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# Shifting environmental baselines in the Red Sea

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ABSTRACT

The Red Sea is among the world's top marine biodiversity hotspots. We re-examined coastal ecosystems at sites surveyed during the 1980s using the same methodology. Coral cover increased significantly towards the north, mirroring the reverse pattern for mangroves and other sedimentary ecosystems. Latitudinal patterns are broadly consistent across both surveys and with results from independent studies. Coral cover showed greatest change, declining significantly from a median score of 4 (1000–9999 $m^2$) to 2 (10–99 $m^2$) per quadrat in 2010/11. This may partly reflect impact from coastal construction, which was evident at 40% of sites and has significantly increased in magnitude over 30 years. Beach oil has significantly declined, but shore debris has increased significantly. Although substantial, levels are lower than at some remote ocean atolls. While earlier reports have suggested that the Red Sea is generally healthy, shifting environmental baselines are evident from the current study.



## 1. Introduction

The Red Sea is one of the world's top marine biodiversity hotspots (Roberts et al., 2002). Its coral reefs contain 333 reported coral species (Dubinsky and Stambler, 2011) and endemism is high (Sheppard, 2000). The region's megafauna, including dugong, turtles and other 'Red Listed' species, are also of importance (Sheppard, 2000). Mangroves and seagrass beds are significant sedimentary ecosystems, especially towards the south (Price et al., 1987, 1988). Fisheries, comprising artisanal and industrial sectors, are a resource of longstanding importance (Sheppard, 2000; Jin et al., 2012). Because of the Red Sea's spectacular reefs, and relatively close proximity to Europe, some parts are now a major diving destination and used heavily (Sheppard et al., 1992; Zakai and Chadwick-Furman, 2002; Price and Harris, 2009).

Saudi Arabia's two marine environments, the Red Sea and Arabian/Persian Gulf (or 'Gulf'), are very dissimilar. In comparison with the Gulf, the Red Sea is naturally a less stressful environment, and human disturbances (e.g. coastal infilling, dredging, sedimentation) were also reported to be less prevalent in the Red Sea (Sheppard et al., 1992). Nevertheless, substantial coastal development has occurred (Kotb et al., 2004), particularly in and around the major cities of Rabigh, Yanbu and Jeddah since the 1980s in the case of Saudi Arabia. Overall, the Red Sea has been reported to be relatively unpolluted, apart from localized areas (e.g. Hanna and Muir, 1990; Sheppard et al., 1992; El Nemr et al., 2004). Sewage and oil pollution are problematic in some regions (Medio et al., 2000). The Red Sea has also been subjected to sea surface warming and coral mortality in 1998 (Sheppard, 2003; Kotb et al., 2004), but impact was less than in the Gulf (Rezai et al., 2004).

In general, few large-scale environmental or ecological surveys in the Red Sea have been published based on site-specific data. One exception is an integrated assessment of the abundance of major ecosystems and magnitude of human resource-uses/impacts at 1200 sites along the eastern Red Sea coast during the period 1982–4 (Price et al., 1998). This was a broadscale ecological study, which also identified conservation and coastal management requirements. The same methodology, rapid environmental assessment (REA), has subsequently been used in various parts of the Indian Ocean, including the Gulf, and Atlantic Ocean (reviews; Price, 2004; Price and Harris, 2009). Comparison between the Gulf in 1986 (Price, 1990) and the Red Sea during the mid-1980s using RAE again showed that the Red Sea *was* relatively unimpacted (see also Price, 1999, Appendix 1; Price et al., 1998). Hence, it might be assumed from its past condition that the current status of the Red Sea would be relatively unpolluted or undisturbed.

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Without periodic and/or long-term assessment, however, environmental changes can easily occur, undetected, as one generation replaces another. This phenomenon is known as the shifting baseline syndrome (Pauly, 1995; Sheppard, 1995). It is observable from data of variable resolution (Pinnegar and Engelhard, 2008; Venkatachalam et al., 2009), although human perceptions of change are not always reliable (Papworth et al., 2009).

Here we examine the environmental status of the Red Sea coast of Saudi Arabia using REA. The survey formed part of a recent coastal resources 'baseline' assessment for Red Sea coastal areas of Saudi Arabia (HUTA and emapsite, 2011). The main aims were to (1) characterize overall condition of coastal ecosystems along the Saudi Arabian Red Seas at 137 sites in 2010/11; (2) assess the nature and extent of any major changes, through comparison with data collected at a sub-set of the sites examined in the 1980s and using the same methodology; and (3) discuss findings in the context of shifting environmental baselines and compensable claims for environmental damage from oil spills and ship groundings.

## 2. Materials and methods

Rapid environmental assessment (REA) was undertaken at 137 coastal sites, distributed at ~10-km intervals (Fig. 1). Sixty-one of these were the same sites examined during the 1980s (Price et al., 1998). Although GPS was not available for the 1980s survey, site locations were determined (e.g. from landmarks, coastal features) and recorded on large-scale maps (1: 50,000) to within an estimated ±500 m of true positions. During the 2010/11 survey, site locations were determined using GPS, thus ensuring good/reasonable concordance of the matched site between surveys. REA sites and data also provided an additional layer of ground-truthing of habitats for a coastal atlas (HUTA and emapsite, 2011). For this and logistical reasons, there are lengths of shoreline where there are no 1980s' records but relatively substantial numbers of new 2010/11 sites. The new sites increase the size of the dataset ($N$) used for spatial analyses, thereby enhancing the power of statistical tests. Although of lesser significance than examination of temporal changes ('shifting baselines'), spatial analyses permitted comparison with independent studies, and thus one means of validating the robustness of REA as a survey methodology.

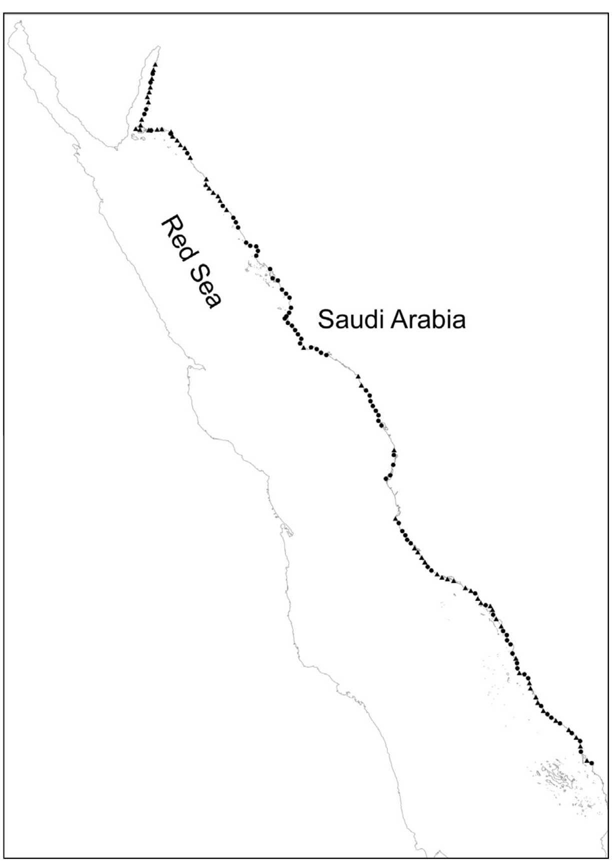


**Fig. 1.** Map of Red Sea coast of Saudi Arabia showing locations of 137 coastal sites at which rapid environmental assessment was undertaken (solid circles – sites surveys in 2010/11; solid triangles – sites surveyed during mid-1980s and in 2010/11.

Semi-quantitative observations were made on coastal habitats/ecosystems, species groups and resource-uses/impacts pressures (Table 1). Data were collected using a method developed for the Red Sea (Price, 2004; Price et al., 1998) and later used elsewhere (review: Price and Harris, 2009). Observations were made within geographically discrete 'site inspection quadrats' of estimated dimensions 500 m × 500 m (Fig. 2).

The intertidal/land component of the quadrat (500 m × 250 m) was determined from observations while walking. The subtidal component (500 m × 250 m) was examined while snorkelling.

### 2.1. Abundance of coastal habitats and species groups

Abundance within each quadrat of biological features and magnitude of human use impacts (Table 1), were scored and recorded concurrently. In the case of terrestrial flora, coralline algae (and other marine flora, when present) and coral reefs, scores are based on estimates of areal extent ($m^2$). For most fauna they reflect the number of individuals, estimated from direct observations, pits or tracks. A score on the logarithmic scale of 0–6 was used for quantifying field estimates of the abundance of biological features; the equivalent arithmetic range in values for each log score is shown in Table 2.

### 2.2. Magnitude of resource-uses/impacts

The same 0–6 scale (Table 2) was also used to score the relative magnitude of coastal uses and environmental pressures. For construction and oil pollution, scores represent estimates of the total area of either construction (jetties, roads, houses, etc.) or oil (tar on the beach and/or in the sea). For solid waste and wood litter, scores represent the estimated number of items, irrespective of their size (with notes made on the dominant items, e.g. plastic bottles or cans, in the case of solid waste). Estimating fishing/collecting pressure by rapid assessment is not straightforward (Price et al., 1998). In the absence of direct evidence of boats or fishers, fishing was determined indirectly from various indicators, including nets and equipment, seemingly in recent or current use. Here, scores for fishing/collecting simply reflect the estimated magnitude of one or more indicators, using an ordinal (0–6) ranked scale of increasing magnitude. Additionally, physical coastal features recorded included details of the shore profile and substratum type, and photographs of each site were taken.

### 2.3. Data analysis

Non-parametric statistical methods were used, as REA utilizes ranked i.e. ordinal data. Wilcoxon's matched pairs test ($Z$ score) was used to discern temporal trends, given that the locations of the comparison sites were closely matched in 1982–84 and 2010/11. Strength of latitudinal association was assessed using Spearman's rank correlation ($R_s$).