marine & coastal environment

of Abu Dhabi Emirate, United Arab Emirates

هيئة البيئة - أبوظبي
Environment Agency - ABU DHABI

مبادرة ابوظبي العالمية للبيانات البيئية
Abu Dhabi Global Environmental Data Initiative

marine & coastal environment

of Abu Dhabi Emirate, United Arab Emirates

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Crown Prince of Abu Dhabi,
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Hamdan bin Zayed Al Nahyan

Deputy Prime Minister

- البيانات
- الأدوات والأساليب
- التوعية
- بناء القدرات
- السياسة

الأوراق القطاعية

خلال السنوات الماضية قامت مختلف القطاعات المعنية بشؤون البيئة بتجميع كم من المعلومات المتنوعة بعدة صور تصف ما هو معروف عن البيئة في إمارة أبوظبي ودولة الإمارات العربية المتحدة والخليج العربي. خلال المرحلة الأولى لمبادرة أبوظبي العالمية للبيانات البيئية، تم تنظيم سلسلة من ورش العمل في عام ٢٠٠٥ لجمع المعنيين من هذه المنظمات ، لتحديد القطاعات ذات الصلة، ووضع إطار العمل لكل ورقة قطاعية، ومعالجة الاحتياجات الاجتماعية والاقتصادية والبيئية الرئيسية في إطار كل القضايا المتعلقة في القطاع . من خلال هذا الورش، تم إعداد ثماني ورقات لقطاعية ونشرها:

- التلوث وإدارة النفايات
- القوانين والسياسات البيئية
- الموارد المائية
- الجغرافيا الطبيعية لإمارة أبوظبي
- البيئة البحرية والساحلية
- التراث التاريخي والأثري والثقافي
- التطور الاقتصادي والسكاني
- التعليم والتوعية البيئية

وتم إعداد قطاع إضافي كجزء من البرنامج الأصلي، ومع ذلك، وسيتم نشرها للمرة الأولى كجزء من المرحلة الثانية:

- البيئات البرية وموارد الأرض

و لأن الأوراق القطاعية هي مجموعة من أفضل المعارف المتاحة المتعلقة بالقطاعات البيئية والاجتماعية-الاقتصادية الرئيسية وتمثل أساس كافة المخرجات التي سيتم إصدارها لاحقا كجزء من المرحلة الثانية للمبادرة، تم مراجعة الأوراق القطاعية الأصلية. وتم خلال ورشة العمل الدولية التي عقدت في عام ٢٠٠٧ تحديد ما يلي:

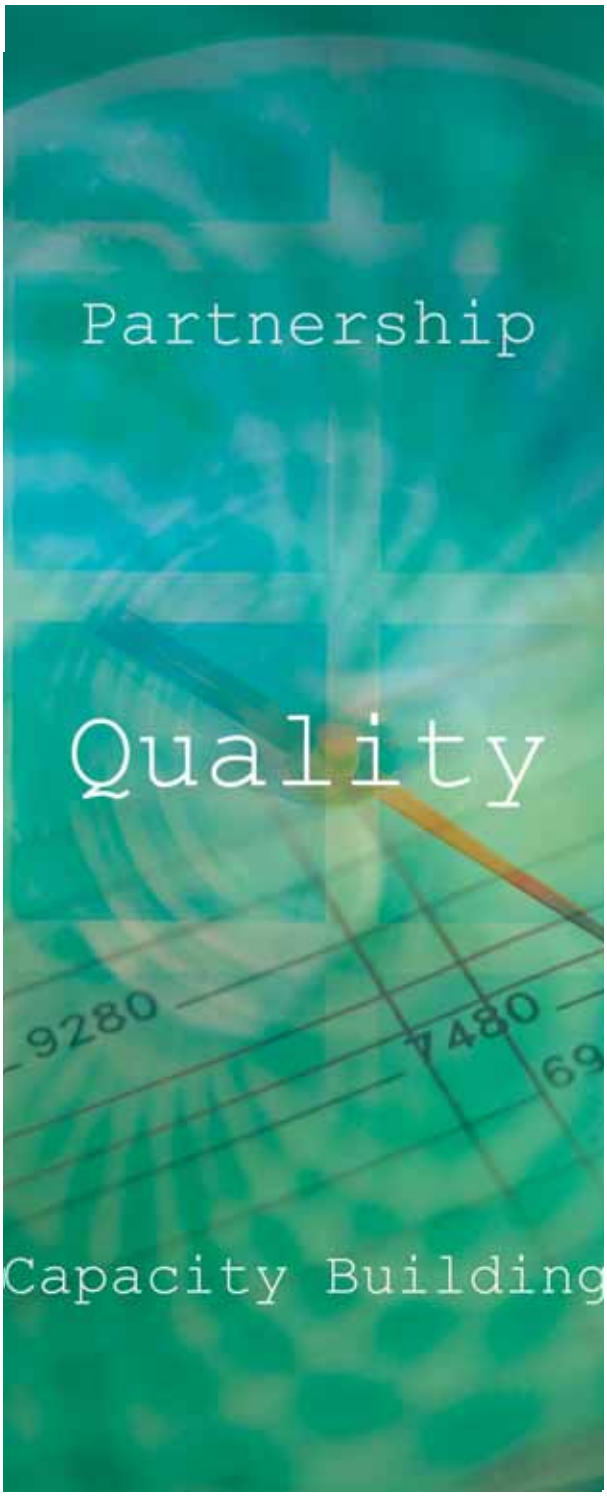
- بشكل عام، تم إعداد الأوراق القطاعية الأصلية بشكل جديد قدم فيها مجموعة قيمة من المعلومات
- لم تصل مشاركة الشركاء والجهات المعنيين إلى الحد المخطط له
- تم أعداد الأوراق القطاعية بدون دعم كافي من الهيئة أو الشركاء والجهات المعنيين، وبالتالي، كان على مؤلف الورقة القطاعية تحمل عبء إعداد ورقة هذا القطاع في وقت زمني محدود نوعا ما
- في بعض الحالات كانت البيانات المستخدمة قديمة نسبيا
- لم يتم إضفاء الطابع المؤسسي على عملية جمع البيانات وتبادلها

تهدف مراجعة المبادرة في إطار المرحلة الثانية إلى معالجة هذه الثغرات، فضلا عن غيرها من الثغرات التي تم تحديدها كجزء من الأوراق الأصلية. ولأن تنفيذ مهمة فرق العمل تم كجزء من المرحلة الثانية من البرنامج، فقد تم تقديم الدعم على جميع المستويات لمساعدة موظفي هيئة البيئة – أبوظبي والشركاء والجهات المعنية على معالجة وتحديد الثغرات، وجمع البيانات وإجراء التحليلات وتطوير مخرجات البيانات المكانية، وبناء العلاقات مع الشركاء والجهات المعنيين، وفي نهاية المطاف ، إعداد الورقة القطاعية وتنقيحها.

وتشكل الأوراق القطاعية مصدرا قيما للمعلومات البيئية والاجتماعية والاقتصادية لأبوظبي وتم استخدمها لمراجعة وتنقيح تقرير حالة البيئة لإمارة أبوظبي فضلا عن إعداد الأطلس البيئي لأبوظبي (النسختين المطبوعة والتفاعلية).

ولمزيد من المعلومات حول المبادرة أو للوصول لنسخة الكترونية من الأوراق القطاعية، يرجى زيارة الموقع الإلكتروني في www.agedi.ae.

ما هي مبادرة أبوظبي العالمية للبيانات البيئية ؟



تم إطلاق مبادرة أبوظبي العالمية للبيانات البيئية في الثاني من سبتمبر ٢٠٠٢ خلال مؤتمر القمة العالمي للتنمية المستدامة الذي عقد في مدينة جوهانسبرغ بجنوب إفريقيا من قِبل دولة الإمارات العربية المتحدة، كمبادرة شراكة من الصنف الثاني، لتكون أداة مبتكرة لتنفيذ الأحكام المتعلقة بالبيئة والواردة في الفصل ٤٠ من جدول أعمال القرن ٢١ وفي الأهداف الإنمائية للألفية.

وفي أوائل عام ٢٠٠٧ ، نظمت بأبوظبي ورشة عمل دولية لاستعراض الانجازات التي حققها برنامج المبادرة ووضع خطة إستراتيجية لمدة خمس سنوات. وعلى هذا النحو، بدأت المرحلة الثانية من المبادرة في عام ٢٠٠٨ بناءا على ما تم انجازه في المرحلة الأولى، في حين تم معالجة الفجوات التي تم تحديها من خلال المعلومات التي وفرتها الجهات المعنية خلال ورشة العمل.

ولا تزال الرؤيا التي تعمل وفقها المبادرة في المرحلة الثانية هي "وضع وتنفيذ نماذج عملية يمكن تكرارها وتكييفها من أجل إنشاء هيكل أساسي للبيانات البيئية المكانية عالية الجودة، للمساهمة في توفير القاعدة العلمية لاتخاذ القرارات". وسيتم في المرحلة الثانية استخدم الدروس المستفادة لتحقيق نجاح أفضل في تنفيذ المبادرة في مرحلته الثانية.

وسيركز البرنامج الحالي على وضع سلسلة من المخرجات التي تتناول قضايا محددة في حين يتم تحقيق نتائج مؤسسية معينة، بما في ذلك:

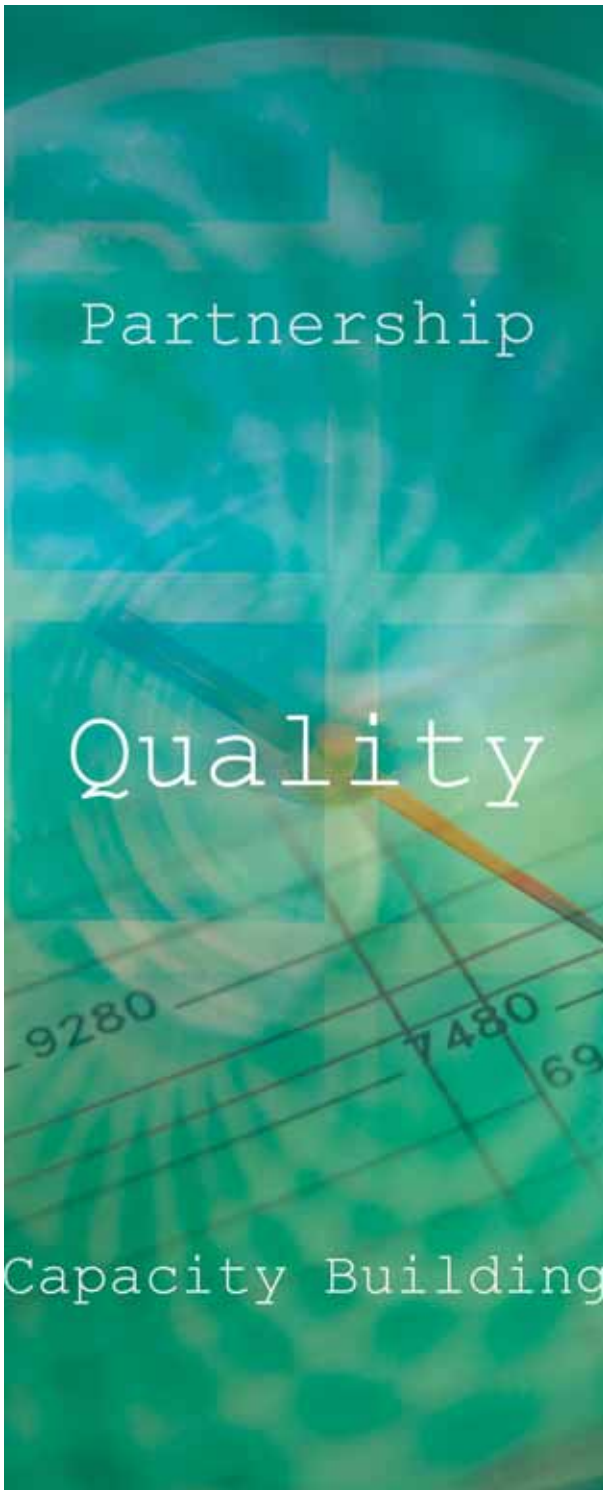
١. توفير بيانات بيئية أكثر جودة
٢. تحديد الثغرات في البيانات والأولويات
٣. تنسيق أقوي وشراكات لتبادل البيانات
٤. أساليب وأدوات أفضل للمعلومات
٥. ربط الإستراتيجية والتشغيل بشكل أفضل
٦. تحسين البنية التحتية البشرية والتقنية
٧. مؤسسة أقوي بشكل عام

والمخرجات التي تم تحديدها في إطار عملية التنمية هي أمور مترابطة ومتعاقبة مع المخرجات الأولية لدعم المعلومات والتفاهمات التي تصب في الأنشطة اللاحقة. وهي تشمل ما يلي :

- مراجعة الأوراق القطاعية وقاعدة المعرفة
- مراجعة وتنقيح تقرير حالة البيئة
- الأطلس البيئي التفاعلي
- تعزيز بوابة البيانات المكانية
- تحسين الموقع الالكتروني
- مؤشر الأداء الحكومي لابوظبي
- برامج وضع الإستراتيجية

ولضمان تحقيق نتائج ايجابية وتوفير الموارد التقنية الكافية للقيام بتطوير المخرجات، تم إنشاء مجموعة من فرق العمل بهدف تجميع الموارد لدعم فرق كل مخرج من المخرجات المبادرة. وتشمل هذه ما يلي :

What is AGEDI ?



The Abu Dhabi Global Environmental Data Initiative (AGEDI) program was fashioned around the United Nations World Summit for Sustainable Development (WSSD) Type II Partnership in 2002 as a tool to support the environmental provisions of Chapter 40 of Agenda 21 and the Millennium Development Goals.

In early 2007, an international workshop was conducted in Abu Dhabi to review the accomplishments of the AGEDI program and develop the next five year strategic plan. As such, AGEDI Phase II began in 2008 building off the accomplishments of the initial phase, while addressing gaps identified through stakeholder input during the workshop.

The vision of AGEDI Phase II remains to be a "replicable, networked, adaptive and working model for the development and use of high quality spatial environmental data by all users within the Emirate of Abu Dhabi that will support sustainable decision and policy making." Phase II will use lessons learned to better guide the successful implementation of AGEDI in its second phase.

The focus of the current program is to develop a series of interrelated products that address specific issues while achieving certain institutional outcomes, including:

1. Better current and quality environmental data
2. Identification of data gaps and priorities
3. Stronger coordination and data sharing partnerships
4. Better information methods and tools
5. Better links between strategy and operation
6. Improved human and technical infrastructure
7. Stronger organization overall

The specific products under development are interdependent and sequential, with early products yielding information and understandings that feed into subsequent activities. These include the following:

- Sector Paper Review and Knowledgebase
- SoE Review and Refinement
- Environmental Atlas
- Interactive Environmental Atlas
- Geospatial Portal Enhancement
- Website Refinement
- EPI for Abu Dhabi
- Programs Alignment Strategy

To ensure positive outcomes and adequate technical resources for carrying out the product development, a series of task forces were established as pooled resources to support each product team. These include:

- Data
- Tools and Methods
- Outreach
- Capacity Building
- Policy

Sector Papers

Over the years, different organizations compiled a variety of information in many forms that describe what is known about Abu Dhabi, the UAE and the Arabian Gulf Region. Through the initial AGEDI phase, a series of workshops were developed in 2005 to bring together stakeholders from all these organizations, identify the sectors that were relevant, design a framework for each Sector Paper, and address the key environmental and socioeconomic issues relevant under each sector. Through this effort, eight Sector Papers were completed and published:

- Waste Management and Pollution
- Environmental Policy and Regulation
- Water Resources
- Physical Geography
- Marine and Coastal Environment
- Paleontological and Archaeological Resources
- Population, Development and Economy
- Environmental Education and Awareness

One additional sector was scoped as part of the original program, however, will be published for its first time as part of AGEDI Phase II:

- Terrestrial Environment

Because the Sector Papers are a collection of the best available knowledge pertaining to key environmental and socioeconomic sectors and serve as the basis for all subsequent products to be developed as part of AGEDI Phase II, a review of the original Sector Papers was conducted. Already known through the international workshop held in 2007 was:

- Overall, the original papers were done well and provided a wealth of information
- Stakeholder participation did not reach the level originally intended
- Sector Papers were developed without much agency or stakeholder support, and therefore, became the burden of the Sector Paper authors under a fairly limited timeframe
- Data used was outdated in some cases
- Data collection and sharing did not get institutionalized

The review under AGEDI Phase II sought to address these gaps, as well as the other gaps already identified as part of the original papers. Because the Task Forces were implemented as part of the Phase II program, support was provided at all levels to assist EAD staff and stakeholders in addressing and identifying gaps, collecting data, conducting analyses and developing spatial products, building stakeholder relationships, and ultimately, developing a refined Sector Paper.

The Sector Papers are a source of valuable environmental and socioeconomic information for Abu Dhabi and were used to review and refine the State of the Environment (SoE) report for Abu Dhabi as well as develop the Abu Dhabi Environmental Atlas (both hard-copy and interactive versions).

For more information and online versions

For more information about AGEDI or to access online versions of the Sector Papers, please visit the AGEDI website at www.agedi.ae

الفهم الصريح للموارد الطبيعية والأنشطة البشرية والتأثيرات الضارة. ونظراً لتنوع ومدى المعلومات المطلوبة لتحقيق الاستخدام المستدام المشترك وأهداف الحماية فانه من الواجب والملح أن تسود ثقافة مشاركة البيانات بين المعنيين.

وفي هذا السياق، توفر الورقة الخاصة بالبيئة الساحلية والبحرية معرفة متكاملة بالبيئة البحرية والساحلية لإمارة أبو ظبي ويشمل ذلك وصفاً لمجموعة الأحياء والمواطن والأنشطة الاقتصادية ومسائل الإدارة الرئيسية. ويتضمن التقرير أيضا تفاصيل الهيكل المؤسسي والسياسة واللوائح والمبادرات الحالية للحماية والإدارة . وتلقي الورقة أيضاً الضوء على الفجوات الموجودة في المعلومات الفنية لكي تساعد في توجيه البحوث المستقبلية.ويشكل العمل جزءً من مجموعة الأوراق القطاعية التي تكون النسخة الثانية من تقرير حالة البيئة في إمارة أبو ظبي الذي يشكل جزءً من أنشطة المرحلة الثانية من مبادرة أبوظبي العالمية للبيانات البيئية(AGEDI).

ويشير ذلك الاستعراض إلى وجود مجموعة من المعلومات الفنية والعلمية الأساسية حول الأحياء البحرية في بيئة أبو ظبي البحرية والساحلية وهناك معرفة جيدة بالأنشطة الاقتصادية وتأثيراتها وموضوعات الإدارة الحاسمة المرتبطة بها. وتمثلت استجابة السياسات لذلك في وضع مدى واسع من مبادرات الإدارة والحماية التي تضمنت إنشاء المؤسسات المُفوضة وسن وتطبيق القوانين والتشريعات الإدارية ووضع خطط الإجراءات الإستراتيجية والبحوث والمراقبة وتحديد وإعلان المناطق المحمية وتشجيع التعليم والتوعية البيئية. وإضافة إلى ذلك كانت عملية اتخاذ القرارات الإدارية كثيراً ما تتم على نحو استباقي وفي الوقت المناسب. ومن الوهلة الأولى ، وبوجود الإرادة السياسية والأمن الاقتصادي والسُلطات والقدرات المؤسسية والإطار القانوني فان مستقبل البيئة البحرية والساحلية في إمارة أبو ظبي يبدو ايجابياً.

ومن ناحية أخرى، ترتبط الوتيرة السريعة للتنمية في دولة الإمارات العربية المتحدة بقائمة متنامية من مسائل الإدارة الحاسمة ذات الصلة بالاستغلال المستدام للموارد الطبيعية. ولقد أدت الأنشطة والاستخدامات المتلاحقة والمتعددة غير المُتحكم فيها في البيئة البحرية والساحلية إلى التدهور البيئي وفي أحوال كثيرة مع عواقب اقتصادية واجتماعية. وإذا ما كان للبيئة البحرية والساحلية في إمارة أبو ظبي أن تحافظ على إنتاجيتها ووظائفها الطبيعية، يجب إحداث تحسينات رئيسية في مجال تخطيط وإدارة التنمية الساحلية واستغلال الموارد. وفي هذا الخصوص تم اقتراح أسلوب لتقدم البيئة البحرية والساحلية في أبو ظبي مع تركيز خاص على النواحي السياسية ذات الصلة مثل: الإطار المؤسسي والتشريعات والتخطيط والبحوث والتقييم والتعاون والاتصال في سياق تطبيق إدارة متكاملة للمنطقة الساحلية(ICZM).

الورقة الخاصة بقطاع البيئة البحرية والساحلية

(ملخص تنفيذي)

تمتع دولة الإمارات العربية المتحدة ببحار إقليمية تقدر مساحتها بـ ٣٧٠٠٠ كيلو متر مربع وسواحل يبلغ طولها ٢٣٩٠ كيلو متر تمتد على طول البر الرئيسي والجزر في الجزء الجنوبي من بحر العرب، قد اوجد مواطن متنوعة في البيئة البحرية والساحلية في إمارة أبو ظبي. وتضم هذه المواطن الكثبان الرملية والشواطئ والجزر والشعاب المرجانية والأعشاب البحرية وغابات أشجار القرم والمسارب المَدية. وبالإضافة إلى قيمتها ودورها الجوهري في الحفاظ على التنوع البيولوجي فإنها توفر فوائد وخدمات للمجتمع من خلال الإنتاجية البيولوجية إلى جانب استخداماتها في النواحي الترفيهية والحماية التي توفرها ضد التعرية الساحلية. وعلاوة على ذلك تشكل البيئة البحرية والساحلية أساساً للتراث الطبيعي والثقافي للمجتمع المحلي.

وقبل تطور قطاعي النفط والغاز الطبيعي كان قطاع صيد اللؤلؤ الركيزة الأساسية للاقتصاد القومي إلى جانب الموارد الساحلية والبحرية الحية الأخرى التي كانت توفر المصدر الرئيسي للغذاء بالنسبة للسكان المحليين.أما اليوم ، فلقد أصبحت البيئة البحرية والساحلية تشكل بؤرة تركيز بالنسبة للأنشطة الصناعية والتجارية والثقافية والترفيهية العديدة والمتنوعة. ولقد أدى التطور الاقتصادي السريع إلى التحضر والتوسع في البنية التحتية اللذان يتقدمان بوتيرة سريعة بالترابط مع زيادة دراماتيكية في السكان. وتتواجد الصناعات الثقيلة على الساحل للاستفادة من مياه البحر في أغراض التحلية أو التبريد. وتعتبر أعمال الردم والحفر من الأنشطة الشائعة كما تفضل السهول المنبسطة الواقعة بين أقصى المد وأقصى الجزر والخلجان كمواقع لأعمال التشييد. وبالإضافة إلى ذلك فقد أدى زيادة الثراء في المجتمع إلى دعم وتعزيز الرغبة في استخدام المناطق الساحلية والبحرية للاستخدامات الترفيهية والسكنية.

ولقد أفضى التصاعد في مدى تنوع الأنشطة في المنطقة الساحلية إلى عدد من العواقب التي تتطلب الإدارة الحاسمة بما في ذلك نفاد الموارد وتضارب الاستخدامات وفقدان المواطن والتلوث والتدهور البيئي. وبسبب الطبيعة متعددة الأوجه لاستخدامات الموارد وترابط مجموعة الأحياء والتفاعل المستمر في المنطقة الساحلية فانه من المتعارف عليه بدرجة واسعة إن أهداف الإدارة يمكن تحقيقها فقط في حالة تطبيق أسلوب كامل ومتكامل في عمليات التقييم والتخطيط واتخاذ القرار. وفضلاً عن ذلك فان وضع الاستراتيجيات للتخفيف من ذلك يتطلب

MARINE AND COASTAL ENVIRONMENT SECTOR PAPER

EXECUTIVE SUMMARY

With some 37,000 square kilometres of the territorial seas of the United Arab Emirates and 2,390 kilometres of coastline along the mainland and islands of the southern Arabian Gulf, a variety of habitats occur in the marine and coastal environment of Abu Dhabi. These include sand dunes, beaches, islands, coral reefs, seagrass beds, mangrove stands and tidal inlets. In addition to their intrinsic value and role in maintaining biodiversity, they provide goods and services to society through biological productivity, recreational use and protection against coastal erosion. Furthermore, the marine and coastal environment forms the basis of the natural and cultural heritage of the indigenous population.

Prior to the development of the oil and natural gas sectors, the pearling industry was the mainstay of the economy with other coastal and living marine resources providing the principal food source to local communities. Today, the coastal and marine environment has become the focus of a wide variety of industrial, commercial, cultural and recreational activities. Rapid economic development has resulted in urbanization and infrastructural expansion proceeding at a fast pace in association with a dramatic increase in the human population. Most heavy industries are located on the coast to make use of seawater for desalination or cooling purposes. Landfill and dredging are common, with shallow intertidal flats and embayments being favoured for construction. In addition, the demand for recreational and residential uses of coastal and marine areas has been fuelled by an increasingly affluent society.

An escalation in the extent and variety of activities in the coastal zone has led to a host of critical management issues including resource depletion, conflicting uses, habitat loss, pollution and environmental degradation. Because of the multifaceted nature of resource use, connectivity of the biota and dynamic interactions in the coastal zone, it is widely recognized that management objectives can only be achieved if the assessment, planning and decision making processes adopt a holistic and integrated approach. Moreover, an intimate understanding of the natural resources, anthropogenic activities and deleterious impacts is required if mitigating strategies are to be developed. Due to the diversity and scope of information needed to achieve common sustainable use and conservation goals, a culture of data sharing among stakeholders is imperative.

In this context, the Marine and Coastal Environment Sector Paper provides a synthesis of the knowledge on the marine and coastal environment of the Emirate of Abu Dhabi. Descriptions of the biota, habitats, economic activities and key management issues are provided. The report also details the institutional structure, policy, regulation, legislation and existing conservation and management initiatives that collectively represent the system of governance. At the same time as indicating what is known, the paper also highlights the technical information gaps that exist so as to provide a guide for future research. The work forms part of a suite of updated sector papers that are intended to contribute to the second edition of the State of the Environment Report as part of the second phase of the Abu Dhabi Global Environmental Data Initiative (AGEDI).

The review indicates that there is a substantive body of technical and scientific information on the biota of the marine and coastal environment of Abu Dhabi. Economic activities, their impacts and associated critical management issues are well recognized. The system of governance has responded with the development of a broad range of management and conservation initiatives including; the establishment of mandated institutions, enactment and enforcement of legislation and management regulations, development of strategic action plans, research and monitoring, designation of protected areas and the promotion of environmental awareness and education. Furthermore, the management decision making process has often been proactive and timely. Given the political will, economic security, institutional capacity and legal framework, the outlook for the marine and coastal environment of Abu Dhabi would initially appear to be positive.

However, the rapid pace of development in the Emirate is matched by a burgeoning list of critical management issues that relate to the sustainable utilization of natural resources. The uncontrolled pursuit of multiple activities and uses in the marine and coastal environment has lead to environmental degradation, often with social and economic consequences. If the marine and coastal environment in Abu Dhabi is to maintain its productivity and natural functions, it is recognised there must be major improvements in the planning and management of coastal development and resource utilization. In this regard, a way forward for the marine and coastal marine environment of Abu Dhabi is proposed with particular emphasis on governance related aspects such as the institutional framework, legislation and planning, research and assessment, collaboration and communication in the context of adopting an Integrated Coastal Zone Management (ICZM) process.

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1 INTRODUCTION

With some 37,000 square kilometres of the territorial seas of the United Arab Emirates and 2,390 kilometres of coastline along the mainland and islands of the southern Arabian Gulf (**Figure 1**), a variety of habitats occur in the marine and coastal environment of Abu Dhabi. These include sand dunes, beaches, islands, coral reefs, seagrass beds, mangrove stands and tidal inlets. In addition to their intrinsic value and role in maintaining biodiversity, they provide goods and services to society through biological productivity, recreational use and protection against coastal erosion. Furthermore, the marine and coastal environment forms the basis of the natural and cultural heritage of the indigenous population.

Prior to the development of the oil and natural gas sectors, the pearling industry was the mainstay of the economy with other coastal and living marine resources providing the principal food source to local communities. Today, the coastal and marine environment has become the focus of a wide variety of industrial, commercial, cultural and recreational activities. Rapid economic development has resulted in urbanization and infrastructural expansion proceeding at a fast pace in association with a dramatic increase in the human population. Most heavy industries are located on the coast to make use of seawater for desalination or cooling purposes. Landfill and dredging are common, with shallow intertidal flats and embayments being favoured for construction. In addition, the demand for recreational and residential uses of coastal and marine areas has been fuelled by an increasingly affluent society.

An escalation in the extent and variety of activities in the coastal zone has led to a host of critical management issues including resource depletion, conflicting uses, habitat loss, pollution and environmental degradation. Because of the multifaceted nature of resource use, connectivity of the biota and dynamic interactions in the coastal zone, it is widely recognized that management objectives can only be achieved if the assessment, planning and decision making processes adopt a holistic and integrated approach. Moreover, an intimate understanding of the natural resources, anthropogenic activities and deleterious impacts is required if mitigating strategies are to be developed. Due to the diversity and scope of information needed to achieve common sustainable use and conservation goals, a culture of data sharing among stakeholders is imperative.

In this context, the sector paper presented here provides a synthesis of the knowledge on the marine and coastal environment of Abu Dhabi. Descriptions of the biota, habitats, economic activities and key management issues are provided. The report also details the institutional structure, policy, regulation, legislation and existing conservation and management initiatives that collectively represent the system of governance. At the same time as indicating what is known, the paper highlights the technical information gaps that exist so as to provide a guide for future research. In order to maintain a manageable size, reference is made to detailed studies for specific subjects and products such as maps available through various sources including the grey literature and unpublished databases. The work forms part of a suite of sector papers that are intended to contribute to the State of the Environment Report as part of the Phase II activities of the Abu Dhabi Global Environmental Data Initiative (**AGEDI**).

Figure 1: Location of Abu Dhabi Emirate

2 CLIMATE AND OCEANOGRAPHY

Abu Dhabi has an arid climate. Rainfall is infrequent and irregular with less than 100 mm per year falling mainly in the winter from November to March. Temperatures range from a low of around 10°C to highs of up to 48°C in the summer. Cold northerly winds (Shamal) during the winter and spring months may reach gale force strengths, generating high seas in the southern Arabian Gulf. The physical geography sector paper provides a more detailed account of the climatic conditions of Abu Dhabi. The Ministry of Communications, now the National Centre for Meteorology and Seismology, has administered the collection, quality control, storage, processing and archival of all meteorological data recorded in the UAE through a data bank established in 1993. The spatially explicit data is obtained through various sources including the UAE Air Force, Ministry of Environment and Water, Ministry of Oil and Mineral Resources, and Airports and Sea Ports. The role of the service is to provide climatic data to planners, research workers and others. The information is published in technical reports (*e.g.* Ministry of Communications, 1996) and monthly bulletins.

The waters off the coast of Abu Dhabi exhibit marked seasonal variability in physical, chemical and biological oceanographic characteristics. Sea water temperatures exceed 34°C in summer and may reach a minimum of 16°C during the winter. Salinity levels are high at 50 ppt over hundreds of km^2 and may attain 70 ppt in shallow areas during the summer months (Sheppard *et. al.,* 2000). These extremes characterise the region and restrict the diversity and abundance of marine life and in particular constrain the development of coral reefs (Subba Rao & Yamani, 2000). In embayments, such as that in the west of Abu Dhabi, high evaporation rates create salinity gradients that drive water circulation. Dense water flows out of the Gulf below the less saline water flowing in through the Strait of Hormuz. A comprehensive survey of the oceanography of the waters off Abu Dhabi revealed that the water column was well mixed during the winter (Shallard & Associates, 2003a). The predominant current flows eastwards from the Qatar peninsula (Sheppard & Wells, 1988) and the flushing time of the Gulf is estimated to be between 3 and 3.5 years (Sheppard *et. al.,* 1992).

In addition to the chemical and physical attributes, there is a well defined seasonal cycle in biological oceanographic characteristics. As an index of primary productivity, the concentration of chlorophyll-a reaches a maximum in December and declines from March onwards. Similarly, zooplankton abundance is low during the summer months and increases as waters cool in the autumn (**Figure 2**). The abundance and distribution of fisheries resources, in

particular the small pelagic species and their prey (e.g. the kingfish known locally as 'Chanaad'), have been shown to be closely associated with the seasonal change in temperature and secondary productivity (**Figure 2**) (Shallard & Associates, 2003a).

Comprehensive oceanographic data sets collected through the 'Fish Resources Assessment Survey' in 2002 and 2003 are located on the Environmental Database of the Environment Agency - Abu Dhabi. Additional oceanographic data has been collected routinely by the Biodiversity Management – Marine Sector through its phytoplankton and water quality surveys. Detailed accounts of the oceanographic conditions in the waters off Abu Dhabi can be found in Sheppard *et. al.* (1992) and more recently the work of Shallard and Associates (2003a).

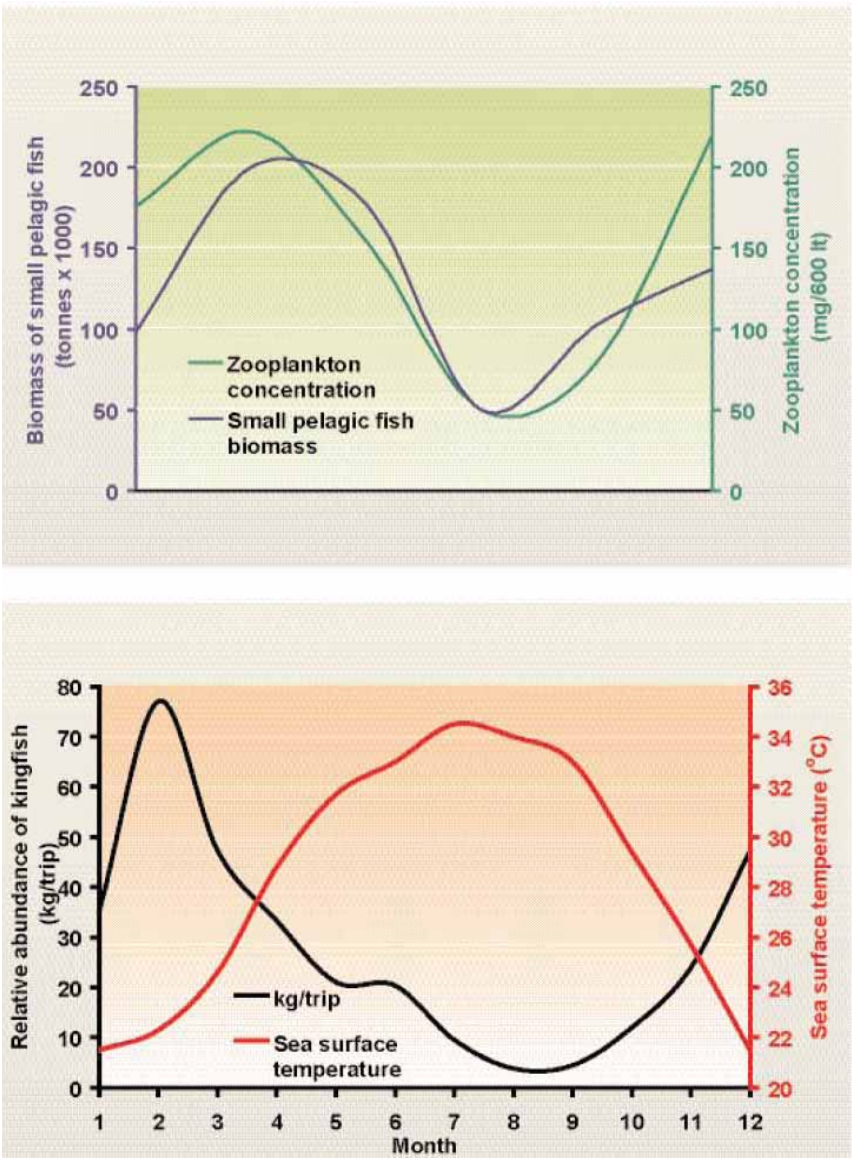


Figure 2: The waters off the Emirate of Abu Dhabi have strong seasonal variations in secondary (zoo plankton) and tertiary (small pelagic species) production (top graph). The abundance of some of the most important fisheries resources such as kingfish are associated.

3 MARINE AND COASTAL HABITATS

3.1 Seagrass beds

Seagrass beds are the most productive coastal ecosystems and cover large areas of shallow water habitats (<10 m water depth) throughout Abu Dhabi Emirate. There are more than 50 species of seagrasses in the world's oceans and three species occur in the Arabian Gulf: *Halodule uninervis* (Forsk.) Aschers, *Halophila ovalis* (R.Br.) Hook, and *Halophila stipulacea* (Forsk.) Aschers. A fourth species, *Syringodium isoetifolium* (Aschers.) was also reported once from Bahrain (collected by R. Good from Jufaer on a coral reef, March 2, 1950), but this species has not been recorded at any other locations since then. It is thus excluded from further discussion here.

Halodule uninervis is the most abundant species of seagrass observed in the waters off Abu Dhabi. There is vast coverage of this species inshore around most, if not all, islands from Abu Dhabi Island northeast to Ra's Hanjurah. Data analysed by the Environmental Agency - Abu Dhabi and Emirates Heritage Club research staff estimated that there were around 5,500 ha. of seagrass in this general area. It should also be noted that seagrass was found to be much more abundant in eastern Abu Dhabi, and that the highest densities occurred north of Abu Dhabi Island around Al Sammaliah Island. Both density and species diversity generally decreased to the west, especially inshore. To the west of Jebel Dannah through to Ra's as Sila, there was no seagrass recorded, despite extensive surveys at depths ranging from 4 to 10m. In the far west however, around Dawhat Al Khuwaysat, seagrass was again abundant, dense and diverse.

There has been limited data published on the seagrasses of the Arabian Gulf (Basson *et. al.,* 1977; Carpenter *et. al.,* 1997; Coles & McCain 1990; De Clerck & Coppejans 1996; Durako *et. al.,* 1993; Kenworthy *et. al.,* 1993; McCain 1984; Price & Coles 1992; Price *et. al.,* 1987; Richmond 1996 and Sheppard *et. al.,* 1992). Recent studies undertaken by Phillips *et. al.* (2002, 2005) in Abu Dhabi Emirate have provided the most recent systematic data on species distribution, cover and density.

The Arabian Gulf is considered to be a very stressful habitat for seagrass growth (IUCN/UNEP1985), characterized by large seasonal temperature variations, fluctuating nutrient levels and high salinities. Seagrass can tolerate a wide range of salinities from 6 ppt. to 60 ppt. Particular species have specific requirements and tolerances. The three seagrass species occurring in Abu Dhabi are considered to be the most tolerant of all seagrass species to extremes of water temperature and salinity. In Abu Dhabi, seasonal Sea Surface Temperature (SST) usually ranges between 13.5°C to 36°C for areas of inshore waters, and 17°C to 34°C for offshore waters.

Greater extremes however have also been reported (Sheppard & Loughland, 2002). Surface water salinities may also rise as high as 58 ppt. along the western coast of Abu Dhabi in both summer and winter, especially in the inshore shallow waters (Price & Coles, 1992; Sheppard *et. al.,* 1992; Phillips *et. al.,* 2002). These extreme western areas are, surprisingly, where dense and extensive seagrass growth occurs in Abu Dhabi (Phillips *et. al.,* 2005).

Research conducted from October-November 1999 by Phillips *et. al.,* (2002, 2005) demonstrated that seagrass immediately inshore and particularly within nearshore environments north of Al Sammaliah Island occurred in extremely high densities, with *Halodule uninervis* having an average of 21,745 leafy stalks per square metre. This was the highest density of sea-grass recorded in all of Abu Dhabi Emirate, and is the highest known density for this species anywhere in the world. The importance of the seagrass systems in Abu Dhabi therefore lies not only in direct food value to wildlife such as dugong and green turtle, but also in its value as a habitat for the growth of both commercial and non-commercial fish and invertebrates, and especially as a refuge from predators for juvenile fish.

Seagrass ecosystems are one of the most valuable marine resources in terms of their overall coastal ecology and fisheries production (Bell & Pollard, 1989; Bostrom & Mattila, 1999; Heck & Orth, 1980; Heck *et. al.,* 1989, 1995; Orth *et. al.,* 1984; Thayer *et. al.,* 1979). The Abu Dhabi seagrass meadows are an important nursery ground that provide stock for both commercial and amateur fisheries, and due to the fact that they grow in close proximity to Abu Dhabi City, are extremely valuable to the capital's residents.

Seagrass areas also create a stable habitat in the inshore and shallow offshore coastal marine and estuarine environments, resulting in significant improvements in water quality. The very high growth rate and primary production of seagrasses also leads to extremely high biodiversity (both plants and animals) within the meadows (Fonseca *et. al.* 1998). In the Arabian Gulf, Basson *et. al.* (1977) and Preen (1989) documented that seagrass beds attracted large numbers of dugongs, green turtles, shrimp, fish, and pearl oysters, and scallops. Dugongs and green turtles feed directly on the living plants, while the other species either find refuge in the seagrass foliage or are supported within the detritus food chains created by the filtering and decomposition of organic material by the seagrass system. These same ecosystems are actually major nutrient recycling pathways for both inshore and offshore habitats.

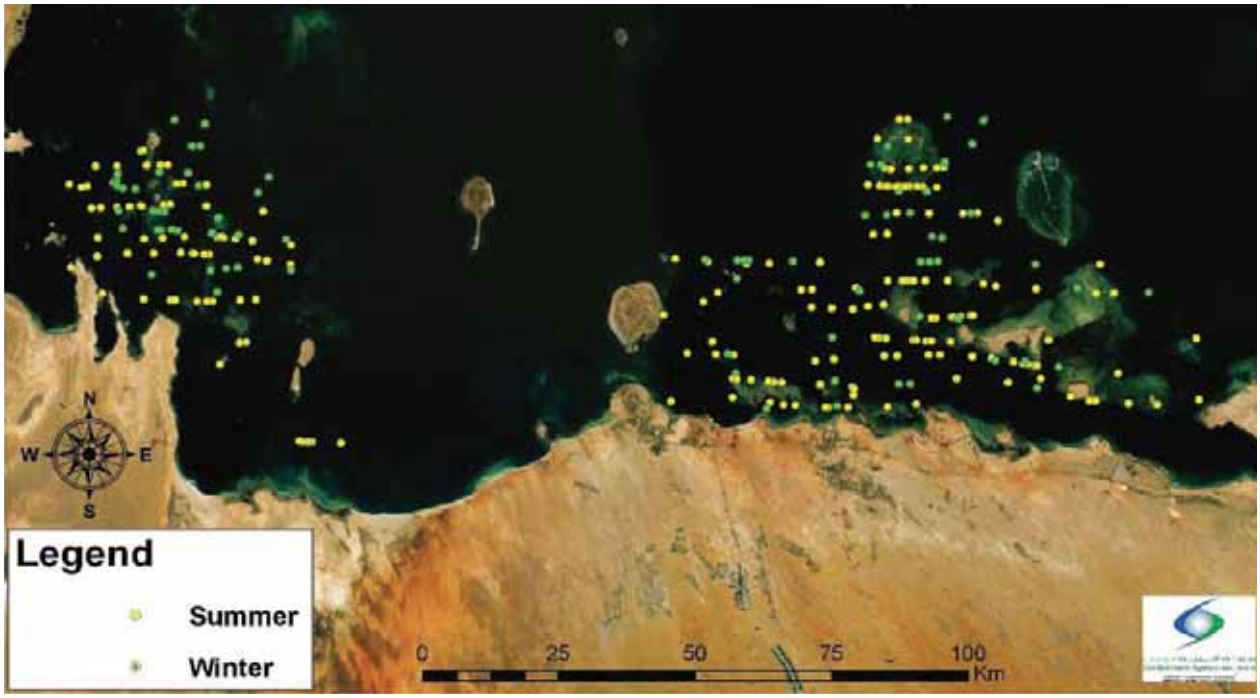


Figure 3: Seasonal seagrass distribution in the waters off the Emirate of Abu Dhabi

3.2 Algal beds

Temperature affects the distribution and abundance of algae, and there are particular seasons for growth of most algae species. For example, the macro algae are usually more abundant in the lower eulittoral zone during the winter when the seawater temperature is lower. During the winter, mixed mats of algae frequently also develop at the edge of rocky platforms where there is ongoing wave action. However, according to John and George (2004), by late May much of this mixed assemblage has completely disappeared and the rock surfaces are virtually devoid of any macro algae. Some of the biotopes on continuous rock substrata are 'forests' characterized by the large brown seaweeds and form distinctive features of the submarine seascape during periods of cooler seawater temperature (below 25 °C). These biotopes are well characterized since the brown algal genera are distinctive and readily identified, although some species of Sargassum can be difficult to recognize with certainty. The perennial biotopes characterized by algae are well-defined and sometimes cover large areas of reef (*e.g.* biotopes characterized by non-geniculate red coralline algae and red algal turf). These biotopes are common in the shallow subtidal over a depth range of about 0.5-5m.

Figure 4: Algal distribution through Emirate of Abu Dhabi coastal areas.

Marine algal biotopes in Abu Dhabi have been investigated in detail by John and George (1998, 2003, 2004), George and John (2005a) and John (2005). Because of the extreme range of water and air temperatures, some algal biotopes in the Emirate persist for only six months of the year or less, there being particular seasons for growth of many of the algal species. For example, fleshy brown macroalgae are usually more abundant in the lower eulittoral and shallow sublittoral zones during the winter and spring when the seawater temperature is lower. During these months mixed mats of algae frequently develop at the edge of rocky platforms where there is

wave action. However, according to John and George (2003, 2004), by late May much of this mixed assemblage has disappeared and the rock surfaces are virtually devoid of any macroalgae. According to John and George (2003, 2004), many low mat or turf forming algae, coralline red algae, and fine filamentous algae persist during the warmer months and three red macroalgae manage to survive on the lower shore for much of the year, although they still tend to be highly vulnerable to bleaching during the peak of the summer. One of the green algae present on rock platforms during the warmer summer months is *Cladophoropsis javanica*, which sometimes forms dense spongy growths in the lower eulittoral and shallow sub-littoral zone. According to John and George (2004), on some rock platforms this alga may cover hundreds of square metres.

Figure 5: Selected corals species of Abu Dhabi *Acropora sp.* (left) and *Platygyra sp.* (right) (Source: Emirates Heritage Club)

3.3 Coral reefs

Coral reefs are Abu Dhabi's most diverse marine ecosystem. The variety of life and the complex interactions of reef organisms are of major fisheries, scientific and tourism value to the Emirate. The reefs formed by corals provide important three-dimensional habitats for numerous phyla of invertebrates (*e.g.* Porifera, Cnidaria, Annelida, Crustacea, Mollusca, Bryozoa, Echinodermata: see **Section 4.3** on Marine Fauna) and many commercially important species of fish. The reefs also act as breakwaters that help to protect coastal areas from erosion and inundation.

Sea levels in the Arabian Gulf have been near present levels for about 2000 years (Lambeck, 1996), and have therefore provided corals with a stable bathymetric environment in which to develop into reefs. The coral reefs of the southern Gulf occur in an area with environment stressors such as extreme fluctuations in seawater temperature and high salinity (Kinsman, 1964; Sheppard, 1988; Sheppard & Sheppard, 1991) as well as frequent high turbidity. In the past, poor development of reefs in the southern Gulf has been attributed to high sedimentation and low winter temperatures (Shinn, 1976).

Until very recently, compared with the situation in areas further north in the Arabian Gulf (*e.g.* see Basson *et. al.,* 1977; Burchard, 1979; Downing, 1985; Coles, 1988; Sheppard, 1988; Sheppard & Sheppard, 1991; Sheppard *et. al.,* 1992; Hodgson & Carpenter, 1995; Vogt, 1996) relatively few scientific investigations had been conducted on the coral reefs that occur off Abu Dhabi's coast apart from the seminal early pioneering work of Kinsman (1964), Evans *et al* (1973), Hughes Clarke & Keij (1973), and Purser & Evans (1973). Kinsman (1964) was possibly the first to report on coastal coral reefs in Abu Dhabi Emirate, Evans *et. al.* (1973) studied the oceanography, ecology and geomorphology of parts of the barrier island complex off Abu Dhabi that included coral reefs, and Hughes Clarke & Keij (1973) investigated the carbonate-producing organisms, including reef corals, in the western region of the Emirate.

Staff of the Natural History Museum, London (NHM), previously known as the British Museum (Natural History), grant-aided by ADCO, studied in detail between 1996 and 2001 the marine biotopes of natural and artificial hard substrata in Abu Dhabi Emirate. This study included examination of the majority of the fringing and patch coral reefs along the length of Abu Dhabi Emirate out to a distance of some 50km from the mainland. They recorded the distribution and abundance of coral species as well as that of the many other organisms that contribute to and inhabit the structures they create (George & John 1998, 1999, 2004, 2005a, b; George *et. al.,* 2001; John & George, 2001, 2003). Simultaneously, Riegl (1999, 2001, 2003) was examining the few remaining coral structures in Dubai Emirate between Ras Ghantoot and Jebel Ali, and later in November 2000, Sheppard & Loughland (2002) looked at live corals present and recruiting on five reefs between Sir Bani Yas and Dubai Emirate.

George (2005a) & John (2005a), on behalf of the NHM, supplied the Biodiversity Mananagement – Marine Sector of the Environment Agency - Abu Dhabi (EAD) information (in spreadsheet form) on the distribution, and abundance of many hundreds of species of fauna and flora associated with the coral reefs of Abu Dhabi Emirate. This data is currently being incorporated into EAD's marine database and GIS mapping system.

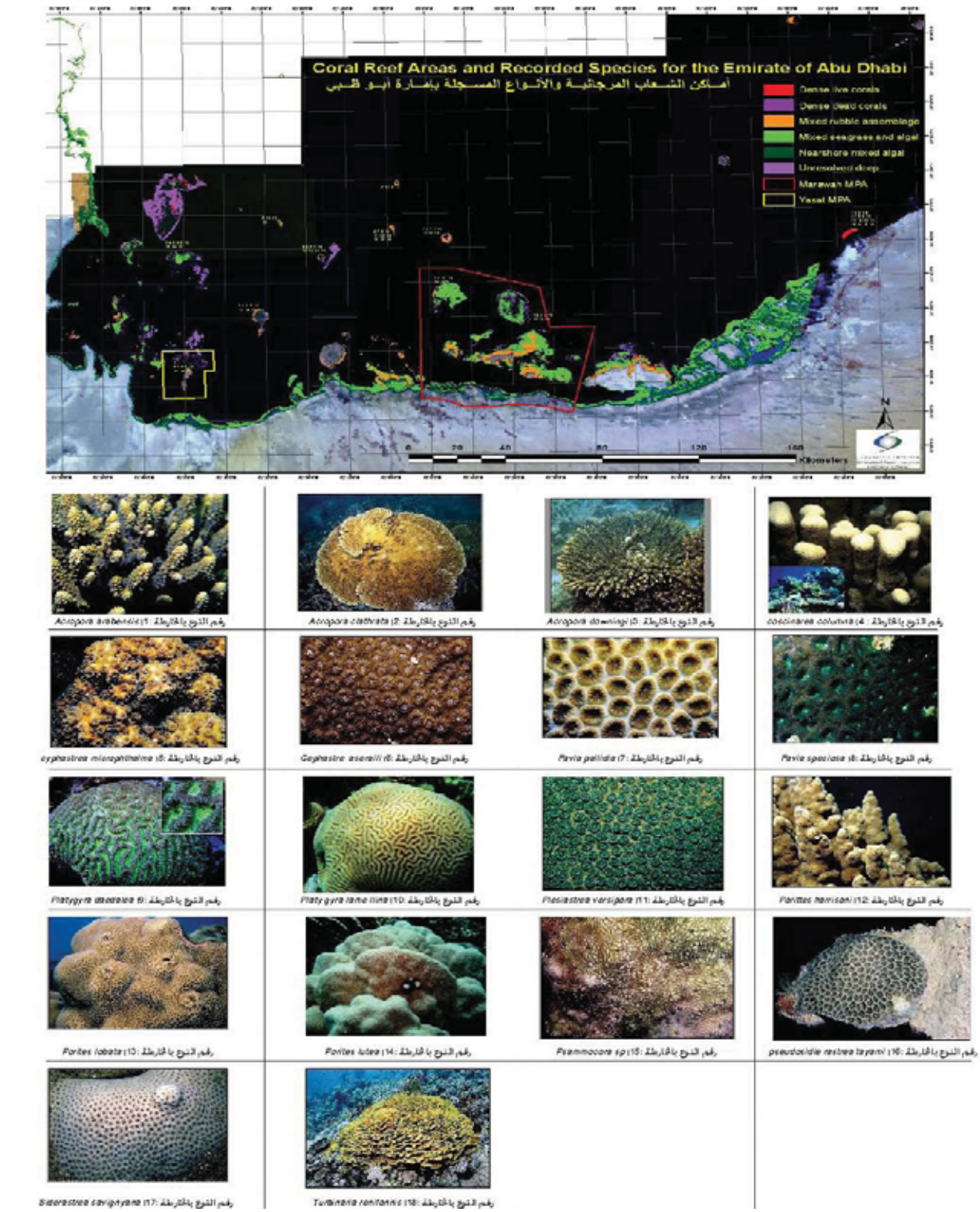


Figure 6: Principal coral species and their distribution in the waters off the Emirate of Abu Dhabi

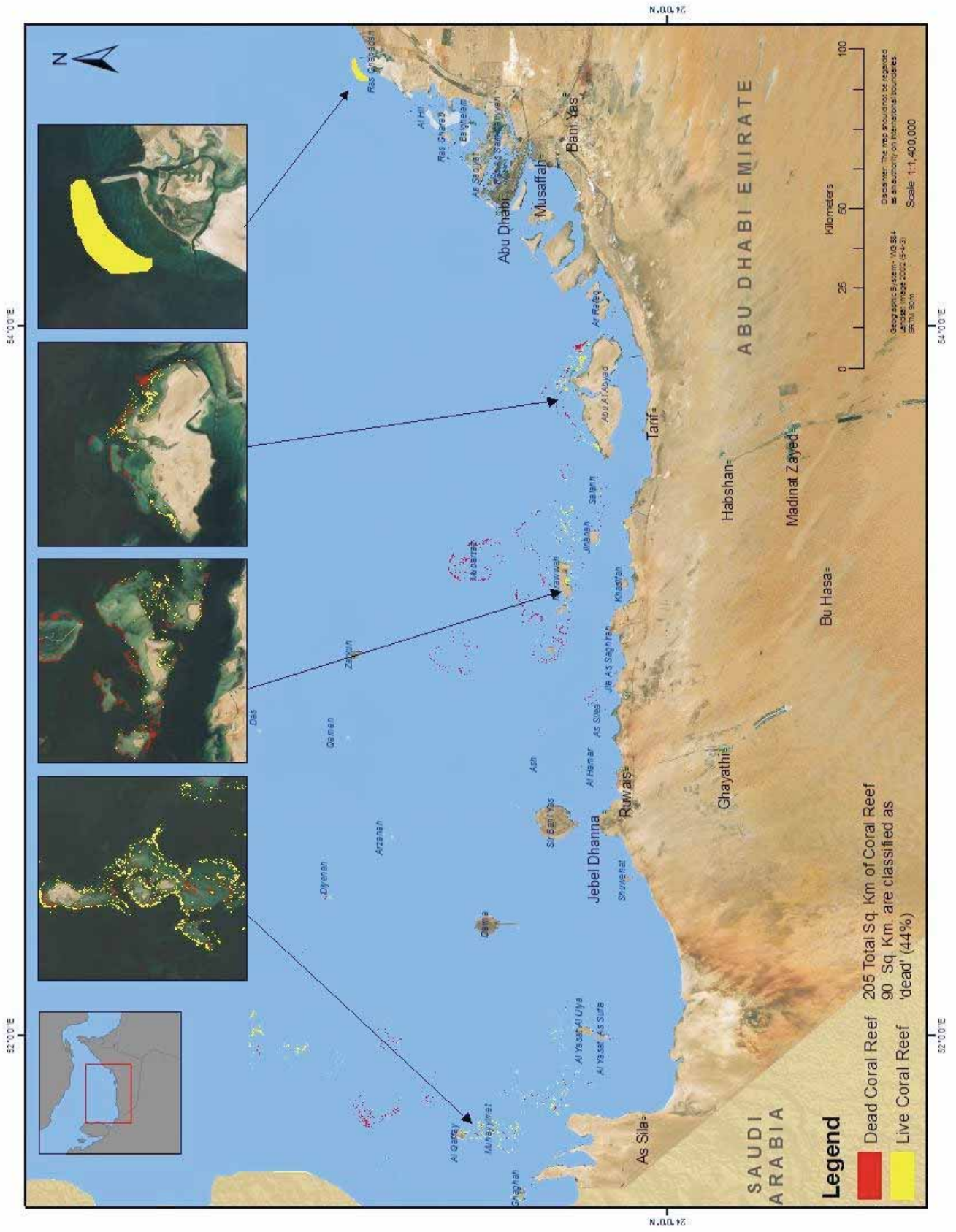


Figure 7: Distribution of live and dead coral reef. It is estimated that 44% of the total coral reef is now dead.

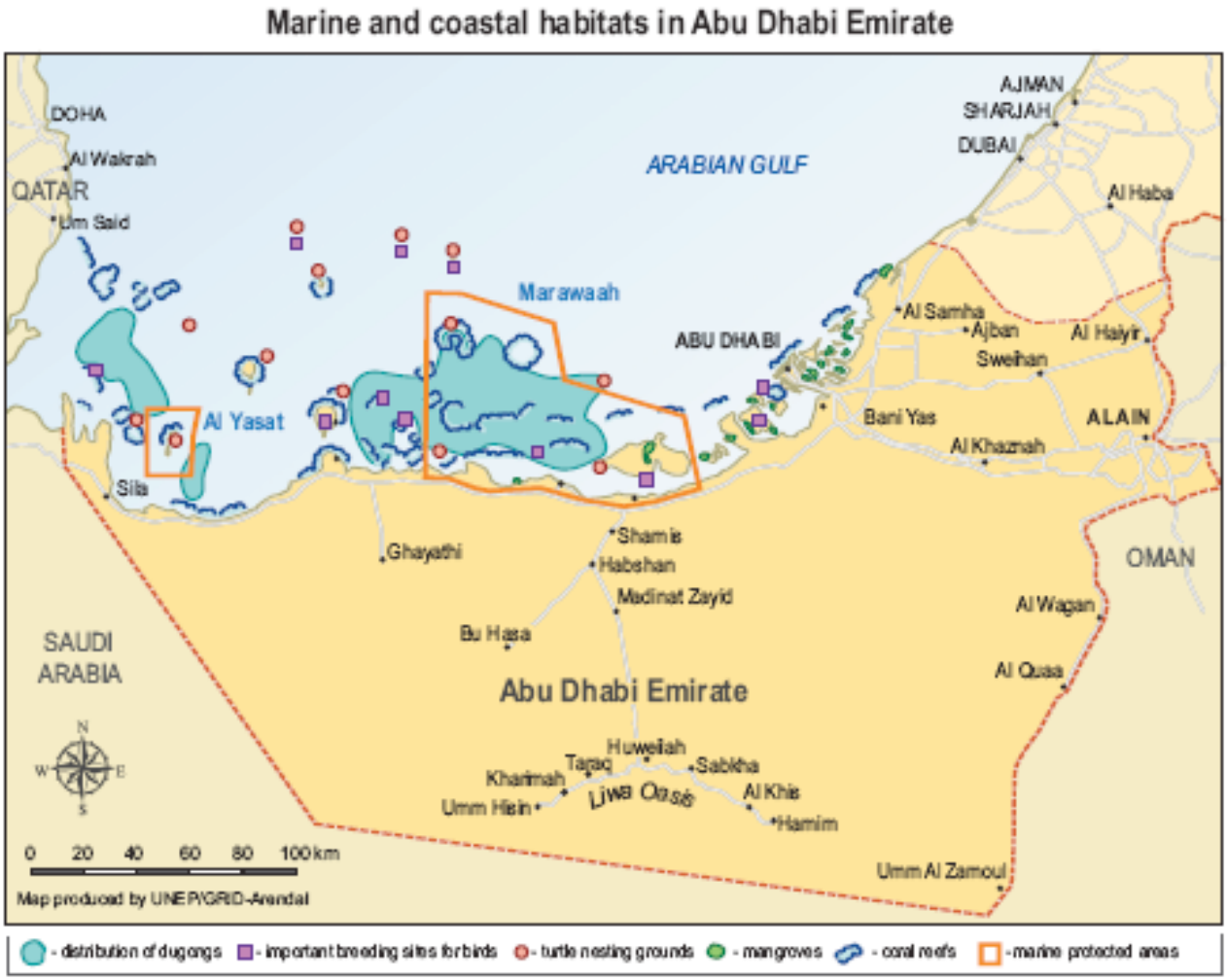


Figure 8: Distribution of dugongs, important breeding sites for birds, turtle nesting grounds and shallow marine habitats in and around the marine protected areas off the coast of Abu Dhabi.

The shallow coastal waters of Abu Dhabi Emirate are generally considered unsuitable for most corals although there are numerous fringing and patch reefs with *Acropora, Porites, Platygyra* and many other smaller faviids prominent (Kinsman, 1964; Hughes Clarke & Keij, 1973; Sheppard & Wells, 1988; George & John, 1998; John & George, 1998). In the top 1-4m of the reefs in central and eastern regions of the Emirate, where some shelter is available from the north westerly shamal winds, both patch reefs and fringing reef slopes are dominated by branching *Acropora* species with an under storey primarily of *Porites*, *Platygyra* and other smaller faviids (George & John, 1998, 2004). At greater depths and in areas exposed to considerable wave action, the reefs are dominated by frame-building *Porites* colonies amongst which various other corals flourish, especially the species that form the under storey in the shallower *Acropora* thickets. At depths below about 6-8 m several species of the dendrophylliid coral *Turbinaria* are often seen, especially where the reefs meets the surrounding sand. The reefs rarely occur at depths greater than 10 m.

Despite the fact that this is considered to be one of the most inhospitable environments for coral growth in the world, some reefs fringing offshore islands and shoals in the Emirate were steadily accreting until recently, their component species of coral having adapted to a greater seawater temperature range and higher salinities than the same species outside the Strait of Hormuz (Purser & Evans 1973; George & John, 1999; George et al., 2001; John & George, 2001).

Riegl (1999), during his study of corals near Jebel Ali in Dubai Emirate was directed to evidence in an unpublished PhD thesis by Titgen (1982) that *Acropora* had been almost completely killed by low seawater temperatures and/or excessive sedimentation sometime between July 1979 and February 1981 in that same study area. However, since this time there is no evidence to suggest that major coral deaths in the Gulf Emirates have been attributable to low winter temperatures, even at the western extremity of the Abu Dhabi coastline where the annual range of seawater temperatures is somewhat greater and coral diversity less as a result (George & John, 1999, 2004, 2005b; John & George, 2001: Riegl, 2003).

Figure 9: Installation of artificial reef units near the shoreline in Abu Dhabi (Source: Emirates Heritage Club).

Since the summer of 1996, high seawater temperatures have often been close to or may have exceeded the physiological tolerance limits of the already well-adapted hermatypic corals forming the reefs of Abu Dhabi. In 1996 and 1998, prolonged higher-than-normal summer seawater temperatures (positive SST temperature anomaly of over 2 C) led to the catastrophic bleaching and death of a large percentage of the previously living corals along the length of Abu Dhabi Emirate (see **Section 4.3.6** on Cnidaria (includes corals) and **Section 6.4** on Climate change for more details). As a result, the structure of many of Abu Dhabi's reefs has changed dramatically since that time and the communities of fauna & flora associated with the reefs have also changed (George and John, 1998, 1999, 2000a, b, 2002, 2004, 2005a, b; John & George, 1998, 1999, 2001, 2003).

The Biodiversity Mananagement – Marine Sector of the Environment Agency - Abu Dhabi (EAD) conducted a survey of the marine area between the islands of Abu Abyadh and Bu Tinah off the coast of Abu Dhabi in 2000. The objectives of the synoptic field survey were to identify critical habitats and areas of high conservation value as part of an effort to designate a marine protected area. The results revealed a patchy distribution, with large coral areas situated to the northwest of Abu Abyadh Island and east and west of Marawah Island along the Bu Tinah Shoals (**Figure 6**). *Acropora* dominated the shallow waters while *Porites (P. lutea* and *P. compressa)* and some Faviids were found in slightly deeper areas. Other groups recorded included Siderastreids and Dendrophylliids (EAD, unpublished data).

More recently, in collaboration with Dolphin Energy, the World Wildlife Fund (WWF), Emirates Wildlife Society (EWS) and the National Coral Reef Institute (NCRI), the Biodiversity Mananagement – Marine Sector participated in a coral reef mapping project which included all shallow areas from Qatar through Abu Dhabi Emirate (**Figure 7**). The output of this study indicated that 44% of the total coral reef is now dead.

3.4 Sand flats

This biotope is usually present adjacent to mudflats or salt marshes. According to John and George (2004), no systematic attempt has yet been made to characterize intertidal sand biotopes based on specific infaunal components (*e.g.*, polychaetes, crustaceans, molluscs). According to these same authors, on occasions, particularly during the summer months, the surface of intertidal sand is discoloured suggesting the presence of large populations of microscopic algae, probably diatoms. Much of the coarse sediment forming a thin covering over shallow rocks on the open coast is not sufficiently stable to provide a suitable habitat for marine organisms. During the stormier winter months a combination of tidal currents and wind-induced waves keeps the sands moving. Only for a short period during the calmer summer months is the sand sufficiently stable to provide a temporary habitat for benthic organisms. Sand and shell gravel accumulates as banks in areas where currents are weakest. When these sediment banks have stabilized sufficiently they are a habitat for infaunal organisms in particular, although epibenthic organisms are sometimes also present (Hornby and Thomas, 1997; George *et al*., 2001). These banks, the higher parts of which are sometimes exposed at low water, contain an infauna that is somewhat similar to that encountered on intertidal sands with a preponderance of polychaete worms (John and George, 2004).

3.5 Artificial reefs

The European Artificial Reef Research Network (Jensen, 1997) defines artificial reefs as 'submerged structures placed on the seabed deliberately to mimic some characteristics of natural reefs', and excludes structures such as breakwaters or piers. Artificial reefs have been used for centuries to enhance fishery resources and fishing opportunities (Jensen, 1997).

Historically, artificial reefs have been created with 'materials of opportunity' such as rock and building rubble, wood, old ships and vehicles and more recently have consisted of tyres, and decommissioned oil and gas platforms (McKaye, 2001). In the UAE, the construction of artificial reefs by sinking rocks and other material onto sandy areas of the seabed was a common traditional fishing practice, which is still continued by some fishermen today (Aspinall, 1995).

The construction of artificial reefs from materials of opportunity is obviously favoured because of their relatively low cost, as well as the ready availability of these materials. The establishment however of artificial reefs in inappropriate locations, built out of unsuitable materials or built under inadequately reviewed conditions can pose long-term ecological problems and is of particular concern for marine and coastal managers. Creating a successful artificial reef implies more than just placing miscellaneous materials into the marine environment. Careful planning, long-term monitoring and evaluation measured against specific goals and objectives must be integrated into each project to ensure the maximum anticipated benefits are derived from each artificial reef project.

In an attempt to improve the efficiency and ecological role of artificial reefs, there has been growing popularity with the use of purpose designed artificial reefs consisting of concrete structures (caste type), and other more novel 'soft and flexible' structured materials primarily consisting of geotextile filled with sand. In Europe, concrete has been the dominant material utilized (Bombace *et al.*, 1993) and concrete is also the key material used in developing Japanese artificial reefs (Pickering *et al*., 1998).

A FAD (Fish Aggregating Device or Fish Attracting Device) is often confused with artificial reefs; these however simply provide a platform or surface area for fish to congregate around. The first observations that objects in the sea, whether man-made or naturally occurring, attracted a variety of fish were no doubt very early. Ancient fishermen possibly noticed that drifting logs and seaweed were usually good places to fish near, or that rafts and canoes themselves attracted fish. Whatever the chain of events, it is a fact that FADs have been around and utilized by man for at least 2000 years.

The use of the term 'Artificial Reef' to describe a FAD or any other material thrown into the sea to create or replicate a marine habitat is unfortunately often misused. For a structure to be given the true title "Artificial Reef" it must conform to the four following requirements:

1. Stability
2. Durability
3. Compatibility
4. Function

To become a productive artificial reef, a structure must also be able to provide similar attributes to that of a natural reef and this can only be achieved through appropriate design and location selection. These attributes, for example, should include the provision of shelter, the penetration of sunlight, adequate flow of clean water (currents), and provision of habitat for a diverse biodiversity of animal and plants that can develop into a self-sustaining ecosystem (containing various food chains and nutrient pathways).

Actions that could be undertaken by the Ministry of Environment and Water and the fishermen's cooperatives in the UAE are the establishment of artificial reefs (caste type) in areas where coral reefs have suffered as a result of the recent bleaching events. This would provide alternative reef habitat in areas where there may now be reduced structural cover. Evaluations of 3 types of artificial reef structure are currently on-going in the Emirate of Abu Dhabi by the Biodiversity Mananagement – Marine Sector.

3.6 Dredged channels

Dredged navigation channels have connected shallow coastal habitats with deeper marine waters allowing for more frequent flushing therefore reducing the salinity and temperature of coastal waters particularly in back lagoon habitats. This has assisted with an increase in natural mangrove vegetation (Loughland, 2006) and has also provided year round habitat for some fish species (e.g. hamoor).

Often dredged channels are cut through calcareous rock platforms, which form stable channel walls. On

the uppermost margin of these channels develop beds of macroalgae similar to those growing on the seaward margin of tidal flats. The vertical walls of these channels are frequently covered with suspension-feeding invertebrates such as sponges, hydroids, serpulid polychaetes, bryozoans, bivalve molluscs, and ascidians (John & George, 2001, 2004). The long-spined sea urchin, *Diadema setosum*, is also usually common.

3.7 Sandy beaches

Many of the sediment beaches in the western and central regions of Abu Dhabi and on both offshore and barrier islands consist of carbonate sand, largely of biological origin (Purser & Evans, 1973; George & John, 2005). Immediately above the high water mark these beaches are utilized by a range of organisms for nesting including marine turtles, marine birds and other species such as ghost crab *(Ocypode rotundata)* which build distinctive sand towers near the entrance to their burrows during the breeding season (John & George, 2001, 2005; George, 2005b). In the finer sand material lower on the shore, live other organisms with the small crab *(Scopimera crabricauda)* being the most obvious because of the pseudofaeces formed by this species all over the sand.

3.8 Rocky shores

The ecology of rocky shores in Abu Dhabi is discussed in some detail by John and George (2004), and according to them, Abu Dhabi's rocky shores closely resemble those to be found on rocky shores elsewhere in the region. In Abu Dhabi however, rocky shores are much less common than sandy shores and most rocky areas are usually associated with headlands formed from sandstone (*e.g.* Jebel Barakah and Shuwaihat). These sandstone areas are sometimes undercut providing intertidal platforms, parts of which remain covered by thin sheets of water at low tide. In other areas of the Emirate, low rocky cliffs are formed of ancient reef limestone and have irregular surfaces due to the presence of many projections, crevices and pits.

On rock surfaces, defined bands of macroalgae and invertebrate animals can often be observed, with these being more evident on steep shores. According to John and George (2001, 2004), rocky areas on the landward side of broad intertidal platforms tend to be wave-sheltered and therefore usually have poorly developed plant and animal assemblages compared with those on more wave-exposed shores.

According to Lewis (1964), the biologically defined bands on rocky shores can be divided into a eulittoral zone with a littoral fringe above and a sublittoral fringe beneath. The eulittoral zone itself, which is influenced by all tides, can be divided into an upper subzone normally characterised by the presence of numerous barnacles and a lower subzone dominated by one or more bands of algae or invertebrates. The littoral fringe is the most obvious band on the shore because it is often black (sometimes tar-like) due to the presence of blue-green algae (cyanobacteria). These algae characterise the area commonly affected by wave splash and occasionally extend downwards into the eulittoral zone. The upper eulittoral subzone is characterised by a band of barnacles, although at its uppermost limit the barnacles are mixed with the blue-green algae of the littoral fringe. Within the sublittoral fringe, many organisms are at the uppermost limit of their vertical distribution and only survive brief periods of exposure to the air unless they on the undersides of rocks or in rock pools. According to John and George (2004), the platform edge is commonly overgrown by mats of fine filamentous red algae during the winter months, with the perennial green alga *(Dictyosphaeria cavernosa)* being the mostly observed one at this shore level.

3.9 Lagoons and creeks

A major feature of Abu Dhabi's shallow coastline is a network of inshore barrier islands. The barrier complex of islands and submerged reefs result in a breakwater effect that provides quiet backwaters consisting of shallow flats and lagoons with fine sediments. Despite these areas having restricted water exchange, mangroves and sea grasses flourish, as do other biologically productive benthic habitats (Purser & Evans, 1973).

Figure 10: The most extensive system of tidal lagoons and creeks lies in the vicinity of Abu Dhabi city behind the barrier island complex. (Source: Emirates Heritage Club)

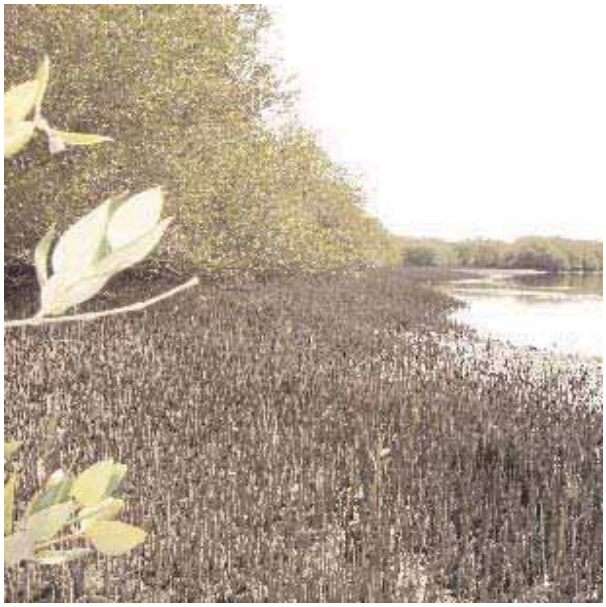


Figure 11: Mangroves are an important habitat for birds and juvenile fish and form a natural barrier against coastal erosion.

The most extensive system of tidal lagoons and creeks lies in the vicinity of Abu Dhabi city behind the barrier island complex. These lagoons (khors) connect to the open sea by relatively shallow and narrow tidal channels. Over the past two decades artificial channels have been dredged to allow safe navigation between many of the lagoons without the necessity of returning to the open sea. Seawater temperature and salinity are raised compared to the open sea although the differential is now reduced due to the increased tidal flushing resulting from the presence of the connecting-channels.

Bordering the main lagoons are thickets of the mangrove *Avicennia marina* that contribute to the detritus-based marine food webs (Saenger *et. al.,* 2004). The sediments in many of the lagoons are not particularly muddy, but rather consist of silty coarse sand that provides a habitat for epibenthic and infaunal organisms (John & George, 2001, 2004). Sometimes finer and more organically rich-sediment accumulate around mangroves whether in lagoons or on depositional shores along more open coasts. Often these occur on more sheltered lee shores (*e.g.*, Marawah Island). Extensive sublittoral beds of seagrass are often also present and these are absent or very sparse where the substratum is of very fine sediment (Phillips *et al*., 2002, 2004). According to John and George (2001, 2004), conditions close to and at the seaward entrance to lagoons are similar to those found on the more open coast. This is reflected in the close similarity in the biological assemblages associated with littoral and sublittoral surfaces.

3.10 Mangroves

Only one species of mangrove, *Avicennia marina,* occurs in the Gulf region although it seems likely that a second species of *Rhizophora* disappeared from the area in historical times (Gale, 1994; Wilcox & Tengberg, 1995; Tengberg, 2002). The mangroves of the UAE are generally of a small size, with an average height of around 5m (Dodd *et al*., 1999; Saenger *et al*., 2001). Essential ecological data on the mangroves of Abu Dhabi has been published recently by Saenger *et al*., (2004). Previous literature concerning the UAE or the Arabian Gulf mentions the localities where mangrove ecosystems could be found (British Admiralty, 1967; Rabamal & Beuschel, 1978; Barth, 1982; Dodd *et. al.,* 1999). In 2004, as part of Abu Dhabi's marine atlas project, the distribution, density and structure of mangrove vegetation throughout Abu Dhabi Emirate was recorded. In 2001 the Emirates Heritage Club also surveyed both natural and planted mangrove sites in order to determine the optimal tidal regime for *A. marina* in the Emirate. This was undertaken to assist with the expansion of mangrove plantations and the results were forwarded to the Abu Dhabi Public Works Department (Loughland and Saenger, 2001).

In Abu Dhabi Emirate, natural mangrove vegetation mostly occurs between Ras Ghanada in the northeast to Marawah Island further to the west at suitable sheltered sites that have reduced wave energy and are protected from strong winds. These sites include both natural and artificial khors (lagoons) and the lee side of peninsulas, spits, islands and shoals. On exposed coasts, mangroves are sparse and may only occupy a fringe position at some suitable sites. The density and height of mangroves generally increases towards the northeast of the emirate.

Figure 12: Mangrove distribution

especially in lagoon systems protected by barrier islands (*e.g*. From Dabbayya - Ras Al Sidre). There have also been significant plantations of mangrove established in Abu Dhabi, and Al Sammaliah Island boasts one of the largest artificial *Avicennia marina* plantations in the world, covering an area of approximately 8 km^2. The environmental benefits of these systems include provision of fish and bird habitat. The mangrove areas are also heavily utilized for environmental awareness programmes (*e.g.* mangrove boardwalk). The mangroves of Abu Dhabi also form a significant part of those of the Arabian Gulf. According to recent estimates based on remote sensing, there are about 40 km^2 of mangroves in Abu Dhabi, of which three quarters are open mangroves with the remaining consisting of dense mangroves (Saenger *et al.*, 2004).

3.11 Mudflats

Intertidal areas of Abu Dhabi Emirate are often gently sloping and therefore extensive, and provide important foraging habitat for many internationally important migratory birds.

Fine sediments can accumulate along with decomposing organic material, such as seagrass and algae in inner marine basins, sheltered embayments, or in quiet areas of lagoons and in the lee of large islands. The resulting habitat is characterised by soft mud that is a relatively organic-rich habitat. Often, such mud in the lower intertidal zone is black and anoxic below the top centimetre or so and only those infaunal invertebrates that can maintain a viable connection to the mud-water interface can survive. According to John and George (2004), no detailed investigations have as yet taken place on the infaunal assemblages. As the mudflats are a rich feeding area for millions of migratory waterfowl, these habitats must contain an abundance of invertebrates and algae. It is important that surveys on the infauna of mudflats is undertaken, in particular those areas known to be frequented by large numbers of wading bird species.

3.12 Sabkha

The coastal area of Abu Dhabi often includes an inner zone of littoral fringe flats (where blue-green algal mats are well developed) and broad areas of supratidal salt flats designated as 'sabkha'. Sabkha is the local Gulf Arabic word for flat, salt-crusted desert. There are two types of sabkha, coastal and continental or inland sabkha. The Abu Dhabi coastal sabkha is some of the best documented in the world, as a result primarily of their vastness and because of early research undertaken on them by geologists (Evans *et al*., 1969; Bush, 1973, Purser & Evans, 1973). The large sabkha of the Emirate is one of the few areas of the world where geologists can observe the relationship between carbonate and evaporite sedimentation.

Coastal sabkha, saline flats and salt formations are represented by eight major sub-classes and create the highest landform diversity in Abu Dhabi Emirate (Böer & Gliddon, 1997). These saline landforms are a major feature of the Abu Dhabi coastline, covering 62% of the mainland coast (Böer & Gliddon, 1997). Sabkha ecosystems in the Arabian Peninsula and adjacent countries were reviewed in detail in Barth and Böer (2002), inclusive of land use and development potential. In this volume much of the field data was derived from Abu Dhabi Emirate. Sabkha landforms have developed generally where hard rock lies below the groundwater table, allowing water to remain close to the surface and to be susceptible to evaporation. Radiocarbon dating has indicated that the coastal sabkha of Abu Dhabi was formed over the last 7000 years (Evans *et al.*, 1969). The following provides more descriptive detail on the characteristics of the sabkha occurring in the UAE.

Coastal sabkha: a coastal flat at or just above the level of normal high tide. Its sediments consist of sand, silt or clay and its surface is often covered with a salt crust formed by the evaporation of water drawn to the surface by capillary action or from occasional marine inundations. The coastal sabkha is characterised by the presence of algal mats and the occurrence of gypsum and anhydrite within its sediment. It is subject to deflation down to the water table.

Figure 13: Large areas of the coast of Abu Dhabi consist of salt flats or "Sabkha".

Inland sabkha: a flat area of clay, silt or sand, commonly with saline encrustations, that is typical of desert areas of inland drainage and some interdunal areas. The salts occurring in these sabkha may be formed by evaporation of surface water, or from water drawn to the surface from the water table through capillary action.

Coastal sabkha covers the surfaces of much of the coast and low islands southwest and just to the northeast of Abu Dhabi Island. Along the north eastern emirates coast, in particular at Umm al-Quwain and Ra's al-Khaimah, the development of long shore sediment bars has resulted in the creation of a series of shallow lagoons, which have tidally formed deltas at their mouths (Glennie, 1970; Purser & Evans, 1973). Wave action has built the long shore bars into beaches, from which sands are blown into the lagoons. In addition, as small carbonate-shelled creatures living in the lagoons die, their shells are deposited on the lagoon floor, which becomes shallower and eventually builds up to, or even above, normal high-tide level. This process eventually leads to a coastal sabkha inclusive of a mat of algae.

Inland sabkha differs from the coastal variety in having no direct marine influence on its development. Supply of water comes from rare rainfall and the presence of a water table within capillary reach of the surface; a balance is achieved between evaporation and deflation at the surface and the supply of water from below, both being affected seasonally. Algae may be present, but extensive algal mats are not well developed and gypsum crystals form a layer below the surface. Within the UAE, extensive inland sabkha is found in three areas; at the landward margins of the coastal sabkha beyond the reach of storm

Figure 14: Coastal sabkha in Abu Dhabi Emirate

tides and extending into some adjacent interdunal areas; or in the large broad interdunal areas between the huge dunes of for example the Liwa, Umm az-Zamul; and at Sabkha Matti, a low lying area in the far west of Abu Dhabi which is one of the largest sabkha in the region being around 60km across and extending south from the coast for almost 150km. This sabkha is both coastal and continental.

The sabkha ecosystems of Abu Dhabi Emirate are unique, and are a valuable teaching resource for geologists, yet they are being degraded by infilling and fragmentation caused through development. These interesting landforms are worthy of protection as representations of the Emirate coastline and require special zoning for their long-term conservation.

3.13 Sandy coastline and dunes

Sandy coastlines in Abu Dhabi Emirate are usually found where high-energy waves impact on the shoreline. In some locations large amounts of beach sand are deposited into coastal dunes that are usually stabilized by coastal vegetation such as halophytes. These habitats were initially classified by Böer and Gliddon (1997). The coastal dunes are a reservoir of beach sand (*i.e.* storm berm) that are usually in equilibrium with the natural beach sediment budget, and therefore assist in preventing the erosion of the beach.

3.14 Rocky coastline

According to Hornby and Thomas (1997) and John and George (2001, 2004) loose boulders and beach slabs on the surface of the shoreline or partly buried in sand provide a habitat on their undersides for invertebrates that do not flourish when exposed to direct sunlight. The diversity of species existing in this habitat and in rock crevices, particularly if they are kept free of sediment accumulation by water currents is considerably higher than that found on the upward- facing surfaces of rocky shores (John & George, 2001, 2004, 2005). The undersides of larger rocks are often coated with a colourful variety of sponges and other encrusters such as tunicates spirorbid worms. Bivalve and gastropod molluscs are also plentiful in this biotope. Other animals found under rock slabs at low tide include polychaete worms, amphipods and crabs, the mantid shrimp *Gonodactylus chiragra*, and the cushion star *Asterina burtoni*.

3.15 Artificial coastline

The coastal zone of Abu Dhabi Emirate continues to be transformed by the construction of new developments such as marinas, breakwaters and islands, the dredging of channels, reclamation, and the expansion of areas of existing islands by dredged seabed material. Some islands and breakwaters have been armoured by stone blocks (usually of limestone) or, less commonly, by concrete tetrapods. The new rock-armoured islands, rough stone breakwaters, jetties and pier piles become rapidly colonized by fouling animals. Suspension-feeding invertebrates frequently come to dominate pier piles and floating pontoons whereas corals commonly develop on rough stone breakwaters (George & John, 2004, 2005; John & George, 2001). According to John and George (2004), new corals, such as those developing on the breakwaters fronting Abu Dhabi City, are often accompanied by mats of red algae and clumps of seasonal brown algae.

Artificial hard surfaces occurring in the littoral zone are infinitely variable in their composition and include vertical iron cladding, harbour walls, concrete blocks, and the normal flotsam and jetsam. As long as these surfaces are not toxic to marine life and are reasonably hard and stable then they acquire a coating of marine organisms similar to those found on natural rocky shores. For example, vertical concrete or metal surfaces often have a distinctive band of barnacles extending upwards from the mid-tide level similar to the barnacle zone of natural rocky shores (John & George, 2001, 2004, 2005). According to these authors, sessile animals that represent the final stage in a successional sequence frequently dominate fixed or permanently submerged structures. Many of these invertebrates are also present on subtidal rocky surfaces, but tend to be subordinate members of a very complex assemblage. Pier piles and other permanently submerged hard surfaces are usually covered with a mass of suspension-feeding invertebrates including sponges, hydroids, bryozoans, ascidians, and numerous bivalve molluscs and brittlestars.

3.16 Near-shore, off-shore and artificial islands

A major feature of Abu Dhabi's shallow coastline is a network of inshore barrier islands. The barrier complex of islands and submerged reefs result in a breakwater effect that provides quiet backwaters consisting of shallow flats and lagoons with fine sediments. The importance of these barriers for the development of coastal plant communities is evident northeast of Abu Dhabi Emirate, within Dubai Emirate, where the exposed coast is characterized by high-energy beaches and a distinct lack of inshore coastal

plant communities. Inshore barrier islands have grown landwards mainly by spit formation under the process of predominantly northwest wind-dominated leeward accretion, and Dabb'iya has actually been connected to the mainland (Purser and Evans, 1973).

The offshore islands of Abu Dhabi Emirate are important for nesting green turtle (*Chelonia mydas*) and hawksbill turtle (*Eretmochelys imbricata*). The islands also provide nesting and feeding habitat for thousands of migrating and resident birds, with some islands being internationally significant, containing the main nesting sites for threatened and endangered species, such as Socotra Cormorant (*Phalacrocorax nigrogulasis*).

Artificial islands have been developed in Abu Dhabi Emirate and usually consist of the dredged spoils from marine works undertaken to cut navigation channels in shallow marine areas or to deepen harbours or existing channels. The artificial islands are often then developed for agricultural production or as private facilities. The development of artificial islands in the Emirate until presently has not been for investment purposes, and most of the islands so far developed have been utilized by the government for public amenity, e.g. Al Sammaliah Island, Masnoa Island and Lulu Island. The growth in popularity of the development of artificial islands for real estate investment, as is occurring in other areas of the region, is a looming threat to the coastal resources of the Emirate and planning for the adoption of coastal management principles in Abu Dhabi is urgently required.

Figure 15: Satellite image of Abu Dhabi and its barrier complex of islands.

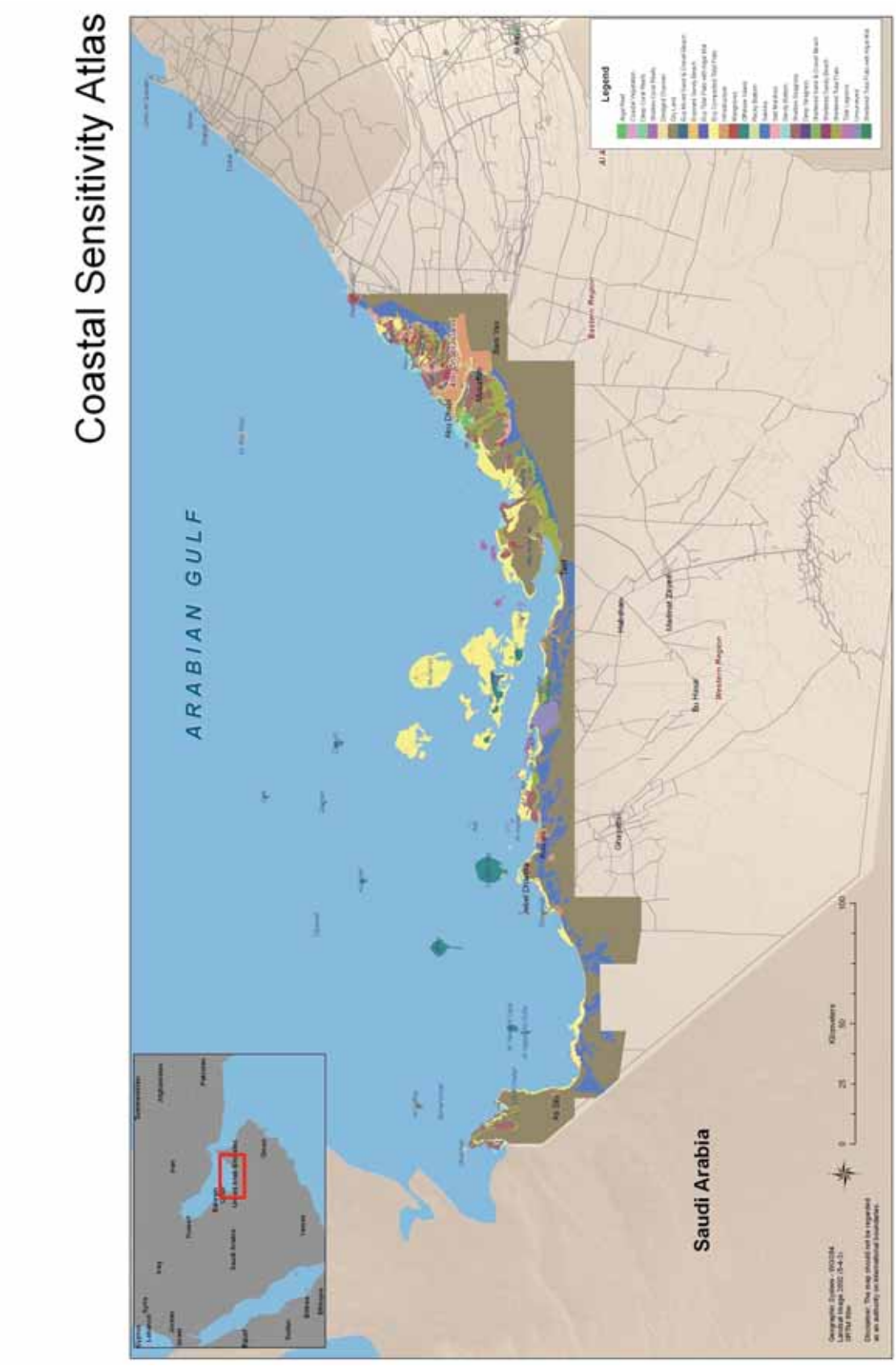


Figure 16: Distribution of marine and coastal habitat in the Emirate of Abu Dhabi

4 SPECIES DIVERSITY

4.1 Marine Flora

4.1.1 Benthic algae

Marine algae or seaweeds are non-vascular and non-flowering marine flora ranging from individual microscopic cells to huge plants more than 30 metres long. In the Arabian Gulf, the marine flora is continuous along the coast but varies in species richness and composition (John & George 2004; 2005; Clerck & Coppejans, 1996). Zonation patterns within algal assemblages are dictated by tidal exposure, wave impact, and substrata type as well as grazing by invertebrates and by competition for space and light. Studies on seaweeds of the region are few (John & George 1998; 2003; 2004; Clerck & Coppejans, 1996; Al-Majed *et al*., 2000) and deal mostly with qualitative audits of species composition in relation to habitat types. Comprehensive surveys of the seaweeds along the coast carried out over 5 years by John and George (1998; 2004; 2005) document a total of 121 species - 67 Rhodophyta (Red Seaweeds), 18 Chorophyta (Green Seaweeds), 23 Phaeophyta (Brown Seaweeds), 1 Xanthophyta (Yellow-Green Seaweeds) and 12 Blue-green algae from Abu Dhabi waters. About 10 of the taxa require further investigation and are simply recorded as 'species'.

A spreadsheet containing site-specific records of all the marine algae of Abu Dhabi is available at the Biodiversity Management – Marine Sector of the Environment Agency Abu Dhabi. It covers all known marine algae recorded for Abu Dhabi and the 110 recording sites in mangrove areas, littoral and sublitoral rocks, seagrass beds, artificial surfaces, *etc*. The numbers of algae in the spreadsheet is slightly different to that published in John (2005):

- Chlorophyta: 20 (2 extra)
- Phaeophyta: 24 (1 extra)
- Rhodophyta: 70 (3 extra)
- Cyanophyta: 11 (-1)
- Xanyhophyta: 1

Unlike other tropical coasts, seaweeds are not very common in supra-littoral and inter-tidal zones due to the extreme climatic conditions, except during the winter months when the seawater temperature is lowest (Clerck & Coppejans, 1996). As seaweeds generally depend on the presence of hard substrate for their development, rocky and coral areas along the coast, including the patch reefs, show well developed algal growth. In the period when the seawater is usually below about 25 degrees Celsius (about October to May), *Sargassum* and sometimes *Cystoseira* forms dense bushy stands, completely covering the sub-strata locally and so forming a distinct biotope with a large biomass.

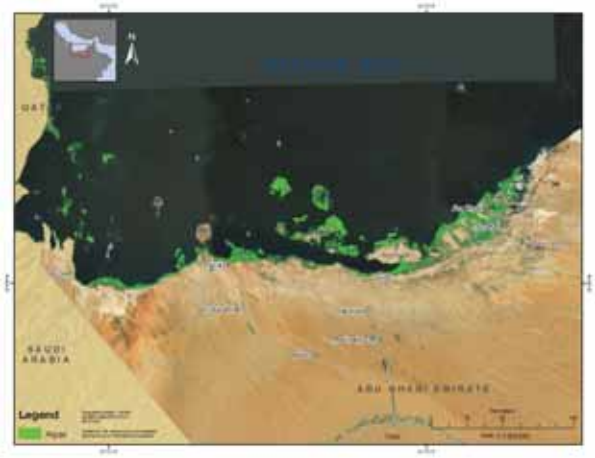


Figure 17: Distribution of algae

Common seaweeds in Abu Dhabi waters include: *Cladophora sp., Acetabularia calyculus* especially in shallow tide pools and tidal channels over small stones or shell fragments; *Hormophysa cuneiformis, Cystoseira myrica* in deeper rock pools of upper and middle intertidal zones down to about 5m depth; and *Dictyosphaeria cavernosa, Cladophora* sp*., Chondria dasyphylla, Chondrophycus papillosus, Hypnea cornuta* in shallow pools close to the low water line. Along the exposed coasts of many offshore islands *Cladophoropsis sundanensis* forms cushion like growths in the rocky fringes. The sub-tidal zone supports *Avrainvillea amadelpha* and *Caulerpa sertularioides*, which colonize patches in and around seagrass meadows. Brown algae such as *Colpomenia sinuosa* (only present in April/ May period), *Sargassum* sp., and *Hormophysa cuneiform* are common in coral reef fringes of the sub-tidal zone. Between the coral heads and sand covered hard substrate, an algal community develops which is generally represented by *Hormophysa cuneiformis, Cystoseira trinodis* and *Sargassum* spp., mixed with large amounts of *Padina* sp., and *Dictyota* spp. On deep rocky substrate between 4 - 8 m depth, *Sargassum latifolium* is the dominant species. Species of the genus *Enteromorpha* are common along the dredged channels close to industrial areas and developed off-shore islands.

4.1.2 Phytoplankton

There are two major groups of phytoplankton, the diatoms and dinoflagellates, which collectively form the basis of the marine ecosystem. These microscopic, single-celled plants are most diverse in the nearshore waters of the Emirate of Abu Dhabi. As phytoplankton are indicators of environmental change, monitoring work has been conducted in the Emirate of Abu Dhabi since 2002. Prior to this, there was no scientific information available on the distribution and abundance of the different species. The studies conducted to date have revealed that phytoplankton populations in Abu Dhabi waters are dominated by diatoms followed by dinoflagellates. 77 species of dinoflagellates and 114 species of diatoms and blue green algae have been identified so far.

Diatoms are microscopic, unicellular, eukaryotic algae found in all marine and fresh waters. The most common diatoms encountered in Abu Dhabi waters are; *Chaetoceros sp*, *Coscinodiscus sp*. *Navicula sp, Nitzschia sp*, and *Rhizosolenia sp*. Regarding spatial variation of diatom species, *Coscinodiscus radiatus, Leptocylindrus danicus, Pleurosigma normani, Rhizosolenia stolterforthii* and *Skeletonema costatum* were recorded at all stations followed by *Chaetoceros brevis, Psuedonitzschia sp* and *Rhizosolenia calcar-avis* in 7 stations.

Dinoflagellates are unicellular, flagellate and free swimming organisms that are often photosynthetic. They secrete a cell wall of cellulose-like organic matter. Most species have whip-like flagella that permit them to migrate. About 77 species of dinoflagellates have been identified so far with *Ceratium* species and *Prorocentrum* species being dominant. Observations made at all sample stations show distinct spatial variation in species composition, while the *Ceratium furca, C. fusus, Prorocentrum micans* and *Protoperidinium* divergens were recorded at all stations, *Gymnodinium* sp and *Noctiluca* sp were noted only in 7 stations (Rajan, 2003; 2004).

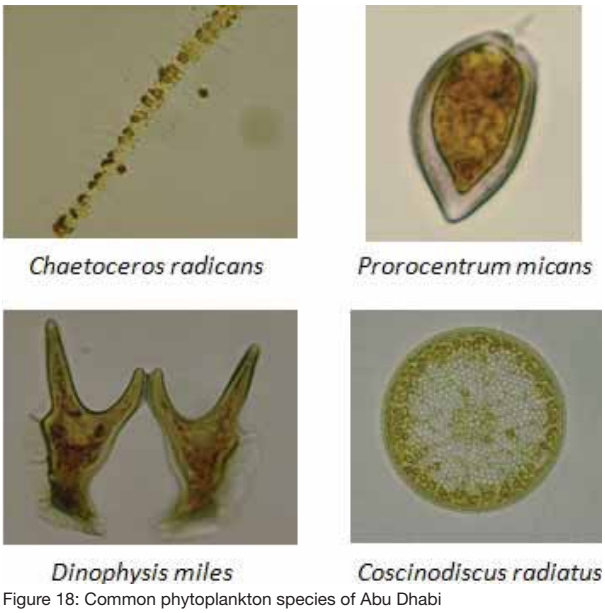


Figure 18: Common phytoplankton species of Abu Dhabi

The loose lying assemblages of diatoms causing the brown discoloration of sand in seagrass beds and sandy areas amongst coral down to a depth of 10 m probably contain plankton forms as well as those normally associated with sediment surfaces. These species are listed in John (2005) in which 95 species are mentioned.

4.1.3 Angiosperms (Seagrass)

Seagrasses are submerged vascular plants belonging to two families and twelve genera. In contrast to other submerged marine plants (*e.g.* seaweeds), seagrasses flower, fruit and produce seeds. They also have true roots and an internal system for the transport of gases and nutrients. Seagrasses are extremely widespread, occurring in the shallow waters of every coast and sea except the polar region. Of the twelve genera, seven are considered tropical while the remaining five are mostly confined to temperate waters.

Despite a recent surge in research activity, studies on seagrasses within the Arabian Gulf have remained relatively few in number. Large regions and a major stretch of coastline of the countries within the Gulf are still un-surveyed for seagrasses. The earlier studies (Jupp *et al.* 1996, Price and Coles 1992; Philips *et al.* 2002; Philips *et al.* 2004) document seagrass species off the coast of Oman, Red Sea coast of Saudi Arabia and UAE. During the study of Dugongs in UAE waters, seagrasses of the area were surveyed and monitored by the Environment Agency - Abu Dhabi (Anon, 2003) as part of the strategy to protect dugong foraging habitats.

Three species *(Halodule uninervis, Halophila ovalis* and *Halophilastipulacea)* are recorded from UAE waters. Diverse coastal geomorphological features in the Emirate of Abu Dhabi, namely (1) inter-tidal and sub-tidal zones, (2) shallow sandy bays, (3) mangrove flats of fine mud and sand, (4) sheltered habitats having sediment with organic matter and (5) shallow open coast were identified as sites for seagrass growth. *Halodule uninervis* occur in all habitat and substratum types. However, *Halophila ovalis* and *Halophila stipulacea* are selective and are found on sand, coral and mud-sand habitats respectively. In the Emirate of Abu Dhabi, localities with large areas of seagrass include western Abu Dhabi off-shore around Muhayimat and Umm Al Hatab, Marawah Marine Protected Area and sub-tidal zones around Abu Dhabi - Baharani islands up to Abu Al Abyadh. *Halodule uninervis* is the most common of all the species being present in all sampling sites.

Halodule uninervis is the dominant species with a very high relative abundance of 62 % (winter) and 50 % (summer) followed by *Halophila ovalis* with relative abundance of 13 % (winter) and 7 % (summer). The third species, *Halophila stipulacea,* was least common with an average abundance of 8 % in winter and 5 % in summer. Sites within the Marawah Marine Protected Area (MMPA) record a high percentage of seagrass cover both during the summer and winter; however, the pattern of dominance remains the same. Similarly, western Abu Dhabi waters around Muhayimat Island support extensive seagrass beds with abundance levels similar to the MMPA. The distribution of seagrass in relation to depth is principally a function of light (Dennison 1987). Light penetration and thus availability is affected by water column turbidity. Worldwide, only a few species grow below 20 m depth (Phillips and Menez 1988) in Australian and the ASEAN region. In the UAE, seagrasses are distributed up to 13 m at low tide. However, the percentage cover and presumably biomass of seagrasses at depths of 2 - 6 m was high compared to seagrasses at depths beyond 6 m and below 2 m Both *Halodule uninervis* and *Halophila ovalis* occurred at all depth ranges. *Halophila stipulacea* was observed between 2 to 6 m.

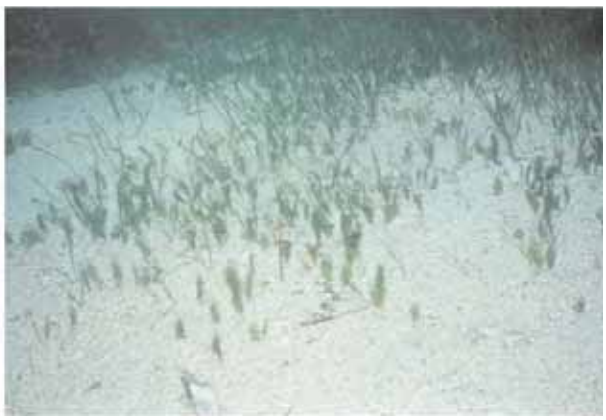


Figure 19: A seagrass bed off Abu Dhabi and Seagrass bed (*Halodule uninervis* and *Halophila* ovalis)

4.2 Coastal Flora

The coastline of Abu Dhabi Emirate lies exclusively on the Arabian Gulf, and is predominantly flat, with warm, shallow waters. However, in some areas, especially in the west, rocky cliffs in excess of 20 m are a prominent landscape feature. An overview of the major terrestrial coastal habitat types is given by Brown and Boer (2004). They include mangroves, salt marsh, intertidal flats with cyanobacteria mats, rocky cliffs and headlands, sandy, gravelly and rocky beaches, sabkha and coastal sand sheets. Brown and Boer (2005) have provided general descriptions of the coastal vegetation of Abu Dhabi, whilst Deil (1198, 2000) has examined the vegetation of the coastline of the entire Arabian Penninsula.

A broad differentiation between halophytic (*i.e.* influenced by salt) and non-halophytic vegetation can be carried out. It should be noted that it is not unusual for non-halophytic vegetation to occur within a few meters of the seashore. When compared to many inland habitats, the coastal vegetation of the Emirate is extremely productive. However, our knowledge of the natural coastal vegetation is fragmentary, and due to the enormity of the impacts over recent decades, this will remain the case.

4.2.1 Non-halophytic coastal vegetation

The sands close to the coast are derived from recent marine sediments. They are rich in carbonate and, as a result, appear distinctly white. In contrast to most other coastal areas, these sands, often located in close proximity to the shoreline extending up to about 10 km inland, are not saline and are often remarkably species-rich. Of particular importance are the open xeromorphic grasslands dominated by the perennial tussock grass *Panicum turgidum* and the dwarf shrub *Spharocoma aucheri*, and have been described as a 'coastal white-sand community'. This community, in which vegetation cover is relatively high, extends along a narrow coastal belt northwards into Kuwait. In Abu Dhabi Emirate, it is best developed in the north-east towards Dubai, and is of outstanding local conservation value. Common perennial associates include the shrubs *Calligonum comosum* and *Leptadenia pyrotechnica*, the dwarf shrubs *Rhanterium epapposum* (locally) and *Heliotropium bacciferum*, and the graminoids *Lasiurus scindicus, Pennisetum divisum, Stipagrostis plumosa*, as well as *Cyperus conglomeratus*. After wet winters, the coastal sand sheets are often rich in annuals, particularly in the north-east of the Emirate, with species such as *Eremobium aegyptiacum, Lotus halophilus, Neurada procumbens, Plantago boissieri* and *Silene villosa* sometimes abundant. Wind-blown drifts

Figure 20: Knowledge of the coastal vegetation of Abu Dhabi is fragmentary due to the extent of anthropogenic impacts over recent decades.

of these coastal white sands are occasionally found up to 50 km from the present coastline, but most of the characteristic species are lacking due to the more pronounced harshness of the climate in the interior. Tertiary rocky exposures ('jebels') occur in many scattered localities along a broad coastal zone, mainly to the west of Abu Dhabi Island. They vary in height considerably, but are usually up to about 5 - 8 m tall. Depending on the influence of salinity from their immediate surroundings (often sabkha), the vegetation can contain a large number of halophytes. On higher 'jebels', vegetation reminiscent of that of the coastal white sands has been found, but much more research is necessary.

4.2.2 Halophytic vegetation

The halophytic vegetation of Abu Dhabi Emirate broadly corresponds to the situation Deil (1998, 2000) described for Qatar. Highly saline habitats are generally characterized by azonal vegetation types, *i.e.* ones that are predominantly determined by extreme factors and are not associated with any particular climatic regions. Although it is often quite species-rich, a striking feature of halophytic vegetation is that the individual stands tend to be species-poor or even monospecific, *i.e.* one species can occupy large patches. Abrupt changes in key abiotic factors are reflected in corresponding changes in the vegetation cover, leading locally to the formation of small-scale vegetation mosaics and a characteristic zonation of the vegetation. The main abiotic factors controlling community composition in coastal habitats are salinity of the water and/or substrate, frequency and extent of inundation and the water-holding capacity of the substrate.

Halophytic perennials, belonging mainly to the Chenopodiaceae, but also *Zygophyllum qatarense*, play a major role in the coastal vegetation on substrates influenced by salinity. Most of these species are succulent, semi-woody dwarf shrubs. Occasionally, halophytic annuals such as *Biernertia cycloptera, Suaeda aegyptiaca* and *Zygophyllum simplex* are more conspicuous. True grasses (Poaceae) can also dominate the vegetation

locally, especially *Sporobolus iocladus*, a large, somewhat salt-tolerant grass which also occurs locally in coastal white sand vegetation. The perennial grass *Halopyrum mucronatum* which occurs on sands just above the high-tide mark appears to be very rare in the Emirate, known only from a handful of locations on Zirku and near the border with Dubai.

Above the high-tide mark, one to several low storm beach ridges, rising from just a few centimetres to decimetres above the surrounding coastal flats and running parallel to the coast, are a locally conspicuous feature, especially to the west of Abu Dhabi Island. The chenopods *Halocnemum strobilaceum*, *Halopeplis perfoliata* or *Suaeda vermiculata* form monospecific, sometimes quite dense stands on such ridges with cover values up to 95 %. In sheltered locations on the coastline which are only occasionally inundated, gelatinous cyanobacterial mats form biological soil crusts and dominate large expanses. If a veneer of aeolian sand can accumulate on the surface of the mats, higher plants such as *Halopeplis perfoliata* and *Halocnemum strobilaceum* are able to colonise them.

With increasing distance from the coastline, the ground gradually rises and the surface becomes more permanently covered with sand. *Zygophyllum qatarense* is the dominant species on somewhat saline sand sheets, attaining cover values in excess of 75% in favourable situations. It is occasionally accompanied by *Halopeplis perfoliata*, which becomes more prominent around the edges of hypersaline depressions. In the far west of the country, a community in which *Suaeda vermiculata*, *Seidlitzia rosmarinus*, *Salsola* cf. *arabica* and *Zygophyllum qatarense* co-dominate colonises saline sand sheets close to the coast. *Zygophyllum qatarense* and occasionally chenopods, for instance *Arthrocnemum macrostachyum* and *Halocnemum strobilaceum*, are the host plants of two striking parasitic species, namely *Cynomorium coccineum* and *Cistanche tubulosa*. The two parasites are particularly common in coastal areas, but also occur inland. In salt-marsh environments, species such as *Arthrocnemum macrostachyum*, *Halocnemum strobilaceum, Halopeplis perfoliata, Limonium axillare* and *Suaeda vermiculata* are locally very common. *Salsola drummondii* is also frequent along many sections of the coastline.

Sabkha is originally an Arabic term referring to flat, salt-encrusted desert that is usually devoid of any significant plant cover. The high concentration of salts on the sabkha surface prevents the growth of most plant species, and as a consequence, landscapes dominated by sabkha appear distinctly barren. This accumulation of salt is possible in areas where the water table lies close to the surface. Coastal sabkha is a major landscape feature in Abu Dhabi Emirate, and extends for over 300 km from near Sila, close to the border with Saudi Arabia in the west, to the border with Dubai Emirate in the east. The maximum width of coastal sabkha is about 25 km, intergrading with inland sabkha in some parts of the Emirate. Although sabkha occurs in deserts throughout the world, Goudie (2002) describes the coastal sabkha of Abu Dhabi as the best example of this landform type to be found anywhere, and deserving of World Heritage status. It lies less than a few meters above high-tide level. After heavy rainfall or severe northerly coastal storms in association with high tides, parts of the sabkha may become flooded for up to several weeks.

Plant life is mainly restricted to the margins of the sabkha, with halophytes predominating, including *Zygophyllum qatarense* and the *chenopods Agriophyllum minus, Arthrocnemum macrostachyum, Bienertia cycloptera, Salsola imbricata* and *Seidlitzia rosmarinus. Halopeplis perfoliata* is probably the most salt-tolerant of halophytes and common in moist depressions around coastal sabkha. The chenopod Anabasis setifera is a characteristic pioneer species of reclaimed sabkha in coastal areas, sometimes together with extensive stands of Salsola drummondii. A more detailed overview of the sabkha ecology of the Emirate has been provided by Brown (2006). Mangroves are well-developed along parts of the coastline. The only tree species to occur naturally here is Avicennia marina. Impressive stands of mangroves can be observed at a number of localities, including on Abu Dhabi Island. Detailed information has recently been provided by Böer and Aspinall (2006).

4.3 Marine Fauna

Vertebrates The coastal and marine ecosystems of Abu Dhabi support a spectrum of marine wildlife including large populations of turtles, dugongs and fish. With exception of a few studies on sea turtles and dugongs (Das and Al-Abdessalaam, In Press; Das *et al*., 2005; Preen, 2004, 1989; Miller, 1989), published work for other marine wildlife has been relatively low. In Abu Dhabi waters, dugong - a marine mammal, and two species of sea turtle (the Hawksbill and the Green) are of common occurrence and considered as flag-ship and umbrella species. Since 1999, the Environment Agency - Abu Dhabi (EAD) has been carrying out studies on the status and conservation of dugongs and sea turtles in the waters off Abu Dhabi. Following these studies, there is now an improved base of information on the distribution and abundance of

these species and the status of their habitats in the UAE. Some of the key developments which emanated from the studies include the preparation of conservation plans for the protection of these species in the UAE and the establishment of the Marawah Marine Protected Area. The results have also been instrumental in strengthening the country's regulations on the conservation of dugongs and sea turtles and other endangered marine species.

4.3.1 Mammals

The species of small cetacean occurring in the Arabian Gulf are not at present considered to be threatened at the global level. No large cetaceans are resident in the Gulf - the few existing reports are of isolated individuals and occasional strandings. However, recent studies by Preen (2004) reported a significant decline in dolphin populations within the gulf.

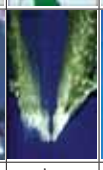
Dolphins Three species of dolphins, namely the Indo-Pacific humpback Dolphin (*Sousa chinensis*), the Bottlenose Dolphin (*Tursiops truncatus*) and the Common Dolphin (*Delphinus delphis*), occur in Abu Dhabi waters. The humpback dolphin is currently listed on Appendix I of CITES while the other two species are placed under Appendix II. Both humpback and bottlenose dolphins are relatively common and are sighted in water less than 15 m. The common dolphin occurs in deeper water and despite its name it is less abundant than the other two species. The Finless Porpoise (*Neophocaena phocaenoides*) is found in shallow, warm waters, however, the species has only been rarely recorded from the Gulf. It is listed on Appendix I of CITES, and is currently listed by IUCN as "Not Threatened".

In addition, other whales, porpoises and dolphins found in UAE waters, along with their IUCN status, include the following:

Dugongs: Believed to be the origin of the legend of

Figure 21: The Indo-Pacific humpback Dolphin (*Sousa chinensis*) which is found in the waters around Abu Dhabi. Listed on Appendix I of CITES (Photo copyright ©: Ron Carlson).

Examples of whales and dolphins of the UAE

English Name	Scientific Name	Picture	Distribution	IUCN Status
Risso's dolphin	*Grampus griseus (G.Cuvier, 1812)*			Data Defficient
Blainville's beaked whale	*Mesoplodon densiros-tris (Blainville, 1817)*			Data Defficient
False killer whale	*Pseudorca crassidens (Owen, 1846)*			Not Listed
Pantropical spotted dolphin	*Stenella attenuata (Gray, 1846)*			Lower Risk, conservation dependent
Rough-toothed dolphin	*Steno bredanensis (G.Cuvier in Lesson, 1828)*			Data Defficient
Bottlenosed dolphin	*Tursiops truncatus (Montagu, 1821)*			Data Defficient
Ginkgo-toothed whale	*Mesoplodon gink-godens Nishiwaki and Kamiya, 1958*			Data Defficient
Finless porpoise	*Neophocaena phocaenoides (G.Cuvier, 1829)*			
Indian humpback dolphin, plumbeous dolphin	*Sousa plumbea (G.Cuvier, 1829)*			
Spinner Dolphin	*Stenella longirostris (Gray, 1828)*			
Common Dolphin	*Delphinus delphis Linnaeus, 1758*			

the mermaid, the dugong (*Dugong dugon*) is one of the world's most endangered species of marine mammal. The United Arab Emirates supports a part of the largest known dugong population outside Australia. Few scientific records are available on the abundance, distribution and behaviour of the species (Preen, 2004; Das et al., 2004; Das and Al-Abdessalaam, In press). The first quantitative estimation of dugongs in the region including UAE waters was conducted by Preen (1989) under a research programme of the Meteorology and Environment Protection Agency (MEPA), Kingdom of Saudi Arabia. The findings of the dugong research programme of EAD (Anon, 2003; Das et al., 2004) and results of the survey conducted by Preen (1989, 2004) indicate the abundance, distribution and conservation status of dugongs in the UAE.

Seasonal aerial surveys for dugongs have been

Figure 23: The waters of Abu Dhabi support part of the largest known dugong *(Dugong dugon)* population outside of Australia.

conducted over an area of 6,454 km2 in the inshore waters of Abu Dhabi covering five zones and 36 transects in 2001 and 2004. The survey indicated that the number of dugongs in the region is almost stable. The population of dugongs was estimated to be 2,925 (+ 410) for winter and 2,291 (+ 329) for summer. In winter 2004, 60.4 % of sightings were of group size 1 and 31.2 % were of group size >1. The largest group observed had six individuals. Mother and calf groupings were observed in 8.4 % of the cases. Similarly, during the summer of 2004, 58 % sightings were of group size 1, 34.5% of group size > 1 and 7.5% were calves. Overall, 66.2 % of dugongs occur within the Marawah Marine Protected Area (zone 1 and 2) followed by 16.5 % in areas around the islands Muhayimat, Kafai and Ghagha (zone 5) - close to the Qatar border.

Survey Season (Year)	Estimated population (±SE)	Area covered (km2)	Overall Density (no./km2)
Summer (2000)	1861 (±411)	6075	0.31
Winter (2001)	2185 (±382)	6697	0.33
Winter (2004)	2925 (±410)	6454	0.45
Summer (2004)	2291 (±329)	6454	0.35

Table 1: Abundance (estimated population) of dugongs in Abu Dhabi waters (2000-2001 and 2004)

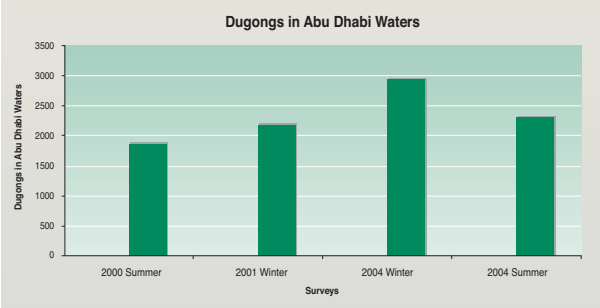


Figure 24: Estimated dugong population in Abu Dhabi 2000-2004

4.3.2 Reptiles

Marine turtles: Sea turtles in the Arabian Gulf in general are not extensively studied (Hasbun *et. al.,* 2000). However, studies on nesting and population status have been undertaken in detail in the UAE (EAD, 2002; 2004), Saudi Arabia (Miller, 1989) and in Oman (Ross and Barwani, 1995). Of the seven species of marine turtles, two species, the hawksbill turtle (*Eretmochelys imbricata*) and the green turtle (*Chelonia mydas*), predominate in the waters off the Emirate of Abu Dhabi. Worldwide, the IUCN

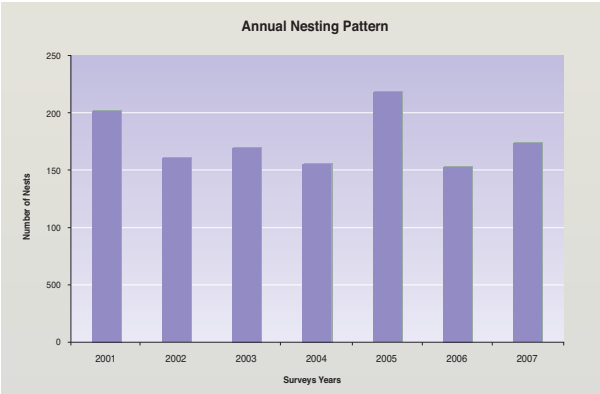


Figure 25: Inter-annual nesting variability of hawksbills in the Emirate of Abu Dhabi

Figure 26: Hawksbill turtle

Red-list (IUCN 2000) lists the hawksbill turtle as critically endangered and the green turtle as endangered. At the local and regional level, the populations of these species are threatened and the number of foraging habitats and nesting grounds are continually declining.

These two species use Abu Dhabi's waters extensively for foraging, and the hawksbill nests on sandy beaches with outcrops of vegetation on several offshore islands. Nesting is limited to fifteen offshore islands in the emirate of Abu Dhabi and Sir Bu nu'er in the emirate of Sharjah (EAD, 2004). Major nesting islands are Zirku, Jarnain, Arzanah, Bu Tinah, Diynah, Ghasha, Al-Yasat Al-Ulya, Al-Yasat Al-Sufla and Muhayyimat. The nesting season extends from March through till June with an average clutch size of 58 eggs and an incubation period of 8 weeks.

Foraging hawksbills occur in tidal and sub-tidal coral and rocky reef habitats in Abu Dhabi waters. The green turtles have the most widespread distribution of any sea turtle, being found in sub-tropical and tropical seas. The green turtle hasbeen found to forage in and around seagrass meadows and coral reef habitats in Abu Dhabi waters. There are no records of nesting of the species in the emirate of Abu Dhabi. Estimates of the foraging population made during an aerial survey in 2004 (Das *et al*., 2004) suggested that about 5,500 sea turtles inhabit Abu Dhabi waters in winter and 7,500 in summer.

Figure 27: Foraging green turtle surfacing to breath

Sea snakes: At least nine species of sea snake (Hydrophiidae) reportedly occur in Gulf waters (see list below). A further two species are present in the Arabian Sea (northern Indian Ocean) and might also occur in the Gulf.

Although elsewhere certain species have been observed in great abundance locally, very little is known about the population status of sea snakes in general and virtually nothing about their status in the waters of Abu Dhabi. None of the following species known to occur in the Gulf is currently identified as of special conservation concern: *Enhydrina schistose, Hydrophis cyanocinctus, H. lapemoides, H. ornatus, H. spiralis, Lapemis curtus, L. viperina (Praescutata viperina), Microcephalophis gracilis (Hydrophis gracilis), Pelamis pl.*

Three species of sea snakes, *Hydrophis lapemoides*, H. *ornatus* and *Pelamis platurus* occur in Abu Dhabi waters. Their identification was based on examination of dead specimens from the Abu Dhabi mainland and offshore islands. The average length of *Hydrophis lapemoides* (Arabian Gulf sea snake) and *Pelamis platurus* measured 96.5 cm, 75.1 cm and 38 cm respectively.

4.3.3 Fish

The Arabian Gulf is a comparatively young sea which originated about 16,000 years BP (Sheppard *et al.*, 1992). Sea level in the Gulf is generally believed to have not reached its present level until around 6000 years BP during the Holocene. This means that pre-Pleistocene historical factors do not account for the formation of the species of fish now living in the Gulf (Greenwood *et al.*, 1966). The present day fish fauna was established by the penetration of species from the Indian Ocean through the Gulf of Oman and Straits of Hormuz. Although high levels of endemism have been supposedly reported for Arabian Gulf fish, in actual fact a very low number of species exist solely within the Gulf. Kuronuma and Abe(1986) report that only 7 (1.5%) out of a total of 465 species (which they recorded as being present within the region) are endemic species. They noted that 89% of the species present were derived from both the Indian and Pacific Oceans, only 11% being restricted to the Indian Ocean.

Various opinions exist concerning the precise number of

Figure 28: Spangled emperor *(Lethrinus nebulosus)*

fishes present within the Arabian Gulf and it is clear that many earlier records of species are questionable (Randall 1995). Many published accounts unfortunately do not provide detailed distribution data and it is not possible to determine if a particular species occurs in the Arabian Gulf or in the Gulf of Oman or in both (*e.g.* Relyea, 1981; White and Barwani, 1971). What is clear, however, is that there appears to be somevariation in species richness throughout the Gulf. The deeper waters of the northern part of the Gulf and along the Iranian coastline are noted as being richer in species than the southern region. Studies have shown that habitat area (MacArthur and Wilson, 1967) and its differentiation into zones can affect species richness (Goldman and Talbot, 1976; Roberts, 1986). The harshness of the environmental conditions in the Gulf (*e.g.* extreme temperatures and high salinity) certainly appears to inhibit reef growth (Downing, 1985; Sheppard, 1988), and it is likely that this has reduced species richness within the region.

Despite the fact that marine ecological research in the region dates back as far as the Danish expedition in 1775, which involved Forsskål, comparatively little is still known about the Arabian Gulf marine fauna. Although there have been a number of publications specifically concerning Gulf fishes (*e.g.* Al-Baharna, 1986; Al-Sedfy, 1982; Kuronuma and Abe, 1972, 1986; Relyea, 1981; Sivasubramaniam and Ibrahim, 1982; White and Barwani 1971) these have been criticized in recent years for including many records based on old literature rather than on actual specimens (Randall 1995)

The few systematic fisheries surveys carried out in the Arabian Gulf using SCUBA-equipped observers have largely concentrated on reef fish assemblages. These appear to be far less diverse than elsewhere in the Indian Ocean, or even in the Red Sea at similar latitude. Downing (1987) counted only 85 species on Kuwaiti reefs. Basson *et al.* (1977), McCain *et al.* (1984) and Coles and Tarr (1990) only 70, 101 and 106 species respectively along the east coast of Saudi Arabia. Smith *et al.* (1987) recorded only 72 species in reefs off the coast of Bahrain. Roberts (quoted in Sheppard *et al.,* 1992) observed only 35 species during a 10 hour observation of inshore reefs in Qatar. Unfortunately, comparatively little is known about the fish fauna of the UAE Gulf coastline. The few popular publications which exist suggest however that the number of species present is also low in number (Dipper and Woodward, 1989). A number of fish landing surveys were carried out some twenty years ago by the Ministry of Environment and Water in the UAE (Ali and Thomas, 1979; Ali *et al.,* 1980; Ali & Cherian, 1983). These consist of landing data from Khorfakkan and Kalba on the east coast of the Emirates. A problem with the interpretation of such data is that many non economic fish species may not be included, and there is also the problem of discarded by-catch. Furthermore such landings data do not provide adequate samples from all coastal habitats and of all species for statistical analysis.

A detailed study of fishes in Oman identified 930 fish species within the entire region, with at least 95 families and 361 species being recorded as present within the Arabian Gulf (Randall, 1995). One of the most comprehensive recent attempts to systematically update the taxonomy and list of fishes occurring in the Arabian Gulf is the “FAO Species Identification Field Guide for Fishery Purposes for Kuwait, Eastern Saudi Arabia, Bahrain, Qatar, and the United Arab Emirates” (Carpenter et al., 1997). This publication covers 17 families including 46 species of Chondrichthyes, and 101 families with 493 species of bony fishes.

A review of the demersal fisheries of the Arabian Sea, Gulf of Oman and Arabian Gulf noted the presence of over 350 commercial fish species in this entire area (Siddeek et al., 1999). Primary families represented were emperors (Lethrinidae), seabream (Sparidae), groupers (Serranidae), rabbitfish (Siganidae), croakers (Sciaenidae), butterfishes/ pomfrets (Stromateidae), snappers (Lutjanidae), cutlassfishes (Trichiuridae) and breams (Nemipteridae).

Between 2002 and 2003, the Marine Environment Research Centre, MERC, part of the then Environmental Research and Wildlife Development Agency, ERWDA

Figure 29: Black spot snapper *(Lutjanus fulviflamma)*

(now known as the Biodiversity Management – Marine Sector of the Environment Agency - Abu Dhabi, EAD) conducted a Fish Resources Assessment Survey in Abu Dhabi and UAE waters. A total of 239 fish species were recorded within the area during trawl surveys (Shallard & Associates, 2003b).

Dr. Shigeyasu Tamaei, a Japanese fisheries scientist who has been working in the UAE for more than twenty years, has recorded a total of 218 species from 71 families of sharks, rays and bony fishes within the Gulf region of UAE waters (Tamaei, 2004). Fishes were observed at fish markets and by diving, some small fishes being collected with a fine mesh sieve net towed from beaches and on seagrass beds. He noted that the greatest variety of fishes could be observed during the winter season from November to April, and that the variety dwindled in the hot summer months. In 2004, the Commission for Environmental Research (CER), now known as the Department for Environmental Research (DER), of the Emirates Heritage Club, published "The Marine Atlas of Abu Dhabi" (Loughland *et al.,* 2004). This included detailed descriptions of Abu Dhabi's shallow water habitats, mangroves, intertidal and subtidal benthic communities, seagrass, coral reefs, fish fauna, marine turtles, sea snakes, marine mammals and birds, along with recommendations for their conservation. A summary of the research on the fishes of the region, including fisheries research can be found in Beech (2004b).

There is still much to learn about the present day fish fauna of the Arabian Gulf. Many UAE fish species have spawning seasons between April-June, and the timing of this may be linked to sea water temperature. Further studies are urgently required, however, concerning the physiology of the fishes, age determination of the fishes by study of their otoliths and scales, as well as hydrographical and ecological studies of local conditions before firmer conclusions can be drawn (Ali *et al.,* 1984). We only have detailed information about a limited number of species. As the fisheries of the area has such a broad range of target species there is still some way to go on our understanding of their biology, ecology and community interactions.

There is an urgent requirement for long-term underwater monitoring programmes for key habitats and fish species. Only by having a time series of data can the situation be adequately modeled. Sheppard *et al.* (1992) have recognised that important ecological gradients or controls in species distribution and abundance have to be taken into consideration in understanding the biogeography of fishes in Arabia. One of the key problems is the lack of ecological data on fish habitat preferences. Preliminary work by Basson *et al.* (1977), McCain *et al.* (1984), Downing (1987), Smith *et al.* (1987) and Smith and Saleh (1987), all suggest that certain fish may be associated with particular habitats and that their occurrence may be highly seasonal. Underwater monitoring should go hand in hand with the evaluation of the effectiveness of a network of protected marine areas. Only through the successful management of these areas will there be hope for the future survival of fisheries in the region.

4.3.4 Marine and coastal avifauna

Diversity of marine and coastal avifauna

Birds are an important component of overall biodiversity as they constitute nearly 81% of the overall higher vertebrate biodiversity (mammals, birds, reptiles) in the United Arab Emirates. Nearly 409 species of birds are known to occur in Abu Dhabi Emirate alone out of the total 435 species recorded for the country. This relatively high number of species recorded from the emirate is because of the diversity of habitats which include an extensive coastline, mud flats, mountains and inland wetlands. Abu Dhabi Emirate occupies roughly 80% of the total geographical area of the country.

The extensive coastline of Abu Dhabi is one of the most important wintering and feeding sites for numerous water birds. The inter-tidal mudflats, tidal lagoons and mangroves support up to 300,000 water birds during the main migratory season (Scott, 1995; Aspinall, 1995).

There are 145 (about 35%) species of birds out of 409

species which are categorized as water birds and can be seen along the coast, on islands and inland wetlands. Nearly 76, or 52%, of the 145 species are largely coastal and marine species more frequently seen along the coast or on islands. As many of the species occurring on the coast are also found on the islands, especially breeding terns, birds of islands and coastal habitats are not separated here. This is also true as islands may not differ from the coast in general geomorphology and their categorization as separate habitat is based on their value as important breeding areas for many seabirds.

Of the 76 marine or coastal species, the majority are shorebirds, mainly waders such as Turnstone *(Arenaria interpres),* Oystercatcher *(Haematopus ostralegus),* Lesser Sand Plover *(Charadrius mongolus),* Greater Sand Plover *(Charadrius leschenaulti),* Little Stint *(Calidris minutus)* and Dunlin *(Calidris alpina)*. They use extensive inter-tidal mud flats along the coast and around several islands such as Marawah, Al Yasat, Muhayyamat and Jenana. Several species of terns, especially the migrant breeders such as Lesser Crested Tern *(Sterna ben galensis)* White-cheeked Tern *(Sterna repressa),* Bridled Tern (*Sterna anaethetus*) and Crested Tern *(Sterna begrii)* are confined to the near shore and offshore islands during the summer where they congregate in large numbers to breed.

Due to the strategic location of the UAE in the Center of the Afro-Eurasian Flyway, the country receives a significantly large number of Palearctic migrants from their breeding grounds across Europe. Additionally, species from the Central Asian Flyway *i.e.* those which breed in Central Asia also winter or stopover in the UAE during annual spring and autumn migration. Nearly 89% of all the water birds in the Emirate are migratory and only 11% are resident indicating the importance of the Emirate and its coastline for migratory water birds. Such a high proportion of migratory water birds is due to the diversity of coastal and marine habitats along the coastline and islands (Javed, unpublished) and also possibly due to higher primary productivity of the Gulf waters (Butler *et al.* 2001). Of the 145 water birds in the Emirate, a vast majority of resident breeders are those which are restricted mainly to inland wetlands. Nearly 15 coastal and marine species breed in the Emirate (**Table 2**). Most of these species are regarded as a national priority for conservation (Aspinall 1996, Aspinall *et al.,* 2001) based on the presence of 1% of the breeding population levels in the Emirate. Breeding colonies of the globally threatened and regional endemic Socotra Cormorant *(Phalacrocorax nigrogularis),* Crab Plover *(Dromas ardeola),* Red-billed Tropicbird *(Phaethon aethereus),* and five tern species (**Table 2**), Sooty Gull *(Larus hemprichii)* have national, regional as well as global importance.

The 15 important coastal and marine breeding birds also include two raptors. The inclusion of the Osprey *(Pandion haliaetus)* and Sooty Falcon *(Falco concolor),* as resident and migratory breeders in the Emirate is because of their dependence on undisturbed coastal and marine habitats for breeding. Both are also listed as national priority species based on fulfilling the criteria of 1% of the breeding population.

Common name	Scientific name	Status
Red-billed Tropic bird	*Phaethon aethereus*	Migratory Breeder
Socotra Cormorant	*Phalacrocorax nigrogularis*	Resident Breeder, Post breeding dispersal
Western Reef Heron	*Egretta gularis*	Resident Breeder
Greater Flamingo	*Phoenicopterus ruber*	Resident Breeder, Winter Migrant
Osprey	*Pandion haliaetus*	Resident Breeder
Sooty Falcon	*Falco concolor*	Migratory Breeder
Crab Plover	*Dromas ardeola*	Migratory Breeder, some wintering in UAE
Kentish Plover	*Charadrius alexandrinus*	Resident Breeder and Migrant
Sooty Gull	*Larus hemprichii*	Migratory Breeder
Caspian Tern	*Sterna caspia*	Migrant and Occasional Breeder
Crested Tern	*Sterna bergii*	Migratory Breeder
Lesser Crested Tern	*Sterna bengalensis*	Migratory Breeder
White-cheeked Tern	*Sterna repressa*	Migratory Breeder
Bridled Tern	*Sterna anaethetus*	Migratory Breeder
Saunders' Little Tern	*Sterna saundersi*	Migratory Breeder

Table 2: Important breeding bird species of the coastal and marine habitats in Abu Dhabi

Figure 30: Important Bird Areas (IBAs) in the Emirate of Abu Dhabi

Other than the breeding species, the coastal and marine habitats of the Emirate also support nationally important numbers of Lesser and Greater Sand Plovers, Dunlin, Bar-tailed Godwit *(Limosa limosa)* and several species of gulls such as Great Black-headed Gull *(Larus icthyaetus)* and Slender-billed Gull *(Larus genei)* (Javed 2004, Aspinall *et al.* 2001).

Threatened avifauna of marine and coastal habitats Of the 15 important breeding birds, only the Socotra Cormorant is globally threatened and is listed as vulnerable (VU) as per the list of globally threatened species (Birdlife International, 2005). Birdlife International (2005) lists 15 species from the country as threatened, of which 5 species are water birds and the remainder land birds. The Persian Shearwater *(Puffina persicus),* the Corn Crake *(Crex crex),* Ferruginous Duck *(Aythya nyroca)* and Great Snipe *(Gallinago media)* are listed as Near-threatened (NT). However, most of these four species are vagrant or occur infrequently. Nearly 60% of all the important breeding coastal and marine bird species are also listed in Appendix II of the Convention on the conservation of the Migratory Species (CMS) and are regarded as important species in the newly proposed Action Plan for the Central Asian Flyway (CAF).

Islands, in particular are of high importance for the conservation of breeding seabirds, especially, those islands in the Emirate which support breeding colonies of Socotra Cormorant, Crab Plover, Red-billed Tropicbird, terns, Sooty Gull, Osprey and Sooty Falcon (Javed & Khan, 2003). Abu Dhabi Emirate has 9 Important Bird Areas (IBA's) recognized by Birdlife International (Evans, 1994). Using the same criteria, five new IBAs (**Figure 30**) were added in the Emirate (Javed and Khan, 2003) making a total of 14 IBAs alone in the Emirate. Of the 14 IBAs, 12 are on islands and their categorization is based on the breeding seabird colonies. Javed and Khan (2003) assessed 26 islands for their importance to birds, particularly breeding seabirds and identified 15 islands important for conservation of seabirds. These 15 islands also include all the IBAs. The study also established that 15 important islands account for nearly 85% of all the known tern colonies, and 99% of their breeding numbers in the Emirate. These 15 islands are also important for all the known breeding numbers of Sooty Gull, Red-billed Tropicbird and 97% of all the breeding numbers of the globally threatened Socotra Cormorant.

Nearly all important species of breeding and wintering coastal and marine birds are protected under the Federal Law no. 9 (with the sole exception of the Socotra Cormorant) and also under the Federal Law No. 24. The two laws prohibit killing, catching or the collection of eggs, however, occasional cases of violations are reported. Although current regulations may provide an adequate framework for conservation of breeding seabirds in the UAE, there is a need for strict enforcement and an education programme targeted both at the general public and administrators.

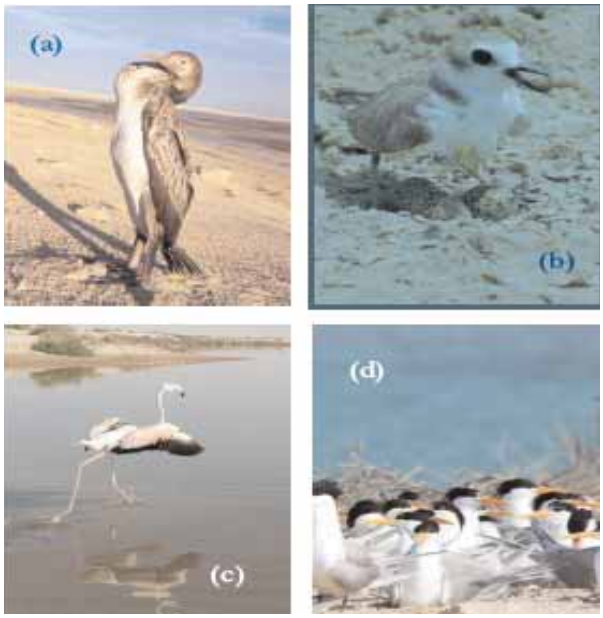


Figure 31: Some important breeding species of the coastal and marine environment of Abu Dhabi

(a) Socotra Cormorant (*Phalacrocorax nigrogularis*) (b) Kentish Plover (*Charadrius alexandrinus*) (c) Greater Flamingo ***(****Phoenicopterus ruber****)*** (d) Lesser Crested Tern Tern (*Sterna bengalensis*)

Nearly 20% of all the important islands are currently protected legally (most of them as part of the Marawah–Biosphere Reserve). Many islands are under private ownership and in most cases relatively well protected. It is important to increase the coverage of the important islands under the protected area network in the near future and include some of the islands which have already been recommended.

Flamingo tracking

Greater flamingo is an important wintering species in the UAE. It has also bred on few occasions at Abu Dhabi's Al Wathba Wetland Reserve. To understand origin of UAE flamingos and understand their movement and migration patterns, Environment Agency – Abu Dhabi started a satellite tracking programme under which flamingos have been tagged and tracked since November 2005.

Satellite tracking has clearly demonstrated the importance of key coastal an inland wetlands throughout the UAE (**Figure 32**) and highlighted the importance of protection of important coastal and inland wetlands in the Emirates to protect migratory birds and overall marine biodiversity.

Wild Bird Monitoring for Avian Influenza

Monitoring of important wintering and breeding sites for birds have been regularly undertaken by the Environment Agency – Abu Dhabi, however after the incidence of highly pathogenic Avian Influenza (HPAI) in many parts of the world, wild birds are regularly monitored throughout the UAE from permanently identified sites under the National Avian Influenza Action Plan. The programme has continued since October 2005 for protection based on the prioritization of important sites for coastal and marine avifauna (Javed & Khan, 2003). As Important Bird Areas do not have any legal status, bringing them under the umbrella of the protected area network would be an important step in ensuring the long-term conservation of important coastal and marine avifauna.

Invertebrates

Due to the harsh environmental conditions that exist in the shallow waters of the southern Arabian Gulf (year-round high salinities and particularly high air and seawater temperatures in the summer), the invertebrate fauna tends to be less diverse than that present in the Gulf of Oman and in the Indian Ocean as a whole. However, the presence of species able to withstand these harsh conditions is of interest in itself. A publication in 1977 on the biotopes of the western Arabian Gulf by Basson *et al.* (an area which in many ways has environmental conditions similar to those in Abu Dhabi Emirate) contains lists of invertebrate species from different habitats along the Saudi Arabian Gulf coast, many of which are likely also to occur along the coastline of the Emirate. Similarly, a field guide primarily to the seashores of Kuwait (Jones, 1986) refers to many invertebrates that could well occur in the Emirate.

Despite the importance of the part played by marine invertebrates in the food webs in the southern Gulf, very little attention has been paid to them in the past unless they were directly consumed by man or were of some commercial value. Hence, information on the invertebrate species in Abu Dhabi Emirate that were of no apparent commercial importance was, until recently, very scarce and produced mainly from collections made by interested local inhabitants, members of the Emirates Natural History Group or by scientists from elsewhere taking

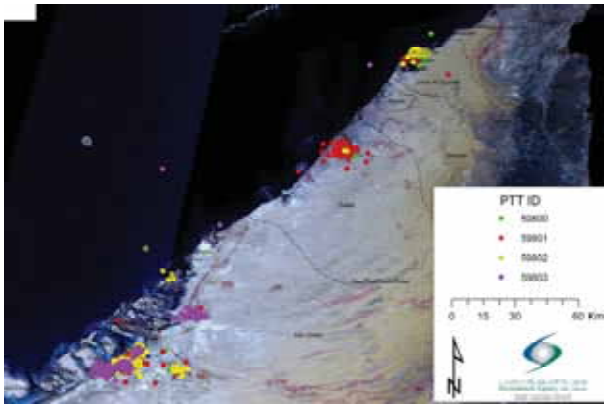


Figure 32: Key coastal and inland wetlands as determined through flamingo satellite tracking.

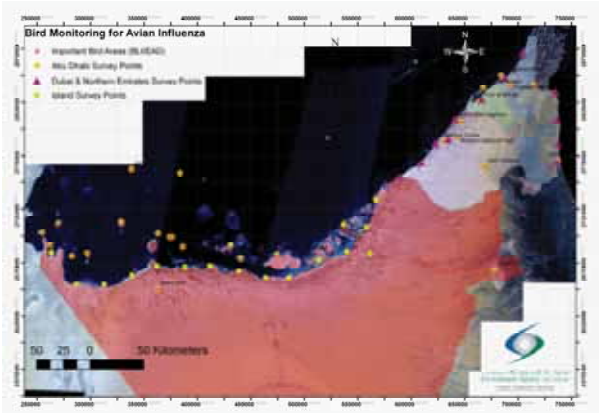


Figure 33: Wild bird monitoring sites

part in expeditions to the Emirate. Notable amongst the scientists were coastal geomorphologists from Imperial College, London whose invertebrate collections made in the early 1960s were passed to invertebrate taxonomists in the British Museum (Natural History) [now Natural History Museum, London] for identification (*e.g.* see Biggs, 1973; Kinsman, 1964; Purser and Evans, 1973) and incorporation into the NHM's permanent collections, where they would be available for later investigators to study. More recently, marine biologists from the NHM carried out detailed studies along the length of the Emirate between 1996 and 2001 (grant-aided by ADCO) on the invertebrate (and algal) communities with particular reference to those of coral reefs and other 'rocky substrata' both intertidal and subtidal (*e.g.* see George & John, 2004, 2005b; John & George, 2004, 2005). The site-based distribution and identification data from these investigations has recently been sent to EAD in spreadsheet form for incorporation into its marine GIS database (George, 2005a).

Since the discovery of rich reserves of oil and gas in the waters off Abu Dhabi Emirate, concerns about degradation and pollution of the marine environment have resulted in the introduction of the requirement for environmental impact assessments before developments by that particular industry. These have been conducted by contractors on behalf of the industry and have resulted in a plethora of information of varying quality on the identity and ecology of invertebrates living in particular marine areas of the Emirate. Much of the relevant information contained in these confidential reports (the so-called 'grey literature') has not as yet been checked by specialists and/or found its way into the marine databases of EAD because of the reticence of oil and gas companies to release 'commercial-in-confidence' information collected on their behalf during their exploration and monitoring activities. Unfortunately, most of the specimens collected during marine surveys of this type in Abu Dhabi waters have probably long since been discarded and the identity of specimens can no longer be checked and inserted into EAD databases with confidence. [It would certainly be advantageous if future legislation required companies to retain in good condition marine biological specimens collected during surveys for a certain number of years subsequent to the surveys or require the specimens to be lodged in a well-curated specimen storage facility maintained by EAD staff.]

At present very little is known about the ecological impacts of coastal and offshore developments on invertebrate populations in the Emirate despite the rapid rate at which developments are taking place. Many invertebrate species, and the vertebrate species that depend on them, may have already reached critically low numbers as their natural habitats disappear. The prolonged higher-than-normal summer seawater temperatures in the seas flanking the Emirate in the last decade in particular (first noted in the scientific literature by George & John, 1999), possibly due to global warming, is also taking its toll on invertebrates, particularly corals.

4.3.5 Crustacea

The Crustacea, belonging to the great group of invertebrates known as the Arthropoda, is possibly the best-known invertebrate group in Abu Dhabi Emirate because of the use of many of its species as a food by the population (Carpenter et al., 1997). Shrimps and prawns (now synonymous terms) are one of the staple foods of the population with *Penaeus semisulcatus* being the dominant shrimp on sandy bottoms and *Metapenaeus affinis* also being caught over muddier bottoms in shallow inshore waters. The spiny lobster, *Panulirus versicolor* is found in shallow rocky areas and on coral reefs where SCUBA divers sometimes see it hiding in crevices during the day. It rarely appears in markets however, since it avoids entering traps and as a result is a highly prized item when caught. Several crab species on the other hand, are quite common in the Emirate and the swimming crab, *Portunus pelagicus*, is taken commercially for human consumption. Other species of crab are sometimes consumed, but are more usually captured by recreational fishermen for use as bait.

Figure 34: *Ocypode rotundata*

Stephensen (1949) published a large paper on the Brachyura (true crabs) of the 'Iranian' Gulf, based on a collection made by Danish Expeditions during fisheries investigations carried out on behalf of the Iranian government in 1937 and 1938. This necessarily concentrated on the Iranian side of the Gulf (apart from a brief diversion across the Gulf to Bahrain) that has a fauna more diverse than that in the southern Gulf because of the less stressful environmental conditions that exist in the sea there. An unpublished D.Phil. thesis by Titgen (1982) lists the decapods found in Dubai Emirate as well as information on their ecology. Al-Ghais and Cooper (1996) investigated the identity and ecology of brachyuran crabs in areas of mangrove cover in the khor at Umm al-Qaiwain and Hogarth and Beech (2001) recorded the first modern record of the mangrove crab *Scylla serrata* in the UAE from a mangrove area in Ra's al-Khaimah.

The earliest published records of crabs known to be from Abu Dhabi Emirate (around some of its offshore islands) was by Nobili (1905, 1906) who examined the collections made by Mission J. Bonnier et Ch. Pèrez, (Golf Persique, 1901). Cooper (1997) published a paper on 13 mangal-associated crab species collected from the small islands to the north-east of Abu Dhabi city during 1993 and 1994. Apel and Spiridonov (1998) produced an up-to-date contribution to the taxonomy and zoogeography of the portunid brachyuran crabs of the Arabian Gulf and adjacent waters with several records of these crabs from Abu Dhabi Emirate (including a new species description) from collections made by Apel in June 1995. Apel and Türkay (1999) added further records of crabs found in Abu Dhabi Emirate in their paper on grapsid and ocypodid crabs from soft bottoms in the Arabian Gulf.

It is difficult to find references in the published literature to the identity and distribution of crustaceans other than brachyuran crabs within Abu Dhabi Emirate, but Basson *et al.* (1977) contains lists of crustacean species additional to those of brachyuran crabs collected from different habitats along the Saudi Arabian Gulf coast, many of which are likely also to occur along the coastline of the Emirate. Similarly, a field guide to the seashores of Kuwait (Jones, 1986) refers to many other benthic crustaceans besides brachyuran crabs that could also occur in the Emirate because of the similarity in ecological conditions, and Stubbings (1961) published on some barnacles from the Arabian Gulf.

Evans *et al.* (1973) in their paper on the ecology, sedimentology and geomorphology of the 'Barrier Island complex' of Abu Dhabi Emirate listed many crustacean species other than brachyuran crabs, identified by the then NHM staff, particularly species of ostracod. Hornby (1997) produced an annotated checklist of Crustacea on the mainland coast of the UAE that included approximately 30 species that he had found at various localities in the Emirate of which 18 species were not brachyuran crabs. George and John (2004, 2005b) and John and George (2004, 2005) refer to many species of crustaceans in their accounts of benthic communities in the Emirate. To date 54 crustacean species encountered during the NHM's research on invertebrate communities throughout the Emirate have been entered on the marine GIS database of EAD. Hogarth and Beech (2005) surveyed the southern Gulf coastline from Ghagha Island and Ras Ghumeis on the Sila peninsula in the western region of Abu Dhabi to Sham in Ras Al-Khaimah, close to the border with the Musandam/Sultanate of Oman. In addition to taxa identified in the published literature, they report a total of 107 crustacean species from 18 families.

Several groups of benthic Crustacea that are important in the marine food webs of the Emirate such as the Amphipoda and the Copepoda have yet to be studied in detail.

Figure 35: *Porites Harrisoni*

4.3.6 Cnidaria

The phyllum *Cnidaria*, formerly known as the Codenterata, contains three well-known groups: the Scyphozoa, Hydrozoa, and Anthozoa. There are few species of Scyphozoa (jellyfish) represented in the waters of Abu Dhabi Emirate, but a single species can occur in very large numbers on occasions and their "blubbery" bodies have been known to temporarily block the seawater intakes of coastal power stations and desalination plants. The stinging tentacles of some jellyfish can also be a hazard to swimmers. Hydroids (belonging to the Hydrozoa group) are to be seen everywhere on hard natural and artificial substrata and on seaweeds within Abu Dhabi Emirate,

but rarely dominate in any particular habitat although they are often referred to as “fouling” organisms. To date 13 species of hydroid have been recorded during the NHM’s surveys.

The Anthozoa contains the anemones and the all important scleractinian corals that are responsible for building the reefs that house so many other organisms besides the hard corals [See Sections 3.3, 6.1, and 6.4 for more information regarding coral reefs in Abu Dhabi Emirate]. Until relatively recently little has been published on the number and identity of coral species that occur in Abu Dhabi Emirate. Although it is clear that the species have originated from Indian Ocian stock (Rosen, 1971), species diversity is limited by the severe environmental conditions that they need to tolerate in order to survive in the souther Gulf (Kinsman, 1964). Kinsman (1964) was probably the first to publish on corals in Abu Dhabi Emirate, listing 11 species of scleractinian coral. Importantly, in the light of recent events, he drew attention to the high seawater temperatures and salinities that occurred there and identified these as possible factors affecting the development of corals in the Emirate. Evans *et al*. (1973) whilst studing the ecology of parts of the ‘Barrier Island complex’ of the Emirate increased the number of coral species recorded to 18.

Occasional mention has been made in the 1990’s to the genera and species of coral occurring the Abu Dhabi coastal waters, but mostly in the extensive ‘grey literature’ of environmental reports commissioned by oil companies and coastal developers. Sheppard, price, and Roberts (1992) estimated that about 30 species of coral existed off the Gulf Emirates. Sheppard (2000) stated that this part of the Gulf (southern Gulf?) was known to have about 50 coral species prior to recent bleaching events, and after a rapid 15hr survey in November 2000 of five reefs in the central and eastern regions of Abu Dhabi found 18 species still living (Sheppard and Loughland, 2002).

Detailed investigations of corals along the full length of Abu Dhabi Emirate began by NHM scientists in 1996 seconded 31 species of scleractinian coral still surviving the in the Emirate, albeit often in small isolated pockets, after the last episode of severe coral bleaching/mortality in 1998 (George, 2005a), with the greatest diversity of species still to be found at the eastern end of the Emirate where less severe environmental conditions prevail as reported early on in their study (George & John, 1998, 1999, 2000b). Cose by at a poorly developed reefal complex near Jebel Ali in Dubai Emirate Riegl (2002) found survivors of 27 species after the bleaching mortality events of 1996 and 1998.

Accounts of the ecology of some of the more abundant corals and other cnidarian species in Abu Dhabi Emirate are to be found in The Marine Atlas of Abu Dhabi Emirate (George & John, 2004; John & George 2004) and in The Emirates – A Natural History (George & John 2005b; John & George 2009; John & George 2005). Details of the distribution of Cnidarian species found between March 1996 and February 2001 by NHM staff have been lodged in spreadsheet form with EAD (George, 2005a).

Figure 36: *Cerithium scabridum.*

4.3.7 Mollusca

The Mollusca, with three major classes, the Gastropoda, Bivalvia and Cephalopoda, is one of the better known phyla of marine invertebrates in Abu Dhabi. One of the reasons for this is the use of certain species of the group as a food source by the local population (Carpenter *et. al.,* 1997) that dates back to Neolithic times (*e.g. Asaphis violascens, Pinctada radiata, Lunella coronata* - see Beech *et. al.,* 2005) and to later harvesting of certain species for pearls. Since the decline of the pearling fishery concentrated on the “Great Pearl Banks” (see Carter, 2005), some information on the occurrence and distribution of hard-shelled species in the very shallow waters of the Emirate has been derived from both amateur and professional shell-collectors searching for shells to add their own collections and, in some cases, for sale in the shell-trade. Certain genera in some families such as the Conidae (Cone shells), Muricidae (Rock shells) and Cypraeidae (Cowries) may have become scarce as a result of over-collecting.

It was not until the early 1970s that a publication by Biggs (1973) gave a long list of species, with locality and habitat details, gathered solely from within the Emirate. He was reporting on a collection made by Dr. G. Evans and his team from Imperial College, London in

Abu Dhabi Emirate in the 1960s (see Evans *et. al.,* 1973) and listed 1 polyplacophoran, 103 gastropods (including 3 opisthobranchs) and 108 bivalves. Smythe (1979) examined molluscs collected between 1971 and 1973 (chiefly by Major M. D. Gallagher) from neighbouring Dubai, Sharjah, Ajman, Umm al Qaiwain and Ras al Khaimah, all situated further to the northeast on the southern Gulf coast than Abu Dhabi. From here she identified 225 gastropods (including 27 opisthobranchs), 119 bivalves and 3 cephalopods and gave relevant locality and habitat details. Although this publication is not directly applicable to Abu Dhabi Emirate, where mollusc diversity is likely to be lower because of the more extreme environmental conditions prevailing in the west of the Emirate, she notes that almost 50% of the species she identified were also recorded in Abu Dhabi by Biggs. More recently, a general invertebrate collection was made by Dr. J. D. George of the NHM between 1995 and 2001 from mainly intertidal and subtidal hard substrata (including coral reefs and their environs) during the course of investigations into the marine communities existing in this habitat. This collection, of mainly the commoner species, was made along the full length of Abu Dhabi Emirate and revealed many mollusc species. These were mostly examined and identified by Prof.

J. D. Taylor and E. Glover of the NHM (see p. 358-359 in George, 2005), revealing 6 polyplacophorans, 87 gastropods (including 10 opisthobranchs), 69 bivalves and 3 cephalopods. All the specimens from the 3 collections referred to above are housed in the permanent collections of the NHM along with corresponding locality and habitat information and are available for examination by researchers. However, further work is needed to ensure that the specimen identifications reported by Biggs are upgraded in the light of recent taxonomic developments before they are inserted in the marine databases of EAD. A principal identification guide to marine mollusca in the region is given by Dance (1995).

4.3.8 Echinodermata

An exclusively marine phylum of invertebrates that includes the familiar starfishes, sea-urchins and sea-cucumbers. The historical record of echinoderms in the Arabian Gulf is reasonable and Mortensen (1940) in his account of the starfishes (Asteroidea, Ophiuroidea) and sea-urchins (Echinoidea) of the 'Persian Gulf' gives a good summary of the published records prior to his paper. Within Mortensen's paper, Gislén deals with the feather-star (Crinoidea) records, and Heding (1940) in another paper with the sea-cucumbers (Holothuroidea) recorded

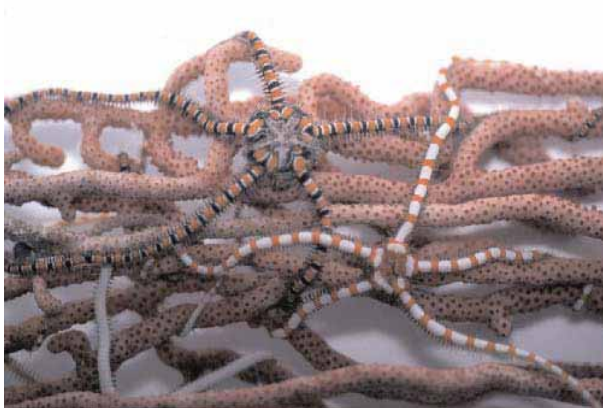


Figure 37: *Ophiothela venusta*

in the Gulf. Between them these three authors recorded some 68 species. However, except for a few isolated records off the coast of Bahrain these papers deal almost exclusively with echinoderms on the eastern side of the Arabian Gulf off Iran that is likely to have a richer fauna than the western and southern Gulf due to more favourable environmental conditions. The first published records from the shallow waters of the western Arabian Gulf were by Clark and Bowen (1949) who described 15 echinoderm species from the Tarut Bay area of Saudi Arabia and included some excellent field observations and habitat notes. Clark and Rowe (1971) in their monograph of the shallow-water Indo-West Pacific echinoderms added a few more records to the total previously known from the Arabian Gulf. Basson *et. al.* (1977) during their extensive investigations of marine life along the Gulf coast of Saudi Arabia refer to the occurrence of many echinoderm species and since that time one of these authors has published in detail on the echinoderms collected during these earlier investigations (Price, 1981, 1982, 1983), recording a total of 57 species (14 asteroids, 17 ophiuroids, 12 echinoids, 13 holothurians and 1 crinoid).

The earliest records of echinoderms from the southern Gulf Emirates were by Hughes Clarke and Keij (1973) from off the southern Gulf as a whole (12 species) and Evans *et. al.* (1973) from the 'Barrier Island complex' of Abu Dhabi Emirate (21 species identified by the NHM's Ailsa M. Clark). Until recently, the records of Evans *et. al.* (1973) were the only echinoderm records from Abu Dhabi Emirate apart from those in the 'grey literature', although John and George (2003) make reference to the algal grazing activities of the sea-urchins *Echinometra mathaei* and *Diadema setosum* along the coastline of Abu Dhabi. More recently, more information has been published on the identity, ecology and distribution of 18 shallow-water echinoderm species in Abu Dhabi Emirate (George, 2005b;

George and John, 2004, 2005 a, b; John and George, 2004, 2005). In particular, George and John (2005a) have drawn attention to the large increase in numbers of *Echinometra mathaei* since the dramatic death of many corals in 1996 and 1998 in the Emirate and the way in which the grazing activities of this urchin species in particular is hastening the collapse and destruction of dead coral reefs.

It is likely that the tally of echinoderm species present in the waters off Abu Dhabi Emirate will rise from the total so far recorded (about 30 valid species) as more attention is given by specialists to the epifaunal and infaunal echinoderm species of both inshore and offshore soft sediments.

4.3.9 Porifera

Of all the major phyla of invertebrates occurring throughout the seas flanking Abu Dhabi Emirate, the filter-feeding sponges (Porifera) are the least well-known taxonomically due to the difficulties associated with their identification. In the majority of cases it is not possible to identify sponges with any certainty from their external characters alone, as the shape and colour of a species can vary considerably depending on the habitat in which it lives. At present, identification of a species often depends on microscopic examination of the various 'spicules' that make up its internal supporting framework. Unfortunately, there are few specialists capable of identifying sponges with any certainty at the present time. Despite this fact, particular groups of species such as the 'bath' sponges have been in human use for millennia and were once cultivated in some quantity in the Mediterranean and the Caribbean as a body-washing aid because of the remarkable water-retentive powers of their flexible skeleton (now a scarce and costly resource and largely replaced by the coarser loofah [plant pod] and synthetic substitutes). More recently, interest of the pharmaceutical industry has been aroused by the discovery of chemicals within the tissues of sponges that are promising as future drugs for treatment of human disorders.

Figure 38: *Dysidea chlorea*

Within the region of the western or southern Arabian Gulf,various authors have made reference to sponges (usually without identifying the species involved) as being common on hard substrata, fouling artificial structures, and/or causing damage by boring into commercial shellfish such as pearl oysters (*e.g.* Evans *et. al.,* 1973; Hughes Clarke and Keij, 1973; Basson *et. al.,* 1977; Jones, 1986; Dipper and Woodward, 1989). During investigations by NHM scientists along the coast of Abu Dhabi Emirate between 1996 and 2001, numerous sponge species were found to be common under slabs of intertidal rock, on rocks and dead coral subtidally, and on any hard (or even relatively soft - polythene buoys) artificial substrata permanently immersed in the sea (George, 2005b; George & John, 2004, 2005 a, b; John & George, 2004, 2005). The specimens collected during this period allowed an Indo-Pacific sponge specialist (Dr Michelle Kelly-Borges), who was then a staff member of the NHM, to identify 95 distinct species units most of which are new records for the Arabian region and a number of which are almost certainly new species (see George, 2005 p.356 for her species list).

Sponge numbers have increased considerably on the many coral reefs in poor condition since the mass mortality of corals in summer 1996 and 1998 (see sections: 3.3, 4.3.6, 6.4). In particular, the boring sponge *Cliona* sp. is rampant within the branches of dead Acropora causing them to eventually weaken and collapse (George & John 2005a). Yellow-bar Angelfish *(Pomacanthus maculosus)* and some other species of fish make considerable use of sponges in the Emirate as a readily available food source, as do Hawksbill turtles *(Eretmochelys imbricata).*

4.3.10 Annelida

The phylum Annelida (bristleworms) contains a large group of soft-bodied worms known as the Polychaeta that are found in large numbers in all seas of the world where they are a major source of food for many other animals higher up the food chain. Until recently, knowledge of the polychaetes occurring in the seas of Abu Dhabi Emirate was virtually non-existent and mainly confined to unpublished 'grey literature' reports compiled by consultants contracted by companies preparing to extract hydrocarbons from beneath the sediments of the southern Arabian Gulf. Unfortunately, identifications made by such

consultants have generally not been checked by polychaete specialists and have frequently been made without recourse to the detailed scientific literature on the group. However, Wehe and Fiege (2002) published a checklist of polychaete species of the seas surrounding the Arabian Peninsula which included all those polychaetes that had been recorded in the scientific literature as occurring in the Arabian Gulf (*e.g.* Wesenberg-Lund, 1949). The comprehensive list of species, in an appendix in their paper, included some 231 species supposedly occurring in the Arabian Gulf, although unfortunately none were recorded as being from the Emirates flanking the southern part of the Gulf.

During the NHM's investigations of the biotopes of hard substrata (and sometimes the surrounding soft sediments) between 1996 and 2001 in Abu Dhabi Emirate their specialists identified some 75 species of polychaete from various habitats throughout the Emirate, although members of some families still remain unidentified. Attached to hard substrata intertidally in many localities are aggregations of calcareous tubes in which the species *Pomatoleios krassii* resides (George, 2005b), although other serpulid worms with protective calcareous tubes such as species of Hydroides and Janua also survive in these harsh conditions (John & George, 2004, 2005). Most other polychaetes to be found intertidally either burrow in the soft sediments or hide in crevices and under rocks to gain protection, at least during low tide. Nereidid species are seemingly the most diverse and numerous in the intertidal sediment habitats so far examined.

Subtidally, the situation remains similar with hard substrata and coral skeletons supporting tube-dwelling polychaetes such as serpulids on open surfaces and other tube-dwellers with soft tubes confined mainly to crevices or hidden under overhangs. SCUBA divers sometimes see small mobile carnivorous and omnivorous worms (*e.g.* polynoids and syllids) searching for food on coral reefs and hand-disturbance of subtidal gravel, sand and mud reveals onuphids, opheliids, maldanids, nereidids and capitellids. It must be emphasized that many intertidal and subtidal polychaetes, dwelling in soft sediments in particular, are a major prey item for many adult and juvenile bottom-feeding fish, and also for birds feeding in the intertidal zone during low tide. Thus any loss of sediment habitats due to dredging and land extensions seaward should be discouraged in order to protect this valuable food source along with other desirable infauna such as crustaceans and molluscs.

Common Name	Scientific Name	IUCN Red List 2004
Ethiopian Hedgehog	*Hemiechinus aethiopicus*	Not Listed
Kuhl's Pipistrelle	*Pipistrellus kuhlii*	Not Listed
1Sand Cat	*Felis margarita*	NT
*Feral Cat	*Felis cattus*	Not Listed
*Red Fox	*Vulpes vulpes*	Not Listed
Honey Badger	*Mellivora capensis*	Not Listed
1Mountain Gazelle	*Gazella gazella cora*	VU
1Sand Gazelle	*Gazella subgutturosa marica*	NT
Cape Hare	*Lepus capensis*	Not Listed
Lesser Jerboa	*Jaculus jaculus*	Not Listed
*Brown Rat	*Rattus norvegicus*	Not Listed
*House Mouse	*Mus musculus*	Not Listed
Cheesman's Gerbil	*Gerbillus cheesmani*	Not Listed

Table 3: List and status of mammal species occurring on the coast and islands of Abu Dhabi Emirate.

Note: [1]Species listed in the 2007 IUCN Red List of Threatened Species in the World (IUCN 2007) and included in the proposed National Red Data List of mammalian species of Abu Dhabi (Drew et. al. 2004; Drew and Tourenq 2005). Species indicated with * are considered to be pest species and their presence along the entire length of Abu Dhabi's coastline is indicative of the rate and extent of urbanization. IUCN (World Conservation Union) Red List Categories (IUCN 2003): LC: least concern, NT: near threatened, VU: vulnerable.

4.4 Coastal Fauna

4.4.1 Mammals

The coastline and islands of Abu Dhabi are diverse both in terms of landforms and in terms of vegetation structure. Consequently, there are numerous habitats which could be used by many of the native species of wildlife within the Emirate. There are 51 species of terrestrial mammals known to occur either naturally, as introduced species, or to have become extinct within the last 75 years in the UAE. These mammals exist within 18 Families of 8 Orders *(Carnivora, Perissodactyla, Artiodactyla, Rodentia, Hyracoidea, Lagomorpha, Insectivora and Chiroptera)*.

Of these 51 species, 2 species *(Oryx leucoryx and Capra aegagrus)* are known to be extinct in the wild. Two further species *(Canis lupus arabs and Hyaena hyaena)* are probably extinct in UAE with species from Oman or Saudi Arabia that cross the border being seen occasionally. From the remaining 47 species, 10 species have been introduced in UAE under recent geological times, either accidentally or as domesticated animals, and can be found in the wild: the Cat *(Felis cattus)*, the Dog *(Canis familiaris)*, the Camel *(Camelus dromedarius)*, the Donkey *(Equus asinus)*, the Goat *(Capra aegagrus hircus)*, the Rock Hyrax *(Procavia capensis)*, the House Shrew *(Suncus murinus)*, the Black Rat *(Rattus rattus)*, the Brown Rat *(Rattus norvegicus)*, the House Mouse *(Mus musculus)*.

Of the 47 terrestrial mammalian species known to occur in the Emirate of Abu Dhabi, only 13 have been recorded so far along or close to the coast (**Table 3**). The House Shrew *(Suncus murinus)* and the Black Rat *(Rattus rattus)* have not yet been formally recorded on the coast of Abu Dhabi. However, due to the rapid colonization abilities, these species are likely to occur, especially around human settlements. The reason for the relatively low diversity in species might be due to (1) a general lack of data and prospection since access to some of these areas is difficult (sabkha, private land, oil companies, etc.), (2) the development/urbanization of the coast that induces either a direct or indirect disturbance, such as the presence of high numbers of commensal species (red fox, feral cat, rats and mice) that compete or prey on the native fauna.

Species accounts

Order Insectivora - insectivores

Ethiopian Hedgehog (Hemiechinus aethiopicus): Found even in extensive sandy areas, this species is said to be the most widespread hedgehog in Abu Dhabi Emirate (Duckworth 1996, Böer et. al. 1999, Drew et. al. 2003a, Drew et. al., 2004). It is classified as Least Concern in the proposed Red Data List of mammalian species of Abu Dhabi (Drew & Tourenq 2005).

House Shrew (*Suncus murinus*): The native range of this species stretches across southern Asia from Afghanistan to the Malay archipelago and southern Japan. It has since been introduced into northern and eastern Africa, as well as much of the Middle East (Ruedi et. al., 1996). This commensal species is present in ports throughout the Arabian Peninsula but to date, has still not been recorded in the UAE (Harrison & Bates, 1991; Duckworth, 1996; Cunningham, 2004). The House Shrew has not yet been formally recorded on the coast of Abu Dhabi. However, due to their rapid colonization abilities, these species are likely to occur, especially around human settlements. Note that this commensal and adaptable shrew is a growing ecological threat, classified as one of the 100 World's Worst Invasive Alien Species by the IUCN, predating on or competing with many plant and animal species.

Order Chiroptera - bats

Kuhl's Pipistrelle (*Pipistrellus kuhlii*): This species was reported only in Al Ain, Jebel Hafeet and some coastal areas of Abu Dhabi Emirate (Duckworth, 1996; Stuart & Stuart, 1998; Drew & Al Dhaheri, 2003, EAD unpublished data). Since it is said to be the most common bat around human settlements and gardens in the Gulf Region (Harrison, 1981), more surveys are needed to identify the distribution and status in other towns and farmlands of the coastal areas of Abu Dhabi Emirate. It is classified as Data Deficient in the proposed Red Data List of mammalian species of Abu Dhabi (Drew & Tourenq, 2005).

Order Carnivora - carnivores

Red Fox (*Vulpes vulpes*): Native to Europe, Asia, North Africa, and boreal regions of North America, European red foxes have been introduced into Australia and temperate regions of North America. They are now the most widely distributed carnivore in the world and have negative impacts on many native species, including smaller canids and ground nesting birds in North America, and many

small and medium-sized rodent and marsupial species in Australia. The red fox is classified as one of the 100 World's Worst Invasive Alien Species by the IUCN (http://www.issg.org).

In the Emirate of Abu Dhabi, the red fox is considered to have expanded its range benefiting from expansion of urbanization, agricultural plantations, afforested areas, and domestic livestock farms. Despite human persecution, the species does not meet any of the criteria for critically endangered, endangered, vulnerable or near threatened and consequently is assessed as being Least Concern in the proposed Red Data List of mammalian species of Abu Dhabi (Drew & Tourenq, 2005).

Honey Badger or Ratel (*Mellivora capensis*): Until recently, it was not entirely clear whether or not honey badgers existed in UAE. There had only been two records of tracks in 1991 and 1992 between Liwa and Umm al Zummoul and in the Baynoonah area respectively, (Osborne, 1992; Mackinlay & Macdonald, 1992). However, an individual was observed and photographed in summer 2005 in Ruwais area (Aspinall pers. com.). The species is therefore classified as Data Deficient in the proposed Red Data List of mammalian species of Abu Dhabi (Drew & Tourenq, 2005).

Domestic/Feral Cat (*Felis cattus*): This commensal and adaptable species is a rapid colonizer and a growing ecological threat, classified as one of the 100 World's Worst Invasive Alien Species by the IUCN (http://www.issg.org), causing or contributing to the extinction of many species of wildlife. This species is common around human settlements of the Abu Dhabi coastline, where there is an abundance of food and water resources. It was also introduced as a pet on islands of the Arabian Gulf, such as Zirku and Arzanah, where it constitutes a threat to seabird species of conservation concern (Javed et. al., 2004). On land, feral cats have benefited from the expansion of human settlements and forest plantations in the desert and along the seashore and can be observed in the most remote areas of Abu Dhabi Emirate. Some feral cats might however exhibit behavioural and phenotypic patterns very similar to Gordon's wildcat (Felis silvestris gordoni), which is also present in UAE (Duckworth 1996), and only genetic studies can separate the two species. Further research including survey work and genetics studies (to quantify the extent of cross-breeding with feral cats) is required to facilitate an assessment of the status of both species. The status of the feral/domestic cat is 'Not Applicable' in the proposed Red Data List of mammalian species of Abu Dhabi (Drew & Tourenq, 2005).

Sand Cat (*Felis margarita*): This species is present in Abu Dhabi Emirate but due to its secretive and nocturnal habits, it is seldom observed. Intensive surveys and trapping by EAD in favourable habitats since 2002 have not revealed any confirmed records. There have been only 4 authenticated sighting records of this species within the last 10 years: one individual was recorded in the Sweihan area five years ago (Cunningham, 2002); one individual was found for sale in a pet shop in 2002, having been caught south of Al Ain (Drew, unpublished data); one individual was seen again in the Sweihan area in Autumn 2004 (Eichaker, pers. com.); and one observed and photographed in the Baynoonah area of Western Abu Dhabi in 2005 (Judas, unpublished data). Due to their similarities with domestic cats, sand cats may benefit from a traditional religious respect because of their association with the Prophet Mohammed, and are less likely to be persecuted (Dragesco-Joffé, 1993). However, this species may suffer from competition with feral cats (causing both a reduction in area of occupancy as well as the introduction of diseases such as feline immunodeficiency lentivirus, leukaemia, *etc.*) that benefit from expansion of human settlements in the desert (Nowell & Jackson, 1996; Bunaian *et. al.,* 1998; Ostrowski *et. al.,* 2003). It may also suffer indirectly from foxes' persecution (poisoning and trapping). With an estimated population size of less than 250 mature individuals within the Emirate of Abu Dhabi, the species is assessed as Endangered in the proposed Red Data List of mammalian species of Abu Dhabi (Drew & Tourenq, 2005).

Order Artiodactyla - even-toed ungulates

Mountain Gazelle (*Gazella gazella cora*): This species is confined to the north east and coastal strip of the Emirate of Abu Dhabi, especially in Jebel Ali area (EPAA 2003). Captive herds are held in many private collections and forest plantations (around 5,500 individuals) and gazelles of mixed origins are known to have escaped or been released into various places. Consequently, there is concern that the gene pool within the wild population may have become polluted following releases of dorcas gazelle (*Gazella dorcas*), originally from Africa, and other non-indigenous species (EPAA 2003). Unlike the sand gazelle population, which lives within a largely unpopulated area, mountain gazelles exist within areas where there is continued

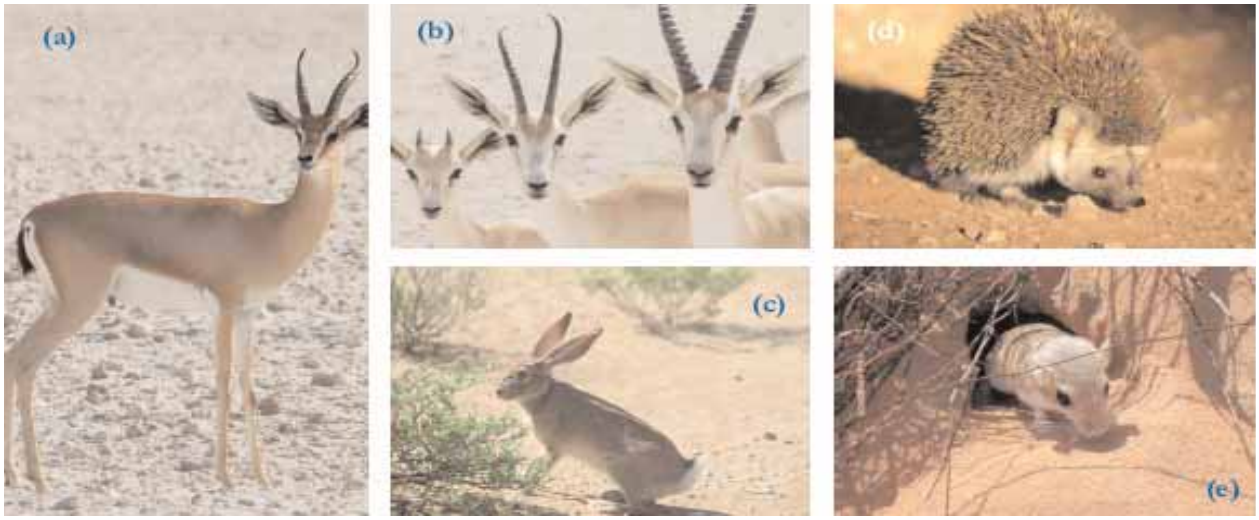


Figure 39: Selected mammals of the coastal environment of Abu Dhabi

(a) Mountain Gazelle (*Gazella gazella cora)* (b) Sand Gazelle *(Gazella subgutturosa marica)* (c) Cape or Desert Hare *(Lepus capensis*) (d) Ethiopian Hedgehog *(Hemiechinus aethiopicus*) (e) Cheesman's

anthropogenic impact and infrastructure development such as the Al Ain Region and the coast. Consequently, available habitat is decreasing rapidly and it is thought that this would result in a population decline. Based on the extent of occurrence, habitat fragmentation and a declining population size of less than 2,500 individuals, the taxon is classified as Endangered in the proposed Red Data List of mammalian species of Abu Dhabi (Drew and Tourenq, 2005).

Sand Gazelle *(Gazella subgutturosa marica)*: Captive herds of sand gazelles are held in many private collections and forest plantations of UAE (EPAA 2003). A large number, possibly 7,500, occur on Sir Bani Yas Island but these were not included in the overall total as they probably have mixed origins and cannot be considered as free-ranging. In the wild, the species is commonly found in the sandy south eastern parts of the Emirate of Abu Dhabi. Based on population size and fragmentation of the habitat, the species is assessed as being Vulnerable in the proposed Red Data List of mammalian species of Abu Dhabi (Drew and Tourenq, 2005).

Order Lagomorpha - rabbits, hares and picas

Cape Desert Hare *(Lepus capensis)*: This species is found throughout all the landforms in the Emirate the Abu Dhabi, from the coastal shores to the dunes of the Empty Quarter (Drew, 2000; Drew 2004). It was also introduced into some islands of the Arabian Gulf, such as Al Yasat and Abu Al Abyad (Duckworth, 1996). Releases of individuals imported from southern and central Asia, have been implicated in deaths of native hares due to the introduction of disease (suspected to be rabbit hemorrhagic disease; Drew 2004). The species is classified as Least Concern in the proposed Red Data List of mammalian species of Abu Dhabi (Drew and Tourenq, 2005).

Order Rodentia - rodents

Lesser Jerboa *(Jaculus jaculus)*: Duckworth (1996) mentions two records on the coast of Abu Dhabi Emirate. This species occurs mostly in interdunal plains of sandy areas of the whole of Abu Dhabi Emirate (Böer *et. al.,* 1999; Drew *et. al.,* 2003a; Drew *et. al.,* 2004; Drew *et. al.,* 2005a; Drew *et. al.,* 2005b). Lesser jerboas may be under-represented as the tracks they leave on gravel plains are difficult to spot and identify (Drew *et. al.* 2005a). Further surveys are needed to identify the distribution of this secretive species. It is classified as Data Deficient in the proposed Red Data List of mammalian species of Abu Dhabi (Drew & Tourenq, 2005).

Black Rat *(Rattus rattus)*: This commensal and adaptable species is a rapid colonizer and a growing ecological threat, classified as one of the 100 World's Worst Invasive Alien Species by the IUCN (http://www.issg.org), causing or contributing to the extinction of many species of wildlife. This introduced species

is common in towns, around major settlements and agricultural areas of the Arabian Peninsula (Harrison & Bates, 1991) and Abu Dhabi Emirate, where it was introduced by the early 2nd Millennium BC (Cunningham, 2004). Although it was not yet formally reported along the coast, the Black Rat might be present around urban areas. The species is classified as Least Concern in the proposed Red Data List of mammalian species of Abu Dhabi (Drew & Tourenq, 2005).

Brown Rat *(Rattus norvegicus)*: This commensal and adaptable species is a rapid colonizer and a growing ecological threat and classified as one of the 100 World's Worst Invasive Alien Species by the IUCN (http://www.issg.org). This rat is globally widespread and costs primary industry hundreds of millions of dollars each year. It has caused/contributed to the extinction/range reduction of native mammals, birds, reptiles and invertebrates through predation and competition. This species is commonly found in towns of the Arabian Peninsula (Harrison & Bates, 1991) and Abu Dhabi Emirate. Its presence is also reported on islands of the Arabian Gulf, such as Zirku, where it constitutes a threat to seabird species of conservation concern (Javed *et. al.,* 2004). In June 2005, Abu Al Abyad, one of the only two colonies of crab plover (*Droma ardeola*) in UAE was heavily predated by brown rats with an estimated loss of 273 eggs on 588 nests (Javed *et. al.,* in prep.). The species is classified as Least Concern in the proposed Red Data List of mammalian species of Abu Dhabi (Drew & Tourenq, 2005).

House Mouse *(Mus musculus)*: This commensal and adaptable species is a rapid colonizer, growing ecological threat and classified as one of the 100 World's Worst Invasive Alien Species by the IUCN (http://www.issg.org). They do considerable damage by destroying crops and consuming and/or contaminating food supplies intended for human consumption. They have also been implicated in the extinction of indigenous species in ecosystems they have invaded and colonized which are outside their natural range. The house mouse is found as a commensal species in towns and settlements throughout the Emirate of Abu Dhabi. As human settlements expand into previously unsettled areas, new habitat is 'created' for house mice. Consequently, the population is thought to be expanding its geographic range and increasing in absolute numbers. This species is also found on islands of the Arabian Gulf, such as Zirku and Arzanah, where it constitutes a threat to seabird species of conservation concern (Drew et. al., 2003b; Javed et. al., 2004). The species is classified as Least Concern in the proposed Red Data List of mammalian species of Abu Dhabi (Drew & Tourenq, 2005).

Cheesman's Gerbil *(Gerbillus cheesmani)*: Cheesman's Gerbil is said to be the most abundant mammal of Abu Dhabi Emirate (Duckworth 1996). It is commonly found in sandy and gravel parts of the whole Abu Dhabi Emirate, except islands of the Arabian Gulf (Böer *et. al.,* 1999; Javed *et. al.,* 2004). The species is classified as Least Concern in the proposed Red Data List of mammalian species of Abu Dhabi (Drew & Tourenq, 2005).

4.4.2 Reptiles

The United Arab Emirates has a total of 67 species of amphibians and reptiles (Hornby, 1996). There have been various herpetological surveys carried out on the islands of Abu Dhabi Emirate, including visits by natural history groups and scientific surveys (Soorae, 2003; ENHG, 1977 and 1990). A herpetological survey conducted between 2003 and 2005 on some of the islands off Abu Dhabi Emirate have recorded a total of six species of geckos, two lizard species, one skink species (new record for UAE) and three snake species. Details of the species present on each island are given in Soorae (2003). The island of Marawah also has an introduced Spiny- tailed Lizard *(Uromastyx aegyptia)* population. In 2004 the Golden Skink *(Mabuya aurata septemtaeniata)* was recorded from Jarnain Island which was a new distribution record for the UAE and increased the number of skink species in the UAE from

Figure 40: Two adult Baluch rock geckos *(Bunopus tuberculatus)*

five to six (Soorae, 2005). Species recorded are listed in **Table 4**.

There are over 30 major islands in the waters off Abu Dhabi, ranging in size from 0.5 km^2 to over 350 km^2. Some are uninhabited (*e.g.* Muhayamat Island) whilst others like Dalma and Sir Bani Yas have large human populations. Islands such as Arzanah and Zirku are off-shore oil-field sites with related infrastructure, and others, such as Marawah and Al Bazam, are encompassed within protected areas. There are some privately owned islands, such as Ushsh and Al Aryam, whilst others have restricted access due to military activities. The Islands of Sir Bani Yas, Arzanah, Zirku and Jarnain have some of the highest number of reptile species and were the only islands with three species of snakes recorded. There is a large movement of cargo, soil for land reclamation, and feed for wildlife from the mainland which may result in the possible introduction of species. On the other islands, such as Arzanah and Zirku, which are oil-field islands, there are species, in particular nocturnal gecko species, which utilize associated human-infrastructure, *e.g.*, buildings, planted trees and oil-field related machinery.. The two jmost common species recorded on the majority of islands are the Short-nosed Sand Lizard (*Mesalina brevirostris*) and Baluch Rock Gecko (*Bunopus tuberculatus*) (**See Figure 40**), which are also found on many small, uninhabited islands. It is evident that many islands are being influenced by anthropogenic activities, such as construction, and this will probably affect the species composition through introductions by human agency.

LIZARDS	
Family: Agamidae	Spiny-tailed Lizard *(Uromastyx aegyptia)*
Family: Lacertidae	Short-nosed Sand Lizard *(Mesalina brevirostris)*
GECKOS	
Family: Gekkonidae	Yellow-bellied House Gecko *(Hemidactylus flaviviridis)*
	Turkish Gecko *(Hemidactylus turcicus)*
	Rough-tailed Bowfoot Gecko *(Crytodactylus scaber)*
	Rock Sephamore Gecko *(Pristurus rupestris)*
	Gulf Sand Gecko *(Stenodactylus khobarensis)*
	Baluch Rock Gecko *(Bunopus tuberculatus)*
SKINKS	
Family: Scincidae	Golden Skink *(Mabuya aurata septemeniata)*
SNAKES	
Family: Viperidae	Saw-scaled Viper *(Echis carinatus)*
Family: Colubridae	Schokari Sand Racer *(Psammophis schokari)*
	Rat Snake *(Coluber ventromaculatus)*
	Diadem Snake (*Spalerosophis diadema*)
Family: Boidae	Arabian Sand Boa (*Eryx jayakari*)

Table 4: Terrestrial reptiles recorded on Islands off Abu Dhabi.

5 ECONOMIC USES AND VALUES

5.1 Archaeological evidence for exploitation of the marine and coastal zone

Archaeological evidence suggests that the earliest inhabitants of the Arabian Gulf relied on marine resources as an invaluable component of their diet. Animal bones and shells analysed from archaeological excavations demonstrate the importance of these food sources to coastal communities. The majority of food remains recovered from archaeological excavations of coastal settlements in Abu Dhabi consist of fish bones and marine mollusca, only small quantities of marine mammals, reptiles and terrestrial mammals being recovered. This suggests that fishing as well as shell gathering has been of vital importance to coastal communities since the earliest known settlements to appear in the region some 7,500 years ago.

The oldest known settlement in Abu Dhabi emirate is that of site MR11 on Marawah island which was occupied between 7500-6500 years ago (Beech *et. al.,* 2005). Here the inhabitants consumed a variety of fish including sawfish, requiem sharks, groupers, emperors and seabream, as well as sheep or goat, dugongs, turtles and birds. Marine mollusca regularly collected and consumed included the bivalves *Asaphis violascens* and pearl oyster *(Pinctada spp.),* as well as the gastropod *Lunella coronata.* Small quantities of swimming crabs (Portunidae) were also exploited.

A detailed study of fish bones from archaeological excavations of different periods throughout the Gulf indicated that a similar range of species was exploited in the past to the present day (Beech 2002, 2003, 2004a). Variations in the types of fish and marine mollusca consumed appeared to be more related to macro regional differences in habitat types (Beech & Glover, 2005; Glover & Beech, in prep.).

The archaeological record provides some evidence of the kinds of fishing equipment utilized in the past. Examples of stone net sinkers as well as copper-bronze fishhooks have been discovered from the 4000 year old Bronze age settlement on Umm Al-Nar island. Traces of stone fish traps have also been identified at a number of locations, e.g. on Dalma island (Beech, 2003). It is unfortunately quite often difficult to date these.

Another important marine resource exploited in the past was mangroves. Although only a single species, *Avicennia marina,* is known at the present day in the Gulf, there is archaeological evidence supporting the

presence of Rhizophoraceae mangroves from a number of sites. Both Tell Abraq and Ed-Dur located in Umm Al-Qaiwain emirate, close to the border with Sharjah emirate, have yielded charcoal fragments of *Rhizophora* or *Bruguiera* genus (Tengberg, 2002), which date back to between 2500-400 BC. Rhizophoraceae seems to have disappeared sometime between the first centuries AD and the present. Elsewhere in the Gulf, the presence of Rhizophora has been identified on an Early Dilmun (4,000 year old) settlement site in Bahrain (Gale, 1994). An important question therefore arises. Were Rhizophora mangroves growing in association with Avicennia in the Gulf in antiquity or was the wood imported - perhaps from elsewhere in the Gulf or further afield, *e.g.* from the Indian subcontinent? Rhizophora was commercially important for both timber and fuel and the existence of trading routes from the Indus Valley (native home of several species) to Mesopotamia suggests that this wood may have been imported.

5.2 Historical evidence for exploitation of the marine and coastal zone

Both Arrian's "Indica" and "The Periplus of the Erythraean Sea", written in 100 AD by a well known trader operating within the Red Sea and Indian Ocean, provide a detailed insight into the coastal communities of the region. Both documents refer to certain coastal communities of the Arabian and Makran coasts as being the "Ichthyophagi" or "Fish-Eaters", suggesting that fishing played an important part of their lifestyle. Historical sources mentioning the exploitation of marine resources are discussed in more detail in Beech (2004).

One of the most important documents providing an insight into the region during the pre-oil era is the "Gazeteer of the Persian Gulf, Oman and Central Arabia" by J.G. Lorimer (Lorimer 1908-15). This provides an unprecedented quantity of qualitative and statistical data relating to the pearl trade in the region. The estimated total number of boats involved in pearling almost doubled during the 19th century, from ca. 2300 in 1818, according to Captain Taylor (Hughes Thomas 1985: 19, 22 and 39) to 4500 at around 1907 (Lorimer 1908-15: 2262).

By the early 20th century it was clear that the economy of every single emirate on the Gulf side was dependent on pearling. The subsequent collapse of the pearl trade in the Gulf was largely due to a combination of the introduction of cultured pearls from the Far East, as well as the general economic recession between the two world wars. The pearl trade increasingly became subject to the demands of the global environment.

5.3 Traditional fishing methods

Traditionally, most inshore fishing was carried out using a “shasha”, a traditional canoe-type of boat made from interwoven date palm fronds. These remarkable vessels were built using the ubiquitous date palm. Dried palm fronds were also used to weave basket traps to catch fish.

In the past, there was far less pressure on the fisheries resources of Abu Dhabi, partly because the population and amount of fishing activity was far less than we see today. Various types of fishing gear that were used in the past and the principal target species can be found in Beech (2004a). The ancient fishing gear utilised are more or less the same as those used today, only the designs and type of materials used to manufacture them have often changed. Basket traps, known locally as “gargoor”, were traditionally often hemi-spherical in shape with a cone-like entrance, the whole trap being made from interwoven palm fronds.

One of the other traditional fishing methods used in shallow waters were tidal barrier traps, known locally as “hadrah” (or “al Hadhra”). Such traps were made traditionally by driving a row of palm fronds and wooden stakes into the mud-sand bottom supported by stones at their base. A frond fence was then placed between these stakes out towards the outer circular/pentagonal enclosure, which in turn surrounded an inner chamber. With the receding of the tide, fish were thus channeled by the wings of the trap into first an outer, then an inner chamber. The modern versions of the hadrah are usually made with steel or iron poles and wire mesh or nylon netting. In the UAE, these traps are used especially during the summer months to catch the blackspot snapper *(Lutjanus fulviflamma)* (**Figure 29**). Other typical kinds of fish caught using hadrah include needlefish (Belonidae), jacks (Carangidae), seabream (Sparidae), mullets (Mugilidae), barracuda (Sphyraenidae) and rabbitfish (Siganidae). Other bottom species may also be occasionally caught in these traps.

Other variants of tidal barrier traps also exist in the UAE. One is a wide fence of nets linked by wooden posts called “Sakkar”. This may be stretched across narrow estuaries or gaps in lagoons. This is particularly used in the capture of mojarras (Gerreidae) and goldstriped seabream *(Rhabdosargus sarba).* Sometimes a second fence called “dafaf” is added behind the “Sakkar”, and this may catch fish like seabream *(Acanthopagrus spp.)* and flathead mullets *(Mugil cephalus).*

Figure 41: A traditional inshore fishing vessel known as a ‘shasha’.

Gillnets, known locally as “liekh”, are often set on the bottom. These catch a variety of fish including grunts (Haemulidae), seabream (Sparidae), emperors (Lethrinidae), goatfish (Mullidae), rabbitfish (Siganidae), pomfrets (Stromateidae) and others. A further type of gillnet is known as “hayal”. These are special drifting gill nets which are normally used during the winter to capture in particular the narrow-barred Spanish mackerel *(Scomberomorus commerson),* which is abundant at that time. Two nets are used, one is movable whilst the other is fixed with weights. Such a method is also used to capture cobias (Rachycentridae), jacks (Carangidae), barracuda (Sphyraenidae) and tuna (Scombridae).

Two other types of fishing nets are used. Beach seines, known locally as “yaroof”, can be up to 40m or more in length. One end of the seine is moved rapidly from the shore in a wide arc in an effort to surround fishes; both ends of the seine are then pulled to shore. Speedboats with outboard motors and even four wheel drive vehicles are used at the present day to pull these seine nets to the shore, but traditionally this was done by a large group of men. Fishing using this method is especially good at catching mojarra (Gerreidae), flathead mullets *(Mugil cephalus)* and rabbitfish (Siganidae). Many other fishes can also be caught including small needlefish (Belonidae) and jacks (Carangidae).

The other type of fishing net which is sometimes used is the casting net, known locally as “Salieya”. This is only used at particular times of year when fish like the Indian oil sardinella *(Sardinella longiceps)* and flathead mullets *(Mugil cephalus)* may be abundant in shallow inshore waters. The fishermen wade into shallow waters and throw a bell-shaped fine net onto the surface of the water which has small weights around its base to make the net sink and surround the fish.

A method which resembles a sort of harpoon, known locally as “oumla”, is sometimes used. A large wooden spear referred to as “al katra” with a sharp metal unit called “al jalala” is inserted into another metal unit called “al kaber”. This latter section has a float attached to it. The “oumla” is particularly used for the spearing of large pelagic fish like tuna, narrow-barred Spanish mackerel and was even occasionally used on Cetaceans in the past.

All other traditional fishing methods utilised rely on hook and lines of one sort or another. In its most simple form, the hook and line method, known locally as “hadaq”, is particularly used for the capture of groupers (Serranidae), cobias (Rachycentridae), jacks/trevallies (Carangidae), grunts (Haemulidae), emperors (Lethrinidae), seabream (Sparidae), and Spanish mackerel (Scombridae: *Scomberomorus commerson*). Sometimes, longlines, known locally as “manshalla”, are used which may have 10-20 or more smaller lines and hooks. These are reputed to be good for catching requiem sharks (Carcharhinidae) and groupers (*Epinephelus* spp.). Another local variant is “Shab”, which is a nylon line with 4-8 shorter lines and hooks which have lures (small feathers or pieces of coloured material) fastened to them. This is apparently very good at catching Blacktip trevally *(Caranx heberi),* golden trevally *(Gnathanodon speciosus)* and queenfish (*Scomberoides* spp.). The final method which is used from moving boats is a trolling line, known locally as “lafah”. This is particularly used for the capture of larger fish like giant trevally *(Caranx ignobilis),* barracuda (*Sphyraena* spp.), narrow-barred Spanish mackerel *(Scomberomorus commerson),* tuna (mostly *Euthynnus affinis*/*Thunnus* spp.), and occasionally sailfish *(Istiophorus platypterus).*

5.4 Traditional use of marine resources

Fish, as well as marine mollusca, were traditionally dried to be preserved for later consumption. Some fish was dried not for human consumption but for use as animal feed or fertilizer. Popular types of fish which were preserved by drying and salting, or by salting in brine included tuna and kingfish.

Although the consumption of shellfish has almost disappeared from the markets in the UAE, occasionally quantities of venus clams (Veneridae) can be seen on sale. Nowadays these are largely purchased by expatriate communities.

In addition to fisheries, the marine and coastal environment of Abu Dhabi was historically used for transport, habitation and hunting. Mangrove areas in Abu Dhabi have also been used for centuries as sites for honey production. Some of the other traditional and cultural activities maintained today include boat racing and various other activities promoted by the Emirates Heritage Club.

5.5 Recreation and tourism

The current economic policy places a high priority on the development of the tourism sector. Tourism in Abu Dhabi relies heavily on the coastal and marine environment. Both tourists and residents are increasingly using the sea for recreation through activities such as fishing, sailing, snorkeling and scuba diving. Not only are most hotels and recreational facilities situated along the coast, but the marine environment also provides a major attraction for tourists visiting the country as well as for its citizens and residents (Al Abdessalaam, 2005a). Abu Dhabi’s sandy beaches and near shore islands are favourable to recreational and tourism activities. From an historical perspective, fishing and pearling have been the most important economic uses of the regional coastal habitat. Pearling was the mainstay of the economy, particularly between the 18th to mid 20th centuries. However, with increased country-wide economic development over the past few decades, the demand and use of coastal areas for recreational and tourism requirements has increased.

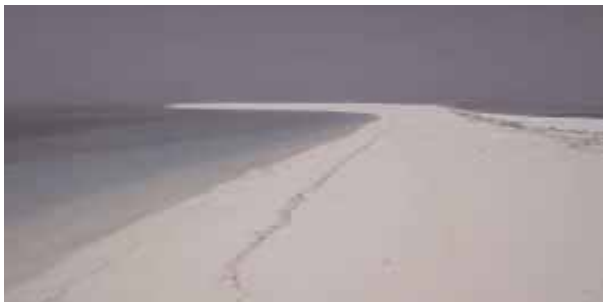


Figure 42: The sandy beaches of Abu Dhabi are an important tourism resource.

Coastal beach areas are arguably the most popular because they are easily accessed, and include public access areas as well as private beaches associated with hotel establishments. Islands and coastal waters, accessible only by boat, are also popular for various activities. Some of the most popular beach and water-based activities include: picnics, camping, swimming, sunbathing, exercising, bird watching, fishing, scuba diving, windsurfing, parasailing, jet skiing, water skiing, pleasure cruising and boat racing. The economic importance of these activities is wide-ranging and includes generation of both direct revenues and down-stream "value-added" revenues associated with ancillary services, of which all represent substantial financial investment and employment for the local economy. A few examples of direct revenues include hotel tariffs, charter operator charges and equipment purchase expenditures. Examples of value-added revenues, generated from ancillary services, include equipment repair and servicing, fuel expenditures, recreational clothing and sundry items.

Coastal recreational and tourism economies are among the fastest growing in the world. For Abu Dhabi, this economic sector is diverse, requiring a substantial infrastructure and personnel. Eco-tourism and cultural heritage tourism are being developed, *e.g.* Al Raha beach hotel - future trips to Sammaliah Island, Dhannat Hotel at Jebel Dhanna - trips to Sir Bani Yas.

At present, there have been no surveys carried out to measure the extent of recreational activities, nor is there any programme to monitor the impact of such activities on the coastal habitat. This indicates an important gap in the knowledge required to manage coastal resources effectively. There is probably scope for sustainable growth of recreational and tourism activities in the Emirate that can contribute to economic prosperity, while conserving the natural habitat and resources; however, efforts are required to gain baseline knowledge pertaining to the types and level of activities currently underway, and expectations for future development.

5.6 Urbanization, industrial and coastal development

During the past three decades, rapid development in the industrial (*e.g.* oil and gas), recreation, transportation, residential and tourism sectors have occurred in the coastal and marine environment of Abu Dhabi. The activity in these sectors primarily occurs in coastal areas and is often associated with the marine environment. Consequently, most of the industrial and residential infrastructure is concentrated within urban centres along the coast (Al Abdessalaam, 2005a). Industrial and urban development are often cited as a principal agent of environmental degradation and habitat loss/ fragmentation in Abu Dhabi. However, there is little quantified empirical data in support of these observations. One of the key technical information gaps therefore for the marine and coastal environment is data on the extent of urbanization, industrial and coastal development and its associated ecological impact.

5.7 Fishing

The fisheries resources of Abu Dhabi provide a source of income, employment and recreation whilst maintaining traditional forms of livelihood and the cultural heritage of the population. Fish are the most important exploited living marine resource and constitute a large component of the local food production. Fishing is primarily conducted from two vessel types namely, the 'lansh' and 'tarad' **(Figure 47)**.The lansh is a decked vessel usually constructed of wood and powered by an in-board engine. They are capable of trips of up to 10 days duration although the average trip length is between 3 and 5 days. There are about 400 lansh licensed in Abu Dhabi. Whilst less numerous than tarads, they land the majority of the total catch due

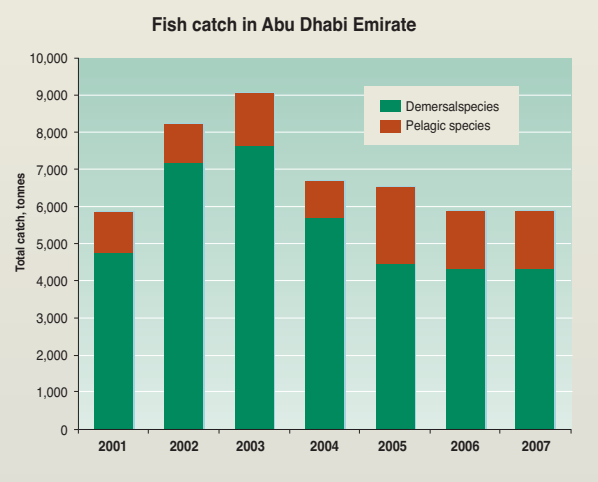


Figure 43: Total landings in the Emirate of Abu Dhabi between 2001 and 2007 by major species category.

The decline in landings in 2004 was associated with the introduction of regulations that were intended to reduce fishing effort and the retention of juvenile fish.

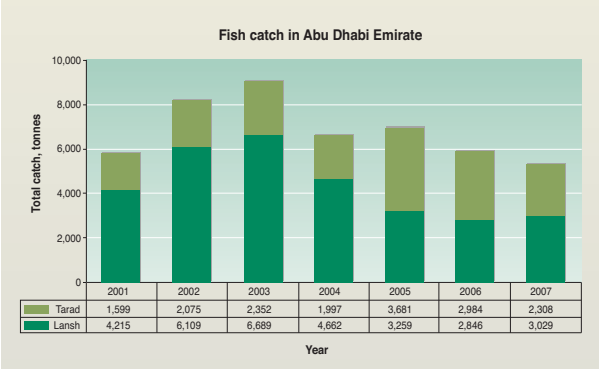


Figure 44: Trend of total catch by boat type in the period 2001-2007.

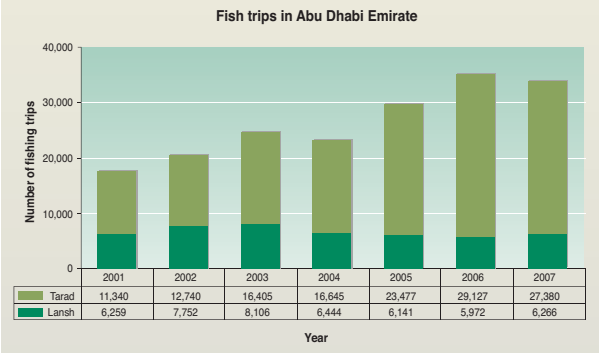
to their greater effective fishing capacity. The tarad is an open dory usually of fibre-glass construction and powered by outboard motors, fishing trips may be conducted during the day time and at night depending on the gear type being used and target species. Due to the small size of the vessels, trip durations do not usually exceed 24 hours. There are currently about 600 tarads licensed in Abu Dhabi.

Dome shaped wire traps are the most commonly used fishing gear although a variety of other methods exist including; fixed inter-tidal traps, gillnets, handlines and trolling lines. Catches are typically diverse and characteristic of a multi-species tropical fishery, with over 100 species from 35 families commonly caught. Target species are primarily composed of representatives of the families; Carangidae (Jacks), Lethrinidae (Emperors), Haemulidae (Grunts), Serranidae (Groupers), Scombridae (Kingfish), Siganidae (Rabbitfish) and Sparidae (Seabreams). A description of the various fishing methods and associated target species is given in section 5.1 here and in Beech (2004b), who also provides a synthesis of the fisheries research work that has been conducted and a checklist of the major species.

Trends in the total commercial landings show that catches declined to little more than 5,000 tonnes, after it attained a maximum level in 2003 (**Figure 43**). The decline from 2004 onwards, is attributed to the implementation of fisheries management regulations in 2003 that were designed to reduce both fishing effort and the retention of juvenile fish (see section 6.5). The management regulations affected mainly the lansh fleet which saw a reduction in fishing activity from more than 8,000 fishing trips in 2003 to 6,000 trips in the years after. The tarad fleet, on the other hand, saw an explosive expansion from 16,000 trips in 2003 to 27,000 trips in 2007. The Free Port accounted for 54% of the total catch landed in the Emirate of Abu Dhabi during 2007. The orange spotted grouper (*Epinephelus coioides*), known locally as Hamour, was the most valuable species. It alone represented 38% of the ex-vessel value of the total catch of 63.2 millions Dirhams during 2007.

Details of the catches, fishing effort, species composition, relative abundance indices and value can be found in the Annual Fisheries Statistics Technical Reports produced by the Marine Environment Research Centre of the Environment Agency - Abu Dhabi (Grandcourt *et. al.,* 2002; 2003a; 2004a and Hartmann *et. al.,* 2005a, 2006, 2007a, 2008). **Sections 6.5** and **7.3.1** of this report describe the impacts of fishing and fisheries stock assessment and monitoring activities respectively. Whilst the commercial fisheries are well studied, there is a dearth of information on the recreational fisheries of Abu Dhabi and this is one of the key technical information gaps for this economic sector.

Figure 44 shows the trend in the landings by boat type for the period 2001 – 2007. Landings by lanshes decreased enormously from more than 6,000 tonnes in 2003 to 3,000 tonnes in 2007, the decline is associated with decreasing catch rates for major species, such as Sweetlips (Farsh, Haemulidae), Groupers (Hamour, Serranidae) and Emperors (Shaari, Lethrinidae). Tarad landings fluctuated between 2,000 to 2,400 tonnes, with the exception of the years 2005 and 2006 having exceptional high landings of Kingfish by the Halaq fisheries.



	2001	2002	2003	2004	2005	2006	2007
Tarad	11,340	12,740	16,405	16,645	23,477	29,127	27,380
Lansh	6,259	7,752	8,106	6,444	6,141	5,972	6,266

Figure 45: Trend of fishing trips by boat type in the period 2001-2007.

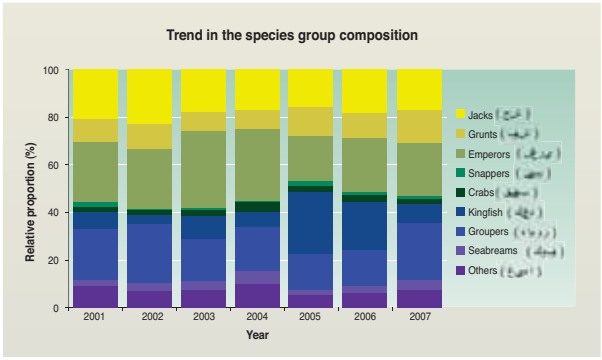


Figure 46: Trend in the species group composition during the period 2001 – 2007

Figure 45 shows the trend in fishing trips by boat type for the period 2001-2007. Fishing trips by lanshes declined from around 8,000 trips in 2003 to 6,000 trips in 2007, the decline may be attributed to a range of management regulations including fishing effort and gear restrictions introduced in 2003. Tarad fishing trips more doubled during 2001 – 2007.

Figure 46 shows the trend in the relative composition of major species groups landed during the period 2001 – 2007. The decline in the composition of Kingfish is attributed to a mid-season ban on Halaq fisheries in 2007.

Figure 47: Some of the fishing vessels and gears used in Abu Dhabi
(a) traditional dhow or 'lansh' (b) dory or 'tarad' (c) recreational (sport) fishing vessel
(d) inter-tidal fence net 'Al Hadhra' (e) wire trap 'gargoor' and (f) encircling gillnet.

Figure 48: Whilst aquaculture development in Abu Dhabi is limited, it represents an important potential food source and method of rehabilitating wild populations

5.8 Aquaculture

Abu Dhabi has a long coastline with many lagoons and large areas of Sabkha (salt flat) which are suitable for aquaculture. Whilst the development of aquaculture in Abu Dhabi is limited, it represents an important potential food source and method of rehabilitating wild populations, which is particularly important given the depleted status of fish stocks in the Emirate (see **Section 6.5**).

Some commercially important species such as rabbitfish, seabream, mullet, tilapia and green tiger shrimp have been cultivated from egg to commercial size by the Marine Resources Research Center of the Ministry of Environment and Water in Umm Al Qaiwain. Fish farming is generally conducted on a small scale in Abu Dhabi although facilities at Sammaliyah Is, Shahama and Ajiban are apparently on a relatively large scale. An experimental scale aquaculture facility has been established on Al Aryam Island. The project involves the cultivation of gray mangrove trees *(Avicennia marina)* which are nourished by aquaculture effluents in Sabkha areas that are otherwise unsuitable for mangrove colonization and growth. The mariculture project on Abu Al Abyad Island was set up to enhance wild stocks of fish and shrimp in the surrounding waters through the release of larvae and fingerlings. Facilities include, floating cage nets, tanks and tidal ponds. The cultured species include the green tiger shrimp, white shrimp, various seabreams, mullet, rabbitfish and grouper. A small scale integrated aquaculture-agriculture system has also been established in order to boost agricultural production and improve the efficiency of freshwater use (Yousif, 2002). Recently, trials using *Pinctada radiata* have produced the first cultured pearls in Abu Dahbi.

5.9 Shipping, transport and port facilities

Shipping is a large industry in Abu Dhabi with most of the incoming cargo entering, and almost all oil leaving the emirate through the sea. There are numerous marinas, commercial ports and harbours along the coastline and port development is a major industry. With the rapid development of tourism and growth in the coastal recreational sector, the construction of marinas has also become an important and fast growing activity along the coast (Al Abdessalaam, 2005a). Only a brief mention of activities and economic uses of the marine and coastal environment of Abu Dhabi is given here, for a more detailed account of this subject, the reader is referred to the sector paper on ‘Population, Development and Economy’.

6 MANAGEMENT ISSUES

6.1 Habitat loss and degradation

The coastal and marine environment of Abu Dhabi includes the supralittoral, intertidal and subtidal zones which comprise a number of diverse and interdependent habitats including coastal wetlands largely dominated by mangroves, lagoons, coral reefs and seagrass beds. The long-term sustainability of the coastal and marine environment and the habitats and resources therein are threatened by human activities. Physical alterations of the coastal zone have significantly impacted on the coastal habitats and resources leading to habitat degradation, fragmentation and loss. These include land reclamation, grading, dredging, channelization and coastal defence measures such as diking, armouring and erection of beach stabilization structures (breakwaters, groynes, sills) plus urbanization,. Coastal landfill is particularly widespread and a significant portion of the shoreline, particularly in Abu Dhabi, is artificial. Habitat degradation tends to lower the ability of the habitat to support biological communities thereby leading to a reduction in productivity. Fragmentation often leads to isolation of interdependent habitats which in turn results in the impairment of the functioning of these habitats. Significant portions of coral reefs, mangrove, salt marsh habitats and inter-tidal flats have been destroyed or damaged along the coast as a result of uncontrolled development and land reclamation programmes. Dunes and beaches, on the other hand, are mined for sand or graded to make way for shorefront hotels, leisure facilities and homes. The destruction of these habitats is not only manifested in the loss of biodiversity but also in the loss of valuable goods and services that these habitats provide particularly with regards to coastline protection (Al Abdessalaam, 2005a).

Human activities, especially urbanization, usually result in increased levels of pollution in the coastal and marine environment, particularly in the near shore areas. Such pollution leads to degradation in water quality and subsequent impairment of the coastal ecosystems. To ensure sustainability of the coastal and marine resources, therefore, it is essential to take into consideration the sensitivity and interdependence of the coastal and marine habitats in the midst of increasing pressures from the numerous human activities (Al Abdessalaam, 2005a).

Loss of coral reef habitat

Natural threats: Mortality associated with coral bleaching events has been considerable in the Gulf Emirates, with over 98% loss of *Acropora* in 1996 on the extensive reefs of Abu Dhabi Emirate and mortality of many of the remaining colonies during the 1998 bleaching event (George & John,

1999, 2000a, 2004, 2005a, John & George,2001) [Also see **Section 3.3** and **6.4**]. The small Jebel Ali reefs off Dubai Emirate also suffered extensive mortality in the late summer of 1996, the total coral fauna being reduced from 34 to 27 species off Jebel Ali according to Riegl (2001). In *Acropora* dominated areas of these reefs, live coral cover was reduced from 90% to about 26% in 1996, while in 1998 a reduction from 26% to 22% of the remaining coral cover occurred (Riegl, 2002).

The increase in the frequency and prolongation in positive seawater temperature anomalies suggests that the future of coral reefs in the Gulf Emirates is bleak if this trend continues according to George & John. It has been predicted that within the next few decades, the once coral-dominated reefs will be transformed into ones composed of coralline and turf-forming algae seasonally dominated by dense forests of fleshy brown algae (George & John, 2002).

The Crown-of-Thorns starfish (*Acanthaster planci*) is periodically abundant on reefs off the east coast of the UAE, causing considerable damage to corals and influencing coral communities (Sheppard *et al*., 2000). At Khor Fakkan, large numbers of Crown-of-Thorns were recorded and had severely damaged reefs in the area (Al Majed et al., 2000). However, this destructive starfish has not yet been seen in Abu Dhabi Emirate where the majority of the surviving corals in the Gulf Emirates are to be found. Other natural threats to coral reefs include the high incidence of disease in the southern Arabian Gulf. A new disease, Yellow-Band disease, has recently been reported from the southern Arabian Gulf alongside the more common Black-Band and White-Band diseases (Riegl, 1998).

Anthropogenic threats: Most heavy industries are located on the coast to make use of sea water for cooling purposes (*e.g.* electricity generating plants, petro-chemicals and oil refining, aluminum and steel smelting). Concentrated brine and cooling water discharges add to the already high salinities and temperature stress experienced by corals. A recent proposal to build a combined electricity generating and desalination plant on the shore near the Jebel Ali Wildlife Sanctuary would discharge water at 10 deg. C above the ambient temperature, threatening to exacerbate existing bleaching and the prevalence of disease (Wilson *et al.*, 2002).

Landfill and dredging are common activities in the coastal zone. Areas which include intertidal flats and shallow embayments are favoured for residential and industrial construction. These activities impact coral reefs by direct habitat loss and various secondary effects such as smothering by sediment (*see* **Figure 49**) and a loss in illumination (Sheppard, *et al.*, 2000).

Areas in the Jebel Ali Marine Sanctuary and Al Jazira (Abu Dhabi) have been affected by dredging spoil plumes, which had either prevented or delayed recruitment to replenish *Acropora* populations killed during the 1996 temperature anomaly (Riegl, 2001). The construction of ports and artificial islands through dredging also disrupts water movements and has dramatically affected those reefs near to the shore (Pilcher *et al.*, 2000).

Despite the detrimental impact of coastal developments, coral-dominated biotopes have been found developing on breakwaters off Abu Dhabi city and on other man-made structures primarily of rough-hewn limestone boulders (John & George, 1998a, b, 2001, 2004, 2005b; George & John, 2004). The *Acropora*, faviid, poritid, and Turbinaria recruits observed by them were healthy and considered to be capable of developing into narrow fringing reefs with diverse assemblages of marine life if summer seawater temperatures do not continue to rise. Oil and industrial pollutants may pose a threat to reefs although effects on ecosystem structure and function are generally not well known. The immediate impact of oil spills and discharges on coral reefs are less than would be expected, suggesting a high resilience among reef communities (Wilson *et al.*, 2002). Pearson *et al*. (1995) assessed the environmental impact of the 'Seki' oil spill of the coast of Fujairah on the east coast in which 16,000 tonnes of light Iranian crude was released into the marine environment. The total cost of the damage was estimated at US $ 48.5 million, the majority relating to marine fisheries. Whilst 10% of the damage occurred to habitats, the extent of the damage specifically relating to coral reefs was unknown because the proportion of oil reaching sub tidal habitats could not be determined.

The effects of fishing represent threats to corals reefs through over-exploitation and from the damage caused by operations, lost and/or discarded fishing gear and anchor damage. A particular concern is the density of discarded fish traps and their potential to 'ghost fish' and cause direct mechanical damage to corals. Both hard and soft coral cover is considered to be declining due to the impact of nets, traps, anchors and other fishing related activities. The situation is exacerbated by the presence of domestic and urban refuse over large areas of reef (Amer, 1996). Whilst a host of anthropogenic factors threaten the coral reefs on a local scale, the majority of coral mortality

in Abu Dhabi is thought to result from an increase in the prolongation and frequency of positive seawater temperature anomalies (George & John, 1998, 2000b). Grandcourt (2003a) provides additional information on the status and management of the reefs of Abu Dhabi and the UAE in a national report to the Regional Organization for the Protection of the Marine Environment (ROPME).

Loss of Sandy Beaches and sea turtle nesting habitats

Populations of sea turtles have been declining mostly due to deleterious human activities which include:

- **Development:** Activities such as the clearing of coasts to create residential and recreational areas has destroyed large areas of turtle nesting beaches. These disturbances can also damage seagrass beds and coral which are important turtle foraging habitats.
- **Fishing:** Sea turtles become entangled in nets and some die by swallowing hooks.
- **Marine debris:** Sea turtles may feed on plastics, such as balloons and bags, which block their digetive system. Rubbish lining beaches can prevent turtles from nesting.
- **Pollution:** Marine pollution causes damage to foraging habitats of sea turtles (Coral reefs and seagrass).

Traditionally, sea turtles were probably nesting on sandy beaches off the Abu Dhabi mainland. Nesting is currently limited to 15 offshore islands. Quantification of the loss of nesting habitats in the emirate of Abu Dhabi is not available due to the absence of any previous baseline information.

Loss of seagrass habitat

If seagrass habitats are destroyed or degraded, the loss to the fishing industry and the environment generally is enormous. These potential losses must be considered when planning for construction activities in shallow marine areas including laying pipelines, dredging channels and undertaking reclamation of marine and intertidal areas. Other impacts on seagrass can occur from frequent boating and increased coastal nutrients. Nutrients are a particular problem in estuaries and bays with reduced tidal flushing.

Despite the adaptive responses of seagrasses to a fluctuating environment, several human-related activities can impede the ability of the plants to persist. Dredging and eutrophication pose the greatest threats to seagrass ecosystems (Godcharles 1971; Lewis 1977; Lewis and Estavez 1988; Phillips 1978, 1979). Not only are the plants physically removed by dredging, but the entire physical, biological, and chemical structure of the ecosystem is

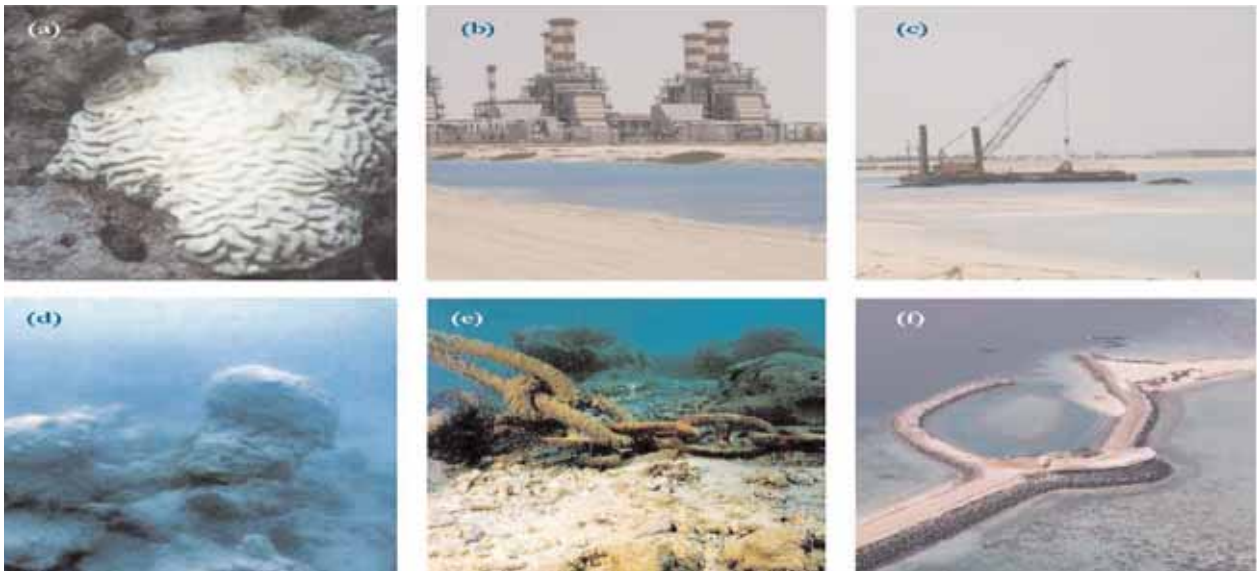


Figure 49: Threats to the coral reefs of Abu Dhabi

Bleaching (a) mortality and subsequent algal overgrowth, hyper-saline thermal water discharges (b), loss of habitat due to dredging (c) and the indirect effects of sedimentation such as smothering and loss of illumination (d), anchor damage (e) and construction as shown by this breakwater/harbour situated on a coral reef (f)

changed. Siltation is considered to be the greatest single form of marine pollution threatening seagrasses (Sloan, 1993). The extent of the area affected by the dredging depends on the sediment fall-out from the actual dredging site, and the resulting turbidity in the water column that prevents light penetrating. The extent of this impact depends on tidal range, current strength, and sediment texture in the area. Sediment curtains can help, but are ineffective in areas with strong currents. After dredging, seagrass can only recolonize the remaining sediments that are within the photic zone (<10 m), and only after the pre-impact physio-chemical conditions have been returned within the sediments. This may take many years.

The impact of effluent discharges on seagrass is also well documented. In many other parts of the world, large areas of sea-grasses have been lost due to epiphyte loads on seagrass blades near sewage or storm water discharge pipes. In the vicinity of Al Sammaliah Island we currently do not have large populations, however the proposed 150,000 residents at Al Raha will certainly result in eutrophication issues.

All seagrasses have upper and lower temperature tolerance levels for their various life history stages. Raising the temperature regime can have far greater effects than a similar modification in a temperate environment, since organisms in tropical waters live much closer to their upper thermal limits. It would be natural to assume that since the waters of the Gulf reach extreme limits of temperature and salinity, the same would be true for the three seagrass species that live in it.

Documentation of the effect of oil on seagrasses is lacking, with the few existing reports stating that direct contact of the oil with the seagrass plants is needed to cause death of the plants. Studies performed on seagrasses where very large oil spills have occurred have shown that the seagrass plants themselves were not impacted, ie. they persisted and did not appear to be harmed. A sound toxicological study relating oil and petroleum fractions to the growth and development of seagrass plants, and effects on food chain organisms, and also on the sediment is one of the most pressing needs in the field of seagrass research at present.

Threats to rocky shores

Natural rocky shores are rare in Abu Dhabi, and are valuable for their diverse range of intertidal inhabitants. The main problem facing these habitats is marine oil pollution that can be devastating if washed over organisms during low tides, and the large quantities of accumulated rubbish that smothers these productive areas.

Threats to coastal vegetation and important coastal plant areas

The rapid economic upturn in the Emirate over the past decades has inevitably left its scars on the natural environment, especially in many coastal areas. Despite the obvious need for infrastructure development, some of the destruction that has occurred in recent years has been totally unnecessary. It is now virtually impossible to find a stretch of coastline, on the mainland at least, that has not been subjected to some form of negative human impact. In the initial rush for economic prosperity, lasting damage is being inflicted on the environment at unprecedented rates. Deil & Müller-Hohenstein (1996) foresaw the pending destruction of most of the coastal vegetation in the vicinity of Dubai. It is vital to bear in mind that today's species assemblage in the vegetation cover may have only little similarity to that which prevailed in the recent past. In other words, without proper documentation, there is no way of knowing the true natural vegetation of an area. Dune vegetation is under threat from grazing of domestic stock such as camels and goats and the driving of four-wheel vehicles. More recent impacts include the construction of tourism and recreation facilities in the dune zone (*e.g.* weekend chalets) and this not only promotes erosion of the beach, but also puts the developments at risk of flooding during storm events.

Oil pollution is potentially a problem in many coastal areas, and due care should be taken to prevent spills from occurring. Although there is evidence to suggest that certain ecosystems, such as mangroves, can recover from moderate or even large oil spills, the immediate impact on wildlife is often quite devastating (Böer, 1993). When oil spills occur in terrestrial habitats, the natural breakdown of the oil can be a long process under the prevailing adverse climatic conditions (Brown & Porembski, 2000).

The management of coastal vegetation in Abu Dhabi and the UAE in general has not been the focus of attention, despite the importance of vegetation in coastal protection and providing vital habitats, although the issue was briefly addressed on a GCC level by UNESCO in the context of ecosystem and water management (Brown *et al.*, 2006).

Parts of the coastline in the far west of the Emirate on the Sila'a Peninsula are botanically important, with coastal plant communities well developed over large areas. The mangroves and salt-marsh communities between Abu Al

Abyad and Ras Ghanada are also of high conservation value. These communities require special attention to protect them from the bogus 'conservation' initiatives that have led to their destruction in some other Emirates in favour of infrastructure development. Coastal white-sand communities on low dunes close to the coastline are also highly threatened, extremely valuable coastal habitats, especially in the north-east of the Emirate.

6.2 Population growth and urban sprawl

Abu Dhabi has experienced dramatic population growth in a relatively short period of time spanning only 3 decades (see the sector paper on population, development and economy). Parallel with the population growth has been the rapid expansion of urban areas, most of which occur along the coast. Except for Al Ain, all the major cities and towns are located along the coast. Urbanization is, however, not limited to the cities and towns but is spread out throughout the coastline in a phenomenon that has come to be known as urban sprawl. Urban sprawl may be defined as the development and growth of settlements beyond the boundaries of urban centres. Most of the time the development of such urban sprawl is poorly planned and its growth is largely unmanaged.

The twin issues of population growth and coastal urbanization comprise a significant threat to the wellbeing of the coastal and marine environment. Potential impacts include habitat fragmentation and loss due to replacement of natural habitats with infrastructure (buildings, roads, landscaping *etc.*), increased pollution from point and non-point sources, reduced productivity because of the loss of essential habitats such as coral or mangrove communities and proliferation of invasive species. Apart from population growth and urbanization within proper urban boundaries, the phenomenon of urban sprawling which results in the establishment of settlements horizontally along much of the coastline further adds to the problems in the coastal zone because it is difficult to establish appropriate facilities to cater for sewage treatment, waste disposal and other services as the settlements resulting from such sprawling are too spread out (Al Abdessalaam, 2005a).

6.3 Coastal development

Erosion of the coastline is intensified by human actions, such as the removal of mangroves, reefs, dunes and other coastal landforms. These natural barriers provide resistance to erosion and protection against storms and waves. Activities such as construction of jetties, breakwaters, groynes, and other coastal protective structures, channelization and dredging disrupt coastal sediment transport patterns and reduce the supply of sand required for natural replenishment of beaches resulting in increased erosion along many shorelines in the process. Tourism, an emerging national industry, is heavily dependent on a healthy coastal environment especially the beaches therein. Careful and proper management of coastal erosion is thus prerequisite to a viable tourism industry in the country (Al Abdessalaam, 2005a).

The construction of ports and harbours results in the use of critical coastal habitats and impacts on the coastal and marine environment through activities such as dredging and filling. Furthermore, dredged material if not properly disposed of may also adversely affect coastal and marine habitats. Port maintenance activities such as maintenance dredging, are an integral part of the port and harbour management. These activities also adversely affect the marine environment, especially in the nearby shore areas (Al Abdessalaam, 2005a).

Some of the impacts of tourism include habitat loss and degradation as a result of construction of hotels and other facilities in sensitive areas, pollution from sewage, wastewater and other sources of waste discharges and marine debris. These pollutants often result in serious deterioration of the water quality leading to problems in human health, declines in biodiversity and resource depletion.

Beach erosion due to tourism development activities and coastal protection structures is another issue of major concern. Considering that beaches are the focal point of coastal tourism and recreation, the loss and degradation of beaches due to erosion could have serious impacts on the success of industry in the long term. Loss of public access to beaches and other coastal areas is another problem stemming from tourism. Tourism infrastructure may limit or even deny access to traditional uses of the coastline such as fishing, swimming and other recreational uses. Apart from the social and economic impacts, such losses of access may result in serious user conflicts (Al Abdessalaam, 2005a).

6.4 Climate Change

Coral Bleaching/Mortality

Bleaching in hermatypic corals is caused by the loss of algal symbionts and/or their pigments in response to environmentally stressful conditions. In the majority but not in all cases this then leads to the death of the

corals. Environmental stresses that trigger bleaching are varied and may include changes in salinity, increased sedimentation, prolonged darkness (usually resulting from sedimentation or algal blooms), exposure to the atmosphere at low tide, fluctuations in sea temperatures and strong and prolonged solar radiation. In recent years throughout the tropics coral bleaching has more usually been associated with elevated temperatures of the seawater in the shallows where coral reefs are to be found. Only a small positive anomaly of around 1-2 degrees Celsius for a prolonged period during the summer can trigger bleaching.

The increase in frequency of coral bleaching incidences worldwide at the end of the 20th Century coupled with significant sea-surface temperature (SST) rises in the same period is thought to be associated with anthropogenically -induced stress manifested through global warming which is set to continue for the foreseeable future according to a majority of climatologists. It is well-known that the corals of the shallow reefs of the Gulf Emirates already existed under extremely stressful environmental conditions that include high summer and low winter seawater temperatures and high salinities (*e.g.* Kinsman, 1964), as well as high sediment loads in the water column as a result of persistent winds from land or sea and consequent wave action throughout much of the year.

In 1996 and 1998 two catastrophic coral bleaching and mortality events occurred on the reefs of Abu Dhabi Emirate in association with prolonged positive summer seawater temperature anomalies. Marine scientists from the Natural History Museum, London were the first to notice and report these phenomena (George & John, 1998, 1999; John & George, 1998b) and subsequently gave in February 2000 a detailed paper on the subject at an 'International symposium on the Extent and Impact of coral bleaching in the Arabian region' (George & John, 2000a, 2005a) at which similar catastrophic coral deaths in 1996 and 1998 in Bahrain and Qatar were also reported (Al-Qaseer & Uwate, 2000, 2005). At the 2nd Arab International Conference in April 2000 that concentrated on Coastal Habitats, George & John drew attention to the cline of damage to the coral reefs in the Emirate running from most damaged least diverse reefs in the west to least damaged most diverse reefs in the east and related this cline closely to SST and salinity data (George & John, 2000b, 2004). Similar coral deaths in 1996 and to a lesser extent in 1998 at the few remaining coral assemblages in Dubai Emirate have been reported by Riegl (1999, 2002) and related to positive SST anomalies, and Riegl (2003) also noted a stronger seawater temperature variability in the western region of Abu Dhabi Emirate than in the eastern region whilst carrying out a comparison of affects of climate change on coral reefs in the Arabian Gulf and South Africa.

Since the catastrophic coral mortalities in Abu Dhabi Emirate in 1996 and 1998 some regeneration of partly damaged corals has occurred, as has settlement of coral larvae to form new colonies (George *et al*., 2001; John & George, 2001; Sheppard & Loughland, 2002). However, new colonies have often started to develop on unstable coral rubble in shallow waters and are unlikely to survive in this precarious position during violent storms. The prognosis for the survival of coral reefs in the Emirate in the long term if summer seawater temperatures continue to rise is not good as the corals have probably now reached their upper physiological temperature limit. Every effort should be made, therefore, to prevent further damage to surviving corals and coral reefs in the Emirate by affording them strict protection from harmful human activities.

From a management point of view, remaining coral reefs need to be protected so as to provide a spawning resource for the restoration of impacted reefs. Activities such as dredging and reclamation in the vicinity of, or up current from these surviving reefs should be prohibited, as additional stress from sedimentation may add to the corals existing problems of surviving in a warmer environment. Heat and salinity impacts can be exacerbated by the discharge from desalination plants in the vicinity of reefs. Other activities such as unmanaged recreational diving and fishing activities should also be strictly controlled at remaining coral sites. The development of large artificial coastal islands may also impact on reefs through the disruption of established current patterns that normally disperse coral spawn from the Indian Ocean or from one remote Gulf reef to another.

Changes in ambient water quality

As sea surface temperatures are expected to increase, leading to increased evaporation, and because most of the total desalination capacity of the world is located around the Arabian Gulf (discharging brine ranging up to 70 ppt and 45°C), an increase in overall salinity in the study area is expected. Increases in salinity have been observed elsewhere in shallow waters in several tropical regions where desalination is used to supply freshwater (Ferrier-Pages *et al*., 1999).

Further increases in salinity in the study area resulting from increased temperatures and evaporation of sea surface water could also have negative effects on marine ecosystems (Walker and McComb, 1990). Changes resulting from fluctuating salinities are known to effect the distribution and abundance of benthic vegetation (Montague and Lay, 1993). This occurs because osmotic adjustments resulting from salt stress compete for energy, carbohydrate and nitrogen, and limit overall growth (Stewart and Lee, 1974; Cavalieri, 1983; Yeo, 1983). Corals are also sensitive to increases in salinity because they have no mechanisms for osmotic regulation (Muthiqa and Szmant, 1987) and changes in salinity can affect their metabolism and survival ability.

The effects of salinity on coral reefs and reef organisms have not been very thoroughly studied despite the earliest data on coral tolerance to salinity being collected in Florida more than 70 years ago (Wells, 1932).

Elevated salinities can also affect reef organisms other than corals, and Evans *et al.* (1973) and Clark and Keij (1973) reported the disappearance of several important faunal groups in high salinity waters in Abu Dhabi, and at the entrance to the Gulf of Salwah, within the southern Arabian Gulf. The number of species and individuals of benthic infauna is also limited by increasing salinities along the Saudi Arabian Gulf coast (Coles and McCain 1990). In these studies, hypersalinity was found to be the most important environmental factor affecting the benthos.

Generally, the numbers of coral species decrease with increasing salinity (Coles 1988, Sheppard 1988), and coral populations show systematic decreases in numbers of species with increasing salinity along the coasts of Bahrain (Sheppard, 1988), Qatar (Shinn, 1976), Saudi Arabia (Coles, 1988) and Abu Dhabi (Kinsman, 1964; Connell and Hawker, 1992). In Abu Dhabi, massive Porites survive salinities up to 48 ppt, and relatively fewer *Acropora, Favia, Stylophora* and *Pocillopora* species survive in waters with salinities in the range of 45-48 ppt (Connell and Hawker, 1992). Sheppard (1988) reported that there was a decrease of approximately one coral species with an increase of each part per thousand across the 42-50 ppt salinity range in Bahrain. As environmental stresses seldom act independently, other factors that may also have additional or synergistic effects on marine ecosystems (*e.g.* increasing temperature and salinity) are also important.

Change in sea level

Sea level reached its present level at around 6000 years B.P., and has since remained relatively stable allowing the development of complex Holocene coastal landforms (Saenger et al., 1983). However, according to the Intergovernmental Panel on Climate Change (IPCC, 1996), average global sea levels are again rising, with much of the rise attributed to an increase in global mean temperature.

Due to the great regional variation of each coastal area, the idea of a single sea level curve having global relevance has generally been discarded (Kidson, 1982), and regional changes in sea level are now providing more detailed information on variations in past sea level around the globe.

In the southern Gulf, studies have examined sea level rise relative to historic shorelines (Evans *et al.*, 1969, Taylor & Llling, 1969; Purser & Loreau, 1973; Dalongeville *et al.*, 1993; Lambeck, 1996; Kirkham, 1997). Others have examined sea level in relation to geology (Uchupi *et al.*, 1999), or Gulf floor sedimentation (Stoffers & Ross, 1979; Sarnthein, 1972; Reynolds, 1993).

Previous higher sea levels are also evident in the study area by fossilized mangrove rhizoliths that occur on the wave-cut platforms around 80cm above today's high-water mark. These are particularly well seen at Qasasir in the lagoon between Al Aryam and Futaisi Islands, just west of the island of Abu Dhabi, and on the island of Marawah, further west.

Rapid sea level rise is actually the problem, and according to Titus (1988 and 1990) and Mitchell (1991), the characteristics of rapid sea level rise will include both elevation in the mean level of the ocean surface and increase in the tidal variation around the mean. According to Short and Neckles (1999), the direct effects of sea level rise on the coastal oceans will be to increase water depths, change tidal variation (both mean tide level and tidal prism), alter water movement and increase sea water intrusion into estuaries and rivers. These effects should be quite noticeable in the shallow Arabian Gulf.

Tidal height and tidal range effects on available light, current velocities, depth, and salinity distribution are all factors that regulate the distribution and abundance of shallow water marine ecosystems such as coral reefs and seagrasses. A major impact of all these changes will be a redistribution of existing habitats. Increased water depth, which reduces the amount of light, will directly reduce plant productivity where plants are light limited.

The overall impact of increased water depth will vary between locations, depending on local topography where seagrasses are currently growing. However, the projected 0.66m increase in water depth due to sea level rise over the next century could reduce available light by 50%, which in turn may cause a 3040% reduction in seagrass growth (Short and Neckles, 1999). The shifting of seagrass beds shoreward will be impeded in most developed coastal areas by shoreline construction and armouring, already in place and which probably will be expanded to protect coastal real estate. In some cases, the natural geomorphology would also not permit shoreward movement of seagrass communities.

All intertidal plants rely on generation time to alter their range, and some plants like salt marsh are more able to adapt (faster generation), but large slow-growing mangrove communities usually have a larger generation time. The threat to the study area's important wildlife populations as a result of rapid sea level rise will concern mostly the physical loss of habitat especially foraging areas such as subtidal, intertidal and supratidal plant communities and other intertidal habitats such as mud flats and rocky shores. Nesting sites for marine turtles and birds may also be affected by rising sea levels and, coupled with storm surges, shoals containing sea bird nesting colonies and areas of turtle nesting beaches may be periodically inundated or badly eroded.

6.5 Impacts from fishing

Prior to the year 2000, there was limited scientific information on the status of the fish stocks of Abu Dhabi. The only previous resource survey in UAE waters was completed in 1978, although it only formed a small part of a wider survey of the Arabian Gulf (FAO, 1981). In response to these concerns, the Marine Environment Research Center of the Environment Agency - Abu Dhabi implemented a programme of research activities aimed at establishing existing levels of exploitation and the carrying capacity of commercially important species. The projects were collectively designed to provide the scientific basis of a management regime for the fisheries of the Emirate of Abu Dhabi in line with one of the Environment Agency's principal strategic goals. The direct impacts of fishing on the fisheries resources of Abu Dhabi have subsequently been established through the 'Fish Resources Assessment Survey' and the 'Fish Landings and Population Dynamics Project', which are described in section 7.3.1.

The critical management issues faced by the industry are that the majority of commercially exploited demersal species and the most important pelagic species are being exploited well in excess of sustainable levels (**Figure 50**). When considered in terms of their proportion of the total annual catch, demersal species that are over-exploited represent 71% of the resource base and pelagic species that are over-exploited represent 48% of the resource base. In the case of the orange-spotted grouper (*Epinephelus coioides*), which is the mainstay of the demersal trap fishery, the fishing mortality rate is more than six times the sustainable level (Grandcourt et al., 2005a). Furthermore, selectivity characteristics of the fishing gears result in a large proportion of catches being composed of immature fish that have not achieved their full growth potential. The most striking example is the kingfish (*Scomberomorus commerson*) for which 95% of the landed catch is immature (Grandcourt *et al.*, 2005b). Independent biomass per recruit analyses for some of the most important commercially exploited species corroborate the declines of over 80% in the average stock size for all commercial species that was derived by comparing the results of the 'Fish Resources Assessment Survey' (Shallard and Associates, 2003b) with those obtained by the previous survey in 1978 (FAO, 1980).

Of all the demersal species that have been assessed, the only resources that were found to be underutilized were the lizard-fish (Family: Synodontidae), breams (Family: Nemipteridae), barracuda (Family: Sphyraenidae) and some representatives of the family Carangidae. The abundance of small pelagic resources has not changed since 1978, however, whilst

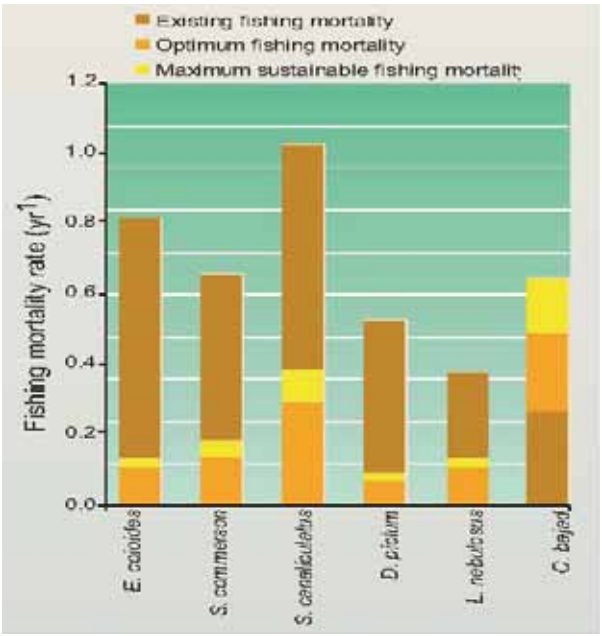


Figure 50: Stock assessments have shown that the existing fishing mortality rate is well in excess of sustainable limits for most species in the demersal and pelagic fisheries (Error bars show 95% CI's).

there is a potential sustainable yield of small pelagic species available, the small school sizes makes any attempts at commercial exploitation of these resources difficult.

Management simulations have revealed that measures that achieve an increase in the size at first capture of demersal species would result in an increase in both the spawning stock abundance and catch. Furthermore, such measures would have to be accompanied by significant reductions in fishing effort if stock rebuilding and resource conservation objectives are to be achieved. The results of the stock assessments for the principal fisheries resources of Abu Dhabi have prompted authorities to implement a wide variety of management regulations including fishing effort and gear restrictions, closed areas and seasons.

Figure 51: One of the indirect impacts of fishing is the entanglement and drowning of marine wildlife in feashing gear as shown here for a dugong.

with more detailed investigations into the impact of fishing on the age, size and sexual structure of populations of commercially important species. This will be achieved through an experimental fishing programme which will also assess other aspects of the fishery such as the incidence of by-catch.

Whilst the direct impacts of fishing have been well defined, the indirect impacts are relatively poorly investigated. These include the deleterious impacts of fishing on habitats such as corals reefs through damage caused by operations, lost and/or discarded fishing gear and anchor damage. A particular concern is the density of discarded fish traps and their potential to 'ghost fish' and cause direct mechanical damage to corals. Both hard and soft coral cover is considered to be declining due to the impact of nets, traps, anchors and other fishing related activities. In the absence of any empirical data, management authorities have taken a precautionary approach with trap fishing being banned within 3 miles of the shore. Other indirect effects of fishing include the mortality of marine wildlife from drowning due to entanglement in fishing gear. Whilst the incidence rate has decreased since 2003

Figure 52: One of the critical management issues faced by both the demersal and pelagic fisheries, is the high proportion of immature fish in landings.

In the case of the Kingfish or Chanaad (Scomberomorus commerson) shown above, 95% of the landed catch is compo of fish that have not achieved sexual maturity.

due to the bans on drift net fishing, dugongs and sea turtles still become entangled and drown in certain types of fishing nets.

Coastline modifications including activities such as dredging, land reclamation and channeling of the seabed have paralleled major declines in demersal fish stocks. The fact that both commercial and non-commercial stocks have been affected suggests that these declines may be associated with environmental changes and habitat degradation. Many of the marine habitats threatened by coastal development include those which are known to be important as nursery and spawning areas for commercially important fishes. However, there is a dearth of spatially explicit ecological data on the distribution of marine habitats and the importance of specific sites to the reproduction

Figure 53: Coastline modifications including activities such as dredging, land reclamation and channeling of the seabed have paralleled major declines in demersal fish stocks.

Many of the marine habitats threatened by coastal development include those which are known to be important as nursery and spawning areas for commercially important fishes.

of commercially exploited species. Some of the other indirect impacts of fishing include the ecosystem effects such as prey release and species interactions. However, it may be difficult to address such gaps immediately because of demanding data requirements and resource limitations.

In order to protect biodiversity and meet conservation objectives, marine protected areas (MPA's) have been established in the waters of the Emirate of Abu Dhabi (see section 7.4). They are also intended to serve a role in fisheries management by conserving fisheries resources. It is anticipated that the exclusion of commercial fisheries will result in protected areas having a higher density of larger more fecund fish that can export eggs, larvae, juveniles and adults to neighbouring fishing grounds. At the moment, the extent to which the marine protected areas of Abu Dhabi are achieving this is unknown and a monitoring programme is required to ascertain whether MPA's are meeting their objectives in this regard.

6.6 Aquaculture

As aquaculture activities in Abu Dhabi are generally on a small experimental or pilot project scale, the input of effluent waters into the marine environment is negligible. Sites are usually remote from urban and industrial areas and there are no conflicts with other users due to their small size. Nevertheless, if allowed to develop without regulation, cages and other infrastructure could cause congestion in coastal waterways. Also, a particular concern for the industry is the culture of imported species that do not occur naturally in the waters of the Emirate and their potential ecological impact if released into the wild. Whilst aquaculture has been relatively benign with no significant environmental impacts, the absence of operating guidelines, regulations and legislation to govern the development of the industry is probably the single most pressing management issue.

6.7 Harmful Algal Blooms

Harmful algal blooms (HAB's) can be defined as a visible- or non-visible patch of micro algae (phytoplankton) in coastal waters that negatively impact on the health of marine ecosystems and/or human health. These phytoplankton blooms may cause harm by shading other forms of aquatic life, depleting the dissolved oxygen content and causing damage to the ecosystem, economy and public health. These events are referred to as 'harmful algal blooms' (HABs), although they are also called 'red tides'. There are four categories of deleterious impacts namely; risks to human health, loss of natural or cultured seafood resources, impairment of tourism and recreational activities and damages to non-commercial marine resources and wildlife. One of the most significant public health problems created by phytoplankton are the production of toxins such as paralytic shellfish poisoning (PSP); diarrhetic shell fish poisoning (DSP); amnesic shellfish poisoning (ASP); neurotoxic shellfish poisoning (NSP) and ciguatera fish poisoning (CFP).

The occurrence of these blooms in the Arabian Gulf region has increased over the past few decades. There are also reports of fish kills in Abu Dhabi waters, presumably as a result of algal blooms. Prior to 2001, no studies were available on phytoplankton in Abu Dhabi, consequently EAD started a project on harmful algal blooms in Abu Dhabi waters to gather information on the biological, chemical and physical factors that regulate harmful algal bloom dynamics and impacts they have on the environment, economy and public health. The information gathered is intended for the development of procedures for mitigation and management of harmful algal blooms in the Emirate of Abu Dhabi.

The data collected through the 'Harmful Algal Blooms' project has revealed that the phytoplankton population was represented by more than 191 species in Abu

Figure 54: Harmful algal blooms (shown here in Mussafah Channel) cause fish kills and are a threat to public health.

Dhabi. Among them only 9 were toxic and capable of producing DSP (Diarrhetic Shell fish Poisoning), PSP (Paralytic Shellfish Poisoning) and NSP (Neurotoxic Shellfish Poisoning) toxins. Mussafah, one of the areas observed continuously, showed blooms throughout the year. The blooms were initiated with Cyanobacteria, continued with *Prorocentrum* species and again replaced by the Cyanobacteria. During one year of observation, the Cyanobacteria bloom was recorded for 6 months (summer months), Prorocentrum species for four months (winter months) and the bloom was mixed with both Cyanobacteria and Prorocentrum species for another two months.

Fish kills, which are a common phenomenon in Abu Dhabi waters, are one of the impacts of harmful algal blooms. These incidents have been recorded in Mussafah Channel since 1998. The species affected was *Nematolosa nasus*, a member of the Clupeidae family. The analyses showed that the water quality of the Mussafah south channel was completely deteriorated by nutrient enrichment and the hydrographic parameters were abnormal. The dissolved oxygen concentration was low in bottom waters and the area was filled with phytoplankton blooms throughout the year. This condition clearly showed that industrial effluents were causing eutrophication in the area. Details of water quality, blooms, and fish kills can be found in the annual and technical reports of the Marine Environment Research Center of the Environment Agency Abu Dhabi (Rajan, 2003; 2004). Phytoplankton studies have been conducted over limited spatial and temporal scales, given their importance as indicators for environmental change, the survey should be continued and extended to other areas in the Emirate of Abu Dhabi. Furthermore, studies are required to determine the toxicity of the available harmful species, in particular for the Cyanobacteria which are responsible for the blooms in the Mussafah area.

6.8 Invasive species

Invasive species in the marine environment are one of the most serious threats to biodiversity. The introduction of non-native species are increasing in frequency and extent as human movements become more global and international trade increases. The impacts of non-indigenous species are many, and include ecological, economic, cultural and social considerations. Although the impacts of most invasions remain unexplored, there is no doubt that

Figure 55: Ballast water discharges from commercial vessels are the principal agent of transmission with some 3000 to 4000 invasive species being transported around the world on a daily basis. Abu Dhabi is particularly vulnerable due to its heavy reliance on international shipping.

biological invasions have become a major force of ecological change, as well as economic and human health impacts operating on a global scale. The apparent increase in invasion rate, combined with significant impacts, has further elevated public and scientific concerns about invasions in recent years.

In the marine ecosystem, the main source of invasion is ballast water. It has been estimated that 3000 to 4000 species are transported around the world on a daily basis by ballast water (Carlton 1995). The United Arab Emirates is dependent on international shipping for most of its trade and has a high level of ship traffic. Since thousands of oil tankers and cargo ships are using the Gulf, the chances of invasion of exotic species through ballast water are tremendous. The investigation made by the Environment Agency - Abu Dhabi on Harmful Algal Blooms in Abu Dhabi waters has shown the presence of a higher number of harmful algae in areas of high shipping traffic. A detailed study is essential for any attempt to control the spread by shipping of introduced exotic marine species. This information is lacking for all UAE waters especially the ports.

Recognizing the need for a baseline study, the Environment Agency - Abu Dhabi is undertaking an invasive species research program with the goal to minimize the introduction of non-indigenous species and manage established populations of aquatic invasive species. This information is central to the development of a national marine invasive species management strategy and a key component in domestic ballast water management and port risk assessment.

6.9 Pollution and water quality

Water quality is critical to the wellbeing of Abu Dhabi's coastal and marine environment. Recognizing this fact, the government has established water quality standards in keeping with Federal Law number 24 on the protection and development of the environment and relevant by laws. Other efforts include the setting up of water quality monitoring programmes by the relevant regulatory authorities in some emirates and the undertaking of clean-up operations along the coastline. Despite these efforts, however, the problem of pollution persists and is probably abated both by gaps in existing regulations and a lack of adequate monitoring facilities at the regulatory level.

Figure 56: A hyper-saline thermal water outfall.

The quality of water is affected by both point and non-point sources of pollution. Point source pollution refers to pollution that enters the marine environment through known and specific facilities such as the numerous outfalls. Non-point source pollution, on the other hand, refers to pollution that enters the coastal and marine environment from a variety of non specified sources such as runoff from urban areas and the random introduction of pollution from other land uses. While point source pollution is relatively easier to control by setting conditions for discharges and monitoring programmes including mechanisms for self regulation at known locations, the situation is somewhat different with non-point source pollution because of the non specific nature of the origin of this type of pollution.

A broad range of pollutants including sediment, nutrients, hydrocarbons, bacteria and probably heavy metals are introduced into the coastal and marine environment through different routes. Most of this pollution originates from mundane and widely dispersed sources from both land and sea. Land based pollution, however, probably accounts for the larger share given that globally over 75% of marine pollution is land based being mainly generated by urban and industrial uses.

Discharges of sewage, processing wastes and drainage from urban and industrial facilities are of particular concern. An over abundance of nutrients derived from sewage and other sources has resulted in localized episodes of eutrophication in some areas that are largely enclosed. Occasionally, this has triggered a process of rapid growth and decay of algae accompanied by oxygen depletion and the mortality of fish and other marine life. Vegetation clearing, grading and settlements occurring far inland can also exacerbate the problem of pollution of coastal systems. Not only do these activities cause increased siltation of the coastal waters but also because through the loss of vegetation, these areas are deprived of natural filters of pollution.

Marine-based activities, such as oil extraction, shipping, dredging, recreational boating and fishing also cause pollution of the marine environment and the coastline. Marine debris such as plastics, discarded lines and wooden pieces are common along the shorelines of Abu Dhabi. Some of the debris, such as discarded lines, can entangle marine turtles, while plastic bags may be mistaken for food and ingested. Every year a small number of turtles die in Abu Dhabi waters due to ingestion of marine debris. Wooden planks and plastic along sandy beaches physically obstruct turtles from nesting. Although Abu Dhabi has been largely spared of major oil spills, significant amounts of oil still reach the sea annually from a variety of sources, both land and sea-based such as industrial discharges, leaks from offshore oil installations, ships and boats. Hence, unless appropriate action is taken to reduce the threat of pollution, the coastal and marine environment could lose its aesthetic and economic potential through pollution (Al Abdessalaam, 2005a).

Figure 57; The accumulation of urban refuse on beaches poses a threat to wildlife such as nesting sea turtles.

6.10 Tourism and recreation impacts

Probably the first and foremost impact of tourism and recreation is the destruction and loss of natural habitats resulting from development. Construction of beachfront hotels and ancillary facilities represent the most obvious habitat alterations brought about by the tourism and recreation sectors. New project development and construction is underway at a rapid pace along many parts of the coastline of Abu Dhabi. These developments are causing immediate threats to wild flora and fauna through direct loss and alteration of habitats. There is usually additional habitat destruction to areas adjacent to development sites; often these are associated with activities such as construction of access roads and the laying of pipelines and cables. Terra-forming activities can affect drainage and runoff, resulting in erosion and impacts on vegetation. Marine dredging activities can destroy marine life both directly and indirectly through habitat alteration. Examples of the impacts of tourism and recreation include:

- Littering and pollution.
- Disruption of breeding activities for species such as ospreys, sooty falcons, shore birds and sea turtles.
- Beach habitat destruction from walking, camping and car use.
- Overfishing.
- Coral destruction from divers and anchors.
- Fuel and oil leakage from boats and personal water craft.
- Personal water craft noise pollution, which can disturb wildlife.

6.11 Issues specific to islands

Due to the remote location of many of Abu Dhabi's islands, turtles and birds are able to nest mostly undisturbed. However, illegal egg collection, and the disturbance of nesting sites by driving vehicles along the beach are threats to both nesting turtles and birds. Another threat occurring on off-shore islands is the release of domestic cats, which soon become wild with disastrous consequences for ground nesting birds. The red-billed tropicbird *Phaethon aethereus indicus*, has its only known Gulf nesting sites in Abu Dhabi Emirate, being located on three offshore Islands (Zirku, Arzannah and Qarnein). Unfortunately the tropicbird population is in decline due to cats that have been released on the islands, and which prey directly on the adult birds and their chicks. The construction of causeways from the mainland to near-shore islands also allows predators such as cats and foxes access to nesting sites. The development of harbours, airstrips and buildings on remote islands can result in severe disturbance to important bird nesting areas. The accumulation of rubbish on the coastlines of islands in the emirate is now also a threat to nesting marine turtles, and their young after hatching as they attempt to reach the sea (Loughland and Darwish, 2004).

6.12 Transportation and the oil industry

Boating and shipping cause dangers for marine wildlife. Fishing and recreational boats, especially high-speed vessels strike marine wildlife. Dugongs and sea turtles are the most common victims of collisions.

The oil industry constitutes the mainstay of the economy of Abu Dhabi. Most oil is extracted offshore and oil exploration and extraction operations are largely self managed and regulated by the oil companies. Oil operations may have significant impacts on the coastal and marine environment. Some of these impacts include: (i) Direct loss of habitat due to erection of oil facilities and pipelines in areas possessing critical habitats (ii) Coastal and marine ecosystem degradation due to the cumulative effects of oil and air pollution emanating from installations (iii) oil spills from oil exploration, exploitation and transport operations. Effective conservation requires that the undertaking of all coastal and marine development activities, including oil exploration and extraction, consider the limitations of natural systems and balancing the need for their conservation with the demands of the relevant development activities (Al Abdessalaam, 2005a).

6.13 Awareness

Faced with unprecedented growth in population and consumption patterns, the Emirate of Abu Dhabi is faced with some serious environmental problems. With its linear settlement patterns stretched along the coastline, it is only natural that waste accumulates along the shores and as marine debris in the sea. Most solutions to these problems include public education, decision making and the stakeholders' participation for success. Prioritized marine issues for awareness and education so far have been: (1) declining fisheries resources, (2) marine pollution, in particular marine debris (3) the plight of the marine endangered species and (4) coastal zone management awareness.

Despite the variety of efforts in marine awareness issues, it has not managed to reach a large population. Most of the fishermen are actually expatriate labour, (South Asians) and most of them are illiterate so do not comprehend

either English or Arabic. Even among the fishermen, there are different cultural groups speaking different languages from South Asia. To make the awareness efforts effective and reach out to a significant section of the population, there is a need to develop a well structured multilingual awareness campaign with the fishermen in a language and manner which they can comprehend.

Efforts with students though sustained have also not yet reached out to a significant number. For the target audience other than students, there is no regular or structured dissemination plan of action. There is an urgent need to conduct an assessment of the awareness levels achieved so far. No evaluation of the efforts already made has been done. Once this is done, issues can be prioritized and strategies can be formulated.

6.14 Enforcement and regulatory legislation

More than 10 federal laws and 20 emir decrees relating to the marine and coastal environment have been produced by the UAE since 1971. However, none of these provide a comprehensive framework for integrated planning and management of the coastal zone. Furthermore, the existing legislation relating to the marine and coastal environment requires a comprehensive review as it has some major omissions including (1) poor mandating and definition of executive authority (2) penalties are not always clearly stated (3) liability and indemnity against environmental damage are not emphasized (4) monitoring, control and surveillance schemes, and mechanisms of enforcement are not explained and (5) specific regulations for the coastal zone are not present. It is clear that there is a need to develop and implement legislation for Integrated Coastal Zone Management. The proposed draft 'Coastal Zone Management Law for the Emirate of Abu Dhabi' (Al Abdessalaam, 2005b) once implemented will fill some of the existing omissions.

The levels of compliance within the Marawah Marine Protected Area to date have been less than satisfactory and both the extent and frequency of offences has remained high due to a lack of proper monitoring control and surveillance. The absence of an appropriate by law for administering a penalty regime and staff educated with laws and regulations are another reason for poor management performance. The Environment Agency has proposed a review of the current rules and regulations pertaining to fisheries *i.e.* law (23/1999) and expansion of its MCS unit to take responsibility of implementation of the fisheries regulations for Abu Dhabi in coordination with the Coast Guard and Marine Police.

6.15 Planning, coordination and follow up

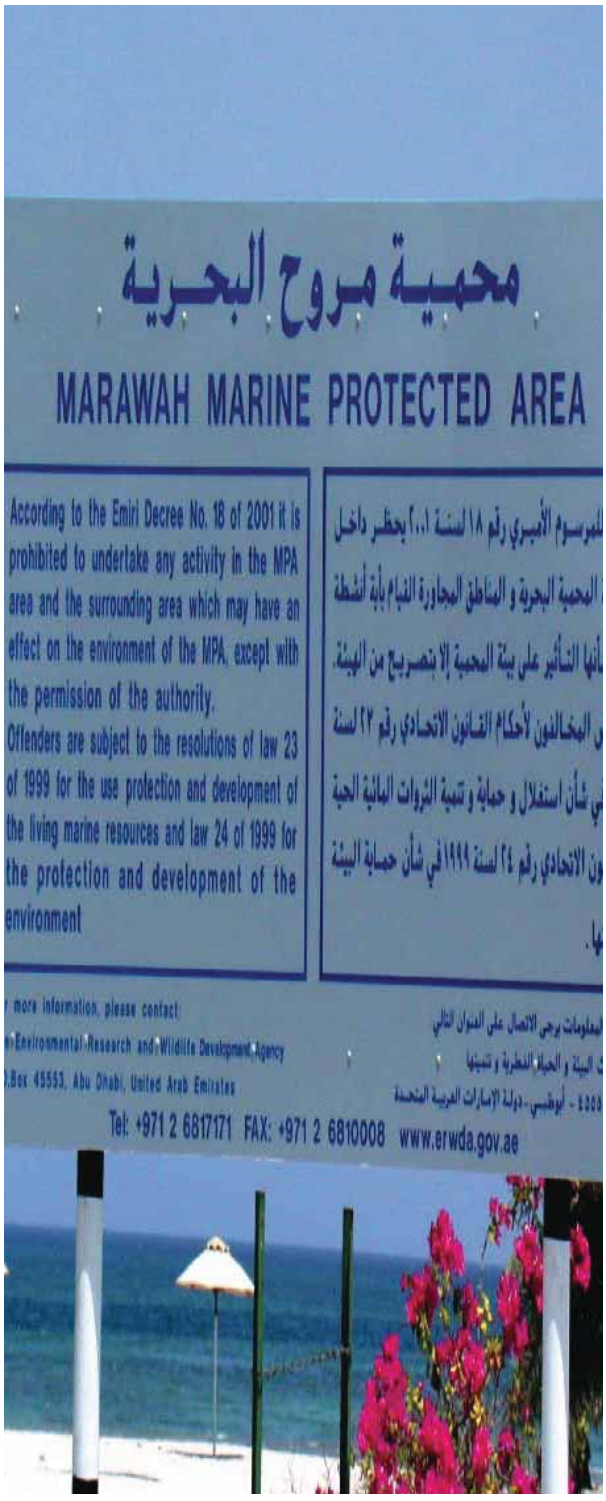
The federal and local authorities of the municipalities, environmental organizations and town planning departments of Abu Dhabi are responsible for the management of over 890 km of shoreline of the main land and more than 1500 km of shoreline of the offshore islands. Coastal zone planning may occur at two distinct levels. The strategic level for coastal / marine plans (*e.g.* 1:250,00 scale) is designed to identify broad goals, objectives, and strategies for the coastal and marine environment. The local level coastal / marine plans (*e.g.* 1:50,000 to 1:5,000 scales) are designed to identify a range of land tenure opportunities and allocated areas for developmental activities are partially present in municipalities and town planning departments. However, most of these plans are not prepared according to the guidelines of a comprehensive ICZM approach.

During 2005, coastal zone planning and policy issues were raised and discussed, in particular during the ICZM workshop held in Abu Dhabi and the international symposium on the marine environment and coastal engineering held in Dubai. Several discussion papers were presented to analyze the current situation and to recommend ways forward. It was found, that the coordination between different agencies and stakeholders of the marine and coastal environment is a key factor of the success of any marine and coastal planning / management initiative and that interagency coordination needs to be improved in order to:

- Conserve coastal and marine biodiversity and ecosystems and maintain physical and biophysical processes.
- Ensure longevity of current and future uses of the coast and marine environment (Ecologically Sustainable Development).
- Integrate planning and management across the coast and marine zone.
- Build the capacity and capability to manage coastal and marine resources effectively.
- Reduce redundancy in the activities of the different authorities, especially those involved in data collection.

The National Environmental Strategy and Workplan of the United Arab Emirates was published in September 2000. 57 participants of more than 40 governmental and non-governmental organizations in the UAE set up the policies and objectives of the 10 sectors of the strategy. However, the mechanism of procurement of the required budget and follow-up of the achievements and execution of the national strategy is inadequate. There have sunsequently been dramatic improvements in strategic planning within Abu Dhabi with local plans now being aligned with the national strategy.

7 MANAGEMENT AND CONSERVATION INITIATIVES



7.1 Institutional structure

When the federation of seven Emirates that form the UAE was established as a state in 1971, powers and areas of responsibility were allocated to the new federal institutions. Mandates were also given to the local governmental organizations by individual Emirates. However, there is an overlap in the responsibilities of federal and local government institutions, in particular those relating to living coastal and marine resources. Some of the principal international, state/local government and non-governmental organizations involved in the governance of the marine and coastal environment of Abu Dhabi are mentioned here. **Table 5** presents a synthesis of the responsibilities and activities of various Government Agencies at the emirate and federal levels with regards to the marine and coastal environment.

Federal Government Organizations

Ministry of Environment and Water: The Ministry has jurisdiction over matters relating to wildlife conservation and the marine environment. The Fisheries Department undertakes applied coastal and marine research relating to commercial activities. The Ministry of Environment and Water is also involved in the monitoring, assessment and management of living marine resources.

Federal Environmental Agency**:** The government of the United Arab Emirates established the Federal Environmental Agency in 1993. The mandate for the agency covers the development and protection of environmental resources within the UAE, this includes marine and terrestrial wildlife. The **Federal Environment Agency** took the place of the former Higher Environmental Authority by Federal Law No.7, 1993.

Local Emirate Government Organizations

Public works are carried out by the Abu Dhabi Municipality. Many large towns or towns distant from the central Municipality also possess their own Municipality or sub-office. Public works such as groundwater supplies, reclamation, sewage and waste-water treatment and disposal, irrigation and drainage are mainly conducted by these authorities. In 1994, Abu Dhabi Emirate approved the establishment of an Environmental Protection Committee to oversee the protection of areas falling under the jurisdiction of Abu Dhabi Municipality.

The Environment Agency - Abu Dhabi (EAD) is designated as the competent authority charged with the assessment and management of the environment and living coastal

Government Agency	Level	Activity / Responsibility
Ministry of Environment and Water	Federal	Fisheries management
Ministry of Communication	Federal	Roads, ports, shipping, maritime affairs, marine pollution
Ministry of Petroleum and Minerals	Federal	Gas and oil exploration and production
Ministry of Defence	Federal	Hydrographic surveys, EEZ security, bathymetric charts and mapping
Ministry of Finance and Industry	Federal	Industrial policy and permitting
Ministry of Public Works and Housing	Federal	Infrastructure development
Federal Environmental Agency	Federal	Lead federal agency on environmental protection and development
Ministry of Justice	Federal	Legislation
ETISALAT	Federal	Marine telecommunications
Ministry of Planning	Federal	Coastal planning
UAE University	Federal	Research
The Coast Guard Group	Federal	Enforcement of regulations, offshore operations
Environment Agency - Abu Dhabi	Emirate	Lead agency on environmental protection and development in Abu Dhabi
Dubai Municipality	Emirate	Lead agency on environmental protection and development in Dubai
Department of Environment and Protected Areas	Emirate	Lead agency on environmental protection and development in Sharjah
Municipalities in Ras Al Khaimah, Ajman, Um Al Quwain and Fujeirah	Emirate	Lead agency on environmental protection and development in Ras Al Khaimah, Ajman, Umm Al Qaiwain and Fujairah
Abu Dhabi Municipality	Emirate	Waste management, coastal defence, Abu Dhabi
Food and Environment Control Center	Emirate	Public Heath, Abu Dhabi
Planning Department,	Emirate	Planning, Abu Dhabi
Town planning Department	Emirate	Town planning, Abu Dhabi
Abu Dhabi Tourism Authority	Emirate	Tourist infrastructure & planning, Abu Dhabi
ADNOC and sister companies	Emirate	Oil and gas development, offshore operations, independent environmental programmes under HS&E departments, Abu Dhabi
ADWEA	Emirate	Water management, Desalination plants, Abu Dhabi
Sea Port Authority	Emirate	Ports, shipping, Abu Dhabi
Department of Tourism and Commerce Marketing	Emirate	Tourist infrastructure & planning, Dubai
Dubai Port Authority	Emirate	Ports, shipping, Dubai
Lands Department	Emirate	Coastal planning, land tenure, Dubai
Environment and wildlife section, private department of the President	Emirate	Environmental, wildlife, Abu Dhabi

Table 5: Responsibilities and activities of various Government Agencies at the emirate and federal levels with regards to the marine and coastal environment (Source: Al Abdessalaam 2005a)

and marine resources in the Emirate of Abu Dhabi. The agency has a sector (Biodiversity Management – Marine Sector) that undertakes a suite of research and management activities relating to marine and coastal resources.

Non-governmental organizations

Oil companies, whose responsibilities include some of the offshore islands, are often engaged in activities associated with Independent consultants are often called in to undertake environmental assessments in advance of construction developments or other operations. Shell Ltd. has provided funds for mangrove and turtle studies. The Abu Dhabi National Oil Company (ADNOC) and Abu Dhabi Company for Onshore Oil Operations (ADCO) finance a variety of marine environmental research. Between 1996 and 2001, the Natural History Museum of the United Kingdom carried out investigations on the hard bottom biotopes of Abu Dhabi with financial assistance from the Abu Dhabi Company for Onshore Oil Operations (ADCO).

The United Arab Emirates University (UAE University) based in Al Ain houses a Marine Environment Research Section. This section deals with both independent and collaborative research with other national institutions. Other non-governmental organizations include the Emirates Natural History Group which conducts lectures and field excursions and promotes conservation and awareness on issues concerning

the wildlife and cultural heritage of the UAE. Similarly, the Emirates Environmental Group campaign on environmental issues throughout the UAE and conduct public education and awareness activities. The Emirates Diving Association is involved in raising public awareness in relation to marine environmental issues, especially among school children. The organization also holds clean-up dives and beach clean-up campaigns.

International organizations

A number of international organizations have both direct and indirect inputs into the assessment and management of the marine and coastal environment of Abu Dhabi. These include the Gulf Cooperative Council (GCC) and the Gulf Area Oil Companies Mutual Aid Organization. The UAE is, along with other Gulf states, a signatory to the Kuwait Action Plan, drawn up by the Regional Organization for Protection of the Marine Environment (ROPME). Several other notable international organizations include the Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA), the United Nations Environment Programme (UNEP), the United Nations Development Programme (UNDP) and International Union for the Conservation of Nature (IUCN).

7.2 Legislation, regulations and strategies

The principal legal instruments of the federal government of the UAE relating to the marine and coastal environment are Federal Law no. 23, 1999 on the Exploitation, Protection and Development of Marine Biological Resources in the UAE and Federal Law no. 24 for the Protection and Development of the Environment.

Federal Law no. 23 includes regulations for fisheries and the exploitation of living marine resources. Federal Law no. 24 relates to environmental protection, pollution control, the conservation of biological diversity, sustainable exploitation and compliance with associated international and regional conventions. The law also specifically relates to protected areas (Ch. IV, Articles 63-68). The UAE hunting law, Federal Law no. 9, 1983, was introduced in recognition of the decline in desert and marine species in the UAE. The law prohibits the hunting, gathering or destruction of a variety of wildlife including sea birds and the dugong (Dugong dugon).

In addition to federal laws, decrees issued at the Emirate level play an important role in the governance of coastal and marine resources. The Marawah Marine Protected Area, which has recently been declared as a UNESCO Biosphere Reserve, for example was declared by Decree no. 18 of 2001. A 'Coastal Zone Management Law for the Emirate of Abu Dhabi' (Al Abdessalaam, 2005b) has been drafted and addresses some of the shortcomings of the existing legislation, however, the law was not enacted at the time of writing.

The following is a chronological list of the principal legislation relating to the marine and coastal environment of Abu Dhabi:

1. Federal law No. (21) of 1981 concerning the establishment of the General Authority for Water Resources Management in the UAE.
2. Federal law No.(26) of 1981 concerning the Maritime Commercial Law and its amendments.
3. Federal law No.(9) of 1983 concerning Regulation of Birds and Animals Hunting in UAE.
4. Law No. (4) of 1989 concerning the establishment of the National Avian Research Center (NARC).
5. Federal law no. (7) of 1993 concerning the establishment of the Federal Environmental Agency (FEA).
6. Federal law No.(19) of 1993 concerning the delineation of the maritime zones of the UAE.
7. Law No. (4) of 1996 concerning the establishment of the Environmental Research and Wildlife Development Agency (ERWDA).
8. Federal law No.(23) of 1999 Concerning the Exploitation, Protection and Development of living aquatic Resources of the UAE.
9. Federal law No.(24) of 1999 for the Protection and Development of the Environment - Ministerial Council Decision No. (37) of 2001 Pertaining to Executive Orders to this law.
10. Emiri Decree No.(18) of 2001 for the Establishment of Marawah Marine Protected Area.
11. Federal law no. (11) of 2002 regulating and monitoring the International Trade in Endangered Species of Wild Fauna and Flora.
12. Law No. (16) of 2005 concerning re-organization of the Environment Agency Abu Dhabi.
13. Emiri Decree No.(33) of 2005 for the Establishment of Yasat Marine Protected Area.

The UAE is also party to a variety of international conventions that relate to the coastal and marine environment as follows:

1. Convention on International Trade in Endangered Species of Fauna and Flora (CITES) - signed and ratified in 1990.
2. Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment - signed in 1978 and ratified in 1980.
3. Convention on the Control of the Transboundary Movement of Hazardous Wastes and their Disposal (Basel Convention) - signed in 1989.
4. Convention on Biological Diversity - signed in 1992.
5. United Nations Framework Convention on Climate Change (UNFCC) - signed and ratified 1995.

In addition to the legislation, a number of environmental strategies and action plans have been developed for the region, nationally and specifically for the Emirate of Abu Dhabi. Some of the regional action plans include the 'Regional Action Plan for the Conservation of Coral Reefs in the Arabian Seas Region' and the 'Kuwait Action Plan' both developed by the Regional Organization for the Protection of the Marine Environment (ROPME) and member states.

The 'National Environmental Strategy and Work Plan of the United Arab Emirates' was published in September 2000. The preparation of the strategy was funded by the Federal Environment Agency with the financial and technical support of the UNDP. 57 participants from more than 40 governmental and non-governmental organizations in the UAE set up the objectives of the 10 sectors of the strategy. The plans and priority projects of the marine sector of the UAE national strategy included: (1) Survey of marine biodiversity (2) Conservation of endangered species (3) Public awareness and environmental education (4) Protection of marine water quality (5) EIA legislation (6) Sustainable commercial fishing and (7) Marine Pollution.

Strategic environmental plans specifically for the Emirate of Abu Dhabi have been developed for the 2000-2004 and 2003-2007 periods by the Environment Agency in conjunction with stakeholders including those of other Emirates. Detailed work plans within these strategies address the six strategic goals of the agency namely: (1) Environmental regulatory system (2) Environmental monitoring system (3) A management regime for fisheries (4) A management regime for water resources (5) A regime for the management and restoration of wildlife (6) A society with increased environmental education and awareness.

The Environment Agency has also developed management plans for the conservation of the Dugong (*Dugong dugon*) and sea turtles in the Emirate of Abu Dhabi. The 'Marawah Marine Protected Area Management Plan' outlines the framework of activities aimed at preserving diversity and the coastal marine environment of the protected area. Other conservation and management initiatives include the development of oil spill contingency plans, in which marine and coastal areas have been classified according to their sensitivity and priority for protection in the event of an oil spill.

7.3 Research and monitoring

7.3.1 Fisheries stock assessment and monitoring

The state of knowledge on the living marine resources of the UAE has reached unprecedented levels over the last five years following the implementation of a suite of fisheries research activities by the Marine Environment Research Centre of the Environment Agency - Abu Dhabi. The 'Fish Resources Assessment Survey' provided the first fisheries independent data set for the UAE's demersal and small pelagic species since 1978, and the first extensive survey of these resources. The 'Fish Landings and Population Dynamics Project' established the first empirically derived estimates of yields taken in the fisheries of the Emirate and has provided stock assessments for the most important commercially exploited species.

These projects form part of a strategy (ERWDA, 2002) to develop a management regime for the fisheries of Abu Dhabi, which is one of six strategic goals of the Environment Agency. The strategy details a comprehensive programme of research and monitoring specified over a five year period which includes; the study of life history and population dynamics of the major species, stock distribution, fish population abundance, socio-economic aspects, anthropogenic induced stresses, ecosystem and climate studies and technological innovations and productivity.

The 'Fish Resources Assessment Survey' consisted of an extensive survey of the fisheries resources of the United Arab Emirates between February 2002 and January 2003. The methods used included trawl, trap and acoustic surveys. Plankton tows, satellite imagery and conductivity/temperature/depth sensors were used to collect oceanographic data (**Figure 58**). The overall goal was to carry out an assessment of fish and marine resources in UAE waters and provide information on abundance, distribution and potential yields. Specific objectives of the

project included; establishing the stock sizes of demersal and small pelagic resources, conducting biological studies of selected key species, determining estimates of safe harvest levels for commercially important species and providing oceanographic and ecological data relevant to fisheries resources.

The 'Fish Landings and Population Dynamics Project' is an on-going monitoring programme of the fisheries of the Emirate of Abu Dhabi with two distinct components. A catch and effort data recording system is used to estimate yields taken by the fisheries and the amount of fishing effort used to derive these catches. The second component relates to the population biology of the key exploited species. Objectives include estimating demographic attributes such as growth and mortality rates, biological reference points and the size at maturity. These key parameters facilitate definition of resource status using sustainability indicators known as biological reference points. The direct impacts from fishing derived from these monitoring and assessment activities are described in section 6.5, a synthesis of some of the other key findings are given below.

The fisheries resources of the Gulf coast of the UAE inhabit an extreme, shallow water environment where

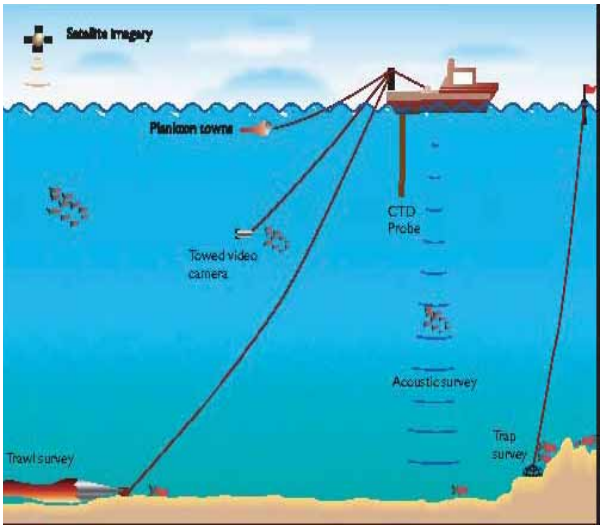


Figure 58: Schematic representation of the methods used during the 'Fish Resources Assessment Survey'.

The project, which was conducted during 2002 and 2003, provided management authorities with detailed information on the abundance and distribution of the fisheries resources of Abu Dhabi and the UAE. One of the critical issues identified was the depletion of stocks of commercially important species by more than 80% on average since 1978.

water temperatures and salinities reach very high levels during the summer months. The abundance and distribution patterns of most demersal and small pelagic species are closely associated with seasonal changes in oceanographic parameters and biological factors such as productivity and spawning periods. The biomass of demersal species is at a maximum during winter and a minimum during summer in the Gulf region of the UAE. The Arabian Gulf waters, especially the waters off the Emirate of Abu Dhabi, are an important spawning ground for many demersal species. The abundance of small pelagic species is highly seasonal, reaching a maximum in late winter and a minimum in late summer and these changes in biomass are closely associated with plankton abundance.

The results of the 'Fish Resources Assessment Survey' are presented in a series of technical reports that give details on; the distribution and abundance of commercial fish stocks (Shallard & Associates, 2003b), distribution and abundance of small pelagic resources (Shallard & Associates, 2003c), biological characteristics of the major demersal fish species (Shallard & Associates, 2003d), stock assessment of the demersal and small pelagic fish stocks (Shallard & Associates, 2003e) and the options for management of the demersal and small pelagic resources (Shallard & Associates, 2003f). Whilst the management implications of the results are discussed for the UAE as a whole, spatially explicit data from the study are held on the 'Environmental Database' of the Environment Agency - Abu Dhabi. These include data specific to strata in the waters off Abu Dhabi.

Detailed fisheries statistics have been produced as technical reports by the Biodiversity Management – Marine Sector of the Environment Agency – Abu Dhabi since 2001 (Grandcourt et al., 2002;2003a;2004a and Hartmann et al., 2005a; 2006; 2007a; 2008). The data collection system was upgraded in 2005 with a higher resolution at the species and fishing effort levels. The design of the initial data collection system used between 2001 and 2004 is described in Grandcourt (2002). Hartmann et al. (2004) and Hartmann et al. (2005b) describe the upgraded data collection and database design respectively. The data are currently housed as MS Access database tables as part of the FELDEAD programme (Fisheries Effort and Landing Database for the Emirate of Abu Dhabi). On-going activities in collaboration with the Ministry of Environment and Water include the expansion of the system to cover the entire UAE (Hartmann et al., 2007b). It is also intended that the system is expanded to cover recreational and traditional fisheries.

Database for the Emirate of Abu Dhabi). On-going activities in collaboration with the Ministry of Environment and Water include the expansion of the system to cover the entire UAE. It is also intended that the system is expanded to cover recreational and traditional fisheries.

Fish stock assessments and biological investigations have been produced as journal articles (Grandcourt *et al.* 2004bc; 2005ab; 2006) and technical reports (Grandcourt *et al.*, 2005c), which have been used to develop management options for the demersal fishery (Grandcourt *et al.*, 2004d) and provide advice to decision making authorities. Assessments have been made for 11 of the most important commercially exploited species (see section 6.5) using quantified sustainability indicators. Length frequency and biological databases for these species have been developed by the Biodiversity Management – Marine Sector of EAD. The current monitoring programme will investigate the management effectiveness of existing fisheries regulations in relation to stated objectives. Additional activities include detailed investigations into the impact of fishing on the reproductive biology of key species and spatial variability in the size, age and sexual structure of key species.

As many of the commercially important demersal fisheries resources appear to be mobile in relation to the oceanographic conditions in the waters off Abu Dhabi, it is apparent that the geographical boundaries of the unit stock for many species invariably lie outside the waters that fall under the jurisdiction of the Emirate. It is imperative therefore that fisheries monitoring and assessment activities take into account seasonal movements. In order to achieve this, a substantial increase in collaboration at the local, national and regional level is required. Research in the area of stock delineation using genetic techniques and conventional tagging methods needs to be increased for the region as a whole. Furthermore, there are additional technical information gaps that relate to ecological issues and the indirect and ecosystem impacts of fishing as mentioned in **section 6.5.**

Gear types used	**Federal Law** / Bylaw / Decree / EAD Regulation	Description
Commercial Fisheries	**23/1999** and bylaws	Pertaining to utilization, protection and development of marine living resources in UAE
Hadaq (including Shab, Lafaah, Mehaya and Flyfishing)	Bylaw Article No (22/3-4)	Pertaining to the regulation of Hadaq and affiliated fisheries, depending EAD / FOC ratification.
Leikh (including Al Yaroof, Nesabah, Al Saaliyah)	Bylaw Article No (23)	Pertaining to the regulation of Leikh and affiliated fisheries, depending EAD / FOC ratification
Al Sakkar	Bylaw Article No (22/6) + EAD decree No (1/2005)	Pertaining to the regulation of Al Sakkar and Al Defara fisheries
Al Defara	Bylaw Article No (23) + EAD decree No (1/2005)	Pertaining to the regulation of Al Sakkar and Al Defara fisheries
Al Hadhra	Bylaw Article No (22/5)	Pertaining to the regulation of Al Hadhra fisheries
Gargour	Bylaw Article No (22/2) and EAD Decree No 1/2003 and 2/2004	Pertaining to the regulation of Gargour fisheries in Abu Dhabi Emirate
Traditional Fisheries	**23/1999** and bylaws	Pertaining to utilization, protection and development of marine living resources in UAE
Hadaq (including Shab, Lafaah, Mehaya and Flyfishing)	Bylaw Article No (53)	Pertaining to the regulation of Hadaq and affiliated fisheries, for traditional fishermen.
Leikh (including Al Yaroof, Nesabah, Al Saaliyah)	Bylaw Article No (53)	Pertaining to the regulation of Leikh and affiliated fisheries, for traditional fishermen.
Oumlah	Bylaw Article No (23)	
Recreational Fisheries	**23/1999** and bylaws	Pertaining to utilization, protection and development of marine living resources in UAE
Hadaq (including Shab, Lafaah, Mehaya and Flyfishing)	Bylaw Article No (53)	Pertaining to the regulation of Hadaq and affiliated fisheries, for recreational fishermen.
Banned	**23/1999** and bylaws	Pertaining to utilization, protection and development of marine living resources in UAE
Manshalah	Bylaw Article No (21/6)	
Halaq	EAD Decree No 3/2007	
Al Hiyaal	Bylaw Article No (22/5)	Gear types are banned, either explicitly mentioned in the Law or Bylaw, or after mediation by the EAD and FOC authorities.
Tabaq tayer	Bylaw Article No (23)	
Tadmeer	Bylaw Article No (21/3)	
Karrafah	Bylaw Article No (21/2)	
Spear diving	Bylaw Article No (23)	

Table 6: Fisheries regulations

7.3.2 An Evaluation of the Impact of Fisheries Management Regulations on the Demersal Fisheries in Abu Dhabi

Background

The status of the three most important demersal species exploited in the Emirate of Abu Dhabi **(Table 7)** has been assessed and monitored since 2001 using size frequency, biological and size at age data obtained from samples of commercial catches. The status was ascertained by comparing the existing fishing mortality rates with reference points of sustainable exploitation. Evaluations of the fishery are also made by comparing the mean size at which fish become vulnerable to the gear with the mean size at which first sexual maturity is achieved.

Scientific name	Arabic name	English name
Epinephelus coioides	Hamour	Orange spotted grouper
Diagramma pictum	Farsh	Painted sweetlips
Lethrinus nebulosus	Shaari	Spangled emperor

Table 7: Key stock assessment species for Abu Dhabi (2001 – 2007)

The results of the assessments indicated that all species were heavily overexploited. Furthermore, fish became vulnerable to the principal gear type (traps, known locally as gargoor) at a mean size and age below that at which sexual maturity was achieved. As a result, the reproductive capacity of the populations was impaired and the full growth potential of these resources was not realized.

As a response to these critical management issues, a variety of fisheries regulations have been introduced. These included restrictions on the number of traps used and the establishment of marine protected areas. Escape panels with a degradable attachment were also introduced to allow the escape of juvenile fish and prevent ghost fishing. A complete list of fisheries regulations is given in **Table 6**.

The time series data generated through the stock assessments has enabled evaluations of the management effectiveness of regulations designed to (a) reduce fishing mortality and (b) modify fishing gear selectivity to reduce the retention of juvenile fish in traps. This section describes these data sets by species and evaluates the degree to which fisheries management objectives are being achieved for the demersal fisheries of the Emirate of Abu Dhabi.

Species Specific Assessments

Hamour

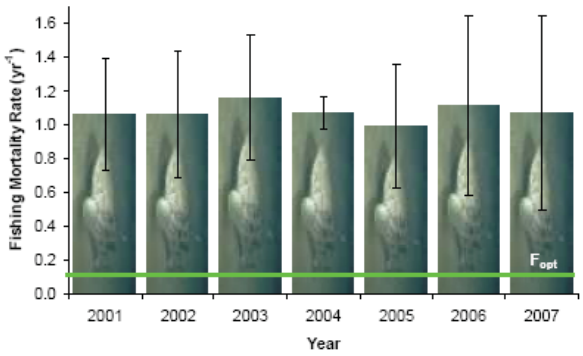


Figure 59: Fishing mortality for Hamour (2001-2007) showing the optimum level (Fopt)

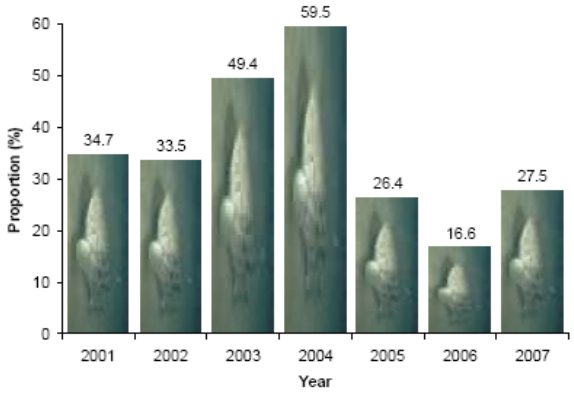


Figure 60: Proportion of juveniles in landings of Hamour (2001-2007)

The Hamour (*Epinephelus coioides*) was the most heavily over-exploited species with fishing mortality rates at about 10 times the optimum sustainable level (**Fig. 60**). The proportion of juveniles in landings after 2004 were lower than the levels in years before escape panels were introduced, indicating that the management regulation is having a positive impact (**Fig. 61**).

Farsh

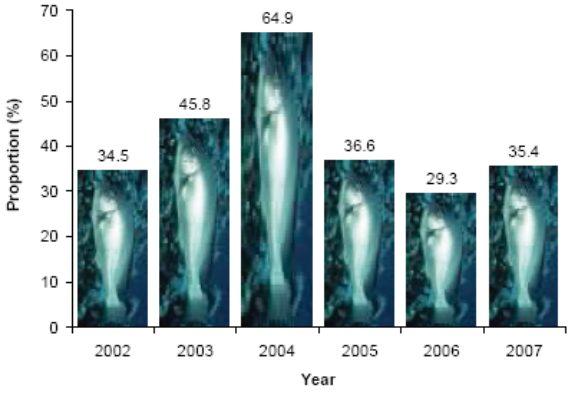


Figure 61: Proportion of juveniles in landings of Farsh (2002-2007)

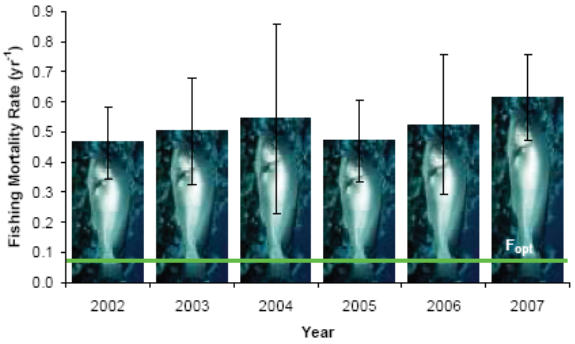


Figure 62: Fishing mortality rate for Farsh (2002-2007) showing the optimum level (Fopt)

The Farsh (*Diagramma pictum*) was also heavily over-exploited with fishing mortality rates almost 9 times the sustainable level (Fig. 62). The proportion of juveniles in landings declined from 2004 onwards indicating that escape panels are achieving the desired outcome (Fig.63).

Shaari

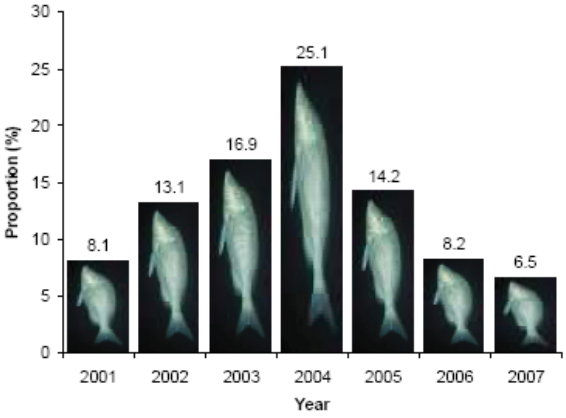


Figure 63: Proportion of juveniles in landings of Shaari (2001-2007)

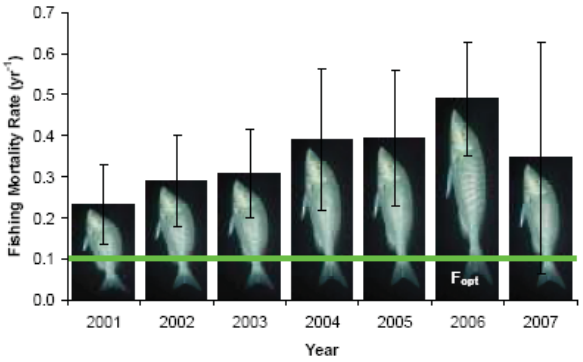


Figure 64: Fishing mortality rate for Shaari (2001-2007) showing the optimum level (Fopt)

The Shaari (*Lethrinus nebulosus*) was heavily over-exploited with the fishing mortality rate being more than 3 times the sustainable level on average (Fig. 64). Nevertheless, the fishing mortality rate had decreased considerably since 2006 and the proportion of juveniles in landings has decreased substantially since the introduction of escape panels (Fig. 65).

Summary

The principal demersal fisheries resources of the Emirate of Abu Dhabi are heavily over-exploited and further reductions in fishing effort are required if management targets are to be achieved. However, there are indications from the assessment of Shaari that the regulations designed to reduce fishing mortality are having a positive impact. Furthermore, there is evidence demonstrating that escape panels are having a desired effect, with all species having declining trends in the proportion of juvenile fish retained when compared to the years before escape panels were introduced.

7.3.3 Marine wildlife and endangered species surveys

Aerial surveys of marine wildlife including dugong, dolphin, whale and sea turtle are being done seasonally in Abu Dhabi waters. The fixed width transect techniques developed for surveying marine wildlife from the air provides a standardized estimate of minimum population size and produces density distribution maps for monitoring trends in abundance over large spatial scales and over a long time period.

The life histories and biology of endangered species particularly dugongs and sea turtles have been derived mostly from examination of dead specimens. For the past 4 years, information and data have been collected from

stranded dead dugongs and sea turtles by the researchers of EAD. The information collected by EAD includes morphometrics, biological information detailing life history and information that seeks to establish the cause of death. The information available provides baseline data and direction for further research.

Movements of post nesting sea turtles have been tracked using satellite telemetry in Jarnain Island, Emirate of Abu Dhabi. Satellite telemetry provides point source information over a time of up to 10 months. Satellite tagging and tracking to study movements for dugong in UAE waters is being planned. Although the methods are expensive, they provide detailed information on the movements of species. The benefits of such studies would have to be carefully evaluated against the risk of mortality due to capture stress.

With the exception of sea turtles and dugongs, there has been little research on marine macro fauna in Abu Dhabi. Sighting records for sea snakes, dolphins and whales are available, however, no research has been done on their distribution, habitat requirement, life history and biology. The research and monitoring of marine wildlife is required to focus on following themes:

- Status of species, life history and biology.
- Trends in seasonal distribution and abundance of selected species such as dugongs, sea turtles, sea snakes, dolphins, whales and sharks.
- Documentation and inventory of invertebrate fauna and their distribution (seasonal, by depth gradient and habitat types).
- Water quality and pollution monitoring in selected areas covering near-shore and off-shore waters, including marine protected areas, oil fields, dredged channels and near industrial areas.
- Impact of natural and anthropogenic pressures on wildlife, bio-accumulation of toxins and effects of habitat loss.
- Population dynamics, movement patterns, behaviour and habitat use of species.
- Distribution, abundance and home range.

7.3.4 Phytoplankton surveys

Since 2002, an intensive monitoring programme for harmful algae has been carried out in the coastal waters of Abu Dhabi by the Marine Environment Research Center of the Environment Agency - Abu Dhabi. The primary objectives of the programme include quantitative and qualitative estimation of phytoplankton, including harmful algae, distribution and abundance of phytoplankton, bloom monitoring, spatial and temporal variation of bloom forming species and determination of the physical and biological factors causing blooms in Abu Dhabi waters. The information is intended to increase the capability of prediction, develop procedures for mitigation and management of harmful algal blooms (HAB) in Abu Dhabi and help implement an Emirate wide action plan for HAB's. Some of the results of the on-going survey are presented in **sections 4.1.2 and 6.7.**

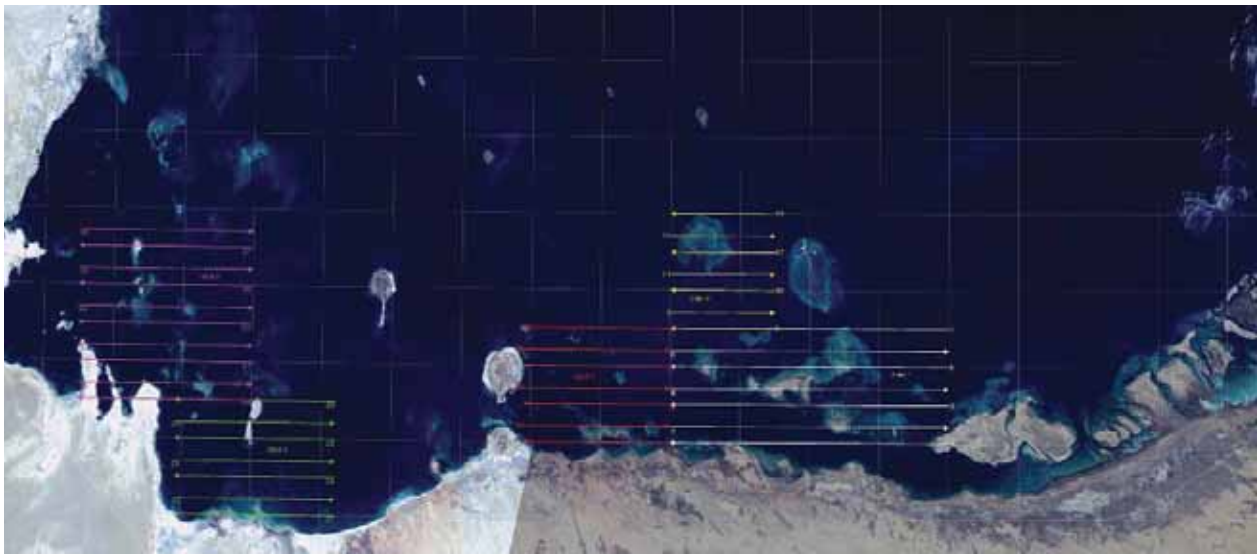


Figure 65: Aerial transects for marine wildlife surveys in the Emirate of Abu Dhabi.

7.3.5 Fish movement studies

Conservation management measures that allow sustainable use of natural resources, while ensuring the protection of biodiversity, are a vital component for any successful long-term development of coastal habitat resources. In terms of Gulf marine fisheries, species-specific knowledge of biological and life history characteristics is required for informed development of sustainable-use management plans. Since harvesting, habitat degradation and alteration can be deleterious to fish populations, it is necessary to understand species ecological requirements for effective management. Specifically, it is crucial to understand the characteristics of "essential fish habitat", defined as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity". It is equally important to understand that fish do not recognize political boundaries and move freely between Abu Dhabi and neighbouring Gulf countries. Therefore, these resources may be shared by various stakeholders and issues regarding movement and shared management become more significant.

Acquiring knowledge about fish movements can involve a variety of methods such as direct fishing studies, monitoring of fish landings, tagging and genetic analyses. Generally, fish are managed on a stock based model, which most often is demarcated as a harvested portion of the population from a specific locale. This may not, however, adequately define the biological or genetic stock structure of the individuals present in a particular area. For example, two separate stocks may inhabit the same area at different times of the year due to spawning and migration activities. Clearly, knowledge of this occurrence increases our understanding of population dynamics, leading to better management. In the UAE, a one-year trawl and acoustic survey study for demersal and small pelagic fish species was conducted during 2002 (Shallard, 2003g).

This study generated sufficient data to expose temporal and spatial abundance of important species, thus indicating movement of species to and from specific habitat areas.

For large pelagic species, tagging and genetic analyses have been used to ascertain movement and population structure within the Gulf. Conventional plastic streamer tags have been deployed on sailfish (*Istiophorus platypterus*) through a cooperative tagging programme operated by the Environment Agency -Abu Dhabi (EAD) (Hoolihan 2001). This programme has revealed an annual springtime migration of sailfish from UAE waters, leading northwest further into the Gulf (Hoolihan 2003). Tag recaptures occurred only within the Gulf, suggesting the possibility of year-round residency of this population. Further studies using molecular analysis for sailfish both inside and outside the Gulf indicated the population inside was genetically isolated and that there was little exchange, or movement, of individuals across the Strait of Hormuz (Hoolihan, Premanandh *et al.*, 2004). The knowledge of restricted sailfish movements has obvious ramifications pertaining to safe harvesting limits and biodiversity protection that should be considered for the Gulf population. Moreover, it suggests the Gulf population should be afforded the status of a separate stock.

Movement studies on sailfish using ultrasonic tagging and tracking indicated that Gulf sailfish spend approximately 85% of their time in the upper 10 m of the water column (Hoolihan 2004b). This information on habitat preference has direct relevance to sailfish susceptibility to gillnet fishing gears. A marked decrease in the abundance of Gulf sailfish over the last several years has been largely attributed to the extensive use of gillnet fishing gears in Iranian territorial waters (Hoolihan 2004a). Because sailfish spend so much time near the surface, their susceptibility to capture in these nets increases.

Iranian gillnet fishing efforts for large pelagic species in the Gulf cease during the summer, while fishermen target the more lucrative shrimp fishery using bottom trawl gears. This effectively eliminates the capture of tagged sailfish during this period, but at the same time leaves their summertime residency location unknown. To discern the movements and habitat preferences during this period, pop-up satellite archival tags (PSATs) have been deployed on sailfish through the collaborative efforts of EAD, Emirates Wildlife Society and the World Wildlife Fund (EWS-WWF). These particular tags are "fisheries independent" and do not require recapture. Rather, they release from the sailfish on a pre-programmed date, float to the surface, and transmit location data to the research scientist via satellite. To-date, two PSATs have released successfully inside the Gulf during the month of August, which is consistent with earlier tagging and genetic studies suggesting a year-round resident population.

Hoolihan and Luo (2007) describe sailfish movement patterns and suggest a preference for sailfish to move in near-surface depths (**Figure 66**), and therefore, a greater susceptibility to capture by gillnets and other surface gears. This then raises concern regarding effectiveness of regional movement, as well as conservation of the species.

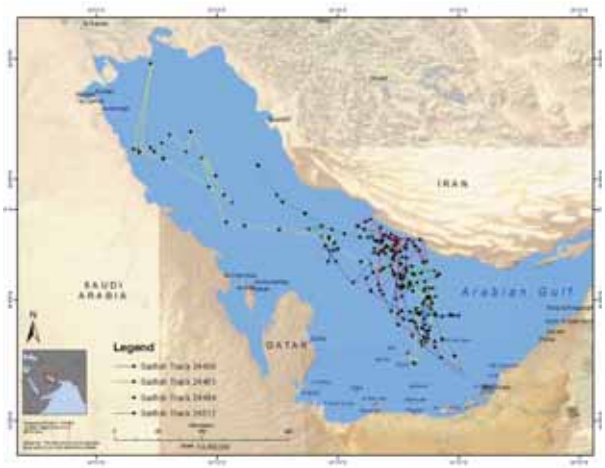


Figure 66: Example sailfish movement paths derived from data provided by Hoolihan and Luo (2007). 4 sailfish tracks are shown in this example.

The kingfish (*Scomberomorus commerson*), a large pelagic predator and important commercial resource, exhibits very different stock structure characteristics than that of the sailfish. A study of regional kingfish using restriction fragment length polymorphism and direct sequencing analyses of mitochondrial DNA revealed no significant difference between the genetic compositions of the populations tested. This suggests that intermingling, or admixture, of populations is occurring, which would support anecdotal claims by fishermen that this species migrates in and out of the Gulf. One limitation of using molecular markers to determine stock structure is that very few mixing individuals are required to maintain homogeneity throughout a population. Therefore, in the case of kingfish, additional information gained from tagging studies, testing other neutral molecular markers or examining otolith microchemistry would help to elucidate the presence of stock substructure.

These examples provide some of the techniques and results that have been used to study fish movements in the Gulf; and, when used effectively they add benefit to long-term management goals. Realizing the geographical scope of the Gulf and the numerous species requiring management, then it is apparent that large gaps remain in our knowledge of regional marine ecology. Further research, including long-term, systematic studies on the biology and ecological interaction of marine species with their environments is warranted.

7.3.6 Marine habitat surveys

The marine and coastal areas of Abu Dhabi have a variety of critical habitats including; coastal marshes and tidal-flats, coral reefs, seagrass beds and mangroves. The adjacent land area also supports a number of key terrestrial habitats, including desert biotopes. Not much is known about the distribution and abundance of these habitats, though some research programmes such as a coral reef survey and seagrass and salt marsh mapping are being pursued by EAD. The following themes provide an overview of the research information needs for the emirate.

- Status and management of coral reef ecosystems.
- Mapping and characterization of coastline, tidal flats, mangroves, seagrasses and salt marshes.
- Status, trends and threats to biodiversity.
- Trends in the condition of major habitat types.
- Monitoring of marine habitats - water quality and pollution.

7.3.7 Marine water quality monitoring

Concerns of the effects of developmental activities on the marine and coastal environment of Abu Dhabi highlight the need for a comprehensive long term marine water quality monitoring program. The occurrence of algal blooms and related fish kills in Abu Dhabi waters also stresses the importance of continuous monitoring of the marine environment. Certain water quality parameters are currently measured by EAD (see **sections 4.1.2 and 6.7**). The marine water quality study by the Environment Agency - Abu Dhabi is focusing on assessing the long-term, as well as short-term, environmental effects associated with developmental activities. The marine water quality monitoring programme includes interdisciplinary research involving biological, chemical, geological, and physical oceanographic components. This includes scientific baseline studies of the sources, levels and effects of marine pollutants, ecosystem studies, and studies of coastal and marine activities in the context of the impacts on water quality. Assessments will also be made of the social and economic factors that relate to environmental degradation and the status and effectiveness of national environmental legislation.

The sampling (water and sediment) will be conducted on a monthly basis at seventeen stations. The sampling sites cover the areas close to public beaches, harbours, industrial areas, disposal sites and sewage outlets, desalination plants and dredged channels. In addition, beaches will be included for tar balls, marine litter, oil

spill, dead marine flora and fauna and human activities. The parameters monitored include hydrography (salinity, temperature, pH, dissolved oxygen), light penetration, nutrients, heavy metals, effluents (BOD, COD, TSS), total PCBs, PAH, total toxins and microbiology. Besides standard *in-situ* sampling techniques, satellite remote sensing and geographical information systems are intended to be used on a regular basis as a supplement to field investigations and information from other sources. As an example, data collected in 2003 from the marine water quality monitoring stations are provided in **Figure 68**.

7.3.8 Sea turtle nesting habitat monitoring

The Environment Agency - Abu Dhabi has implemented a sea turtle nesting habitat protection and monitoring programme, the overall goal of which is to promote the long term survival of the endangered sea turtle populations by:

- Safeguarding critical nesting habitats of offshore islands.
- Undertaking studies on inter-annual nesting variability and nesting pattern.
- Providing important information to managers of the islands to keep the beach free of debris and prohibit movement of man and vehicle on the nesting beaches.
- Prohibiting any coastal development activities on or close to the nesting beaches that have not gone through proper environmental permitting procedures.
- Directly involving the local community in the programme, in order to promote a better understanding of the importance of long-term conservation.
- Reducing impacts on turtle populations by preventing predation of hatchlings on entry to sea, conducting beach clean-up, relocating nests from erosion sites, *etc.*

Figure 67: Sea turtle nesting pattern 2001-2007

7.3.9 Sea bird nesting surveys

The Environment Agency-Abu Dhabi (EAD) has a focused research and monitoring programme on coastal and marine avifauna of the Emirate. All bird related programmes, with the exception of bustards and falcons are implemented by the Avian Ecology Programme at the Terrestrial Environment Research Center of the Agency. For the last four years, islands and coastal water birds have been regularly monitored. Regular monitoring, particularly of breeding seabirds is essential to document trends in bird numbers of key breeding species. Such regular monitoring also allows taking appropriate management intervention to protect the colonies. Key islands sites and target species have been identified and intensive monitoring is conducted during summer breeding period of terns, Sooty Gull and Crab Plover and for winter breeding species such as Socotra Cormorant, Osprey and Red-billed Tropicbird.

Standard survey methods such as line transects (Buckland et al., 1993), fixed duration point counts (Bibby et al., 1992 and Siegel et al., 2000), total count counts and nest counts have been used to count numbers of breeding seabirds and to obtain simple count numbers as well as density estimates.

However, the choice of methods varies from species to species and number of nesting birds. For Lesser Crested Tern, which breeds in very large numbers (20,000-25,000 breeding pairs) on Jarnain Island, in addition to total count, non-invasive methods such as such as photo counts, nest counts are also used to get reliable estimates of their numbers. Longterm conservation of important breeding

Figure 68: EAD has implemented a monitoring programme for coastal and marine avifauna such as the Crab Plover, a national priority species.

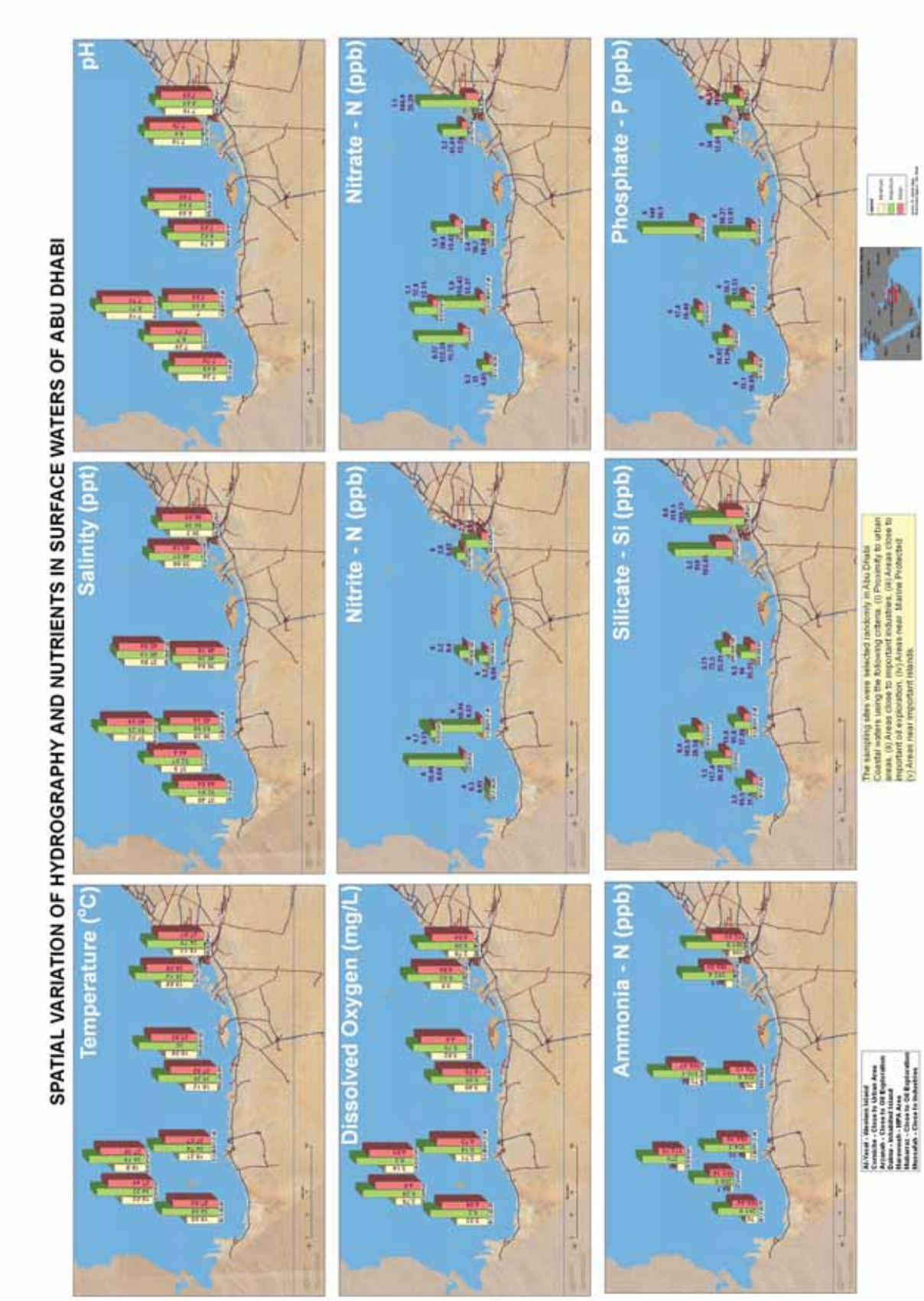


Figure 69: Example data collected in 2003 as part of the sea water quality monitoring program

seabirds is dependent on assessment of key nesting habitats and their availability. Extensive habitat mapping has been done for several islands, integrating remote sensing and Geographical Information Systems. Habitat mapping has also helped in identifying species specific habitat requirements, particularly for breeding seabirds and is regarded as key towards better understanding and management of their breeding habitats (Javed *et al.*, 2005).

The importance and dynamic nature of the seabird colonies and their regional and international significance require a proper monitoring framework to reveal the population trends. Such programmes with national focus should have regional or international outreach. Regional or international collaboration is a must for groups such as birds which move and migrate over long distances covering many countries. The concept of range countries for bird flyways is recognition of this fact and is one of the best possible ways of protecting birds. A Satellite Tracking programme for important seabirds has just been initiated to understand the dynamics of movement and migration pattern and their use of wetland complexes in the country. Information on their migration routes, stopover sites and use of wetlands locally, while in the country is vital for their conservation. This will also fill in major gaps in understanding of origin, migration routes and stopover sites of key migratory species and will complement the actions under the Action Plan for water birds under the Central Asian Flyway (CAF). Need for such studies have gained much more significance following the recent outbreaks of Avian Influenza and implication of migratory water birds in the spread of the disease. The potential of Avian Influenza becoming pandemic has serious human health, economic and wildlife conservation implications and requires suitable national, regional and international response. The Environment Agency biologists have already worked on such collaborative projects in the past. Currently another collaborative project, combining satellite tracking with virological studies is envisaged.

7.3.10 Coral community monitoring

A bilateral coral reef project between Abu Dhabi Emirate and Eastern Qatar was initiated in January 2005. Sponsored by Dolphin Energy Ltd., the project ran for three years and was a partnership between the Emirates Wildlife Society and World Wildlife Fund (EWS-WWF), Environment Agency - Abu Dhabi (EAD) and the Supreme Council for the Environment and Natural Reserves (SCENR), Qatar. The executants are the National Coral Reef Institute (NCRI). Supported by land and boat based surveys, this project aimed to build the capacity of local managers and scientists to work towards a self-sustaining monitoring and conservation project for the reef systems of the South-Eastern Arabian Gulf. The project delived an exhaustive GIS database of shallow coral distribution in the territorial waters of Abu Dhabi and Eastern Qatar, which formed the basis of a bi-national management and conservation plan. The project has undertakenlarge scale mapping of coral habitats using satellite imagery, ground verification, field work around islands off the Abu Dhabi coast and training (theoretical and practical) of scientific personnel.

The Natural History Museum of the United Kingdom has carried out investigations of the hard bottom biotopes of Abu Dhabi (George & John, 1998). The project covered a period during which two catastrophic coral bleaching and mortality events occurred in association with prolonged positive seawater temperature anomalies during 1996 and 1998 (George & John,2005a).

The Biodiversity Management – Marine Sector of the Environment Agency - Abu Dhabi conducted a survey of the marine area between the islands of Abu Abyadh and Bu Tinah off the coast of Abu Dhabi in 2000. The objectives of the synoptic field survey were to identify critical habitats and areas of high conservation value as part of an effort to designate a marine protected area. MERC also conducted aerial surveys for dugongs, turtles, dolphins and marine macro fauna in the waters off the Emirate of Abu Dhabi. Whilst the survey was not specifically designed to monitor coral reefs, it does record habitat type along transects, the categories used include sea-grass, seaweeds, corals and sandy bottom. Additional data collected of relevance to reef monitoring includes the pressure on habitats (number of vessels, fishing nets observed, oil pollution and turbidity).

Other efforts in coral reef monitoring include those of the Emirate Diving Association. A committee of dedicated members carries out inspections of dive sites on a monthly basis.

Protected Areas

The Marawah MPA, which was recently awarded the status of UNESCO Biosphere Reserve, was established to conserve and protect fisheries and marine resources, endangered and threatened species (mainly dugong and sea turtles), and habitats which include coral communities, mangroves and seagrass beds. It was declared by the Emir Decree Number 18 of 2001. The MPA covers an

area of 4,255 km2 and contains representative examples of most habitats and species that occur in the region. It includes numerous islands, the most important of which are Marawah, Jenanah, Salahah, Al Bazm, Al Gharbi and Bu Tinah, and a coastline stretching over 120 km.

The habitats of national and regional significance include sea grass beds, coral reef communities, macroalgae outcrops and mangroves. The MPA is of global importance as a shelter and feeding ground for dugongs (*Dugong dugon*). The area also provides crucial nursery and spawning grounds for a wide variety of fish species and is regionally important as a foraging habitat for green and hawksbill turtles. Furthermore, the islands inside the protected area provide important nesting sites for hawksbill turtles and a number of migratory birds. The Marawah MPA is managed according to the IUCN guidelines of a Category VI managed resources protected area.

7.4 Fisheries enforcement and licensing

Article 1 of the Federal Law 23 of 1999 on the exploitation, protection and development of living aquatic resources, grants the responsibility for fisheries management to respective competent authorities in each Emirate. The Environment Agency - Abu Dhabi was subsequently appointed as the competent authority for fisheries management in the Emirate of Abu Dhabi. As part of its mandate, the Environment Agency has issued a number of fisheries regulations in addition to those provided in Federal law 23 and it's by law.

The Environment Agency has directly enforced the Marawah marine protected area through its Monitoring, Control and Surveillance unit (MCS). Monitoring involves

the collection, measurement, analysis and reporting of information on activities pertaining to fisheries resources exploitation and marine environment utilization, conservation and development. Control involves the regulatory conditions and specifications of the terms under which fish and marine resources are exploited and utilized. Surveillance relates to the checking and supervision of fishing and marine resources and habitat utilization activities to ensure that relevant laws, by laws and decrees are correctly and adequately implemented.

Under the current regulatory regime, licenses and permits are issued for commercial fishing, recreational fishing, traditional fishing, fishing gears, apprentice and sports diving institutions. Attempts are currently underway to initiate action towards establishing permitting requirements for fishing rights in seas 'Al Buhoor' and other activities including various aspects of water sports, fishing competitions and of artificial reefs as stipulated in Federal Law No. 23 and relevant by-laws.

7.5 Awareness and national capacity building

Strategic planning for education and awareness

The 'Environmental Strategy and Action Plans for the Emirate of Abu Dhabi 2003-2007', designated EAD and the Ministry of Environment and Water (MAF) as the leading bodies to be responsible for developing and implementing a well defined education and awareness action plan for preserving and managing fisheries and marine resources. In addition, the Environment Friends Society (EFS) and Fisheries Cooperatives were designated as partners. Furthermore, the partnership of EAD with the Emirates Diving Association also ensured manpower and infrastructural assistance for underwater marine clean ups.

The action plan identified five major target groups for awareness. They were: (1) Boat owners - this group comprises mostly nationals, though they personally do not participate in the fishing operations, they were seen as major investors who have a primary interest in the long term viability of the fishery sector (2) Fishermen - apart from the captains of the fishing boats, this group comprises mostly Indians, Pakistanis and Bangladeshis. As they are temporary residents, they are driven more by short term gains rather than a long term sustainability of the resource (3) General Public - this group comprises various nationalities, knowledge levels and capabilities (4) Market - a subset of the general public, these members are perceived as being able to participate and assist in the

implementation of management measures (5) Students - again a component of the general public, this group represents a more organized forum.

The strategy also outlined the broad topics to be covered in the awareness processes. These included: (1) promoting an understanding of the provisions of the fisheries law - the prospective audience for this were to be the fishermen and the boat owners (2) protection of vital habitats including coral reefs, marine wetlands (mangroves) and sea grass beds (3) code of conduct on responsible fisheries - this was to cover the principles and standards pertaining to conservation, management and development of fisheries (4) specific fisheries conservation and management measures - these measures were to cover the regulatory controls that need to be exercised on gear restrictions, establishment of closed seasons and protected areas. Tools for delivering the above included seminars and workshops, group meetings, posters, semi structured interviews, community environmental assessment, video films, visual images and the media.

The main contributors to marine awareness in Abu Dhabi are the Ministry of Environment and Water (MAF), Environment Agency - Abu Dhabi, Emirates Heritage Club, Emirates Environment Group and Abu Dhabi Municipality. The main audience targeted so far by all these organizations have been students, the general public, fishermen, fish cooperatives, boat owners, Island managers, corporate sector and the oil sector.

Awareness efforts with fishermen, boat owners, island managers etc:

Efforts with fishermen, fish cooperatives, boat owners and island managers have been done mainly by the EAD and MAF. Resource material such as multilingual brochures, posters *etc.* have been produced and disseminated among these groups. Besides this, regular meetings and discussions with the targets on subjects such as fishing laws, rules and regulations with regard to gear restrictions *etc.* have been conducted. On the issue of marine endangered species, EAD with sponsorship from TOTAL is reaching out (as of date) to the relevant stakeholders through their awareness campaigns on the marine endangered species (refer to the Education and Awareness sector paper for details).

Awareness with community and other professional groups and agencies

Community groups or the general public are the end users of marine resources and to that effect need to be educated about the status of the marine resources and ensure their cooperation in conserving it. Besides educating them about awareness on marine issues through public awareness posters, brochures and other resource materials, they need to be targeted through a participatory approach. 'Marine Debris' is an issue of great importance and concern in Abu Dhabi. EAD in conjunction with oil companies such as ESNAAD and the Emirates Diving Association have organized marine clean up operations. These clean up campaigns have reached out to the community. Besides these, other NGO's such as the Emirates Environment Group also conducts clean up campaigns on an annual basis all over the UAE, including Abu Dhabi. The Emirates Environmental Group has also reached out to the community through lectures by professionals and experts on issues like the, 'Status of Coral Reefs in the Arabian Peninsula', 'Oil spills- A dark threat to the marine environment', 'Colourful Underwater World of the UAE,' *etc.*

Targeting students

The Environment Agency has targeted students through a structured awareness program. The Agency started its awareness efforts with the students by sending the 'Nature Bus' to give students a glimpse of the 'marine experience' in 1998 and later through marine ecology field courses (see the Education and awareness sector paper). Students are also encouraged to take part and express their awareness of the marine environment through art competitions, short story competitions and the like. Senior students are encouraged to write researched scientific reports on marine issues such as pollution *etc.* Besides educational efforts with schools and higher educational establishments, EAD has also produced awareness material such as posters, books and brochures *etc.* The Emirates Heritage Club has also addressed students by conducting teaching programmes for them on marine birds, marine turtles, mangroves *etc.* Besides these, the EHC has also produced resource materials such as posters on fishes in UAE waters, documentary films *etc.*

8 TECHNICAL INFORMATION GAPS

The management of natural resources and associated human activities in marine and coastal areas requires basic scientific and technical information. This often includes aspects such as an understanding of the population biology and ecology of exploited species, the carrying capacities of populations/habitats and the magnitude and distribution of exploitative or impacting anthropogenic activities. The synthesis of knowledge on the marine and coastal environment of Abu Dhabi has enabled the identification of missing information which is required for the management decision making process. This section presents a collation of the key technical information gaps that have been identified here for the coastal and marine environment of Abu Dhabi, it has particular value in that it provides for the orientation and focus of future applied research activities.

8.1 Marine and coastal fauna

With the exception of surveys of sea turtles and dugongs, there has been little research on the marine macro fauna of Abu Dhabi. Sighting records for sea snakes, dolphins, dugongs and whales are available, however, additional research on marine wildlife is required, in particular on the following: (1) status, life history, biology and ecology (2) trends in seasonal distribution and abundance (3) the impact of natural and anthropogenic pressures on wildlife, bio-accumulation of toxins and effects of habitat loss (4) population dynamics, movement patterns, home ranges, behaviour and habitat use. An MOU relating to the conservation of sea turtles in the UAE was signed between the Environment Agency – Abu Dhabi and the IOSEA (Indian Ocean South East Asia) in Jan 2007. Furthermore, the 'Global Dugong Action Plan' was initiated in October 2007 and consists of a 'Conservation and management Plan for Dugongs and their Habitats'. These initiatives are currently being implemented and will to some extent fill critical technical information gaps relating to management of these species and their habitats. Nevertheless information regarding the biology of species, migratory routes and foraging habitats is still pending. It is also worthy of note that the 'EAD Strategic Plan 2008-2013' aims at achieving a fully operational conservation plan for marine macro fauna (sea turtles, dugongs and cetaceans).

In terms of the invertebrates, several groups of benthic Crustacea important in the marine food webs of the Emirate such as the Amphipoda and the Copepoda have yet to be studied in detail. Furthermore, it is likely that the tally of echinoderm species present in the waters of Abu Dhabi will rise from the total so far recorded (about 30 valid species) as more attention is given by specialists to the epifaunal and infaunal echinoderm species of both inshore and offshore

soft sediments. Additional research required includes the documentation and inventory of invertebrate fauna and their distribution by season, depth gradient and habitat types, although George (2005 a, b); George and John (2004, 2005b); John and George (2001) of the Natural History Museum, London (NHM) did much between 1996 and 2001 to increase knowledge of benthic marine invertebrates present in the Emirate. Invertebrates are the principal prey items for many species of commercially exploited fishes. Their habitats, in particular in coastal areas, are either being lost completely or seriously impacted by various economic activities. Applied studies on invertebrate infauna should therefore examine the ecological impacts of anthropogenic activities.

As sediment flats are a rich feeding area for millions of migratory waterfowl, these habitats contain an abundance of invertebrates and algae. It is important that surveys of the epifauna and infauna of sediment flats is undertaken, in particular those areas known to be frequented by large numbers of wading bird species. Until recently, very few investigations had been undertaken on the corals that occur off Abu Dhabi's coast since the early seminal works of Kinsman (1964) and Evans et al (1973). However, a comprehensive coral and coral reef survey was undertaken by George and John of the NHM, grant-aided by ADCO, between 1996 and 2001 to resolve this information gap (George, 2005a, b; George & John, 1998, 1999, 2000a, b, 2002, 2004, 2005a, b; George et al, 2001; John & George, 1998, 2001, 2003). Furthermore, the spatial distribution of shallow corals has been mapped as part of the 'Coral Reef Project' implemented by the Environment Agency – Abu Dhabi in collaboration with EWS-WWF, SCENR, the National Coral Reef Institute (NCRI) and funded by Dolphin Energy. On-going activities, include the mapping of deep coral habitats and the monitoring of corals at 12 stations. A major outcome of the project was a management plan for the coral reefs of Abu Dahbi, which is currently being implemented.

Despite a comprehensive body of fisheries research that has developed over the last eight years, there is still much to learn about the present day fish fauna of Abu Dhabi. Fish collections using ichthyocides would probably increase the number of smaller cryptic species recorded for the Emirate, in particular given that few collections have been made in this way. Detailed demographic information is available for 11 of the most important commercially exploited species, however, there are over 100 species caught in the fisheries of Abu Dhabi. Investigations into the status and fisheries biology are therefore required for other subordinate and by-catch species in the demersal and pelagic fisheries. In addition to basic data on the population biology such as growth rates and spawning seasons, additional information required includes ecology and community/species interactions.

In this context, the 'EAD Strategic Plan 2008-2013' targets the assessment of 20 fish species by 2012, work towards which is currently on-going within the Biodiversity Management – Marine Sector. Specifically, this will provide demographic parameters such as growth and mortality rates, fishery parameters, such as the rate of fishing induced mortality and the size at which fish are vulnerable to capture. The data will enable the exploitation status to be ascertained for (1) key exploited species (2) by-catch species and (3) discarded species. Collectively, the data will also enable a multi-species approach to the evaluation of different management strategies and provide the scientific basis for management planning and decision making relating to the fisheries of Abu Dhabi.

As many of the commercially important demersal fisheries resources appear to be mobile in relation to the oceanographic conditions in the waters off Abu Dhabi, it is apparent that the geographical boundaries of the unit stock for many species invariably lie outside the waters that fall under the jurisdiction of Abu Dhabi. As it stands, many of the fisheries resources of the Emirate appear to be part of larger populations inhabiting the Arabian Gulf and even the Gulf of Oman. This has critical implications for both the assessment and management approaches used for these species. It is imperative therefore that fisheries monitoring and assessment activities take into account seasonal movements, even for those stocks that are traditionally considered to be site attached. In order to achieve this, a substantial increase in collaboration at the local, national and regional level is required. Research in the area of stock delineation using genetic techniques and conventional tagging methods needs to be increased for the region as a whole.

Furthermore, there are additional technical information gaps that relate to ecological issues and the indirect and ecosystem impacts of fishing as mentioned in section 6.5. Specifically, it is crucial to understand the distribution of essential fish habitat, defined as 'those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity'. Comprehensive marine and coastal area resource maps which define critical and sensitive habitats are required and it is imperative that these are incorporated into the planning and decision making process. The on-going 'Fish Eggs and Larvae Project' of the Biodiversity Management Sector – Marine of EAD has been specifically

designed to fill certain aspects of this technical information gap. The targets of the EAD Strategic Plan 2008-2013 to map and characterize 8 key marine and coastal habitats by 2012 will also pave the way forward in this regard. In addition, the development of the 'Coastal Resources Atlas' which is an on-going activity of the Biodiversity Management Sector – Marine of the Environment Agency – Abu Dhabi will provide a means for integrating this information and a critical tool for planning and decision making.

Some species form spawning aggregations at distinct times of the year in very specific locations and it is paramount that such aspects of the reproductive biology are taken into account in management strategies. Detailed reproductive studies are urgently required especially given the heavily depleted status of some species. Such studies have been conducted for the most important demersal species, the orange spotted grouper, known locally as 'hamoor' (*Epinephelus coioides*) (Grandcourt et al., 2008) and on-going activities under the EAD Strategic Plan 2008-2013 include a detailed reproductive study for the Shaari (*Lethrinus nebulosus*).

Whilst efforts have been made by the Environment Agency Abu Dhabi to delineate the geographical boundaries of the stock of the kingfish, known locally as 'Chanaad', one of the limitations of using the genetic techniques (molecular markers) is that very few mixing individuals are required to maintain homogeneity throughout a population. In the case of kingfish, which is the most important highly migratory species in the emirate, additional information gained from tagging studies, testing other neutral molecular markers or examining otolith microchemistry would help to elucidate the presence of stock substructure within the region. Realizing the geographical scope of the Gulf and the numerous species requiring management, it is apparent that large gaps remain in our knowledge of regional marine ecology. Further research, including long-term, systematic studies on the biology and ecological interaction of marine species with their environments is warranted.

The recent establishment of marine protected areas (MPA's) in the Emirate calls for underwater monitoring programmes for marine fauna. One of the expectations of MPA's is that they provide a tool for achieving conservation and resource management goals for fisheries. Underwater visual census is therefore required initially to establish baseline data and a permanent monitoring programme is needed to determine the response of fish and other faunal components to protection. This will provide the data requirements for an evaluation of the management effectiveness of the marine protected areas and help to facilitate strategic planning.

For the coastal fauna, more surveys are needed to identify the distribution and status of mammals in the coastal areas of Abu Dhabi Emirate. For example, to determine the distribution of the Kuhl's Pipistrelle (*Pipistrellus kuhlii*) and species which are categorized as data deficient in the proposed Red Data List of mammalian species of Abu Dhabi, such as the honey badger (*Mellivora capensis*) and Lesser Jerboa (*Jaculus jaculus*). In addition to distribution and abundance surveys, genetics studies are required, in particular to evaluate the extent of cross-breeding of the Sand Cat (*Felis margarita*) with feral cats (*Felis cattus*) so that an assessment of the status of both species can be made. As for the marine fauna, spatial distribution maps of critical and essential coastal habitats are required and these need to be incorporated into the decision making and planning processes. The targets of the EAD Strategic Plan 2008-2013 to map and characterize 8 key marine and coastal habitats by 2012 will pave the way forward in this regard.

8.2 Marine and coastal flora

Studies on seaweeds of the region are few and deal mostly with preliminary species composition in relation to habitat types. Detailed long term studies of the species composition, distribution, life cycle and biology of seaweeds is necessary for the region. Despite a recent surge in research activity, studies on seagrasses within the Arabian Gulf have remained relatively few in number. Large regions and a major stretch of coastline of the countries within the Gulf are still un-surveyed for seagrasses. Documentation of the effect of oil on seagrasses is lacking. A sound toxicological study relating oil and petroleum fractions to the growth and development of seagrass plants, and effects on organisms in the food chain, and also on the sediment is one of the most pressing needs in the field of seagrass research at present.

Phytoplankton studies have been conducted over limited spatial and temporal scales, given their importance as indicators for environmental change, surveys should be continued and extended to other areas in the Emirate of Abu Dhabi. Furthermore, studies are required to determine the toxicity of the available harmful species, in particular for the Cyanobacteria which are responsible for the blooms in the Mussafah area. The establishment of marine protected areas (MPA's) in the Emirate calls for underwater monitoring programmes for marine flora. Again, this will provide the data requirements for an evaluation of the management effectiveness of the marine protected areas and help to facilitate strategic planning.

The current knowledge of the natural coastal vegetation of Abu Dhabi is fragmentary. Whilst today's species assemblage in the vegetation cover may have only little similarity to that which prevailed in the recent past, vegetation surveys and detailed maps of coastal vegetation are very much needed for planning and management purposes. In particular the location of critical habitats.

8.3 Marine and costal ecology, ecosystems and habitats

The marine and coastal areas of Abu Dhabi have a variety of critical habitats including; coastal marshes and tidal-flats, coral reefs, seagrass beds and mangroves. The adjacent land area also supports a number of key terrestrial habitats, including desert biotopes. Not much is known about the distribution and abundance of these habitats, though the large amount of data produced by some research programmes such as that of NHM staff, primarily on the intertidal and subtidal hard bottom habitats and biotopes of the Emirate (including coral reefs), has been currently being incorporated into EAD's marine databases by the Marine Environment Research Centre (MERC) of EAD. Coral reef mapping has been conducted by EAD in collaboration with EWS-WWF and Dolphin Energy Ltd. The following themes provide an overview of the research information needs for marine and coastal habitats of the Emirate: (1) current status and future management of coral reef ecosystems (2) mapping and characterisation of the coastline, tidal flats, mangroves, seagrass beds, salt marshes and other critical and sensitive habitats (3) status, trends and threats to biodiversity and (4) trends in the condition of major habitat types. The current focus in this regard is on the mapping and characterization of seagrasses, mangroves and salt marshes. Furthermore, through the EAD Strategic Plan 2008-2013, 8 key marine and coastal habitats are targeted to be mapped and assessed by 2012. Associated on-going activities in this regard include the development of a coastal resources atlas and marine biodiversity index for the Emirate of Abu Dhabi, which will be a component of a wider Environmental Performance Index (EPI).

8.4 Economic activities and uses

Industrial, urban and coastal development: Industrial and urban development are often cited as a principal agent of environmental degradation and habitat loss/fragmentation in Abu Dhabi. However, there is little quantified empirical data in support of these observations. One of the key technical information gaps therefore for the marine and coastal environment is data on the extent of urbanization, industrial and coastal development and its ecological impact. This includes an extremely broad range of studies and monitoring programmes associated with environmental impact assessments for specific economic activities on species, habitats and ecosystems. As a first step to addressing this gap, the AGEDI program has initiated a rapid assessment, urban land cover change analysis from 1973 – 2000. This will complement a more exhaustive land use/land cover change analysis for roughly the same period. The objective is to better understand the patterns of natural and anthropogenic change over time, thus allowing for an evaluation and better understanding of the potential impacts development has had on Abu Dhabi coastal species, habitats and ecosystems.

Fishing: Whilst the commercial fisheries are relatively well studied, there is a dearth of information on the traditional and recreational fisheries of Abu Dhabi and this is one of the key technical information gaps for this economic sector. Currently, EAD is planning to expand the existing catch and effort data recording system to include the traditional fisheries so this information gap will be filled to some extent in the future.. Socio-economic aspects of the fisheries are also a key technical information gap. Although some limited information will become available on completion of the current activities of the 'Experimental Fishing Project' being implemented by the Marine Environment Research Center of EAD, a comprehensive socio-economic survey of the fisheries of Abu Dhabi will still be required. The extent of discards in the fisheries of Abu Dhabi has also yet to be assessed, although the issue is currently being addressed through the EAD Strategic Plan 2008-2013.

The indirect impacts of fishing have not been investigated. These include the deleterious impacts of fishing on habitats such as corals reefs through damage caused by operations, lost and/or discarded fishing gear and anchor damage. Coastline modifications including activities such as dredging, land reclamation and channeling of the seabed have paralleled major declines in demersal fish stocks. The fact that both commercial and non-commercial stocks have been affected suggests that these declines may be associated with environmental changes and habitat degradation. Many of the marine habitats threatened by coastal development include those which are known to be important as nursery and spawning areas for commercially important fishes. However, there is a dearth of spatially explicit ecological data on the distribution of marine habitats and the importance of specific sites to the reproduction of commercially exploited species. The recently completed coral distribution maps (for shallow water) by the EAD/ EWS-WWF/Dolphin Energy Ltd. 'Coral Reef Project' and

the 'Fish Eggs and Larvae Project' of EAD have to some extent helped to some of the data requirements associeated with these gaps. Some of the other indirect impacts of fishing include the ecosystem effects such as prey release and species interactions. However, it may be difficult to address such gaps immediately because of demanding data requirements and resource limitations.

In order to protect biodiversity and meet conservation objectives, marine protected areas (MPA's) have been established in the waters off the Emirate of Abu Dhabi (see section 7.4). They are also intended to serve a role in fisheries management by conserving fisheries resources. It is anticipated that the exclusion of commercial fisheries will result in protected areas having a higher density of larger more fecund fish that can export eggs, larvae, juveniles and adults to neighbouring fishing grounds. At the moment, the extent to which the marine protected areas of Abu Dhabi are achieving this is unknown and a monitoring programme is required to ascertain whether MPA's are meeting their objectives in this regard.

Aquaculture: The aquaculture potential for a variety of species in Abu Dhabi, has been investigated, however, there are other commercially important species with the potential for aquaculture which have yet to be studied. This is particularly important given the depleted status of fish stocks in the Emirate and the potential for aquaculture in stock enhancement. However, the effectiveness of existing stock enhancement and rehabilitation activities needs to be evaluated and a baseline survey of the industry is required and management regulations and guidelines need to be developed. A survey of potential aquaculture sites is also warranted.

Tourism and recreation: At present, there have been no surveys carried out to measure the extent of recreational activities, nor is there any programme to monitor the impact of such activities on marine and coastal habitats. This indicates an important deficiency in the knowledge required to manage coastal resources effectively. There is probably scope for sustainable growth of recreational and tourism activities in the Emirate that can contribute to economic prosperity, while conserving habitats and natural resources, however, efforts are required to gain baseline knowledge pertaining to the types and level of activities currently underway, and expectations for future development.

Shipping: A detailed study is essential for any attempt to control the spread by shipping of introduced exotic marine species. This information is lacking for all UAE waters especially the ports. Recognizing the need for a baseline study, the Environment Agency - Abu Dhabi is currently undertaking a marine invasive species research program. This information is central to the development of a national marine invasive species management strategy and a key component in domestic ballast water management and port risk assessment. In this context, whilst much of the baseline data required is still missing, a biosecurity strategy for the Emirate of Abu Dhabi has recently been developed (Sharma et al. 2008). The strategy presents an evaluation of the current capability and capacity of the existing system and proposes an organizational structure for the Emirate of Abu Dhabi. Of particular note in the evaluation is the non-existent or very low capacity to manage ships ballast water.

8.5 Water quality and pollution

Concerns of the effects of developmental activities on the marine and coastal environment of Abu Dhabi highlight the need for a comprehensive long term marine water quality monitoring program. The occurrence of algal blooms and related fish kills in Abu Dhabi waters also stresses the importance of continuous monitoring of the marine environment. Water quality parameters are measured by the Environment Agency - Abu Dhabi (*see* sections 4.1.2 and 6.7). The marine water quality studies implemented by the Environment Agency is focusing on assessing the long-term, as well as short-term, environmental effects associated with developmental activities. The marine water quality studies include inter-disciplinary research involving physical, biological and chemical oceanographic components. This includes scientific baseline studies of coastal and marine activities in the context of the impacts on water quality. Assessments will also be made of the social and economic factors that relate to environmental degratdation and the status and effectiveness of national environmental legislation (section 7.3.6).

To date, the section presented here is the most comprehensive synthesis of the technical information gaps relating to the coastal and marine environment of the Emirate of Abu Dhabi. However, this will soon be superseded by the development of an 'Environmental Baseline Data and Decision Support Strategy' which is an on-going activity of EAD being conducted by Gartner Lee Ltd. The purpose is to 'develop a data strategy that aligns the current data resources with the business processes, identifies gaps and missing parameters relateive to best practices for environmental agencies such as EAD and recommends an implementation plan for acquiring the data and developing the applications for information management and decision support'.

9 OUTLOOK AND WAY FORWARD

There is a substantive body of technical and scientific information on the biota of the marine and coastal environment of Abu Dhabi. Economic activities, their impacts and associated critical management issues are well recognized. The system of governance has responded with the development of a broad range of management and conservation initiatives including; the establishment of mandated institutions, enactment and enforcement of legislation and management regulations, development of strategic action plans, research and monitoring, designation of protected areas and the promotion of environmental awareness and education. Furthermore, the management decision making process has often been proactive and timely. Given the political will, economic security, institutional capacity and legal framework, the outlook for the marine and coastal environment of Abu Dhabi would initially appear to be positive.

However, the rapid pace of development in the Emirate is matched by a burgeoning list of critical management issues that relate to the sustainable utilization of natural resources. The uncontrolled pursuit of multiple activities and uses in the marine and coastal environment inevitably results in competition for finite resources leading to environmental degradation, often with social and economic consequences. If the marine and coastal environment in Abu Dhabi is to maintain its productivity and natural functions, there must be major improvements in the planning and management of coastal development and resource utilization. Effective coastal management must be based on a solid scientific foundation, which takes into account the limitations of natural systems while balancing and integrating the demands of the various sectors that depend on these systems for their operation and wellbeing (Al Abdessalaam, 2005a). In this regard, a way forward for the marine and coastal marine environment of Abu Dhabi is proposed here with particular emphasis on governance related aspects.

9.1 Legislation and planning

Legislation is required to provide a comprehensive framework for integrated planning and management of the coastal zone. The following points have been proposed by Al Abdessalaam (2005b) in relation to the requirements for improving the legal arrangements for the marine and coastal environment of Abu Dhabi: (1) undertake a complete and thorough inventorying and reviewing of all laws, regulations and decrees pertaining to the coastal zone at the Federal, Emirate and Municipal levels in the UAE; (2) consolidation of the laws, regulations and decrees in order to minimize fragmentation and duplication of responsibilities and

ensure more coordination in the management of the coastal zone. In this connection it is strongly proposed to consider the enactment of one law to cover conservation, uses and development; (3) enactment and enforcement of the proposed 'Coastal Zone Management Law for the Emirate of Abu Dhabi' (Al Abdessalaam, 2005b).

There are a variety of specific requirements for the regulation of activities in the marine and coastal environment such as fishing, construction etc., but probably the most pressing need is the requirement to enforce existing regulations. Furthermore, improvements are required in strategic planning in particular the coordination and synergistic development of strategic action plans among organizations. Integration among the local, Emirate and Federal Government initiatives is required and it is imperative that planning is conducted according to the guidelines of a comprehensive ICZM approach. ICZM initiatives were initiated in 2005 and have lead to the development of a draft policy and a draft 'Coastal Zone Management Law for the Emirate of Abu Dhabi' (Al Abdessalaam, 2005_b, 2007). There has also been a marked increase in co-ordination, with strategic planning at the local (Emirate) level being aligned with Federal Strategic Planning initiatives. Also worthy of note, is the introduction of performance management systems into governmental organisations in the Emirate of Abu Dhabi.

9.2 Institutional framework

A comprehensive review of the existing institutional framework is required. Implicit in this is the need to identify overlaps in mandates and areas of duplication. An assessment / audit of the management effectiveness would also be prudent in the context of evaluating capacity and the ability of institutions to effectively implement their mandates. Another critical aspect that relates to the institutional framework is the need to resolve the responsibility of oversight for Integrated Coastal Area Management and cross sectoral co-ordination. Section 9.6 elaborates the institutional requirements in the context of the development of integrated coastal zone management.

9.3 Regulations, management and strategic actions

Specific management and strategic actions required, both regulatory and non-regulatory, have been identified by Al Abdessalaam (2005a) as follows:

Urbanization and urban sprawling
- Establishment of urban development boundaries;
- Adoption of management and regulatory measures to achieve protection and restoration of coastal ecosystems;
- Set critical areas and no - development zones;
- Protect coastal landscapes and other sites of value;
- Prevention of habitat fragmentation.

Pollution and water quality
- Permitting programme for point source discharges;
- Treatment facilities for point source pollution;
- Develop non point source pollution management plan;
- Regulations on disposal of dredged material;
- Garbage disposal and marine debris action plan;
- Water quality monitoring programme.

Habitats and biodiversity
- Develop measures to maintain and enhance coastal processes;
- Classification and mapping of coastal areas in GIS showing their current usage;
- Establish an inventory of particularly sensitive areas and essential habitats which should be granted special attention in the legislation;
- Conservation of essential habitats and establishing MPA's as a means of maintaining biodiversity;
- Undertake complete resource inventories in the coastal and marine environment;
- Regulate fisheries (gear restrictions, closed seasons, effort limitations);
- Wetland restoration;
- Regulations on dredging, landfill and land reclamation.

Shore erosion
- Coastal erosion policy development ;
- Classification of proposed new developments and their consideration for approval in the context of an ICZM plan
- Regulations on coastal protection structures;
- Rules on specific types of projects (beach bulldozing; grading, fencing and bulkheads, jetties, piers, groins);
- Dune creation and stabilization;
- Regulations on coastal hazard avoidance.

Ports and Harbours
- Dredging regulations;
- Protected areas and no - development zones;
- Reception facilities;
- Oil spill contingency plans.

Oil exploration and extraction
- Develop oil spill response planning and preparedness;
- Preparation of detailed contingency plans;
- Establishing oil spill monitoring and early warning network;
- Develop standard procedures to report oil spills;
- Regulations on offshore oil production facilities;
- Regulations on vessel and marine terminal safety.

Tourism and recreation
- Environmental Impact Assessment;
- Guidelines for environmental management of sewage discharge, shoreline erosion, site clearance, grading, construction activities and landscaping;
- Zoning and setback policies;
- Guidelines for maintenance of water quality;
- Exclusion of development on geologically unstable areas.

Fisheries
- Setting up of explicit targets for management in relation to agreed reference points derived from fish stock assessment studies;
- Incorporation of fishing gear regulations based upon outcomes of studies on gear selectivity;
- Take serious steps to addressing the problem of by-catch and discards;
- Establishment of fisheries management plans;
- Establishing effective monitoring, control and surveillance;
- Adopting the principles of precautionary approach to managing fisheries;
- Harmonization of legislation across UAE and develop mechanisms to improve the coordination between competent authorities and the Ministry of Environment and Water.

9.4 Research and assessment

From a recent review of the 'Strategic Environmental Action Plans for Abu Dhabi', it has been proposed that applied environmental research and research designed to enhance transformation towards sustainable patterns of development should remain a major activity for the Environment Agency Abu Dhabi (Abdulraheem, 2005). The review also suggested that the development of a research strategy and programme should seek linkage with research institutions, especially universities and other agencies research programmes on environmental protection, conservation of biodiversity and sustainable agriculture, industry and other areas of human activities. (Abdulraheem, 2005). The review proposed the establishment of the 'Environmental Research Advisory Committee' (ERAC) which would have the role of (1) developing a strategy to support research in the areas of environment protection, sustainable development and transfer of technology; (2) identification of priority research areas; (3) evaluation of proposals and recommendation for funding; (4) reviewing project outputs.

One of the critical fallbacks of existing research activities is the lack of synergy and coordination among agencies. Furthermore, active engagement in regional collaboration should be promoted in particular given the shared nature of many natural resources in the marine and coastal environment and commonality in critical management issues. The section on technical information gaps (8.0) outlines some of the existing deficiencies in the current scientific and technical information required for the management planning and decision making processes.

9.5 Collaboration, communication and cooperation

It is widely recognised that because of the cross sectoral nature of activities and uses of resources in the marine and coastal environment, a high level of collaboration, communication and co-operation is required for the success of any management strategy. For this reason, it is imperative that partnership building at the national, federal, regional and global levels is strengthened. In a review of the 'Strategic Environmental Action Plans for Abu Dhabi', it was proposed that cooperation with other partners on an ad hoc basis needs to be replaced by long-term programmed joint implementation activities, with well defined budgets, timetables and personnel (Abdulraheem, 2005). This would be prudent, in particular given the relatively limited participation of partners in the strategic actions plans that have been implemented in the Emirate since 2000. The recent focus on stakeholder based issues by EAD should provide a catalyst to the enhancement of collaboration, communication and cooperation.

9.6 Integrated Coastal Zone Management (ICZM)

An analysis of the requirements for effective ICZM has been conducted by Al Abdessalaam (2005a). Whilst the study was conducted for the UAE as a whole, the key elements are applicable to the governance of the marine and coastal environment of Abu Dhabi and are re-iterated here.

The aims of the governance structure should be:

- Facilitating integrated planning;
- Promoting and strengthening inter-agency and intersectoral collaboration;
- Reduction of inter-agency rivalry and conflicts and minimizing duplication of functions;
- Provision of a forum for conflict resolution;
- Monitoring and evaluating the progress of ICZM projects.

To achieve these targets the following actions have been proposed:

- Identify and inventory relevant agencies dealing with coastal zone management and planning issues at the federal, emirate and municipal levels;
- Establish a federal committee to coordinate activities pertaining to the planning and management of the coastal zone and coastal and marine environment;
- Establish emirate level committees to coordinate activities pertaining to the planning and management of the coastal zone at the emirate level.

Federal ICZM Committee

A key objective of ICZM is to ensure that all uses and activities in the coastal zone are coordinated. The proposed Federal ICZM committee, which should be stipulated by law, is intended to provide the necessary structure and mechanism for coordination in the coastal zone. Rather than being responsible for detailed management of activities, the committee shall provide the overall guidance and coordination towards coastal zone management. The committee should have as its member's heads of agencies with coastal and marine environment management responsibilities (head of FEA and heads of competent authorities in each emirate). The committee will report directly to the Minister of Presidential Affairs.

The specific functions are to: (1) develop broad principles and national goals and objectives for the management of the coastal zone and the marine environment and periodically review and revise these goals and objectives; (2) in association with relevant agencies and stakeholders, develop a strategic action plan for the UAE's coastal zone and marine environment; (3) oversee coastal development and coordinate and integrate the activities of relevant agencies and organizations in the country to ensure sustainable coastal resource use and development; (4) identify overlaps, redundancies or gaps in coastal regulations and develop strategies to resolve conflicts and address new and emerging coastal zone matters; (5) determine appropriate information requirements and guide effective use of science in coastal zone planning and management to provide information for decision-making and solve coastal environmental problems; (6) develop and support partnerships among relevant government agencies and other stakeholders; (7) develop capacity building initiatives and oversee efforts towards education and public awareness on coastal issues; (8) assess, as appropriate, the state of UAE's coastal and marine environment and gauge the achievements of coastal zone management initiatives; and (9) coordinate with emirate-level ICZM committees.

Emirate-Level ICZM Coordinating Committee

Department directors and heads with coastal environment, resource planning and management responsibilities at the emirate level in each emirate are required as members of the committee. The head of the agency serving as the competent authority on coastal and marine environment matters in each emirate shall serve as chair person of the committee. The committee will report to directly to the Secretary General of the Executive Council in the respective emirate.

The functions include: (1) providing a forum for coordination of inter-agency and cross sectoral coordination at the emirate level; (2) coordinate and participate in the development of integrated planning of coastal development and use in the emirate; (3) in coordination with relevant government agencies in the emirate and other stakeholders of the coastal zone, prepare guidelines for development and use of the coastal zone resources; (4) facilitate sharing of information on the coastal zone among government agencies and other stakeholders; (5) prepare guidelines and protocols for the monitoring and reporting on the status of the coastal zone; (6) assess, as appropriate, the state of coastal and marine environment in the emirate and gauge the achievements of coastal zone management initiatives; (7) determine appropriate information requirements and guide effective

use of science in coastal zone planning and management to provide information for decision-making and solve coastal environmental problems; (8) develop, expand and support education and public awareness activities on the coastal zone.

Planning

Planning constitutes and integral and vital part coastal zone management. The role of planning should be to reconcile coastal use and development requirements with the need for conservation and protection of natural coastal and marine resources. In this context its general aim would be to set up a vision for the future and the steps to attain this vision. Key attributes of planning for the marine and coastal environment include: (1) setting up the vision, goals and objectives; (2) collection and analysis of relevant data and information; (3) evaluation of alternative scenarios and establishment of priorities; and (4) establishment of a monitoring and evaluation process and feedback mechanisms.

Action plans constitute a powerful and useful tool for coordinating conservation actions. These plans may be used for particular groups of species or areas. They basically function to: (1) present priorities for action on particular issues; (2) call attention to critical issues and problems; and (3) outline specific conservation measures. To be effective, these plans should be prepared in close collaboration with organizations and individuals that will be directly involved in the implementation of the proposed plans. EAD is already using action plans and has prepared conservation plans *e.g.* for dugongs and sea turtles and an action plan for the Marawah Marine Protected Area and is in the process of preparing one for the demersal fisheries. The development and implementation of these plans should however be made the norm and a legal requirement.

Environmental Impact Assessment

Environmental impact assessment (EIA) is a process used to evaluate the environmental consequences of proposed projects and programmes. For EIA's to be effective as a planning tool, the following are proposed: (1) there should be a clear identification of projects and activities that should be subject to EIA; (2) the EIA process must be undertaken before a decision has been reached to undertake the activity; (3) the EIA process should take a holistic, interdisciplinary approach and should consider impacts derived from both natural and anthropogenic causes; (4) the EIA process should not only consider environmental issues but also social and economic factors and how these interact with each other and with the environment; (5) provide provisions for reopening the EIA process if new findings are fundamentally different in terms of impacts from the initial assessment.

Acknowledgments

The authors of this report are indebted to the Environment Agency – Abu Dhabi and the leadership of H. H. Sheikh Mohammed bin Zayed Al Nahyan Honorary Chairman of the Environment Agency – Abu Dhabi and H. H. Sheikh Hamdan bin Zayed Al Nahyan, Chairman of the Board of Directors, for financing and supporting the AGEDI initiative under which this sector paper was produced. Thanks are also extended to H. E. Mohammed Al Bowardi, Managing Director of EAD and Mr. Majid Al Mansouri, Secretary General EAD for supporting the production of this sector paper. Thabit Zahran Al Abdessalaam provided literature and presentations from which information was extracted and included here. David John provided comments on the sections relating to marine algae. In addition to the authors, photos used here have been taken by Ron Carlson, M. Al Qarqaz and C. Drew. The AGEDI team is thanked for administrative and technical support, in particular Ahlam Al Marzouqi, Jane Glavan and Dr. Mohammad Afzal. MERC staff at EAD are thanked for their review of early drafts. Ahmed Abdul Rahman Al-Janahi, Director of the Fisheries Department of the Ministry of Environment and Water provided constructive comments on the development of the sector paper and first draft. The content of the Marine and Coastal Environment Sector Paper was determined during a planning workshop at the Cultural Foundation of Abu Dhabi in June 2005. The participants of the workshop are thanked for their contributions: Saud A. Alnajjar (UAE Coast Guard), Fadhl Alashqar (ADNOC), Capt. Rashid Ali Al Marzouqi, Ahmed Abdul Rahman Al-Janahi (Ministry of Environment and Water), Ahmad Areiqat (ADWEA) Khaled A. Mohamed (ADWEA), Hussain Rafat (Met. Office), Salem Rashed (UAE Armed Forces), Adel Mohamed (FEA), Saeed Jaber Al Ali (Department of Planning), Nayaz S. Syed (ADFCA), Wissam Serhan (ADFCA), Youssif Nasser (Met. Office), Sulaiman Moh. Mahmood (EAD), Khaldoun Kiwan (EAD), Himansu Das (EAD), Edwin Grandcourt (EAD), Yasser Othman (EAD), Gayatri Raghwa (EAD), Manisha Pillai (EAD), Entasar Al Hosani (EAD), Ahlam Al Marzouqi (EAD), Anil Kumar (EAD), Pritpal Soorae (EAD), John Hoolihan (EAD), Salim Javed (EAD), Waiel Al Nuaimi (EAD), Christophe Tourenq (EWS-WWF) and Anbiah Rajan (EAD). Aditya Agrawal and the AGEDI technical team facilitated the update of this sector paper as part of the Phase II Agedi activities.

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