – Priority conservation area.
- Rank 2 – Strategic environmental management areas,
- Rank 1 – Multiple Use area,

**1. Priority Conservation Areas**

From this assessment, three large priority conservation areas were identified:

- the mouth of the Gulf of Aqaba - Tiran Area,
- Al-Wajh Bank and south to Umluj - Sharm Shabaan and
- Al-Hajir (N of Ra's Masturah).

**2. Strategic Environment Management Areas**

These areas included most of the remainder of the study region, excluding cities and towns, and highlights the generally high levels of ecological integrity of the habitats of the region. Key habitats for conservation management planning include the benthic communities in open and semi-enclosed bays (sharms) and offshore islands, which provide important breeding areas.

**3. Multiple Use Areas**

These areas include the major coastal cities and towns of the region, where most coastal development, land reclamation, construction of desalination plants, sewage and solid waste disposal, has occurred. Such developments require careful management in

order to maintain the quality of life for city dwellers and to minimise human impacts on Priority Conservation Areas and Strategic Environment Management Areas.

These three categories of conservation importance have identified large areas of special importance for future Marine Protected Areas management. Smaller key locations for conservation of each of the various biotic groups - corals, other benthos, fish, turtles and marine mammals, algae and seagrasses, birds and coastal vegetation – have been identified in the relevant sections of the report.

**Recommendations**

1. Establishment of large marine protected areas in the Priority Conservation Areas and selected Strategic Environment Management Areas.
2. Establishment of management programmes including zoning plans in the Priority Conservation Areas and Strategic Environment Management Areas.
3. Application of a multiple-use approach to Marine Protected Areas, management, incorporating various zones of increasing protection, based on the NCWCD-IUCN plan.
4. Initiation of further studies and monitoring programmes.
5. Establishment of international cooperation for coral reef monitoring.
6. Promotion of education and public awareness programmes for conservation of the coastal and marine environment.

An action plan is also suggested to implement these recommendations and to comprehensively conserve the marine environment of the Red Sea. The action plan is

described in six groups at three levels. The six groups are Policy / Legislation, Institutional Measures, Environment Management, Protected Areas, Public Awareness / Education, International Cooperation and Establishment of Core Facilities. Three levels are national, NCWCD and survey / research levels. Schedules and necessary expertise and equipment for NCWCD and survey / research levels are also proposed.

# الملخص


مقدمة:

بناء على اتفاقية التعاون المشترك المبرمة في الرياض بتاريخ ٢٤ مارس ١٩٩٧م بين الهيئة الوطنية لحماية الحياة الفطرية وإنمائها والوكالة اليابانية للتعاون الدولي (جايكا)، قام الفريق العلمي المشترك للهيئة وجايكا بتنفيذ مشروع دراسة البيئات الساحلية والبحرية وكائناتها في الجزء الشمالي من الساحل السعودي للبحر الأحمر والتي استغرقت سنتان بدأت في ٢٢ ديسمبر ١٩٩٧م وانتهت في ٢٤ نوفمبر ١٩٩٩م.
ويهدف مشروع الدراسة إلى التالي:

١- دراسة البيئات الساحلية والبحرية وكائناتها في الجزء الشمالي السعودي من ساحل البحر الأحمر من أجل توفير المعلومات الأساسية لغرض المحافظة والإدارة المناسبة للبيئات الطبيعية والتنوع الأحيائي لها.
٢- نقل التقنيات إلى فريق المشاركين السعوديين خلال الدراسة.

ولقد تمت الدراسة على مراحل أربعة كالتالي:

المرحلة الأولى : جمع وتحليل المعلومات المتوفرة
المرحلة الثانية : خواص منطقة الدراسة ميدانيا وتحديد المنطقة النموذجية
المرحلة الثالثة : دراسة تفصيلية للمنطقة النموذجية المرشحة للمحافظة
المرحلة الرابعة: إعداد الدراسات البيولوجية/ الخرائط بصفة عامة وللمنطقة النموذجية بصفة خاصة.

منطقة الدراسة:

يغطي المسح الجزء الشمالي من البحر الأحمر وبامتداد ١٠٠٠ كيلومتر ويبدأ من شمال مدينة جدة إلى مدينة حقل، ويبلغ عرض المنطقة من حد الماء ولمسافة كيلومتر تقريبا على اليابسة، وحتى عمق ١٥م داخل مياه البحر، وقد تتغير هذه الأبعاد لمنطقة الدراسة لمسافة أكبر لكي يضم بيئات أخرى لا تقع ضمن هذا الإطار. كذلك تم دراسة الجزر القريبة وأيضا البعيدة عن الشاطئ والواقعة على امتداد الساحل.

النتائج:

تمت دراسة المرجان في ١٤٥ موقعا لعدد ٨٦ من الشعاب في منطقة البحث. وتوصلت الدراسة إلى تسجيل ٢٥٠ نوع من المرجان الساحل السعودي للبحر الأحمر منها ٤٠ نوعا مستوطنا تمثل ٥٨ رتبة و١٤ عائلة منها ٣٠ نوعا من المرجان الطري. وتتضمن الأنواع المسجلة ٦ أنواع جديدة على نطاق العالم.

تمت دراسة ١٩٧ موقعا للحشائش البحرية والطحالب في منطقة الدراسة، ولقد تم تسجيل ١٨٨ نوعا منها ٨ أنواع من الحشائش البحرية و ١٨٠ نوعا من الطحالب تضم ٦٨ نوع من الطحالب الخضراء و ٣٠ نوع من الطحالب البنية و ٨٢ من الطحالب الحمراء. ولقد وجد أن التنوع للطحالب يتصاعد خلال الحيود والقطع المرجانية. كما وجد أن العديد من الحشائش البحرية تنمو في الممرات المائية حيث يقل أو ينعدم تراكم حبيبات السلت (حبيبات قطرها أقل من ٦٣ ميكرون) غير الملائمة لنمو هذه النباتات. وتنتشر الحشائش البحرية بشكل عام في المنطقة الداخلية من الحيود المرجانية وفي البحيرات الواقعة خلف الشعاب المرجانية والشروم والممرات المائية.

تم دراسة الأسماك في ١٢١ موقعا في ٢٥ منطقة في نطاق الدراسة، وتوصلت الدراسة إلى تسجيل ٣٧٨ نوعا من الأسماك تمثل ١٧٥ جنسا وتقع تحت ٦٥ عائلة وضمن هذه الأنواع ٣٤ نوع من الأسماك المستوطنة. وتم خلال الدراسة تسجيل ٥ أنواع من الأسماك لأول مرة في البحر الأحمر.

تم دراسة الأحياء القاعية في ٩٦ موقعا في ٢٥ منطقة داخل نطاق الدراسة. ودلت دراسة الأحياء القاعية على وجود وتسجيل ٣٤١ نوعا تقع تحت ١٢٣ عائلة. أظهرت دراسة الأنواع السائدة من الأحياء القاعية على عدم وجود اختلاف جوهري في توزيعها الجغرافي، كما دلت الدراسة على وجود تنوع عالى للأحياء القاعية في الجزء الشمالي من منطقة الدراسة. كما أن الأحياء القاعية متوفرة بكميات كبيرة في كل من ضفة الوجه وخليج العقبة.

أثبتت دراسات الثدييات البحرية والسلاحف البحرية المعتمدة على الاستبيان والمقابلات الشخصية على وجود عرائس البحر في كل من مدخل خليج العقبة، وضفة الوجه وشرم هبان وفي المنطقة الواقعة بين رأس بريدي وينبع وبعض الشروم جنوب ضبا وبالقرب من جزيرة برقان. بينما دلت المسوحات الجوية على مشاهدة ٧ قطعان من عرائس البحر، في ستة منها يضم القطيع حيوانان أو أقل، وأكبر قطيع ضم ٤ حيوانات من عرائس البحر. كما دلت الاستبيانات الخاصة بالصيادين وحرس الحدود على أن السلاحف البحرية تنتشر من عند شمال مدينة جدة إلى خليج العقبة.

ولقد دلت المسوحات الجوية على وجود حفر السلاحف أو آثار لزحفها على رمال الشاطئ في جزر صنافير وشوشه، وجزر النعمان والشيخ مريبط وبريم والوجادي، وأربع جزر صغيرة أخرى إلى الغرب من مركز حرس حدود الخرج، وستة جزر صغيرة إلى الغرب من مركز حرس حدود القرايز، وسبع جزر صغيرة تقع إلى الغرب مركز حرس حدود الحرة، وجزر جبل حسان ولبنه ومليحه. كما ترتاد السلاحف البحرية الأرض اليابسة حيث شوهدت آثارها على شواطئ منطقة رأس بريدي، وخريم وجنوب حرس حدود المويلح وجنوب حرس حدود الحرة وشمال ضبا وشمال شرم جبا وجنوب حرس حدود زبيده وشمال رأس عبيد ورأس مريج (جنوب شرم عنتر) ورأس مريبط ورأس أبو مله (جنوب الوجه).

تم دراسة النباتات الساحلية في ٢٦ موقعا في منطقة الدراسة كان من ضمنها ثلاث جزر بعيدة عن الشاطئ . ولقد دلت دراسة الغطاء النباتي في ٦٩ مربعا على أن هناك ٨ نماذج نباتية، تضم ٢٩ مجتمعا من النباتات. ولقد لوحظ تمنطق الغطاء النباتي من عند الشاطئ وباتجاه اليابسة في جميع المواقع تقريبا.

دلت الدراسات النباتية دلت على أن هناك ١٥٩ نوعا من النباتات الوعائية تقع تحت ٤٣ فصيلة منها نوعان من المانجروف. وتضم المنطقة نباتات ملحية ونباتات جفافية وتحتوي هذه الأنواع على ١٢ نوع مستوطن.

كما تمت دراسة الطيور في ٢٤ موقعا في منطقة الدراسة. ودلت الدراسة على أن هذه المواقع تشكل ٦ طرز من البيئات المختلفة ونظرا لقساوة الطقس في منطقة الدراسة خلال فصل الصيف، فإن العديد من الطيور الأرضية لا تعشش في هذه المنطقة بالشكل المتوقع، ومع ذلك تعد المنطقة موقعا هاما للطيور المهاجرة والطيور المشتيه. ويعتمد التنوع في المواقع المختلفة على بيئة المنطقة وكثافة الغطاء النباتي لها ويعد الموقع في منطقة الدراسة، وتعد بيئات الوديان وبيئات المانجروف أكثر المناطق التي تضم تنوعا عاليا من الطيور. كما أن وفرة الأعداد للطيور تعتمد أكثر على نوعية النباتات وكمية الغطاء النباتي المتوافر لها.

## المنطقة النموذجية:

تم اختيار "ضفة الوجه" كمنطقة نموذجية لدراستها تفصيليا نظرا لأنها غنية بالأحياء وتضم جميع أنواع البيئات المختلفة الموجودة في ساحل البحر الأحمر السعودي، كما أن الجزء الجنوبي منها غني بالتنوع المرجاني وهام لبيئات المانجروف، إضافة إلى أن "ضفة الوجه" منطقة مقترحة للحماية من قِبل الهيئة.

ونظرا لكبر مساحة المنطقة النموذجية "ضفة الوجه" وحتى يتمكن فريق الدراسة القيام بإجراء دراسة أحيائية تفصيلية، فقد تم تحديد قطاع في جنوب "الضفة" يضم أكبر عدد من البيئات. كما دلت الدراسة التفصيلية على أن المنطقة النموذجية تضم بقعا لتراكيب من الشعاب المرجانية متكاملة مع بعضها البعض بدرجة عالية. تتشكل هذه التراكيب من الحيود المرجانية الشاطئية والحيود المرجانية حول الجزر، والتراكيب المرجانية المستوية، القطع المرجانية، والحواجز المرجانية. وتتميز "ضفة الوجه" بوجود أطول حاجز مرجاني شبه متصل يقع في منطقة الدراسة بامتداد ١٠٠ كم. ويتقطع الجزء الخارجي منه بواسطة عدة قنوات (عرضها ٢٠٠م). وتم تسجيل ٢٠٠ نوع من المرجان الصلد في المنطقة النموذجية يضم ٥٨ جنسا تقع تحت ١٤ عائلة، إضافة إلى ٣٠ نوعا من المرجان الطري. وتمثل مجاميع المرجان الأربعة الرئيسية في المنطقة النموذجية نفس مجاميع المرجان الموجود في منطقة الدراسة.

دلت دراسة الحشائش البحرية والطحالب على تسجيل ٨٢ نوعا تتضمن ٩ أنواع من الحشائش البحرية و ٧٣ نوعا من الطحالب. وأكبر عمق وجدت فيها الحشائش كانت في ممر مائي يقع عند عمق هو ٢ر١٢م. ولقد سجل في ساحل الخواره "بضفة الوجه" نوع يسمى *Enhalus acoroides* والذى كان يعتقد من قبل بأنه من الحشائش البحرية المحصورة على ساحل مدينة جدة فقط.

تختلف أعداد وأنواع الطحالب قليلا في فصل الصيف مقارنة بفصل الربيع وتتغير مساحة غطاء الأعشاب البحرية حسب الفصول حيث تقل أعداد وأنواع الطحالب في فصل الصيف مقارنة بفصل الربيع. يكثر نوع *Turbiraria* في الربيع ويبدأ بالتناقص في فصل الصيف، أما الطحالب جنس *Sargassum* و *Cysloceria* فتكون متوفرة في فصل الصيف مقارنة بفصل الشتاء.

تم مسح ٢٩ موقعا عند أعماق مختلفة تقع في ٢٤ منطقة في إطار الدراسة، وخلال هذا المسح تم تحديد ٣٣ نوعا من الأسماك لدراستها تفصيليا ولقد لوحظ أن ٣ أنواع من الأسماك (أسماك أم عطية *Heniochus intermelius* والحريد *Hipposcarus harid* والأسماك الملائكية ذات البقعة الصفراء *Pomacanthus maculosus* ، تسود في جميع المواقع.

ولقد دلت كثرة ملاحظة خيوط النايلون الخاصة بالصيد التقليدي وشباك الصيد إضافة إلى تهشيم المرجان الناتج من خطاطيف الزوارق البحرية عند رسوها في معظم المواقع على أن هناك بعض الضغوط البشرية ناتجة من جراء عمليات الصيد هذه.

تم مسح ٤٨ موقعا تقع في ١٧منطقة في إطار الدراسة بغرض الأحياء القاعية تم تعيين ١٩ نوعا من الأحياء القاعية السائدة في ساحل البحر الأحمر السعودي لدراستها في البيئات المختلفة بالمنطقة النموذجية. تعتبر بيئة نباتات المانجروف الواقعة في منطقة "دقم سبق" من أهم أنواع البيئات الخاصة بالأحياء القاعية الموجودة في المنطقة النموذجية وهذا عائد إلى احتوائها على السرطانات جنس *Macrophthalmus* و *Uca* الهامين للنظام البيئي الخاص بالمسطحات المدجزرية، وعدم توفرهما في البيئات المشابهة في المنطقة النموذجية، ولمحدوديتهما في منطقة الدراسة . لذا تعد منطقة بيئات المانجروف الموجودة في منطقة "دقم سبق" من أهم بيئات الأحياء القاعية نظرا لاحتوائها على النوعان المشار إليهما من السرطانات لما لهما من أهمية للنظام البيئي لهذا النوع من البيئات.

وتقل وفرة الأنواع في منطقة المد والجزر داخل المنطقة النموذجية مقارنة بالمناطق الأخرى بشكل عام، وهذا عائد إلى أن معظم هذه المنطقة هي رملية أو سلتية. وتميز المنطقة بشكل عام بأعداد قليلة من الأحياء القاعية وذات وفرة ضئيلة و "حجم البصر" *Tridacna maxina* هنا أصغر منه مقارنة بالمناطق الأخرى. وتعد بيئة ضفة الوجه بيئة مناسبة للأحياء القاعية التى يبلغ حجمها ٥ر٠مم والتى تعيش داخل الرمل والسلت عن الأحياء التى أحجامها أكثر من ١سم .

قدر عدد حيوان عرائس البحر في ضفة الوجه بـ ٣٣٥ حيوان. ولقد لوحظ أن الحيوان يتغذى بالحشائش البحرية من نوع *Syringodium isoetifolium*، وتعد البيئة البكر في المنطقة النموذجية عامل مهم في بقاء هذه الكائنات تحت هذه الظروف البيئية القاسية. لذا يجب أن تعطى بيئة الحشائش البحرية عناية خاصة لحمايتها وإدارتها إدارة صحيحة. ويعشش في المنطقة نوعان من السلاحف البحرية هما السلحفاة الخضراء وسلحفاة صقرية المنقار.

ولقد تم اختيار جزيرتي "جبل حسان" و"الوجادي" لدراستهما ضمن المنطقة النموذجية. وتم رصد أثر لعدد ١٥ سلحفاة صقرية المنقار خلال هذا الموسم في جزيرة جبل حسان ورصد أثر ٣٨ سلحفاة خلال هذا الموسم ورصد ٣٩ أثرا في موسم العام الماضي (١٩٨٨م).

دلت دراسة قطاعات البيئات الساحلية على أن هناك تمنطق واضح للنباتات في كل قطاع والتغير في تمنطق النباتات من حافة الماء على الشاطئ وباتجاه اليابسة كان كالآتي، نباتات المانجروف منتشرة في القنوات المائية والمناطق الشاطئية الضحلة وخلف المانجروف تنمو نباتات المستنقعات الملحية والتى تضم مجموعة عجيرمان *Halocnemum strobilaceum* وشوع *Arthrocnemum macroslachyum* في شكل حزام ضيق غزير موازى للشاطئ. ويلي هذا النطاق نباتات حريز *Halopeplis perfoliata* وتكون مجموعة قليلة الغطاء تنمو في المراوح الفيضية الرملية ويحل محلها تدريجيا مجموعة نباتات الهرم - الرطريط *Zygohyllum album*.

تنمو نباتات المانجروف من جنس الشورة والقندل في شرق وجنوب الموقع النموذجي، وهذا عائد إلى تأثير الرياح السائدة والتى تهب من الشمال، وتنمو نباتات القندل والتى تعد قليلة الانتشار في ساحل البحر الأحمر السعودي على ضفاف القنوات في الجزر وتمثل نباتات القندل الموجودة في جزيرة أم رومة (.. ٤٤ْ ٢٥ْ ش) أقصى امتداد لهذه النباتات في المنطقة العربية من جهة الشمال.

دلت دراسة الطيور على أن الطيور قليلة في البيئة الصحراوية، أما بيئة مستنقعات النباتات الملحية فتكثر بها الطيور ولكن بأنواع محدودة. وتوجد في الوديان أنواع مختلفة من الطيور مقارنة بتلك الموجودة على الساحل وتكثر الطيور في هذه الأودية في فصل الشتاء. وتشكل نباتات المانجروف أماكن استراحة للطيور المهاجرة.

أظهرت الدراسات الاقتصادية الاجتماعية على أن المنطقة الواقعة بين مركز حرس حدود الخرج ومدينة أملج تقع تحت ضغط رعي جائر. ولوحظ أن عملية الزراعة الجارية في الوديان في المنطقة النموذجية ليس لها مردود اقتصادي ، ولقد أدى اتساع المدن إلى زيادة في مناشط حرفة الصيد نظرا لزيادة الطلب المحلي على الأسماك.

ولقد دل الاستبيان للعاملين في ٢٠ قارب صيد أن ثمانية قوارب منها يعمل أصحابها عليها وأن ١٢ قارب يملكها رجال أعمال لكل فرد منهم اثنان إلى ثلاث قوارب. كما دل الاستبيان على أن هنالك ضغوط بيئية من جراء الصيد للأسماك تقع في الجزء الجنوبي من منطقة الدراسة وهذا عائد إلى الكثافة السكانية المستهلكة في هذه المنطقة.

## الخرائط البيئية:

تم من خلال تحليل تدرج الألوان في الصور الجوية والتى تم تصويرها في الفترة من ٣ يونية إلى ١٢ يولية ١٩٩٨م لأجل عمل الخرائط البيئية لمنطقة الدراسة بمقياس رسم ١:١٠٠,٠٠٠، كما تم عمل خرائط بيئية تفصيلية مستقلة للمنطقة النموذجية بمقياس رسم ١:٥٠,٠٠٠، ونظرا لعدم تمكن فريق الدراسة من تصوير خليج العقبة والمنطقة الواقعة جنوب رابغ، فقد تم الاستعانة بصور الأقمار الصناعية في إكمال عمل الخرائط البيئية لمنطقة الدراسة. وتم تحسين عملية تحليل خرائط البيئات من خلال المعلومات التأكيدية الحقلية وخصوصا أثناء دراسة المنطقة النموذجية.

## نظام المعلومات الجغرافية وقاعدة المعلومات:

يبين نظام قاعدة المعلومات الجغرافية وقاعدة المعلومات العلاقات بين مصادر المعلومات المختلفة وعلى سبيل المثال يمكن إيجاد العلاقة بين البيئة الاجتماعية والمصادر الحيوية، كذلك يمكن من خلالها هذا النظام عمل مقارنة لمعرفة التغيير الحاصل للبيئات أو أحيائها عن طريق مقارنة المعلومات المستجدة بالمعلومات المسجلة سابقا على قاعدة المعلومات.

ولقد تم اختيار بعض المناطق المحمية في منطقة الدراسة تبعا للتالى:

١- مناطق حماية ذات أولوية:
ومن خلال هذا التقييم تم اختيار ثلاث مناطق بحرية كبيرة لحمايتها وهي:
- من مدخل خليج العقبة إلى منطقة تيران.
- "ضفة الوجه" وجنوب أملج إلى شرم شبعان.
- الحجير (شمال رأس مستورة).

٢- إدارة المناطق ذات الاستراتيجية بيئيا:
توجد هذه المواقع ضمن بقية مناطق الدراسة ويستثنى منها المدن والقرى، وهي ذات قيمة بيئية متكاملة عالية للإقليم. وتكمن أهمية بيئات هذه المناطق نظرا لاحتوائها على المجاميع القاعية في الخلجان المفتوحة والشبه مغلقة (الشروم) والجزر البعيدة عن الشاطئ والتى تعد مناطق مهمة للتكاثر.

٣- مناطق متعددة الاستخدام:
تضم هذه المناطق المدن والقرى الساحلية في الإقليم حيث تكثف العمليات الإنمائية، واستحواذ على الأراضي، وإقامة محطات التحلية والصرف الصحي ومواقع رمي النفايات الصلدة وتتطلب مثل هذه النشاطات مراقبة دقيقة بما في ذلك توفير بيئة جيدة للقاطنين في هذه المدن ولتقليل الضغوط البشرية للمناطق ذات الأولوية في الحماية والمناطق الاستراتيجية لإدارة بيئتها.

## التوصيات:

١- إقامة بعض المناطق البحرية المحمية الكبيرة ثم تعيينها تبعا للأولويات الخاصة بالحماية والتى رشحت لها منطقة تيران "وضفة الوجه" ومنطقة الحجير.

٢- البدء في إجراء برامج إدارية تتضمن إدارة النطاقات الهامة في المناطق ذات الأولوية في الحماية وإدارة المناطق ذات الاستراتيجية بيئيا .

٣- تطبيق الاستخدامات المتعددة في المناطق المحمية، ودرج وتضمين المناطق البيئية المختلفة وذلك لزيادة فعالية إدارتها.

٤- إجراء المزيد من الدراسات المستقبلية والمراقبة.

٥- الحث على انضمام المملكة لبرنامج المراقبة الدولي للشعاب المرجانية.

٦- تعزيز ودعم برامج التعليم والتوعية البيئية لأجل حماية البيئات الساحلية والبحرية.

# TABLE OF CONTENTS

TABLES

**FIGURES**



**APPENDICES**



**Abbreviations and Acronyms**

| | |
|---|---|
| GIS | Geographical Information System |
| GPS | Global Positioning System |
| JICA | Japan International Cooperation Agency |
| MEPA | Meteorology and Environmental Protection Administration |
| NCWCD | National Commission for Wildlife Conservation and Development |
| SCUBA | Self-contained underwater breathing apparatus |

# 1. INTRODUCTION

## 1.1. Background of the Study

The Red Sea Coast holds a rich and valuable biological diversity of global importance. The coastal areas of the Red Sea have been undergoing increasing industrial and tourism development which is having an inevitable impact on the coastal and marine environment. However, the true state of the precious environment is not fully understood.

The Kingdom of Saudi Arabia recognises the value of this biodiversity as a national and international asset, and requested the Government of Japan to cooperate in conducting a comprehensive biological study in the northern part of the Red Sea Coast.

The Study aims to close the gap by conducting a thorough study of the northern part of the Red Sea Coast of Saudi Arabia. The results will be utilised to devise a framework for the conservation and sustainable management of the coastal and marine environment.

The JICA Study Team has been conducting the Study with the National Commission for Wildlife Conservation and Development (NCWCD) of Saudi Arabia, on the basis of the Scope of Work agreed upon and signed by NCWCD and the JICA Preparatory Study Team in Riyadh on 24 March 1997.

The two objectives stated in the Scope of Work are as follows.

1. To conduct a basic inventory survey on the coastal and marine habitats and biota in the northern section of the Red Sea Coast in order to supply basic information on the conservation and appropriate management of the natural environment and its biological diversity.
2. To transfer survey-taking technologies to the Saudi counterpart personnel in the

course of the Study.

## 1.2. Study frame and objectives of each phase

The Study consists of the following four phases.

| | |
|---|---|
| Phase I: | Gathering Existing Data |
| Phase II: | Inventory Study in the Entire Study Area |
| Phase III: | Model Area Study |
| Phase IV: | Preparation of Biological Inventory / Map |

The objectives of Phase I were to accumulate and review references and existing data, to carry out a reconnaissance field survey in the Study Area and to obtain an overview of the entire Study Area.

The objectives of Phase II were to conduct an inventory survey and a socio-economic survey of the Study Area, categorise the habitats and analyse the aerial photographs for drafting a habitat map for the entire Study Area, digitise 1:150,000 maps as the base map of the GIS and input some of the results of the inventory and socio-economic surveys. This phase was considered as the preparatory stage for Phase III and IV.

Phase III aims to supply basic information on the conservation and appropriate management of the natural environment of an area in the Study Area and its biological diversity based on collected information and the results of the analysis in Phase II.

In Phase IV, all data collected during Phases I, II and III are analysed and this information is presented as GIS database and habitat maps of the entire Study Area and the Model Area.

In order to achieve successfully the objectives of the Study, the Study Team is divided into the following four groups, each with its own specific role and objectives.

**Biological Inventory:** Marine team (coral, seagrasses / algae, fishes and benthos), marine mammals / marine turtles team, terrestrial team (mangroves / terrestrial vegetation and birds)

**Social Environment**

**Habitat Map**

**GIS / Database**

### 1.3. Participants

The National Commission for Wildlife Conservation and Development (NCWCD) of Saudi Arabia is the counterpart organisation for the Study and respective personnel from NCWCD have been working equally with the Study Team as counterparts (Appendix 1).

## 1.4. Schedule

The schedule is summarised as Table 1.

**Table 1.** Principal activities of each phase of the Study.

| Phase | Schedule | Principal activities |
|---|---|---|
| I | December 1997 – March 1998 | **Gathering Existing Data**<br>• Preparatory work<br>• Preparation and discussion of the Interim Report<br>• Preparatory arrangements<br>• Formulation of work plan<br>• Rapid biological assessment<br>• Preparatory visit for socio-economic survey<br>• Examination of aerial photographs<br>• Aerial verification<br>• Preparation of GIS<br>• Preparation and submission of Progress Report (1) |
| II | May 1998 – November 1998 | **Inventory Study of the Entire Study Area**<br>• Habitat categories<br>• Inventory survey<br>• Socio-economic survey<br>• Analysis and assessment of aerial photographs<br>• GIS database format<br>• GIS base map and input of data<br>• Preparation and submission of Progress Report (2)<br>• Analysis and assessment of survey data<br>• Draft habitat maps of the entire Study Area<br>• Preparation of the Interim Report |
| III | February 1999 – June 1999 | **Model Area Study**<br>• Submission and discussion of the Interim Report<br>• Workshop on the Model Area Study<br>• Detailed biological study of the Model Area<br>• In-depth socio-economic survey<br>• Preparation and submission of Progress Report (3)<br>• Analysis and assessment of survey data<br>• Drafting of habitat map of the Model Area<br>• Input of data to GIS database |
| IV | July 1999 – January 2000 | **Preparation of Biological Inventory / Map**<br>• Analysis and assessment of survey data<br>• Installation of GIS<br>• Preparation and submission of Progress Report (4)<br>• Finalisation of the biological inventory, the socio-economic data, the habitat maps and the GIS database<br>• Compilation and evaluation of all data<br>• Preparation of the Draft Final Report (DFR)<br>• Presentation and discussion of the DFR<br>• Seminar on the Study<br>• Preparation of the Final Report (FR)<br>• Submission of the FR |

### 1.5. Study Area

The Study shall cover the northern part of the Red Sea coast, encompassing approximately 1,000 kilometres (excluding the coastal area of Jeddah city) (Fig. 1). The range of the area to be studied extends from the water's edge out to one kilometre from the shore, and down to a depth of 15 metres.

The actual width of this zone may vary in practice in order to accommodate certain species whose distribution does not fall exactly within the limits. Islands and their coasts will chiefly be surveyed using aerial photographs and visual observation from aircraft.

### 1.6. Acknowledgements

This Study has been conducted in the hope that it will help the Kingdom of Saudi Arabia to develop the most scientific and effective conservation management programmes for marine protected areas in the Red Sea. More than most studies, this Study is a work of collective effort and enthusiasm.

First of all, our most sincere thanks are due to H.R.H. Prince Saud Al Faisal, the Managing Director of NCWCD, and H.E. Prof. Dr. Abdulaziz H. Abuzinada, for their understanding and support. Mr. Takahisa Kusano, Regional Representative of JICA, is gratefully acknowledged for his kind help and advice. The following deserve special mention for supporting the Study and for supplying information and suggestions: Dr. Iyad A. Nader, Mr. Yusuf Al-Wetaid, Dr. Eugene Joubert, Dr. Friedhelm Krupp, Tarik M. A. A. Al-Abbasi, and Qutaibah Al-Sa'don, NCWCD; Mr. Ahmad H. Badah, Ministry of Petroleum and Mineral Resources; Mr. Shosuke Mohri, JICA Expert; Dr. Shaukat Ali Chaudhary, Ministry of Agriculture and Water; Mr. Mohammed S. Al Yami, Ministry of Defence and Aviation; Mr. Ernst-Detlef Gruebel, and Mr. Joost Strater, Hansa Luftbild German Air Surveys; Mr. Junji Wakui, JICA Office in KSA; Mr. Kazunobu Suzuki, JICA; Mr. Daizaburo Kuroda, Mr.

Akitoshi Kawamoto, and Dr. Hiroshi Kidono, JICA Advisory Committee; Dr. J.E.N. Veron, Australian Institute of Marine Science; Dr. C.C. Wallace, Museum of Tropical Queensland; Dr. M. Guillaume, Curator of corals, Museum of Natural History, Paris, France; and Dr. G. De'ath.

The field surveys were accomplished with the valued assistance of the Coast Guard Stations at Rabigh, Umluj, Al-Wajh, Duba, Maqna and Haql and various field bases. The Saudi Arabian Navy dive rescue team provided valuable safety back-up and use of their zodiac during the February-March 1999 field surveys.

The Study researchers and collaborators deserve a special mention. Their enthusiasm and commitment contributed significantly to the success of the Study.

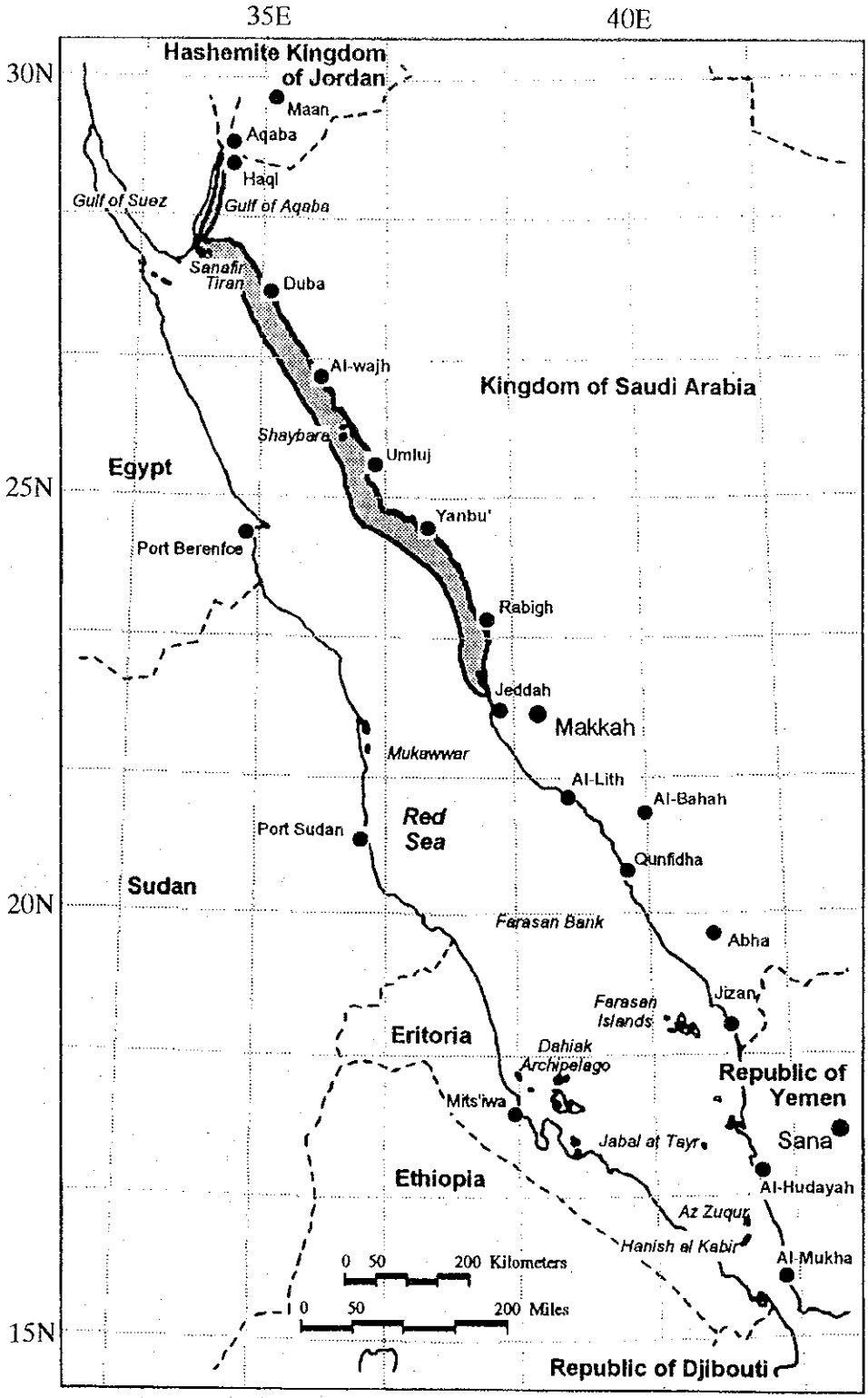


**Fig.1.** Map of the Red Sea and the Study Area (shaded area).

# 2. BIOLOGICAL INVNETORY

## 2.1. BIOLOGICAL INVENTORY

### 2.1.1. Introduction

The biological inventory surveys in the following fields were conducted in the entire Study Area from May – July and from September – November 1998 (Phase II).

Coral, seagrasses / algae, fishes, benthos, marine mammals / marine turtles, mangroves / coastal vegetation and birds

One of the main objectives of the surveys is to collect basic data on each component as much as possible. Specimens of all components, except birds, were collected specimens for further references.

**1. Temperature and water level measurement**

To understand physical phenomena in the Study Area, 15 temperature loggers and four water level recorders were set at several spots. Fig. 1 and Appendix 1 show the locations of the survey spots. At the end of the study period, 12 temperature loggers and all water level recorders were retrieved. Only data on nine temperature loggers are analysed, and no datum on water level recorders was used for analysis. This is because they were damaged. After recovery of the data, eight temperature loggers were set at six spots.

**1-1. Water temperatures**

Since some of these data, however, during the period from January 1999 to June 1999, are unstable and doubtful, analysis of water temperatures is conducted on the data during the period from 4 July 1998 to 31 December 1998.

### 1-2. Water level

No data on water level were obtained because of damage to the equipments.

### 1-3. Discussion

Through all spots and measured period, minimum temperature was 17.1°C (Al-Muraysi, December) at upper layer (1m depth) and 15.1°C (Al-Muraysi, December) at lower layer (9m depth). Maximum temperature was 36.6°C (Yanbu', July) at upper layer (1m depth) and 32.4°C (Sharm Habban, August and September) at lower layer (10m depth). At the upper layer, however, mean temperature through the measuring period tends to be higher in the north (Maqna) than in the south (Yanbu'). The temperature at Al-Muraysi fell during December, which suggests temperature falling at Al-Muraysi may be the influence of upwelling. Daily temperature differences at the lower layer were not obvious at every spot. It is suggested that the marine environment around Yanbu' is influenced by the tide actions in the Indian Ocean coming through Bad Al-Mandab Strait.

## 2.1.2 Coral

### 1. Introduction

Coral communities of the central and northern Red Sea coast in the Kingdom of Saudi Arabia were assessed in terms of their faunistic composition, representativeness-uniqueness and 'quality' (i.e. high species diversity, high coral cover, and importance as reservoirs of biodiversity and replenishment, including representation of rare and endemic taxa). The main objectives of the study were to assess:

i. distribution of coral habitats and reef development,

ii. levels of coral cover,

iii. species diversity and coral community types,

iv. present status – effects of natural disturbances and human impacts,

v. conservation value of individual reefs and larger sub-regions,

and to provide

vi. management recommendations, and

vii. training and technology transfer to Saudi Arabian counterpart personnel.

### 2. Methods

#### 2-1. Field

Bio-inventory and ecological surveys were conducted at 145 sites on 86 reefs in the study region, from near Rabigh in the south to Haql in the Gulf of Aqaba in the north, in 1998-99. The surveys were undertaken at a representative range of habitats, including mainland fringing reefs, sharms (coastal bays), island fringing reefs, patch reefs and barrier reefs. The sites were accessed by car (mainland) or boat. At each site, the coral communities were surveyed using SCUBA.

Where reef slopes descended to > 5 m depth, deep (6 - 15 m) and shallow (1 - 5 m)

sites were surveyed separately. Two types of information were assimilated and recorded on water-proof data-sheets during the ~ 40 min. survey swims: 1) a detailed inventory of sessile benthic taxa; and 2) an assessment of the relative percent cover of the substrate by the major benthic groups. These data provided 'ground-truth' points for interpretation of aerial photos in preparation of the Habitat Maps. A standard set of 'environmental' variables, including depths of the sites (maximum and minimum), average angle of reef slope to the horizontal, amount of reef development, level of exposure to waves, sea temperature and underwater visibility were recorded. The presence of any unique or outstanding biological features, such as particularly large corals or unusual community compositions, bleached corals (partial or total loss of pigments on living corals), coral predators and other causes of coral mortality were recorded. A comprehensive reference collection of coral specimens and photos was prepared.

**2-2. Analysis**

*1). Site description:* Principal components analysis was used to illustrate relationships between the benthic cover and environmental variables. Relationships between coral community types and the cover and environmental variables were also illustrated using PCA.

*2). Community types:* Site groups defined by coral community type were generated by hierarchical cluster analysis of species-abundance data in the bio-inventories of each site. The species that best characterized each community group (key indicator taxa) were determined, based on relative abundance and fidelity (percentage occurrence of sites in each group).

*3). Conservation value:* The relative conservation values of the sites, in terms of their importance as reservoirs of biodiversity and replenishment, were determined using ecological indices.

## 3. Results

### 3-1. Reef types and development

The study region supports a near-continuous coral reef tract composed of a wide range of reef types of generally high ecological integrity. These include mainland fringing reefs, island fringing reefs, platform and 'reticulate' patch reefs, 'pinnacles' and barrier reefs. Reefs were often developed in sharms along the mainland coast, a characteristic reef-form largely restricted to the Red Sea. Notable reef formations of the study region included the barrier reef system developed along the seaward edge of the Al-Wajh Bank, and the reticulate patch reefs developed in the Tiran area and S Al-Wajh Bank. Levels of reef development varied widely, from subsurface patch reefs with no reef flat (mostly in the Al-Wajh Bank), to narrow 'contour' fringing reefs with reef flats < 30 m wide (in the Gulf of Aqaba) to large platform and barrier reefs with reef flats often > 100 m wide.

### 3-2. Coral cover

Benthic cover of reef-building stony corals at individual reefs ranged from < 10 % to > 75 % (regional average ~ 35 %), while soft corals ranged up to 50 % cover (regional average ~ 9 %). High cover of living corals was associated with reefs of relatively high exposure to wave energy and high water clarity. There was little evidence of disturbance or local human impacts on most reefs (average dead coral cover ~ 7 %), although higher cover of dead coral (> 20 %) occurred on some reefs following coral bleaching or predation.

### 3-3. Species diversity and community composition

The coral communities were composed of ~ 250 species of reef-building stony corals from 58 genera in 14 families of the Scleractinia, with the families Acroporidae, Faviidae and Poritidae being predominant, both in terms of species composition and

contributions to coral cover. A further ~ 30 taxa of soft corals, hydrozoan 'fire corals', gorgonians, corallimorpharians and zoanthids were also present, several species of which (*Millepora* and *Sinularia* spp.) were major reef-builders on some reefs.

Some species in the communities have very widespread Indo-Pacific distributions, others are widespread in the Indo-west Pacific, others in the central Indo-west Pacific, others only in the Indian Ocean, W Indian Ocean or 'endemic' to the Red Sea. The communities also included six species new to science (*Montipora sp. nov., Anacropora sp. nov., Goniopora sp. nov., Cyphastrea sp. nov., Echinopora sp. nov. 1, Echinopora sp. nov. 2*) and ~ 40 species geographic distribution range extensions into the Red Sea. Overall, there was a high degree of homogeneity in species composition within the region, with most sites having a subset (ranging from ~20-100 spp., average 61 spp.) of the regional species-pool. There were however, major differences in abundance of particular taxa in certain biotopes, and thus clear zonation patterns in the structure of coral communities, related largely to degree of exposure, water clarity, depth and steepness of reef slope.

***1). Exposed - semi-exposed biotopes***

***Community A, characteristic of mid - lower reef slopes***

Mid - lower reef slope coral communities were composed of diverse mixed assemblages of encrusting and massive coral taxa. Key indicator species include *Montipora danae, Fungia* spp., *Astreopora myriophthalma* and *A. gracilis, Pachyseris speciosa, Stylocoeniella guentheri* and *Leptoseris* spp.

***Community B, characteristic of reef crests – upper reef slopes***

Coral communities of exposed shallow reef crests and slopes were dominated by stout taxa of low growth-form, adapted to high wave energy (~ 2 m) and high water clarity. Key indicator species include *Acropora gemmifera, Leptoria phrygia, Hydnophora microconos, Stylophora wellsi, Favia stelligera, Favites pentagona, Pocillopora verrucosa*

and *Millepora* spp.

*2). Sheltered biotopes*

***Community C, characteristic of turbid areas***

Coral communities of sheltered biotopes were developed on the protected sides of patch reefs, in lagoons behind barrier reefs and inside sharms. These communities experience little wave energy (< 0.5 m), although resuspension of fine sediments can reduce water clarity. Key indicator species include *Montipora* spp., *Pavona decussata, Fungia concinna, Cantharellus noumeae, Echinopora fruticulosa* and *E. forskaliana* and *Platygyra lamellina.*

*3). Biotopes of moderate exposure*

***Community type D, characteristic of reef 'cusps'***

This community occurred in a wide range of habitats and depth ranges, but was commonest on moderately-exposed reef corners ('cusps'). This community had relatively low fidelity among indicator taxa. Key indicator species include *Acropora pharaonis, Oulophyllia crispa, Favia rotundata, Diploastrea heliopora, Barabattoia amicorum* and *Ctenactis echinata.*

**3-4. Present status - disturbances**

Overall, most reefs of the region were in good to excellent condition in 1998-99. There was little to no direct human impact (e.g. destructive fishing, anchor damage, coral mining or pollution) on the great majority of reefs, other than some reefs in urban areas subject to land reclamation or littering. Coral communities on some reefs had also been adversely affected to greater or lesser extent by coral bleaching or predation.

Bleaching was patchily distributed and highly variable in intensity within the region. Bleaching was most intense on reefs near Rabigh, where > 2/3 of total coral cover was bleached or recently dead ( ~ 20 – 40 % absolute cover). On worst affected reefs, bleaching

occurred to the base of the reef-slopes (> 20 m depth), but was usually most intense in depths < 6 m, where > 1/2 of all coral species had been affected. High mortality (> 90 %) occurred to the most susceptible taxa, notably fire-corals *Millepora* spp. and soft corals. Bleaching followed development of a warm-pool of surface waters in July-September 1998. Patterns of mortality to upper coral colony surfaces suggest that radiation effects may also have been implicated at some locations.

The bleaching formed part of a global event affecting coral reefs in all oceans during 1997-98. In the global context, most reefs in the study region were little affected. Most notably, reefs bathed by cool waters (< 28 °C) associated with coastal upwelling, particularly those near Ra's Baridi (N of Yanbu) and in the Gulf of Aqaba were little affected or unaffected. Proximate cause of the bleaching was clearly attributable to elevated sea surface temperatures, however ultimate cause(s) remains unclear. In some reef regions of the world bleaching was associated with the major 1997-98 ENSO climate event, the largest on record, perhaps compounded by global warming.

Other forms of coral mortality in the study region included predation by crown-of-thorns starfish *Acanthaster planci* and muricid snails *Drupella* spp. Such predation had no noticeable effect on coral cover or community composition on most reefs, where starfish and snail populations were at low levels. However, coral cover and community structure had been affected by larger populations of the starfish on some patch reefs in the Al-Wajh Bank (see Model Study).

## 4. Conclusions

### 4-1. Conservation value

The entire study region, from Rabigh in the south to Haql in the Gulf of Aqaba in the north, is one of the most important coral reef areas globally for marine protected areas (MPA)

management. Most of the region is little affected by local human impact, other than in the vicinity of towns and villages where reef fishing, land reclamation and some coastal littering has occurred. Some reefs also appear to be naturally buffered against the worst effects of coral bleaching, because of the prevalence of cool water upwelling. Reefs of special conservation significance in terms of representativeness-uniqueness and 'quality' (i.e. high species diversity, high coral cover, and importance as reservoirs of biodiversity and replenishment) were widely distributed, from the Gulf of Aqaba and Tiran areas in the north, Duba - Al-Wajh, the Al-Wajh Bank, Umluj – Ra's Baridi and Yanbu' - Rabigh in the south. Individual reefs of exceptional conservation value are listed in Table 2. On a larger geographic scale, three sub-regions are of special conservation importance.

**The Gulf of Aqaba** - for the high levels of coral cover and species diversity, including endemic species that are rare in other parts of the study region (e.g. *Cantharellus doerderleini*). Of particular note were the characteristic narrow 'contour' reefs (< 50 m in total width) developed on steep coastal slopes. These narrow reefs were among the most species-rich of the study region. The high diversity is particularly significant given the restricted reef area, cool sea temperatures, and given that the Gulf of Aqaba is at the north western-most extent of reef development in the entire Indo-Pacific region.

**The Tiran area** (extending from the mainland coast north of Duba to the entrance to the Gulf of Aqaba) - for the wide variety of different biotopes and reef types (barrier reefs, island and mainland fringing reefs and patch reefs, including shallow 'reticulate' patches). These reefs form unique complexes with high zoogeographic significance, supporting high species diversity including Red Sea endemic corals, presently undescribed coral species and species with apparently restricted distributions otherwise rare in the region.

**Al-Wajh Bank** - for the wide variety of reef types (and other marine and coastal habitats). As with the Tiran area, reefs of Al-Wajh Bank support Red Sea endemic corals, presently

**Table 2.** Sites of special management significance in terms of high conservation values. Reef names and GPS locations are listed in Appendix C1. Reef types: B – Barrier, P – Patch, IF – Island Fringing, MF – Mainland Fringing, SF – Sharm Fringing. Hard coral cover ranks: 2 = 11-30 %, 3 = 31-50 %, 4 = 51-75 %. Coral species diversity, ratings (1-145) within the study region for indices of replenishment potential (CI) and rarity (VI), the presence of undescribed species and coral community type are listed for each site.

| Site | Location | Reef Type | Hard coral cover | Species diversity - all corals | Replenishment (CI) | Rarity (VI) | Undescribed spp. | Community Type |
|---|---|---|---|---|---|---|---|---|
| C32b | Tiran area | IF | 4 | 107 | 2 | 9 | | B |
| C77a | N of Umluj | P | 4 | 110 | 4 | 6 | | A |
| C74a | Al-Wajh Bank | B-P | 3 | 111 | 1 | 11 | y | A |
| C78b | N of Umluj | P | 4 | 108 | 3 | 22 | | B |
| C86b | Tiran area | P | 4 | 97 | 6 | 18 | y | A |
| C77b | N of Umluj | P | 4 | 70 | 7 | 33 | y | B |
| C85a | Tiran area | P | 3 | 109 | 26 | 13 | | A |
| C40b | Yanbu' - Rabigh | SF | 4 | 85 | 5 | 36 | | B |
| C26b | Gulf of Aqaba | MF | 4 | 90 | 8 | 53 | | A |
| C41b | Umjuj – Yanbu' | MF | 4 | 93 | 9 | 46 | | B |
| C70b | Al-Wajh Bank | P | 3 | 67 | 65 | 1 | y | C |
| C82b | Al-Wajh Bank | P | 4 | 53 | 92 | 2 | y | C |
| C31b | Tiran area | P | 4 | 56 | 37 | 4 | y | C |
| C31a | Tiran area | P | 2 | 52 | 121 | 3 | y | C |
| C30a | Gulf of Aqaba | MF | 2 | 90 | 91 | 5 | | A |
| C86a | Tiran area | P | 3 | 94 | 13 | 14 | y | A |
| C24b | Duba - Al-Wajh | MF | 5 | 66 | 15 | 73 | | B |
| C12a | Umluj - Yanbu | SF | 3 | 63 | 82 | 57 | y | A |
| C14b | Umluj | IF | 3 | 56 | 85 | 114 | y | B |
| C49a | S of Al-Wajh Bank | P | 2 | 69 | 110 | 111 | y | D |
| C62a | Al-Wajh Bank | P | 2 | 65 | 108 | 51 | y | C |
| C67a | Al-Wajh Bank | P | 3 | 65 | 88 | 19 | y | C |
| C73b | Al-Wajh Bank | B-P | 2 | 87 | 74 | 35 | y | A |
| C79a | Al-Wajh Bank | P | 2 | 62 | 112 | 55 | y | C |

undescribed coral species and species with apparently restricted distributions. Its size and diversity of reef habitats, and likely high level of ecological connectedness in terms of larval dispersal in ocean currents, both within the Bank and to other parts of the Red Sea, afford it great significance for future conservation (see Model Study).

### 4-2. Management Implications

The near-continuous coral reef tract of the central - northern region of the Saudi Arabian Red Sea has high local, regional and global conservation significance and generally low levels of human use and impact. The region includes most of the world's major reef types, supporting coral communities of high cover, species diversity and unique community composition, including species endemic to the region and others presently undescribed. The communities also support other reef-associated species of high conservation value and/or economic importance. High quality reefs were distributed widely throughout the study region. Results of the present study support the earlier NCWCD-IUCN assessments of the Gulf of Aqaba, Tiran area and Al-Wajh Bank as Environmentally-Sensitive Areas of special conservation importance.

*1). Future monitoring:* It is recommended that NCWCD develop a dedicated coral reef monitoring team. The geographic scale of the reef tracts of Saudi Arabia (both in the Red Sea and Arabian Gulf) are such that an adequate monitoring program would require a minimum of four dedicated full time personnel. Following training and technology transfer during this study, sufficient expertise exists within the NCWCD Marine Department to develop such a team. This would facilitate coral reef monitoring and research within the Kingdom, essential adjuncts to future MPA management.

*2). Further Research:* Additional studies that would be useful for management include:

- Coral reproduction – timing,

- oceanographic connectivity within the region, in terms of determining likely 'source – sink' dispersal relationships for maintenance and replenishment of populations,
- coral recruitment and growth rates,
- recovery of coral cover and community structure following disturbance,
- genetics – linkages within the region and with other reef areas.

### 2.1.3. Seagrasses/Algae

**1. Introduction**

Climatic and oceanographical conditions in the Red Sea put severe stresses on intertidal and shallow sublittoral biological communities (JONES et al., 1987). Seagrasses and algae, a principal components of the intertidal and shallow sublittoral communities, are exposed to the severe physical environment of high water temperature and low exchange rate of shallow coastal water, though the physical condition varies in places, such as wave action, current, turbidity of water and bottom sediment, since coral reefs have a wide variety of configuration of the physical features of habitats. This unique environment in the Red Sea has an effect on species diversity and biomass.

Besides the physical impact, seagrasses and algae receive the influence of grazing by herbivores which enter the seagrass/algal habitats mainly from offshore open areas. Breaking wave areas where wave action keeps them away are the exception.

Some authors have reported 11 species of seagrass from the Red Sea. A species list of seagrasses in the Indian Ocean (DEN HARTOG, 1970) shows that there is basically the same flora in the Indian Ocean and the Red Sea.

It has been known that, in general, the algal species of the Red Sea belong to the circumtropical and subtropical marine flora occurring in the Indo-Pacific Ocean, Mediterranean and Caribbean Seas (WALKER 1987). PAPENFUSS (1968) recorded 485 species of algae from the Red Sea. Sea. SILVA et al. (1996) published a catalogue of algae in the Indian Ocean including the Red Sea, analysing the taxonomy of algae and pointed out many synonyms. Their suggestions require special attention to identifying the species of algae to prepare a correct inventory which gives basic information for an appropriate environmental management.

## 2. Methods

The fieldwork was carried out during 31 May to 6 July and 27 September to 14 November 1998, covering 197 survey spots. Surveys were conducted by snorkelling and SCUBA diving, employing the quadrat method. At least two dried specimens of the collected samples for each species were made.

## 3. Results

The Study recorded 188 taxa in total; eight Seagrasses, 68 Chlorophyta, 30 Paeophyta and 82 Rhodophyta. They include 11 species of algae reported newly to the Red Sea.

Geographical distribution of species number is summarised in Table 3. Intensively studied sub-area revealed a large number of species.

Diving observation found key locations which showed high species diversity of seagrass or algae. Algae diversified their flora at patch reefs and fringing reefs where the rough wave action interfered with invasion of herbivorous fish. Many seagrass species occurred in inlets with an appropriate water movement which prevented the accumulation of silt particles. The species number in the Tiran area or Al-Wajh Bank would increase if such key locations had been surveyed more.

**Table 3.** Species number of seagrasses and algae.

| | **Gulf of Aqaba** | **Tiran** | **Duba/ Al-Wajh** | **Al-Wajh Bank** | **Umluj / Ra's al-Bardi** | **Yanbu'/ Jeddah** |
|---|---|---|---|---|---|---|
| No. of Site | 3 | 2 | 7 | 5 | 6 | 4 |
| No. of Spot | 39 | 12 | 51 | 37 | 30 | 28 |
| Seagrass species | 4 | 2 | 7 | 5 | 7 | 5 |
| Algae species | 75 | 48 | 130 | 77 | 60 | 78 |

In general, the seagrass beds occured in the inner part of fringing reefs, lagoons in inner reefs, sharms and inlets. *Thalassodendron ciliatum* and *Halophila stiplacea* were common in the subtidal zone, and they made extensive seagrass beds. *Halodule uninervis* was common in the intertidal zone.

Macro algal beds of *Sargassum* and *Cystoceira* developed in the southern part of the Study Area. *Sargassum* were distributed on the reef flat which generated overtopping waves. *Cystoceira* grew on the shallow bottom within the reef flat. A lot of turf and small algae thrive on the reef edge. On the reef slope, the algal community was not abundant.

In the southern Al-Wajh Bank, there was found an aggregate of drifted algae, *Sargassum* sp. on the shallow sandy bottom.

## 4. Discussion

### 4-1. Seagrasses

In the Study Area, species composition of seagrasses showed little geographical difference. *Halodule uninervis* and *Halophila ovalis* were the principal species within the barrier reef, and occurred even in tide pools and shallow lagoons where they experienced the extremely high water temperature. Some sharms and inlets provided seagrass species with a suitable environment, if the water movement there is enough to sweep silt particles away.

It was obvious through the aerial observation that there were many key locations for growth of many seagrass species in Al-Wajh Bank. The condition for a key location for seagrass is water movement which removes silt from bottom sediment and leaf surface. These locations were found in tidal pools, lagoons, sharms, inlets and the inner part of fringing reefs. Therefore, Al-Wajh Bank was recognised as an important candidate area for the Model Study.

### 4-2. Macro Algae

Macro algae showed the geographical difference in formation of beds in the entire

Study Area, though the entire algal flora did not differ in six sub-areas either. Macro algal beds developed more extensively in the southern half of the Study Area than in the northern half. In the southern area, reef flats extend widely, offering a large substrate for algae. Many reef patches provide macro algae with a suitable habitat which has strong current flow originated from waves and prevents herbivorous fish from invading the areas.

The Study found that a principal factor for growth of rich seagrass / algal flora is the micro-scale topography of the sea bottom, which regulates the water movement. For seagrass communities, wave and current flow plays an important role to eliminate silt particles from the bottom and the leaves. Sharms and inlets were typical areas providing such a condition. It also functioned for algal communities to keep herbivorous fish away from reef patches and reef edges.

For the selection of the Model Area, it was thought reasonable to choose Tiran area or Al-Wajh Bank, because they have many such key locations to study abundant and diversified seagrass / algal communities.

### 2.1.4. Fish

#### 1. Introduction

#### 1-1. Literature survey

Eight scientific documents are used to list fishes in the Red Sea. These documents list a total of 127 families, 536 genera and 1,354 species, including 50 endemic species.

#### 1-2. Inventory survey

The survey was basically undertaken through SCUBA and snorkel diving.

Species which were difficult to identify in the water were photographed with digital video cameras or digital still cameras, and were later identified in the laboratory. Sampling collections were also conducted when necessary.

Gillnets, hand nets and throwing nets were used to collect samples. Angling was also undertaken for the same purpose. Samples were fixed with formalin-aqueous solution, and were identified in the laboratory.

65 families, 175 genera and 378 species were observed in the course of the survey, which was undertaken at 121 spots in 25 sites.

The ten most frequently observed species were seen at every diving site. This may imply there is no strong locality effect on species distribution within the Study Area.

Among the 50 endemic species in the list, 34 species were observed in the Study.

#### 1-3. Collection of specimens

Fish specimens collected by gillnets, hand nets, throwing nets and fishing lines amounted to 373 (271 for the Kingdom of Saudi Arabia and 102 for Japan) which were fixed with formalin-aqueous solution.

#### 1-4. Newly recorded species

Five species are considered to be fish which have the possibility of being recorded in the Red Sea for the first time. Since specimens of almost all of them were collected, further

study in the future may be expected.

## 2. Discussion

### 2-1 Habitats and species

44 survey spots which were surveyed by diving or snorkeling to observe fishes are categorized into the two types; inside habitats and outside habitats, taking into consideration the differences between the habitats; physical conditions and human impacts (accessibility).

Composition of the 10 major fish families in the inside and the outside habitats is shown in Fig. 3. There is no significant difference in predominant fish families between the inside and the outside habitats.

The outside habitats have greater abundance in comparison with the inside, although the two types do not show any difference in species richness.

## 3. Selection of the Model Area

A comparison of diversity, productivity index and endemism among these areas is shown in Table 4 and Fig. 3.

**Table 4.** Consideration for the Model Area.

| Area | Diversity | Productivity | Endemism |
|---|---|---|---|
| Gulf of Aqaba | | 3 | |
| Tiran | | | |
| Duba / Al-Wajh | 3 | 2 | 3 |
| Al-Wajh Bank | 2 | | 1 |
| Umluj / Ra's Baridi | 1 | 1 | |
| Yanbu' / Jeddah | | | 2 |

3: very good, 2: good, 1: not good, blank: there are not sufficient data for evaluation.

The wide area from Al-Wajh area to Umluj / Ra's Baridi area is considered as a

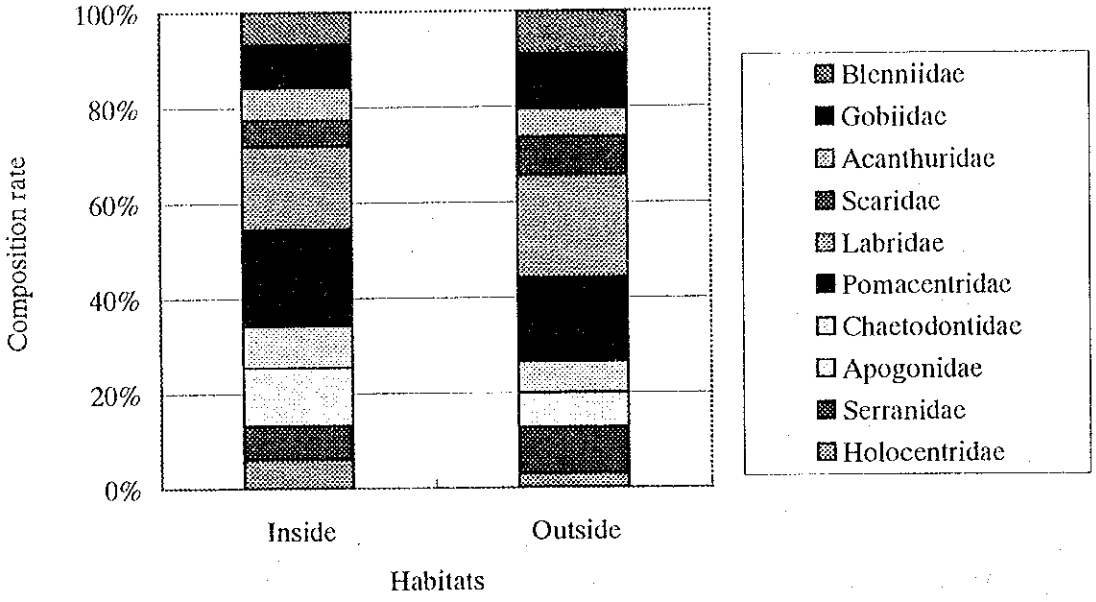


**Fig.2.** Composition of major 10 fish families in the inside and outside habitats.

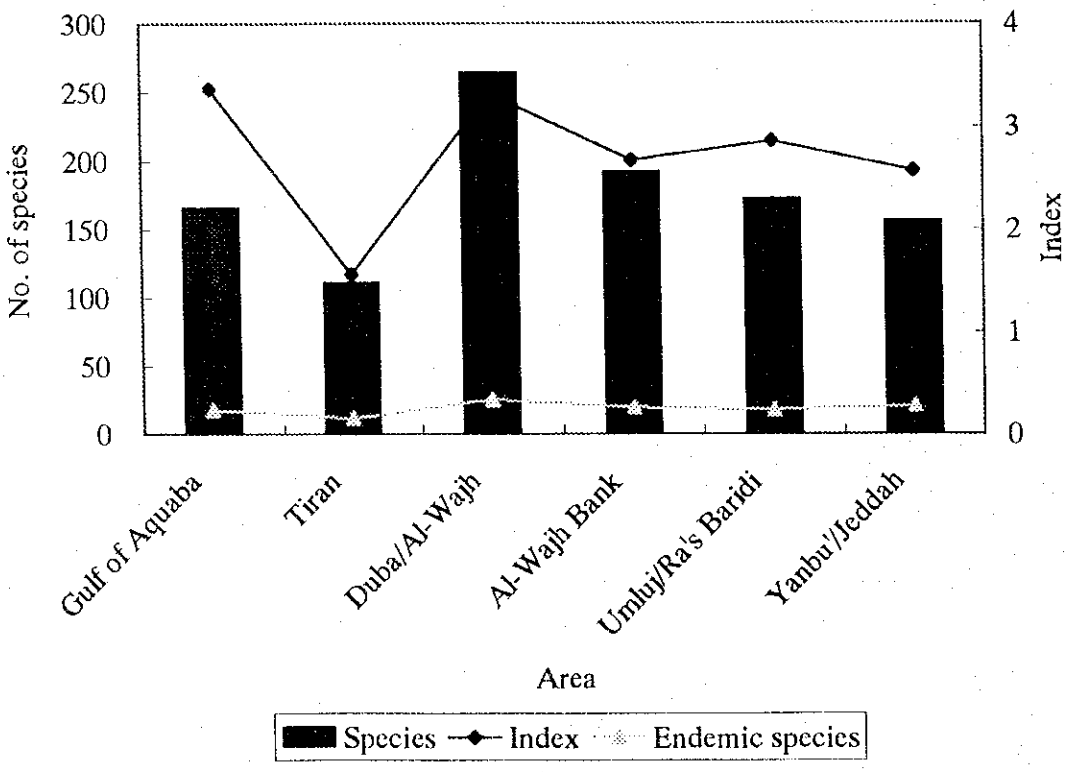


**Fig.3.** Comparison of diversity, productivity and endemism.

candidate for the Model Study Area for Phase III because of its high diversity, productivity and endemism. Al-Wajh Bank has many kinds of habitats, such as seagrass bed, patch reef, outside reef, and it is also considered as a good candidate for the Model Area.

### 2.1.5. Benthos

#### 1. Methods

The survey was conducted on foot in the supertidal zone, mainly by snorkeling and occasionally SCUBA diving in the intertidal zone, and by SCUBA diving in the subtidal zone.

In each tidal zone, survey spots were selected in order to survey various habitats, such as sand and mud bottoms, bedrock, seagrass bed, and patch coral. The time duration for the survey at each spot was about 30 to 60 minutes.

Scientific names and the abundance of the benthos over about 1cm (megarobenthos) observed in each spot were recorded in the field. Species that could not be identified in the field were collected and identified in the laboratory. Photographs of benthos were taken by underwater camera, and samples including empty shells, were collected whenever possible.

#### 2. Results and discussion

The number of survey sites was 25 and the number of survey spots was 96.

In the field survey of Phase II, 123 families and 341 species, including empty shells, were identified. There was no significant difference in the geographical distributions among the dominant species.

Sites that showed a high number of species were more prevalent in the northern sections of the Study Area, and the largest number of species were observed at Site 3 in the area of the Gulf of Aqaba (82 species, Fig.4). The biomass of benthos was high in the Gulf of Aqaba area and Duba /Al-Wajh area. In contrast, the biomass was low in Al-Wajh Bank area and Yanbu' / Jeddah (Fig.5).

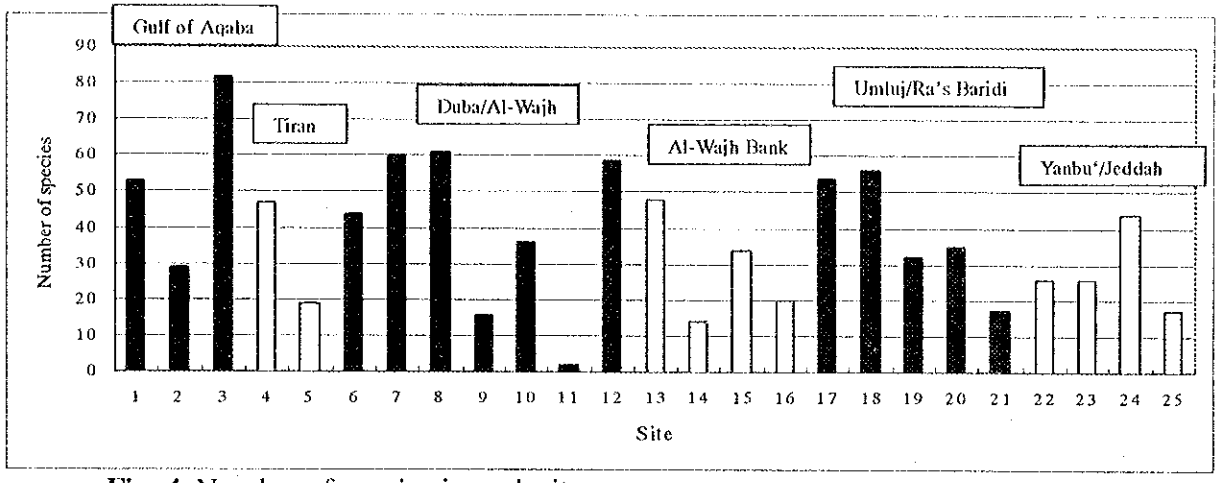


**Fig. 4.** Number of species in each site.

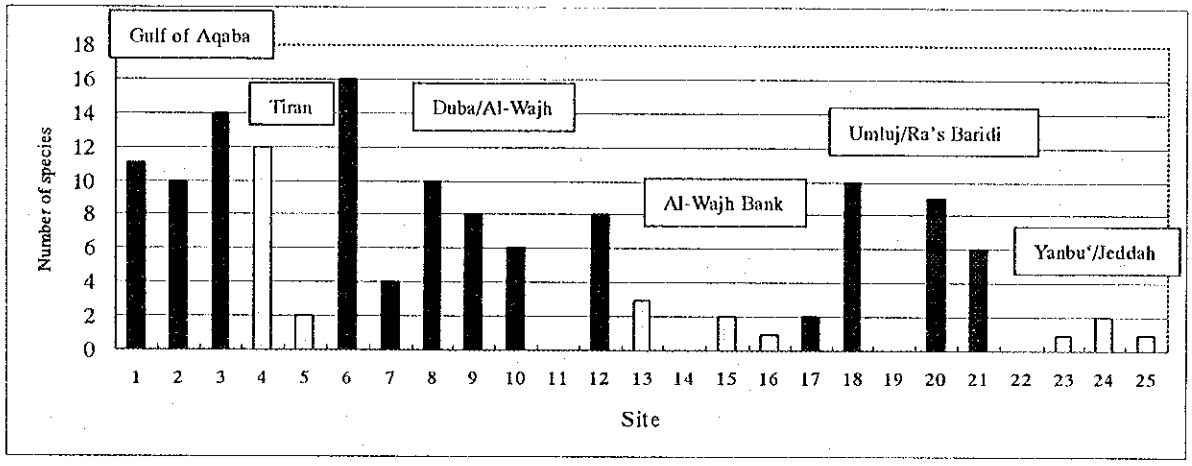


**Fig. 5.** Species number of benthos of abundance level 3 in each site.

Survey spots were classified into several habitat types according to their tidal situations and features of the sea bottoms. Many species were seen in habitats of sand, bedrock and patch reefs. The number of species observed in seagrass bed and rock habitats was low. It is thought that the patch reefs in the subtidal zone are an especially important element for sustaining a benthic community with a high degree of diversity, based on a comparison of habitats composed of sand and bedrock in the two zones. The muddy tidal flats were rare in the Study Area, and these were mainly observed around a mangrove thicket. Species observed only in such habitats were, stalk-eyed crab *Macrophthalmus* cf. *convexus*, fiddler crab *Uca* cf.*lactea perplexa*, fiddler crab *Uca* cf.*tetragnon*.

A Model Area to be surveyed further in Phase III should have a high species diversity and biomass and a minimal degree of impact from human activities.

Each area in the Study Area is assessed in terms of the above-mentioned criteria in order to select the Model Area. The results of the assessment of the areas are summarised in Table 5.

The area that has the highest general score of assessment is Duba /Al-Wajh. Al-Wajh Bank should be appreciated in point of number of habitats next to Duba / Al-Wajh.

**Table 5.** Assessment of the Study Area.

| Point of view | Key Issue to Assess | Gulf of Aqaba | Tiran | Duba/ Al-Wajh | Al-Wajh Bank | Umluj/ Ra's Baridi | Yanbu'/ Jeddah |
|---|---|---|---|---|---|---|---|
| Species diversity | Maximum number of species in eacl site of the area | 3 | 2 | 3 | 2 | 2 | 2 |
| Biomass | Maximum number of species tha were observed above abundance leve 3 in each site of the area | 3 | 2 | 3 | 1 | 2 | 1 |
| Number of habitata | Observations in field survey (Especially mangrove) | 1 | 1 | 3 | 3+ | 3 | 3 |
| Human impacts | Observations in field survey | 3 | 3 | 2 | 2 | 2 | 1 |

3: very good, 2: good, 1: not good

## 2.1.6. Marine Mammals / Marine Turtles

### 1. Marine Mammals

With given time and resources, Questionnaire / Interview, the shoreline aerial survey and sighting were simultaneously implemented with marine turtle survey.

### 1-1 Results and Discussion

*1).Questionnaire / interview survey*

Dolphins are the only marine mammals occurring throughout the Study Area known by the respondents. Common Dolphin *Delphinus delphis* and Bottle-Nose Dolphin *Tursiops truncatus* on illustrated books were the most commonly pointed out by the interviewees, followed by Risso's Dolphin *Grampus griseus*. The respondents' description of large whales sighted would indicate the occurrence of two different species; one with an apparent dorsal fin and the other without.

The interview results indicate the occurrence of Dugong in the mouth of the Gulf of Aqaba to the north of Duba, and Al-Wajh Bank, Sharm Shabaan, Ra's Baridi to the south of Yanbu'. In addition to the above area, sightings were also reported in sharms south of Duba where small seagrass habitats were expected. Dugong sightings were mostly of solitary animals. One fisherman at Baraqan island reported the sighting of a large Dugong group near the island. No respondent told of any increase in Dugong sightings. No intentional exploitation of Dugong was known by the respondents. Only accidental catches with fishing nets are known to occur.

*2). Shore line aerial survey*

Seven groups of Dugong were sighted during the shore line aerial survey. Six out of seven sightings were of two or less Dugongs and no calf was sighted. The largest group seen was four Dugongs. Whether the results are due to the characteristics of their reproduction,

their migration pattern, or survey bias needs to be carefully studied.

*3). Sighting during the field surveys.*

Dugong and Indo-Pacific Hump Back Dolphins were sighted during the survey. The species were identified on the basis of their descriptions.

### 1-2. Conclusion

The priority areas are evaluated in terms of 1) species occurrence, 2) reproduction habitat, 3) endangered/ endemic species, 4) exploitation (human impacts), 5) mortality. The evaluation is basically done in the Dugong conservation. Major distributed area for Dugong: Tiran area and Al-Wajh Bank are evaluated as high priority areas. However, the seagrass habitat in open sharms from Duba to Al-Wajh Bank and Al-Shabaan to Yanbu' need to have special attention. Dugong, and Bottle-Nosed Dolphin in the Red Sea are described by some authors as taxonomically different from those of the Indo-Pacific region. Three inshore species; the above two species and Indo-Pacific Hump Back Dolphin, need to have special consideration in the conservation management in the Study Area.

## 2. Marine Turtles

In order to evaluate the extent of marine turtle distribution, nesting habitats, 1) questionnaire / interview, 2) shore line aerial, and 3) actual on-site beach survey were conducted.

### 2-1. Results and Discussion

*1). Questionnaire / interview survey*

42 coast guards and 17 fishermen were interviewed with the questionnaire. The results indicate that marine turtle nesting occurs from north of Jeddah to the mouth of the Gulf

of Aqaba, though the intensity seems to be low. No respondents considered that the marine turtle nesting is increasing. In the Jeddah and Yanbu' areas where much coastal development has taken place, four of the respondents out of twelve said there was a decrease. Significant yearly fluctuation of the nesting activities and sighting were suggested in the Al-Wajh and Umluj areas. No significant exploitation of eggs and/or turtles was known by the respondents. There is, however, some intentional harvesting of marine turtles for medicinal purposes, according to some respondents.

***2). Shore line aerial survey***

Islands where many body pits and truck were found by the shore line aerial survey (N24°45-N28°00) are; Sanafir, Shusha, Al-Norman, Al-Shikh Marbat, Birrim, al-Waqqadi, four islets west of Al Khurj coast guard station (inside Al-Wajh bank), six islets west of Qara'ir coast guard station (N25°34'E36°40'—N25°34'E36°46'), seven islets west of Al-Hara coast guard station (N25°13'E37°08'—N25°09'E37°09'), Jazirat Jabal Hassan, Libnah, Malihah. Mainland coast areas where evidence of turtle nesting was found are; Ra's Wadi Tiryam, south of Al Muwaylih coast guard station, south of sharm al Harr, north of Duba, north of sharm Jubbah, south of Zubaydah coast guard station, north and south of Ra's a Ubayd, Ra's Marjah (south of sharm Antar), Ra's Muraybit (north of Haramil coast guard station) and south of Ra's Abu Mullah (south of Al-Wajh).

***3). Ground truth beach survey.***

***Nesting beaches***

A high nesting intensity is observed only in Baraqan, al-Waqqadi and Jabal Hassan islands, south of Al-Shabaan, and Ra's Baridi. The number of nests seems to be relatively low compared with the number of body pits found on the beaches.

***Nest examination***

The average number of normal eggs per nest of Hawksbill Turtle was 66.3±19.0

(n=9). The number and percentage of yolkless eggs per nest was 30.0±19.2, 30.2%±14.5 (n=9). It would be indicating the characteristics of the reproduction condition of Hawksbill Turtle in the Study Area. Two nests of Green Turtle examined in Ra's Baridi had 124 and 128 normal eggs, respectively, with five yolkless eggs in one nest.

***Nest Temperature***

The temperature of the nesting beach at Ra's Baridi in late August to October, which is regarded as the nesting peak season of the Green Turtle, is from 32°C down to 28.5°C. The same range of temperature was available from the end of April to July. Significant nesting activities of Green Turtles on Ra's Baridi and Jazirat Jabal Hassan island were noted in June 1999. The Green Turtle nesting activities may have two phases or start from April, but a confirmation survey is needed.

***Nesting females***

One nesting female of Hawksbill Turtle at al-Waqqadi island on June 1999, five new nesting females and one tagged female of Green Turtle at Ra's Baridi on October, 1998 and one at Jazirat Jabal Hassan on June 1999 were observed. The Hawksbill Turtle was relatively small. The five new nesting female Green Turtles within the very limited time indicates some level of the recruitment.

***Mortality***

Seven mortality cases were found during the beach survey. One adult male Hawksbill Turtle was harvested for male organ on Umm Libnah island. The sex of marine turtles is usually biased toward the female. If the sex is biased considerably toward the female in the Red Sea, the selective hunting pressure on the male might have some impact. One dead nesting female at Ra's Baridi was found in the Survey. The mortality of the reproductive population causes a significant impact on the population as a whole. The cause and the rate of mortality need to be assessed for effective management.

## 2-2. Conclusion

The priority areas are evaluated in terms of 1) species occurrence, 2) extent of nesting habitat, 3) endangered/ endemic species, 4) exploitation (human impact), 5) mortality. The Study area is divided into 6 characteristic areas and the importance evaluated into three levels. Al-Wajh Bank and the Tiran area are evaluated as high priority areas for conservation with the same level, followed by Duba / Al-Wajh where scattered nesting habitats were found.

### 2.1.7. Mangroves / Coastal Vegetation

#### 1. Introduction

The north of the Red Sea including the Study Area belongs to the Saharo-Arabian Floristic Region, under the hyper - arid and subtropical climate with low precipitation and high temperatures. Under these harsh climatic conditions, the Red Sea coastal area is widely covered by barren land. Some of the offshore islands and shorelines are, however, covered by mangroves which have adapted to the highly saline waters.

There are a couple of reports on the vegetation of the Red Sea coastal zone. VESEY-FITZGERALD (1956) describes the vegetation of the coastal plain and highlands north of Jeddah in Saudi Arabia. Four mangrove species exist in the Red Sea area, and two species (*Avicennia marina* and *Rhizophora mucronata*) were recorded on the eastern coast of the Red Sea (SHEPPARD et al. 1992). The extent of mangroves has almost certainly been reduced over time by felling for timber and for fuel (ORMOND et al. 1986). Degradation of the mangrove forest caused by grazing of camels has also been reported (MIYAMIOTO & AL-WETAID 1993, MOHAMED 1984).

#### 2. Inventory Study

##### 2-1. Methods

25 sites including three offshore island sites were selected for examining the typical pattern of coastal vegetation in the Study Area. Each site was in the coastal zone within 1 km from the shoreline, and its area was approximately 1,000 m x 500 m (maximum). Every plant community in the Study Area was surveyed using the quadrat method of BLAUN-BLANQUET (1964), mainly in May-June 1998. Distribution of plant communities in each site was sketched as a vegetation map and a profile of the site. Additionally a flora survey was conducted at each site in the same way as the vegetation survey. All observed species at each

site were recorded as a flora list. Plants were collected for specimens whenever possible.

## 2-2. Results

### *1). Vegetation*

As the results of 69 quadrat surveys, eight vegetation types, including 29 plant communities, were found as follows; mangrove thicket (two communities), desert shrub (five communities), succulent salt marsh (10 communities), desert succulent half-shrub (three communities), grassland salt mash (three communities), reed (two communities), desert grassland (one community), others (three communities). Forming zonation was observed clearly from the seashore to the inland side at almost all sites. As for mangroves, *Avicennia marina* thickets were found in eight sites, *Rhizophora mucronata* existed in only two sites at Al-Wajh Bank with association with *A. marina*.

### *2). Flora*

As the result of the preliminary and the inventory survey of 26 sites, 159 vascular plants (43 families) including two mangrove species were recorded. The flora of the Study Area was mainly characterised by halophytes (e.g. CENOPODIACEAE, ZYGOPHYLLACEAE, GRAMINEAE) and xerophytes (e.g. LEGUMINOSAE, EUPHORBIACEAE, CAPPARACEAE). The sites with characteristic and/or unique geomorphological features, such as Jazirat Jabal Hassan with a steep slope and Tip Esim, a narrow-bottomed gorge, tended to have their own flora. The number of species at each site varied from 2 (minimum) to 44 (maximum). The monotonic habitat sites were usually poor in species diversity. The sites with a wide variety of habitats supported have many plants. It seems that habitat variation is a very important factor for the species diversity at each site. The field survey found 12 endemic and/or endangered plants in the Study Area (Table 6).

**Table 6.** The distribution of the endemic and / or endangered plants in the Study Area.

| No. | Scientific name | Literature ① | Literature ② | Site 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | Frequ -ence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Rabigh | | | | | | Umluj | | | | | | Al-Wajh | | | | | | Duba | | | | | | | Haql | |
| 1 | *Zygophyllum boulosii* | + | | | | | | | | | | | | | | | -- | | | | | | | | -- | | | | | 2 |
| 2 | *Salvadora persica* | | L | | | | | | | | | | | | | -- | -- | -- | | | | | -- | | | | | | | 4 |
| 3 | *Ziziphus spina-christi* | # | | | | | | | | | | | | | | | | | | | | | | | | | | | -- | 1 |
| 4 | *Sphaerocoma aucheri* | # | | | | | | | | | | | | | -- | -- | -- | -- | -- | -- | -- | -- | | | | | | | | 8 |
| 5 | *Cornulaca ehrenbergii* | # | | | | | | | -- | | | | | | | | | | | | | | | | | | | | | 1 |
| 6 | *Acacia ehrenbergiana* | | L | -- | -- | | -- | | | -- | | | | | | | | | | | | -- | -- | | | | | | | 6 |
| 7 | *Acacia oerfota* | + | | | | | | | -- | | | | | | | | | | | | | | | | | | | | | 1 |
| 8 | *Acacia tortilis* | | L | | -- | | -- | | | -- | | | | | | -- | -- | -- | -- | -- | | -- | -- | -- | -- | -- | | -- | -- | -- | 15 |
| 9 | *Taverniera lappacea* | # | | -- | | | | | | | | | | | | | | | | | -- | | -- | | | | | | | 3 |
| 10 | *Rhizophora mucronata* | | V | | | | | | | | -- | -- | | | | | | | | | | | | | | | | | | 2 |
| 11 | *Convolvulus asyrensis* | + | | | | | | | | | | | | | | | | | | | | | | -- | | | | | | 1 |
| 12 | *Hyoscyamus albus* | # | - | | | | | | | | | | | | | | | | | | | | | | | | | -- | | 1 |
| | **Number of species** | 8 | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | |

①: COLLENETTE 1998. ②: FARHAN 1998.

+ : Endemic not endangered, # : Non-endemic endangered, L : Lower risk, V : Vulnerable.

## 2-3. Discussion

The value of the sites for plants and vegetation was evaluated to select the Model Study Area. The evaluation is based on the results of the field survey from the following points of view: biological diversity (the number of species), endemic and/or endangered species, and biomass (plant coverage). The Study Area is divided into six areas and is evaluated according to the three criteria. As a result, Duba / Al-Wajh and Al-Wajh Bank are given high value points totally (Table 7).

**Table 7.** Assessment of the Study Area.

| Area / Criteria | Gulf of Aqaba | Tiran | Duba / Al-Wajh | Al-Wajh Bank | Umluj / Ra's Baridi | Yanbu' / Jeddah |
|---|---|---|---|---|---|---|
| Diversity | 1 | 2 | 3 | 1 | 2 | 2 |
| Endemic or endangered plants | 1 | 1 | 3 | 3 | 1 | 1 |
| Biomass | 1 | 1 | 2 | 3 | 1 | 2 |

3: very good, 2: good, 1: bad.

### 2.1.8. Birds

In the northern part of the Red Sea coast area, the avifauna is dominated by Palearctic species, and a few Afrotropical species have been recorded (JENNINGS 1995).

The avifauna of Saudi Arabia has been studied for a long time but its harsh climate and poor accessibility to some areas have limited a systematic study. The northern part of the Red Sea coast has not been systematically surveyed.

Mangroves are important for birds, providing safe feeding, nesting and roosting places for many of them (BALDWIN & MEADOWS 1987, LOBLEY). Migration time is especially fruitful, in March / April and September / October (LOBLEY).

#### 1. Methods

The Birds team coordinated its field survey work closely with the Mangrove / Coastal Vegetation team in order to understand the area's avifauna together with the vegetation on which the bird species depend heavily for their survival. At each spot, no route was set up and observers walked around to observe as much as possible.

The surveys were conducted in February 1998, May – June and October 1998.

10 x 40 and 8 x 30 binoculars, and a 24 x 60 telescope were used for the survey. In the autumn survey, mist nets were used to capture and ring birds. The bird list is based on the checklist in PORTER et al. (1996).

#### 2. Results

In February 1998, 82 species were recorded in the Study Area. In May – June 1998, 64 species were recorded at 21 sites, and five other species were recorded outside the sites. In October 1998, 86 species were recorded at 10 sites, and three species were recorded outside the sites. Mist netting was used at one site in October.

As the result of the field survey of Phase II and the Preliminary Study, 134 species were recorded in the Study Area.

In Phase III, Red-rumped Swallow *Hirundo daurica* was added to the biological inventory, and 135 species were identified during the whole Study period.

In February it seemed that more species were observed in the northern section than in the southern section of the Study Area (Table 8). Distribution of wintering birds seems to differ between the northern and southern sections.

In May – June and October, a total of 24 sites were surveyed (Table 9).

Crested Lark *Galerida cristata* was the most commonly seen species throughout the three seasons all over the entire Study Area. Breeding of Kentish Plover *Charadrius alexandrinus* and Sooty Gull *Larus hemprechii* was confirmed. Nine species were categorised as probable breeding". Four species were categorised as "possible breeding". Twenty species were only recorded in February 1998.

White-eyed Gull *Larus leucophthalmus* (globally vulnerable) and Pallid Harrier *Circus macrourus* (globally near-threatened) were recorded in the Study Area. Two species which are threatened or declining throughout all or large parts of their range in the Middle East were recorded (Goliath Heron *Ardea goliath* and Sooty Falcon *Falco concolor*), and ten species which have relatively small total world ranges with important populations in the Middle East were recorded in the Study Area.

Seven sites were surveyed in May – June and October. 13% to 30% of the recorded species at sites are considered to be migratory species, including wintering species, in the Study Area.

Mist netting was conducted at B8 (Sharm 'Antar) on both 10th and 11th October. Eight individuals of six species were caught and ringed.

Twenty four sites were categorised into the following six habitats; wadi, mangroves,

mangroves and arid area, mangroves / wadi and farm, arid area, and farm and palm trees.

## 3. Discussion

### 3-1. Species diversity

The climate is very harsh in the summer and so many terrestrial species do not breed in the Study Area. The area seems to be more important for migratory and wintering species. There were no big differences among sites. Species diversity at each site depends more on the site's habitat and its vegetation coverage than on its location in the Study Area. Wadis and mangroves are the key elements of habitat which have high species diversity.

### 3-2. Abundance

The abundance of each species is relatively low throughout the Study Area and during each season. Abundance of species may depend on the composition of site's vegetation rather than its coverage. Although sea birds generally have a high number of individuals, their numbers were not counted in this Study.

### 3-3. Threatened and endemic species

Al-Wajh Bank and an Madinat Yanbu' al-Sinaiyah are important for threatened species.

### 3-4. Seabirds

NEWTON et al. (1987) recommends a more comprehensive study of seabirds in Al-Wajh Bank.

**Table 8.** Areas and species.

| No. | Area name | Start | | End | | Number of species |
|---|---|---|---|---|---|---|
| | | Latitude (N) | Longitude (E) | Latitude (N) | Longitude (E) | |
| a | Maqna to Zubaydah | 28° 22′ 18″ | 34° 43′ 44″ | 26° 54′ 14″ | 36° 02′ 05″ | 47 |
| b | Sharm 'Antar to Wadi Marakh | 26° 36′ 01″ | 36° 15′ 26″ | 25° 16′ 27″ | 37° 08′ 56″ | 43 |
| c | Wadi Marakh to Sharm Hisay | 25° 16′ 27″ | 37° 08′ 56″ | 24° 37′ 40″ | 37° 20′ 00″ | 50 |
| d | Ra's al-Mukharraf to Masturah | 24° 16′ 27″ | 37° 31′ 31″ | 23° 04′ 07″ | 38° 48′ 44″ | 35 |
| e | Rabigh to Tuwal | 22° 46′ 22″ | 38° 58′ 41″ | 22° 17′ 24″ | 39° 05′ 44″ | 32 |

**Table 9.** Sites and species.

| Site number | Site name | Latitude (N) | Longitude (E) | Number of species |
|---|---|---|---|---|
| 1 | Al-Durah | 29° 20′ 26″ | 34° 57′ 07″ | 19 |
| 2 | Maqna | 28° 22′ 18″ | 34° 43′ 44″ | 3 |
| 3 | Ash Shaykh Humayd | 28° 06′ 00″ | 34° 35′ 41″ | 7 |
| *4 | Sharma | 28° 02′ 37″ | 35° 13′ 46″ | 24 |
| 5 | Ash Sharma | 28° 01′ 27″ | 35° 12′ 09″ | 9 |
| 6 | Sharm al-Badu | 27° 35′ 24″ | 35° 32′ 22″ | 10 |
| 7 | Rawd az-Ziyan | 27° 25′ 49″ | 35° 36′ 09″ | 18 |
| *8 | Al-Quff | 27° 08′ 11″ | 35° 47′ 39″ | 30 |
| 9 | Jazirat an Numan | 27° 07′ 58″ | 35° 45′ 09″ | 11 |
| *10 | Zubaydah | 26° 54′ 14″ | 36° 02′ 05″ | 35 |
| *11 | Sharm 'Antar | 26° 36′ 01″ | 36° 15′ 26″ | 38 |
| 12 | Sharm Haramil | 26° 22′ 27″ | 36° 22′ 21″ | 7 |
| 13 | Habban | 26° 03′ 40″ | 36° 35′ 43″ | 5 |
| 14 | Wadi al-Hamd | 25° 57′ 33″ | 36° 43′ 31″ | 5 |
| 15 | Al-Muraysi | 25° 50′ 26″ | 36° 41′ 06″ | 5 |
| 16 | Duqm Sabq | 25° 36′ 11″ | 36° 57′ 53″ | 16 |
| 20 | Jazirat Shaybarah | 25° 24′ 52″ | 36° 53′ 25″ | 8 |
| *21 | Duqum | 25° 07′ 18″ | 37° 15′ 46″ | 34 |
| 22 | Jazirat Jabal Hassan | 24° 57′ 11″ | 37° 06′ 04″ | 10 |
| 23 | Ash Shabaan | 24° 47′ 38″ | 37° 10′ 29″ | 11 |
| 24 | Marsa al-Khawr | 24° 17′ 20″ | 37° 38′ 06″ | 9 |
| 25 | Yanbu' | 23° 55′ 38″ | 38° 17′ 43″ | 15 |
| *26 | Masturah | 23° 04′ 07″ | 38° 48′ 44″ | 45 |
| *27 | Rabigh | 22° 46′ 22″ | 38° 58′ 41″ | 14 |

Note: Site numbers with asterisks indicate that the sites were surveyed in both seasons.

Site 17 (Duqum Sabq – 2), 18 (Jazirat Qumma'an) and 19 Qara'ir) were surveyed in Phase III.