EXPEDITION REPORT

Expedition dates: 26 October – 1 November 2014
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Underwater pioneers: studying & protecting the unique coral reefs of the Musandam peninsula, Oman.

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Authors:
Jean-Luc Solandt
Marine Conservation Society

Matthias Hammer (editor)
Biosphere Expeditions

Abstract

Coral reefs are important biodiversity hotspots that not only function as a 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 extreme conditions such as high salinity and temperatures, existing – indeed thriving – in what would be considered marginal and highly challenging environments for corals in other parts of the world.

Although Musandam corals exhibit extraordinary resilience, there is concern that any additional stress, as a result of natural disasters and/or anthropogenic impacts, for example, may induce coral die-off. For the past decade, reefs within the Arabian Gulf have been devastated by major coral bleaching events, cyclones, harmful algal blooms and extensive coastal developments. Fisheries of the area have also declined, with longlining significantly reducing shark numbers, whilst targeted hammour (grouper) fisheries in the region are in decline in many regions.

Between 26 October and 1 November 2014, Biosphere Expeditions conducted its sixth annual coral reef survey using the Reef Check methodology in five different dive sites along the eastern Musandam peninsula coastline. Surveys were undertaken in a significant 'khor' (or embayment) called Khor Hablain. This large bay measures about 20 km from east (open sea) at the mouth, to west (enclosed coastline). There are no built-up areas in the entire area, with only sporadic observations of handline use by fishing boats, and only a single incident of a line of fish traps being set. The area was said to have been declared a Marine Protected Area, but there is no such evidence either in official documents, conversations with government or management or enforcement procedures in place.

The main objectives of the expedition were to (1) monitor the health of and impacts on the Musandam peninsula's coral reefs, (2) train local scholars in the Reef Check methodology and involve these individuals in surveys, and (3) use and disseminate these findings for the purposes of management, education and conservation by local government and non-governmental organisations (NGOs).

Coral cover generally increased towards the mouth of the bay (khor) where there was greater wave action 'True coral reefs' could be seen at the survey/dive sites of Osprey point, Paradise Point and Gargoyle Cliffs, with the diversity of reefs increasing the further west the surveys occurred. Osprey Point has many reefs similar to those outlined in the 2013 annual survey - *Pocilliopora*-dominated in shallow waters, with deeper areas *Porites* dominated with very high coral cover (88%). Reefs at Gargoyle Cliffs resembled communities heavily influenced by sediments, but remaining stable over hundreds of years. Here large (>3 m tall) blocks of *Porites lobata* dominated the seabed. At Paradise Point, the most exposed site, reefs were the most diverse with both scleractinian corals, but also large areas of soft corals in slightly deeper waters. Inner areas of the khor were heavily dominated by sedimentary communities with few 'true' reefs (only isolated coral colonies occurred separated by sand). Indeed sites over 20 km from the 'open' sea had coral cover of only 3% (Urchin Heaven). There was little evidence of any coral disease, bleaching or predation.

The grouper populations were relatively low with usually fewer than 5 animals (>30 cm) seen at each transect replicate (5 per 100 m^2). Numbers were higher at the more exposed condition at the mouth of the bay at Paradise Point, where numbers reached five individuals per 100 m^2. Snapper populations were large at two sites – Gargoyle Cliff (105 individuals per 100 m^2 and Pharaoh's Cliff (24 individuals per 100 m^2).

Invertebrate populations were dominated by *Diadema* urchins as is the case for all Musandam sites. These animals are ubiquitous from the shallowest reef flats, within *Pocillopora* colony framework, and in the deeper waters where the more open water *Echinothrix diadema* feeds out on sand flats, particularly during night-time foraging. There were very few other invertebrates recorded, although large *Pinna* bivalves were recorded in the very sheltered waters of Urchin Heaven, well within the khor.

The entire Musandam peninsula itself, with so many clear natural waypoints, bays, inlets and geological features, lends itself to very effective marine protected area conservation measures at a discrete scale. It is recommended that these natural features are used to their maximum potential to zone areas for different protection measures for habitat protection (limited damage to corals) and to protect fish (with restrictive fish management).

ملخص

تعتبر الشعاب المرجانية من المكونات الرئيسية الهامة للتنوع البيولوجي مما لها من أهمية شديدة ليس فقط كموائل بالغة الأهمية للعديد من الكائنات الحية، ولكن أيضا لما توفره للبشرية من مجموعة من السلع والخدمات، كمصدر للغذاء وكذلك كحماية للشواطئ. على الرغم من هذا، تعتبر بيئات الشعاب المرجانية مهددة في جميع أنحاء العالم من التأثيرات السلبية البشرية المباشرة والغير مباشرة كمثال التلوث والاستغلال المفرط للموارد الطبيعية والتغير المناخي. تقع الشعاب المرجانية لشبه جزيرة مسندم (عمان) في منطقة شبه الجزيرة العربية على مضيق هرمز، تتحمل الظروف القاسية مثل ارتفاع نسبة الملوحة ودرجة الحرارة، موجودة بالفعل ومزدهرة فيما يمكن اعتباره بيئات هامشية وصعبة للغاية مقارنة ببيئات الشعاب المرجانية في أجزاء أخرى من العالم.

على الرغم من أن الشعاب المرجانية بمنطقة مسندم تبدي مرونة غير عادية للظروف الصعبة التي تواجهها، مازال هناك قلق من أن أي ضغط إضافي، على سبيل المثال نتيجة للكوارث الطبيعية و/أو التأثيرات البشرية يمكن أن يتسبب بالموت الفوري للشعاب المرجانية. على مدى العقد الماضي، دمرت الشعاب المرجانية في الخليج العربي عن طريق ابيضاض المرجان والأعاصير وتكاثر الطحالب الضارة والتطورات الساحلية واسعة النطاق. وتراجعت أيضا الثروة السمكية في المنطقة، لوحظ انخفاض أعداد أسماك القرش بشكل ملحوظ، في حين نتيجة زيادة ضغط الصيد على أسماك الهامور (الوقار) أدى ذلك لانخفاض أعدادها في العديد من المناطق.

أجرت بعثات المحيط الحيوي في الفترة بين (26 أكتوبر -1 نوفمبر)، المسح السنوي السادس للشعاب المرجانية باستخدام منهجية اختيار الشعاب المرجانية في خمسة مواقع غوص مختلفة على طول الساحل الشرقي لشبه جزيرة مسندم. أجريت الدراسة البحثية الاستقصائية في منطقة يطلق عليها خور الحبلين.

هذا الخليج الكبير يقاس بحوالي 20 كيلومترا من الشرق (البحر المفتوح)، إلى الغرب (الساحل المغلق). يخلو الساحل بأكمله من أي مباني او انشاءات، مع بعض المشاهدات المتفرقة للصيد بواسطة الخيط اليدوي بقوارب الصيد البسيطة، مع تسجيل حالة واحدة للصيد بواسطة مصايد الأسماك وقد قيل إن المنطقة أعلنت محمية بحرية، ولكن لا توجد ولكن لم يستدل على ذلك في الوثائق الرسمية، والمحادثة مع الجهات الحكومية حيث لا توجد إجراءات تنفيذية على أرض الواقع.

تمثلت الأهداف الرئيسية للدراسة إلى:

(1) متابعة حالة الشعاب المرجانية والأثار المترتبة على ذلك بشبه جزيرة مسندم.

(2) تدريب الباحثين المحليين عن طرق دراسة الشعاب المرجانية وإشراكهم في الدراسة

(3) استخدام ونشر النتائج لأغراض الادارة والتعليم والحفاظ على الموارد من قبل المنظمات الحكومية والجمعيات الاهلية.

يزداد كثافة الغطاء المرجاني عموما كلما اقتربنا من مصب الخليج (الخور) حيث يتواجد نشاط أكبر من حركة الأمواج ويمكن تسجيل " الشعاب المرجانية الحقيقية" وذلك عند دراسة مواقع مثل منطقة العقاب، والجنة وكذلك منحدرات جارجويل حيث يزداد تنوع الشعاب المرجانية باتجاه الغرب من منطقة الدراسة. يعتبر تنوع الشعاب المرجانية بمنطقة العقاب مشابهة للدراسة السابقة والتي تمت عام 2013، حيث ينتشر النوع ***Pocilliopora*** بمنطقة المياه الضحلة وفى المقابل ينتشر النوع ***Porites*** في منطقة المياه العميقة بنسب عالية تصل الى (88%). تشبه الشعاب المرجانية بمنطقة منحدرات جارجويل تلك الشعاب المتأثرة بشدة جراء الترسيبات، ولكن ظلت ثابتة على مدار مئات السنين. هناك يتواجد بكميات كبيرة النوع ***Porites lobata*** والذى يبلغ طوله اكثر من ثلاثة أمتار ويسود قاع البحر.

تعتبر منطقة الجنة من أكثر المناطق تعرضا ونجد أن الشعاب المرجانية بتلك المنطقة أكثر تنوعا ولكن هناك أيضا مجموعات وفيرة من الشعاب المرجان الرخوة في المياه المتوسطة العمق. ولقد ظهرت سيادة مجتمعات الشعاب المرجانية الرسوبية في المناطق الداخلية للخور وع بعض أنواع من الشعاب المرجانية الحقيقية حيث يتواجد تلك المجموعات منفصلة عن بعضها بواسطة الرمال. تغطى الشعاب المرجانية حوالي 3% من مساحة الموقع المقدرة بحوالي 20 كم ومع ذلك لم يسجل أي عرض سلبي على الشعاب المرجانية كوجود اى أمراض أو تبييض للشعاب أو أي أثر من أثار الافتراس واقع عليها.

سجلت أعداد منخفضة من تجمعات أسماك الهامور أقل من خمس أفراد في كل تكرار للمقاطع العرضية من مناطق الدراسة (خمس لكل 100متر مربع). وكانت الأعداد أكبر كلما كانت المنطقة مفتوحة أكثر عند مصب الخليج حيث بلغ أكثر من خمسة أفراد لكل مائة متر مربع. كانت أعداد أسماك النهاش كبيرة في موقعين أثنين حيث سجل مائة فرد لكل مائة متر مربع في موقع والموقع الاخر تم تسجيل عدد 24 فرد لكل مائة متر مربع.

بالنسبة للافقاريات سادت أعداد القنافذ البحرية في كل مواقع الدراسة بشبه جزيرة مسندم. توجد تلك الأنواع اللافقارية في كل مكان من المناطق الضحلة للشعاب المرجانية والمناطق العميقة حيث تتغذى في الأعماق الرملية المستوية وبالأخص في الليل. تم تسجيل بعض الأنواع اللافقارية الأخرى ولكن بصورة اقل بكثير من القنافذ البحرية.

تعتبر منطقة شبه جزيرة مسندم وما تمثله من مناطق طبيعية وخلجان وأخوار وخصائص جيولوجية من أكثر المناطق البحرية صلاحية لإنشاء وتفعيل تدابير حفاظ وحماية فعالة لتلك البيئات في نطاقات منفصلة. من المستحسن ان يتم استخدام تلك المميزات الطبيعية لأقصى إمكانياتها في تفعيل إجراءات حماية لتلك الموائل مع تقليل الأضرار الواقعة على الشعاب المرجانية للحد الأدنى وحماية الأسماك وإدارة مستدامة للمصايد السمكية.

Contents

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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.

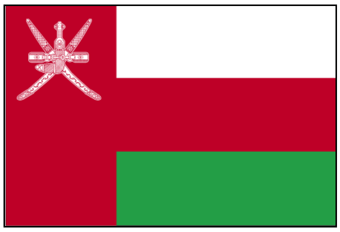
This project report deals with an expedition to the Musandam peninsula that ran from 26 October – 1 November 2014 with the aim of monitoring the health of the Musandam peninsula's reefs, fish and invertebrate communities so that informed management, education and conservation decisions can be made by 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 Reef Check EcoDivers.

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 peninsula 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 one week, and was composed of a team of international research assistants, scientists and an expedition leader. Expedition dates were:

2014: 26 October – 1 November.

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 en-suite toilet 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 boat. 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 temperatures during the expedition were 30 - 35°C with sunshine and no clouds on all but a few rare days. Water temperature during the expedition ranged from 28 to 31°C.

Field communications

The live-aboard boat 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 Biosphere Expeditions' social media sites such as Facebook, Google+ and the Wordpress blog.

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 no serious incidents during the expedition and emergency procedures did not have to be invoked.

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. Scientist

Dr Jean-Luc Solandt is a Londoner with a degree in Marine Biology from the University of Liverpool. After graduating, he spent a year diving on the Great Barrier Reef assisting field scientists in studies on fisheries and the ecology of soft corals and damselfish. He returned to the UK and enrolled in a Ph.D. in sea urchin ecology in Jamaica, based both in London and Jamaica. He went on to be an expedition science coordinator for projects in Tanzania, the Philippines and Fiji, and is now undertaking campaign and policy work in planning and developing Marine Protected Areas in the UK. He has been the Reef Check coordinator for the Maldives since 2005 and has thus far led three expeditions to undertake surveys inside and outside Marine Protected Areas on the islands. Jean-Luc has 1000 dives clocked up since he trained to be a marine biologist 23 years ago.

1.6. Expedition Leader

The expedition was led by Catherine Edsell, who was born in the UK into a family of mountaineers, skiers and adventurers. With wanderlust in her blood and a BA Hons in Creative Arts under her belt, she left her career as a choreographer, and set off to the jungles of Central America and Indonesia, lived in the Himalaya with locals, trekked through the Namib Desert in search of elusive elephants and dived the oceans. Her passion for conservation grew as she sought out and trained with expedition organisations who echoed her ecological beliefs, and for seven years straight, her feet barely touched British soil as she lived the expedition life in all sorts of terrains. Catherine joined Biosphere Expeditions in 2012 to realise her ambition to participate in true conservation work.

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):

26 October – 1 November 2014

Nasser Al-Khanjari (Oman, placemen), Jan Biekehoer (Germany), Kristoffer Brandström (Sweden), Nadège Brandström (Sweden), Hari Pemmaraju (Oman, placement).

1.8. Other Partners

On this project Biosphere Expeditions is working with the Marine Conservation Society, Reef Check, local dive centres, businesses & resorts, the local community, Sultan Qaboos University, the Oman Ministry of Environment and Climate Affairs, as well as the United Nations Environment Programme, the World Conservation Monitoring Centre and the International Coral Reef Action Network (ICRAN). A special thanks to the Oman Ministry of Tourism for its support of the project.

1.9. 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 to 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. Biosphere Expeditions also gratefully acknowledges grant support from the Waterloo Foundation. The Anglo-Omani Society and the Friends of Biosphere Expeditions kindly supported the placements on this expedition.

1.10. 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 via www.biosphere-expeditions.org.

1.11. Expedition Budget

Each team member paid towards expedition costs a contribution of £1,280 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	3,840
Grants	11,000
Expenditure	
Research vessel includes all board & lodging, ship's crew, fuel & oils, other services	5,002
Transport includes transfers & visas	296
Equipment and hardware includes educational & research materials & gear purchased in UK & Middle East	340
Staff includes local and international salaries, travel and expenses	3,513
Administration includes registration and other admin fees	46
Team recruitment Musandam as estimated % of PR costs for Biosphere Expeditions	6,525
Income – Expenditure	**- 2,089**
Total percentage spent directly on project	**114%***

*This means that in 2014, the expedition ran at a loss and was supported by Biosphere Expeditions over and above the income from the expedition contributions and grants.

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2. Reef Check Survey

Jean-Luc Solandt
Marine Conservation Society

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 Arabian Gulf) and the Gulf of Oman (Rezai et al. 2004).

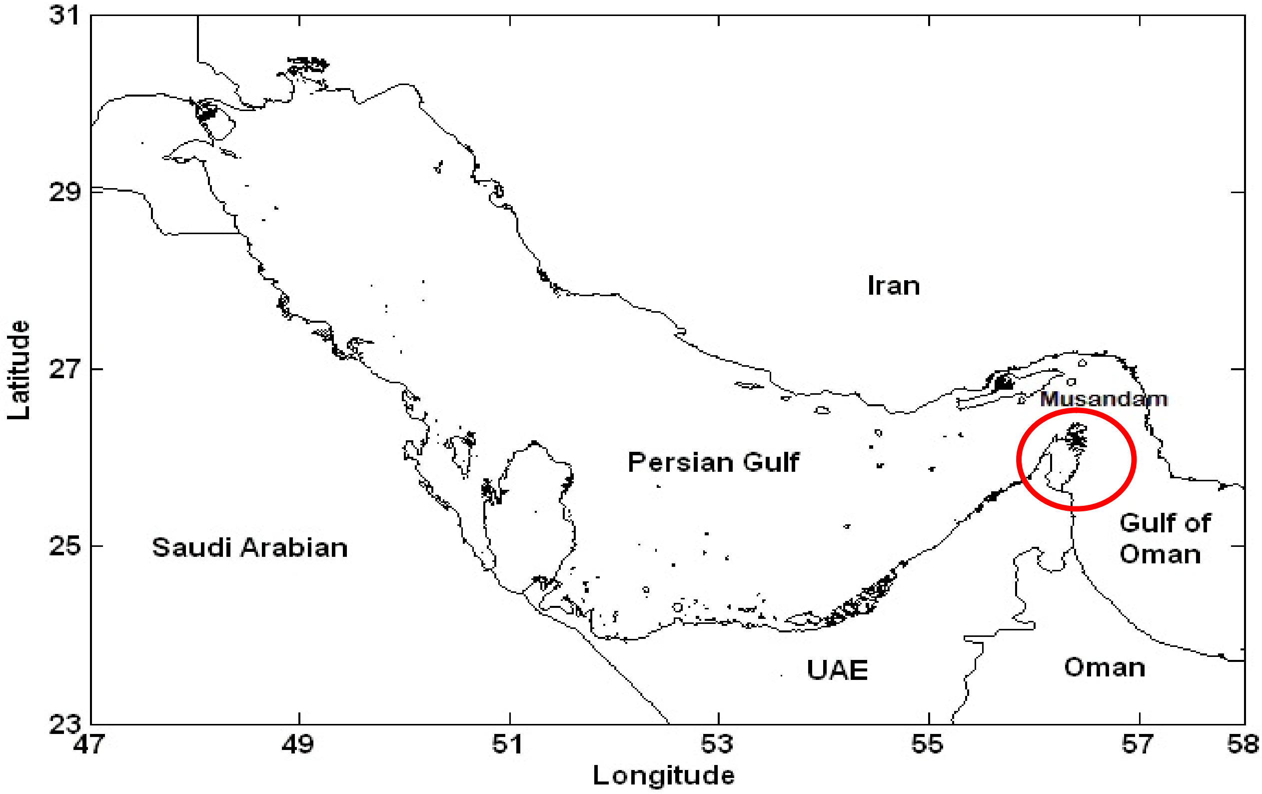

Figure 2.1a. Location of the Musandam peninsula in the Middle East.

The Arabian Gulf is a shallow semi-enclosed basin measuring about 1,000 km by 200 – 300 km. It has an average depth of 35 metres, dipping down towards the north to a maximum of about 60 metres near Iran, and inclined downwards to about 100 metres 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 Arabian Gulf is characterised by strong variations in sea surface temperatures (SSTs), ranging from 12ºC in winter to 36ºC in the summer, and high salinity values of 43 year-round (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 Arabian Gulf, the Gulf of Oman and Arabian Sea are deep seas (more than 2,000 metres 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 (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 extremely harsh conditions for terrestrial life.

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 Arabian Gulf, evaporation averages 144 to 500 cm/yr, most occurring in the shallow bays in the south where evaporation locally exceeds 2,000 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 Arabian Gulf lead to the formation of 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).

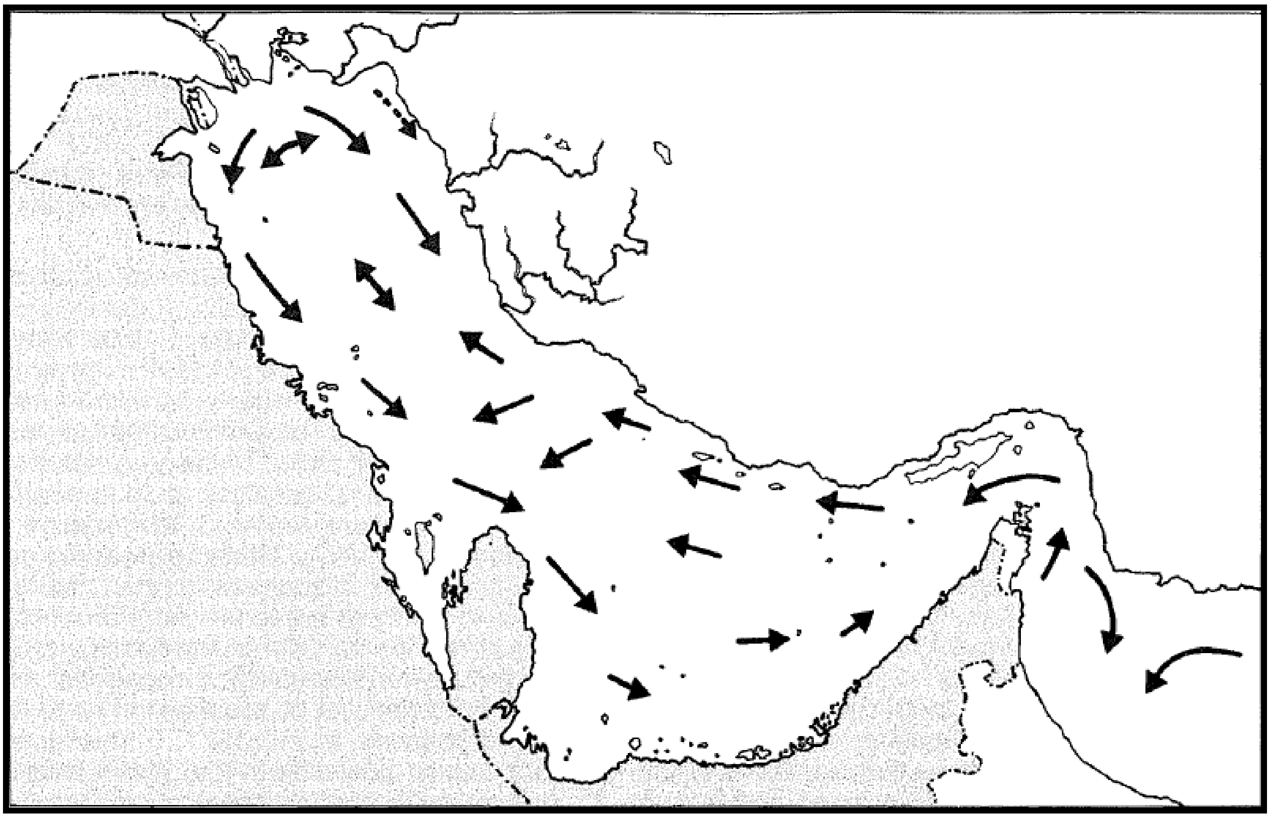

Figure 2.1b. Major current patterns of the Arabian Gulf and northern Arabian Sea (Reynolds 1993).

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 those 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 and 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 Arabian 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 Arabian Gulf exceed the optimum range for coral reef in other tropical regions in the Atlantic and Pacific, which 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 SST values observed in the Arabian 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 range is normally only 19ºC, with the normal upper limits between 33ºC and 34ºC and the lower limits between 13 and 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 species in different regions can 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 Arabian 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 Arabian Gulf (Sheppard et al. 1992). Although the species composition of Arabian Gulf corals is typically Indo-Pacific, with a few regional endemics, the coral diversity in the Arabian 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 Arabian 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 (Coles 2003).

Due to the varied coastline of Oman, where upwelling effects are attenuated by bays, reef growth typically continues fringing reef development, particularly on the more exposed headlands and islands. 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 Arabian Gulf’s corals are unique and seem to endure extremely harsh conditions 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 Arabian 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 suspended sediments are dispersed from the dredge or reclamation sites. In addition, coastal currents are diverted by coastal engineering, altering the movement of sediments and 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 in the region 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 was 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 lutea*, *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 metres 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 cyclone Gonu, significantly changed the habitats and biodiversity in the area. Both the Arabian Gulf and Gulf of Oman have a high phytoplankton biodiversity, with 38 taxa being 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. 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 that 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 alga 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 a 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 is 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 and 5 metres and between 6 and 12 metres (Hodgson et al. 2006). Data for point 1 is collected prior to and after the dive.

Aims and objectives

The primary aim of this project was to continue 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 26 October and 1 November 2014, five 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 dive sites included areas well within the sheltered 'Khor Hablain' to the southeast of the peninsula, to the more exposed sites of the khor (Fig 2.2a). The surface area of this site is enourmous, with approximately 100 km^2 of marine area. It is only 5 km wide at the mouth of the bay and extends at least 20 km west into the sheltered waters of the inner bay. This provides the bay with very unique conditions for Arabia and the rest of Oman, as it provides extremely sheltered bays and inlets in an area of minimal rainfall. Exposure at the southern end of the mouth of the bay is more apparent (as it is north-easterly facing), compared to the northern coast of the khor facing south. 8 km into the bay, the site becomes more 'convoluted' with many prominent headlands reaching far into the bay, decreasing wave action on the western side of these areas.

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 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.

Figure 2.2a. Location of the five Reef Check sites in Khor Hablain, surveyed in October 2014.

Table 2.2a. Dive sites surveyed during the 2014 expedition.

Site name	Date surveyed	Location
Gargoyle Cliffs	28 October 2014	26°5'38"N, 56°25'408"E
Osprey Point	29 October 2014	26°8'60"N, 56°28'399"E
Pharaoh’s Cliff	30 October 2014	26°9'8"N, 56°22'856"E
Urchin Heaven	30 October 2014	26°11'163"N, 56°23'262"E
Paradise Point	31 October 2014	26°5'299"N, 56°28'67"E

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.Reef Check.org](http://www.reefcheck.org).

Figure 2.2b. Khor Hablain showing typical sandstone geology of the region, with relatively steep slopes (often covered in seabird guano) falling into the sea. Photo courtesy of Wouter Kingma.

The team also recorded two minke whales (*Balaenoptera acutorostrata*) within the khor, and 2 Indian Ocean humpback dolphins (*Sousa chinensis*) (at a well-known dolphin hotspot) outside the khor on the steam back to the port at Khasab (the port to the west of the peninsula).

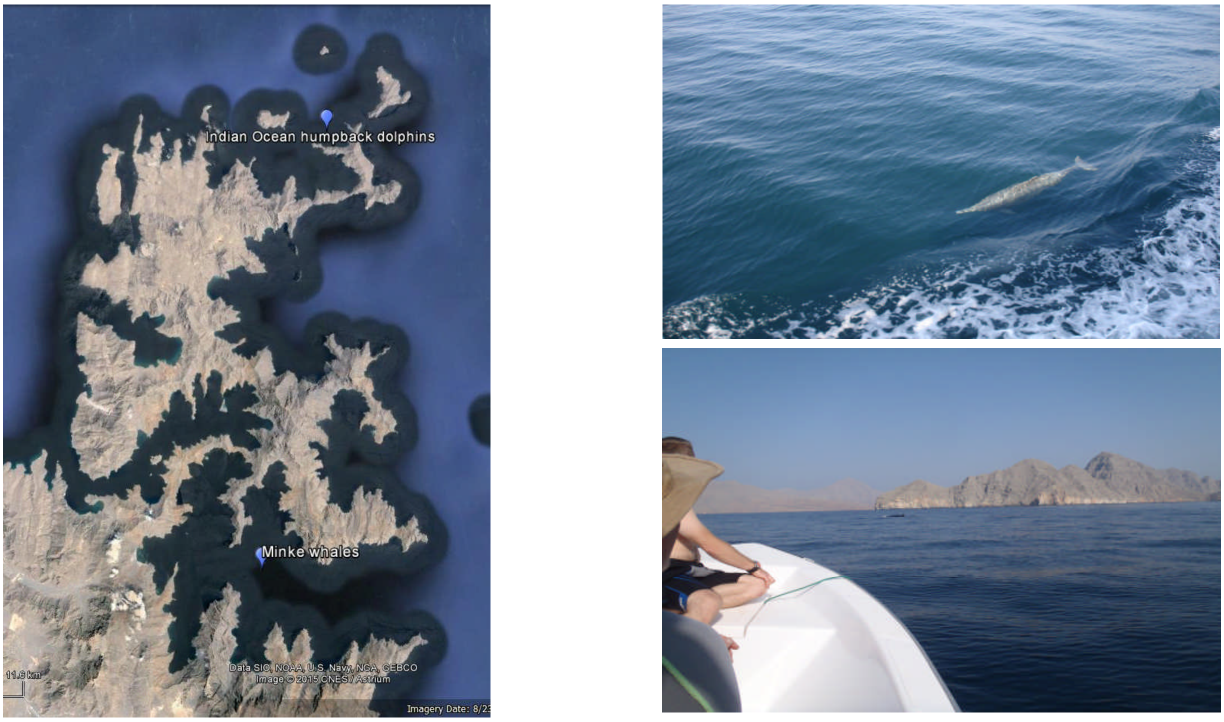

Figure 2.2c. Location of two minke whales (28 October 14)
and two Indian Ocean humpback dolphins (31 October 11), recorded during the expedition.

Belt transect surveys

Four segments of 5 m high, 5 m wide and 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 undulatus*) and the Bumphead parrotfish (*Bolbometopon muricatum*).

The same four 5-metre wide by 20-metre 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 cucumber 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 invertebrate survey, anthropogenic impacts were also assessed. These included coral damage by anchors, dynamite, or ‘other’ factors, and the presence of 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 (both at the colony and population level) was also measured along each 20 metre transect.

Substrate line transect surveys

Four 20-metre 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).

Coral Point Count

Photo transects were undertaken at six locations. These photo transects capture images of the reef from vertical view at about 2m from the seabed. Post-hoc analysis occurs with the software CPCe (Coral Point Count with excel extensions) (Kohler and Gill, 2006). Various categories of substrate can then able to be recorded at greater resolution including coral lifeforms.

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 taxon. The substrate line transect data were converted to mean percentage cover of each substratum category per depth contour.

All mean data from 2014 surveys are presented as ± Standard Deviation (SD).

2.3. Results

General human use and surface observations

These observations were made using the 'site description' form. Water temperature varied depending on depth (shallower hotter than deeper) and distance form the open sea (sites near to the mouth of the khor had lower temperatures). The lowest temperature was 27^{0}C at 10 m at Paradise Point. Most other sites had temperature variance of 28 – 30^{0}C. 31^{0}C was recorded at Urchin Heavan, a very sheltered inshore site that probably has little water circulation due to its large (>20 km) distance form the outer sea, and shelter on three sides from large sandstone cliffs.

Visibility ranged from 5 to 20 m. The best visibility was at Paradise Point, to the southeast of the khor, an area with strong currents. Visibility reduced further into the khor. Air temperatures ranged from 30 to 35°C.

There was very little evidence of fishing gear in the water. Evidence of fishing line was seen at Gargoyle Cliffs, Osprey Point and Pharaoh's Cliff. However, only between one and three pieces were seen during the entire surveys at these sites – indicating very low intensity of fishing. A large, buoyed fishing net (or series of traps) was seen on the northern side of the khor on 27 October 2014 (Fig. 2.3a). This was the only evidence of larger-scale active fishing in the khor during our visit to the site.

There was evidence of fishing nets on the intertidal and adjacent to some coves and beaches, fishermen's huts and some infrastructure (e.g. some small fishing skiffs) that were associated with low-scale artisanal fishing in some remote areas, were observed.

Figure 2.3a. There was only one observation of fish, set in deeper waters toward the north of the khor.

Figure 2.3a (continued). Location of fish trap observed.

The local osprey nest had two nesting birds. A scythe triggerfish was seen in the talons of one of the birds, taken back to the nest and feeding a chick.

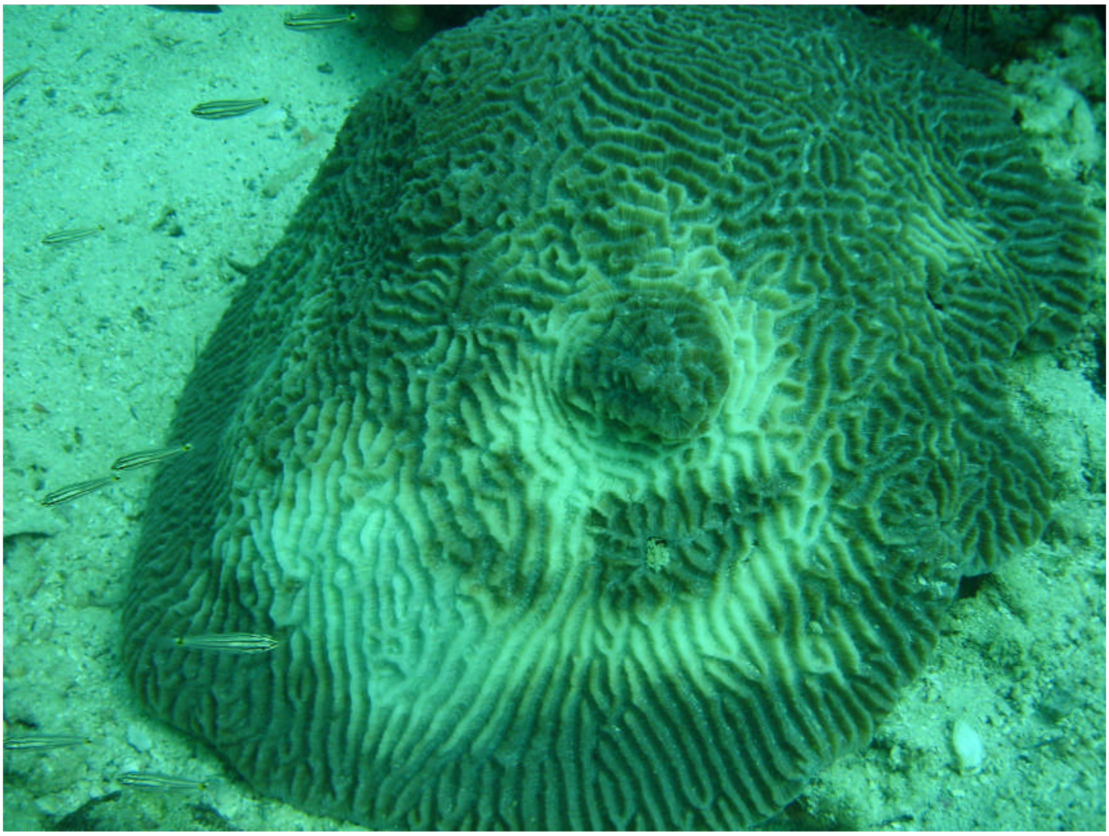

Figure 2.3b. Partially bleached colonies at Osprey Pt (above) and Gargoyle Cliffs (below).

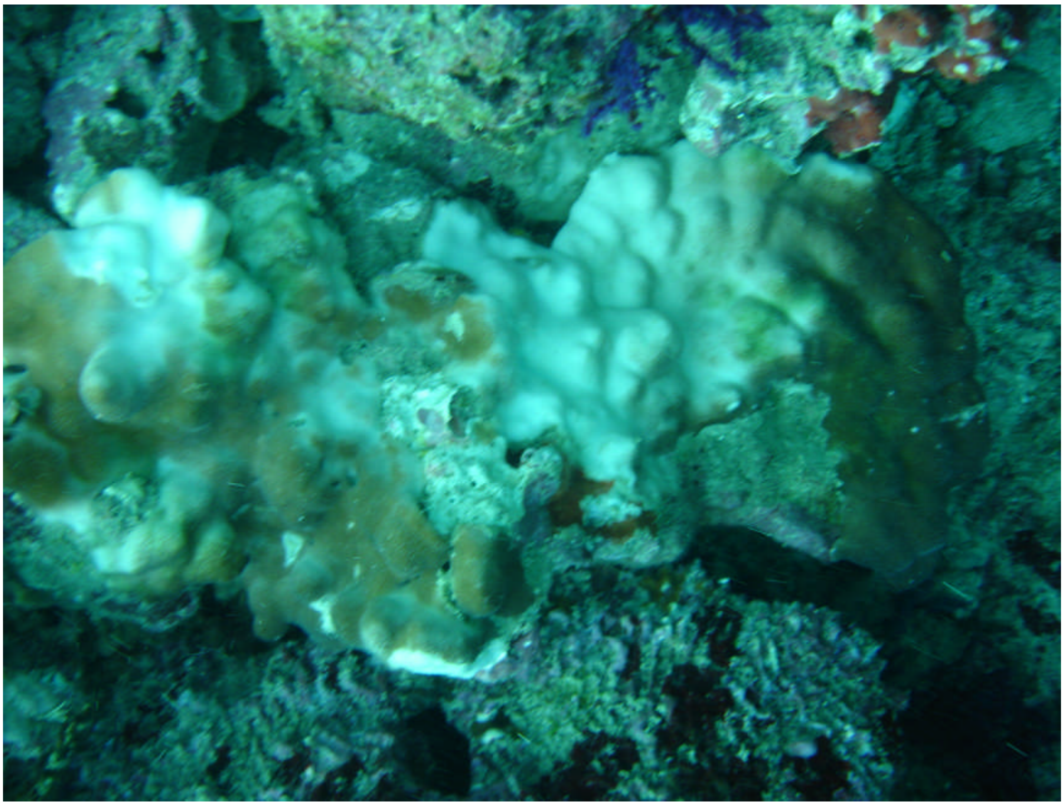

Figure 2.3b (continued). See explanation above.

Although there were few areas of large concretions of reefs in the deep inner portions of the reefs, the survey team did come across extensive areas of staghorn *Acropora* in relatively shallow waters (not more than 10m water depth). These 'thickets' in some cases extended for over 20 m by 5 m wide. These were recorded on recreational night dives, but deserve a mention, as they provide reasonably mature coral habitat in sheltered inshore waters.

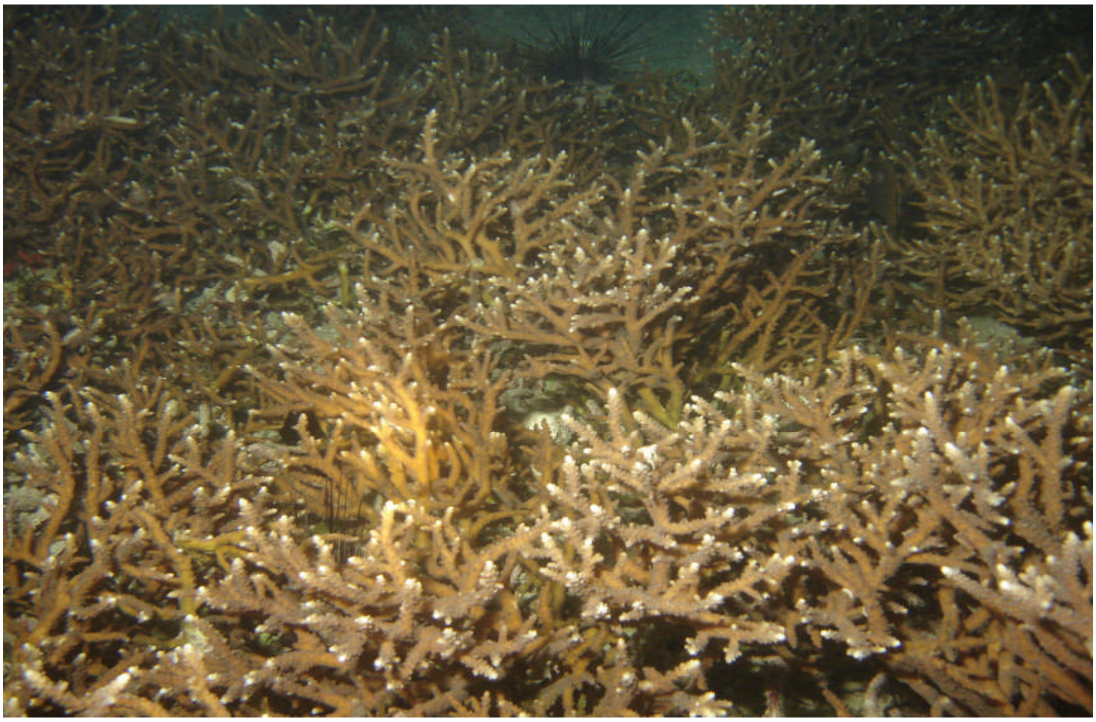

Figure 2.3c. *Acropora* thickets seen in some areas in the inner khor.
These thickets extend considerable distances (in some cases over 20 m) and are dominated by a single species.

Figure 2.3c (continued). Location of *Acropora* thickets.

Seabed cover at sites surveyed

Seabed cover generally became more heavily dominated by hard corals, the further towards the open sea the surveys were carried out (Fig. 2.3d). The greatest live coral cover was seen at the sheltered, but 'outer' sites such as Osprey Point and Gargoyle Cliffs. Osprey Point is similar to many reefs of the northern sector of the Musandam peninsula (dominated by *Pocillopora* in shallow waters and *Porites* deeper down), whilst Gargoyle Cliffs is an area similar to a backreef environment, with large *Porites* colonies in an area of heavy sediment. At Gargoyle Cliffs there is an area of sediment slope above the water level between two hard vertiginous cliff slopes. Presumably this is an area where there is occasional movement of the sediment into the sea (probably via periodic rainfall or during high winds). This has 'cut' the *Porites*-dominated area in half. The most diverse site was Paradise Point to the south of the outer (mouth) of the bay. This was the most exposed site, with waves of 1-2 m bouncing off the cliffs in the area. There was also considerable current in the water. Here, there was greater dominance of gorgonian coral colonies (slightly deeper than where the transect tape was laid).

Fish community

Chaetodon melapterus and a single snapper species, the widespread *Lutjanus ehrenbergii* (blackspot snapper), were observed on the surveys (Fig. 2.3e).

Butterflyfish were more abundant at sites near to the mouth of the khor (Paradise Point and Osprey Point) (Fig. 2.3f). Grouper were most abundant at Paradise Point, possibly the most difficult site to safely fish from. All grouper from this site were *Cephalopholis hemistiktos.* The site is most exposed to easterly winds, wave action, and has current running around the point. Snapper were common at most sites (other than Paradise Point), but were abundant at the southern Gargoyle Cliffs site, where there were 105.3±44.1 individuals per 100 m^2.

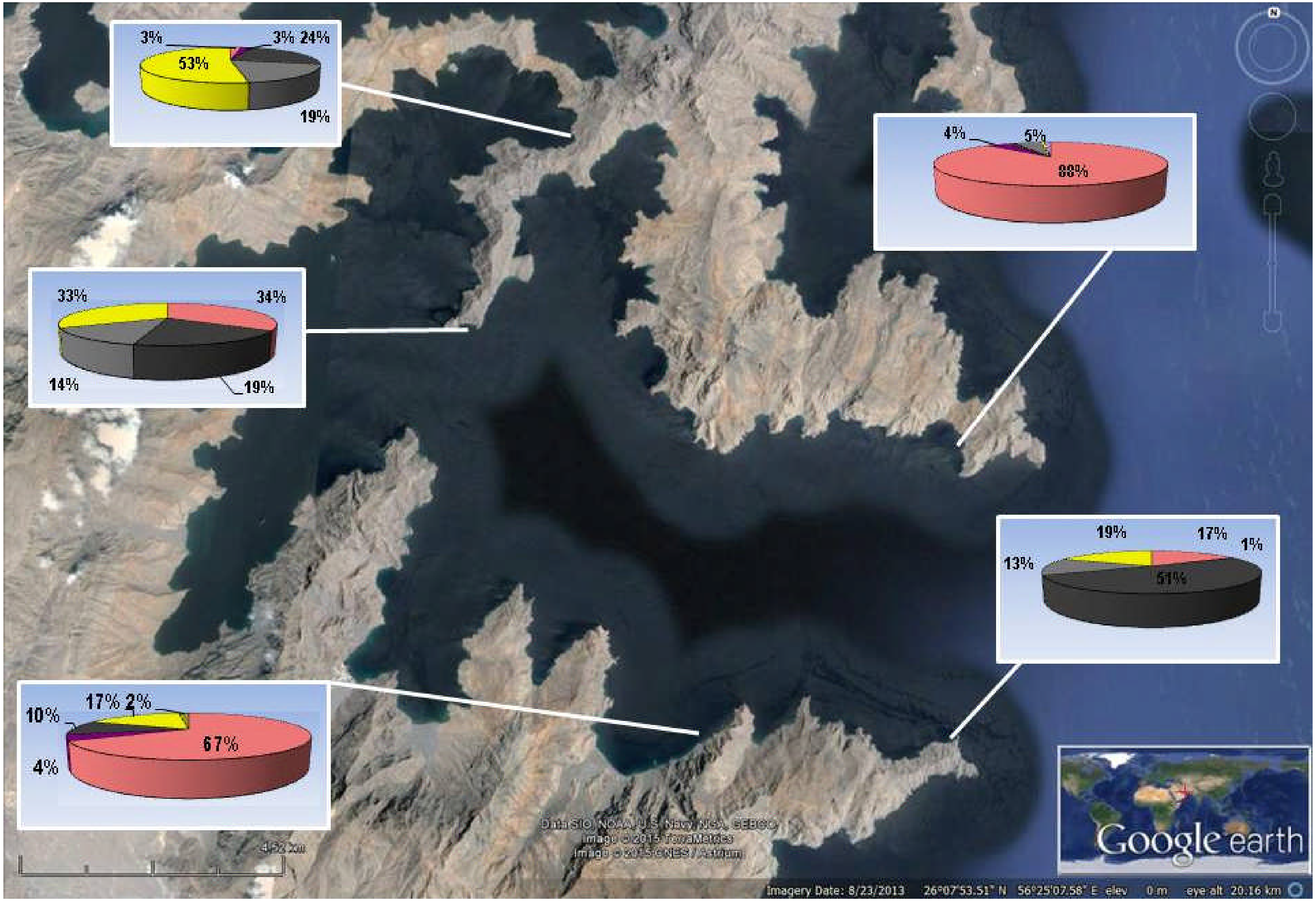

Figure 2.3d. Substrate cover associated with Reef Check surveys at five locations from the inner to outer waters of the khor.
Peach: live hard coral; **Dark grey**: rock; **light grey**: rubble; **Yellow**: sand; **Pink**: soft coral; **Green**: silt.

Figure 2.3e. *Lutjanus ehrenbergii* (left) and *Chaetodon melapterus* (right) were dominant during surveys.

Parrotfish – an essential grazer on coral reefs – were most abundant at Paradise Point (6±2.9 individuals per 100 m^2) and Osprey Point (13.25±25.8 individuals per 100 m^2). The large deviation at Osprey Point is because a very large school of 52 individuals was recorded in one replicate area of the site, whist only one individual was recorded from the three other replicates. This is not unusual in shallow coral reefs. Parrotfish often school in large numbers to avoid predation and to be in the most productive (shallow) waters for algal growth (their principle food source). They also produce large schools to overwhelm territorial species that may be nurturing the algae in their territories as a food source, and to attract mates. Other sites, particularly in the more sheltered areas where coral reef was less abundant, had relatively low parrotfish abundance. No sweetlips were observed on any dive. Humphead wrasse and bumphead parrotfish were also absent from surveys. One moray eel each was recorded (0.25 individuals per 100 m^2), both at Gargoyle Cliffs and Osprey Point. Large trevally (that are not specifically reef-associated species and therefore not recorded on Reef Check transects) were regularly recorded at Paradise Point (where ten were seen).

Schooling striped mackerel (*Rastrelliger kanagurta*) were seen feeding in tight schools slightly deep off the 10 m transect tape at both Osprey Point and Paradise Point (Fig. 2.3g). This indicates that this is a site rich in plankton supply, coming in from the open ocean to the east. Large numbers of fusiliers and red-toothed triggerfish (*Odonus niger*) were also seen at this point. These are also planktivores, indicating further the productive nature of the site. An eagle ray (*Aetobatus narinari*) was also recorded at the site before entering the water.

The most sheltered site of all, Urchin Heaven, hosted an eagle ray, a feathertail stingray (*Pastinachus sephen*), trevally and mackerel alongside the other species recorded on the survey.

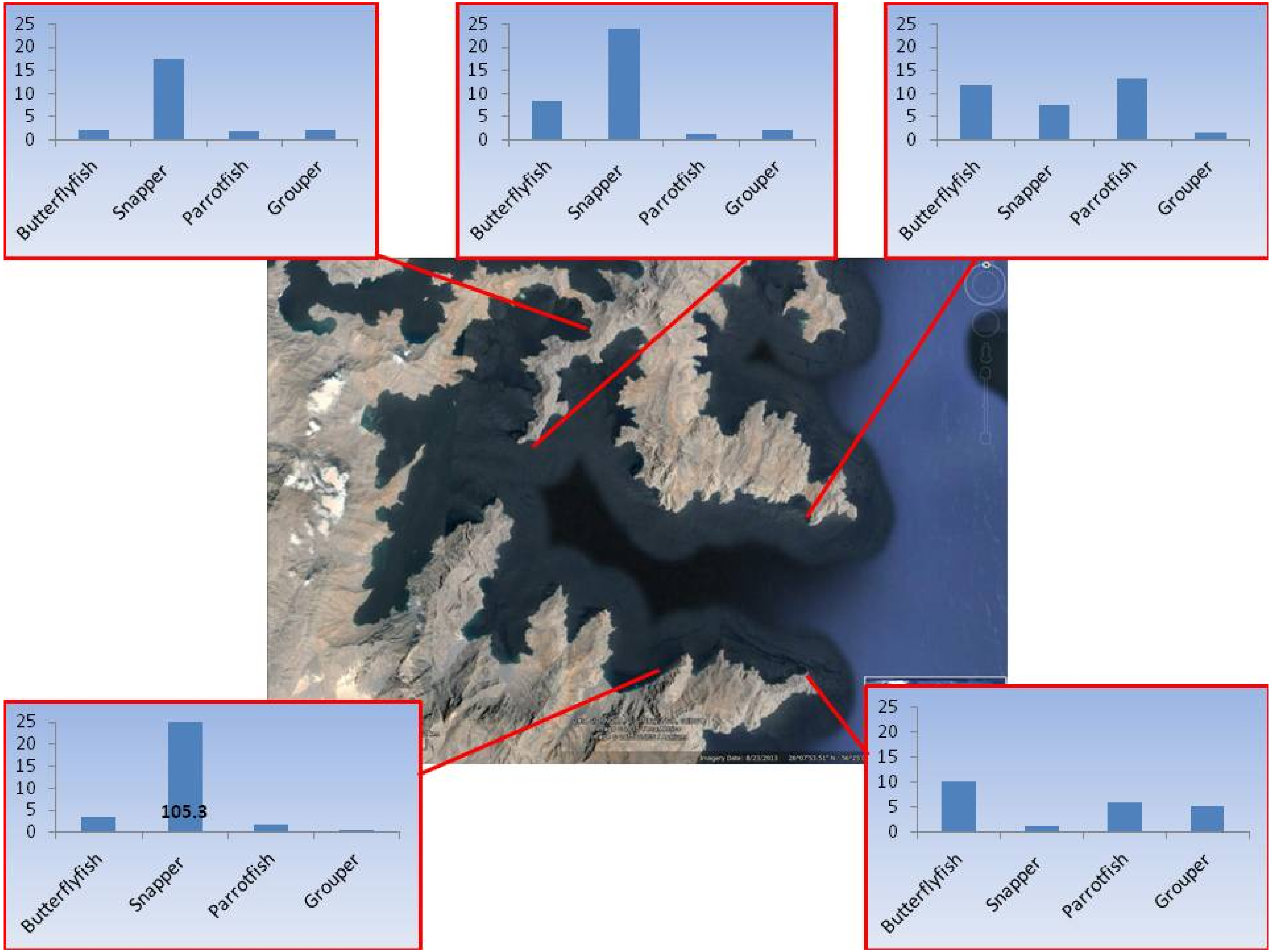

Figure 2.3f. Fish numbers (means) at the five Khor Hablain sites surveyed.

Figure 2.3g. Striped mackerel (*Rastrelliger kanagurta*) feeding in abundant schools were recorded at the mouth of the khor (this image was taken at Paradise Point, where over 1000 were recorded).

Invertebrates

Table 2.3a. Invertebrate populations recorded at the five survey sites.

Site	BCS*	Diadema	Pencil urchin	Sea cucumber	COTS**	Lobster
	All numbers mean number of individuals per 100 m^2					
Urchin Heaven	0	130	0	0	0	0
Pharoes Cliff	0	178	0	0.25	0	0
Gargoyle Cliffs	1	105	1	3	0.25	0
Osprey Point	0	79	0.38	2.5	0	0.13
Paradise Point	0	41	0	1	0.75	0

*BCS: Banded Coral Shrimp
**COTS: Crown of Thorns Starfish

The *Diadema* urchin *Diadema savignyi,* the most common *Diadema setosum*, and *Echinothrix diadema* (mostly found on flatter, deeper, sandier sediment-dominated habitat) were the most abundant invertebrates in the surveys (Fig. 2.3h). *Diadema* reached densities of 178±94 individuals at Pharaoh's Cliff. At these densities, they are able to exert a major eroding and structuring role on the living coral and bedrock of the ecosystem.

Figure 2.3h. *Diadema* numbers at the five survey sites. Densities are generally lower, the more exposed the site is.

2.4. Discussion & Conclusions

Coral reefs

The health of the reefs in the Khor Hablain region appears to be good. There is generally high coral cover in the areas we would expect higher coral cover. This is in the outer reef areas nearer to the open sea and in areas of stable conditions. The Gargoyle Cliffs dive site coupled with another dive undertaken a little further into the bay southwest of the Reef Check site recorded high coral cover of over 50%. Most of the analysis (from CPC pictures) of the coral cover shows a majority of the colonies being *Porites* hard coral. *Porites* does well in sedimentary conditions, where corals with more emergent polyps (such Acroporid corals) do not perform so well. Osprey Point is typical of many sites in the northern part of the archipelago where bays sheltered from current occur in areas with good water flow with less heavy sediment influence (Fig. 2.4a). Sites dominated by *Pocillopora* in shallow waters and *Porites* in deeper waters are Coral Gardens and Eagle Bay. Sites similar to Pharaoh's Cliff (where there are slightly more exposed conditions) are also seen at Faq Al Asad in the northern part of the archipelago.

Figure 2.4a. Typical reef 'types' seen at Musandam. See explanation below.

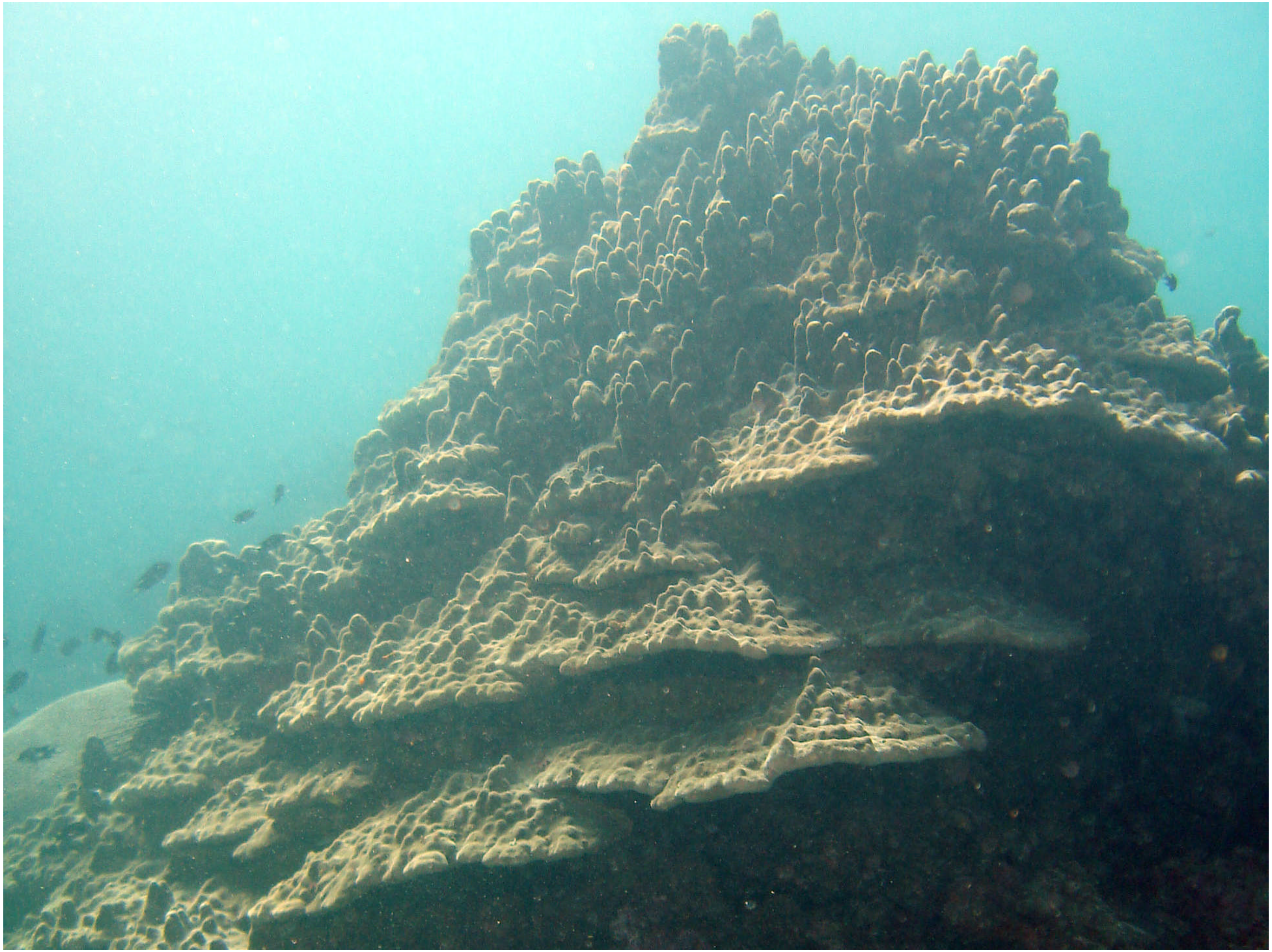

Figure 2.4a (continued)

'Blue pin' site

sediment heavy
sheltered 'backreef'
Porites dominated.

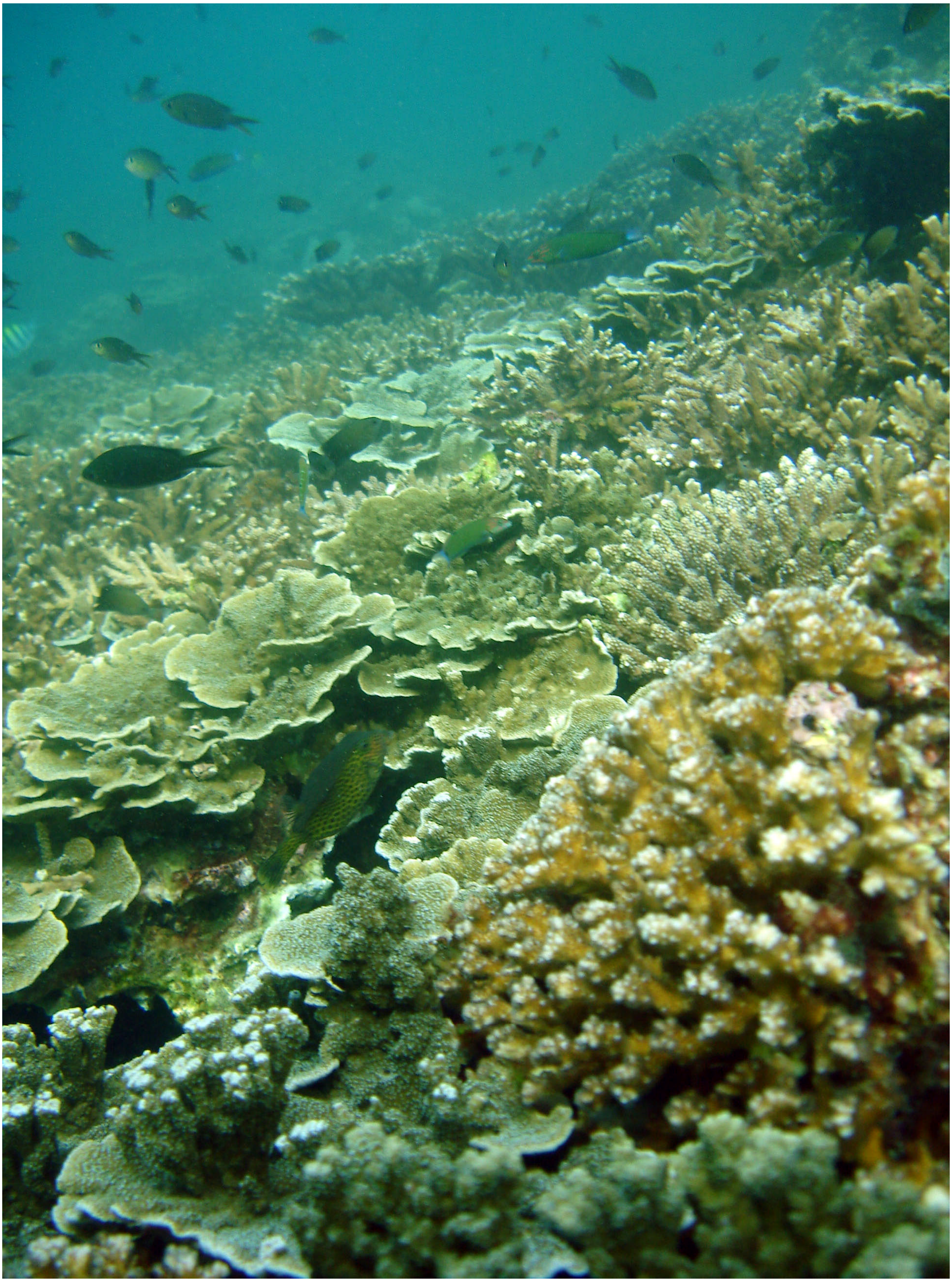

Figure 2.4a (continued).
'Green pin' site
moderately exposed
diverse corals
high urchin numbers

Figure 2.4a (continued)

'Yellow pin' site

low sediment
sheltered *Pocillopora* shallows
Proites deep

This study last visited the reefs of Khor Hablain in 2009 at Osprey Point and Gargoyle Cliffs, when good coral cover (45% at Osprey Point, 43% at Gargoyle Cliff) was found. In 2014 coral cover was 88% in shallow (4 m) and 53% in deeper (9 m) waters. At 4 m depth at Osprey Point there is a monospecific stand of *Pocillopora dammicornis.* It is likely that the 2009 survey was carried out in the deeper waters, therefore the value of our survey at 9 m (53%) is more similar to the 2009 survey result (45% coral cover). The Gargoyle Cliff site in 2014 had coral cover of 67%, a considerable increase on the result for 2009.

Fish community

The whole peninsula has a fairly naturally low fish biodiversity (compared to the diversity of the Philippines, coral triangle area, and even the Maldives). The harsh conditions of the waters of the area (sedimentation, high productivity within the Musandam area making it plankton rich, and with high temperatures from the west within the Arabian Gulf) has reduced the numbers of species recruiting, and able to colonise the area. The reduced benthic biodiversity has further reduced the diversity and biomass of numerous damselfish and wrasse species – species that often represent the largest contribution to reef species diversity.

Fish populations of species and families other than grouper mirrored the numbers recorded in previous years. Diversity of the peninsula is low. Commonly only one bream species, one snapper and one lethrinid were seen on surveys. However, the numbers of these species were reasonably healthy.

The average number of groupers over 30 cm recorded from all sites is 2.5 fish per 100 m^2 from the surveys in Khor Hablain (ranging from 0.5 fish per 100 m^2 at Gargoyle Cliff to 5.25 fish per 100 m^2 at Paradise Point). The average number of grouper recorded from last year's surveys (concentrating on reefs to the north of the Musandam peninsula) was 2.4 animals per 100 m^2 (Solandt and Hammer 2014). So, even though the area is more isolated from greater human fishing pressure (e.g. at Khasab and Kumzar), there is still a remarkably similar grouper density per reef area in this part of the peninsula.

Schooling mackerel were seen at two sites (Osprey and Paradise Point), further indicating that the deeper water areas of the reefs could protect stocks of these planktivorous fish species. There were no bait balls of larger tuna seen whilst diving, or transiting between dive sites, unlike at the northern part of the peninsula where bait balls were commonly observed at Faq Al Asad (Solandt and Hammer 2014).

New proposed fisheries management measures for the area

We believe there should be no-take-zones (NTZs) within at least half of the peninsula before the human population of the area expands and before the fish population crashes. Solandt and Hammer (2014) have already detailed the types of management measures that would be needed. At the very least, Paradise Point and Osprey Point and 5 km square radii of waters around these sites should immediately be established as NTZs (Fig. 2.4b).

Figure 2.4a. Options for small (approx 5 km^2) no-take-zones (NTZ) around the productive headland and Paradise Point, and rich coral community of Osprey Point to the north of the mouth of Khor Hablain. The channel between the proposed NTZ allows cables to be laid and passage of shipping if the Khor is to be developed in future for commercial or recreational purposes.

With NTZs in place, the fish population for a large area (at least that of Khor Hablain) could be sustainably fished at current level of effort. Indeed, given the strong currents at Paradise Point, if there was any spawning at this location, protecting this site should secure reasonable yields outside the boundary of the NTZ in years to come. Large female groupers are exponentially more productive (given studies from elsewhere) where even quite small sites were protected (e.g. Hol Chan marine reserve in Belize).

Increased awareness of the life history requirements of the species amongst local fishermen (and fish buyers) will be necessary to tie in with management measures as discussed above (i.e. that groupers start life as males and change to females in time / at a given size). Otherwise, there will be little compliance and too many small (male) fish will be taken from the population without the opportunity to grow to be spawning females.

Many of the fish populations in the Arabian 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 (e.g. 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).

Last year the Khor Hablain and Khor Najd areas were said to have been designated Marine Protected Areas (Fig. 2.4b). This is why this current expedition targeted the reefs of Khor Hablain for the entire duration of the surveys outlined in this report. Our current understanding is that Khor Hablain and Najd have not been properly gazetted by the government at the time this report is published. We have asked questions of government as to why these measures have not progressed, but are yet to receive simple and coherent answers. We understand that there is great geo-political interest in the area and perhaps this is why any nature conservation action is being delayed. If so, this is unfortunate, as it will delay the necessary management measures that are urgently needed to ensure a sustainable fishery and healthy coral population for the reefs we visited on this expedition.

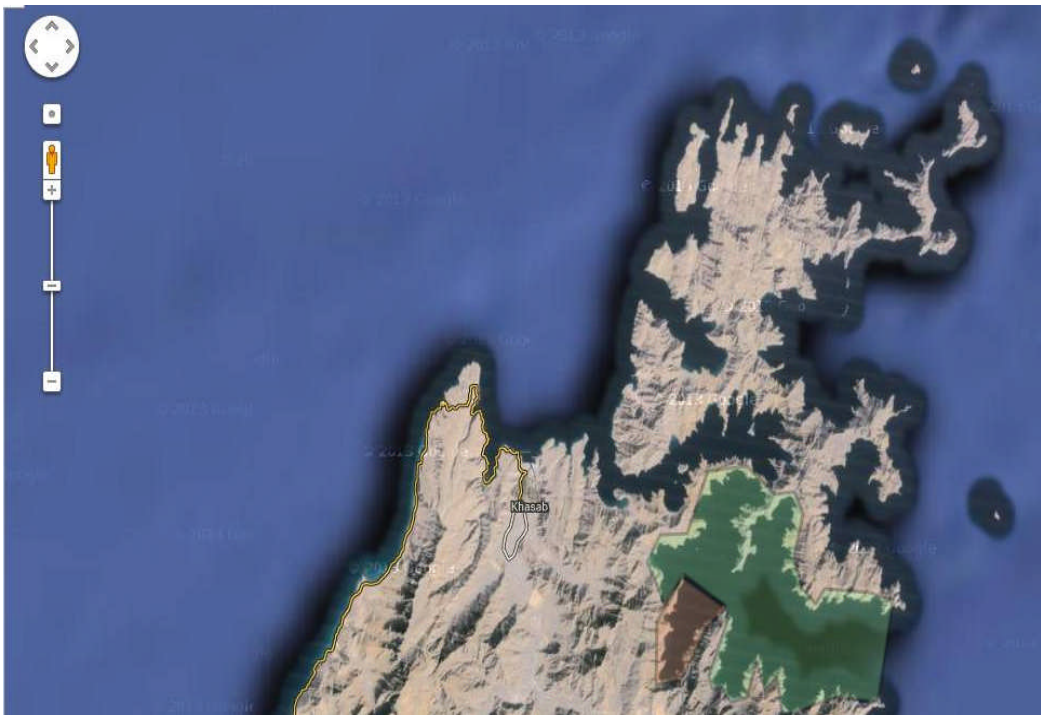

Figure 2.4b. The new Marine Protected Area measures in the Musandam peninsula.
They are in the bays of Khor Najd (smaller inlet – brown) and Khor Hablain (green). Image courtesy of Google Earth.

If proper management and proactive conservation measures are not forthcoming from central government, then we recommend to local fishing communities to take the opportunity to develop small NTZs as outlined above (Fig 2.4a) in order to boost the long-term prospects of their own fishery.

Convention on Biological on Biological Diversity meeting & Oman strategy

In April 2015 the Secretariat of the Convention on Biological on Biological Diversity (CBD) held a regional workshop to identify areas meeting the criteria for Ecologically or Biologically Sensitive Marine Areas (EBSAs) in Dubai, United Arab Emirates. Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) was designated to provide official technical support to the CBD.

Musandam was put forward at this workshop and highlighted as an important area, especially considering the Strait of Hormuz as a key migratory pathway into the Arabian Gulf. Oman proposed three EBSAs including Musandam, Daymaniyat Islands and the Oman Arabian Sea Coast from Ras Al Hadd to Salalah (including Masirah and Halaniyat Islands). Although all three proposals were well presented and supported during the first and second round of presentations, Musandam, very disappointingly, did not end up making it during the final round, despite presenting the strongest case. Musandam was highly supported at the beginning of the workshop even asked by the secretariat to upgrade some of the ratings that had been provided. But opinions then shifted by the end of the workshop, even though others from the plenary tried to continue to support Musandam.

Figure 2.4c. Position of Musandam within the Gulf region.

We believe this was due to political (territorial and economic) reasons, because the Strait of Hormuz is a very strategic entry / exit point for all trade among the countries that are inside the Gulf (Fig 2.4c). The UAE has a very strong interest to keep this trade route as open as possible and apparently even considers declarations of marine protected areas a threat to unfettered access through the strait.

Despite this, there is now an official government "Musandam Strategy & Action Plan" that was recently prepared for Oman's Supreme Council for Planning.

Invertebrate community

The number of *Diadema* urchins was high at all sites. More research needs to be conducted in the region regarding this species, because although *Diadema* urchins are responsible for grazing algae from the reef surface, very high densities of *Diadema* results in increased bioerosional activity, making it difficult for new coral recruits to settle (e.g. the numbers at Pharaoh's Cliff). An increase in numbers in different areas of the world's oceans is often indicative of overfishing of their predators, such as large emperor and triggerfish (Levitan 1992). Urchins can also graze around the bases of large coral colonies, destabilising coral heads and increasing their susceptibility to getting knocked over by storm waves (Hodgson and Liebeler 2002).

Crown-of-thorns starfish (COTS, *Acanthaster planci*) numbers were very low (other than at Paradise Point, where three were recorded). COTS abundance needs to be monitored carefully, firstly because coral mortality caused by the predatory COTS can be catastrophic or near-catastrophic in scale and secondly, because no tritons (a 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. Plagues of COTS are increasingly reported around areas of human activities with two strong hypotheses for this phenomenon being advanced. The plagues may be initiated and certainly exacerbated by 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). Excess nutrients are not a direct cause for concern in the Strait of Hormuz, probably because of the considerable tidal flushing of the area and limited terrestrial development coupled with a very low population pressure.

The number of lobsters recorded during surveys is very low (only one was recorded from all dives) 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). The same author has also shown that lobster landings in the region have been dropping steadily, from a peak of 4,570 tons in 1991 to 2,032 tons in 1996. More fisheries landings studies need to be conducted in the region to understand if this number is still decreasing.

2.5. Recommendations for management of the Musandam peninsula

We recommend a further progression of zoned area-based management measures throughout the peninsula that includes:

1. Minimum and maximum landing sizes for reef fish, particularly grouper, snapper, emperor and breams,
2. Minimum landing sizes for invertebrates (particularly molluscs),
3. Closed fishing during grouper spawning seasons, and at spawning points,
4. Closed seasons for fishing bait balls,
5. Entire closed areas for reef and pelagic-associated fisheries,
6. Reference areas where no extraction or deposition is allowed for preservation of all biodiversity (such as fish, motile invertebrates and coral populations),
7. Restrictions on longlining in the entire area, with potential full closures of this fishery in the area out to 3 nm from the nearest landmass,
8. No Take Zones (5 km^2) established around Paradise and Osprey Point (Fig. 2.4a),
9. Clarity on the designation of marine protected areas and proper enforcement and management of any areas designated.

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

The implementation of a wider marine protected area around the whole Musandam peninsula will help to mitigate the impacts of stresses found by the expedition, as well as create benefits such as

1. conserving biological diversity and associated ecosystems that cannot survive in most intensely managed seascapes,
2. promoting natural age structures in populations, increasing fish catches locally (by protecting critical spawning and nursery habitats) and in surrounding fishing grounds,
3. providing refuge for species that cannot survive in areas that continue to be fished,
4. providing alternative incomes for local communities and alleviating poverty,
5. protecting sensitive habitats from disturbances and damage from fishing gear,
6. eliminating “ghost fishing” by lost or discarded gear,
7. serving as a point of reference for undisturbed control reference sites that can be used as baselines for scientific research and also to measure fishery effects in other areas and thereby help to improve fisheries management and
8. acting as focal points for public education and awareness on marine ecosystems and human impacts upon them (IUCN-WCPA 2008).

Involving the local community in future studies and marine protected area (MPA) design is extremely important in order to mitigate for any current lack of awareness and knowledge of conservation management measures. 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 port 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 triton shells (such as *Charonia* spp.) is also needed, since their harvesting could 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 that provide a good picture of the relative health of the different sites. Reef Check is also useful to pick out extraordinary events such as red tides, bleaching, COT outbreak and major local damage, and with the Biosphere model, allows training of local participants to take on the surveillance and training to local communities.

2.6. References

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Appendix I: Expedition diary and reports

A multimedia expedition diary is available on http://biosphereexpeditions.wordpress.com/category/expedition-blogs/musandam-2014/

All expedition reports, including this and previous expedition reports, are available on www.biosphere-expeditions.org/reports.