Chapter 3

Seagrasses and Mangroves of Yemen's Red Sea

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Introduction

In the northern Red Sea, species composition, abundance and distribution of seagrass and mangrove habitats are well established (Fishelson 1971; Por et al. 1977; Lipkin 1979; Jacob and Dicks 1985). More recently, the abundance and distribution of these habitats have been documented along the Red Sea coast of Saudi Arabia (Price et al. 1987; Price et al. 1988; El-Demerdash 1996; Price et al. 1998). In contrast, much less is known of these habitats along the Red Sea coast of Yemen.

The Red Sea coast of Yemen lies on the eastern shore of the southern Red Sea. Approximately 730km long from the Saudi Arabian border to Bab Al Mandab, this coastline varies in its exposure to high wave energy and the type of substrata (loose sediment versus rock) found along its length. Unlike the Gulf of Aden coast of Yemen, where the abundance of sea grass and mangroves appears to be minimal (MacAlister Elliott 1995), the Red Sea coast of Yemen supports large areas of these habitats.

Much of what is known of species composition, abundance and distribution of seagrasses and mangroves in Yemen is largely derived from Barratt et al. 1987. In 1985 they undertook a survey of marine habitats along the Red Sea coast of Yemen as far south as Dhubab. They concentrated their survey along the mainland coast where a predominance of unconsolidated sediments favours the development of seagrass and mangroves over coral. However, they visited few islands during their survey.

In 1996, 1997 and 1998 staff from the GEF Yemen Project (hereafter referred to as the Yemen Project) surveyed marine habitats around islands off the Red Sea coast of Yemen, and some areas of the mainland (Figure 8.1 in Chapter 8). Islands visited included shelf islands, such as Kamaran Island, and off-shelf islands, such as Az Zubayr Island. Shelf islands are located on the continental shelf, and are composed of consolidated and unconsolidated sediments, and raised 'fossil' reefs. Off-shelf islands are situated beyond the continental shelf, hence their name, and are of volcanic origin (see Chapter 1). At least 100 shelf islands and about 70 off-shelf islands are found off Yemen's Red Sea coast.

Coral assemblages and coral and coralline algae reefs were the predominant marine habitats found adjacent to Yemen's Red Sea islands (see Chapter 2). In contrast, seagrass, in particular mangroves, were recorded at a small number of sites. Nevertheless, the limited amount of data gathered on these habitats during the Yemen Project adds to our knowledge of seagrass and mangroves in the southern Red Sea.

This chapter is divided into two sections, seagrasses and mangroves, and each section is divided into two subsections. Subsection one summarises what is known of the distribution and abundance of these habitats along the Red Sea coast of Yemen and is drawn largely from studies by Barratt et al. (1987) and Price et al. (1988). Subsection two includes observations made on these habitats during the Yemen Project, and compares these observations with findings from other studies. The methodology used to sample seagrass and mangrove habitats, during the Yemen Project, is described in Appendix 1.

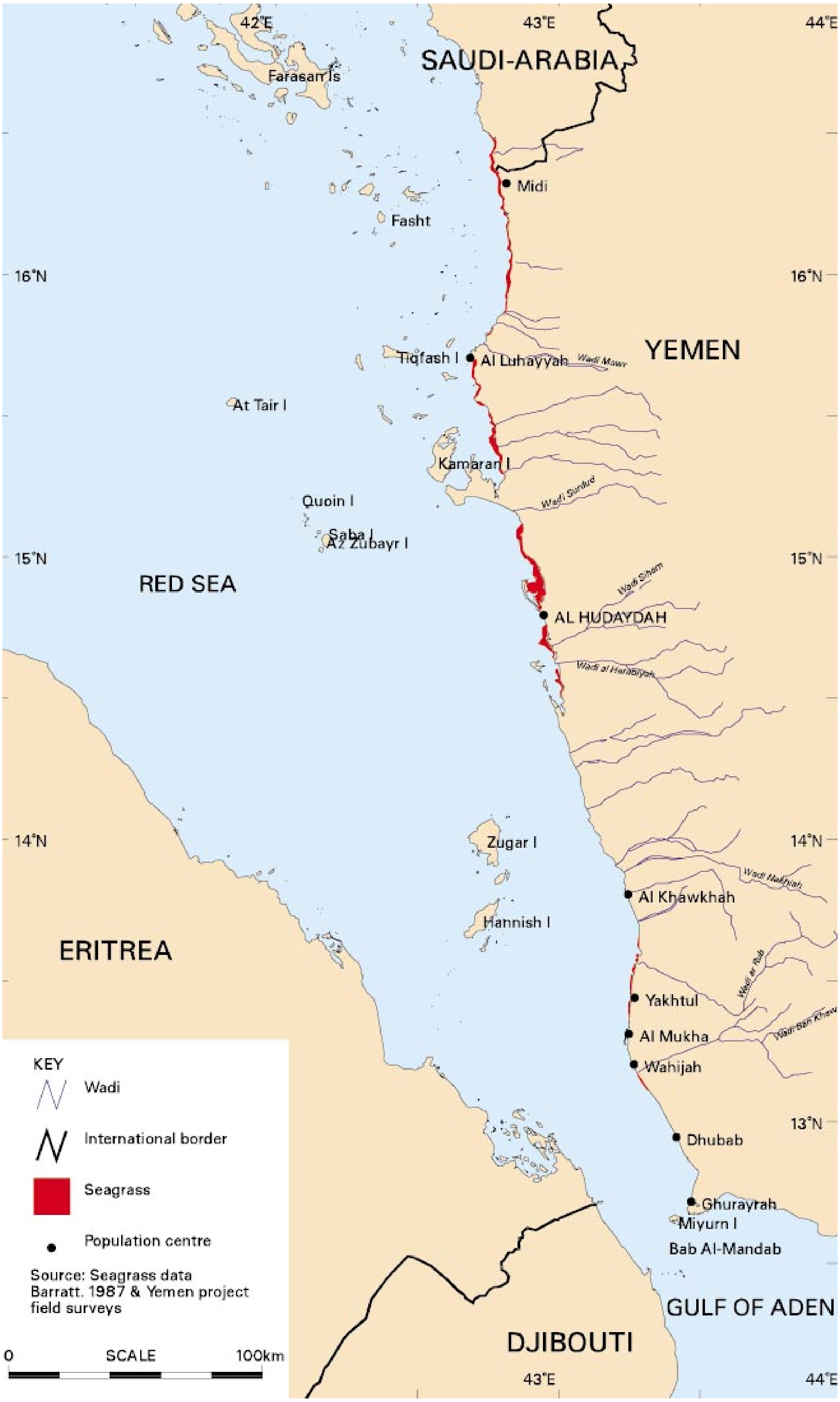

Figure 3.1: Locations where seagrass has been reported along Yemen's Red Sea coast. Small patches of seagrass recorded by Barratt (1987) and the Yemen Project are not shown.

For information on the productivity, standing crop and growth of seagrasses and mangroves in the Red Sea, the reader should refer to Sheppard et al. (1992). However, because oceanographic, geomorphologic and climatic features vary considerably between the northern and southern Red Sea (Chapter 1) results from studies done in the former may not apply in Yemen.

Seagrasses

Seagrasses along the Red Sea coast of Yemen

Fifty-eight species of seagrass, of 12 genera, have been described worldwide (Kuo and McComb, 1989). Eleven species of seagrass have been recorded from the Red Sea, including the Suez and Aqaba Gulfs, and nine along the Red Sea coast of Yemen (Barratt et al. 1987; Table 3.1).

Table 3.1: Species of seagrass recorded from the Red Sea. Species with asterisk(*) were recorded from the Red Sea coast of Yemen by Barratt et al. (1987).

- *Halophila stipulacea**
- *Halophila ovalis**
- *Halophila ovata*
- *Halophila decipiens*
- *Halodule uninervis**
- *Thalassodendron ciliatum**
- *Thalassia hemprichii**
- *Cymodocea serrulata**
- *Cymodocea rotundata**
- *Enhalus acoroides**
- *Syringodium isoetifolium**

Along the eastern coastline of the Red Sea the extent of seagrass increases towards the south (Price et al. 1988). However this trend does not apply to all species. *H. stipulacea*, *S. isoetifolium* and *T. ciliatum* increase in extent towards the north. Price et al. (1988) suggest that the large extent of seagrass in Yemen, compared with Saudi Arabia, is due to the wide and shallow shelf found off Yemen's Red Sea coast and because much of the shelf consists of unconsolidated sediments. They also consider that the lower extremes of salinity and temperature in the southern Red Sea may also favour seagrass growth.

Barratt et al. (1987), reported that seagrass is found along 42% of the Red Sea coast of Yemen (up to 500m offshore). However, the distribution of seagrass is not continuous along Yemen's coast (Figure 3.1), but is restricted to sheltered areas, such as the shoreward side of sand spits, islands and reefs. In these areas wave action is reduced and sediments more stable, allowing seagrasses to colonise and be maintained.

Although seagrass is patchily distributed along the length of Yemen's Red Sea coast, five principal seagrass regions have been identified offshore from Midi, Al Luhayyah, Khawba (Khobah), Al Hudaydah and Dhubab (Price et al. 1988). These regions are sheltered as described above.

Barratt et al. (1987), found that most seagrass meadows formed assemblages dominated by *H. uninervis*, *H. ovalis* and *T. hemprichii*. In addition, they recognised distinct assemblage structure in some areas. *H. uninervis*, *H. ovalis* and *T. hemprichii* are found in the upper intertidal zone, while *Cymodecea sp*. occupies a sparse band in the subtidal zone. At Ras Salif, *H. uninervis* occupies the upper intertidal areas while *Cymodecea sp*. and *T. hemprichii* fringe this in slightly deeper water. Beyond the *Cymodecea*/*Thalassia* 'zone' are patches of *E. acoroides*.

1996, 1997 and 1998 Surveys

Eleven shelf islands and five off-shelf islands (30 sites) were surveyed for seagrass and mangroves. In addition, 25 mainland sites were examined for seagrass and mangroves.

Figure 3.2
Exposed *Halophila*/*Halodule* seagrass assemblage south of Al Hudaydah.

Figure 3.3
Seagrass assemblage off Al Badi Island.

Ten species of seagrass were observed during the Yemen Project (Figure 3.2). All species were recorded by Barratt et al. (1987).

Ten species were recorded from the mainland, seven species from shelf islands (Figure 3.3) and none from off-shelf islands. Species not found around shelf islands, though present on the mainland coast, were *E. acoroides, T. ciliatum* and *S. isoetifolium*. The reason why these species were not observed around the shelf islands may reflect the small number of sites surveyed rather than environmental factors.

The most abundant species, based on qualitative estimates, were the two *Cymodecea* species and *T. hemprichii*. This pattern was evident for mainland and shelf island populations of seagrass. In contrast, Barratt et al. (1987) reported that *H. uninervis*, *H. ovalis* and *T. hemprichii* were the most abundant species. This may reflect a temporal shift in seagrass dominance between 1985, the year of the Barratt survey, and the Yemen Project surveys in 1996,1997 and 1998. It may also reflect confounding associated with site differences, because the majority of Barratt sites were not sampled during the Yemen Project.

It remains unclear why seagrass was not found around off-shelf islands. Despite their steep slopes, off-shelf islands possess large areas of unconsolidated sediments. Further, turbidity is unlikely to be a limiting factor to seagrass development, as water clarity around these islands is usually greater than 20m. However, sediments may not be sufficiently stable to allow seagrass to establish.

No seagrass was observed around Miyurn Island, which lies in the Straits of Bab Al Mandab. Here coral was the most abundant benthic organism (Chapter 2). Mainland

Figure 3.4
Erosion of seagrass meadows north of Al Mukha.

Figure 3.5: Locations where mangroves have been reported along Yemen's Red Sea coast. Small isolated patches of mangroves recorded by Barratt (1987) and the Yemen Project are not shown.

sites south of Dhubab were not examined but extensive fringing reefs along this section of mainland are likely to provide a sheltered environment conducive to seagrass development.

There was little evidence that human activity is responsible for seagrass loss along the Red Sea coast of Yemen. Epiphytes were abundant on seagrass in Khawr Kathib, a location of sewerage discharge. But this may be a natural phenomenon, as epiphytes were found on seagrass in areas far from urban centres. Natural disturbance included erosion of seagrass beds due to strong wave action (Figure 3.4), and dugong feeding trails off Al Luhayyah.

Mangroves

Mangroves along the Red Sea coast of Yemen

Eighty species of mangrove, belonging to about 30 genera, have been described (Hutching and Saenger 1987). Only four species are known from the Red Sea:

- *Avicennia marina*
- *Rhizophora mucronata*
- *Bruguiera gymnorrhiza*
- *Ceriops tagal.*

Three species have been reported from the Red Sea coast of Yemen: *A. marina, R. mucronata and B. gymnorrhiza*. Barratt et al. (1987) believes Draz (1956) misidentified *R. mucronata* for *B. gymnorrhiza* because the latter has not been located in other surveys.

Patches of *A. marina* are found along the entire length of Yemen's Red Sea coast, but is most abundant between Al Urj and the Saudi Arabian border (Figure 3.5). Here it forms a discontinuous, 100m-200m wide fringe covering approximately 84km (12%) of the coastline (Barratt et al. 1987).

South of Al Urj, *A. marina* is found along 38km (5%) of the Yemen's Red Sea coastline. Here *A. marina* does not reach the height (5m) or the patch size it attains near the Saudi Arabian border.

In Yemen, *R. mucronata* is known from an island approximately five kilometres north of Al Hudaydah, and from a few plants on the mainland opposite the island. Barratt et al. (1987) estimated that the area of *R. mucronata* in Yemen is less than one hectare. In comparison, Sheppard et al. (1992) reported that the area of *A. marina* in Yemen is about 3,000 to 5,000 hectares.

Mangrove propagules require sheltered, low wave, energy environments to become established. Barratt et al. (1987), suggested that these requirements are met along the northern Red Sea coast of Yemen because:

- the SSE trade wind dissipates as it moves further from the equator
- Kamaran Island and islands off Al Luhayyah reduce wave energy striking the mainland coast
- of the wide coastal shelf.

In the south there are few islands and therefore the coast is less protected from strong wave action. However, fringing coral reefs are better developed and provide limited shelter for mangroves to become established on this coast.

Species of mangrove also have specific environmental requirements that influence their distribution. For example, *Avicennia* is more tolerant of high saline conditions (60–65‰) than *Rhizophora*. Barratt et al. (1987), suggested that this is one reason why *Avicennia* dominates the northern Red Sea coast of Yemen where the interface between fresh and salt (sea) water occurs inland of the coast.

Figure 3.6
Aerial photograph showing *A. marina* on Al Badi Island.

Figure 3.7
A. marina on Kamaran Island. Much of the mangrove forests on Kamaran Island were logged early in the twentieth century.

Human activity has also influenced the distribution of mangroves in the region. Ormond (1987) believes that *Rhizophora* may have been more extensive along the Red Sea in the past but exploitation of this species for building material may have reduced its abundance. In addition, extensive grazing by camels may also have reduced the extent of mangroves in Yemen (DHV 1990).

Much of the mangrove forests that occurred on Kamaran Island and adjacent mainland were cut by the British at the beginning of the twentieth century (DHV 1990). The timber was used for construction in Aden. Fortunately, large patches of mangrove still exist on Kamaran Island today.

1996, 1997 and 1998 Surveys

Mangroves were not observed on off-shelf islands despite there being areas suitable for mangrove colonisation, such as sheltered lagoons. The Red Sea Pilot (ASD 1987) reported mangroves from lagoons on Saba Island in the Az Zubayr group. Examination of one of the lagoons revealed no mangroves, only large and bushy halophytic vegetation.

A. marina was found on four shelf islands: Al Badi (Figure 3.6), Al Murk, Kamaran (Figure 3.7) and Humara. Mangrove patches on these islands ranged from one hectare on Al Murk to over 500 hectares on Kamaran. It remains inconclusive why only four shelf islands have mangrove growth. The absence of mangroves from other islands surveyed may reflect a lack of sheltered sites for the species to establish.

Patches of *A. marina* were observed along the mainland coast south of Dhubab. The largest stand, approximately 10 hectares, was found north of Ghurayrah (Figure 3.8). Other patches were generally much smaller.

Figure 3.8: Large stand of mangroves north of Ghurayrah.

Figure 3.9
Camels in grazed mangrove forest north of Al Hudaydah.

In 1998 three *R. mucronata* plants were found on Al Kathib Island. This island is situated approximately four kilometres north-west of another island located in Khawr Kathib where there is *R. mucronata*. The three plants, ranging in height from 100cm to 140cm, were located in a dense *A. marina* stand on the south side of this island. *R. mucronata* seeds were also found in the water adjacent to Al Kathib Island.

A large number of *R. mucronata* was also located on Kamaran Island fringing the landward side of a large patch of *A. marina*. The discovery of *R. mucronata* on Al Kathib Island and Kamaran Island increases the number of locations where it is found in Yemen from two to four.

During the Yemen Project three threats to mangroves were observed:

- woodcutters
- camels
- sand drifts.

People living near the coast harvest mangroves for material to construct bird traps and houses. Fishermen were also observed cutting mangroves on shelf islands for firewood. The scale of destruction caused to mangroves by humans is still unknown. Unfortunately at least five *R. mucronata* trees, located on a small island in Khawr Kathib, were badly damaged by woodcutters in 1998. This species is uncommon and may require protection to prevent its extinction in Yemen.

Grazing of mangroves by camels was observed on numerous occasions near Al Hudaydah and Al Luhayyah. On one field trip nearly 100 camels were seen being herded towards a mangrove forest south of Al Luhayyah. The most heavily grazed mangrove forest was found north of Al Hudaydah (Figure 3.9). Over 50% of mangrove trees were intensively grazed or dead, but it is unclear if grazing was the cause of the mortality. Most grazing occurred along the edge of the forest.

South of Al Hudaydah some small, isolated mangrove patches were being covered by drifting sand. At one site south of Al Mukha only the top of the largest trees were still visible above the sand. Surprisingly, the trees, or at least the foliage, appeared healthy. Destruction of mangroves in Yemen by sand drifts was reported by Barratt et al. (1987). This threat to mangroves does not appear to be widespread.

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Chapter 4

Fish and Fisheries of Yemen's Red Sea

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Reef Fish

Introduction

Fish taxonomic and biodiversity studies have a long history in Yemen. Forsskål, a member of the Danish Arabiske Rejse expedition to the Red Sea in 1761–1763, collected fish from Al Luhayyah and Al Mukha before dying of malaria in Yarim in the south-western highlands of Yemen. His specimens and notes were later used to describe the fish fauna of the Red Sea in the publication 'Descriptiones Animalium' of 1775. One hundred and forty-six species of fish were documented, most being new species descriptions. It is noteworthy that most of the commonly observed fish associated with coral reefs in the visual censuses of the present Yemen Project were originally described from Forsskål's work. In particular these include groupers—*Aethaloperca rogaa, Cephalopholis miniata* and *Epinephelus summana*; snappers—*Lutjanus bohar, L. fulviflamma, L. kasmiri*; grunts—*Plectorhynchus gaterinus, P. schotaf*; emperors—*Lethrinus mahsena, L. nebulosus, L. harak*; bream—*Acanthopagrus bifasciatus*; angelfish—*Pomacanthus asfur, P. maculosus*; butterfly fish—*Chaetodon fasciatus*; surgeonfish—*Acanthurus gahhm, A. sohal*, *Naso unicornis*; parrotfish—*Scarus ghobban, S. sordidus, S. ferrugineus, Hipposcarus harid*; wrasse—*Chelinus lunulatus*; triggerfish—*Rhinecanthus assasi*; rabbitfish—*Siganus stellatus*; trevally—*Caranx ignobilis, Carangoides bajad, Carangoides fulvoguttatus*; soldierfish—*Adioryx spinifer* and batfish—*Platax teira*.

These comprise 60% of the common (non-cryptic) fish diversity of the Yemen Red Sea reefs. Collecting expeditions in the 19th century by biologists such as Ruppell, Ehrenberg and Hemprich, and Klunzinger expanded knowledge of Red Sea fish fauna.

The Red Sea is known to have a diverse fish fauna both in total and in reef-associated fish. Botros (1971) estimates total fish species in the Red Sea at 776 while in their review of 1987 Ormond and Edwards (1987) mention 508 species. Dor (1984) lists 1000 while1248 species are mentioned in Goren and Dor (1994). Many of these species are associated with or can be found near coral reefs. Randall (1983) lists 325 species of reef associated fish in his book 'Red Sea Reef Fishes'.

Most Red Sea reef-associated fish have distributions that extend beyond the Red Sea, normally into the Indian Ocean and often throughout the Indo-West Pacific. Endemism in some families is high eg. for Chaetodontidae perhaps even 50% (Righton et al. 1996) but is generally 15% for benthic-associated fish (eg. Randall, 1983 estimates 10% while Ormond and Edwards, 1987 quote 17%). Ormond and Edwards (1987) also note that up to 27% of the western Indian Ocean species are confined to the extreme north-west of the area and are thus probably of Red Sea origin. Endemism is higher in benthic-associated groups but even epipelagic fish such as halfbeaks and needlefish have Red Sea endemic members. Many of the most visually obvious fish on Yemen Red Sea reefs are either endemics or have ranges restricted to the Red Sea, Gulf of Aden and western Indian Ocean. In particular these include *Epinephelis summana, Plectorhynchus gaterinus, Lethrinus mahsena, Acanthopagrus bifasciatus, Pomacanthus asfur, P. maculosus, Acanthurus gahhm, A. sohal* and many of the scarids. This causes the general appearance of the fish assemblages to be quite different from reef fish assemblages on coral reefs in the central and eastern Indian Ocean, South-East Asia or the Western Pacific. But the similarities of many of the characteristics endemic to their wider Indo-Pacific counterparts are also obvious, for example the lined surgeonfish *Acanthurus sohal* (Arabian Seas) and *Acanthurus lineatus* (rest of Indo-Pacific).

Yemen Red Sea waters differ from those further north in receiving a nutrient and phytoplankton rich inflow from the Gulf of Aden (Chapter 1). This makes them much more productive than further north (Shimkus and Trimonis, 1983). Considerable differences in fish fauna north and south of 20°N are recognized as resulting from this factor (Roberts et al. 1992). Larger schools of planktivores and a general increase in biomass can be expected to be present on Yemen Red Sea reefs as a result of this enhanced productivity.

The reduced number of species of most groups of fish in the Red Sea compared to the Indian Ocean suggests isolation in at least some of the glacial period (Findley and Findley, 1989, Briggs, 1974.) However, it has also been argued that the relatively high levels of endemism in Red Sea fish supports the theory that the Red Sea was not cut off from the Indian Ocean at Bab Al Mandab in all of the glacial low sea level stands (Klauswitz, 1989). It is believed that in periods when the Red Sea was cut off from the Indian Ocean at Bab Al Mandab, hypersaline conditions prevailed in the Red Sea precluding coral reef development and presumably the existence of coral reef fish. The period since the sea rose to its present level in this area (about 10,000 years) is believed to be insufficient for the speciation seen in Red Sea fish. Klauswitz (1989) suggests that sea level did not fall below the Bab Al Mandab sill (130 metres below present sea level) in the last ice age. However, varying opinions still exist regarding the speciation seen in Red Sea fish and its relationship to sea level changes and isolation from the Indian Ocean (Ormond and Edwards, 1987, Sheppard et al. 1992). Righton et al. (1996) consider Red Sea chaetodontid species to have survived the hypersaline glacial events in refuges, at least one of which was located outside the Red Sea. They note that Red Sea endemics may be older (that is, have developed earlier) than the most recent glacial low stands.

In the Red Sea, distinct differences in the fish fauna occur north and south of 20ºN (Sheppard et al. 1992, Roberts et al. 1992). The differences were analysed by Roberts et al. (1992) for the butterflyfish, damselfish, parrotfish and surgeonfish. They tentatively attributed the differences to shelf width (narrow in the north, wider in the south) and water quality (highly productive and turbid in the south, less so in the north). Reef fish communities in the Yemen Red Sea are most likely to resemble other southern Red Sea communities, the Yemen Red Sea also having a wide shelf with relatively turbid, productive water. Kemp (1998) postulates the existence of two zoogeographic barriers affecting Yemen Red Sea fish diversity rather than just one at the Bab Al Mandab. One is at 20ºN in the Red Sea as postulated in Roberts et al. (1992), the other in the Gulf of Aden. The barrier in the Gulf of Aden separating the Red Sea and western Gulf of Aden from Oman is also probably linked to current patterns and the upwelling system on the south coast of Oman and eastern Yemen (Randall and Hoover, 1995, Kemp, 1998).

The distribution of reef fish of various families in different habitats within the reef structure has been studied at a number of locations in the Red Sea. This has included work on reef fish zonation in the Sudan (Edwards and Rosewell, 1981), studies in Jordan on chaetodontids (Bouchon-Navaro, 1980), work on herbivorous fish in Gulf of Aqaba (Bouchon-Navaro and Harmelin-Vivian, 1981) and studies on fish distribution on fringing reefs (Roberts and Ormond, 1987).

It has been suggested previously (Behairy et al. 1992, Sheppard et al. 1992) on biogeographic grounds that coral reef development in the southern Red Sea may be limited. To quote from Behairy et al. (1992): '[in the] south [of the Red Sea], the different, highly sedimentary regime mostly excludes any reefs, especially fringing reefs. The south is more a province for soft substrate, mangroves and seagrass beds with occasional reefs in locations that are favorable to corals'.

Present survey work has shown that Yemen Red Sea waters contain numerous areas of coral reef and coral communities both fringing the coast and islands and in patches in open water (Chapter 2). Typically most shallow areas (<30 metres deep) contained coral communities of some type except where it appeared high water temperatures or unstable substrate prevented coral growth. However, the limitations on coral growth postulated by Behairy et al. (1992) while not found to be as serious as they suggest, are present, and reef growth appears to be significantly limited (Chapter 2). The estimated full extent of coral reefs are shown in Figure 8.12. As could be expected from the widespread presence of coral reefs and communities, a widespread and consistent reef fish and reef associated fish fauna was found in Yemen Red Sea waters.

Considerable controversy surrounds the question as to whether a real (ie. obligate) coral reef fish community exists (Robertson, 1998; Bellwood, 1997, 1998). Most fish seen commonly on coral reefs seem to be able to exist in the absence of coral, for example around artificial substrate such as wrecks and jetties or on 'dead' reefs after crown-of-thorns starfish outbreaks or on rocky areas (Bell and

Table 4.1

Fish species observed on reefs in the Yemen Red Sea

- ACANTHURIDAE
  - *Acanthurus gahhm*
  - *Acanthurus mata*
  - *Acanthurus nigricans*
  - *Acanthurus nigrofuscus*
  - *Acanthurus sohal*
  - *Ctenochaetus striatus*
  - *Naso hexacanthus*
  - *Naso lituratus*
  - *Naso unicornis*
  - *Zebrasoma desjardinii*
  - *Zebrasoma xanthurum*
- APOGONIDAE
  - *Apogon annularis*
  - *Apogon cyanosoma*
  - *Apogon taeniatus*
  - *Cheilodipterus quinquelineatus*
  - *Cheilodipterus macrodon*
  - *Siphamia versicolor*
- BALISTIDAE
  - *Balistapus undulatus*
  - *Balistoides viridescens*
  - *Melichthys indicus*
  - *Odonus niger*
  - *Pseudobalistes fuscus*
  - *Rhinecanthus assasi*
  - *Sufflamen chrysopterus*
- SILVER SCHOOL
- BLENNNIIDAE
  - *Atrosalarias fuscus*
  - *Ecsenius midas*
  - *Meiacanthus nigrolineatus*
  - *Plagiotremus rhinorhynchus*
  - *Plagiotremus tapienosoma*
  - *Plagiotremus townsendi*
- BOTHIDAE
  - *Bothus pantherinus*
- CAESIONIDAE
  - *Caesio caerularea*
  - *Caesio lunaris*
  - *Caesio striata*
  - *Pterocaesio ch*rysozona
- CARANGIDAE
  - *Carangoides bajad*
  - *Carangoides fulvoguttatus*
  - *Carangoides plagiotaenia*
  - *Caranx ignobilis*
  - *Caranx melampygus*
  - *Caranx sexfasciatus*
  - *Gnathanodon speciosus*
  - *Scomberoides commersonianus*
  - *Trachinotus bailloni*
- CARCHARHINIDAE
  - *Carcharhinus amblyrhynchos*
  - *Triaenodon obesus*
- CHAETODONTIDAE
  - *Chaetodon auriga*
  - *Chaetodon austriacus*
  - *Chaetodon fasciatus*
  - *Chaetodon larvatus*
  - *Chaetodon lineolatus*
  - *Chaetodon melapterus*
  - *Chaetodon mesoleucos*
  - *Chaetodon semilarvatus*
  - *Heniochus intermedius*
- CIRRHITIDAE
  - *Cirrhitichthys oxycephalus*
- DASYATIDIDAE
  - *Taeniura lymna*
- DIODONTIDAE
  - *Diodon histrix*
- EPHIPPIDAE
  - *Platax teira*
  - *Platax orbicularis*
- GINGLYMOSTOMATIDAE
  - *Nebrius ferrugineus*
- GOBIIDAE
  - *Amblygobius hectori*
  - *Cryptocentris sp*
  - *Ctenogobiops sp*
- HAEMULIDAE
  - *Diagramma pictum*
  - *Plectorhinchus flavomaculatus*
  - *Plectorhinchus gaterinus*
  - *Plectorhinchus gibbosus*
  - *Plectrorhinchus obscurus*
  - *Plectrorhinchus schotaf*
- HOLOCENTRUDAE
  - *Adioryx ruber*
  - *Myripristis murdjan*
  - *Myripristis xanthacrus*
  - *Neoniphon sammara*
  - *Sargocentron caudimaculatum*
  - *Sargocentron ittodai*
  - *Sargocentron spiniferum*
- KYPHOSIDAE
  - *Kyphosus cinerascens*
- LABRIDAE
  - *Anampses lineatus*
  - *Bodianus axillaris*
  - *Chelinus fasciatus*
  - *Chelinus lunulatus*
  - *Chelinus undulatus*
  - *Coris africana*
  - *Coris caudimacula*
  - *Epibulus insidiator*
  - *Gomphosus coeruleus*
  - *Halochoeres zeylonicus*
  - *Halichoeres hortulanus*
  - *Halichoeres marginatus*
  - *Halichoeres nebulosus*
  - *Halichoeres scapularis*
  - *Hemigymnus fasciatus*
  - *Hemigymnus melapterus*
  - *Hologymnosus annulatus*
  - *Labroides dimidiatus*
  - *Larabicus quadrilineatus*
  - *Oxycheilinus digrammus*
  - *Stethojulis albovittata*
  - *Stethojulis interrupta*
  - *Thalassoma hardwicke*
  - *Thalassoma lunare*
  - *Thalassoma purpureum*
  - *Thalassoma klunzinger*
- LETHRINIDAE
  - *Lethrinus harak*
  - *Lethrinus lentjan*
  - *Lethrinus mahsena*
  - *Lethrinus microdon*
  - *Lethrinus nebulosus*
  - *Lethrinus olivaceus*
  - *Monotaxis grandoculus*
- LUTJANIDAE
  - *Lutjanus bengalensis*
  - *Lutjanus bohar*
  - *Lutjanus coeruleolineatus*
  - *Lutjanus ehrenbergi*
  - *Lutjanus fulviflamma*
  - *Lutjanus kasmiri*
  - *Lutjanus monostigma*
  - *Lutjanus sanguineus*
  - *Lutjanus sp*
  - *Macolor niger*
  - *Paracaesio sordidus*
- MONODACTYLIDAE
  - *Monodactylus argenteus*
- MUGILIDAE
  - *Crenimugil crenilabis*
- MULLIDAE
  - *Mulloidichthys flavolineatus*
  - *Mulloidichthys vanicolensis*
  - *Parapeneus cyclostomus*
  - *Parapeneus forsskali*
  - *Parupeneus cinnabarinus*
- MURAENIIDAE
  - *Gymnothorax flavimarginatus*
  - *Strophidon sathete*
- MYLIOBATIDAE
  - *Aetobatus narinari*
- NEMIPTERIDAE
  - *Scolopsis ghanam*
- OSTRACIIDAE
  - *Lactoria cornuta*
  - *Ostracion cubicus*
  - *Ostracion cyanurus*
- PEMPHERIDAE
  - *Pempheris oualensis*
  - *Pempheris vanicolensis*
- PINGUIPEDIDAE
  - *Parapercis hexophtalma*
- PLESIOPIDAE
  - *Plesiops nigricans*
- PLOTODIDAE
  - *Plotosus lineatus*
- POMACANTHIDAE
  - *Apolemichthys xanthurus*
  - *Pomacanthus asfur*
  - *Pomacanthus maculosus*
  - *Pygoplites diacanthus*
- POMACENTRIDAE
  - *Abudefduf saxatilis*
  - *Abudefduf sexfasciatus*
  - *Abudefduf sordidus*
  - *Abudefduf vaigiensis*
  - *Amblyglyphidodon leucogaster*
  - *Amphiprion bicinctus*
  - *Chromis dimidiata*
  - *Chromis pembae*
  - *Chromis trialpha*
  - *Chromis viridus*
  - *Chrysiptera leucopoma*
  - *Chrysiptera unimaculata*
  - *Dascyllus aruanus*
  - *Dascyllus marginatus*
  - *Dascyllus trimaculatus*
  - *Pomacentrus albicaudatus*
  - *Pomacentrus aquilus*
  - *Pomacentrus arabicus*
  - *Pomacentrus sulfureus*
  - *Pomacentrus trichourous*
  - *Pomacentrus trilineatus*
  - *Neoglyphidodon melas*
  - *Stegastes nigricans*
  - *Pseudochromis flavivertex*

Continued

Fish species observed on reefs in the Yemen Red Sea (cont.)

SCARIDAE
Hipposcaris harid
Scarus collana
Scarus scaber
Scarus ferrugineus
Scarus frenatus
Scarus ghobban
Scarus niger
Scarus psittacus
Scarus sordidus
Scarus strongylocephalus
SCOMBRIDAE
Grammatorcynos bilinaeatus
Rastrelliger kanagurta
SCORPAENIIDAE
Pterois miles
Pterois radiata
Scorpaenopsis oxycephala
SERRANIIDAE
Aethaloperca rogaa
Cephalopholis argus
Cephalopholis hemistiktos
Cephalopholis miniata
Cephalopholis sexmaculata
Epinephelus areolatus
Epinephelus chlorostigmata
Epinephelus fasciatus
Epinephelus fuscoguttatus
Epinephelus lanceolatus
Epinephelus malabaricus
Epinephelus microdon
Epinephelus summana
Epinephelus stoliczkae
Plectropomus pessuliferus marisrubri
Variola louti
SIGANIDAE
Siganus argenteus
Siganus luridus
Siganus stellatus
Siganus sutor
Siganus rivulatus
SPARIDAE
Acanthopagrus bifasciatus
Diplodus noct
Rhabdosargus sarba
SPHYRAENIDAE
Sphyraena barracuda
Sphyraena jello
Sphyraena qenie
Sphyraena putnamiae
SYNODONTIDAE
Synodus dermatogenys
THERAPONIIDAE
Terapon jarbua
TETRAODONTIDAE
Arothron diadematus
Arothron hispidus
Canthigaster margaritata

Galzin, 1984; Carpenter et al. 1981). It is also clear that a 'suite' of similar fish are found on most coral reefs with members of many families present even if species vary from biogeographic region to region (Bellwood, 1998). We will refer to this community in this chapter as 'reef fish'.

Typical members of this reef fish community include the damsel fish (pomacentrids), butterfly fish (chaetodonts), parrotfish (scarids), wrasse (labrids), surgeon fish (acanthurids), sweetlips or grunts (haemulids), triggerfish (balistids), groupers (seranids), emperors (lethrinids) and snappers (lutjanids). Another group of fish can be recognized as loosely associated with coral reefs, generally observed near the reef but having a semi-pelagic distribution. This group includes trevally (=jacks and carangids), sharks and barracuda.

Reef Fish Diversity

Two hundred and twenty-nine species of fish were recorded by underwater visual census on the 59 reefs surveyed in the Yemen Project. As described in the discussion of methodology for the Yemen Project (Appendix 1) small cryptic fish species are greatly under-represented in the species recorded by the Yemen Project fish surveys. Thus important, abundant families, such as gobies were rarely recorded even though such species are certainly present with large numbers of both species and individuals. The species list is shown in Table 4.1.

The most commonly observed species at most sites were schools of the reef associated semi-pelagic fusiliers (Caesionidae, Figure 4.1), particularly *Caesio lunaris*; small snappers (Lutjaniidae), particularly *Lutjanus*

Figure 4.1
Schooling fusiliers at Uqban Island.

Figure 4.2
Acanthurids (*A. sohal and A. Gahhm*) and chaetodontids (*C. semilarvatus*).

Figure 4.3
Damselfish (*Abudefduf sexfasciatus*) in foreground.

Figure 4.4
Plectorhynchus gaterinus schooling (possibly spawning) near Six Foot Rocks.

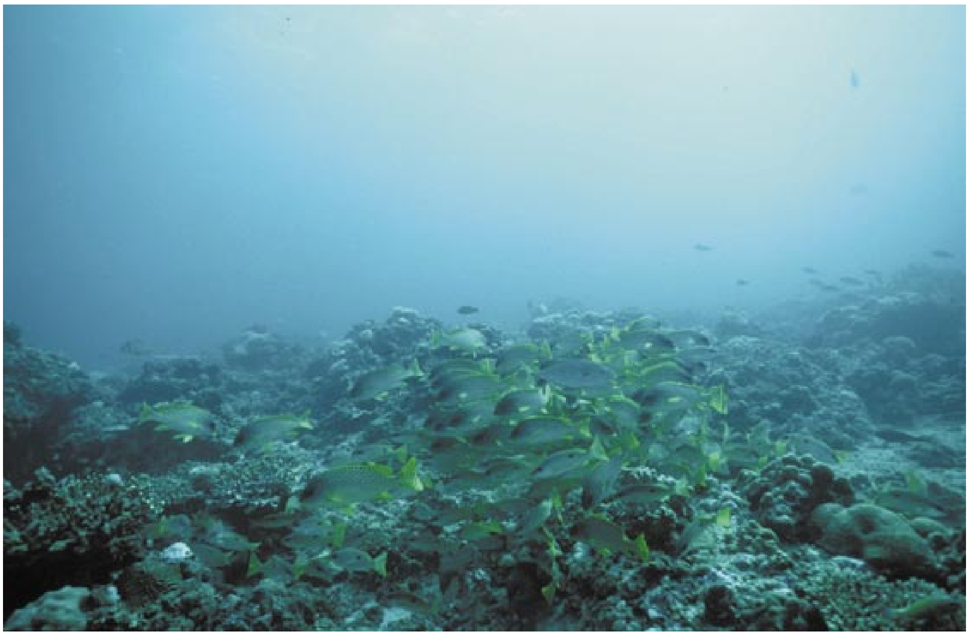


Figure 4.5
Roving parrotfish at Quoin Island.

ehrenbergi, L. monostigma & L. kasmira; acanthurids (Acanthuriidae), particularly *Acanthuris gahhm, A. sohal &, Ctenochaetus striatus* (Figures 4.2 and 4.8); pomacentrids (Pomacentriidae), particularly *Abudefduf sexfasciatus* (figure 4.3), *Abudefduf saxitilis & Chromis* spp; the sweetlip (Haemulidae) *Plectorhinchus gaterinus* (Figure 4.4*) and P. schotaf* and scarids (Scaridae, Figure 4.5), particularly *Scarus ferrugineus*, *S. ghobban & S. sordidus* . Other less common but obvious species included pomacanthids, particularly *Pomacanthus asfur and P. maculosus* (Figure 4.6), butterflyfish, particularly *Chaetodon semilarvatus* and *C. fasciatus* and small serranids, particularly *Epinephelus summana & Cephalopholis hemistiktos.* Noticeably missing from the common fish observed were fish of the genus *Anthias*, a very common group of fishes of the northern Red Sea (Ormond and Edwards, 1987). No *Anthias* spp were recorded in the surveys. Siganids were uniformly uncommon but this is typical of some Red Sea reefs, even those dominated by algae, where the grazing fish communities are dominated by scarids and acanthurids (Bouchon-Navaro and Harmelin-Vivien, 1981).

Patterns in Fish Distribution and Abundance

It might be assumed that few reef fish surveys have been published from both inshore and offshore reefs in the Yemen Red Sea for comparison to the present work. This is true in recent times where the published work of Rushdi et al. 1994; Barratt et al. 1987; and EH and A, 1989 represent geographically limited surveys and collections. However, as noted above, much of the fish fauna had been described as early as the 18th century and many of the type specimens

Figure 4.6
Pomacanthus maculosus at Miyurn Island.

actually come from Yemen. The fish fauna documented in the present study correspond well, with a few exceptions, to the general descriptions of fish diversity, distribution and abundance described in Ormond and Edwards (1987); Randall (1983); and Roberts et al. (1992) for the Red Sea. The 229 species observed are a substantial assemblage compared to other surveys in the area. In the Arabian Gulf, Krupp and Muller (1994) recorded 187 species in an area off northern Saudi Arabia while 124 species are documented in Carpenter et al. (1997) from Kuwait. Kemp (1998) recorded 215 species in recent surveys around Socotra and the adjacent islands of Abd-al-Kuri, Semha and Darsa. For the Red Sea, Randall (1983) includes 325 species of reef fish and reef associated fish in his comprehensive book. In Yemen, intensive fish surveys on reefs around the Ras Isa area, in association with the Environmental Impact Assessment for the oil terminal, documented 108 species of reef fish (EH and A, 1989).

A number of extensions to the known range of fish were observed in the Yemen project, in particular for the chaetodontids *Chaetodon austriacus* and *C. melapterus*. *C. austriacus*, believed to be restricted to the northern and central Red Sea (Roberts et al. 1992), was found at five sites in Yemen including in the mid-Red Sea islands (Zubayr and At Tair) and near Al Mukha (Wahijah). This species was not recorded from Miyurn Island and was not seen by Kemp (1998) at Socotra. *C. melapterus,* previously considered not to occur in the Red Sea but only in the Gulf of Aden (Roberts et al. 1992), was found during the Yemen Project on the mid-Red Sea island reefs (Saba, Zubayr, Quoin, At Tair and Avocet), on the coast near Al Mukha and around Miyurn Island. Roberts et al. (1992) do note the presence of this species at Al Mocha and it thus appears that it has penetrated further into the Red Sea than has been believed. Randall (1994) noted the presence of both species in Yemen Red Sea waters but *C. austriacus* was seen more commonly than *C. melapterus*. Both these species were believed to not occur in the southern Red Sea due to lack of coral reefs in the area forming a barrier to their spread from their normal range. From our results *C. austriacus* and *C. melapterus* are sympatric on Yemen Red Sea reefs as previously suggested by Burgess (1978) and discussed by Blum (1989). The documentation of widespread coral reef areas in the Yemen Red Sea in the Yemen Project(Chapter 2), allows an explanation as to why these fish species are also found in the area. The distribution barriers at 20ºN (Red Sea) and in the Gulf of Aden are thus probably formed by oceanographic conditions rather than substrate availability.

Patterns in fish distribution and abundance have been analysed numerically using cluster analysis and non-metric multidimensional scaling (NMDS) on the full fish data set. Most sites (76%) surveyed contained moderate to high diversity (species numbers > 30) and abundance. Mixed aggregations of acanthurids, scarids, haemulids, small lutjanids and other species were present on most reefs (Figure 4.2). The mean number of species recorded was 36. Variability in species diversity between sites was low.

Most sites had very uniform species and abundance patterns. NMDS analysis (Figure 4.7) group most sites tightly with only a limited division separating sites representing unusual reef conditions. The division marked on Figure 4.7 has sites to the left of the diagram consisting generally of sites inshore with high levels of dead coral or no coral, algal-dominated reefs and sites dominated by seagrass. Sites such as 4.1 (Khawr Kathib), 1.2 (near Al Luhayyah), 46.1 (Ar Rays) and 25.4 (Ghulayfiqah) with mostly seagrass, 1.6 (Al Murk), 6.4 (Atwaq), 3.2 (Al Urj), 25.1 (Al Taufa) and 21.2 (north Kamaran) dominated by sargassum and 4.2 (Khawr Kathib), 1.3 (near Al Luhayyah), 17.4 (Tiqfash) and 3.1 (Al Urj) with high abundance of red coralline algae fall into this group. Schools of *Acanthurus gahhm* were common on these turbid inshore areas (Figure 4.8). The larger tight group on the right of Figure 4.7 represents the reefs dominated by coral. Although there were large differences in the percentage of live coral cover at the coral reef sites, only small differences show in the fish diversity, species composition and abundance.

Fish assemblages on the coral reef sites showed almost no cross-shelf variability. Only four species were found on the mid-Red Sea island reefs that were not also found on the shelf island reefs and coastal reefs. These were *Naso hexacanthus, N. unicornus, N. lituratus* and *Trachynotus balloni*. This lack

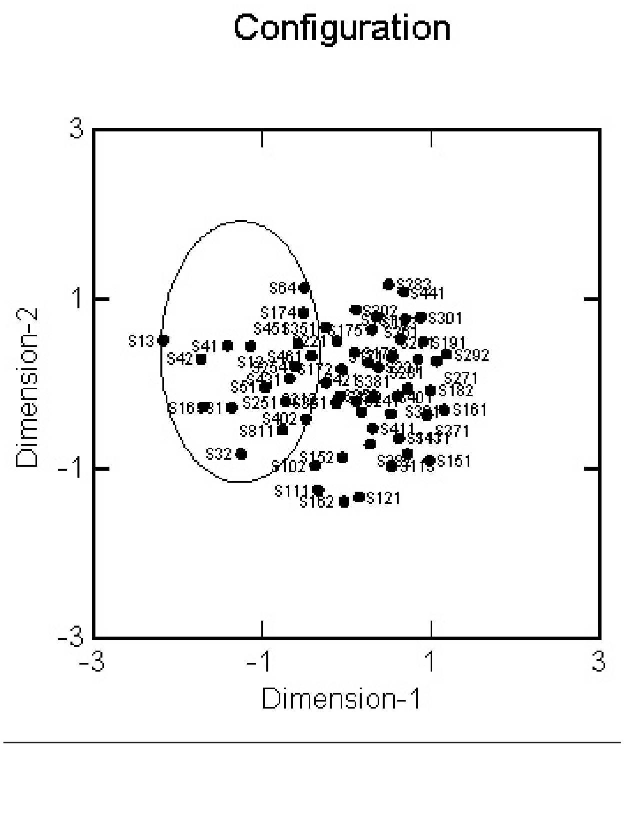


Figure 4.7
Non-Metric Multidimensional Scaling plot for fish species, abundance and site data.

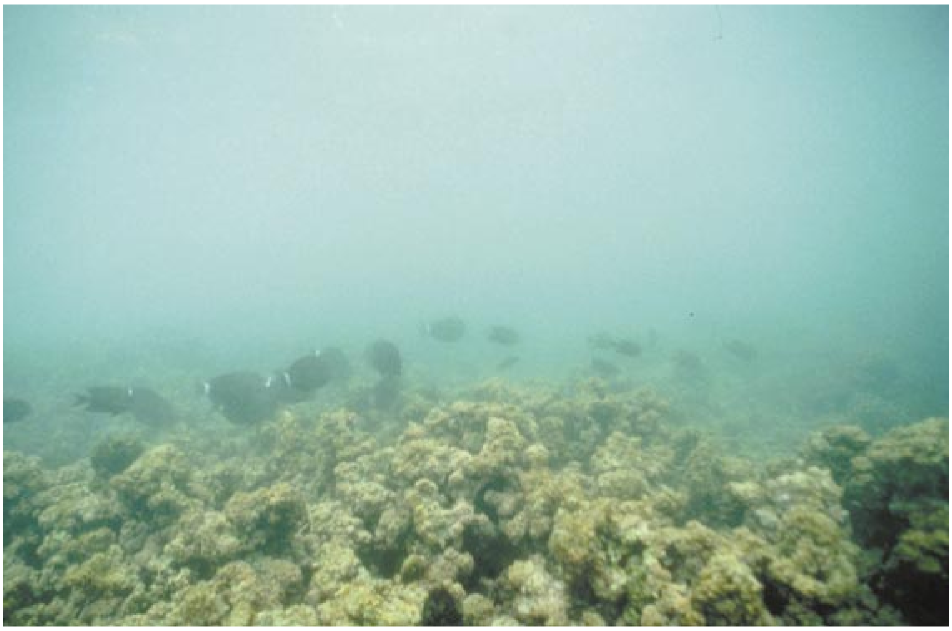


Figure 4.8
School of *Acanthurus gahhm* in turbid inshore water, Al Taufa.

of a cross-shelf gradient in fish species variability is in contrast to the situation in other areas such as the Great Barrier Reef. On the Great Barrier Reef, substantial cross-shelf differences exist in the general fish fauna (Williams, 1982) and notable differences in the herbivorous grazing fish distribution (Russ, 1984). In the Arabian Gulf approximately 50% of species are restricted to either inshore or offshore reefs (Coles and Tarr, 1990). Physical and biological conditions vary widely across the Yemen Red Sea 'shelf' area. Inshore areas are shallow, have high turbidity, higher temperatures and *Sargassum* communities common in reefal areas, while offshore the water is deeper and clearer, macroalgae is less common and reef topography more complex and varied. In other Red Sea studies depth has been found to be a consistent, significant predictor of fish diversity (Roberts and Ormond, 1987). Topography has also been shown to structure fish distribution with more diversity and abundance on reefs with more complex topography (Kaufman and Ebersole, 1984). It is thus surprising in the present surveys to find so little change in the fish assemblage composition resulting from such large environmental differences.

As noted in Chapter 2 many reefs in the Yemen Red Sea have suffered recent extensive mortality and now have low live coral cover. In some areas total live coral cover remains high eg Miyurn Island, while in others only *Porites* and other massive corals remain alive eg. Avocet Rock. These differences in live coral cover are not completely reflected in the fish fauna. In many studies in shallow tropical ecosystems significant relationships between the benthic community and fish assemblages have been found, eg. in Reunion Island (Chabanet et al. 1997) and in the Seychelles (Indian Ocean) (Jennings et al. 1996), in the Pacific (Sano et al. 1984) and for chaetodontid fish in the northern Red Sea (Bouchon-Navaro and Bouchon, 1989). However continued reef fish diversity and abundance have been noted on reefs suffering high coral mortality in a number of studies eg. following crown-of-thorns starfish mortality (Williams, 1986) or coral mortality associated with El Nino-induced high water temperatures (Wellington and Victor, 1985). A similar lack of correlation between fish numbers and diversity and live coral cover was found in other studies in the Red Sea (Roberts and Ormond, 1987) and in the Arabian Gulf (Coles and Tarr, 1990). It appears that while structural complexity for habitat remains in the reef system a diverse fish fauna can be maintained for some time. In addition fish recruitment occurs on relatively long time scales and changes in the fish fauna following extensive coral mortality may take many years to become evident. On reefs in the Yemen Red Sea which have been dead for a considerable time and where the living community is then dominated by coralline red algae or sargassum fish species diversity and abundance are greatly reduced. This pattern can be seen from the distributions in the scaling analysis (Figure 4.7). A particularly clear example was evident in the two adjacent reefs near Al Urj (discussion in Chapter 2). The reef dominated by red coralline algae had far less fish diversity and abundance than the adjacent coral dominated reef, the two reefs being separated only by a shallow (4m deep), narrow (20m wide) channel. Large differences in diversity or abundance of butterfly fishes (chaetodontids) and damsel fishes (pomacentrids) have been recorded by Kemp (pers. comm.) in comparing dead coral areas to live on the island reefs near Kamaran (Kamaran, Uqban, Al-Badi).

From the raw data, in all but two locations, populations of large carnivores-serranids, lutjanids and lethrinids were low while smaller members of these groups were present in moderate numbers. Sharks were also uncommon. The only large piscivores observed regularly were barracuda (*Sphyraena* spp) particularly solitary *S. barracuda* (Figure 4.9).

Figure 4.9
Solitary *Sphyraena barracuda* at Saba Island.

Populations of planktivores and small piscivores were high with large aggregations present at many sites (Figure 4.1). Populations and biomass of 'non-biting' fish (those not caught by handlining methods) eg grazers such as acanthurids and scarids were also high. Superficially this suggests relatively high intensity line fishing for the targeted carnivore species on the reefs of the Yemen Red Sea. It also tends to indicate that destructive fishing practices which indiscriminately target all fish eg. dynamite fishing, cyanide fishing, fine netting, and moro-ami fishing are not occurring to any significant extent on the reefs. The analysis of commercial fish abundance and distribution are discussed later in this chapter.

Fisheries

Introduction

Yemen has important fisheries in both the Red Sea and the Gulf of Aden. The total Yemen fish catch was approximately 100,000 tonnes in 1992 and it was expected that it could be increased to 300,000 tonnes using modern gear (Rushdi et al. 1994). Of the catch, 95% is consumed locally and 5,000 tonnes is exported. The Red Sea catch was about 40,000 tonnes in 1997 (Al-Sorimi, 1998) and has increased steadily over the last 25 years for which data is available (Figure 4.10).

Since the early 1980s investment in Yemen fisheries has increased rapidly with Yemen Government and aid funding. Investment has gone into new fishing boats, fishing centres, an organized auction and marketing scheme, ice plants, fisheries research and fisheries data acquisition. Fisheries data is collected through landing and auction records and survey results (Chakraborty, 1984). Information in this section comes largely from this data collected since 1983.

There are two categories of fishing in the Yemen Red Sea, artisanal and foreign commercial. The Yemen artisanal fishery occurs on shrimp fishing grounds (Figure 5.1 and 5.2)

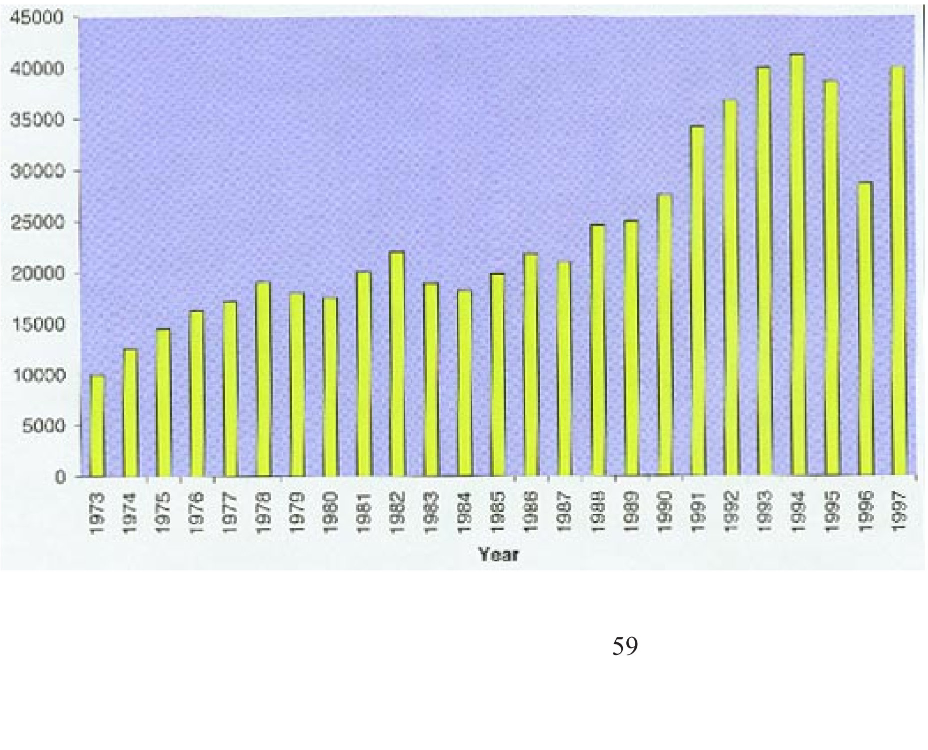


Figure 4.10
Yemen Red Sea fisheries production 1973 to 1997.

Figure 4.11
Sambuk

adjacent to Ras Kathib, Kamaran Island, As Salif and off Al Luhayyah, demersal fishing occurs on the 5,000km^2 of the shelf not suitable for trawling and pelagic fishing occurs on the entire shelf area of 11,200km^2. Commercial fishing by foreign vessels occurs over much of the north of the Yemen Red Sea.

Vessels

The primary vessels used in artisanal fishing are the sambuk, a wooden vessel of length 12 to 20 metres (Figure 4.11), and the houri, a smaller wooden vessel of 7 to 12 metres. Houris are now frequently replaced by fibreglass longboats (Figure 4.12). Sambuks are powered by onboard diesel engines of 33 to 200 HP and produce catches of 170 to 200kg per day. Houris, powered by outboard motors (25-150 HP), may produce 50 to 70kg per day of catch.

Commercial fishing by overseas interests occurs from 'investment' boats with lengths between 20 and 40 metres and powered by 500 to 800 HP motors. Approximately 600 sambuks and 2000 houris are used in the Red Sea fishery, divided between the fishing centres as shown in Table 4.2.

Table 4.2: Fishing vessel numbers in fishing areas

Centre	Houri	Sambuk
Al Hudaydah	377	145
Khawba	470	115
Al Khawkhah	519	130
Midi	320	70
Al Mukha	445	95
Total	**2131**	**555**

Figure 4.12
Houri and fibreglass small fishing boats

Fishing Areas

The principal fishing centres on the Yemen Red Sea coast are at Midi, Khawba, Al Hudaydah, Al Khawkhah and Al Mukha (Figure 5.1). At these centres fish landed go to auction. One or several auctioneers appointed by the Ministry of Fish Wealth, carry out auctions and in some places the auctioneer is a buyer. However the auction operation appears to work quite efficiently in the sense that fish are quickly sold. Due to the larger number of buyers in Al Hudaydah auctions there are more contested but some of the auctioneers are still also buyers. Price levels fluctuate considerably at auctions depending on the location, levels of landings that day and the type of fish. In Al Hudaydah the average price of fish is 111 Rial per kilo. In other places the price is less, often only 25% that of Al Hudaydah. Every auction market has its officially appointed government tax collector. The official tax on fish landed is 10%. In some places the fisherman is also required to pay further money to the auctioneer.

The auction centres gather in fish landed from a surrounding area of fishing villages. Midi includes the area of Hable, Al Luhayyah, Buhays, Buklan and Fasht; Khawba includes Ibn Abbas, Haronia, As Salif, Al Urj, Homara, Gabana, Ras Isa and Kamaran; Al Hudaydah includes Manzar, Nokila, Jahn, Taif, Gulayfiqah, Mogails, Al Fazah and Motina; Al Khawkhah includes Haima, Kutaba, Abu Zahr, Wa'ara, Moshaig, Zohai and Yaktul; and Al Mukha includes Kdaha, Dhubab, and Bab Al Mandab.

There is conflicting evidence on seasonality of fishing activities. The wind plays an important role in the distribution of habitats, species and fisheries along the coast. Prevailing south-southeasterly winds are very strong through the winter (October to March) and weather conditions can at times restrict houri operations almost everywhere along the coast and sambuk operations at bases where anchorages are open to the wind and resulting wave action. In these conditions all boats have to be hauled on shore. The period from autumn (September) to mid-winter (January) appears to be the best fishing season. The landing of commercial fish at Al Mukha and Al Khawkhah falls in winter. In the northern area winds moderate slightly and more extensive sheltered habitats are found upwind of promontories and islands. Landings at Khawbah and Midi increase, resulting in a general winter season migration of Yemen (Red Sea) fishermen to these waters. Oakley and Bakhsh (1989), in their studies of the seasonality of fish catches in the Jizan region of the Red Sea, just to the north of Yemen, found that some of the most important fish species showed strong seasonal catch patterns. Large Spanish mackerel, *Scomberomorus commerson*, were abundant in June and July, apparently moving into the area to spawn. The talang queenfish, *Scomberoides commersonianus*, was common throughout the year although catch rates increased during summer months.

Fishing Methods

The most commonly used fishing methods are hand lines, trolling lines, cast nets, gill nets and traps. Their use depends on the size of the vessel, target species, seasonal catch variations and fishing ground. Gill nets and hand lines are used from sambuks, with the predominant catch being Indian mackerel, barracuda, kingfish and shark. Cast nets and handlines are commonly used from houris with reef fish and kingfish the dominant catch. Trolling lines are also used with two hooks per line. In sloping beaches free of rocks or coral hazards, beach seines with a very fine mesh (20mm) are used to catch sardines, anchovy and other small species. In protected bays, eg. As Salif, stake nets are used to trap small pelagic species entering these shallow, calm waters.

Catch and species

Shrimp

A number of species of shrimp are fished in Yemen Red Sea waters. The most abundant and widely distributed species is *Penaeus semisulcatus*. The next most abundant species of shrimp is *Penaeus indicus*, referred to as white shrimp. *Penaeus japonicus*, referred to as tiger shrimp, is widely distributed in the area but no commercial quantities were encountered. This shrimp appeared to prefer the shallow waters of less than 12m. The fourth species encountered, *Penaeus monodon*, was usually found in deeper waters, 35m-40m, in the southern passage of Kamaran Bay. This shrimp usually exceeded 200mm in total length but was not present in commercial quantities. The average production of shrimp is 346 tonnes annually for local boats (sambuks) but difficult to estimate for overseas investment boats as exact data is not available. An estimate of the production of shrimp annually is 1,000-1,500 tonnes for all boats in the Yemen Red Sea (local and investors) concentrated in the area between As Salif and Al Luhayyah. The estimated shrimp catch has varied widely since 1983 (Figure 4.13). The average catch of shrimp is 25kg per sambuk per day and estimated to be from 600-800kg/day/boat for investment boats. The investment boats have freezing plants and package the shrimps for export.

Open Water Finfish

Shark is a very important fish for the export of fins and is second only to shrimp for fisheries investment in Yemen. The average production of shark over the statistical period is 2,800 tonnes/year with production increasing sharply since 1990 (Figure 4.14). Large quantities of shark are regularly present at the fisheries auction centres (Figure 4.16). Local fishermen concentrate on shark fishing; the fins are removed for export and the carcass sold locally. This practice has confused

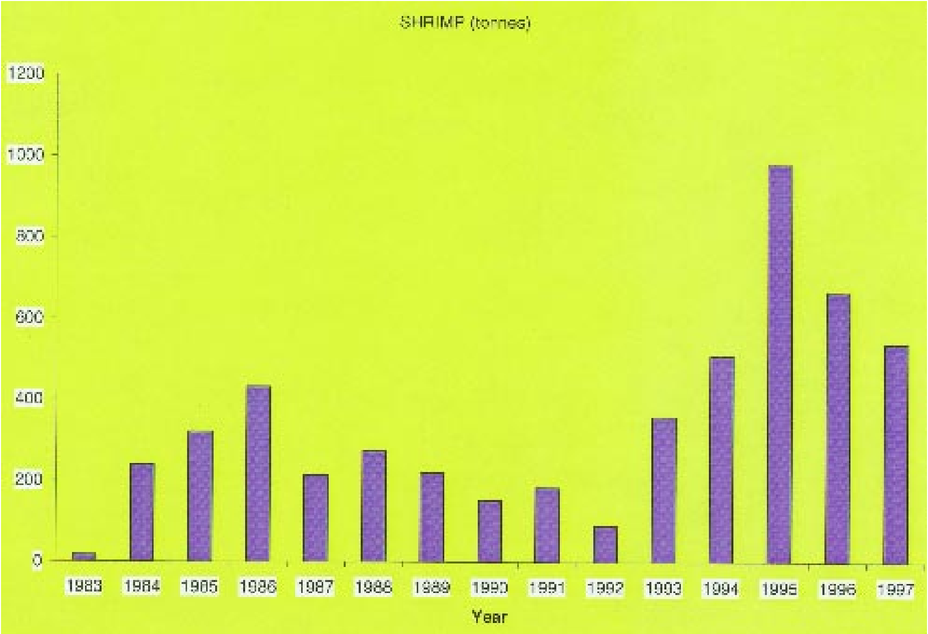


Figure 4.13
Shrimp catch between 1983 & 1997.

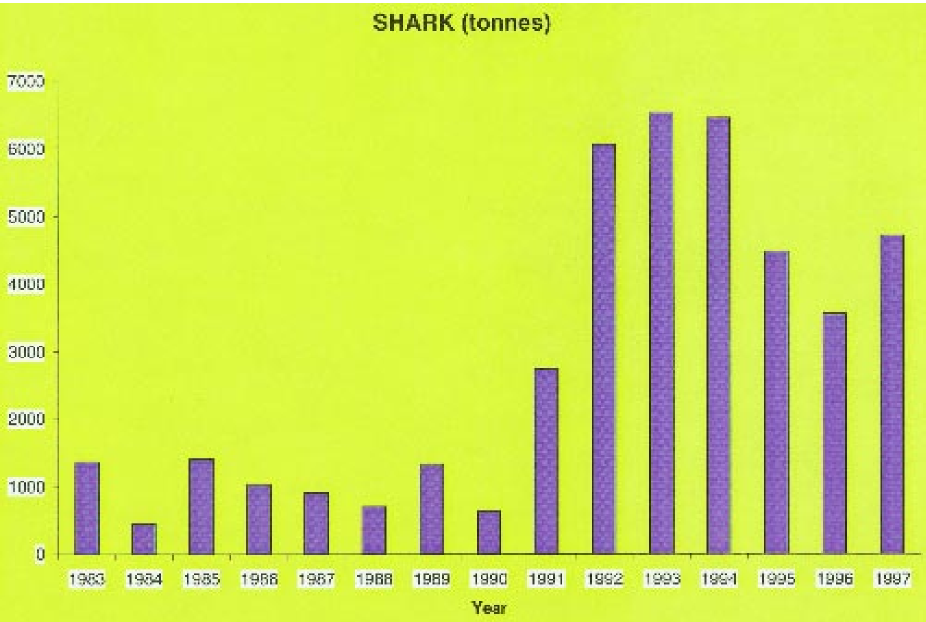


Figure 4.14
Shark catch between 1983 & 1997

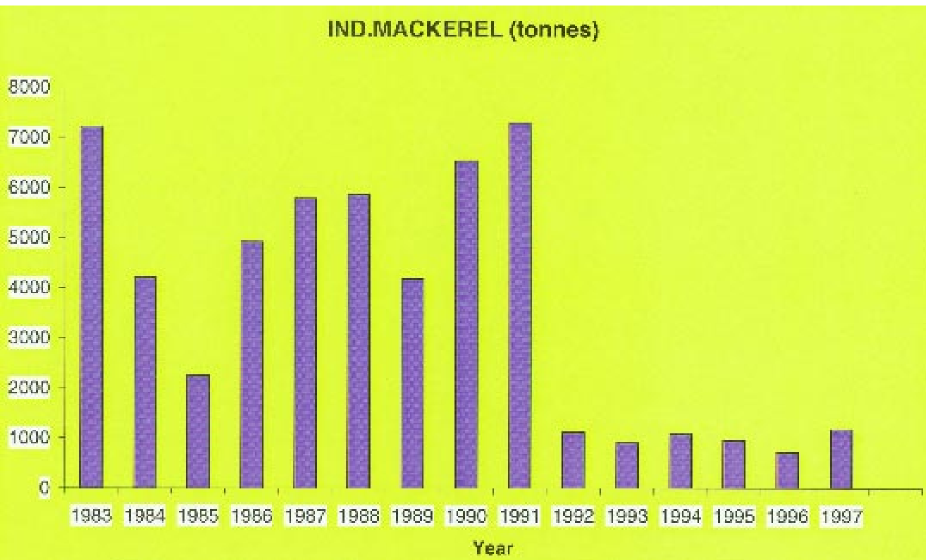


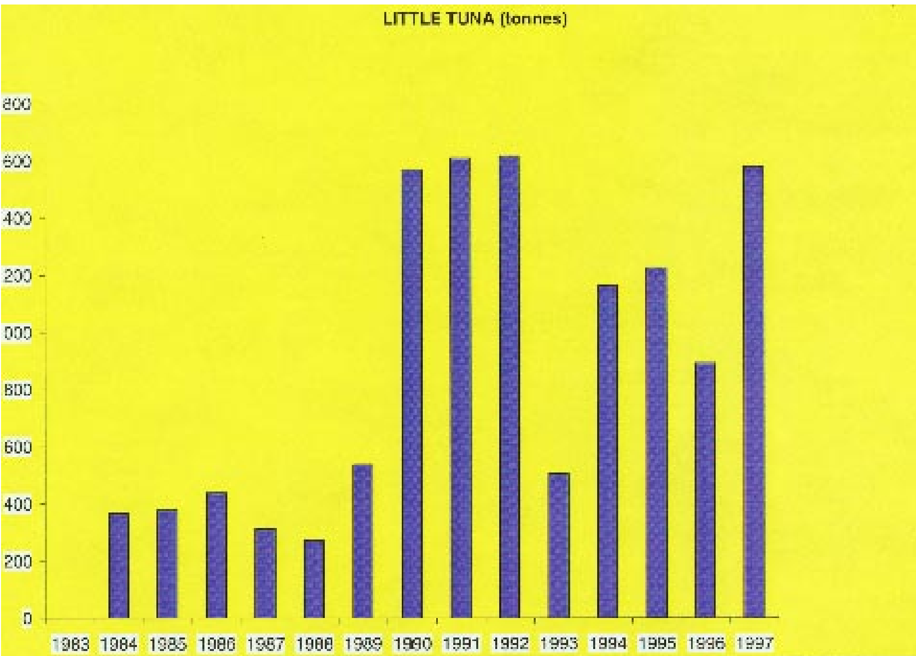
Figure 4.15
Indian mackerel (*Rastrelliger kanagurta*) catch between 1983 & 1997

Figure 4.16
Shark being landed at Al Hudaydah fish market.

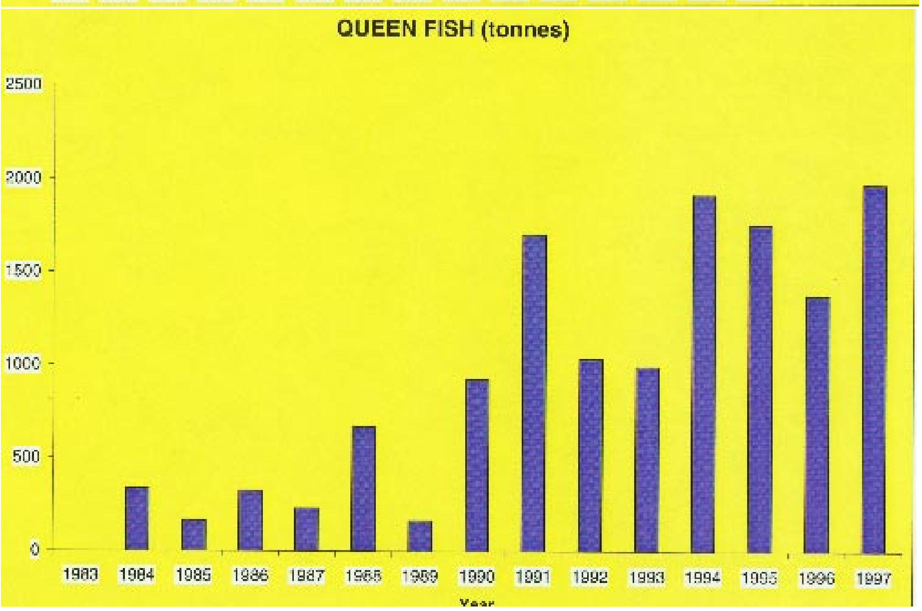
Figure 4.17
Smoking Indian mackerel (*Rastrelliger kanagurta*) near Al Khawkhah

Figure 4.18
Talang queenfish (centre) at the Al Luhayyah fish market

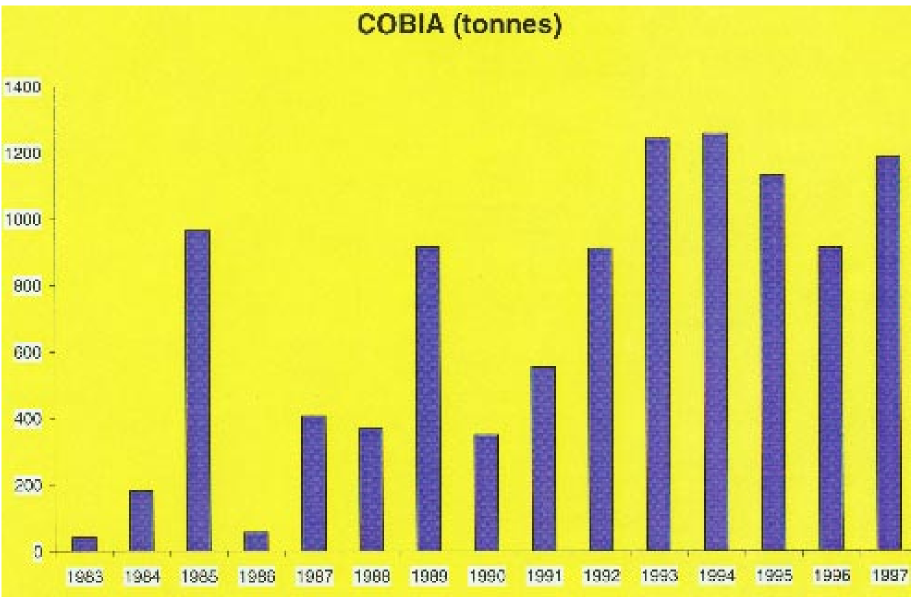
Figure 4.19
Catch of open water finfish in the period 1983 to 1997



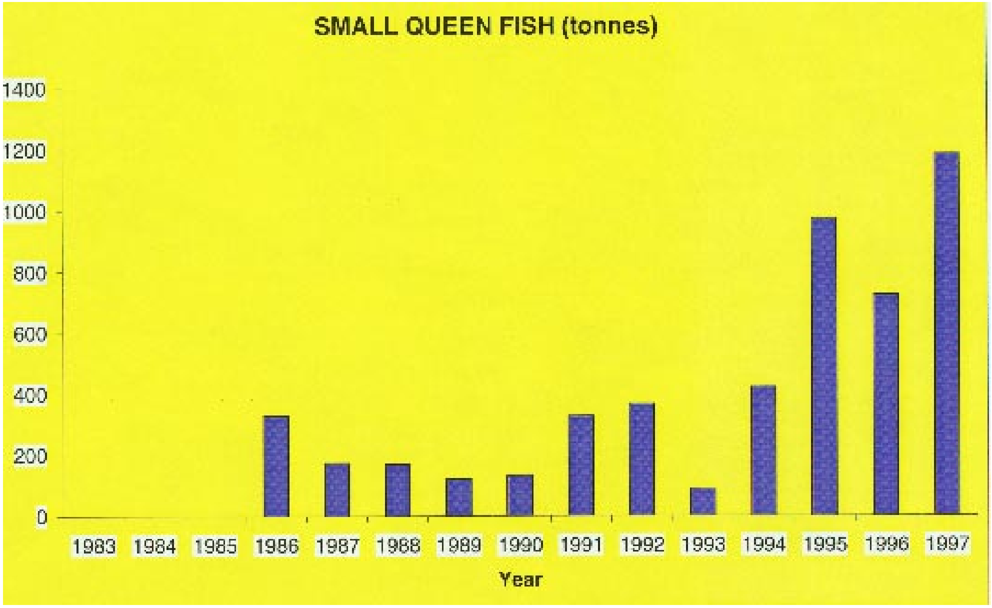
4.19a
Little tuna
(*Euthynnus affinus*)



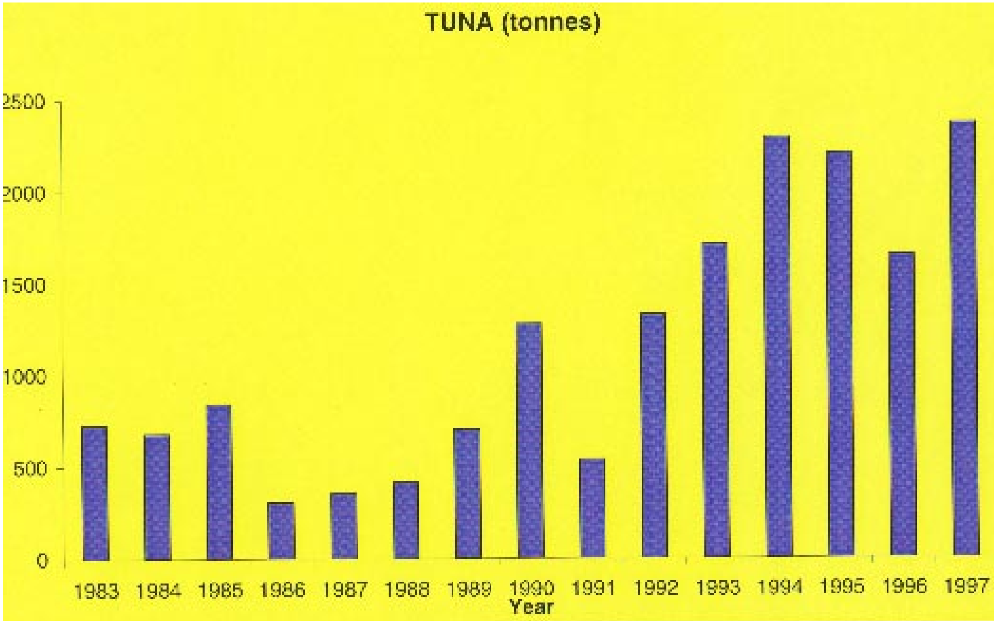
4.19b
Queenfish (*Scomberoides commersonianus*)



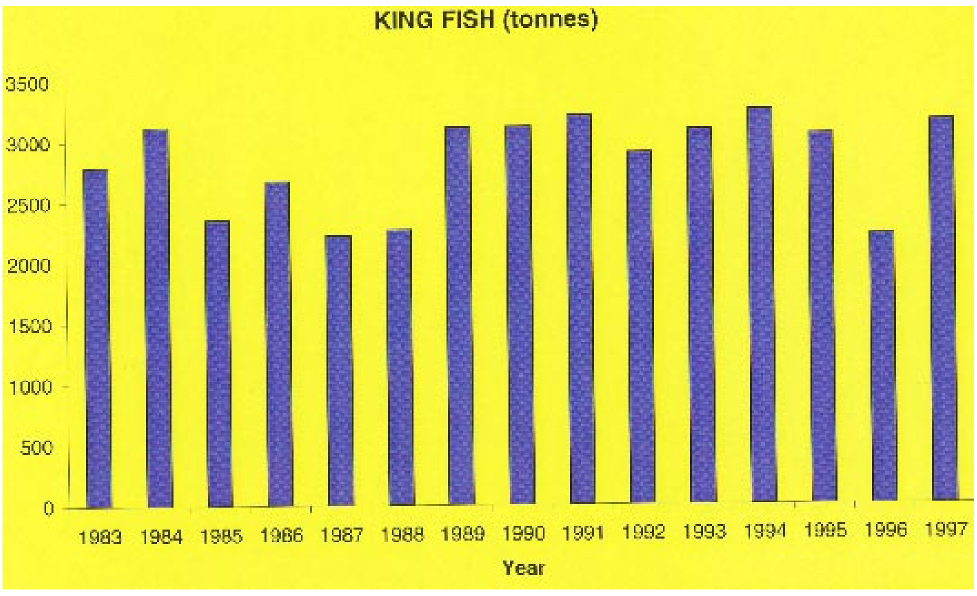
4.19c
Cobia
(*Rachycentron canadum*)



4.19d
Small queenfish
(*Scomberoides* spp)

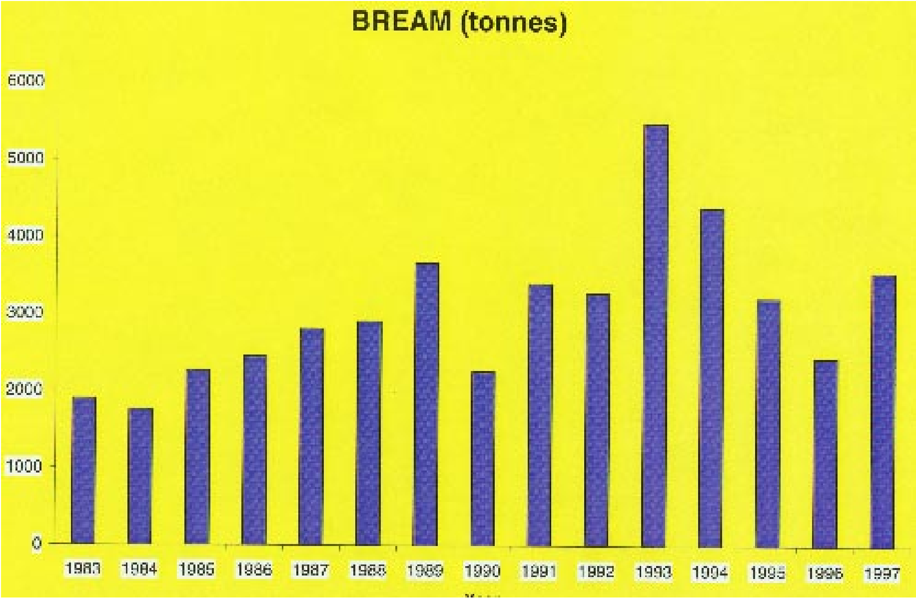


4.19e
Tuna
(*Gymnosarda* spp)

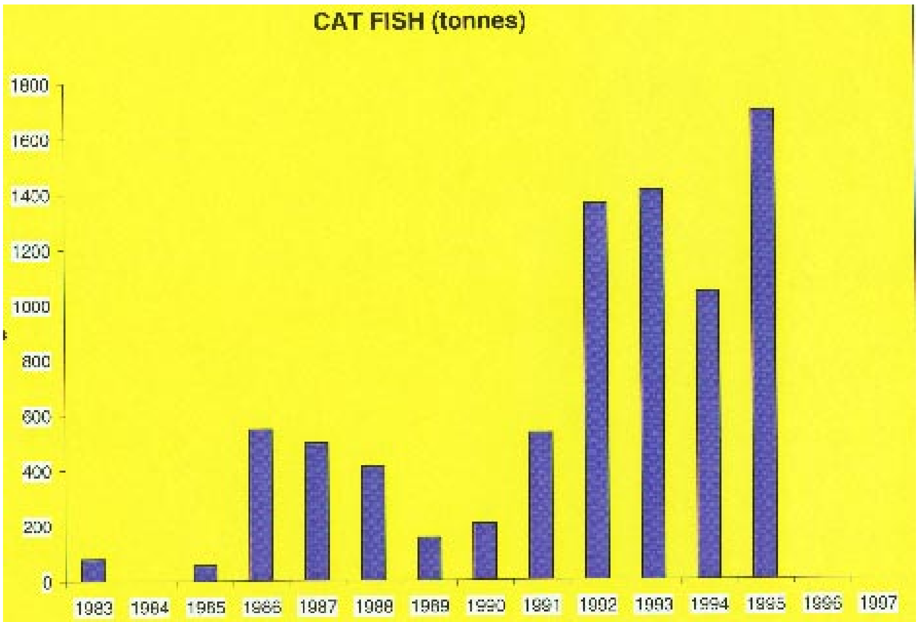


4.19f
Kingfish (*Seriola* spp)

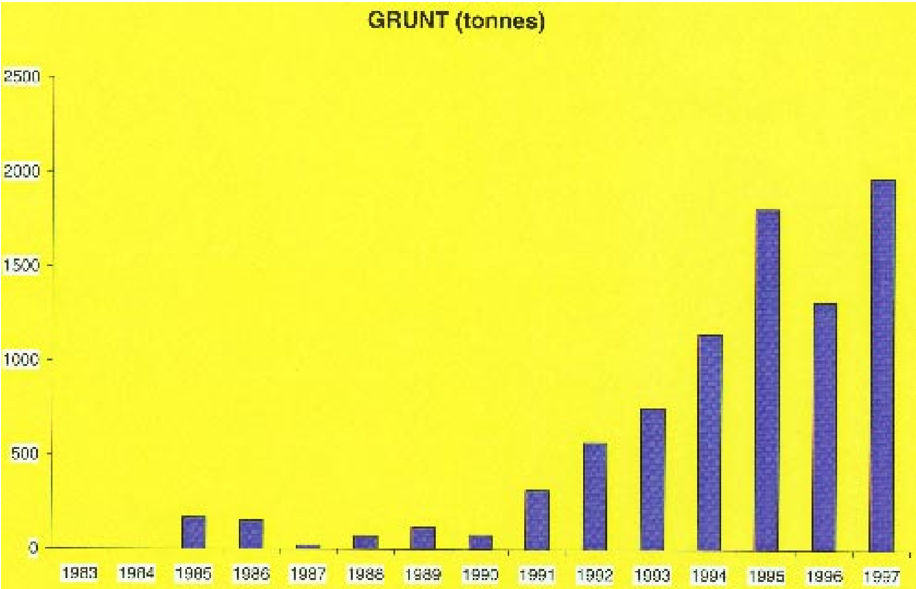
Figure 4.20
Catch of reef fish and associated groups for the period 1983 to 1997



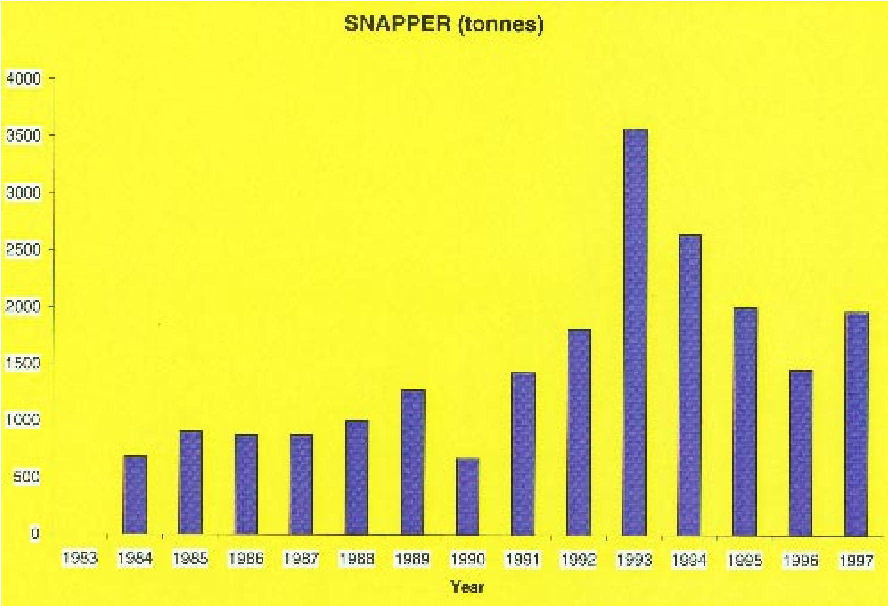
4.20a
Bream (Sparidae)



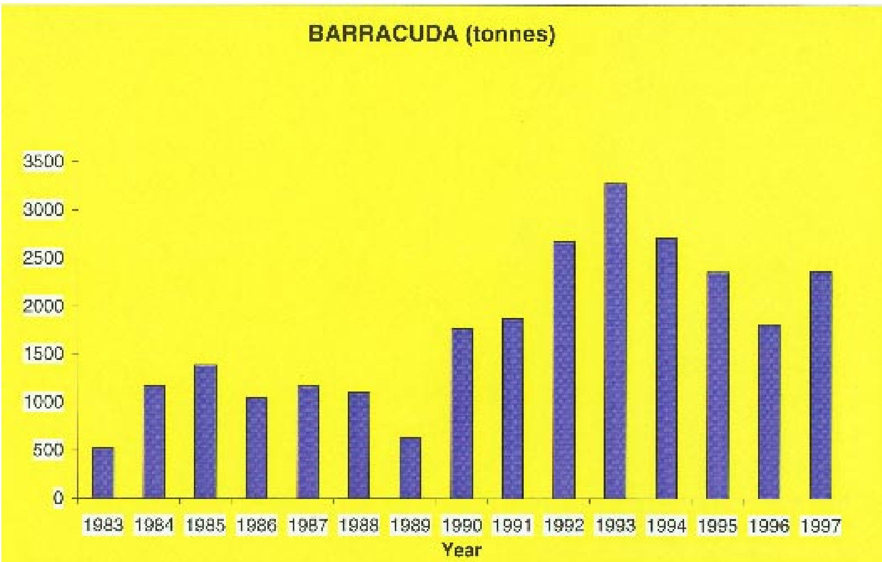
4.20b
Catfish (*Arius* spp)



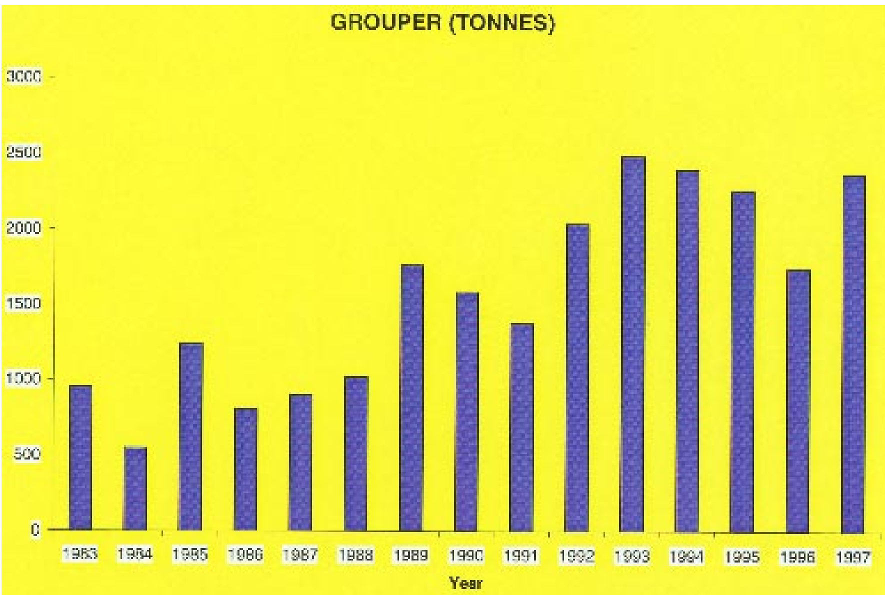
4.20c
Grunts (Haemulidae)



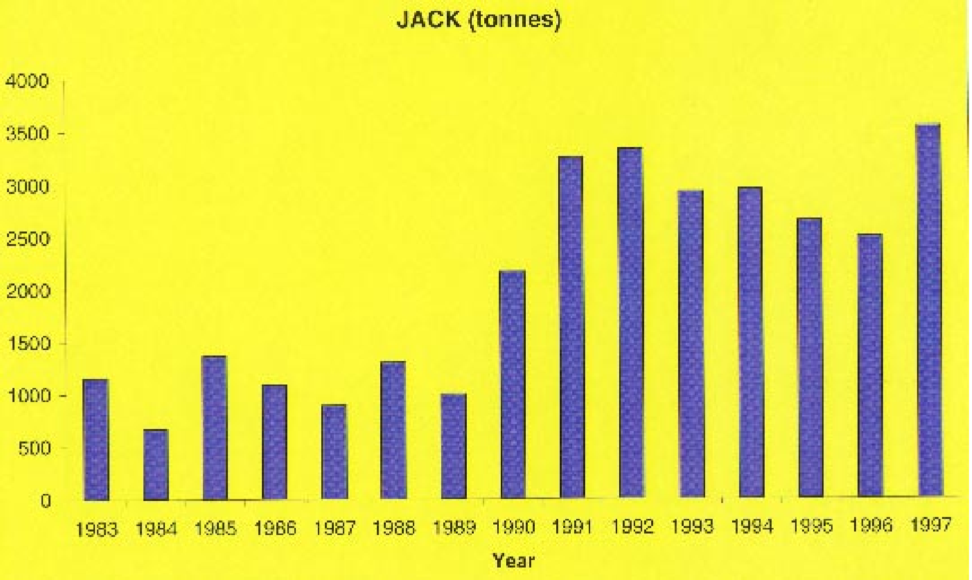
4.21d Snapper (Lutjanidae)



4.21e Barracuda (*Sphyraena* spp)



4.21f Grouper (Serranidae)



4.20g
Jacks (Carangidae)

the assessment of shark catch, resulting in some inability to record the two 'halves' of the catch.

Indian markerel is very important for the fishermen along the coast as it forms a cheap human food for poor coastal people and is also used as bait for other species of fish such as bream and grouper. It is often put through a smoking process and used as an export to the mountain parts of Yemen as well as sold locally (Figure 4.17). The annual average production is 3,618 tonnes but catch has declined sharply after 1991 (Figure 4.15) as fishermen moved to more profitable fish species.

Other important open water finfish include tunas, kingfish, cobia and queenfish. Catch of a number of these species has increased in recent years with investment in boats and marketing facilities. Figure 4.19 shows the temporal change in catch of these species. The Talong queenfish (*Scomberoides commersonianus*) is a particularly sought after species for the market (Figure 4.18).

Coral reef and reef-associated fish

Catches of most of the fish associated with coral reefs have increased significantly in recent years. As a result the total reef catch has also increased (Figure 4.21).

The catch of the important reef fish groups are shown in Figure 4.20 for the statistical period.

Barracuda, especially the schooling types, such as Barracuda querie, are an important component of the high-market value species (Figure 4.22)

Conclusions

There were substantially increased catches in most of the main fished species in the Yemen Red Sea for the period following the increase in fishing infrastructure of the mid-1980s. Since the early 1990s catches have stabilised and may have reached or exceeded sustainable levels. For reef fish the signs of heavy fishing of the top predator trophic layer are already apparent. Heavily fished reefs can be recognized by low numbers of

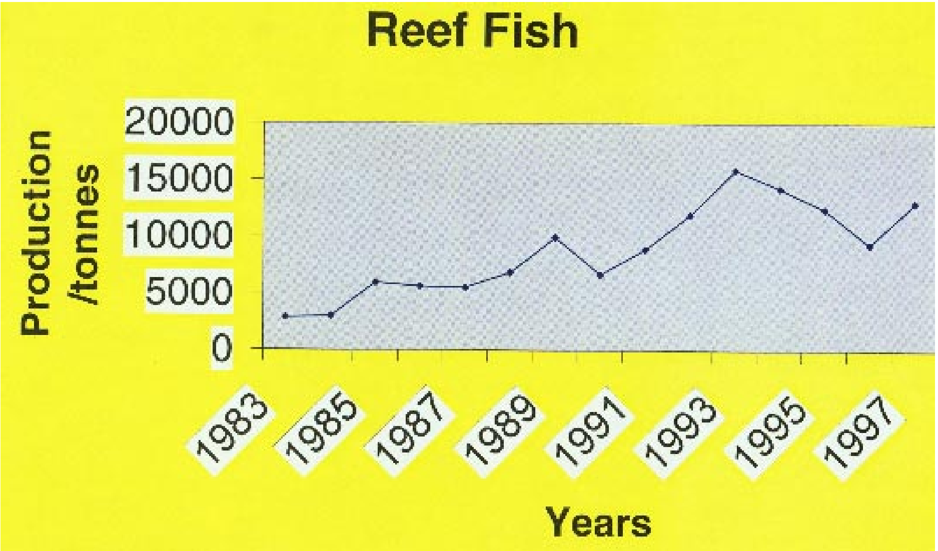


Figure 4.21
Total reef fish catch in the period 1983 to 1997

large snappers and medium sized groupers (Craik, 1981). Yemen Red Sea reefs show exactly this pattern, with only the small species of serranids such as *Epinephelus summana* common, low visible numbers of large lutjanids and lethrinids and very few sharks of any type. Little evidence of damage to reefs from gill nets, either in normal useage or from 'lost' nets, was observed, in contrast to Oman where such damage forms a major impact on coral reefs (Al-Jufaili et al. 1998).

Visual surveys are useful to confirm catch and effort estimates of fish stocks and abundance (Connell et al. 1998). Visual surveys support the catch data of handline-caught species in the Yemen Red Sea and reinforce conclusions as to the stock of these groups left on reefs. There remain, however, high levels of fish biomass on reefs, with substantial schools of fish such as acanthurids, scarids, fusiliers and small lutjanids. It appears exploitation has not extended to the Malthusian overfishing situation seen in many parts of southeast Asia (McManus, 1997), where destructive fishing techniques that destroy the fisheries resource base are commonly used (McManus et al. 1997). Overfishing of reef fish may also lead to major effects on the composition of reef fish species (Bohnsack, 1993; Jennings and Polunin, 1996, 1997; Jennings et al. 1995), on populations of reef invetebrates such as urchins (McClanahan, 1994), on reef processes (Jennings and Lock, 1996) and may reduce the ability of reefs to recover from natural destructive occurrences such as storm damage and bleaching (Roberts, 1995).

The anecdotal evidence of Yemen Red Sea fishing conditions add to the unease about the future of fishing in Yemen. Experienced observers such as Jones (1998) reports large areas of dead floating bycatch, large catches of sharks, with only the fins removed and the rest discarded, uncontrolled aquarium fish collection and expanding intensive commercial prawn trawling. Commercial observers have also expressed alarm about the dangers to Yemen fish stocks from uncontrolled and illegal fishing (*Yemen Times*, 1998).

Acknowledgements

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Thanks goes to the Yemeni Ministry of Fish Wealth, The Great Barrier Reef Marine Park Authority Library, Jerry Kemp, David Wachenfeld, Phillip Jones, Garry Maxwell, Murtada Alwan, David Haynes and David Bellwood.

Figure 4.22
Barracuda at the Al Hudaydah fish market.

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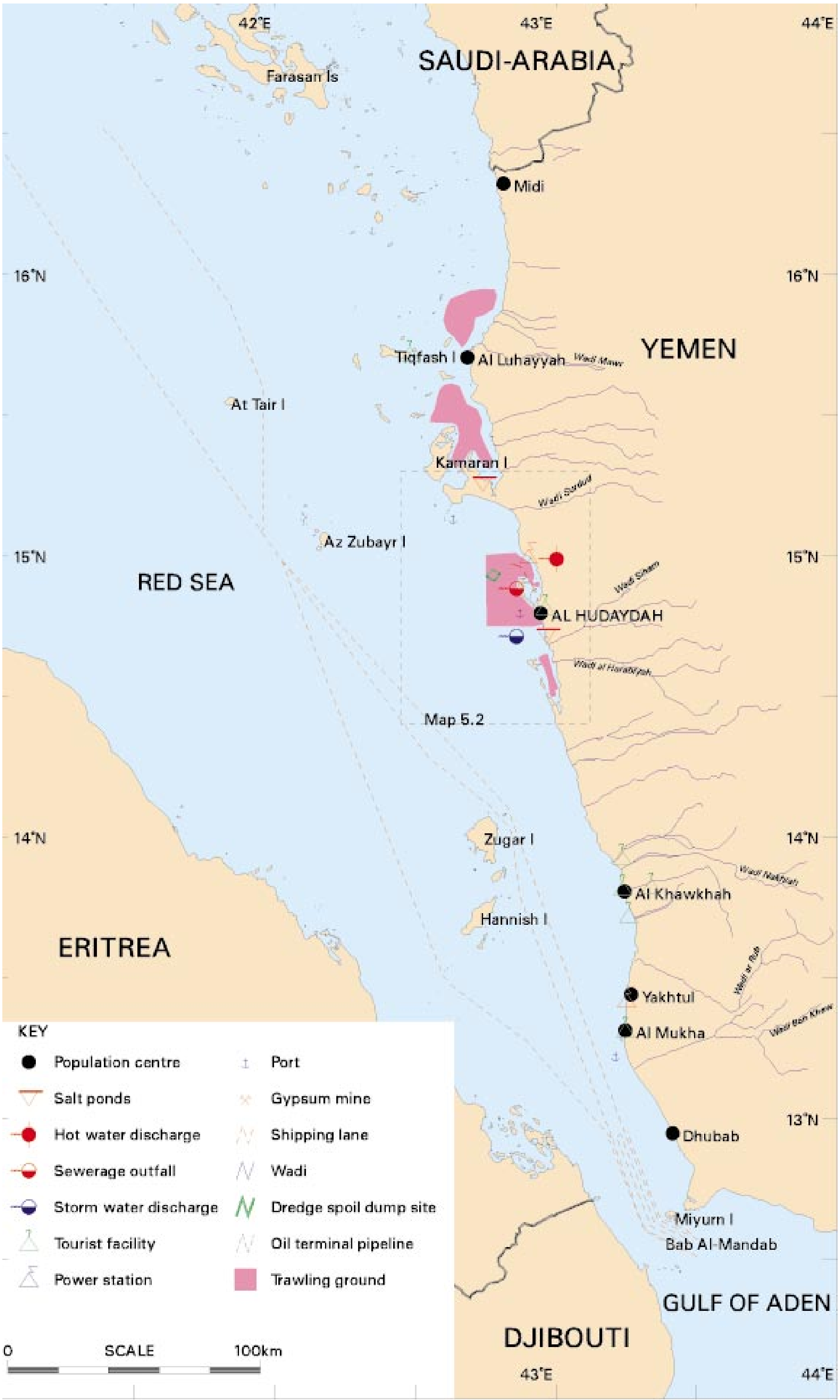

Figure 5.1 Human activities along the Red Sea coast of Yemen.

Chapter 5

Threats to Marine Organisms and Habitats of Yemen's Red Sea

JON BRODIE and EMRE TURAK

Introduction

The Red Sea coast of Yemen extends about 730km along the eastern side of the Red Sea from the town of Midi in the north to Bab Al Mandab in the south. A large number of islands lie off the coast out to a distance of about 100km. They are generally uninhabited apart from Kamaran and Fasht, which have substantial permanent populations. Other islands, particularly mid-Red Sea islands such as Az Zubayr Island, have military garrisons. Population on the coast is scattered, with the major concentrations near wadi (ephemeral river) mouths, port towns and fishing centres. The only city is Al Hudaydah, population about 300,000. Other towns on the coast, such as Midi, Al Luhayyah, As Salif, Al Khawkhah and Al Mukha, have populations less than 10,000. Al Hudaydah is also the major Red Sea port for Yemen, but oil is exported through the offshore facility to the north-east of Al Hudaydah at Ras Isa. About 16,000 ships pass Yemen Red Sea coastal waters per annum. There are smaller ports at As Salif and Al Mukha. Other industrial facilities on or near the coast include the power stations at Ras Kathib (north of Al Hudaydah) and Al Mukha, the gypsum mine and loading facility at As Salif, and a number of small evaporative saltworks. Major fishing centres and coastal tourism facilities are shown in Figures 5.1 and 5.2.

The waters of the Yemen Red Sea are hotter and more saline than most tropical waters. Water temperatures range between 30ºC offshore to 38ºC inshore in semi-enclosed bays during summer (April to October) and in winter are about five degrees cooler. Water from the Gulf of Aden upwells at Bab Al Mandab, providing cooler waters and sharper temperature gradients around Miyurn Island and adjacent mainland. The northern Red Sea is highly saline but Yemen's waters have only slightly elevated salinities. These range from about 36.5‰ in the Bab Al Mandab to 38‰ near Midi.

In many ways the Red Sea marine environment of Yemen is typical of tropical coastal marine environments worldwide. Near Midi the continental shelf extends 100km offshore while in the south it reaches less than half this distance. Beyond the shelf edge are islands rising out of 200-1000m deep water. Mangroves edge long stretches of the coast with seagrass meadows forming a band behind a coral and algal reef zone. Coral reefs and coral communities grow on rock fringing the islands. Some islands have small areas of mangrove and seagrass. Significant populations of pelagic, demersal (both reef and 'soft bottom') and mesopelagic fish occur and these are fished by both artisanal and commercial means. However, Yemen Red Sea environments are set apart from tropical coastal environments elsewhere by a number of contrasting factors.

Yemen lacks true river systems that have regular discharge to the sea. While Arabian wadis may flow in periods of exceptional rainfall, discharge to the sea is uncommon. Thus no true estuarine systems exist with their complex and diverse mangrove communities. Instead, mangrove forests in Yemen form thin bands along the coast, dominated by *Avicennia marina*. However, wadis may still

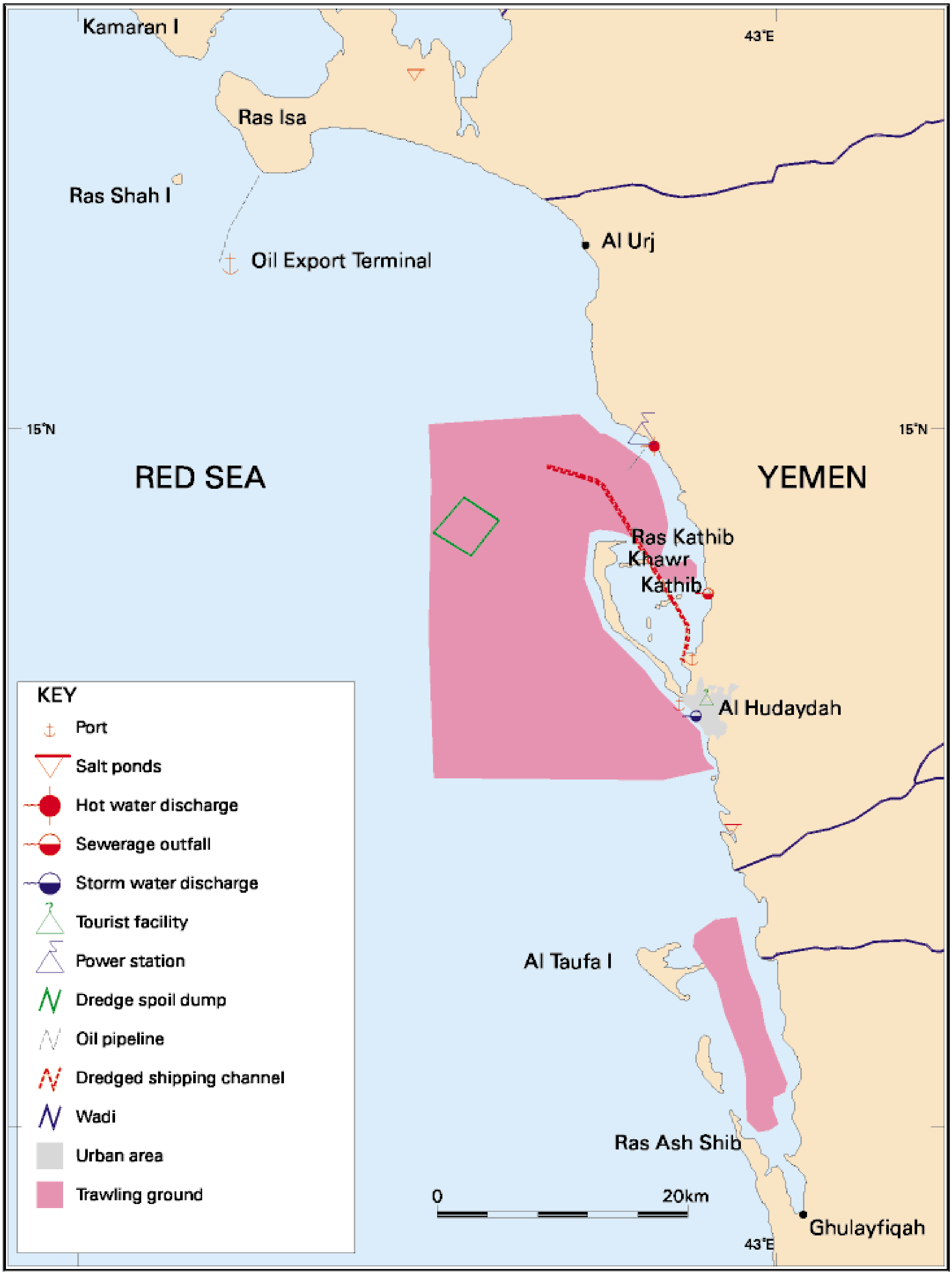

Figure 5.2 Human activities between Ras Isa and Gulayfiqah

influence coastal habitats through regular groundwater discharge and through sediment discharge in rare flood events.

Inshore waters of the Yemen Red Sea are significantly hotter than inshore tropical waters worldwide. Seagrass and coral communities have adapted to the high temperatures along the Red Sea coast of Yemen, so these ecosystems may function differently from their counterparts in other regions of the world. For example, in Yemen there is a predominance of coralline algal reef communities, with presumably lower reef productivity and reduced reef accretion. Red Sea reefs in general appear to have relatively low commercial fish catches and fish productivity (Sheppard et al. 1992).

Potential threats to the Yemen Red Sea environment can be assessed by establishing the impacts found on similar environments in other parts of the world and making appropriate comparisons. Assessments of anthropogenic impacts on tropical marine environments have been made in many areas. A selection of these studies, extending from the Pacific and Carribean islands, through south and southeast Asia to the Indian Ocean and Middle East, will be reviewed to establish a comprehensive list of impact processes.

- In Tonga, Fiji and Samoa, loss of coastal habitats, over-fishing, land-based pollution and crown of thorns starfish have affected reefs, as well as long-lived marine species such as turtles, coconut crabs and giant clams (Zann 1994).
- In Papua New Guinea over-fishing, blast fishing and sedimentation from forestry and mining waste have damaged reefs at a local scale (Huber 1994).
- Rawlins et al. (1998) documented the importance of agricultural pollution as a widespread impact in the Carribean. Reduction in the abundance of coral in the Carribean over the last two decades has been linked to over-fishing of herbivores, the loss of the herbivorous urchin *Diadema antillarum*, and mass growth of algae following cyclonic destruction of coral reefs (Hughes 1994). Corals have been unable to re-establish as there is no space for recruitment on the algal-covered substrates and few herbivores live there to crop the algae. Elevated nutrient levels from land-based sources are seen as also contributing to increased algae abundance (Lapointe et al. 1997).
- On the Great Barrier Reef, fishing (line, netting and trawling) and agricultural runoff are seen as the principal anthropogenic impacts (Wachenfeld et al, 1998) along with lesser impacts from tourism and shipping. Other large-scale threats to corals are crown-of-thorns starfish and coral bleaching (Wachenfeld et al, 1998).
- In Indonesia, Cesar et al. (1997) reported reefs suffering from poison and blast fishing, coral mining, sedimentation, pollution and over-fishing. In addition, Edinger et al. (1998) documented land-based pollution and destructive fishing practices as having led to severe widespread loss of coral reefs in the region.
- In the Philippines, similar reef destruction is associated with sedimentation, over-fishing and destructive fishing practices (Gomez et al. 1994).
- In Sri Lanka degradation of coral reefs has increased greatly in recent decades (Ohman et al. 1993). This is attributed to coral mining, sewage discharge, discharge of oil and other pollutants associated with shipping and port activities, destructive fishing practices, coastal habitat destruction, tourism, coral collecting and aquarium fish collecting.
- In Tanzania coral mining has damaged reefs (Dulvy et al. 1995).
- In Kenya disturbance of reefs is caused by over-fishing and subsequent ecosystem change, leading to sea urchin (*Echinometra matheii)* outbreaks and rapid reef bioerosion (McClanahan, 1994).
- In Oman reef damage is associated with fishing, coastal construction, recreational activities, oil pollution and eutrophication (Al-Jufaili et al. 1998). Coles and Al-Riyami (1996) also noted the extremely high levels of beach tar concentrations on the Omani coast.
- In Saudi Arabia an integrated environmental assessment of the Red Sea coast used the human use/impact categories of oil, litter (including solid waste and pollution), coastal development and fishing, as assessment factors (Price et al. 1998).
- In the Red Sea the corallivorous gastropods, *Drupella* spp. and *Coralliophila* spp.are seen as significant factors in coral reef degradation that may be associated with coral diseases (Antonius and Riegl 1997). Coral diseases, probably linked to combined stresses on the coral, are becoming more common in some parts (Antonius 1988).

In their review of the human impacts of tropical marine ecosystems Hatcher et al. (1989) identify sedimentation, pollution (chemical, sewage, thermal and radioactive), hydrodynamic influences, physical disturbance, extractive activities, exotic introductions, tourism and combination of impacts (synergism) as major threats to coral reefs. They identify woodcutting, aquaculture, change to the hydrological regime and oil spills as the most important threats to mangroves. In seagrass areas, dredging and filling, sedimentation, eutrophication and oil spills are listed as the principal threatening processes (Hatcher et al. 1989). Overfishing, destructive fishing and land runoff of freshwater, sediment and pollutants are seen by Done (1995) as the principal issues for remediation of degraded coral reefs.

On a global scale, concerns are also being raised about the long-term effects on coral reefs of climate change. Wide scale bleaching of corals, often followed by mortality, has occurred world-wide over the last 15 years. Glynn (1991) believed that this may be linked to the greenhouse effect and global climate change. In addition, increasing concentrations of carbon dioxide in the surface ocean may cause decreasing calcification in organisms such as coral, coralline algae and molluscs.

From the above synopsis a comprehensive list of anthropogenic threats can be made for use in a risk assessment for the Yemen Red Sea. Similar assessment schemes, using numerical scoring systems, have been devised for global coral reef status (Wilkinson et al. 1997). The resulting list, as shown below, was used to guide the environmental threat assessment documented in this section.

Anthropogenic threats	**Ecosystems and species at risk**
Oil and related industries	Seagrass, mangroves and salt marsh (sabkhah)
Shipping and harbour activities - harbour dredging and spoil dumping - ballast water discharge	Seagrass, mangroves and coral
Fishing - fisheries stock damage - environmental effects of fishing	Fish stocks
Urban development - coastal development - sewage discharge - stormwater discharge - litter	Seagrass, mangroves, coral, beaches and sabkhah
Catchment pollution - sediment yield to wadi mouth - discharge of agriculture chemical residue	Seagrass, mangroves and coral
Coastal grazing	Mangroves
Tourism - coastal development	Mangroves and coral
Coastal industry - power stations - saltworks	Seagrass, mangroves, coral and sabkhah
Global climate change	Coral
Coral Predators	Coral

Oil and Related Industries

The effects of major oil spills on tropical marine habitats were assessed following the 1991 Gulf War oil spills (Price and Robinson 1993; Readman et al. 1996; Jones et al. 1998; Al Muzaini et al. 1998; Randolph et al. 1998; Watt et al. 1993). The effects were most severe and long lasting on intertidal ecosystems in enclosed and semi-enclosed waters with poor flushing characteristics. The most severely impacted habitats were algal mat communities similar to the sabkhah communities of Yemen's Tihama. Loss of mangroves has occurred at some sites. Shrimp stocks also declined catastrophically. In general, seagrasses, coral reefs and fish showed little short-term degradation. Overall, damage to the sub-tidal marine ecosystem was less than expected.

Oil contamination has decreased rapidly since the Gulf War oil spills (Readman et al. 1996). This is attributed to high microbial activity, due to high temperatures, and high rates of photo-oxidation from intense solar radiation. The growth of algal mats, bioturbation, drying and peeling appear to be the principal stages in the biodegradation of oil (Jones et al. 1998). After four years biodiversity in most communities is similar to unaffected areas, with up to 90% recovery in mangrove communities (Jones et al. 1998). Further, mangrove seedlings have established next to trees killed by the spill. Good recruitment of species with planktonic larval stages has occurred showing that the water column is no longer toxic to plankton. Species without planktonic larval stages have been slower to recover. Recovery has been slowest in the saltmarsh areas.

In the northern Red Sea the mangrove *Avicennia marina* survived an oil spill at Geisum Island near Hurghada, Egypt (Dicks 1986). The mangroves survived despite their pneumatophores being covered by oil.

In tropical areas, such as the Arabian Gulf, recovery of coastal environments after oil spills is more rapid that in colder climates. While this may provide some reassurance for potential oil spills in the Yemen Red Sea, a large oil spill in the Ras Isa area can still be expected to have catastrophic effects on the nearby inshore coastal environment.

Oil pollution detected along the coast of Yemen has included tar balls on beaches near Ras Isa, Ras Al Kathib, Al Khawkhah, Al Mukha and Al Urj, and oil residues in water, sediments and biota. During the Yemen Project tarballs were documented on foreshore areas:

- north of Al Hudaydah in April, 1996
- north and south of Al Khawkhah, 1997
- near Al Fazah in December, 1997
- at Miyurn Island in March, 1998
- Al Murk Island in May, 1998.

Potential sources of oil contamination along Yemen's coast include:

- ships passing through the Red Sea
- the oil export terminal at Ras Isa
- petroleum unloading operations in Al Hudaydah, Al Mukha and the Ras Al Kathib Power Station
- shipping operations in the Al Hudaydah port area
- oil derived from land runoff or groundwater discharge.

In addition, there is potential for significant environmental damage in the event of an oil spill from the Marib-Ras Isa pipeline, where it crosses the sabkhah on the As Salif peninsula (Pencol 1992).

In Yemen, harbours are regulated and managed by harbour authorities, while the oil companies manage oil terminals. Oil spill response is coordinated through the Public Corporation for Maritime Affairs (Det Norske Veritas 1996). Yemen has not yet ratified MARPOL 73/78, the international convention controlling discharges from shipping.

The Red Sea shipping route carries approximately 60 ocean-going commercial vessels per day, of which 20% are oil tankers (Haskoning 1991). One hundred million tonnes of oil transit the Red Sea annually. The Red Sea is defined as a special area under MARPOL where more stringent requirements for the discharge of waste water are required. Anecdotal evidence suggests some vessels may use Yemen waters for tank washing of oily waste water in contravention of MARPOL. This practice is likely to be exacerbated by the absence of any surveillance or enforcement presence in Yemen waters. While operational losses of oil from vessels are probably small, the traffic does present a potential for a large oil spill in the event of an accident in the area. So far, no large oil spill has been recorded in Yemen Red Sea waters. The only large spill in the region occurred in 1989 near Jeddah, Saudi Arabia, from the vessel *Kachenjunga.*

The Ras Isa marine terminal is located on the As Salif peninsula north of Al Hudaydah. Oil is received through the Marib-Ras Isa pipeline at the rate of 165,000 barrels/day and stored in the *Safir*, a 409,000 tonne supertanker converted for storage (Figure 8.2).

Safir sits about 10km offshore, at the end of the seabed pipeline. Loading from *Safir* to export tankers occurs via tandem mooring or, in heavy wave conditions, via floating hoses at a distance of 100m. Crude oil export tankers are normally less than 100,000 tonnes, and approximately 80 tankers use the facility annually (Det Norske Veritas 1996). The terminal has no waste reception system. Some chronic pollution of areas adjacent to the seabed pipeline and loading operation may occur, but the principal concern at this site is the potential for a catastrophic spill from the *Safir* or an export tanker due to collision, fire, storm or warfare.

In the event of a spill of up to 400,000 tonnes the prevailing southerly winds and currents would drive the oil north into the area around Kamaran Island and inshore coastal areas. This area contains extensive coral reef, seagrass, mangrove and sabkhah communities and valuable finfish and shrimp fishing grounds. The modelled spread of an oil spill from the *Safir*/Ras Isa operation of 10,000 tonnes in the prevailing wind and current regime of the area is shown in Figure 8.4.

To minimise the threat of oil spill from the Ras Isa terminal, staff undertake regular infrastructure inspections and have developed an oil spill response plan (Pencol 1992). Oil spill containment equipment kept at the terminal includes:

- a store of dispersants
- an oilspill barge (8,000 barrels capacity)
- containment booms and skimmers.

Regional oil spill response equipment is stored at Djibouti but there is some question as to the organizational capability to mobilize this equipment in the event of a major spill. In any case, a satisfactory response capability for a spill of the maximum possible for this site (~400,000 tonnes) or even a smaller spill (>10,000 tonnes) is at present not technically possible anywhere in the world in coastal areas. If a spill of this magnitude occurred near Ras Isa most of the oil can be expected to move into the area mentioned above, with little possibility of containment or removal.

Petrol, kerosene, aviation fuel and liquefied petroleum gas are imported and distributed through the port of Al Hudaydah (Pencol 1992). The product lines run along the seabed from the jetties to the storage facilities. Bulk products are stored in a large tank depot. Some potential for small spills of refined products from leaks in the seabed lines exists, but such leaks are apparently quickly repaired and pose little threat to marine habitats outside the harbour.

The Al Hudaydah and Al Mukha power stations are located on the coast (Figure 5.3) and receive fuel oil through undersea pipelines from a single mooring close to the shore. Anecdotal reports of small oil spills from coupling/uncoupling operations and from underwater pipe leaks have been made (Pencol 1992). These spills may contribute to the elevated concentrations of petroleum hydrocarbons found in coastal waters and sediments (Rushdie et al. 1991).

On land, used engine oil (sump oil) is dumped on the ground adjacent to service centres (Al-Kahlani, 1991). Lubricant oil use is estimated at 33,000 tonnes per annum with a waste of 25,000 tonnes. Waste oil collected per annum amounts to 4,400 tonnes with some reused as a fuel at local cement works. Considerable potential for contamination of groundwater by waste oil residues exists in coastal areas. However movement of this oil through the groundwater and eventual discharge to the sea is unlikely to be a significant threat to the marine environment.

Figure 5.3
Power station north of Al Hudaydah.

Shipping and Harbour Activities

Harbour dredging and dredge spoil dumping

Dredging and dredge spoil dumping has caused damage to coral reefs and seagrass beds in many parts of the world (Bak 1978; Amesbury 1981). In Jamaica, dredging and spoil dumping led to severe degradation of nearby fringing reefs (Dodge and Vaisnys 1977). Adjacent seagrass beds or coral reefs are affected by increased turbidity, and associated light loss, and sedimentation. When well managed, dredging and spoil dumping operations can be restricted to minor impacts on adjacent ecosystems, as shown in the Townsville harbour operation in Australia (Benson et al. 1994).

Al Hudaydah harbour and the entrance channel are dredged, and dredge spoil is removed to an offshore spoil dump (Figure 5.2). During the Yemen Project, sites surveyed near the Al Hudaydah shipping channel had extensive cover of seagrass. This superficially suggests that extensive damage from dredging has not occurred. A systematic monitoring programme would be required to show the extent of any damage.

Ballast water discharge

In old tankers, ballast water is carried in the oil storage tanks and thus may be contaminated with residual oil. When the water is discharged before oil loading commences the residual oil will also be discharged and may cause localised oil pollution. Facilities for the cleaning of oily ballast water exist at Ras Isa but these are not used and small discharges from this source are common (Pencol 1992). Much of the chronic oil pollution noted in the southern Red Sea is believed to be associated with deballasting.

Near Yemen’s border with Saudi Arabia high concentrations of oil have been detected in open waters (Awad 1988). North of At Tair mean concentrations of 785µg/l of oil were detected, while inshore, near Midi, a mean of 72µg/l was found. In Yemen waters between Al Mukha and Midi concentrations between 40-713µg/l have been detected (Rushdie et al. 1991). Studies of dissolved/dispersed hydrocarbons in the waters of the southern Yemen Red Sea, the Gulf of Aden, Arabian Sea, Gulf of Oman and southern Arabian Gulf (DouAbal and Al-Shiwafi, 1998) showed concentrations in the southern Red Sea of <0.1 to 33µg/l with a mean of 16µg/l. The mean concentration was significantly lower in the southern Red Sea than in the other regions studied.

Ballast water may contain organisms from the waters of the port where it was taken onboard. These organisms are then discharged along with the ballast water at the next port. Exotic organisms, introduced via ballast water, have caused major ecological disruptions in the Black Sea (the ctenophore *Mnemiopsis leiydi*), southern Australia (northern Pacific starfish and Mediterranean tubeworms) and the American Great Lakes (Zebra mussels). Disease organisms such as cholera may also accompany ballast water. No assessment of such risks to Yemen’s ports has been made but with the discharge of considerable quantities of ballast water at Al Hudaydah and Ras Isa the risk is present. Most organisms capable of surviving in the high water temperatures and salinities of the Yemen Red Sea would have originated from similar Indo-Pacific tropical waters and may not be easily detected as introductions to the Red Sea. Fortunately they are also less likely to cause major ecological disturbance in the already highly diverse tropical ecosystems in coastal Yemen.

Figure 5.4
Small fish at Al Luhayyah fish market.

Fishing

Fisheries stock damage

In almost all parts of the world, fishing is the activity that causes most damage to marine and coastal ecosystems. In the Carribean, Southeast Asia and eastern Africa over-fishing and destructive fishing practices have contributed to reef destruction. Over-fishing may have a variety of stages, from growth to Malthusian (McManus 1997), with varying levels of effects on local ecosystems and the fish stocks. When explosives or poisons are used for fishing, large-scale destruction of coral reef systems occurs. In the Arabian region, fishing activities leading to degradation of reefs and fish stocks have been reported from Oman (Al-Jufaili et al. 1998) and Egypt.

In Yemen Red Sea waters catch of 'reef' fish (grunts, bream, groupers and snappers) increased from 5,100 tonnes in 1988 to 8,000 tonnes in 1992. Catch of fish more loosely associated with reefs (sharks, jacks, barracuda) increased from 3,100 tonnes to 12,200 tonnes in the same period (Rushdi et al. 1994). The catch of pelagic fish rose from 12,400 tonnes to 14,200 tonnes. A longer data set for the total Red Sea catch (Al Sorimi, 1998) shows catch rising from about 18,000 tonnes in 1983 to 40,000 tonnes in 1994 and thereafter stabilizing at this level to 1997. There is little evidence that such catch rates can be sustained. Catches of some species, such as the Indian mackerel (*Rastrelliger kanagurta*), have shown a steep decline in recent years, but it is not known whether this is in response to over-fishing, a reduction of fishing effort or natural perturbation.

Figure 5.5
Sharks at the Al Hudaydah fish market.

At Yemeni fish markets, large catches of very small (<15cm) Lethrinids and Lutjanids were often observed (Figure 5.4). Fishing these species at this size may eventually have damaging effects on stocks. Large catches of shark of a variety of species were also regularly seen (Figure 5.5) at the Midi, Al Mukha and Al Hudaydah fish markets.

This contrasts strongly with the underwater surveys where few sharks were observed. Jones (1998) also reported large catches of sharks in Yemen's fish markets. He also noted that many sharks are caught only for their fins. This was evident by the large number of finless shark carcasses he found on Uqban Island. Similarly, members of the Yemen Project found large numbers of finless shark carcasses near Al Khawkhah. Overnight netting for sharks also lead to considerable mortality of bycatch species such as rays and turtles. During the Project, reef surveys recorded low numbers of medium and large sized groupers, snappers, grunts and sharks.

A number of aquarium fish export businesses operate in Al Hudaydah. The fish are caught offshore from Al Hudaydah and as far offshore as Az Zubayr Island (Jones, 1998). The species collected and exported include chaetodontids, pomacanthids, pomacentrids, scorpionids and labrids. The sustainability of this industry with regard to the available stocks has not been assessed. In other parts of the world cyanide is used for aquarium fish collection, causing extensive damage to the rest of the reef system (Pratt 1996). It is unknown whether cyanide is used in Yemen waters. Clownfish (*Amphiprion* spp. which live in a relationship with anemones) are a particular target of aquarium fish collection and anemones on reefs in areas around Kamaran Island and the islands to the north-west (including Al-Badi and Uqban) have been largely stripped of their clownfish (Yemen Project results: J. Kemp and P. Jones, pers.obs.). Kemp (pers.comm.) has documented a possibly new species of clownfish from this area, similar to, but distinct from, *Amphiprion bicinctus.* He also notes that this species is a prime target of the Al Hudaydah-based aquarium fishery.

Environmental effects of fishing

Fishing vessels from Egypt (Figure 5.6) are licensed to fish in Yemeni waters.

Anecdotal reports of Egyptian fishing vessels 'destroying' coral reefs in Yemen waters are common. Reasons given for such destruction included trawlers working too close to the tops of reefs and deliberate damage to prevent Yemen reef tourism competing with Egyptian reef tourism. In the absence of any substantive evidence for these accounts they must be viewed with some scepticism. No reef damage of this type was seen during the Yemen Project.

However, the more usual effects of fish and shrimp trawling are likely to occur. Jones (1998), in his notes on fishing in Yemen in 1997/98, observed 50-60 Egyptian 'Suez-style' fishing boats operating north of Al Hudaydah. He reported large areas covered with bycatch. Floating bycatch was also noticed near trawlers during the Project. Shrimp and fish trawling often net up to 90% bycatch, which may result in long term effects on marine ecosystems. Trawling may also damage benthic ecosystems through the continued action of heavy trawl gear on the bottom (Watling and Norse, 1998). The shelf waters of Yemen appear to contain large areas of complex bottom structure and trawling may be causing damage to these areas. These areas are often important habitat for commercially important fish such as *Lethrinus nebulosus* and sharks.

Trawling and net fishing may also trap turtles as bycatch (National Research Council 1990). In the past, bycatch of turtles was believed not to be a serious problem in Yemen (Hillestead et al. 1981), but with increasing levels of trawling and net fishing this may no longer be the case. Turtles are not harvested to a large scale in Yemen Red Sea waters (Walczak

Figure 5.6
Egyptian trawler north of Tiqfash Island.

Figure 5.7
Building constructed of coral.

1977) although exploitation in the Gulf of Aden was high in the past (IUCN/UNEP 1985). Walczak (1977) recorded the Green Turtle (*Chelonia mydas*), Hawksbill (*Eretmochelys imbricata*) Olive Ridley (*Lepidochelys olivacea*) and the Leatherback (*Dermochelys coriacea*) from Yemen. Turtles were recorded mostly in the shallow areas north of Al Hudaydah where they nest on islands. Coastal people frequently eat turtle eggs, but turtle flesh is rarely consumed (Walczak. 1977). Significant turtle breeding sites occur on islands of the Red Sea coast of Yemen (Ross and Barwani 1981).

Inshore gill net fishing has been shown to have serious effects on coral reefs in Oman (Al-Jufaili et al. 1998). Lost or abandoned gill nets break and abrade corals, and continue to entangle fish and other mobile animals. No evidence of this type of damage to Yemen Red Sea reefs was observed during the Yemen Project. Gill netting is practised but perhaps the milder sea conditions leads to loss of fewer nets.

Destructive fishing practices such as dynamite fishing, coral breaking techniques and poison fishing were not observed during the Yemen Project. Some anecdotal reports were received of explosive fishing but these could not be confirmed. Given the ready access to many types of weaponry and explosives in Yemen the absence of this type of destructive fishing is surprising.

Urban Development

Coastal development

Land reclamation for harbours, canal estates and seawalls can have major impacts on marine environments. With the exception of Al Hudaydah, there is little new urban development along the Yemen Red Sea. Most other urban areas along the coast are in decline, although there is some minor urban construction occurring in Khawbha and Al Khawkhah. In Al Hudaydah, reclamation is confined to rebuilding the city seawalls and the corniche (road adjacent to seawall) damaged by storms in 1987. The fishing-boat harbour is also being enlarged. A number of other fishing centres including Ibn Abbas and Khawbha also had small fishing harbours constructed in the 1980s. This has resulted in only minor damage to the adjacent coastal ecosystem.

Many buildings in the coastal villages on the Yemen Red Sea coast are built from coral blocks (Figure 5.7). DHV (1990) reported that coral has been widely used in construction of houses and mosques for many years in small quantities. More recently they report coral in use for road construction; this is having a devastating impact on reefs. Anecdotal reports of coral block export were also noted. However, mining of coral from living sub-tidal reefs was not seen during the Yemen Project. Most of the coral buildings inspected appeared to be built of fossil coral.

Sewage discharge

Sewage effluent, with high concentrations of nitrogen, phosphorus and organic matter, has the potential to cause eutrophication when discharged into aquatic environments (Dubinsky and Stambler 1996). Examples of coral reefs degraded by sewage discharge include Kaneohe Bay in Hawaii (Smith et al. 1981) and Aqaba in the Red Sea (Walker and Ormond 1982). High nutrient concentrations cause both phytoplankton and macroalgae to bloom and the coral reef may be overgrown by filter-feeding organisms (eg tube worms and sponges) and macroalgae. Seagrass beds may also be degraded (Shepherd et al. 1989) usually by macroalgal and epiphitic overgrowth.

A sewage treatment plant services a small proportion of the population of Al Hudaydah. Sewage from approximately

Figure 5.8
Sewage and stormwater outlet for the 'Old City', Al Hudaydah.

22,000 persons discharges into a series of eleven oxidation ponds. Treated effluent, approximately 7000m^3 per day, enters Khawr Kathib through a small channel north of the city. The sewage ponds and discharge channels form an artificial wetland that is used by large numbers of water birds. Up to 1,500 flamingos were seen in this area in April 1996.

Although Khawr Kathib contains extensive seagrass beds, no damage from nutrient enhancement was evident. Interestingly, the only occurrence of the mangrove *Rhizophora mucronata* recorded in Yemen occurs in the vicinity of the discharge point. It is possible that the fresh water sewage discharge is promoting the growth of this sensitive species that will not tolerate the normally high salinities of the Yemen Red Sea coast.

Sewage not treated by the Al Hudaydah sewage system may reach the sea through groundwater discharge, but this has not been confirmed.

Storm water discharge

Storm water discharge occurs from Al Hudaydah and large towns on the coast. In Al Hudaydah a storm water/sewage drain empties from the old section of the city directly into the sea (Figure 5.8). This was seen to flow during heavy rain in June 1996, but the volume was small. Storm water enters the sea adjacent to popular swimming beaches. Because of the low rainfall along the coast, pollutant transport to the sea from stormwater runoff is likely to be small and more of a public health concern than of ecological significance.

Litter

Lost and discarded material, whether originating from land or from ships, is now recognised as a major form of marine pollution (Laist 1996). Litter can affect marine species by entanglement or by ingestion. Entanglement is a problem for many groups of marine organisms, such as turtles, birds and marine mammals. However, even sessile organisms, such as corals, may be entangled and smothered by plastic bags or netting. While levels of entanglement-related mortality of these groups are probably low, entanglement is a further menace for already threatened species (Laist 1996). Ingestion of plastic bags could also present a problem for the leatherback turtle, which normally eats jellyfish (Mrosowsky 1981). In the Arabian Gulf litter is already a problem and is suspected of hindering turtle breeding and causing physical damage on shallow reefs (Anbar 1996).

Litter may also compromise the aesthetic values of coastal areas, posing a threat to tourism.

The Yemen coastline is substantially impacted by high litter accumulations. While quantitative surveys are yet to be carried out, qualitative inspection indicates a mixture of ship and local urban material. Urban communities in Yemen have very limited forms of garbage collection and disposal, and therefore garbage accumulates in and around the towns (Figure 5.9). The most visible types of material are plastic bags and plastic sheets used to wrap khat. In Dhubab medical waste is disposed of into the sea behind the hospital (Figure 5.10). Plastics, especially bags, were seen covering coral colonies in the Yemen Red Sea but the incidence of such observations was low.

Catchment Pollution

Sediment yield to wadi mouths

The discharge of increased amounts of sediments from rivers, following large-scale catchment modification for agriculture or urban development, has led to coastal ecosystem destruction. Sediment smothering and/or loss of light from increased turbidity (Rogers 1990) may affect

Figure 5.9
Litter on streets in Al Hudaydah.

coral reefs and seagrass beds. This type of damage to reefs and seagrass is common worldwide with well documented examples in central America (Cortes and Risk 1985 but see also Hands et al. 1993), the Philippines (Hodgson 1989), Indonesia (Edinger et al. 1998) and Australia (Preen et al. 1995).

With the export of labour from Yemen to the Gulf region in recent decades, some of the very old elaborate terrace systems on the major wadis (Vogel, 1987) have ceased to be maintained and have deteriorated (Vogel, 1993) (Figure 5.11).

This deterioration has been exacerbated on some wadis, by the construction, under donor programmes, of irrigation systems that do not maintain the terrace system. In addition extensive cutting of timber for firewood has deforested the upper catchment areas (Shidiwan and Adin 1991). On Wadi Zabid, damage to the terrace system and deforestation has caused massive erosion in the uplands and extensive sedimentation in the lowlands (Varisco et al. 1992). Wadis may discharge to the sea after heavy rainfall, but this occurs rarely. It is possible that greatly increased amounts of sediment from the collapse of the terrace systems are discharged to coastal areas near the mouths of wadis. This sediment has been accumulating in the terrace systems for over one thousand years and the amounts involved may be very large. Increased sediment supply leading to increased sedimentation and turbidity in coastal waters may cause localised mortality to seagrasses and inshore reefs. Ephemeral desert rivers are known to have high rates of bedload sediment transport (Laronne and Reid 1993). In the northern Red Sea sediment from ephemeral rivers have little effect on coastal reefs because of adjacent deep water. Sediment is quickly transported down the continental slope out of range of reef growth and resuspension is minimal (Hawkins and Roberts 1994). On Yemen's coast, with its relatively wide shelf, sediments are deposited in shallow water in the range of depths suitable for coral growth. The strong winds common in the area resuspend sediment leading to turbid inshore waters and difficult conditions for coral growth. Unstable bottom sediments also prevent coral colonization and some of the existing distribution of reefs along the Yemen Red Sea coast appears to be governed by bottom sediment type and wadi discharge (Figure 8.12). Estimates of the wadi fluxes of

Figure 5.10
Medical waste in sea at Dhubab.

Figure 5.11
Terrace systems near Manakah

sediment and possible changes in recent times are needed to evaluate the risks to inshore habitats.

The role of dust storms in transporting sediment, along with pesticides and nutrients, to the Red Sea, also requires quantification. Dust storms originating in the mountains occur frequently between April and August and sweep across the Tihama picking up dust and litter, which is then dissipated over the sea (Figure 5.12).

Dust storms are probably a major source of sediment for coastal and oceanic waters (Folger 1970), and also carry soil, contaminants such as pesticides, nutrients and toxic metals. In Saudi Arabia, near Jeddah, dust in dust storms was shown to contain high concentrations of cadmium (Behairy et al. 1985). It was suggested that the cadmium had originated from cement manufacture and oil combustion in the area inland from Jeddah.

Discharge of agricultural chemical residues

Wastewater discharge containing nutrients and pesticides is one of the most serious threats facing coral reefs and tropical seagrass areas around the world. Such discharges have been implicated in reef and seagrass degradation in the Carribean (Rawlins et al. 1998), the Great Barrier Reef (Bell and Elmetri 1995) and Indonesia (Edinger et al. 1998). In Yemen there is little river transport of such pollutants to the coast from agricultural areas. Pesticides are used in agriculture in both the Tihama and the upland terrace systems but the total quantities used are relatively low (DouAbal and Haddad 1996). In Yemen marine organisms

Figure 5.12
Dust storm over the sea near Al Luhayyah.

Figure 5.13
Coastal saltworks near Ras Isa.

have been found to contain low levels of pesticide residues and PCBs (DouAbal and Haddad 1996).

Coastal grazing

The grazing of mangroves by camels has been reported in Yemen (UNEP 1985, Barrett et al. 1987) and Saudi Arabia (Price et al. 1987). During the Yemen Project severe effects of grazing by camels was observed near Al Hudaydah (Figure 3.9) and Al Luhayyah (Chapter 3). Mangroves are also harvested for minor construction needs (houses, bird traps) and for firewood.

Tourism

Coastal development

Expanding coastal tourism has the potential for widespread coastal degradation. Intense tourism development in the northern Red Sea has already caused major damage to inshore areas through reclamation, sedimentation and over-fishing (Hawkins and Roberts 1994). The Ras Mohammed Marine Park, Egypt, has been an extremely successful example of marine protected area management but some reef damage due to intense diving pressure still occurrs (Hawkins and Roberts 1992). The magnitude of damage caused to corals by tourists is related, in part, to the number of tourists visiting reefs (Reigl and Velimirov 1991). Massive expansion of tourism is planned for the northern Red Sea, particularly in Egypt, and further coastal degradation is predicted (Hawkins and Roberts 1994).

Only minimal coastal tourism is present in Yemen, with four small hotels on the coast near Al Khawkhah each catering for about 100 persons. Small boats are available to take guests to the fringing coral reef off Al Khawkhah. These reefs in the 1996 survey (Site 8.2) appeared to be in good condition but coral cover had declined severely by the 1998 survey (Chapter 2). This decline was associated with the apparent continued bleaching of inshore reefs in the area that has led to the widespread coral mortality seen along the coast. Small groups of tourists also visit the reefs near Tiqfash Island. At the present level of visitation, damage to the reefs should be minimal. However, plans for expanded tourism in Yemen are in place and future large-scale coastal tourism possible (Burns and Cooper 1997).

Coastal Industries

Power stations

Seawater warming, associated with power station cooling systems, has been responsible for the death of corals in many places (Dubinsky and Stambler 1996). In most cases a 4-5°C increase over ambient temperature was enough to cause coral mortality.

Oil burning power stations are situated near Ras Al Kathib (Figure 5.3) and Al Mukha, both use seawater for cooling but they are small stations and the volumes of water used is modest. Visual surveys around the Ras Al Kathib station showed no overt ecological effects from the warm water discharge. Measurements in the discharge water channel and in areas just offshore of the outfall showed water temperatures only a few degrees above ambient sea temperatures in the channel and a return to ambient levels within 50m of the cooling water outfall.

Saltworks

Small evaporation salt ponds are common on the Yemen Red Sea coast (Figure 5.13). The ponds are constructed in sabkhah and are uniformly small-scale operations. While some disruption of the functioning of sabkhah must be caused by their operations their scale is such that general effects are minimal.

Global Climate Change

Since the first documentation of wide scale coral bleaching (Glynn 1984) and its link to the El Nino weather pattern, bleaching has occurred in the Indian, Pacific and Carribean oceans on a regular basis (Goreau and Hayes 1994). Repeated bleaching is now common in the Indian Ocean, the Carribean Sea and on the Great Barrier Reef (Brown 1997; Berkelmans and Oliver, 1999). Coral mortality following bleaching can be high but in some cases corals recover and may be able to adapt to bleaching episodes (Glynn 1993; Ware et al. 1996). Perhaps the most intense and widespread bleaching yet observed was in 1998 when Southern Hemisphere bleaching occurred in summer (January-April) on the Great Barrier Reef, in the Indian Ocean and in the Pacific. Northern Hemisphere bleaching occurred from May to September, and affected reefs in the northern Indian Ocean, Red Sea and northern Pacific. Bleaching is a consequence of coral stress and can be produced by a number of factors, including lowered salinity, increased irradiation, high water temperatures, low water temperatures and sharp changes in water temperature. The patterns of global bleaching in recent years appear to be primarily associated with high seawater temperatures (Goreau and Hayes 1994).

The possibility that increased coral bleaching and mortality are caused by global warming throughout the world is now given serious consideration (Brown 1997; Glynn 1996). Rises in average sea surface temperatures (SST) of about 0.5˚ in many coral reef areas have apparently taken corals beyond thresholds where bleaching occurs (Brown 1997). In addition to SST rises, the greenhouse effect is associated with increasing concentrations of carbon dioxide in the surface ocean; the possibility of lowered pH; and decreased calcification of calcifying organisms (corals, coralline algae, foraminiferans, molluscs). Brown (1997) notes that coral reefs subject to a combination of stresses are the least likely to survive. Bleaching, in combination with other stresses such as sedimentation, eutrophication and oil pollution, has led to a long-term decline on many reefs.

Widespread coral mortality has already occurred on Yemen Red Sea coral reefs (Chapter 2). In many areas this appears to have been associated with recent bleaching events. While Yemen corals may be adapted to high water temperatures, small rises above the normal range may be sufficient to bleach and kill coral. Continuing SST rises, as predicted under the most plausible global climate change predictions, are likely to have serious effects on Yemen coral reefs and may even cause ecosystem shifts to algal reef dominance (Chapter 2).

Coral Predators

The two coral predators capable of causing widespread mortality to corals are the crown-of-thorns starfish (*Acanthaster planci)* and corallivore gastropods, such as *Drupella* spp. While these organisms occur naturally on coral reefs it has been suggested that recent global 'outbreaks' in populations are associated with anthropogenic effects and therefore represent a human impact on coral reefs.

Acanthaster planci outbreaks have devastated reefs throughout the Indo-Pacific region since the 1960s (Birkeland and Lucas 1990) and can result in 60-90 % coral mortality on a reef, the starfish preferring plate and branching corals, particularly *Acropora* spp, for food. A long-standing controversy is whether the starfish outbreaks are a natural phenomenon or human induced (Bradbury and Seymour, 1997). Even if outbreaks do occur naturally their frequency and severity may have been increased through human influence in recent times. There are two principal theories linking human activity with starfish abundance. The first suggests that overfishing predators (particularly large fish such as emperors) of the juvenile starfish may be the trigger (Bradbury and Seymour, 1997). The second theory is that increased land runoff of nutrients associated with farming (fertilizers) or urban land use (sewage) has led to phytoplankton blooms in coastal waters. This increases the survivability and growth of starfish because, during their pelagic larvae stage, they eat phytoplankton (Ayukai et al. 1997). Neither theory has been conclusively substantiated by empirical research.

In the Red Sea *A. planci* outbreaks have been reported since the 1960s, particularly in Sudan (Ormond and Campbell 1974; Moore 1990) and more recently in the northern Red Sea. Goreau (1964) in his studies of southern Red Sea reefs in 1962 was the first to suggest that the starfish might be a factor in limiting development of coral reefs.

During the Yemen Project individual starfish were seen on many reefs. Figure 2.22 shows a crown of thorns alongside the characteristic scar. The mid-Red Sea reefs surveyed appeared to have patterns of coral mortality consistent with large-scale starfish outbreak activity and this is discussed further in Chapter 2.

Drupella cornus and other gastropod predators of coral (other *Drupella* spp, *Coralliophila* spp and *Quoyula* spp) have caused large scale coral mortality on reefs in Australia (Ningaloo Reef, Turner 1994), Japan and the Philippines (Moyer et al. 1982) and the Caribbean (Bawley and Adey 1982). Large populations of these gastropods have also been reported from the Red Sea (Schuhmacher 1992; Antonius and Riegl 1997). Overfishing predators of the snails has been suggested as a cause of population outbreaks but not confirmed (Turner 1994).

During the Yemen Project *Drupella* were seen in moderate numbers on many reefs. Figure 2.24 shows a group of *Drupella* feeding on a plate *Acropora* coral, leaving the characteristic white scarred area. The snail's role in the coral mortality observed in the Yemen Red Sea is discussed further in Chapter 2.

Conclusions

From the above assessment the priority threats to the marine environment of Yemen's Red Sea can be summarized as follows:

- unsustainable fishing effort, particularly on reef and reef-associated fish, with resulting stock reduction
- destructive fishing practices resulting in fishing stock collapse and associated coral reef destruction
- chronic oil pollution, small scale but geographically widespread, principally associated with ballast water discharge, tank washing and loading/ unloading operations
- the potential for a major oil spill associated with the *Safir* storage and loading facility
- high levels of litter
- coral reef loss through bleaching associated mortality related to global warming
- limited scale of Yemen Government surveillance, monitoring and management of the marine environment.

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