PROJECT REPORT

Expedition dates: 10 – 23 October 2010
Report published: July 2011

Underwater pioneers: studying & protecting the unique coral reefs of the Musandam peninsula, Oman.

BIOSPHERE EXPEDITIONS.ORG

First Choice Responsible Tourism Awards
BEST VOLUNTEERING ORGANISATION
UK

THE INDEPENDENT ON SUNDAY
BEST FOR GREEN-MINDED TRAVELLERS
UK

responsibletravel.com
TOP RESPONSIBLE HOLIDAY
UK

the guardian
BEST WILDLIFE VOLUNTEERING HOLIDAY
UK

ISLANDS
BEST IN SUSTAINABLE TRAVEL
USA

Umwelt-Online-Award
ENVIRONMENT AWARD
Germany

P.M.
TOP HOLIDAY FOR NATURE
Germany

EXPEDITION REPORT

Underwater pioneers: studying & protecting the unique coral reefs of the Musandam peninsula, Oman.

Expedition dates:
10 - 23 October 2010

Report published:
July 2011

Authors:
Rita Bento
Emirates Diving Association

Matthias Hammer (editor)
Biosphere Expeditions

This report is written in memory of Sala

Abstract

Coral reefs are important biodiversity hotspots that not only function as an crucial habitat for a multitude of organisms, but also provide human populations with an array of goods and services, such as food and coastal protection. Despite this, coral reefs are under threat worldwide from direct or indirect anthropogenic impacts, such as pollution, overexploitation and climate change. The coral reefs of the Musandam peninsula (Oman), situated on the Arabian peninsula in the Strait of Hormuz, endure very harsh conditions such as high salinity and temperatures, existing in what would be considered marginal and highly challenging environments for corals in other parts of the world,.

Although Musandam corals exhibit resilience there is increasing concern that any additional stress, as a result of natural disasters and/or anthropogenic impacts for example, may accelerate coral die-off. For the past decade, reefs in the Arabian Gulf have been devastated by major coral bleaching events, cyclones, harmful algal blooms and extensive coastal developments.

Between 10 and 23 October 2010, and for the second consecutive year, Biosphere Expeditions, in collaboration with the Emirates Diving Association, conducted a research project whereby a coral reef survey using Reef Check methodology was carried out in 18 different dive sites along the Musandam peninsula coastline. The main objectives of the expedition were to (1) monitor the health of and impacts on the Musandam peninsula's coral reefs and (2) use and disseminate these findings for the purposes of management, education and conservation by local government and non-governmental organizations (NGOs).

The main objectives of the expedition were to (1) monitor the health of and the impacts on the Musandam peninsula's coral reefs and (2) use and disseminate these findings for management, educational and conservation purposes by local government and NGOs.

A comparison of findings from the 2009 and 2010 expeditions found no significant changes in the mean average of indicator species or substrate categories. However, there were significant changes of concern in the type and amount of impacts such as an increase in (1) invertebrates harvested for food, (2) tourist diving and snorkelling pressure and (3) artisanal and recreational fishing. There were also other clearly negative trends: although changes in the mean average of indicator species or in the percentage substrate coverage were not alarming, there was a clear trend suggesting that if the increase in pressure and impacts is maintained at its current rate, then future significant and highly detrimental effects for the Musandam peninsula marine life are inevitable.

The continuation of this research project is important for the regular monitoring of the invaluable coral reefs of the Musandam peninsula; a habitat that not only guarantees high biodiversity in the area, but also provides local communities with essential goods and resources. However, without additional actions, Biosphere Expeditions' annual Reef Check surveys are likely simply to document a continuing decline of a reef habitat already near the brink of collapse. We therefore recommend that the following additional projects are instigated by local government and NGOs: (1) fisheries landings studies, (2) patrolling of and new legislation for the diving and fishing communities, (3) creation of a Marine Protected Area (MPA) or a network of MPAs, including the installation and monitoring of fixed and marked mooring buoys and (4) actions to declare the Musandam peninsula a UNESCO Biosphere Reserve and ultimately a UNESCO World Heritage Site.

ملخص

تعتبر الشعاب المرجانية أحد أهم النقاط الساخنة في مسألة التنوع البيولوجي، ليس فقط بوصفها الموئل الذي لا مثيل له للعديد من الكائنات الحية ، ولكن لكونها مصدرا هاما للكثير من السلع الغذائية ، ولدورها الحيوي في حماية السواحل . ولكن وبالرغم من هذه الأهمية القصوى للشعاب المرجانية ، فإن هذا الموئل الحساس يتعرض وباستمرار لشتى أنواع التهديد بتأثير من الممارسات البشرية المباشرة أو غير المباشرة ، كتغير المناخ ،على سبيل المثال.

ويبدو أن الشعاب المرجانية في شبه جزيرة مسندم ، التي تقع على مضيق هرمز في شبه الجزيرة العربية ، قد أصبحت بيئة محفوفة بالمخاطر كغيرها من الشعاب المرجانية في أجزاء أخرى من العالم ، حيث تعاني من ظروف قاسية للغاية تتمثل في ارتفاع نسبة الملوحة ودرجة الحرارة.

على الرغم من قدرة الشعاب المرجانية على التعايش مع العديد من المؤثرات ، فإن العلماء يعربون عن قلقهم المتزايد عن مدى قدرة هذه الشعاب لتحمل أي ضغط اضافي قد ينتج عن الكوارث الطبيعية و / أو الممارسات البشرية التي قد تعجل في هلاك ودمار الشعاب المرجانية المتواجدة قبالة الخليج العربي . على امتداد العقد الماضي ، تعرضت الشعاب المرجانية الرئيسية للدمار بتأثير من ابيضاض الشعاب المرجانية ، و الطحالب الضارة ، والأعاصير ، بالإضافة إلى أعمال التطوير الساحلي والإنشاء التي تتم وعلى نطاق واسع .

في الفترة ما بين بين 10 و 23 أكتوبر 2010 ، أجرى فريق "بعثات بايوسفير الاستكشافية" و بالتعاون مع جمعية الامارات للغوص مشروعه البحثي للسنة الثانية وذلك على امتداد ساحل شبه جزيرة مسندم . تم خلال المشروع مسح الشعاب المرجانية باستخدام " منهجية مراقبة الشعاب المرجانية " و هو بروتوكول دولي لرصد الشعاب المرجانية ، تم تطبيقه في 18 موقعا للغوص.

تتمحور الأهداف الرئيسية للبعثة حول متابعة الحالة الصحية للشعاب ، ورصد تأثير الأرصفة المرجانية في شبه جزيرة مسندم ، واستخدام هذه النتائج لاتخاذ القرارات الإدارية والتعليمية ولغايات جمع بيانات علمية موثقة يمكن استخدامها من قبل المنظمات غير الحكومية والحكومات المحلية مستقبلا .

بمقارنة النتائج التي تم الحصول عليها خلال البعثة في 2009 عام مقابل نتائج البعثة لعام 2010 ، لم يتم رصد أي تغيرات بارزة على متوسط مؤشر الأنواع البحرية أو الفئات النيسية. ولكن تم ملاحظة ورصد تغيرات خطيرة وبالغة السوء في دراسة الآثار المسحية ، حيث لوحظت زيادة في معدلات البحث عن الغذاء لدى اللافقاريات ، كما تم تسجيل ارتفاع ملحوظ في أنشطة الغوص السياحية الحرفية منها والترفيهية و الغطس وصيد الأسماك. وبالرغم من أن التغيرات في متوسط معدل مؤشر الأنواع أو في تغطية نسبة من الفئات المختلفة الرئيسية لم تكن مثيرة للقلق ، إلا أن تغييرات مروعة ستشهدها الحياة البحرية في شبه جزيرة مسندم مستقبلا ،إذا ، اذا تزايد معدل الضغوط والتأثيرات عن معدلها الحالي.

إن استمرار هذا المشروع البحثي في شبه جزيرة مسندم ،هام جدا لإبقاء هذه الشعاب المرجانية القيمة تحت المراقبة المتواصلة ، ليس لكونها الموئل الذي يضمن بقاء التنوع البيولوجي في المنطقة بل لما توفره من موارد أساسية للمجتمع المحلي . كما ينبغي أن تتضافر الجهود من قبل كافة الجهات المعنية في مجتمع الغوص المحلي ، بحيث يتم اصدار تشريعات جديدة وتنفيذ دوريات خفر سواحل في جميع أنحاء شبه جزيرة مسندم ، تقوم بعملها جنبا إلى جنب مع الدراسات الاستقصائية حول الشعاب المرجانية ومصائد الأسماك وذلك من أجل التصدي و بمزيد من التفصيل للآثار الرئيسية التي تم كشفها خلال البعثة . إن تطبيق برتوكول " محمية بحرية" (MPA) أو (مناطق بحرية محمية) من شأنه أن يساعد أيضا في التغلب على جميع هذه المشاكل فضلا عن قلة البيانات المتاحة عن الموارد الطبيعية وعدم وجود عوامات ثابتة وظاهرة للعيان لتحديد المنطقة.
إن مسألة ضم شبه جزيرة مسندم إلى مجموعة اليونسكو العالمية لمحميات المحيط الحيوي، وبالتالي إعلانها في نهاية المطاف كأحد مواقع اليونسكو للتراث العالمي ، أمرٌ ينبغي أن يتم تفعيله على المستوى الحكومي .

Contents

1. Expedition Review

M. Hammer (editor)
Biosphere Expeditions

1.1. Background

Biosphere Expeditions runs wildlife conservation research expeditions to all corners of the Earth. Our projects are not tours, photographic safaris or excursions, but genuine research expeditions placing ordinary people with no research experience alongside scientists who are at the forefront of conservation work. Our expeditions are open to all and there are no special skills (biological or otherwise) required to join. Our expedition team members are people from all walks of life, of all ages, looking for an adventure with a conscience and a sense of purpose. More information about Biosphere Expeditions and its research expeditions can be found at www.biosphere-expeditions.org.

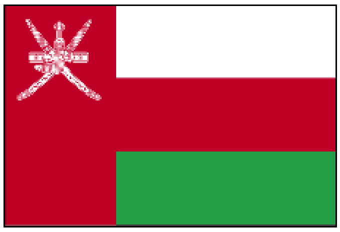
This project report deals with an expedition to the Musandam peninsula that ran from 10 to 23 October 2010 with the aim of monitoring the health of the Musandam peninsula's reefs, its fish and invertebrate communities so that informed management, education and conservation decisions can be made by the government and NGOs. Data on the current biological status of the reefs and of population levels of key indicator species are crucial for educational purposes and to be able to put forward ideas for future marine protection areas. Data collection followed an internationally recognised coral reef monitoring programme, called Reef Check, and will be used to make informed management and conservation decisions within the area. The expedition included training for participants as a Reef Check EcoDiver.

Although popular myth has Arabia down as a vast, flat and empty expanse of sand (and oil), Oman is quite different. In fact, there is a wide range of contrasting landscapes: high mountains, beaches, the desert landscapes of the Empty Quarter, coral reefs and even tropical habitats, where the monsoon touches Oman in the extreme south.

The 650 kilometre coastline of the Musandam peninsula is strewn with rocks and coves, gradual steps, steep rocky slopes and cliffs that plunge to great depths all over the fjord-like landscape. The coral reefs that grow along the margins of this stunning landscape are still relatively untouched as influences such as industrial-scale fishing, pearl or scallop extraction or large numbers of recreational divers have not wreaked their destructive influence there. The area is therefore a prime target for studying intact reef ecosystems, conserving them for future generations and using them in the education of people locally and all over the world.

1.2. Research Area

The Musandam peninsula (sometimes also called the Norway of Arabia) is the northernmost part of Oman jutting out into the Strait of Hormuz at the entrance to the Arabian Gulf. The province, or Governorate of Musandam as it is officially known, is separated from the rest of Oman by various parts of the United Arab Emirates including Ras al Khaimah and Fujairah. The Musandam more or less begins where the mountains rise from the plains of Ras al Khaimah.



Flag and location of Oman and study site.

An overview of Biosphere Expeditions' research sites, assembly points, base camp and office locations is at [Google Maps](#).

The remote and rugged mountains, which rise straight out of the sea creating fjords and stunning landscapes, have had isolated communities for centuries. Many coastal villages can be reached only by boat, as there are no roads on much of the peninsula. Pockets of flat land support subsistence agriculture. The population of approximately 29,000 is concentrated in the capital, Khasab (18,000 in 2004) in the north and Dibba (5,500) on the east coast. Fishing is the principal economic activity supported by employment in government jobs.

Geology

Rocks of the Hajar supergroup in the north appear to be flat-lying but are actually folded in a north-south trending anticline. Thinly-bedded yellowish-orange dolomitic limestones and mudstones indicating a near-shore environment progress upwards into highly fossiliferous shelf limestones. Shell fragments, brachiopods and micro-fossils in limestone indicate continental shelf conditions. These limestones were deposited from the early Jurassic to the Cretaceous period and are reckoned to be older than 65 million years.

"Round the bend"

The British arrived on a lump of rock they called Telegraph Island in the fjords back in the mid-19th century, staying for five years. They were laying a telegraph cable from India to Basra in Iraq. Taking the cable "round the bend" of the Gulf gave rise to the expression, since living on Telegraph Island in the extreme heat of summer must have sent them crazy! These days, the island is noted for its rich underwater life and dhows (the local type of fishing boat) stop off here.

1.3. Dates

The project ran over a period of two weeks divided into two one-week slots, each composed of a team of international research assistants, scientists and an expedition leader. Slot dates were:

2010: 10 - 16 October | 17 - 23 October.

Dates were chosen when survey and weather conditions are most comfortable.

1.4. Local Conditions & Support

Expedition base

The expedition base was a modern and comfortable live-aboard dhow with eight air-conditioned cabins, some of them with on-suite toiled and shower facilities. The dhow had three decks, an air-conditioned lounge, a compressor and all facilities one would expect on a modern live-aboard. Tank refills and dive services were provided by the crew. A professional cook and crew also provided all meals and vegetarians and special diets could be catered for.

Weather & water temperature

The climate is tropical and maritime. The average day temperature during the expedition were 30-35°C with sunshine and no clouds on all but a few rare days. Water temperature during the expedition is ranged from 28-32°C.

Field communications

The live-aboard was equipped with a satellite communication system. Mobile phones worked in some parts of the study site. The expedition leader also sent an expedition diary to the Biosphere Expeditions HQ every few days and this diary appeared on www.biosphere-expeditions.org/diaries.

Transport, vehicles & research boats

Team members made their own way to the Dubai assembly point. From there onwards and back to the assembly point all transport and vehicles were provided for the expedition team, for expedition support and emergency evacuations.

Medical support and insurance

The expedition leader and the expedition scientist were trained first aiders, and the expedition carried a medical kit. The standard of medical care in Oman is very high with a clinic in Khasab. There is also a recompression chamber in Muscat and one in Dubai. Safety and emergency procedures were in place. There were two serious medical incidences during the expedition. One involved a team member with serious internal bleeding who had to be hospitalised using the emergency plans and services in place. The patient subsequently made a full recovery. The other incident involved the death of a crew member who was killed in an accident involving an explosion on the small side vessel whilst the expedition team were on the main research vessel.

Diving

The minimum requirement to take part in this expedition was a PADI Open Water or equivalent qualification. Team members who had not dived for twelve months prior to joining the expedition were required to complete a PADI Scuba Review before joining the expedition.

Standard PADI diving and safety protocols were followed.

Dive groups were divided into different teams, each working on specific areas of survey work. Divers were allocated to teams based on a mixture of personal preference, diving skills and knowledge of the species.

1.5. Local Scientist

Biosphere Expeditions was working with Rita Bento of the Emirates Diving Association on this project.

Rita Bento was born in Portugal. She has a degree in Marine Biology from the University of the Azores and a Masters in Science of the Sea – Sea Resources from Porto University and is currently doing her PhD with Porto University. Her first area of research was bioacoustics of baleen whales, working in the USA with Oregon State University and NOAA (National Oceanographic and Atmospheric Administration). In the last few years she has focussed her research on Marine Protected Areas (MPA) currently working with the Emirates Diving Association on the management plan of Dibba MPA in the UAE. Rita is also a Reef Check Course Director with hundreds of Reef Check dives. Besides her scientific career, she is also a CMAS diving instructor and published the first Portuguese diving guide in 2007.

1.6. Expedition Leaders

The expedition was led by Kathy Gill (group 1) and Ken Atkinson (group 2).

Kathy Gill joined Biosphere Expeditions in 2000. She was born and educated in England. Since gaining her BA in Business at Bristol, she has worked in sustainable development and regeneration for a variety of public sector organisations, most recently the Regional Development Agency for the East of England where she was responsible for developing and supporting partnership working to establish sustainable development activities. At the main office Kathy is also one of two Directors and is in charge of the UK organisation. She has travelled extensively, led expeditions and recced projects all over the world. She is a qualified off-road driver, divemaster, marathon runner, keen walker, sailor, diver and all round nature enthusiast.

Ken Atkinson was born in Australia and has lived in Dubai since 2005. He graduated from the Australia Defence Force Academy (ADFA) and spent five years in the Special Forces in numerous roles and then spent 15 years in the security industry in Australia and Dubai. Ken completed his Open Water diving course at the age of 16 and is now a PADI IDC Staff Instructor. In 2008 he turned his passion in to his new career and now owns his own dive centre and works as an independent instructor. When he is not, leading expeditions, working at completing his Master of Business and Technology or diving he can be found camping, climbing mountains and jumping out of planes.

1.7. Expedition Team

The expedition team was recruited by Biosphere Expeditions and consisted of a mixture of all ages, nationalities and backgrounds. They were (with country of residence):

10 – 16 October 2010

Hilal Al Balushi (Oman), Mohamed Al Dhahab (Oman), Cornelia Beisel (Germany), Susannah Cogman (UK), Tina Lehmuskoski (Finland), Rossella Meloni (Oman), Chun Meng Nolan (UK), Yvonne Rebman (Switzerland), Jon Shrives (UK), Karin Thiele (Switzerland), Melanie Thompson (Australia), Georgina Treherne (The Netherlands).

17 – 23 October 2010

Cornelia Beisel (Germany), Jane Calderbank (UK), Anders Fjeldheim (Norway), Sofie Hofgård (Norway), Helen Savill (UK), Karin Thiele (Switzerland), Georgina Treherne (The Netherlands), Simone Waltenspül (Switzerland).

Staff during the expedition: Ali (boat captain), Poli (cook), Chandu (deck hand), Sala (deck hand).

Sala was killed in a tragic boat accident just as the expedition had finished and Biosphere Expeditions and the expedition team wish to express their deepest sympathies to Sala's family and relatives. This report is written in his memory.

1.8. Other Partners

On this project Biosphere Expeditions is working with Reef Check, the Emirates Diving Association, local dive centres, businesses & resorts, the local community, Sultan Qaboos University, the Oman Ministry for Environment and Climate Affairs, the Oman Tourism Board, as well as the United Nations Environment Programme, the World Conservation Monitoring Centre and the International Coral Reef Action Network (ICRAN).

Biosphere Expeditions also gratefully acknowledges grant support from Six Senses (Zighy Bay), the Ford Motor Company Conservation & Environmental Grants, as well as the Waterloo Foundation.

1.9. Expedition Budget

Each team member paid towards expedition costs a contribution of £1090 per person per 7 day slot. The contribution covered accommodation and meals, supervision and induction, special non-personal diving and other equipment and air, and all transport from and to the team assembly point. It did not cover excess luggage charges, travel insurance, personal expenses such as telephone bills, souvenirs etc., as well as visa and other travel expenses to and from the assembly point (e.g. international flights). Details on how this contribution was spent are given below.

Income	£
Expedition contributions	19,470
Grants & sponsorship	31,748
Expenditure	
Research vessel includes all board & lodging, ship's crew, fuel & oils, other services	22,231
Transport includes transfers & visas	1,418
Educational materials, equipment and hardware includes educational & research materials, research equipment	6,830
Staff includes local & international salaries, travel and expenses	7,944
Administration includes registration fees, educational materials distribution & sundries	1,889
Team recruitment Musandam as estimated % of PR costs for Biosphere Expeditions	4,881
Income – Expenditure	**6,025**
Total percentage spent directly on project	**88%**

1.10. Acknowledgements

This study was conducted by Biosphere Expeditions which runs wildlife conservation expeditions all over the globe. Without our expedition team members (who are listed above) who provided an expedition contribution and gave up their spare time to work as research assistants, none of this research would have been possible. The support team and staff (also mentioned above) were central to making it all work on the ground. Thank you to all of you, and the ones we have not managed to mention by name (you know who you are) for making it all come true. Biosphere Expeditions would also like to thank members of the Friends of Biosphere Expeditions and donors, Land Rover and Swarovski Optik for their sponsorship.

Biosphere Expeditions also gratefully acknowledges grant support from Six Senses (Zighy Bay), the Ford Motor Company Conservation & Environmental Grants, as well as the Waterloo Foundation.

1.11. Further Information & Enquiries

More background information on Biosphere Expeditions in general and on this expedition in particular including pictures, diary excerpts and a copy of this report can be found on the Biosphere Expeditions website www.biosphere-expeditions.org.

Enquires should be addressed to Biosphere Expeditions at the address given below.

2. Reef Check Survey

Rita Bento
Emirates Diving Association

2.1. Introduction

Study site description

The Musandam peninsula, also known as Ru'us al-Jibal, is an exclave of Oman separated from Oman by the United Arab Emirates. It is situated on the Arabian peninsula in the Strait of Hormuz, the narrow passage that links the Arabian Gulf (also known as the Persian Gulf) and the Gulf of Oman (Rezai et al. 2004).

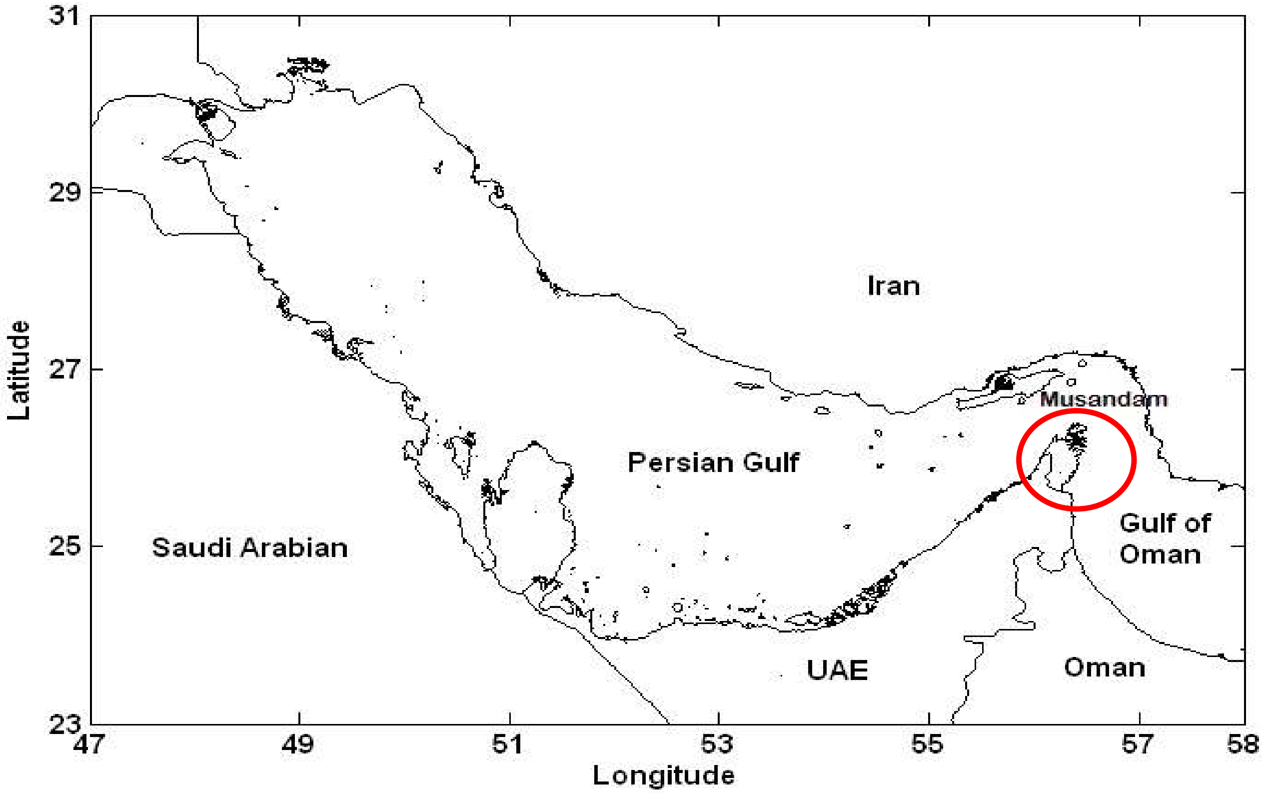


Figure 2.1a. Location of the Musandam peninsula in the Middle East.

The Persian Gulf is a shallow semi-enclosed basin measuring about 1,000 km by 200 - 300 km. It has an average depth of 35 meters, dipping down towards the north to a maximum of about 60 meters near Iran, and inclined downwards to about 100 meters deep at its entrance in the Strait of Hormuz, the only connection to the Gulf of Oman and the Indian Ocean (Sheppard et al. 1992; Carpenter et al. 1997; McClanahan et al. 2000; Pilcher et al. 2000). As a result of its shallow depth and restricted water exchange, the Persian Gulf is characterized by strong variations in sea surface temperatures (SSTs), ranging from 12ºC in winter and 36ºC in the summer, and high salinity values of 43 year-around (on the Practical Salinity Scale, PSS, which has no units), hereby influencing water density, currents, water mixing, and a host of other environmental parameters that therefore influence species composition (Price et al. 1993; Riegl 2001; Coles 2003). In contrast with the Persian Gulf, the Gulf of Oman and Arabian Sea are deep seas (more than 2,000 meters deep) with more stable conditions (Wilson et al. 2002).

The Arabian peninsula is among the hottest areas in the world, where temperatures above 49°C have frequently been recorded at some weather stations in the region (SOMER 2003). The extremely arid nature of the Arabian region, the high temperatures and the constant and intensive sunshine, especially along the coastal areas, results in some parts in a lack of four season variability.

The region lies at the edge of two global weather systems, the Asian and the North Africa weather systems, whose fluctuations cause varied and severe environmental conditions, the summers are hotter and the winters colder than most subtropical zones (Sheppard et al. 1992; Carpenter et al. 1997; McClanahan et al. 2000).

Evaporation by dry winds is as intense in winter as it is during the hot summer. Over the whole Persian Gulf, evaporation averages 144 to 500 cm/yr, most occurring in the shallow bays in the south where evaporation locally exceeds 2000 cm/yr. In these shallow bays salinity exceeds 50 over hundreds of square km, exceeding even 70 in large expanses (McClanahan 2000). These large evaporation rates over the Persian Gulf lead to the formation of a warm and salty water masses, which flow into the Gulf of Oman through the Strait of Hormuz; the mass and salt budget in the Gulf are closed by an inflow of Indian Ocean Surface Water coming from the northern Arabian Sea (Figure 2.1b) (Pous et al. 2004).

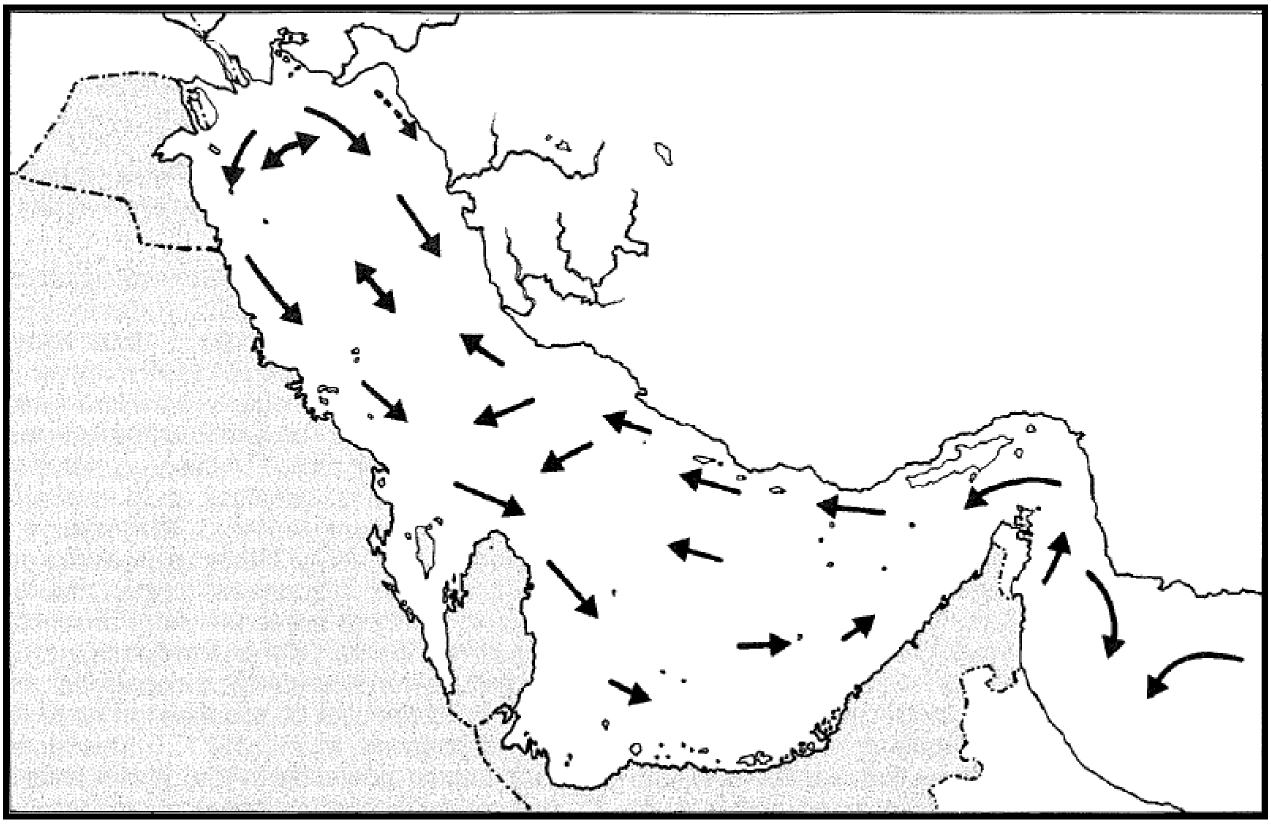


Figure 2.1b. Major current patterns of the Persian Gulf and northern Arabian Sea (Reynolds 1993).

Tides in the Gulf of Oman and the Arabian Sea are oceanic in type where frictional effects are minimal. Tide heights can range from 1.5 metres, in the Arabian Sea, to 2.5 metres in the Gulf of Oman, being predominantly semi diurnal and correlating closely with that of the Indian Ocean. But generally, tidal height is not very marked anywhere in the region, and ranges of 0.25 to 0.75 metres are most common although tidal height can rise near land, especially in the far north and just outside the Strait of Hormuz (Sheppard et al. 1992).

In the Gulf of Oman water temperatures are moderate in comparison to the Arabian Gulf. Typical winter surface water temperatures fall to 22-23°C (minimum recorded of 12°C), while summer temperature is characterised by a highly fluctuating regime caused by the rise and fall of a shallow, but strong thermocline. Summer water temperatures range between 23-31°C (maximum recorded of 35°C), and can often cover this range within one day (Rezai et al. 2004). In the Arabian Sea the seasonally reversing winds induced by the monsoon create a strong upwelling, which causes the remarkable, low sea temperatures off the southeast Arabia peninsula in the hottest summer months (Sheppard et al. 1992; Carpenter et al. 1997). In the Gulf of Oman the cool water influences are less constant, although occasional upwellings occur and can replace surface waters very rapidly such that falls of up to 10°C over one or two days can happen. Such upwellings have a significant impact on the marine ecology, and therefore areas of reef development are few (Randall 1995; Spalding et al. 2001).

Salinity in the Gulf of Oman is generally at 36.5, but due to the influence of the Arabian Gulf 38.9 has been recorded in the surface waters of the Strait of Hormuz, in the Musandam peninsula, to Ra's Al-Hadd at the entrance to the Gulf of Oman (Rezai et al. 2004).

Salinity values experienced in the Persian Gulf exceeds the optimum range of coral reef in other tropical regions in the Atlantic and Pacific that normally show a salinity interval of 35 to 37 and an upper tolerance range between 40 and 45 (Price et al. 1993, Coles 2003). The SSTs values observed in the Persian Gulf are the highest encountered worldwide on reefs, varying by up to 25ºC annually (Sheppard and Loughland 2002; Coles 2003). In other tropical regions the changing range is normally 19ºC only, with the normal upper limits between 33ºC and 34ºC and the lower limits between 13 to 16ºC (Coles 2003). Species that establish populations in the area must therefore be capable of withstanding the stress of osmotic and temperature extremes. Many major shallow water taxonomic groups and species that are prevalent at similar latitudes elsewhere in the Indo-Pacific, and found in adjacent seas, are completely lacking in the area (Carpenter et al. 1997).

Although thought not to be present in extreme conditions beyond 23.5° north and south of the equator, the coral reefs found in the Arabian region are a unique example of adaptation by marine organisms (SOMER 2003). The range of environment, latitude and geological formation combine to produce very varied coral habitats within this region. This results in several different coral communities, which are distributed according to geographic location and depth (Sheppard et al. 1992).

Some corals have the ability to acclimatise by phenotypic changes to more stressful environmental conditions, resulting in the readjustment of the organism's tolerance levels. They have evolved temperature thresholds close to the average upper temperatures of their area, so thermal tolerance varies from region to region. Similar corals in each location live under quite different temperature regimes and thus have different thermal tolerances (Grimsditch and Salm 2006, Marshall and Schuttenberg 2006). Corals and reef communities in some areas (such as the Persian Gulf and Gulf of Oman) tolerate salinity and temperature conditions that are lethal when imposed rapidly on the same species in less extreme environments (Baker et al. 2004, Buddemeier et al. 2004, Riegl et al. 2006).

Rezai et al. (2004) describe coral communities of the Gulf of Oman and Arabian Sea as in good condition, due in part to the mitigating effects of a summer upwelling that cools summer seawater temperatures, possibly protecting the corals from bleaching.

There is a fairly distinct Arabian coral species grouping, and within it, there is a single, principal division into a Red Sea group and a Gulf of Oman/Arabian Sea group, which then fuses with the Persian Gulf (Sheppard et al. 1992). Although the species composition of Persian Gulf corals is typically Indo-Pacific, with a few regional endemics, the coral diversity in the Persian Gulf and parts of the Gulf of Oman is relatively low compared to most parts of the Indian Ocean where it is up to four times higher (Riegl 1999, Rezai et al. 2004). Of the 656 species among 109 genera of zooxanthellate corals for the Indo-Pacific, only about 10%, or 68 species among 28 genera, occur in the Persian Gulf and 120 species among 33 genera in the Gulf of Oman (Rezai et al. 2004). Some combination of factors has probably limited the recruitment, settlement, survival and growth of reef corals in the region, eliminating many species and perhaps favouring a few that are adapted to the uniquely harsh conditions of the region (Coles 2003).

Due to the varied coastline of Oman, where upwelling effects are attenuated by bays, reef growth continues with typically reef flat and reef slope development. Even where reefs do not develop, prolific coral communities grow on many different types of non-limestone rock. Some coral growths develop into vast monospecific beds to a degree seen only in a few other cases in Arabian seas. Numerous areas of exposed, hard substrate are not dominated or even colonised by hard corals; instead soft corals and macroalgae generally dominate (McClanahan et al. 2000).

Even though the Persian Gulf's corals are unique and seem to endure extremely harsh conditions when compared to corals in other parts of the world, scientists are increasingly concerned that any additional stress, imposed by global climate change or regional coastal development may accelerate coral die-off (EWS-WWF 2008; Wilkinson 2004). Reefs in the Persian Gulf have been devastated by major coral bleaching events (in 1990, 1996, 1998 and 2002) and recently by extensive coastal developments along the Arabian peninsula (Burt et al. 2008; Wilkinson 2008). The impact extends beyond the shoreline, since turbidity and suspended sediments are dispersed from the dredge or reclamation sites. In addition, coastal currents are diverted by coastal engineering, altering the movement of sediments causing them to accumulate (Rezai et al. 2004).

The coral reef losses from climate-related devastation and massive coastal development on the Arabian peninsula have made this region amongst the most damaged in the world with the lowest predictions for recovery. According to recent estimates, 30% of the coral reefs are at a threatened-critical stage and up to 65% of the coral reefs may have been lost already due to natural causes (fluctuation of temperatures, diseases) and anthropogenic stresses (oil pollution, unmanaged coastal development, unregulated commercial and recreational fishing and diving) (Wilkinson 2004). Unfortunately coral reef research and monitoring is often way behind other parts of the world (Wilkinson 2008).

Additional external factors affecting the area

On 6 June 2007 the first documented tropical storm occurred in the Arabian Sea. Tropical cyclone Gonu was a category 5 storm and matched the strongest storm recorded in the northern Indian Ocean (Mooney 2007; UNEP 2008). The human and economic costs of cyclone Gonu were considerable with about 75 deaths and 2.88 billion € of damage. In Oman, including Musandam, and on the east coast of the UAE damage by the strong waves along the coast were noted. Corals on exposed shores were almost entirely destroyed and there was variable damage in sheltered bays, coves and islands. Before this natural catastrophe the Musandam peninsula reefs were dominated by Porites and Acropora.

Rich coral communities such as *Porites lutae*, *P. solida*, *Acropora valenciennesi* and *A. valida* were common from Musandam to the capital area of Oman (McClanahan et al. 2000; Sheppard et al. 1992). Gonu affected colonies down to 7 meters with major impacts on *Sinularia*, *Sarcophyton* and *Acropora*. By March 2008 there was significant re-growth of some soft coral areas, although hard coral communities in shallow exposed areas have shown less resilience (Wilkinson 2008).

The existence of a harmful algal bloom (HAB), caused by the algal species *Cochlodinium polykrikoides*, between August 2008 and May 2009, when the marine life was still recovering from the cyclone Gonu, significantly changed the habitats and biodiversity in the area. Both the Persian Gulf and Gulf of Oman have a high phytoplankton biodiversity with 38 taxa potentially bloom-forming or harmful (Subba-Rao and Al-Yamani 1998). The presence of *C. polykrikoides* in the region was noticed for the first time during this period in 2008 and 2009. A pattern of subsequent recurrence of *C. polykrikoides* blooms has been observed in other parts of the world, suggesting that this species may become a persistent HAB problem in the region and further monitoring and protection in Musandam is needed according to Richlen et al. (2010). It is known that increasing human population and demand for resources and development is one of the main reasons for the rise in the distribution and size of harmful algal blooms and dead zones around the globe (Anderson 1997; Hinchley et al. 2007). Ballast water carried in ships has also been recognised as one of the main vectors for the translocation of non-indigenous marine organisms around the world. Based on preliminary analysis, it is suspected that the HAB on the east coast of the UAE and Oman from August 2008 to May 2009 was due to a non-native algae species and therefore that ballast water discharge was involved at some point (Richlen et al. 2010).

Reef Check

Reef Check's survey method uses simple techniques to collect scientifically robust data. This methodology is specially designed for recreational divers that might not have scientific background, so training has to be precise, rapid and understandable in order to guarantee that organism identification is accurate (Hodgson et al. 2006).

To understand the health of a coral reef, Reef Check bases its data collection on "indicator organisms" that are defined as organisms that reflect the conditions of the ecosystem. These indicators can be individual species or even a family. The important thing is that each of these indicators has an economic or ecological value, is sensitive to anthropogenic impacts and easy to identify. A Reef Check team collects four types of data (Hodgson et al. 2006):

1. A site description referring to environment, socio-economic and human impact conditions;
2. Fish indicator species count;
3. Invertebrate indicator species count;
4. Recording different substrate types (including live and dead coral).

Data for points 2-4 are collected along a 100 metre transect, at two depth contours, between 2 to 5 metres and between 6 and 12 metres (Hodgson et al. 2006). Data for point 1 is collected prior and after the dive.

Aims and objectives

The primary aim of this project was to provide data on the health of the Musandam peninsula's coral reefs and current threats. With the beginning of this project in 2009 it was possible, for the first time in Musandam, to collect data through Reef Check surveys in order to quantitatively assess benthic and fish communities and anthropogenic impacts. The data collected are now useful for comparison with the survey conducted in 2009, as well as future surveys, and to provide data from Musandam for the global Reef Check database.

2.2. Methods

Site selection & sampling design

Between 12 and 23 October, 2010, 18 dive sites were surveyed using the Reef Check methodology (Figure 2.2a). All sites were recorded by Global Positioning System (GPS) for future comparative Reef Check surveys. All positions were collected in degrees, minutes and seconds (Table 2.2a).

The chosen diving sites included well-known diving spots regularly visited by divers, areas that are known for their importance to fisheries and areas where divers and fishermen are rare. With this panoply of diving sites it was possible to have, for the first time, a general idea of the coral reef health of the Musandam peninsula.

Training of expedition team members

All data were collected by team members that passed through an intensive Reef Check training and testing procedure. Team members on the expedition were coordinated by a project scientist and an expedition leader. The primary responsibilities of both were to train the 17 team members in Reef Check methodology and also to coordinate and supervise the subsequent surveys and data collection.

Survey procedures & data collection

The Reef Check survey protocol utilises two transects at depths between 2 - 5 metres (shallow) and 6 - 12 metres (medium), chosen for practical reasons of dive duration and safety. Along each depth interval, shallow and medium, four 20 metre long line transects are surveyed with a 5 metre space interval between transects. The distance between the start of the first transect and end of the last transect is, therefore, 95 metres.

An ideal Reef Check team includes six members (three buddy pairs, each pair responsible for fish, invertebrate and substrate data collection respectively) plus support crew, each with different specialties and experience.

The Reef Check methodology is adapted by region, and the area used for this expedition was the Indo-Pacific region. Full details of the methodology and regular updates can be found on the Reef Check website www.reefcheck.org.

Note that during the second group of this expedition, surveys were only conducted between 2 and 5 metres. Therefore for the data analysis in this report only data from 2009 and 2010 collected between these depth ranges were used.

Figure 2.2a. Location of the 18 dive survey sites around the Musandam peninsula.

Table 2.2a. Names and geographic coordinates of the 18 dive sites where Reef Check surveys were undertaken.

Site name * indicates new site not used by pleasure divers and therefore named by the expedition	GPS log number	Coordinates	
Lobster's Demise*	D1	N 26°17'48"	E 056°20'05"
Little Reef Check*	D2	N 26°17'51.8"	E 056°19'57.3"
Ra's Shuraytar	D3	N 26°23'04"	E 056°22'46"
Pipi Beach	D5	N 26°22'30"	E 056°23'01"
Coral Garden	D7	N 26°22'33"	E 056°24'59"
Eagle Ray	D9	N 26°22'55"	E 056°25'06"
Khayl Island	D13	N 26°21'56"	E 056°27'08"
Faqadar Bay	D19	N 26°20'50"	E 056°28'51"
Ballerina Cliffs*	D24	N 26°19'42.4"	E 056°27'38.2"
Death Valley*	D27	N 26°15'50"	E 056°24'38"
Snapper's Tragedy*	D29	N 26°13'49"	E 056°26'09"
Rockface Bay*	D31	N 26°14'08"	E 056°27'36"
Khesa	D32	N 26°13'51.8"	E 056°28'56.0"
Grouper's Escape*	D34	N 26°11'21.0"	E 056°28'16.7"
Cuttlefish Love*	D36	N 26°08'39.2"	E 056°28'24.3"
Osprey Point*	D38	N 26°07'55.8"	E 056°28'25.6"
Gargoyle Cliffs*	D42	N 26°05'01.8"	E 056°25'27.3"
Habalayan Island	D45	N 26°09'45.6"	E 056°21'19.8"

Fish belt transect

Four segments of 5 meters height, 5 m wide by 20 m long (centred on the transect line) were sampled for fish that are typically targeted by fishermen or aquarium collectors and that are sensitive to impacts. In the Indo-Pacific these species and families are any grouper (Serranidae) over 30 cm, sweetlips (Haemulidae), snappers (Lutjanidae), parrotfish (Scaridae) over 20 cm, butterflyfish (Chaetodontidae) and moray eel (Muraenidae). Quantitative counts were made of each species/family. Three more species are counted in the Indo-Pacific Reef Check, but were not taken as species to look for since they do not exist in the Musandam area: the Barramundi cod (*Cromileptes altivelis*), the Humphead wrasse (*Cheilinus undulates*) and the Bumphead parrotfish (*Bolbometopon muricatum*).

The same four 5 m wide by 20 m long transects (centred on the transect line) were also sampled for invertebrate taxa typically targeted as food species or collected as curios. The taxa counted were: banded coral shrimp (*Stenopus hispidus*), long-spined black sea urchin (*Diadema* spp.), pencil urchin (*Eucidaris* spp.), collector urchin (*Tripneustes* spp.), three edible sea cucumbers species (*Thelenota ananas*, *Stichopus chloronotus*, *Holothuria edulis*), lobster (all edible species) and triton shell (*Charonia tritonis*). Quantitative counts were made of each species/family. The giant clam (*Tridacna* spp.) was not included in the species to count since it does not exist in the Musandam peninsula area.

During the invertebrates survey, anthropogenic impacts were also assessed. These included coral damage by anchors, dynamite, or ‘other’ factors, and for trash. Trash is divided by type, i.e. fishing nets or simply ‘other’. Divers valued the damage caused by each factor using a 0 to 3 scale (0 = none, 1 = low, 2 = medium, 3 = high).

The percentage cover of bleaching and coral disease in the coral reef (colony and population) was also measured along each 20 meter transect.

Substrate line transect

Four 20 m long transects were point sampled at 0.5 m intervals to determine the substratum types on the reef. The categories recorded at each 50 cm point were according to Reef Check definitions: hard coral (HC), soft coral (SC), recently killed coral (RKC), nutrient indicator algae (NIA), sponge (SP), rock (RC), rubble (RB), sand (SD), silt (SI) and other (OT).

Data analysis

All data were entered on underwater slates and subsequently transferred onto Reef Check Excel sheets. Belt transect data were used to calculate the mean abundance of each fish and invertebrate taxa. The substrate line transect data were converted to mean percentage cover of each substratum category per depth contour. Anthropogenic data were represented by mean abundance of each impact.

In order to elucidate the differences among the data collected, quantitative assessment of trends was achieved using t-test and Friedman tests. Note on statistical conventions: the results of statistical tests are given by showing the ‘p’ (probability) value of the test. Results that are significant at the $p < .05$ level are commonly considered statistically significant, and $p < .005$ or $p < .001$ levels are often called "highly" significant.

2.3. Results

Basic oceanographic and climatic conditions were recorded during the two week expedition. The mean air temperature was 32.6˚C with standard deviation of 1.9˚C, mean sea surface temperature was 30.0˚C with standard deviation of 1.1˚C, and the mean estimated underwater visibility was 11.8 metres with standard deviation of 4.3 meters (Table 2.3a).

Table 2.3a. Average values of air temperature, sea surface temperature and visibility during the Musandam expedition in 2009 and 2010 (standard deviation values in parentheses) and the respective minimum and maximum values in 2010.

	2009	2010	Min – Max 2010
Air temperature	34.2ºC (0.6ºC)	32.6˚C (1.9˚C)	30 – 35 ºC
Sea surface temperature	27.8ºC (1.1ºC)	30.0˚C (1.1˚C)	28 – 32 ºC
Visibility	9.9 m (2.5 m)	11.8 m (4.3 m)	2 – 20 m

Site description

The Site Description Sheet includes basic information based on observational and historical data regarding impacts and protection of the site. These data are important for interpreting local, national and global trends in the dataset, especially to understand the impacts existing in the area. When comparing the data with what was observed in 2009, an increase in all impacts (except in sewage pollution) was noted. The only decrease found was in sewage pollution, which changed from an impact above low pressure to an impact below low pressure. It is also clear that the number of sites with tourist diving and snorkelling activities has increased from 9 to 16 sites, being 14 of the sites in 2010 with medium level of these activities (Table 2.3b). From 2009 to 2010 there was a significant increase ($p<.05$) in the level of invertebrate harvesting for food from below low to above low (Figure 2.3b), as well as an increase in the level of tourist diving and snorkelling (Figure 2.3c). A highly significant increase ($p<.005$) in artisanal/recreational fishing was also noticed from low to almost medium level (Figure 2.3d).

As shown in Table 2.3b from 2009 to 2010 there has been a large increase in the number of sites used for diving and snorkelling, with sites that showed no diving or snorkelling pressure in 2009, now showing medium pressure. At the same time commercial fishing pressure has increased throughout from low to medium pressure (except in one site where pressure has decreased from medium to low). These two negative trends are the most significant with classifications reaching medium level in many sites.

Table 2.3b. Level of known impacts found on the 18 dive sites surveyed in 2010. (Different values found in 2009 shown in parentheses. Where an increase in impact level was noticed, the appropriate field is coloured red; where a decrease in level of impacts was noticed the appropriate field is coloured green.)

Site name	Harvest invert. for food	Tourist diving/ snorkelling	Sewage pollution	Commercial fishing	Artisanal/ Recreational
Lobster's Demise	Medium (Low)	Low	None (Low)	Medium	Medium (Low)
Little Reef Check	Medium (Low)	Medium	None (Low)	Medium (Low)	Medium (Low)
Ra's Shuraytar	None (Low)	Medium (None)	Low	Medium	Low
Pipi Beach	Medium (Low)	Medium	Low (medium)	Medium	Medium (Low)
Coral Garden	None (Low)	Medium	Low	Medium (Low)	Low
Eagle Ray	Low	Medium	Low	Low (medium)	Low
Khayl Island	None (Low)	Medium (None)	Low	Medium (Low)	Low
Faqadar Bay	Low	Low (None)	Low	Low	Low
Ballerina Cliffs	Low	None (Low)	Low	Low (medium)	Low
Death Valley	Low	None	Medium	Medium	Low
Snapper's Tragedy	Low	Medium (None)	Medium	Medium	Medium (Low)
Rockface Bay	Low	Medium (None)	Low	Medium	Medium (Low)
Khesa	Medium (Low)	Medium	Low	None	Low
Grouper's Escape	Medium (None)	Medium (None)	None (Low)	Medium	Medium (Low)
Cuttlefish Love	Medium (Low)	Medium (None)	Low	Medium (Low)	Medium (Low)
Osprey Point	Medium (Low)	Medium	Low	Medium (Low)	Medium (Low)
Gargoyle Cliffs	Medium (None)	Medium (None)	Low	Medium (Low)	Medium (Low)
Habalayan Island	Medium (None)	Medium (Low)	Low	Medium (Low)	Medium (Low)

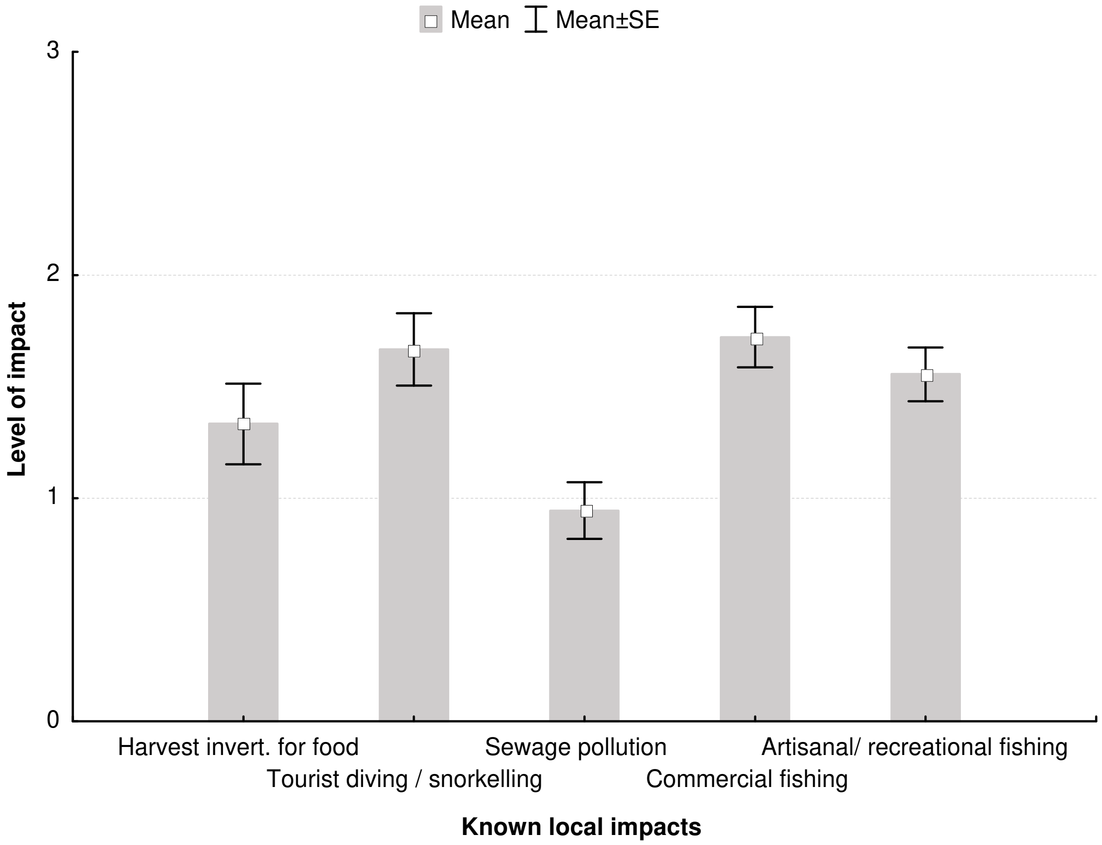


Figure 2.3a. Average level of impacts found in Musandam surveys during site description (0=none, 1=low, 2=medium and 3=high).

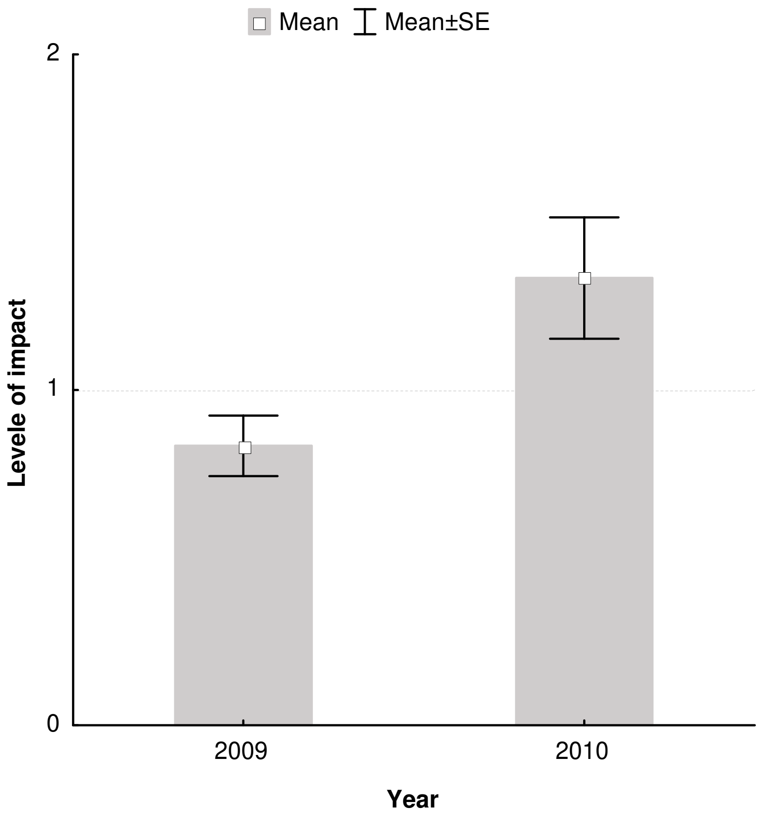


Figure 2.3b. Average level of harvest invertebrates for food in 2009 and 2010 (0=none; 1=low; 2=medium; 3=high).

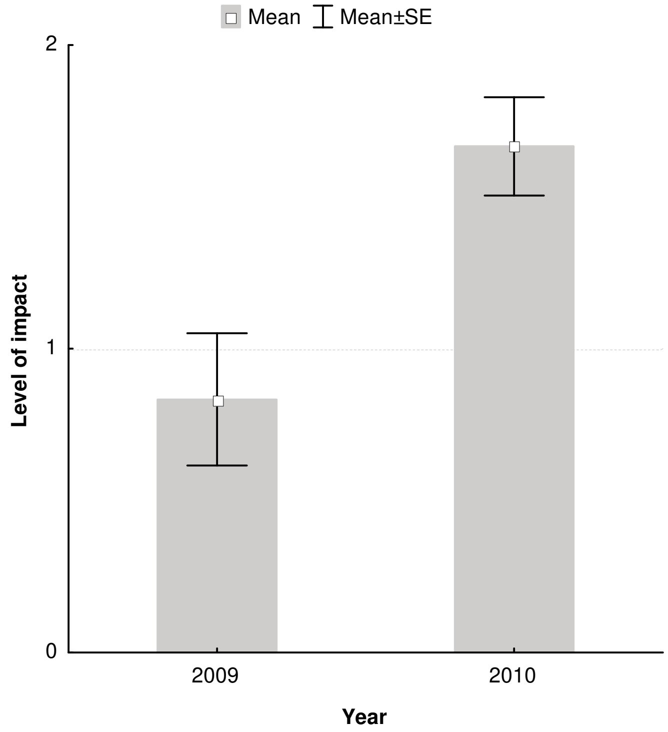


Figure 2.3c. Average level of tourist diving/ snorkelling in 2009 and 2010 (0=none; 1=low; 2=medium; 3=high).

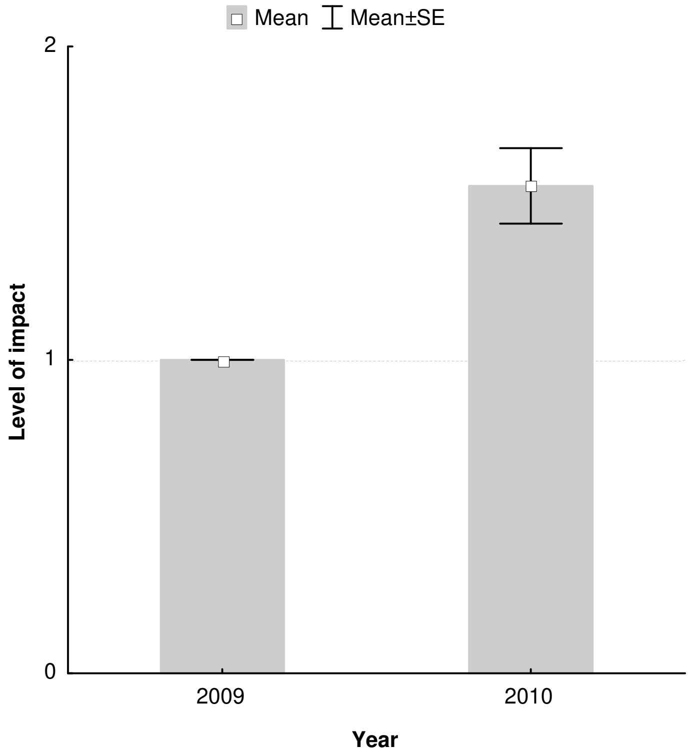


Figure 2.3d. Average level of artisanal / recreational fishing in 2009 and 2010 (0= none; 1= low; 2= medium; 3= high).

Fish community

In both the 2009 and 2010 expeditions, snappers and butterflyfish were the most abundant species seen on transects from the six categories of indicator fish counted in the Reef Check methodology for this expedition (19.8 ± 3.6 and 12.8 ±0.9 per 100 m^2 respectively for 2010). The next most abundant were, as in 2009, the parrotfish (2.6 ± 0.4 per 100 m^2), followed by groupers (1.2 ± 1.3 per 100 m^2). Sweetlips (0 ± 0 per 100 m^2) and moray eels (0.07 ± 0.26 per 100 m^2), which were again the least abundant with the only difference that in 2010 zero sweetlips were counted (Figure 2.3e).

Significant differences were found when comparing the categories of fish over the two survey years. The average number of groupers from 30 to 40 cm was significantly higher in 2010 compared to 2009, changing from a mean of 0.56 ± 0.1 per 100 m^2 to 1.04 ± 0.1 per 100 m^2 ($p<.05$) (Figure 2.3f). As consequence the number of groupers in general also increased from a mean of 0.64 ± 0.1 per 100 m^2 to 1.15 ± 0.1 ($p<.05$) (Figure 2.3g). Moray eels, on the other hand, were less frequent in 2010 (mean of 0.07 ± 0.03 per 100 m^2) than in 2009 (0.34 ± 0.08) ($p<.005$) (Figure 2.3h).

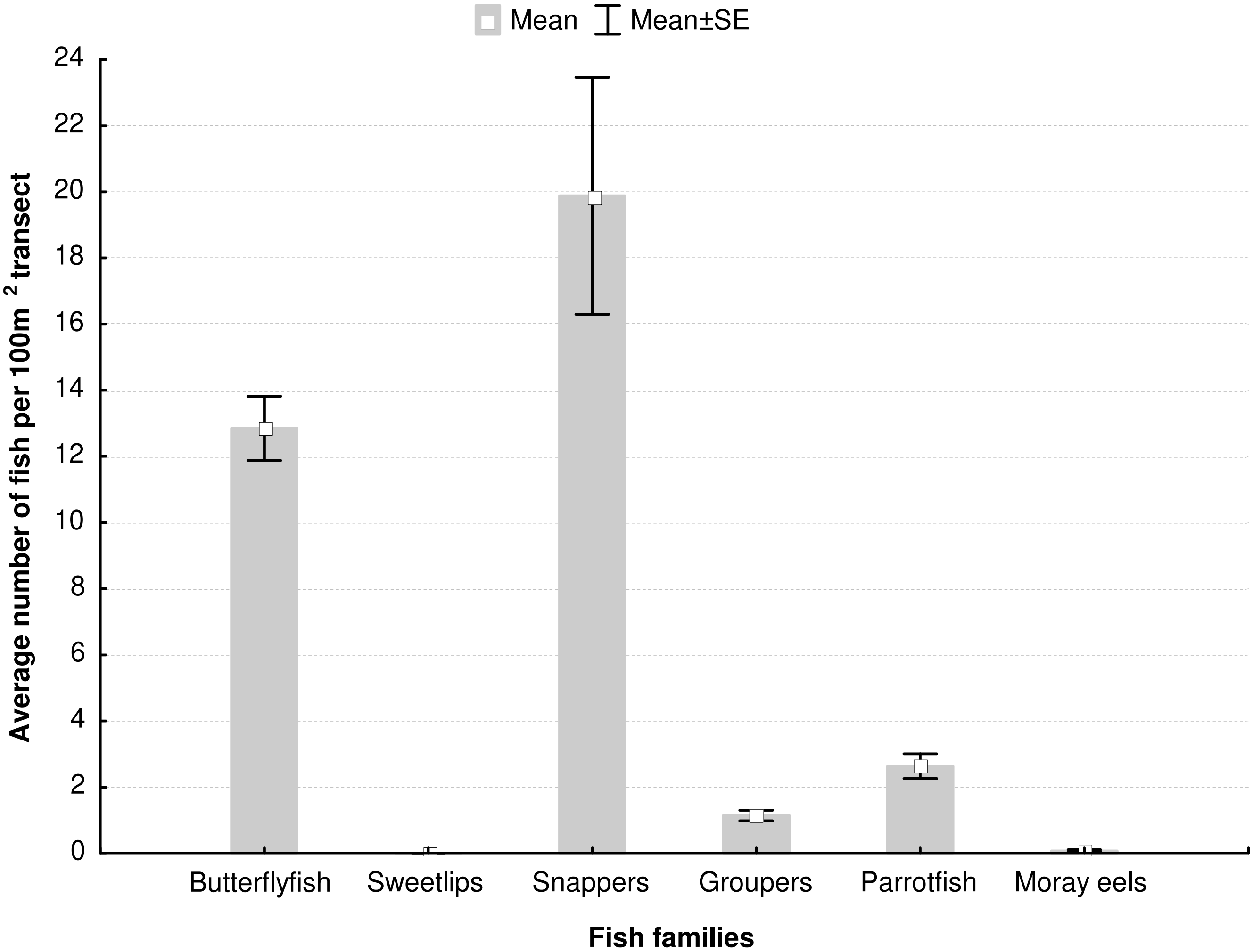


Figure 2.3e. Pooled average numbers of Reef Check indicator fish families per 100m^2 seen in Musandam (N=68).

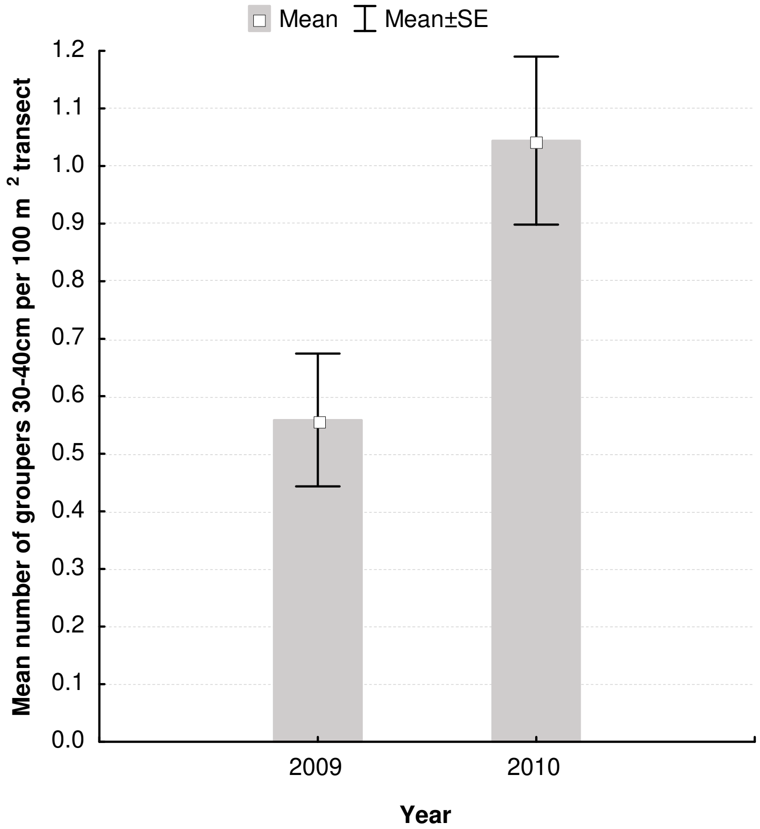


Figure 2.3f. Average numbers of groupers from 30 to 40 cm per 100m^2 transect, in 2009 and 2010.

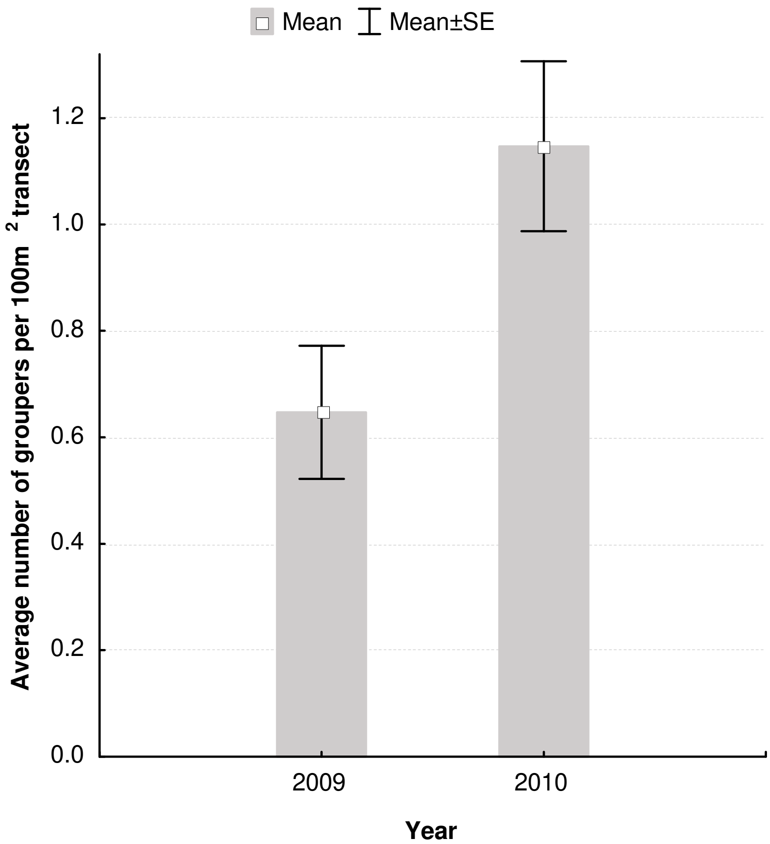


Figure 2.3g. Average numbers of groupers per 100m^2 in 2009 and 2010

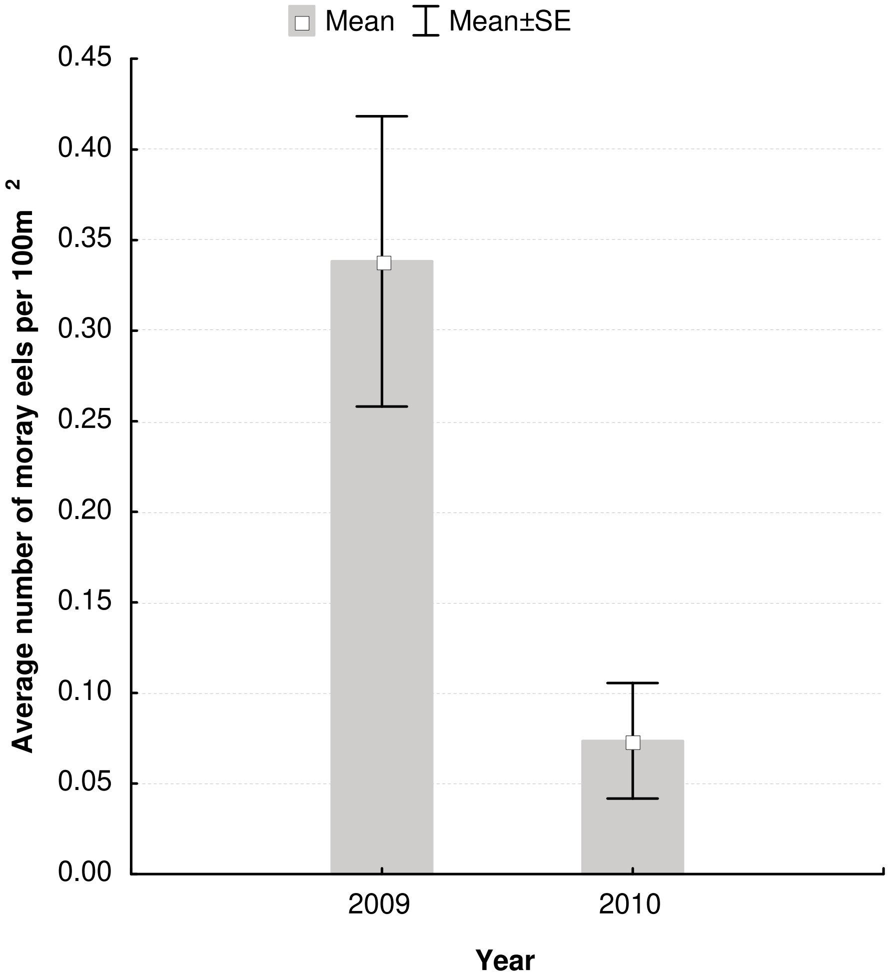


Figure 2.3h. Average numbers of moray eels per 100m^2 in 2009 and 2010.

Invertebrate community

At the invertebrates survey conducted in the 2010 expedition the Diadema urchin was again the most abundant invertebrate in Musandam with an average number of 186 ± 132 per 100m^2, a little lower than in 2009 (216 ± 143 per 100m^2). All the other invertebrates counted had an average number below 2 in 100m^2, as was also observed in 2009 (Figure 2.3i).

When comparing the invertebrates counted in 2009, with the counts from 2010, there are only two significant differences, namely banded coral shrimp and sea cucumber average numbers ($p<.05$). Banded coral shrimps increased from a mean of 0.2 ± 0.6 per 100m^2 in 2009 to 0.6 ± 1.3 per 100m^2 in 2010 (Figure 2.3j). Sea cucumbers also showed an increase from 0.7 ± 2.2 per 100m^2 n 2009 to 2.0 ± 3.4 per 100m^2 in 2010 (Figure 2.3k).

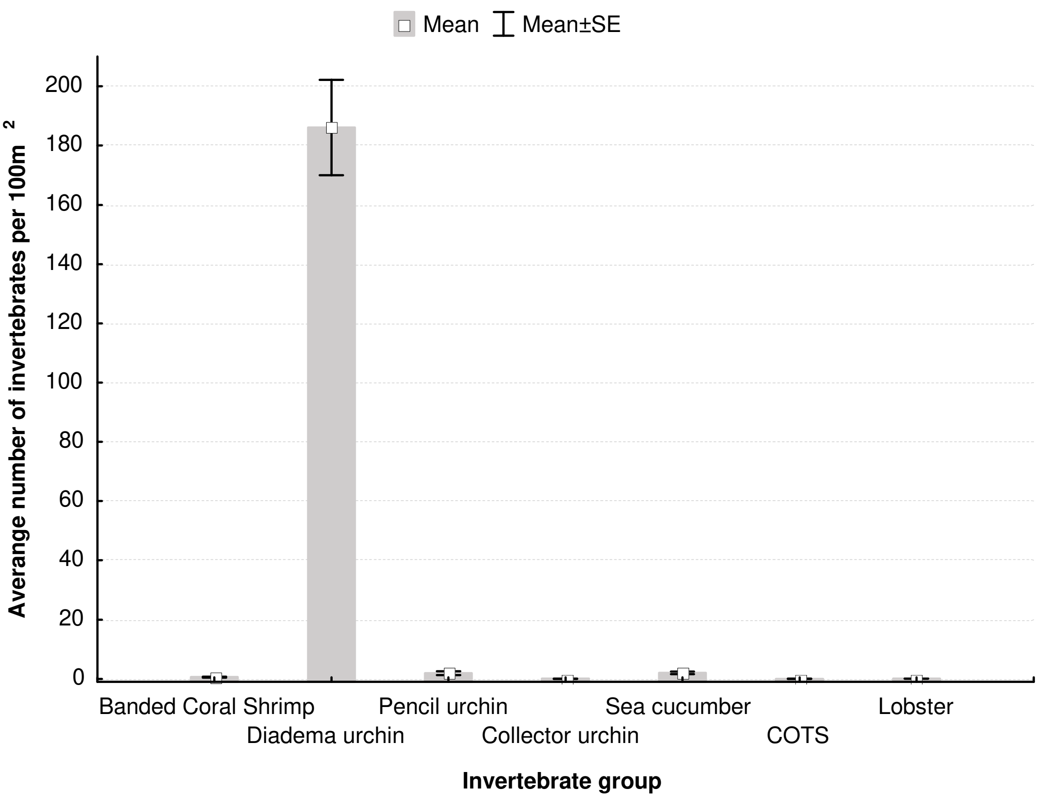


Figure 2.3i. Pooled average numbers of invertebrate indicators per 100m^2.

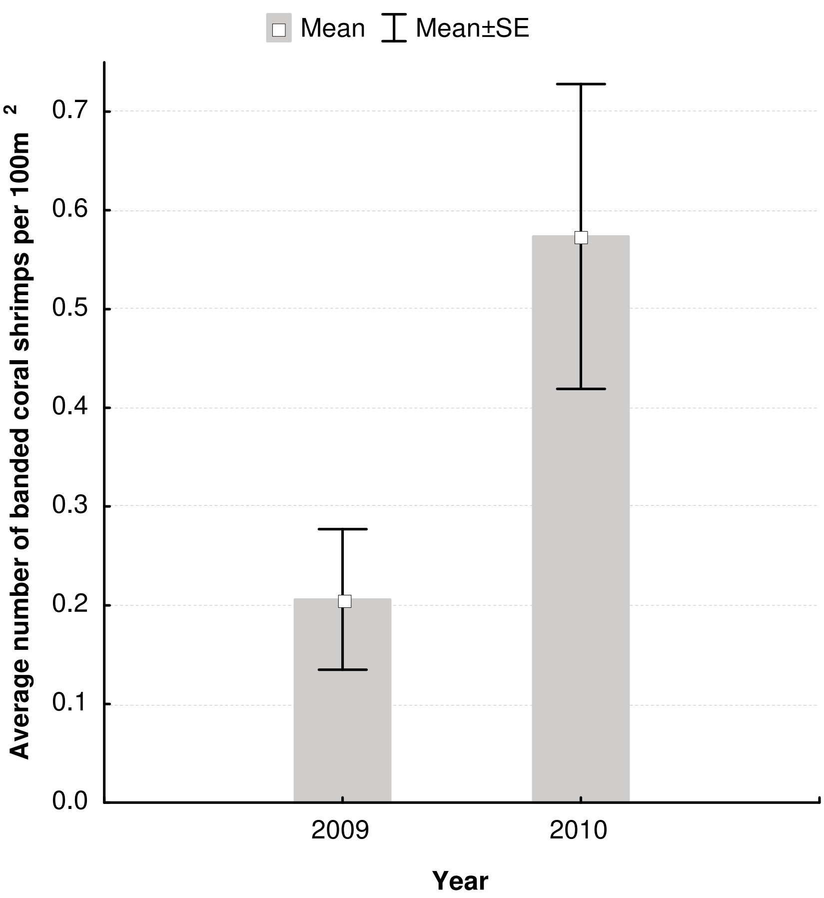


Figure 2.3j. Average number of banded coral shrimps per 100m^2 in 2009 and 2010.

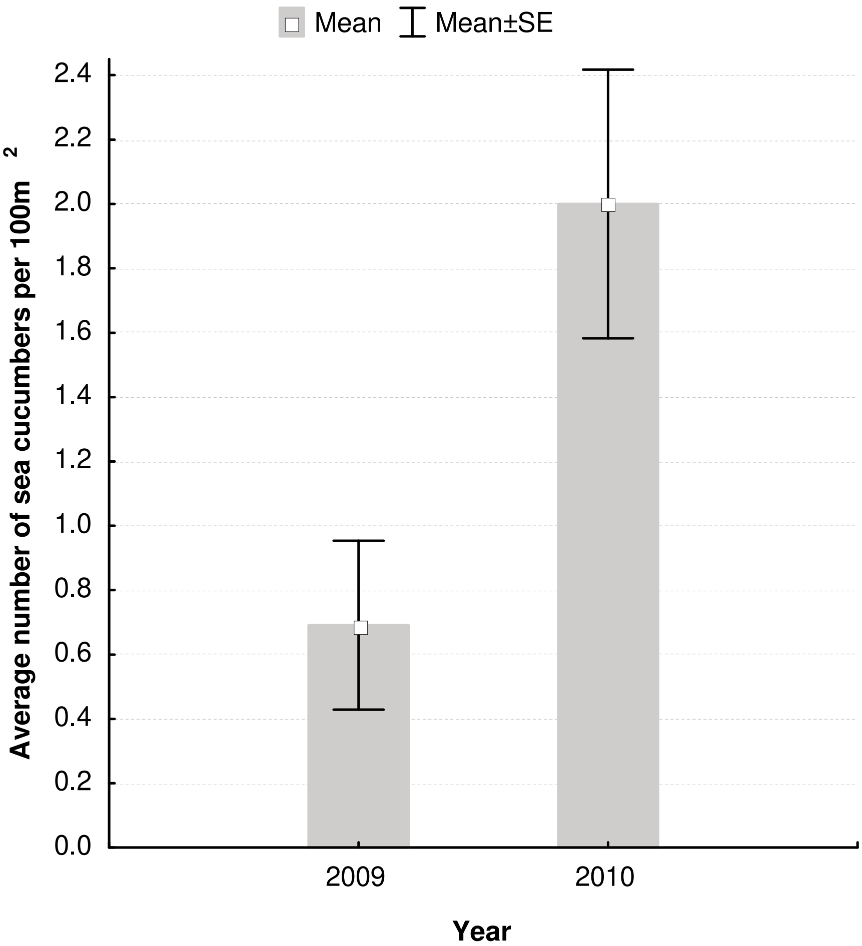


Figure 2.3k. Average numbers of sea cucumbers per $100m^2$ in 2009 and 2010.

Substratum / benthic community

Regarding the 10 different substrate classifications done at each survey, the highest mean average cover per $100m^2$ was of 42.5% ± 3.2 for hard coral (HC), followed by 22.6% ± 2.1 for rock (RC), 17.5% ± 2.2 for rubble (RB), 14.7% ± 1.8 for sand (SD), 1.4% ± 0.3 for others (OT), 0.8% ± 0.3 for silt (SI), 0.6% ± 0.5 for soft coral (SC), 0.6% ± 0.2 for recently killed coral (RKC), 0.5% ± 0.3 for nutrient indicator algae (NIA), and 0.04% ± 0.04 for sponges (SP) (Figure 2.3l).

Significant differences in the substrate mean percentage coverage, between 2009 and 2010, occurred mainly in an increase in nutrient indicator algae (NIA), rock (RC) and other (OT). NIA showed an increase from 0% mean percentage coverage per $100m^2$ in 2009 to a mean percentage coverage of 0.5% ± 0.3 in 2010 ($p<.05$) (Figure 2.3m). An increase was also observed in OT from a mean percentage coverage per $100m^2$ of 0.13% ± 0.1 in 2009 to a mean percentage coverage of 1.4% ± 0.3 in 2010 ($p<.001$) (Figure 2.3n). A decrease in RC cover per $100m^2$ was seen from a mean percentage cover of 34.9% ± 3.0 in 2009 to a mean percentage cover of 22.6% ± 2.1 in 2010 ($p<.005$) (Figure 2.3o).

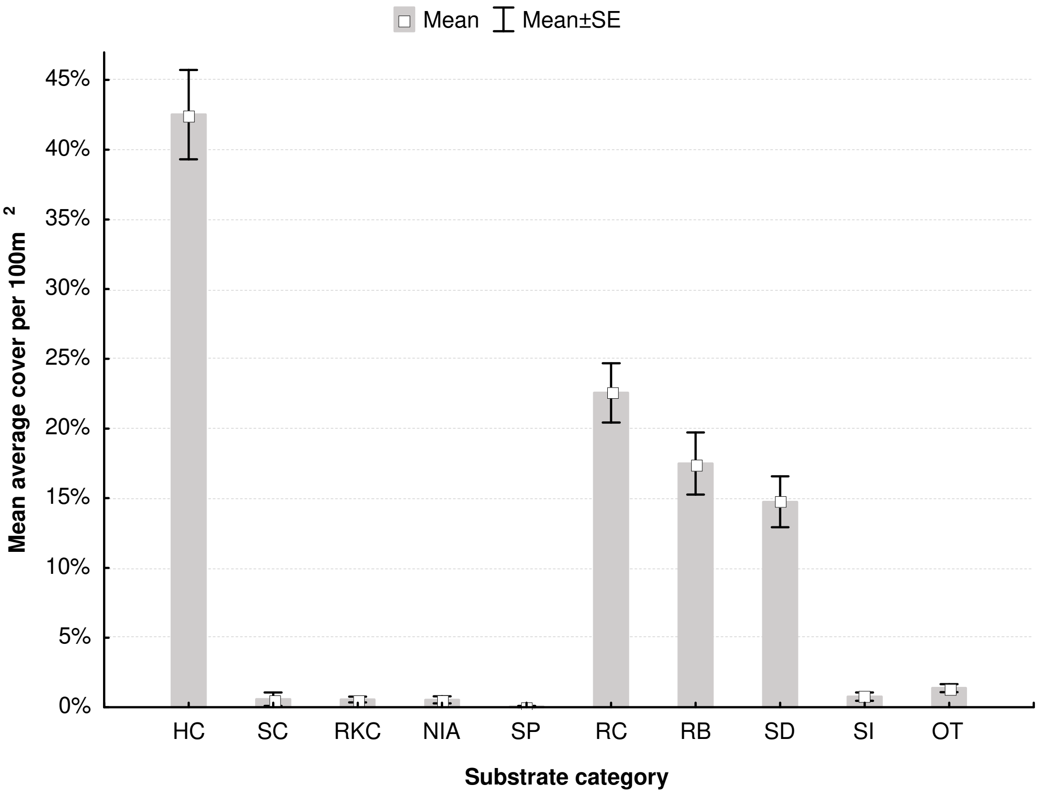


Figure 2.3l. Pooled average percentage cover of different substrates seen in Musandam (HC=hard coral; SC=soft coral; RKC=recent killed coral; NIA=nutrient indicator algae; SP=sponge; RC=Rock; RB=rubble; SD=sand; SI=silt; OT=others).

.

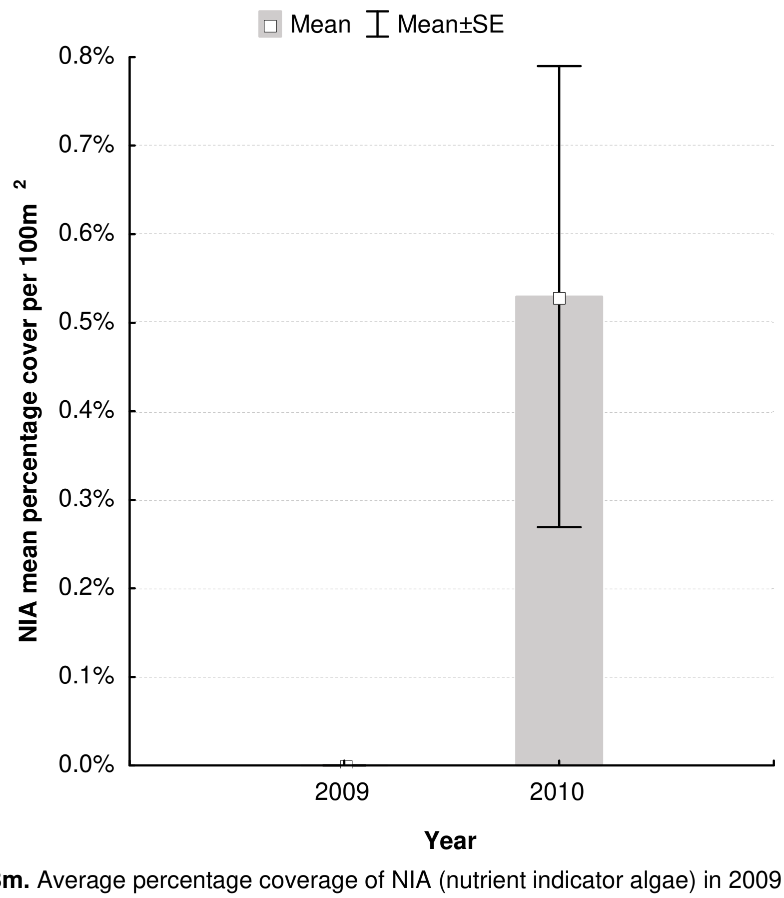


Figure 2.3m. Average percentage coverage of NIA (nutrient indicator algae) in 2009 and 2010.

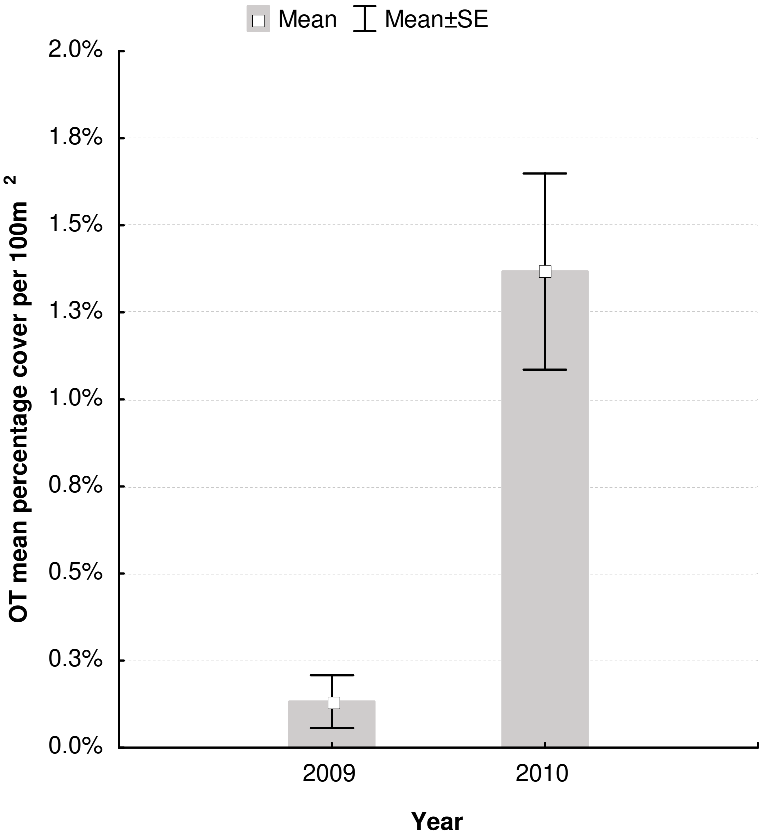


Figure 2.3n. Average percentage cover of OT (others) in 2009 and 2010.

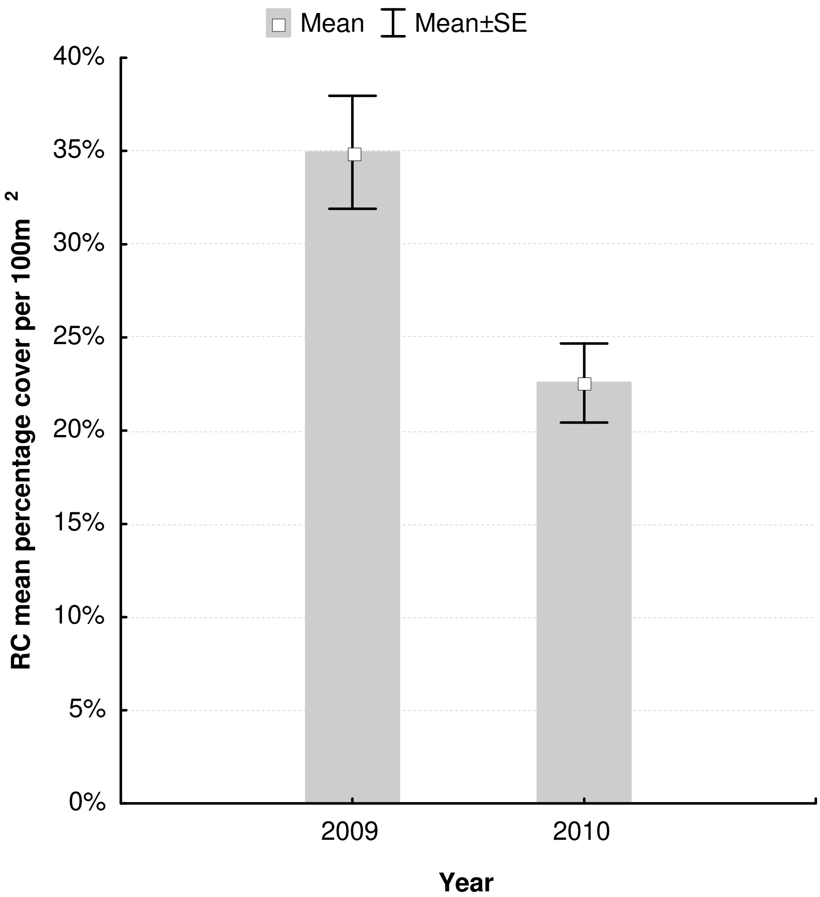


Figure 2.3o. Average percentage coverage of RC (rock) in 2009 and 2010.

Underwater impacts, coral damage and coral disease

Regarding the impacts counted underwater during the surveys, when pooling all data, the main impact with a rank between low and medium impact was “others”. Next in impact significance followed trash nets, boat/anchor damage and fish nets with an average rank ranging between none and low impact (Figure 2.3p).

From all underwater impacts measured during the 2009 expedition, “others” was the only impact that showed a significant increase in 2010, increasing from low to average pressure to low and medium pressure (Figure 2.3q). All the other impacts remained as in 2009, below the low level.

Coral bleaching, due to the loss of the symbiotic algae zooxanthellae, was very low in the coral populations surveyed in Musandam in 2009. Although the average obtained in 2010 was still low, there was a significant increase from 0.1% ± 0.5 per $100m^2$ in 2009 to 1.0% ± 2.7 per $100m^2$ in 2010 ($p<.05$) (Figure 2.3r). The same was noticed in the percentage of bleached coral colonies, with an increase of 3.1% ± 13.4 per $100m^2$ to 11.1% ± 21.9 per $100m^2$ ($p<.05$) (Figure 2.3s). Despite the increases, bleaching remains low.

Coral disease was also very low both in 2009 and 2010, but a significant difference was observed between the two years with an increase from 0.01% ± 0.12 of estimated percentage of disease per $100m^2$ in 2009 to 0.09% ± 0.33 in 2010 ($p<0.5$) (Figure 2.3t).

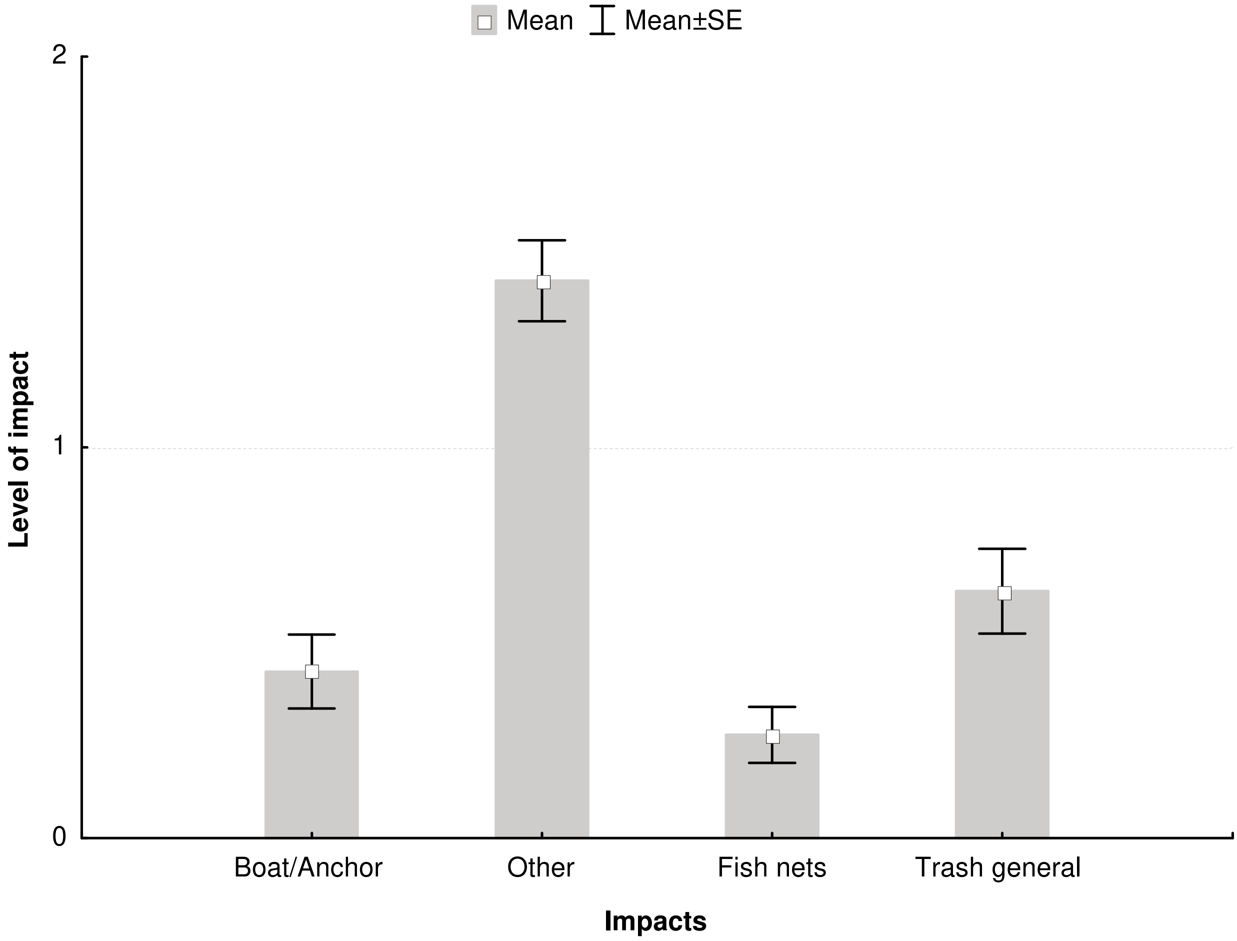


Figure 2.3p. Pooled average number of Reef Check impacts/trash categories (0=none; 1=low; 2=medium; 3=high).

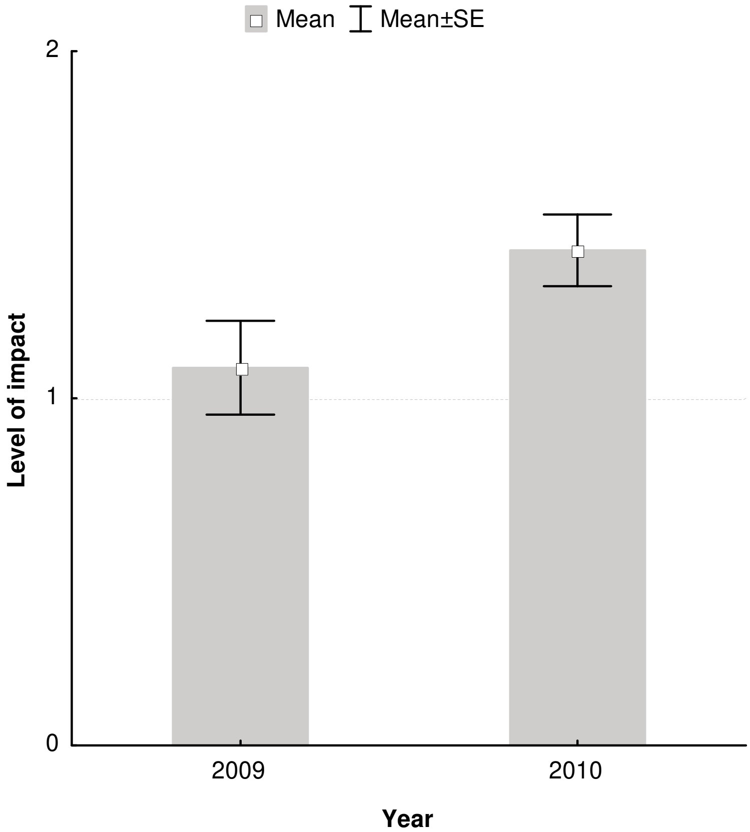


Figure 2.3q. Average level of other impacts in 2009 and 2010 (0= none; 1= low; 2= medium; 3= high).

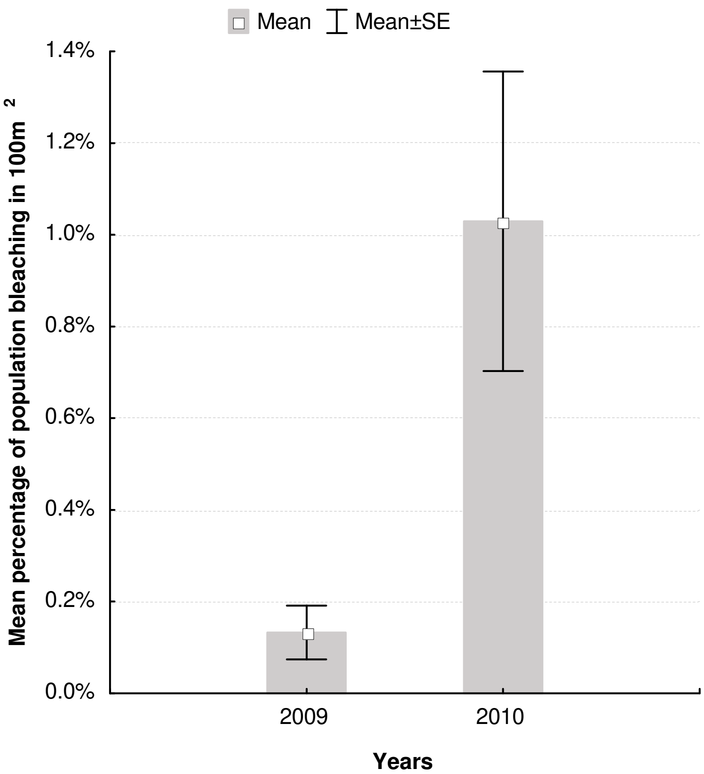


Figure 2.3r. Estimate percentages of bleached coral population per 100 m2 in 2009 and 2010.

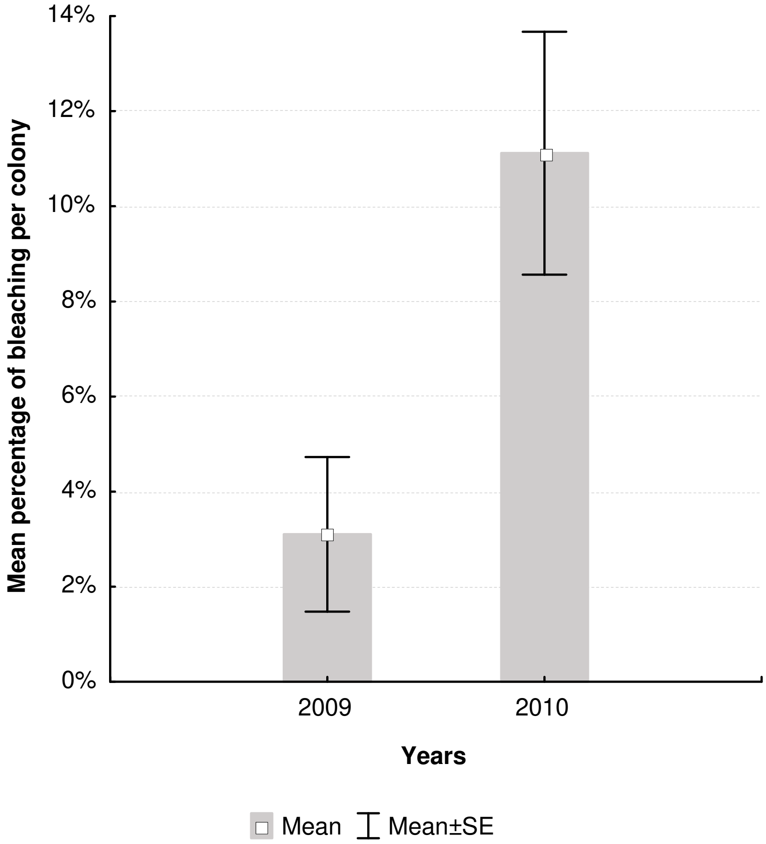


Figure 2.3s. Estimate percentages of bleached area per colony in 2009 and 2010.

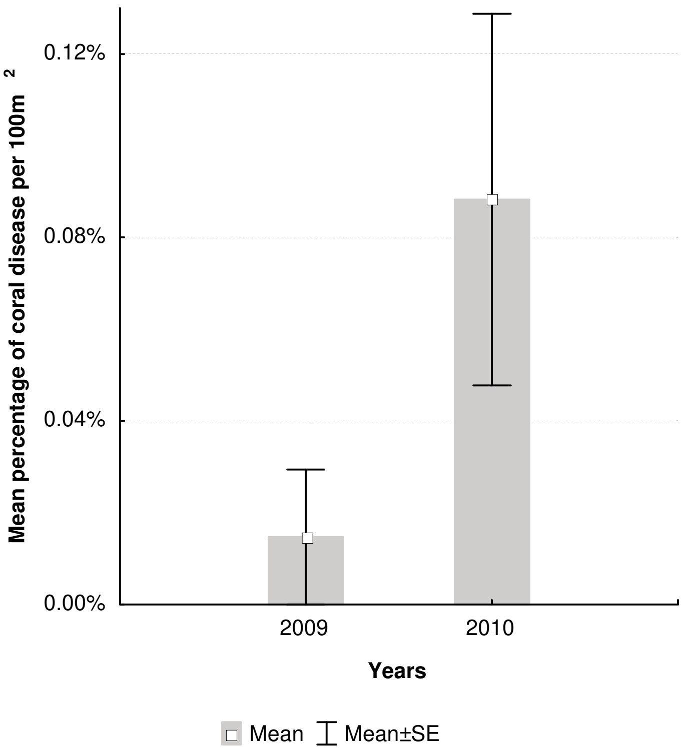


Figure 2.3t. Estimate percentages of coral disease per 100 m2 in 2009 and 2010.

2.4. Discussion & conclusions

In the past decades there have not been many studies on the Musandam peninsula coral reef's biodiversity. The latest research in the region that collected data in the Musandam peninsula includes different topics such as tropical harmful algal blooms (Bauman et al. 2010), kingfish fisheries (Claereboudt et al. 2004), shark fisheries (Henderson et al. 2007) and phytoplankton (Subba-Rao and Al-Yamani 1998). But the last published scientific study done exclusively in Musandam was conducted in 1971 and 1972 (Fraser et al. 1973). It is therefore still difficult to understand if the changes seen between the 2009 and 2010 expeditions are following a typical and already well established trend pattern or if they are changes that started recently.

One of the main objectives of this expedition, besides elucidating the possible impacts on the health of the Musandam coral reefs, is also to understand for the first time what characterises the marine life of the area. By comparing data collected in 2010 with data of 2009 from the shallow reefs of Musandam, and also with future expeditions, it will be possible to apply these findings in management and conservation decisions as well as in local and international education.

Fish and invertebrate community

Higher abundance of fish of the families Lutjanidae (snappers) and Chaetodontidae (butterflyfish), compared to Haemulidae (sweetlips) and Scaridae (parrotfish) in Musandam, both in 2009 and 2010, are in conformity with what is expected on Indo-Pacific reefs according to Hodgson and Liebeler (2002). Major differences were not noticed between 2009 and 2010 in the mean values of these different fish groups. Apart from the fact that not one sweetlip was observed in 2010, probably related to the fact that a slight increase in the commercial fishing was also observed in the same year.

Although an increase in the mean average of groupers was noticed in 2010, the average number is still very low, 1.15 ± 0.1 per 100m^2. Again in 2010, as in 2009, no groupers greater than 50 cm were seen. The low abundance of groupers around the Musandam in 2010 is most likely still due to the high commercial value of this family for fishermen in the region. Many species of groupers, such as *Epinephelus coioides*, are important commercially exploited species in the Persian Gulf (Grandcourt et al. 2005; Siddeek 1999). The highest grouper size class observed is again the smallest class, 30-40 cm, when compared to the number of groupers with more than 40 cm counted. This is likely to be related to fishing pressure, which is not allowing this species to grow. The fact that the increase observed in the average number of grouper per 100 m^2 is not substantial, together with the decrease in moray eels, and the fact that no sweetlips were observed during a two week expedition, can still be associated with a reef system under pressure and in trouble. There is thus a strong need for conservation and management measures, as well as more research in this field.

Many of the fish populations in the Persian Gulf have been heavily exploited and concerns that fishing effort may already have exceeded optimum levels for most species are now receiving some attention from local communities (Grandcourt et al. 2005). Fisheries that remove large individuals can easily eradicate all sexually mature fish and/or create a highly skewed sex ratio with the possibility of reproductive failure (Sadovy and Vincent 2002).

The increase in the average number of coral banded shrimp and sea cucumbers lends further weight to what was referred in the expedition report of 2009, namely that there seems to be no pressure from the curio and aquarium trade or from the tradition of catching sea cucumber as a delicacy around the Musandam peninsula (Bento and Hammer 2010).

The number of Diadema urchins was still high in 2010. More research need to be conducted in the region regarding this species, because although Diadema urchins are responsible for grazing algae from the reef surface, maintaining the balance between algae and coral in a healthy reef system, a high density population of Diadema increases bioerosion activity, making it difficult for new coral recruits to settle. Urchins can also graze around the bases of large colonies, destabilizing coral heads and increasing their susceptibility to get knocked over by storm waves (Hodgson and Liebeler 2002).

The presence of crown-of-thorns starfish (COTS) (*Acanthaster planci*) was still as low as in 2009. However, COTS abundance needs to be monitored carefully, firstly because coral mortality caused by COTS predators can be catastrophic or near-catastrophic in scale, and secondly, because no tritons (COTS predator) were found during the expedition. The existence of tritons in the region is not confirmed and observations of such species have not been corroborated scientifically. Predator plagues of COTS are increasingly reported around areas of human activities with two strong hypotheses advanced. The plagues may be initiated and certainly exacerbated by either overfishing of key starfish predators; and/or increases in nutrient runoff from the land may favour the planktonic stages of the starfish (Goldberg and Wilkinson 2004).

The number of lobsters in Musandam is still low and serves as further evidence of fishing pressure (Hodgson and Liebeler 2002). It is known that lobsters are caught in significant quantities on the south coast of Oman and Yemen by trammel net and lobster pots (Siddeek 1999). Siddeek (1999) has also shown that lobster landings in the region have been dropping steadily, from a peak of 4570 tons in 1991 to 2032 tons in 1996. More fisheries landings studies need to be conducted in the region to understand if this number is still decreasing.

Substrate and benthic community

Knowing that many of the world's best reefs have a hard coral coverage of 32% (Hodgson and Liebeler 2002), the small increase noticed in the shallow reef of Musandam from a mean average hard coral cover of 40.1% in 2009 to 42.5% is outstanding. The increase in percentage cover of the OT (other) category is also an indication of a healthy coral reef, but more surveys need to be done to confirm these values and make sure that the percentages are maintained or increasing. As seen in 2009, the high percentage of rubble in the Musandam area is probably related to cyclone Gonu in June 2007, which reduced great areas of coral to rubble.

Since corals require clear, sediment-free water to ensure sufficient sunlight for photosynthesis by symbiotic algae, siltation is one of the most important parameters to measure. The low incidence of siltation found by the expedition in 2009 and 2010 shows that dredging in this area is still not an issue. However, the increase in the nutrient indicator algae coverage in Musandam is probably related to the ongoing coastal development along the coast of the Musandam as was anticipated in the report of the 2009 Musandam expedition (Bento and Hammer 2010).

Close monitoring of the level of sediments, nutrient indicator algae and sponges needs to continue in order to understand if dredging caused by coastal developments is affecting reefs, and if effluents and waste run-off treatment stations need to be installed in order to avoid nitrification and excessive algal growth along the reefs, although a decrease in sewage pollution was noticed.

Impacts and coral damage

The highest general impact found in the region in both 2009 and 2010 was commercial fishing, albeit still at a low level overall. The level between years was almost the same but the level of pressure coming from tourist diving and snorkelling has increased considerably, as was predicted in the 2009 report (Bento and Hammer, 2010). This heightened demand for diving in such a popular area in the region is mainly due to the current coastal development and increasing number of hotels and dive centres in the Musandam area. Diving activity is constantly increasing in Musandam, and in some popular dive sites the level of activity is extremely high. Although general trash and destruction from boats and anchors are still below the low pressure level, these values are likely to increase in the future as a consequence of the increasing number of boats and divers in the region. Unfortunately mooring buoys have only been installed in one dive site not surveyed in 2010 (Telegraph Island) and even these two buoys are not nearly enough for the number of boats that arrive during the weekends.

Artisanal and recreational fishing is also present in Musandam, and an increase in the harvest of invertebrates for food was also noticed. These pressures negatively influence the number and sizes of fish in the region, especially groupers and lobsters.

On the other hand, the decrease in sewage pollution from 2009 to 2010 is good news and likely be related to the fact that the small populated villages of Musandam house fewer and fewer people each year, who live in the villages just for short periods during the fishing season, and live most of the time in the principal centres of Khasab and Kumzar (Captain Ali, personal communication, October 2010). There is also a general trend away from remote communities and into the bigger centres.

Regarding underwater impacts, it is mostly very difficult to identify the source of impacts, so whenever there was any uncertainty about origin, the classification given was “others”, making this impact the highest found. Although this class combines a variety of impacts and does not give the exact source that needs to be addressed and reduced, it does not mean it is not important. Having an increase in this kind of impact shows that no patrolling is done in the Musandam area and that more surveys need to be done to understand the main changes and management rules that need to be implemented in the Musandam peninsula.

Besides human impacts, the most powerful determinants of coral reef health are temperature and salinity. Higher than normal surface seawater temperature (SST) stresses corals and causes coral bleaching, frequently with large scale mortality. In the 4th Intergovernmental Panel on Climate Change (IPCC) in 2006, it was stated that “corals are vulnerable to thermal stress and have low adaptive capacity. Increases in sea surface temperature of about 1–3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatisation by corals”. When SSTs exceed the summer maximum by more than 1°C for four weeks or more under clear tropical skies, corals bleach. If warmer conditions persist for longer periods, corals can die in large numbers (Bernstein et al. 2007).

Sea surface temperature anomalies around reefs in the Indian Ocean region have increased through the 20th century by 0.50°C/century in the Middle East and Western Indian Ocean and by 0.59°C/century in the Central and Eastern Indian Ocean. Although most of the bleaching is associated with higher sea temperatures and coral death, an alternative hypothesis exist saying that corals, via their symbiotic zooxanthellae, may evolve rapidly by acquiring more thermally tolerant symbionts within a few decades. This would make corals more thermally tolerant and keep pace with rapid climate change. But this would require an adaptation at a rate of at least 0.2–0.4°C per decade and there is no evidence that corals can change their symbiotic relationships or develop temperature tolerance so quickly (Burt et al. 2008; Wilkinson 2008).

The increase in percentage of coral disease and coral bleaching, colony and population, are directly related to the fact that SSTs in 2010 were higher in 2010 (mean average of 30.0°C ± 1.1) than during the 2009 expedition (mean average of 27.8°C ± 1.1). There might be a resistance of local coral communities in Musandam to wide temperature variation, since corals with higher SST temperature variation exist in the region, as for example the Persian Gulf and Eritrean corals where SSTs can fluctuate annually from winter lows less than 12°C to summer highs above 36°C , or even water temperatures that can reach 37.5°C in summer at 10 m depth (Burt et al. 2008; Wilkinson 2008).

Coral disease can be described as the disability of the coral vital functions or systems, and it can affect the individual organism as well as the community where it lives. The corals become more susceptible to diseases from natural and anthropogenic physical and chemical alterations in the environment. In the Persian Gulf, several coral diseases occur that can be a factor of coral mortality: black band disease (BBD) is a common disease on branching corals during summer, but tends to disappear in winter. Infection rates of 25% in some areas on *Acropora* species have been reported in the region. White band disease (WBD) is usually rare and not infectious, even in physical contact situations and appears to infect all species. Yellow band disease (YBD) is the most widespread and contagious disease both in summer and winter and has a fast within-colony spread (Al-Cibahy et al. 2008). YBD is not species-specific and was found on two sites in the Gulf of Oman by Rezai et al. (2004).

2.5. Recommendations & future expedition work

The work of the 2009 and 2010 expeditions shows clearly that Oman has in its stewardship what are probably the best reefs of the region and a unique area of natural beauty as well as commercial importance, not just for fishermen, but also for the local economy as a generator of income from tourism.

However, there is also high demand and stress on them from the diving and fishing community. The contrast values of a high coral coverage of 42.5% and the low average numbers or absence of lobsters, moray eels, groupers, sweetlips and parrotfish show the potential that this ecosystem holds, but also that it is probably on the brink. The increase of NIA coverage due to the coastal development is also a concern when combined with the increase of commercial fishing and diving tourism. Further surveys are needed as they will generate a better understanding of population sizes and trends, as well as the level of impacts and pressures for the area.

If environmental awareness can be created in time, and if the growth of impacts can be controlled, there is a good chance that the number of species can be held stable or increased. Studies on Musandam ports fisheries landings would help our understanding of the demands on this ecosystem, as well as its biodiversity and population levels. More information about the catch of shells, lobsters, groupers and sweetlips will give a good indication of possible future trends for the area and the correct legal framework and enforcement needed in the Musandam region.

It is essential not to neglect the Musandam peninsula and ensure that its marine environment is preserved. Involving local people in the surveys and explaining results, such as the relationship between high coral coverage and high species diversity, might be enough for the empiric understanding of a healthy ecosystem and control the pressure level of artisanal fisheries in Musandam. In order to understand the full impact of fishing in this region, the impacts of selective mortality on specific size classes, colour phases or morphs, and social structure in target population, such as groupers, should be studied (Sadovy and Vincent 2002).

All the studies, new policies and regulations that could be applied in Musandam have to take into account the need to improve the social resilience by helping local communities to adapt to these changes. More strategies and approaches, done by management activities and planning for change are needed to minimise impacts and build resilience. To achieve this resilience, focus should primarily exist on land-based sources of pollution, over-fishing and climate change.

Musandam as a Marine Protected Network

A number of Marine Nature Reserves were declared in the nineties by the Ministry of Environment and Municipality to protect vulnerable marine habitats in Oman (Siddeek 1999). There is Ras' Al-Had Nature Reserve for the protection of green turtle nesting grounds, Damaniyat Island Nature Reserve for the protection of green and hawksbill turtle nesting grounds, coral reefs, birds, and fish, Dhofar Khowrs Nature Reserve (fresh as well as brackish water lagoons) for the protection of sea birds and fish. All of these reserves are located outside Musandam governorate and no protected area has been declared there yet. However, it is a stated government policy to have more reserves in each governorate.

We therefore recommend the implementation of a new marine protected area (MPA) in Musandam governorate or a network of MPAs for the protection of this unique marine environment. The Musandam is an ideal place for an MPA or MPAs as impacts and population levels are still relatively low and coral coverage is high. Having said this, the low number or absence of lobsters, moray eels, groupers, sweetlips and parrotfish shows that this coral reef system may be at the threshold of collapse, and the increase of impacts observed from 2009 to 2010 are a concern.

The strong military presence in the area, due to its proximity to the Strait of Hormuz, is also significant for the implementation of a MPA, since military exclusion zones could form part of a MPA and policing of protected areas could be done by the military with relatively little additional training.

The implementation of a MPA will help to mitigate the impacts of stresses found by the expedition, as well as create benefits such as (a) conserve biological diversity and associated ecosystems that cannot survive in most intensely managed seascapes; (b) promote natural age structures in populations, increasing fish catches locally (by protecting critical spawning and nursery habitats) and in surrounding fishing grounds; (c) provide refuge for species that cannot survive in areas that continue to be fished; (d) provide alternative incomes for local communities and alleviate poverty; (e) protect sensitive habitats from disturbances and damage from fishing gear; (f) eliminate "ghost fishing" by lost or discarded gear; (g) serve as point of reference of undisturbed control reference sites that can be used as baseline for scientific research and also to measure fishery effects in other areas and thereby help to improve fisheries management; and (h) act as focal points for public education and awareness on marine ecosystems and human impacts upon them (IUCN-WCPA 2008).

The Musandam peninsula or parts of it could also be established as a Biosphere Reserves under UNESCO's Man and the Biosphere (MAB) Programme. Biosphere Reserves are areas of terrestrial, coastal and marine ecosystems established to promote and demonstrate harmonious and sustainable interactions between biodiversity conservation and socio-economic well-being of people, through research, education, monitoring, capacity building and participatory management. By being protected under this classification, UNESCO can provide advice and occasionally source funds to start local efforts; it can also help broker projects or set up durable financial mechanisms.

Knowing that implementing a MPA can take several years to accomplish, and with the increase of the diving industry observed during the 2010 expedition, it is necessary to take additional action until an MPA is in place. We therefore recommend the following actions:

- Deployment and maintenance of standardized mooring buoys in all known dive sites would help to decrease the impacts of anchor and boat damage.

- Create, implement and police regulations for the diving industry, such as (1) regulating the number of boats and divers allowed per dive site, (2) not permitting anchoring and (3) the obligatory requirement of a dive guide from the dive centres with every dive group.

- Standard signs, information, and visitor logbooks should be enforced in all dive centres conducting dives in Musandam to provide basic interpretative information visitor regarding Musandam and also to serve as a first control of the number of divers in the area.

Involving the local community in future studies is extremely important in order to mitigate the lack of awareness and knowledge. If awareness can be created in time and if the impacts can be controlled, then there is a good chance that the number of species can be held stable or increased.

Studies on Musandam ports fisheries landings will help our understanding of the demands on this ecosystem, as well as its biodiversity and population levels. More information about the existence of shells (such as *Charonia* spp.) is also needed, since their harvesting can lead to an outbreak of COTS in the region.

Future Reef Check surveys of the Musandam peninsula are required in order to understand the average number of indicator species with lower standard error. Further surveys will also yield a better understanding of trends, population sizes and pressures for the area.

2.6. References

Al-Cibahy, A., Al-Harthi, S., Al-Moati, A., Al-Mansoori, A., Foster, K.A., Launay, F., Al-Mubarak, R., Purkis, S., Riegl, B. & Tourenq, C. (2008) Conservation and Management Plan of Abu Dhabi and Eastern Qatar Coral Reefs (Qatar & Abu Dhabi: Supreme Council for the Environment and Natural Reserves (SCENR) of the State of Qatar, Environment Agency of Abu Dhabi Emirate (EAD), National Coral Reef Institute (NCRI), Emirates Wildlife Society in association with the World Wide Fund for Natures (EWS-WWF)

Anderson, D.M. (1997) Turning back the harmful red tide. Nature 388, 513-514.

Baker, A.C., Starger, C.J., R.McClanahan, T. & Glynn, P.W. (2004) Corals' adaptive response to climate change. Nature 430, 741.

Bauman, A.G., Burt, J.A., Feary, D.A., Marquis, E., and Usseglio, P. (2010). Tropical harmful algal blooms: An emerging threat to coral reef communities? Marine Pollution Bulletin *60*, 2117-2122.

Bento, R., and Hammer, M. (2010). Underwater pioneers: studying & protecting the unique coral reefs of the Musandam peninsula, Oman. In Expedition Report, M. Hammer, ed. (Biosphere Expeditions), p. 51.

Bernstein, L., Bosch, P., Canziani, O. et al. (2007) Climate Change 2007: Synthesis Report (pp. 73. Valencia, Spain: Intergovernmental Panel on Climate Change.

Buddemeier, R.W., Baker, A.C., Fautin, D.G. & Jacobs, J.R. (2004) The Adaptive Hypothesis of Bleaching. Paper presented at: Coral Health and to Disease Meeting, Israel.

Burt, J., Bartholomew, A. & Usseglio, P. (2008) Recovery of corals a decade after a bleaching event in Dubai, United Arab Emirates Marine Biology 154, 27-36.

Carpenter, K.E., Krupp, F., Jones, D.A. & Zajonz, U. (1997) The living marine resources of Kuwait, Eastern Saudi Arabia, Bahrain, Qatar, and the United Arab Emirates. In: FAO species identification guide for fishery purposes (pp. 293). Rome: FAO.

Claereboudt, M.R.G., Al-Oufi, H.S., McIlwain, J., and Goddard, J.S. (2004). Relationships between fishing gear, size frequency and reproductive patterns for the kingfish (Scomberomorus commerson Lacépède) fishery in the Gulf of Oman. In Management of Shared Fish Stocks, A.I.L. Payne, C.M. O'Brien, and S.I. Rogers, eds. (Oxford: Blackwell), pp. 56-67.

Coles, S.L. (2003) Coral species diversity and environmental factors in the Arabian Gulf and the Gulf of Oman: a comparison to the Indo-Pacific region. Atoll Research Bulletin 507, 1-19.

EWS-WWF (2008) Final report January 2005 - December 2007 In: Coral Reef Investigations in Abu Dhabi and Eastern Qatar (pp. 74). Dubai.

Fraser, F.C., Falcon, N.L., Falcon, M., Cornelius, P.F.S., Hugh-Jones, P., Bertram, G.C.L., Shearman, D.J., Glennie, K.W., Glennie, M., Shotton, F.W., Vita-Finzi, C., Roberts, D.G. & Robinson, G.P.G. (1973) The Musandam Expedition 1971-72 Scientific Results: Part I: Discussion. The Geographical Journal 139, 422-425.

Fritz, H.M., Blount, C.D., Albusaidi, F.B. & Al-Harthy, A.H.M. (2010) Cyclone Gonu storm surge in Oman. Estuarine, Coastal and Shelf Science 86, 102-106.

Goldberg, J. & Wilkinson, C. (2004) Global Threats to Coral Reefs: Coral bleaching, global climate change, disease, predator plagues, and invasive species In: Status of Coral Reefs of the World: 2004 (ed. C. Wilkinson), pp. 67-92.

Grandcourt, E.M., Abdessalaam, T.Z.A., Francis, F. & Shamsi, A.T.A. (2005) Population biology and assessment of the orange-spotted grouper, Epinephelus coioides (Hamilton, 1822), in the Southern Arabian Gulf. Fisheries Research 74, 55-68.

Grimsditch, G.D. & Salm, R.V. (2006) Coral Reef Resilience and Resistance to Bleaching (pp. 52. Gland, Switzerland: IUCN.

Henderson, A.C., McIlwain, J.L., Al-Oufi, H.S., and Al-Sheili, S. (2007). The Sultanate of Oman shark fishery: Species composition, seasonality and diversity. Fisheries Research *86*, 159-168.

Harrison, P. (2008) UNEP Year Book 2008: An Overview of Our Changing Environment, UNEP Division of Early Warning and Assessment (DEWA)

Hinchley, D., Lipsett-Moore, G., Sheppard, S., Sengebau, F.U., Verheij, E. & Austin, S. (2007) Biodiversity Planning for Palau's Protected Areas Network: An Ecoregional Assessment. In: TNC Pacific Island Countries. Report No 1/07 (South Brisbane, Australia: The Nature Conservancy, Indo-Pacific Resource Centre.

Hodgson, G., Hill, J., Kiene, W., Maun, L., Mihaly, J., Liebeler, J., Shuman, C. & Torres, R. (2006) Reef Check Instruction Manual: A guide to REef Check Coral Reef Monitoring (pp. 86). California, USA: Reef Check Foundation.

Hodgson, G. & Liebeler, J. (2002) The Global Coral Reef Crisis: Trends and Solutions (pp. 78. Reef Check.

IUCN-WCPA (2008) Establishing Marine Protected Areas Networks - Making it Happen. IUCN-WCPA, National Oceanic and Atmospheric Administration and The Nature Conservancy, Washington, D.C.

Marshall, P. & Schuttenberg, H. (2006) A Reef Manager's Guide to Coral Bleaching (pp. 166. Townsville, Australia: Great Barrier Reef Marine Park Authority.

McClanahan, T.R., Sheppard, C.R. & Obura, D.O. (2000) Coral reefs of the Indian Ocean: theirs ecology and conservation, NY, Oxford University Press.

Mooney, C. (2007) Storm World: Hurricanes, Politics, and the Battler Over Global Warming, Houghton Mifflin Harcourt.

Pilcher, N.J., Wilson, S., Alhazeem, S.H. & Shokri, M.R. (2000) Status of coral reefs in the Arabian/Persian Gulf and Arabian Sea region (Middle East). In: Status of Coral Reefs of the World: 2000 (pp. 55-64. Australian Institute of Marine Science.

Pous, S.P., Carton, X. & Lazure, P. (2004) Hydrology and circulation in the Strait of Hormuz and the Gulf of Oman-Results from the GOGP99 Experiment: 2. Gulf of Oman. J. Geophys. Res. 109.

Price, A.R.G., Sheppard, C.R.C., and Roberts, C.M. (1993). The Gulf: Its biological setting. Marine Pollution Bulletin *27*, 9-15.

Randall, J.E. (1995) Coastal Fishes of Oman, Honolulu, University of Hawaii Press.

Reynolds, R.M. (1993). Physical oceanography of the Gulf, Strait of Hormuz, and the Gulf of Oman--Results from the Mt Mitchell expedition. Marine Pollution Bulletin *27*, 35-59.

Rezai, H., Wilson, S., Claereboudt, M. & Riegl, B. (2004) Coral reef status in the ROPME sea area: Aranian/persian gulf, gulf of Oman and Arabian. In: Status of Coral Reef of the World 2004 (ed. C. Wilkinson), pp. 155-170.

Richlen, M.L., Morton, S.L., Jamali, E.A., Rajan, A. & Anderson, D.M. (2010) The catastrophic 2008-2009 red tide in the Arabian gulf region, with observations on the identification and phylogeny of the fish-killing dinoflagellate Cochlodinium polykrikoides. Harmful Algae 9, 163-172.

Riegl, B. (1999) Corals in a non-reef setting in the southern Arabian Gulf (Dubai, UAE): fauna and community structure in response to recurring mass mortality. Coral Reefs 18, 63-73.

Riegl, B. (2001). Inhibition of reef framework by frequent disturbance: examples from the Arabian Gulf, South Africa, and the Cayman Islands. Palaeogeography, Palaeoclimatology and Palaeoecology *175*, 79-101.

Riegl, B.M., Purkis, S.J., Kohler, K.E. & Dodge, R.E. (2006) Spatial patterns in Arabian Gulf coral assemblages (Jebel Ali, Dubai, U.A.E.) in response to temperature-forcing. Paper presented at: 10th International Coral Reef Symposium, Okinawa, Japan.

Sadovy, Y.J. & Vincent, A.C.J. (2002) Ecological Issues and the Trades in Live Reef Fishes. In: Coral Reef Fishes. Dynamics and diversity in a complex ecosystem (ed. P. F. Sale), pp. 391-420. San Diego: Elsevier Press.

Sheppard, C., Price, A. & Roberts, C. (1992) Marine Ecology of the Arabian Region. Patterns and Processes in Extreme Tropical Environments., London, Academic Press.

Sheppard, C.R.C., and Loughland, R. (2002). Coral mortality and recovery in response to increasing temperature in the southern Arabian Gulf. Aquatic Ecossystem Health and Managemenr *5*, 395-402.

Siddeek, M.S.M. (1999) Marine fisheries resources, fisheries and marine environmental management, coral reefs and marine parks in the Northwest Indian Ocean In: Regional Workshop on Fisheries Monitoring, Control and Surveillance (pp. 101-115). Muscat.

SOMER (2003) State of the Marine Environment Report (pp. 217). Kuwait: Regional Organization for the Protection of the Marine Environment.

Spalding, M., Ravilious, C. & Green, E.P. (2001) World Atlas of Coral Reefs, University of California Press.

Subba-Rao, D.V. & Al-Yamani, F. (1998) Phytoplankton ecology in the waters between Shatt Al-Arab and Straits of Hormuz, Arabian Gulf: A review. Plakton Biology and Ecology 45, 101-116.
Wilkinson, C. (2004) Status of Coral Reef of the World 2004

Wilkinson, C.R. (2008) Status of coral reefs of the world : 2008, Townsville, Australia, Global Coral Reef Monitoring Network, Reef and Rainforest Research Centre.

Wilson, S., Fatemi, S.M.R., Shokri, M.R. & Claereboudt, M. (2002) Status of Coral Reefs of the Persian/Arabian Gulf and Arabian Sea region. In: Status of Coral Reefs of the World: 2002 (ed. C. Wilkinson), pp. 53-62. Australian Institute of Marine Sciences.

3. Expedition leaders' diary: Musandam 2010 by Kathy Gill and Ken Atkinson

6 October

Hello everyone and welcome to the first diary entry for Biosphere Expeditions' second Musandam expedition. My name is Kathy Gill, Strategy Director of Biosphere Expeditions, and I will also be your expedition leader on slot 1 of this project, training Ken Atkinson, who will take over from me for slot 2.

I write this a few hours before boarding my flight to Dubai and surrounded by paperwork and equipment for me to take over there. The paperwork includes an itinerary (attached). As you can see, it's a packed schedule, especially on the first three days with lots of training and some tests before we let you lose on the reef, collecting data and experiencing conservation in action. No doubt you'll need a holiday after the expedition ;), but please try to come rested and fresh in your minds, ready for the challenges ahead.

Please make sure your PADI medical statements are in order (otherwise you ain't getting in the water!), that your dive gear is working and that your buoyancy skills are up to scratch.

Finally, my mobile phone number during the expedition will be +968 92380988. Remember that this is for emergency purposes only (such as being late for assembly, for example).

I'll see you all at the Holiday Inn Express Jumeira in due course!.

Best wishes

Kathy

P.S. This diary is now also on www.biosphere-expeditions.org/diaries and excerpts of it are also on www.facebook.com/pages/Biosphere-Expeditions/132594724471, so please feel free to pass this on to your families & friends for updates on what we are up to.

10 October

Today started very early when Ken and I set off from our boat, the MS Sinbad, to collect the first team from Dubai. We had arrived the day before in Khasab, along with Rita, our scientist, and Jon, a team member who has previously been an expedition leader for us, after a meeting with the Minister in charge of education for the Musandam. We discussed with him about going into some of the local schools to talk about the conservation work that we are doing and about distributing a colouring book for the younger children to raise their awareness of the marine environment. After that we headed straight for the boat to meet the crew and set up for the team's arrival the next day. An early night and then back to Dubai in the morning.

As soon as the team arrived in Khasab there were brief introductions and new friends started laughing together. We though it was laughing with us, but it might have been at us :) A nice lunch by Poly, who will be everyone's best friend very soon, then the formal brief, admin and then all the interested faces started their training with Rita. Everyone is very happy and keen to get in the water and see how their buoyancy is. We might need to encourage good buoyancy with chocolate, which might be counter-productive, so maybe a different incentive.

11 October

The team has been studying hard as Rita takes them through their Reef Check training. Connie and Suse have been great sounding boards for others about how the expedition went last year and their own experiences. A few of us were talking about the chances of seeing dolphins and then two popped up and rode the bow wave and smiled for everyone to take some great pictures. Everyone is full of laughs and can't wait to get in the water tomorrow.

12 October

The end of day two and everyone has at least one star next to their name for Reef Check. A BIG well done to everyone. The in-water test helped everyone understand just what it's like to collect data with snapper by the dozen, groupers, a little shy but they'll be out soon. The Angelina Jolie of fish (sweetlips) hasn't shown herself to many, but fingers are crossed for tomorrow. Diadema urchins are everywhere and we even had a few baby sharks enjoying the Sinabad's night lights. We had another two dolphins show us their graceful agility today, so I think its only fair for next year, that we include dolphin spotting. Tomorrow we start the real reef Checks and its all hands on deck.

13 October

Three Reef Check surveys completed today and two of the HSBC staff, Mo and Hilal, have teamed up and are treating each dive like they've done it 100 times. The guys have been so quick, they often have to sit back and relax while the team in front moves along. The day ended with some card games and you really find out who is competitive when there are chocolates up for grabs.

14 October

Today was certainly the turning point when it comes to embarrassing moments. Suse couldn't understand why her camera wasn't working until she realised she put it in up side down. Rita had to do some serious mask clearing after Jon popped in front of her with a marker peg on his nose. Good thing the data was collected! Mel, diving with her new great computer, finished her checks early because she thought the computer was telling her she had three minutes bottom time remaining when in fact it was telling her to do a three minute safety stop. I think she just wanted to be first to the shower.

15 October

The final three surveys have been completed and we're on our way to a nice secluded area for the night. The Musandam landscape has been breathtaking and cameras have been working overtime. In a tradition which started last year Suse was woken with cold water today! That joke just doesn't wear out. Mel and Chun are keen to do a night dive today and then the night will finish with another round of cards. Australia v UK v Portugal v Italy v Switzerland. Note to next week's group, the Portuguese are very competitive.

16 October

Final day and half the team had a snorkelling session this morning, whilst the other half had a tour of Khasab Castle and some of its surrounding areas. The team has worked really well during the week and a big pat on the back is deserved by everyone. Most of the first group is now back in Dubai while Rita, Connie, Karin and Georgie are minding the MS Sinbad to ensure it's totally ready for group two who starts tomorrow. A special thanks goes to Rita and Jon for their support this week and making the team feel like a well-oiled machine. Just don't play cards with Rita and we'll all be fine :-).

17 October

Ok, we're back on the road heading to Khasab for week two of the Musandam Reef Check Expedition and the sun is shining and the Omani mountains are just a magnificent sight. Six smiley and keen team members from all over the world with all their dive kit on board and three from week one waiting for our arrival on the 'MS Sindbad'. Rita is preparing to do the training and for some reason everyone seems happy to be bribed with chocolate. It is going to be another good week.

18 October

Everyone woke this morning to another one of Poly's fantastic breakfasts (it's the little things that matter). Training went to plan and everyone is reading up on fish, fish and more fish. The first dive was a bit of a test for some, but confidence is high and skill levels will improve every day. Conny, Georgie and Karin are being very polite and still laughing at mine and Rita's jokes.

19 October

A lot of happy smiley faces today with the training complete and everyone with at least one star to their name. Teams will be allocated soon and the work starts tomorrow. We managed to fit in a short pleasure dive, which gave everyone time to fine-tune their buoyancy and have a look for indicator fish. Helen, Simone and I were lucky to see a school of approximately 80 butterfly fish, which was just great. I got some good video footage of a parrotfish and after looking back through the video, noticed a grouper, school of snapper and a butterfly fish in the background. Just needed a sweetlips and I'd be in Reef Check video heaven.

20 October

First day of data collection has gone well. A few minor changes to the schedule to improve data collection and safety and everyone is happy, albeit a little water-logged. Simone and Anders are floating through the water and Sofie and Helen are getting more and more comfortable with being upside down counting diadema urchins and impacts. Jane is enjoying counting fish with Georgie and Karin, Conny and Badar are doing substrate and assisting Rita. After a relaxing card game everyone was full of laughs. Note to self: don't rig the deck while someone is away, they only win and make everyone else almost wet themselves laughing :-)

21 October

Another good day with more than the usual pranks played. Breakfast, check. Dive briefing, check. Kit put together, check. Overcome Georgie trying to push me in the water, check. Overcome Rita trying to push me in the water, not so lucky. I was about to complete my 1000th dive and the team wanted to ensure it was memorable. How could I forget such lovely people :-) There was talk of putting jam in my booties and let the fish gather around, so I was happy with simply being pushed in the water. Sofie had a dream about diadema urchins last night, but she was very keen to get in the water and overcome her demons.

22 October

Last day of data collection and the practical jokes continued. Today Karin completed her 300th dive, so after yesterday it was only fitting to continue the jokes. Only problem was Karin was in a team, which jumped in the water well after everyone else. Not to worry, teams changed and Karin is first in. After finally getting her away from her dive kit, Karin's BCD mysteriously turned itself upside down. She realised something was up quicker than blinking, so it was laughs all round.

23 October

On the way back to Khasab port now, after an easy morning and a leisurely snorkel around Telegraph Island. Most are packed, but I think everyone is waiting to see where Rita stashes all the remaining chocolates. It's been another great week with data collected and plenty of friends made. Emails and numbers have been exchanged and the photos taken throughout the week will be amazing. I hope everyone gets home well and I look forward to seeing you on another Biosphere expedition in the near future. :-)

Ken

><(((o>`•. ¸¸.•´¯`•. ¸><(((o> `•. ¸¸.•´¯`•. ¸><(((o>`•. ¸¸.•´¯`•. ¸><(((o> ¸.•´¯><(((o>`•. ¸¸.•´¯`•. ¸><(((o>