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CHAPTER 3

3.9

Coral Reef Associated Flora and Fauna

Periyadan K. Krishnakumar[1], Yu-Jia Lin[1], and Reynaldo Lindo[1]

Introduction

A typical coral reef ecosystem consists of hard and soft corals together with associated flora and fauna such as macroalgae, sponges, crustaceans, mollusks, sea turtles, dolphins, sharks and several varieties of reef fishes. Sessile macroinvertebrates are usually found in the available spaces between individual corals on most coral reef fronts. This placement enables them to have protection from the ravages of violent seas and potential predators. The reef fishes live over the reef space available for forging. A large number of predators of living corals, sessile macroinvertebrates, and slow moving invertebrates also occupy the space in the reef environment. Several invertebrate species inhabit the coral skeletal substrate, either boring into the skeletons or living in preexisting voids and crevices. Some of the common invertebrates associated with the reefs are sponges, tunicates, gastropods, bivalves, sea urchins and crustaceans. The competition for resources such as food, space, and sunlight are some of the major drivers in determining the abundances and diversity of reef organisms.

Coral reefs create protection for many marine organisms. Different varieties of flora and fauna are associated with the coral reefs in the Arabian Gulf (Basson, et al., 1977; McCain, et al., 1984; Riegl and Purkis, 2012); however, detailed information about the abundance, diversity and distribution of very few non-coral organisms from the western Arabian Gulf are available. Around 540 species of reef animals were recorded from the nearshore reefs located along the Eastern Coast of Saudi Arabia (Basson, et al., 1977; McCain, et al., 1984; KFUPM/RI, 1988; Cole and Tarr, 1990). Some invertebrates inhabit the corals by boring or by hiding among the nooks and crannies. Several species such as rock-boring bivalves, polychaetes, and barnacles tunnel their way into species of *Porites* and find refuge in the coral (Basson, et al., 1977). These animals extend structures outside of the coral to obtain food and oxygen. Other animals, such as caridean shrimp, galatheids, alpheids, palaemonids, xanthid crabs (*Trapezia cymodoce* and *Tetralia glaberrima*), and the goby *Gobiodon citrinus* hide among the branches of corals, while sessile animals such as sponges, hydroids, alcyonarians, bivalves, bryozoans and tunicates take residence on the surfaces of corals (Basson, et al., 1977).

Some seasonal trends have been observed in the abundance and distribution of some of the non-coral reef species (Coles and McCain, 1990). Seasonal blooms of macroalgae consisting of *Sargassum* or *Colpomenia sinuosa* and *Enteromorpha* species *occur* on many nearshore shallow reefs of the Gulf coast of Saudi Arabia from as early as February until about May (Coles, 1988, 2003). This algal invasion of the coral during the winter and early spring seasons has also been noted in the offshore coral islands of Saudi

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Arabia (Basson, et al., 1977; KFUPM/RI, 1988; Coles and Fadlallah, 1991), and in Bahrain and Kuwait (Vousden, 1988). Several herbivorous fishes usually graze heavily on the algae found in the shallow regions of the reef platform and are thought to increase algal biomass by weeding out less productive forms of algae and by excreting nutrients back into the reef (Sheppard, et al., 1992). McCain, et al. (1984) and Coles and Tarr (1990) surveyed the reefs of the Gulf coast of Saudi Arabia and provided detailed information about reef fish assemblages. Around 101 fish species in 35 families were found occurring at the nearshore and offshore reefs (Coles and Tarr, 1990). Recently, John (2012), George (2012) and Grandcourt (2012) provided detailed descriptions about the reef associated marine algae (seaweeds), macroinvertebrates and reef fishes, respectively, from the southeast Arabian Gulf.

In this chapter, a brief description about the general status of reef associated flora and fauna consisting of macroalgae, sponges, crustaceans, mollusks, sea urchins and fishes is provided based on the data collected by KFUPM under various study programs during 1985 to 2012.

Methods of Obtaining Data

Reef Survey Data

The data collected as part of KFUPM's long-term Gulf coral reef monitoring program during 1985 to 2012 (KFUPM/RI, 1986; KFUPM/RI, 1987; KFUPM/RI, 1988; KFUPM/RI, 1994; KFUPM/RI, 2001; KFUPM/RI, 2003; KFUPM/RI, 2008; KFUPM/RI, 2013) is used for preparing this chapter. Eleven coral reefs, Figure 3.82, were monitored four times a year during 1985–1987, while the monitoring frequency was reduced to twice a year during 1991–2012. In addition, the data collected during the study, *Reef Surveys in Support of the Marine and Coastal Damage Assessment* (KFUPM/RI, 2003) was also partially used. This reef survey took place during October to November 2002 (fall); January to February, 2003 (winter); May 2003 (spring) and July 2003 (summer), covering 10 reefs along the Saudi Gulf Coast. The surveyed reefs include seven nearshore and three offshore reefs (islands).

Standard coral reef survey methods were followed for studying the benthic percentage cover (KFUPM/RI, 2001; KFUPM/RI, 2003; KFUPM/RI, 2008; KFUPM/RI, 2013). A visual census of macroinvertebrates was conducted while diving along the 50 m long transects lines attached to the reefs. All macroinvertebrates within a 1 m wide swath covered by the transect length (an area of 50 m^2) were counted. This was done by flipping a 1 m × 0.5 m rectangular frame from one side of the transect line to the other, and then forward until 100 quadrats were visually counted. A tally of individuals from each species or higher taxon was made for each quadrat.

Reef fish surveys involve the observation and enumeration of fishes by researchers while SCUBA diving. The fish biologist moved along a 50 m transect line and recorded the number and species of all demersal fishes encountered within 2.5 m to either side of and up to 5 m above the transect line (KFUPM/RI, 2001, 2013). The observer recorded all cryptic fishes on his way back along the line. Data are recorded on underwater paper on which the names of commonly encountered fishes are printed. Species that were difficult to identify in situ (e.g., those belonging to the family *Labridae*) were listed as sp. 1, sp. 2, and so on. Corresponding descriptions of each unidentified species were recorded and underwater photographs of fishes were taken to aid in further laboratory verification. Typically, the method underestimates populations

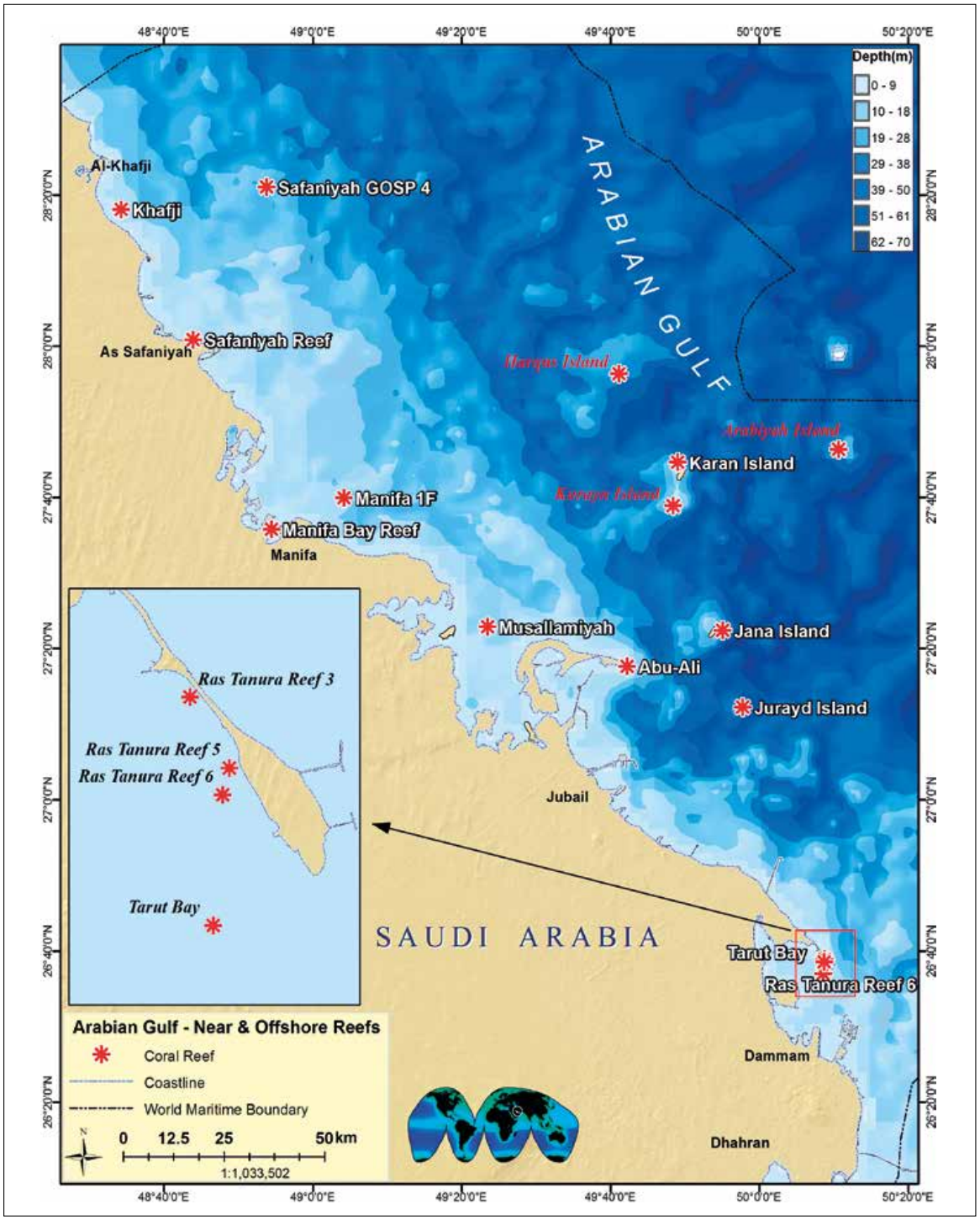

FIGURE 3.82. *Map showing the nearshore and offshore reefs located in the Saudi Arabian waters of Arabian Gulf.*

of nocturnal fishes, and fishes wary of divers. Assuming these limitations to be consistent temporally and spatially, comparisons can be made among transect samples.

The reef fishes from the selected nearshore and offshore reefs were assigned to one of the five feeding guilds such as carnivores, herbivores, corallivores, omnivores and planktivores after following Jones, et al. (1991) and based on the information available on fishbase (*www.fishbase.org*).

Results

Macroalgae and Coralline Algae

Seasonal blooming of macroalgae and coralline algae on the coral reefs was observed on most of the nearshore and offshore coral reefs from the Gulf during winter and early spring, Figure 3.83. The common and the abundant macroalgae found on sublittoral reef flats during winter and spring was *Colpomenia sinuosa*. The common coralline algae are red algae in the order *Corallinales* and the colors of these algae are most typically pink, or some other shade of red. Other macroalgae commonly found on the reefs included the *Sargassum sp., Lobophora variegate* (synonym of *Pocockiella variegate*), *Dictyota sp., Enteromorpha sp., Hypnea sp., Ulothrix* sp., and *Lobophora s.,* Figure 3.84.

The percentage cover of total algae (macroalgae and coralline algae) at the three offshore reefs and seven nearshore reefs, Figures 3.85 and 3.86, respectively, generally decreased with depth on all four offshore reefs. Considering the shallow sites on all 10 study reefs, algal cover was lower on nearshore reefs (KFUPM/RI, 2003; KFUPM/RI, 2013). Seasonal blooms of macroalgae occurred on many nearshore shallow reefs from as early as February until about May (KFUPM/RI, 2001; KFUPM/RI, 2003; KFUPM/RI, 2008; KFUPM/RI, 2013). The macroalgae cover was found to be highest in March (winter), and was primarily consisting of *Sargassum* sp., or *Colpomenia sinuosa* and *Enteromorpha* sp., Figures 3.85 and 3.86.

The amount of algal cover on the nearshore reefs were less compared to that on the offshore reefs. The amount of algal cover on nearshore patch reefs such as Abu Ali, Safaniyah and Tarut Bay were less compared to that on the reefs such as Musallamiyah and Safaniyah GOSP 4, Figure 3.86.

The percentage cover of coralline algae compared to macroalgae, at the three offshore and seven nearshore reefs was low, Figures 3.87 and 3.88. The major coralline alga reported from the study area was *Hydrolithon farinosum*. Coralline algae made up less than 5% of the identified data points on inshore reefs, while its coverage exceeded 50% on offshore reefs (KFUPM/RI, 2003). There were generally more coralline algae at shallow depths on the four offshore reefs, Figures 3.87 and 3.88. The occurrence of coralline algae varied on the four offshore reefs, very little was recorded at any depth on most of the nearshore reefs, while cover of coralline algae declined with increasing depth on the other reefs.

Macroinvertebrates

Nearly 36 macroinvertebrates species were reported from the nearshore reefs from the study area (KFUPM/RI, 2001; KFUPM/RI, 2003; KFUPM/RI, 2008; KFUPM/RI, 2013). The urchin *Echinometra mathaei* was the most prominent non-coral organism observed in all the reefs from the study area. At the

FIGURE 3.83. *Extensive growth of acroalgae (*Sargassum *spp.) (top) and the occurrence of* Colpomenia *spp. and* Sargassum *spp. (bottom) on one of the coral reefs from the study area during the winter season.*

FIGURE 3.84. *The common coralline algae found on reefs; (a) Coralline algae- Lithothamnion sp.; (b) Lobophora variegate (Synonym: Pocockiella variegate); (c) Sargassum boveanum; (d) Close-up view of Sargassum boveanum.*

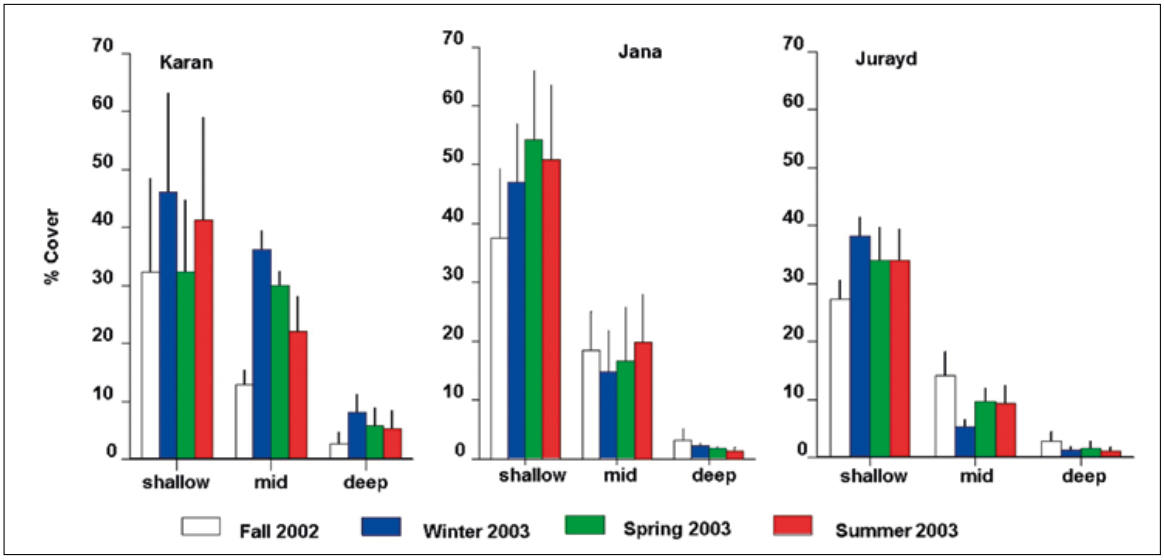

FIGURE 3.85. *Mean percent cover of macroalgae at each depth on the three offshore reefs covering four seasons during 2002 to 2003 (based on KFUPM/RI, 2003 data). Error bars represent Standard Errors.*

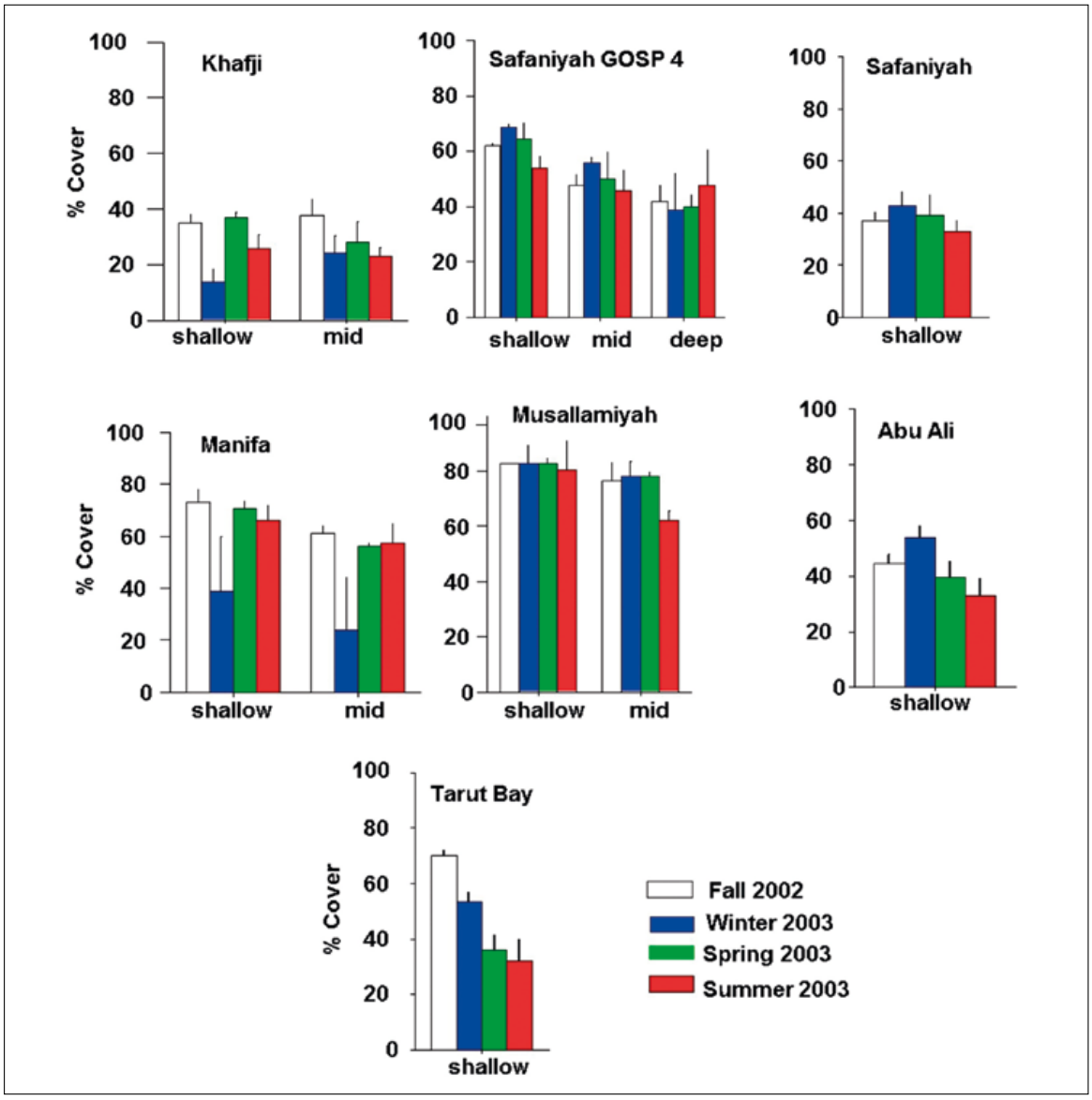

FIGURE 3.86. *Mean percent cover of macroalgae at each depth on the seven nearshore reefs covering four seasons during 2002 to 2003 (based on KFUPM/RI, 2003 data). Error bars represent Standard Errors.*

northern nearshore reefs (Safaniyah, Manifa 1-F and Manifa Bay), the macroinvertebrates were dominated by sea urchins (*Echinometra mathaei*) and bivalves (eight species). While for the central and southern reefs (Abu Ali, Ras Tanura and Tarut Bay), the most numerous were the sea urchins. The rocky substrates of these reefs provided stable support for the attachment of bivalves as well as grazing grounds for *E. mathaei*. The other species of echinoids found in the area were *Diadema setosum* and *Prionocidaris baculosa*.

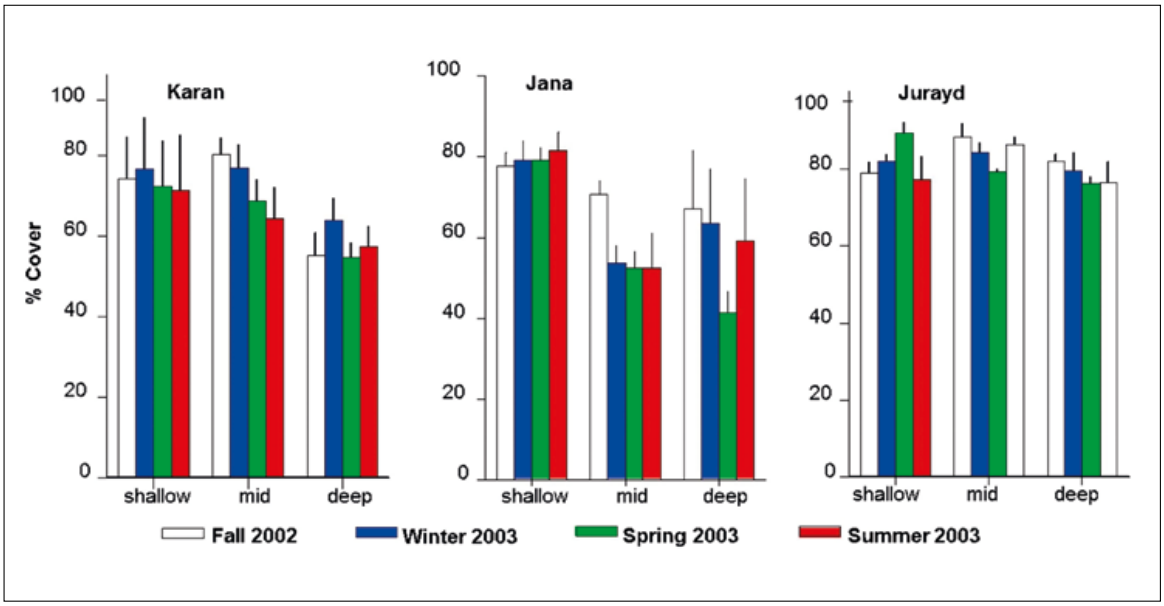

FIGURE 3.87. *Mean percent cover of coralline algae at each depth on the three offshore reefs covering four seasons during 2002 to 2003 (based on KFUPM/RI, 2003 data). Error bars represent Standard Errors.*

Sea urchins were important consumers of benthic algae on coral reefs and most common sea urchin species found associated with the reefs in the Gulf was *E. mathaei,* the burrowing urchin (KFUPM/RI, 2012). *E. mathaei* occurred in large numbers on nearshore reefs while they occurred in very small numbers or rarely on offshore reefs, Figure 3.89.

Five species of Pelecypods (*Barbatia sp., Chama pacifica, Chlamys ruschenbergerii, Lopha cristagalli, Pinctada radiate)* were reported on nearshore reefs from the study area. Crustaceans such as crabs (*Carpilius* sp.) and lobsters (*Thenus orientalis*, *Panulirus versicolor)* occurred at most of the reefs. The holothurian, *Holothuria leucosphilota*, was reported from the offshore reefs (KFUPM/RI, 2001; KFUPM/RI, 2008; KFUPM/RI, 2013).

Reef Associated Fishes

A total of 147 reef fish species belonging to 43 families were recorded from the study area over the period 1985 to 2012, Table 3.31. The damsel fish (*Pomacentridae*) was the most abundant group with respect to numbers of species and average abundance, mostly contributed by small fish, including Indo-Pacific sergeant (*Abudefduf vaigiensis*), Arabian Sind damselfish (*Neopomacentrus sindensis*) and yellow fin chromis (*Chromis xanthopterygia*). The sea bream, butterfly fishes, snappers, herrings, groupers and rabbit fishes were also reported in large numbers.

The average fish abundance (individuals 300 m^{-2}) and species number were high at the offshore reefs compared to inshore reefs (nearshore reefs) prior to 1988, Figures 3.90 and 3.91. The fish abundance and species number of inshore reefs showed a cyclic pattern, declining from 1990 to 1995, increasing from 1995 to 2000,

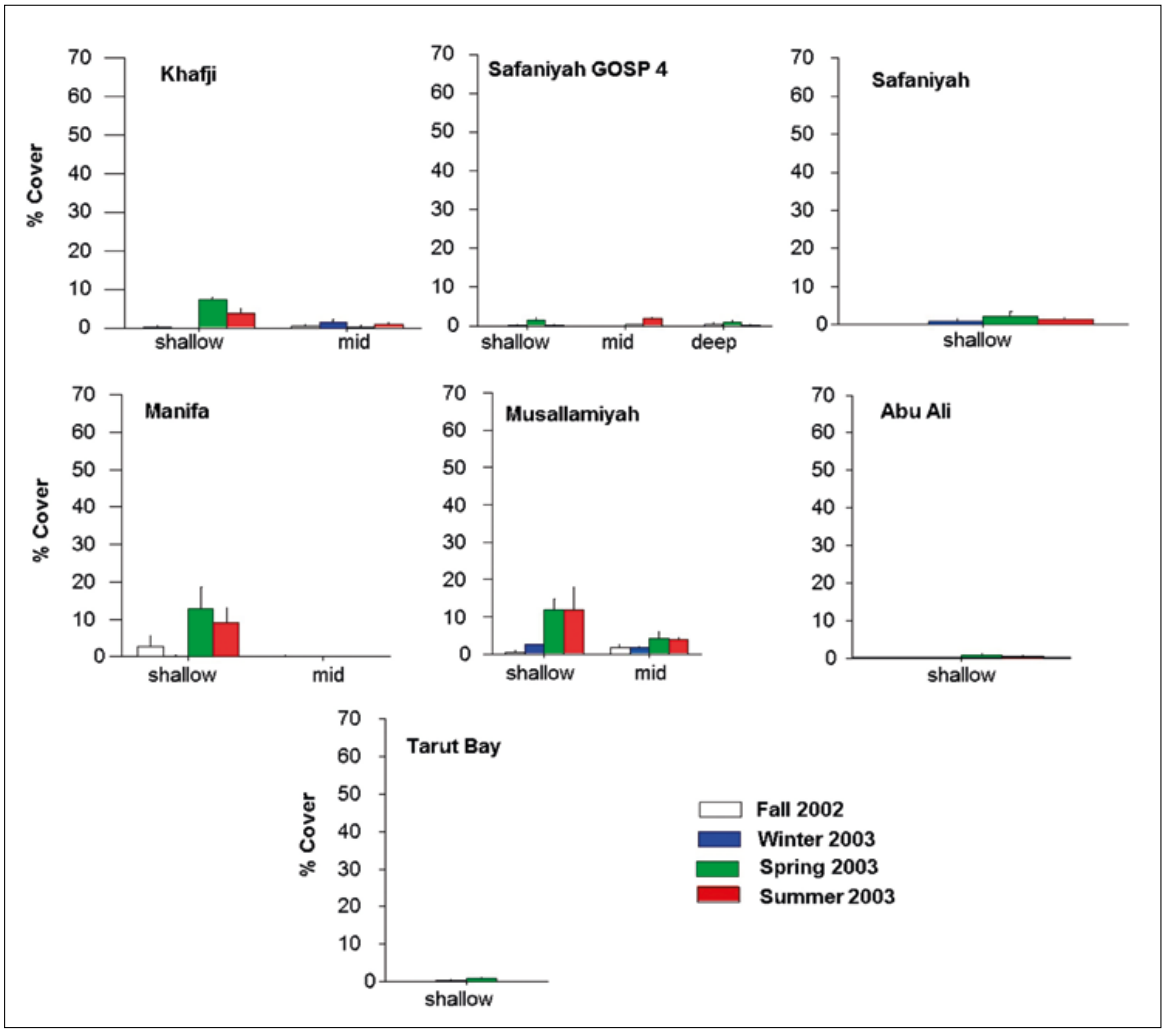

FIGURE 3.88. *Mean percent cover of coralline algae at each depth on the seven nearshore reefs covering four seasons during 2002 to 2003 (based on KFUPM/RI, 2003 data).*

and declining again from 2000 to 2012. The fish abundance on offshore reefs increased from 2003 to 2005, but then showed a declining trend after 2010. The species number on the offshore reefs decreased to 20-30 species during 2003 to 2005 compared to 1985 to 1986 and it reached the lowest values by 2010 to 2012, Figure 3.91.

Shannon's diversity index of the reef fishes from the inshore reefs showed a declining trend, especially during two periods, from 1986 to 1990 and from 2003 to 2009, Figure 3.92. On the contrary, the fish diversity remained relatively stable at the offshore reefs, Figure 3.92. The trophic level of fishes from the inshore reefs was generally stable. Compared to inshore reefs, the fishes from offshore reefs were characterized by lower trophic values, indicating that they were dominated by the herbivores and invertivores, Figure 3.93.

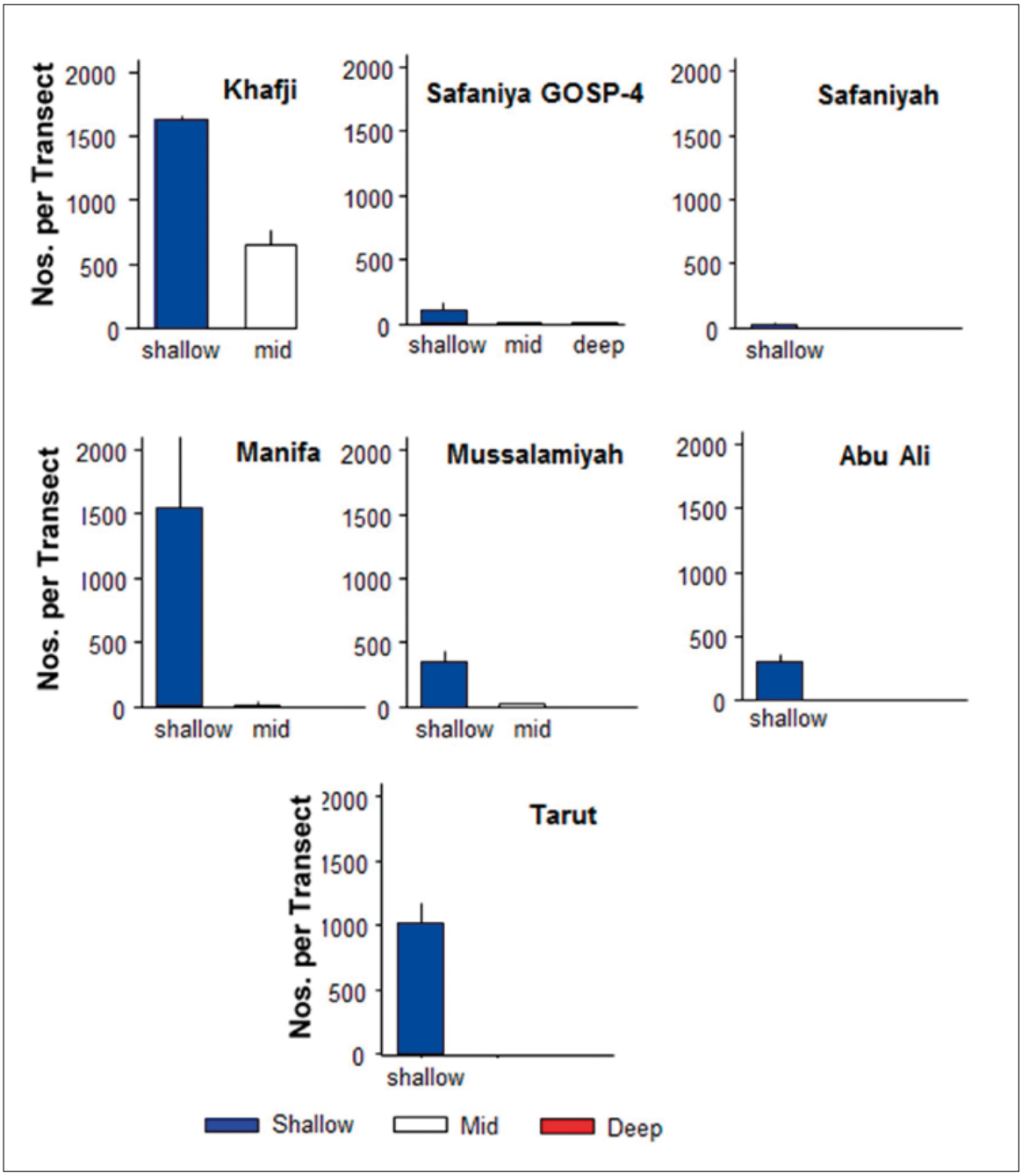

FIGURE 3.89. *Mean numbers of the sea urchin, Echinometra mathaei, at each depth on the nearshore reefs during 2002 to 2003 (based on KFUPM/RI, 2003 data). Error bars represent Standard Errors.*

TABLE 3.31. *List of reef associated fish species recorded from the Saudi Arabian Gulf reefs (KFUPM/RI, 2001; KFUPM/RI, 2003; KFUPM/RI, 2008; KFUPM/RI, 2013).*

Family Name	Species Name	Common Name
Hemiscylliidae (Bamboo Shark)	*Chiloscyllium arabicum*	Arabian carpetshark
Dasyatidae (Stingray)	*Himantura uarnak*	Honeycomb stingray
	Taeniura meyeni	Blotched fantail ray
Myliobatidae (Manta Ray)	*Aetomylaeus nichofii*	Banded eagle ray
Muraenidae (Moray Eel)	*Gymnothorax undulatus*	Undulated moray
Clupeidae (Herring)	*Herklotsichthys lossei*	Gulf Herring
	Sardinella spp	Sadine
Synodontidae (Lizardfish)	*Synodus variegatus*	Variegated lizardfish
Atherinidae (Silverside)	*Atherinomorus lacunosus*	Hardyhead silverside
Belonidae (Needlefish)	*Ablennes hians*	Flat needlefish
	Tylosurus crocodilus	Hound needlefish
Hemiramphidae (Halfbeak)	*Hemiramphus far*	Blackbarred halfbeak
Scorpaenidae (Scorpionfish)	*Pterois volitans*	Red lionfish
Platycephalidae (Flathead)	*Platycephalus indicus*	Bartail flathead
Serranidae (Grouper)	*Aethaloperca rogaa*	Redmouth grouper
	Cephalopholis hemistiktos	Yellowfin hind
	Epinephelus coeruleopunctatus	Whitespotted grouper
	Epinephelus coioides	Orange-spotted grouper
	Epinephelus malabaricus	Malabar grouper
	Epinephelus multinotatus	White-blotched grouper
	Epinephelus spp	Grouper
Pseudochromidae (Dottyback)	*Pseudochromis aldabraensis*	Orange dottyback
	Pseudochromis dutoiti	Neon dottyback
	Pseudochromis persicus	Bluespotted dottyback
	Pseudochromis spp	Dottyback
Terapontidae (Terapon)	*Pelates quadrilineatus*	Fourlined terapon
	Terapon puta	Small-scaled terapon
	Terapon theraps	Largescaled terapon
Apogonidae (Cardinalfish)	*Apogonichthyoides nigripinnis*	Bullseye cardinalfish
	Apogonichthyoides taeniatus	Twobelt cardinalfish
	Archamia fucata	Orangelined cardinalfish
	Cheilodipterus arabicus	Tiger cardinalfish
	Cheilodipterus novemstriatus	Twospot cardinalfish
	Cheilodipterus persicus	Persian cardinalfish
	Cheilodipterus quinquelineatus	Five-lined cardinalfish
	Ostorhinchus aureus	Ring-tailed cardinalfish
	Ostorhinchus cyanosoma	Yellowstriped cardinalfish
	Apogon spp	Cardinalfish

Family Name	Species Name	Common Name
Carangidae (Jack & Travelly)	*Alepes melanoptera*	Blackfin scad
	Alepes vari	Herring scad
	Atule mate	Yellowtail scad
	Carangoides bajad	Orangespotted trevally
	Carangoides ferdau	Blue trevally
	Caranx ignobilis	Giant trevally
	Gnathanodon speciosus	Golden trevally
	Scomberoides tol	Needlescaled queenfish
	Selaroides leptolepis	Yellowstripe scad
	Seriola dumerili	Greater amberjack
	Trachinotus blochii	Snubnose pompano
Lutjanidae (Snapper)	*Lutjanus argentimaculatus*	Mangrove red snapper
	Lutjanus ehrenbergii	Blackspot snapper
	Lutjanus fulviflamma	Dory snapper
	Lutjanus kasmira	Bluestripe snapper
	Lutjanus russellii	Russell's snapper
Caesionidae (Fusilier)	*Caesio lunaris*	Lunar Fusilier
	Caesio varilineata	Variable-lined fusilier
	Caesio spp	Fusilier
Gerreidae (Silverbiddy)	*Gerres longirostris*	Longtail silverbiddy
	Gerres oyena	Common silverbiddy
Haemulidae (Sweetlip and Rubberlip)	*Diagramma pictum*	Painted sweetlips
	Plectorhinchus gaterinus	Blackspotted rubberlip
	Plectorhinchus pictus	Trout sweetlips
	Plectorhinchus schotaf	Minstrel sweetlips
	Plectorhinchus sordidus	Sordid rubberlip
Sparidae (Seabream)	*Acanthopagrus bifasciatus*	Twobar seabream
	Diplodus sargus	White seabream
	Rhabdosargus haffara	Haffara seabream
	Rhabdosargus sarba	Goldlined seabream
	Sparidentex hasta	Sobaity seabream
Lethrinidae (Emperor)	*Lethrinus borbonicus*	Snubnose emperor
	Lethrinus lentjan	Pink ear emperor
	Lethrinus nebulosus	Spangled emperor
Nemipteridae (Monocle Bream)	*Scolopsis ghanam*	Arabian monocle bream
	Scolopsis taeniata	Black-streaked monocle bream
	Scolopsis spp	Monocle bream
Mullidae (Goatfish)	*Parupeneus forsskali*	Red Sea goatfish
	Parupeneus heptacanthus	Cinnabar goatfish
	Parupeneus margaritatus	Pearly goatfish
	Upeneus tragula	Freckled goatfish
Chaetodontidae (Butterflyfish)	*Chaetodon melapterus*	Arabian butterflyfish
	Chaetodon nigropunctatus	Black-spotted butterflyfish
	Heniochus acuminatus	Pennant coralfish

Family Name	Species Name	Common Name
Pomacanthidae (Angelfish)	*Pomacanthus maculosus*	Yellowbar angelfish
Pomacentridae (Damselfish)	*Abudefduf sexfasciatus*	Scissortail sergeant
	Abudefduf vaigiensis	Indo-Pacific sergeant
	Amphiprion clarkii	Clark's anemonefish
	Chromis ternatensis	Ternate chromis
	Chromis weberi	Weber's chromis
	Chromis xanthopterygia	Yellowfin chromis
	Dascyllus trimaculatus	Domino damselfish
	Neopomacentrus cyanomos	Regal damselfish
	Neopomacentrus sindensis	Arabian demoiselle
	Pomacentrus albicaudatus	Whitefin damselfish
	Pomacentrus aquilus	Dark damselfish
	Pomacentrus leptus	Slender damselfish
	Pomacentrus trichrourus	Paletail damselfish
Labridae (Wrass)	*Cheilinus lunulatus*	Broomtail wrasse
	Halichoeres margaritaceus	Pink-belly wrasse
	Halichoeres marginatus	Dusky wrasse
	Halichoeres stigmaticus	U-spot wrasse
	Labroides dimidiatus	Bluestreak cleaner wrasse
	Leptojulis cyanopleura	Shoulder-spot wrasse
	Paracheilinus mccoskeri	McCosker's flasher
	Stethojulis interrupta	Cutribbon wrasse
	Thalassoma lunare	Moon wrasse
Scaridae (Parrotfish)	*Chlorurus sordidus*	Daisy parrotfish
	Scarus ferrugineus	Rusty parrotfish
	Scarus ghobban	Blue-barred parrotfish
	Scarus persicus	Gulf parrotfish
	Scarus psittacus	Common parrotfish
	Scarus spp	Parrotfish
Pinguipedidae (Sandperch)	*Parapercis hexophtalma*	Speckled sandperch
	Parapercis robinsoni	Small-scale grubfish
Blenniidae (Blenny)	*Ecsenius pulcher*	Combtooth blenny
	Omobranchus punctatus	Muzzled blenny
	Petroscirtes ancylodon	Arabian fangblenny
	Petroscirtes mitratus	Floral blenny
Tripterygiidae (Threefin Blenny)	Enneapterygius pusillus	Highcrest triplefin
Gobiidae (Goby)	*Amblygobius albimaculatus*	Butterfly goby
	Asterropteryx semipunctata	Starry goby
	Cryptocentrus lutheri	Luther's prawn-goby
	Gnatholepis anjerensis	Eye-bar goby
	Gobiodon citrinus	Poison goby
	Valenciennea persica	Valencia goby
	Eviota spp.1	Fringefin goby
	Eviota spp.2	Fringefin goby

Family Name	Species Name	Common Name
Ptereleotridae (Dartfish)	*Ptereleotris arabica*	Arabian dartfish
Ephippidae (Batfish)	*Platax orbicularis*	Orbicular batfish
Acanthuridae (Surgeonfish)	*Acanthurus sohal*	Sohal surgeonfish
	Acanthurus tennentii	Doubleband surgeonfish
	Zebrasoma xanthurum	Yellowtail tang
Siganidae (Rabbitfish)	*Siganus canaliculatus*	White-spotted spinefoot
	Siganus javus	Streaked spinefoot
	Siganus luridus	Dusky spinefoot
	Siganus rivulatus	Marbled spinefoot
	Siganus spinus	Little spinefoot
Sphyraenidae (Barracuda)	*Sphyraena jello*	Pickhandle barracuda
	Sphyraena obtusata	Obtuse barracuda
	Sphyraena spp.	Barracuda
Scombridae (Mackerel)	*Scomberomorus commerson*	Narrow-barred Spanish mackerel
Balistidae (Triggerfish)	*Rhinecanthus assasi*	Picasso triggerfish
	Sufflamen albicaudatum	Bluethroat triggerfish
Monacanthidae (Filefish)	*Paramonacanthus spp.*	Filefish
Ostraciidae (Boxfish)	*Ostracion cyanurus*	Bluetail trunkfish
Tetraodontidae (Puffers)	*Arothron stellatus*	Stellate puffer
	Chelonodon patoca	Milkspotted puffer
	Cyclichthys orbicularis	Birdbeak burrfish

Statistically significant differences were observed for fish abundance between the different feeding guilds while no significant seasonal variations were observed, Figures 3.94 and 3.95 (KFUPM/RI, 2001; KFUPM/RI, 2003; KFUPM/RI, 2008; KFUPM/RI, 2013). The planktivores fishes were most abundant in the nearshore reefs followed by carnivores, herbivores, omnivores and corallivores, Figure 3.94. In the offshore reefs, the omnivores were the most abundant followed by planktivores, herbivores, corallivores and carnivores, Figure 3.95.

No statistically significant seasonal differences in fish abundance at the individual reefs were observed during the study period, Figure 3.96 (KFUPM/RI, 2001; KFUPM/RI, 2003; KFUPM/RI, 2008; KFUPM/RI, 2013). The mean fish abundance was high during the winter season at Jana Island reef, Safaniyah reef, Musallamiyah reef, Ras Tanura 6 reef and Tarut Bay reef. Subsequently, the mean fish abundance was high during the summer season at Karan Island reef, Manifa 1A reef, Manifa 1F reef, Ras Tanura Reef 3 and Ras Tanura Reef 5.

Discussion

Macroalgae and Coralline Algae

Depending on the availability of light, macroalgal coverage was noticed on most of the nearshore and offshore reefs within the study area. Dramatic changes in bottom cover on the reef occurred seasonally,

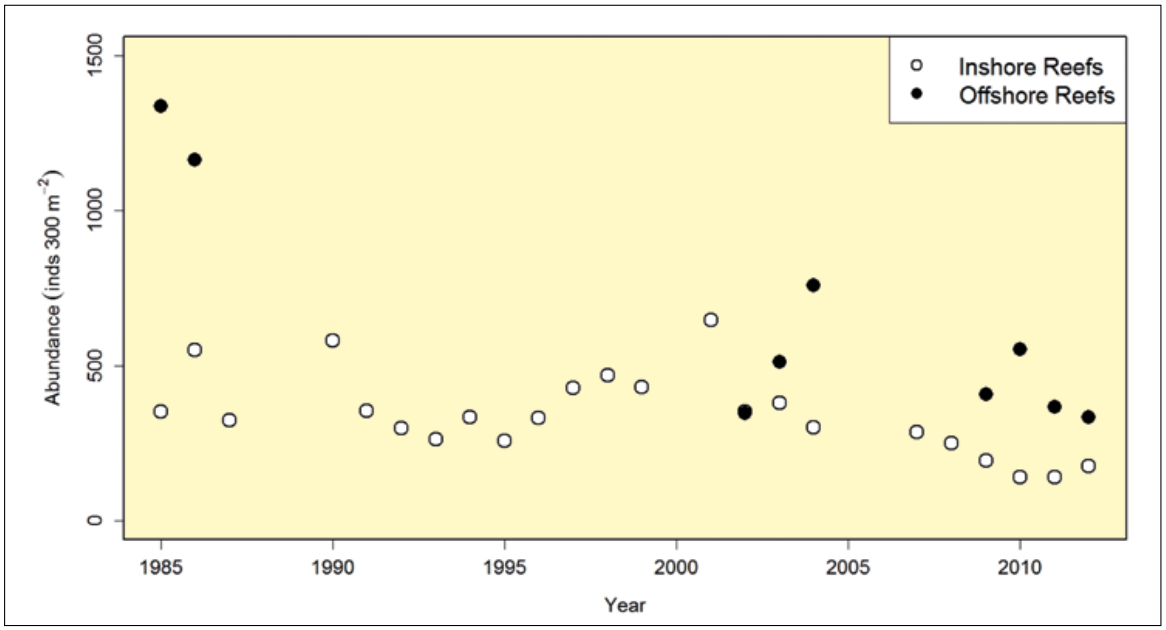

FIGURE 3.90. *Average fish abundance for the inshore reefs (open circles) and offshore reefs (solid circles) during 1985 to 2012 (KFUPM/RI, 2001; KFUPM/RI, 2003; KFUPM/RI, 2008; KFUPM/RI, 2013).*

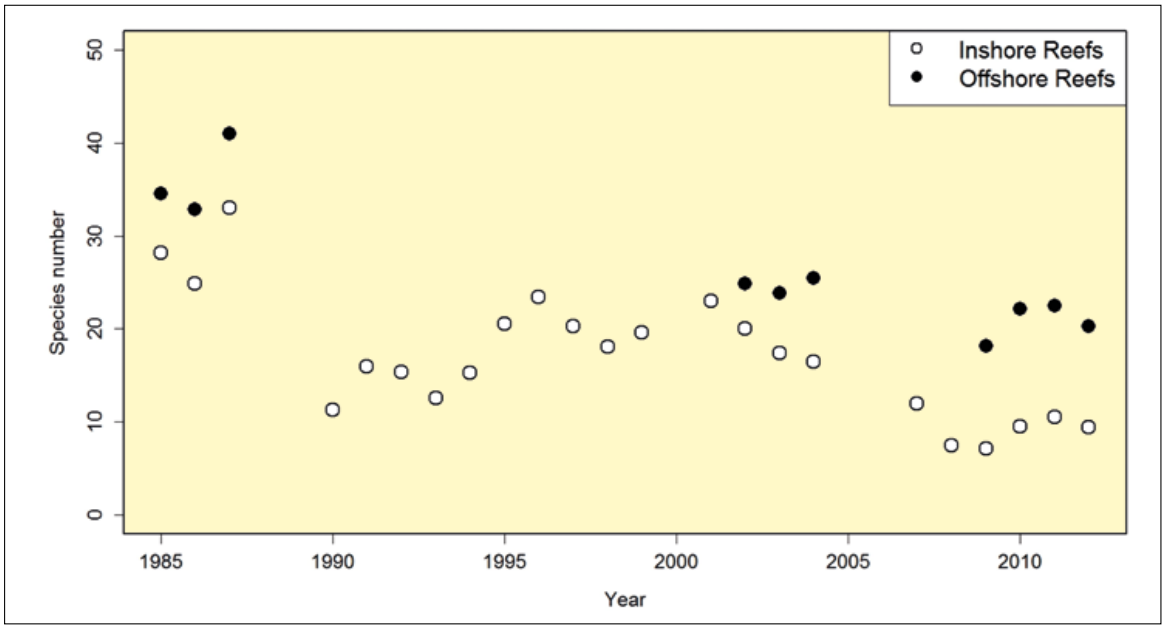

FIGURE 3.91. *Average fish species number for the inshore reefs (open circles) and offshore reefs (solid circles) during 1985 to 2012 (KFUPM/RI, 2001; KFUPM/RI, 2003; KFUPM/RI, 2008; KFUPM/RI, 2013).*

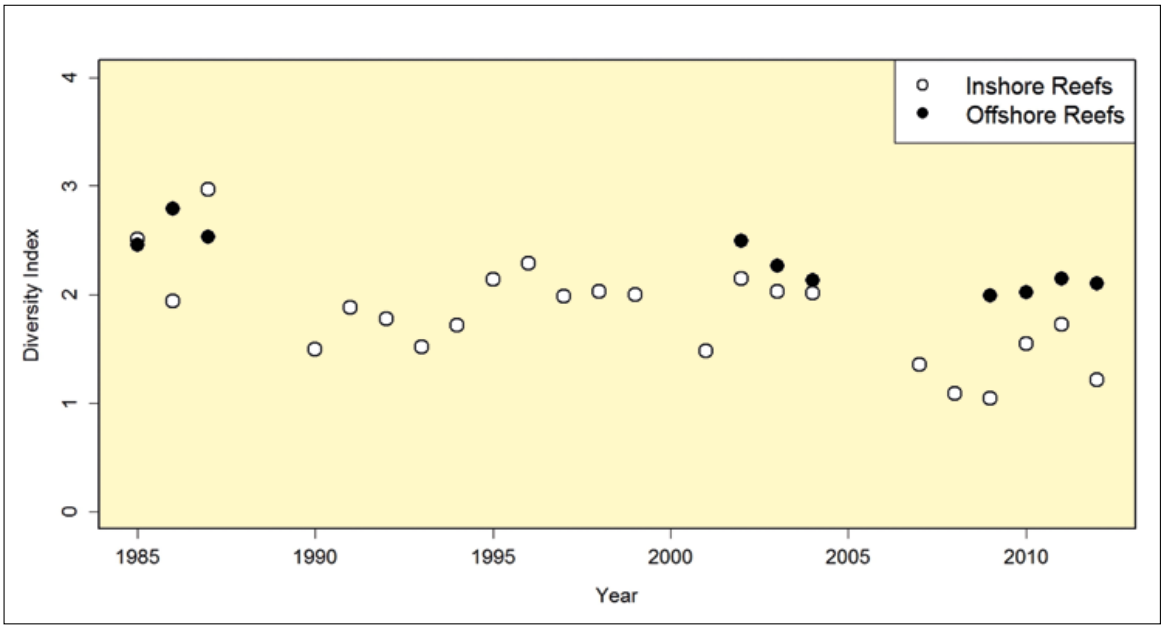

FIGURE 3.92. *Shannon's diversity index for the fishes from inshore reefs (open circles) and offshore reefs (solid circles) during 1985 to 2012 (KFUPM/RI, 2001; KFUPM/RI, 2003; KFUPM/RI, 2008; KFUPM/RI, 2013).*

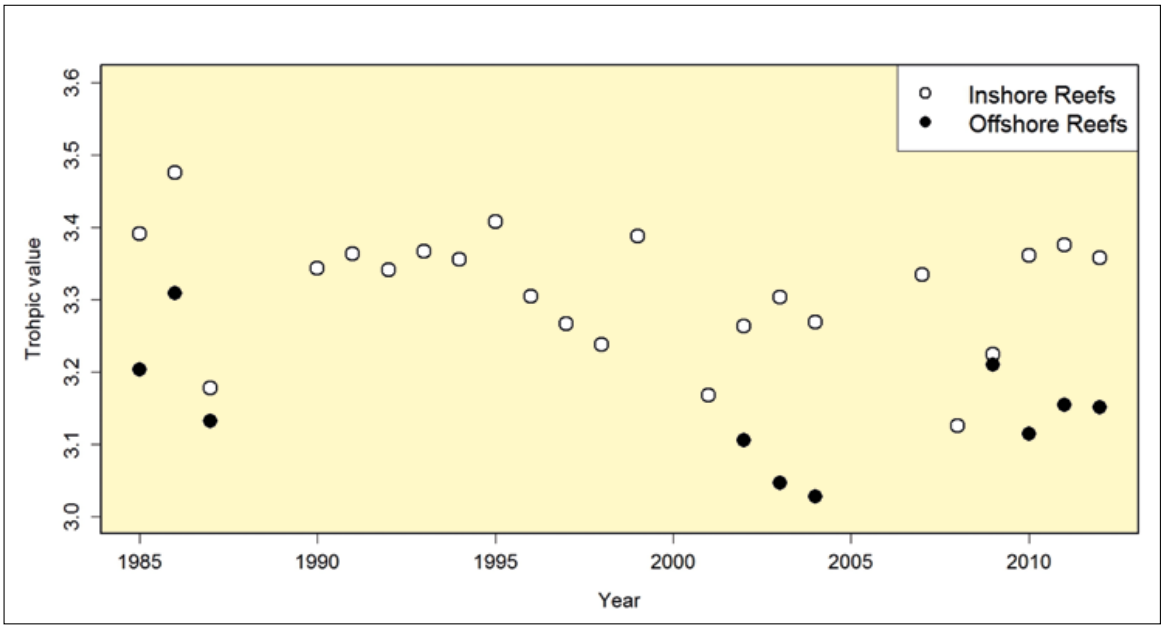

FIGURE 3.93. *Average trophic value for the fishes from inshore reefs (open circles) and offshore reefs (solid circles) during 1985 to 2012 (KFUPM/RI, 2001; KFUPM/RI, 2003; KFUPM/RI, 2008; KFUPM/RI, 2013).*

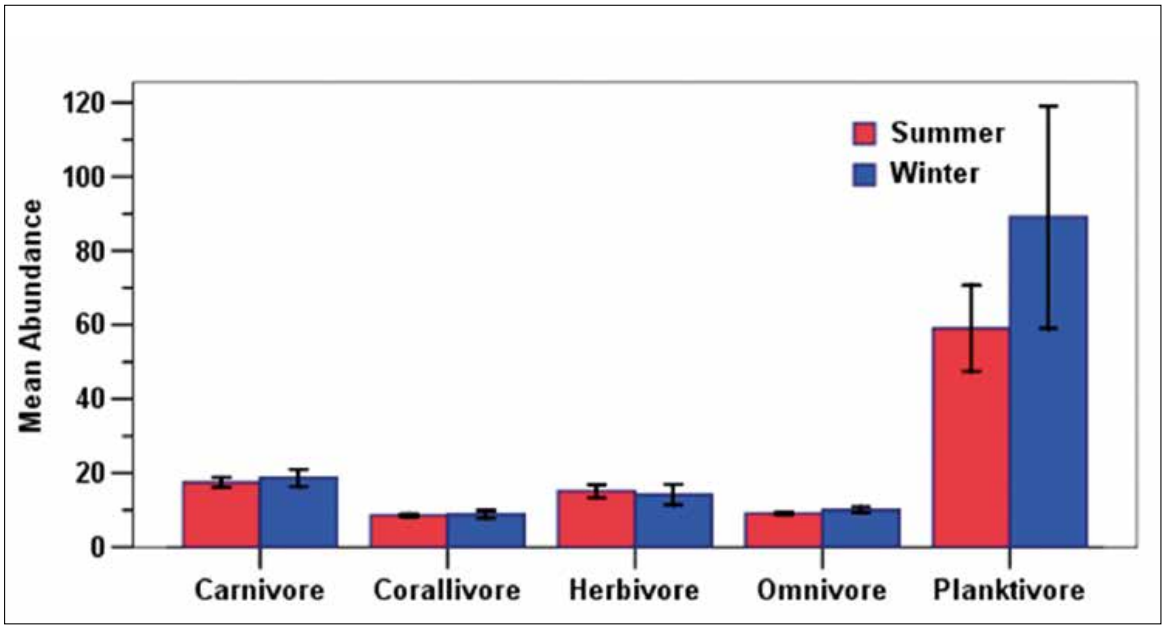

FIGURE 3.94. *The mean relative abundance of reef fishes belonging to different feeding guilds at the nearshore reefs during the winter and summer seasons.*

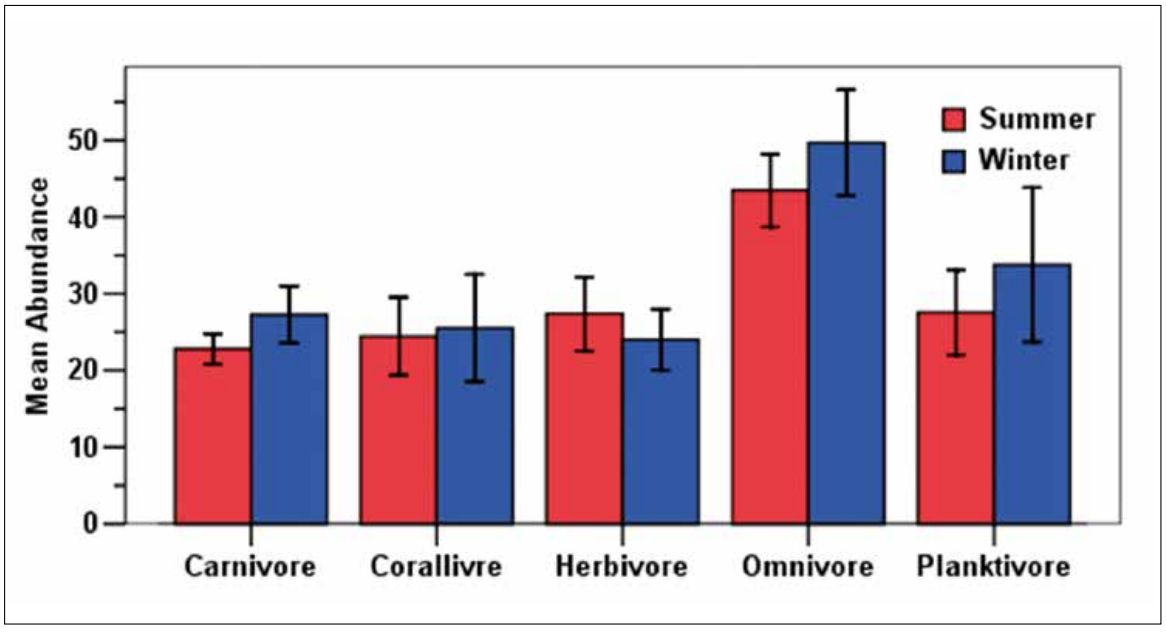

FIGURE 3.95. *The mean relative abundance of reef fishes belonging to various feeding guilds at the offshore reefs during the winter and summer seasons.*

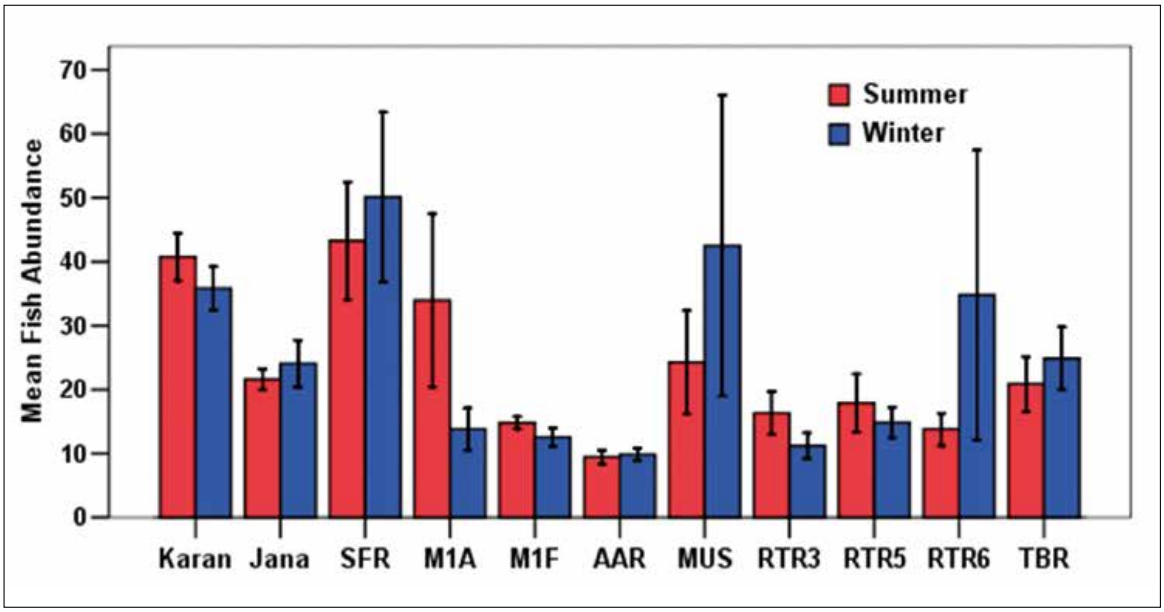

FIGURE 3.96. *The mean abundance of reef fishes during the winter and summer seasons at the individual reefs (AAR = Abu Ali Reef; SFR = Safaniyah Reef; M1A = Manifa 1A reef; M1F = Manifa 1F reef; MUS = Musallamiyah Reef; RTR = Ras Tanura Reefs; TBR = Tarut Bay Reef), (KFUPM/RI, 2001; KFUPM/RI, 2008; KFUPM/RI, 2013).*

with macroalgae such as *Colpomenia sinuosa* and *Sargassum* sp. completely covering corals and reef surfaces in shallow water on inshore reefs during winter months, and disappearing during spring warming (Coles, 1988; Coles and Tarr, 1990). The macroalgae cover was found to be highest in March, and was primarily consisting of *Sargassum* sp. or *Colpomenia sinuosa* and *Enteromorpha* sp., Figure 3.86. On offshore reefs, where a greater number of coral species occur, the seasonal pattern of algal vs. coral dominance was less pronounced, Figure 3.85, probably due to the less extreme seasonal temperatures offshore. Consequently, in deeper water at some offshore reefs, an opposite annual cycle of summer blooms of the algae *Dictyota* sp. and *Lobophora variegata* alternating with winter reductions of the coverage of these algae was found (KFUPM/RI, 2001; KFUPM/RI, 2003; KFUPM/RI, 2008; KFUPM/RI, 2013).

Algal communities, dominated by highly productive small filamentous algal turf can hamper coral settlement and overgrow coral recruits, thereby contributing to the decline of a coral population (McCook, et al., 2001). Subsequently, no injury or mortality of corals due to macroalgal blooms was reported during the survey of the Gulf corals and macroalgae in 1982 (McCain, et al., 1984) and during 1985 to 87 (KFUPM/RI, 1988; Coles, 1988). It has been reported that reef corals in the Gulf are subject to both extreme temperature stress and to competition for habitat from macroalgal growth (Coles, 1998). Competition between coral and algae is likely to be important in some offshore areas but nearer the shore the physical conditions tend to favor algae (Sheppard, 2010). In general, the seasonal algal growth on coral reefs from the study area has not, apparently, impacted the reefs (KFUPM/RI, 2001; KFUPM/RI, 2008; KFUPM/RI, 2013).

The common and the abundant macroalgae found on Gulf reefs was *Colpomenia sinuosa* and the common coralline algae belonging to the order *Corallinales. Colpomenia sinuosa* was reported by Basson (1979a) from the Saudi Arabian Gulf coast, De Clerck and Coppejans (1996) from the Jubail Marine Wildlife Sanctuary of Saudi Arabia, recorded by Newton (1955b) and Basson, et al. (1989) from Bahrain and by Newton (1955a) and Al-Hasan and Jones (1989) from Kuwait. De Clerck and Coppejans (1996) reported the algal die off during spring, resulting in the accumulation of enormous amounts of loose lying material and it completely disappeared by summer.

Lobophora variegate (synonym of *Pocockiella variegate*) was a common macroalgae found on *Acropora* dominated reef compared to *Porites* dominated reefs. This alga used to grow very well between the branches of *Acropora,* where it completely covers its basal parts (De Clerck and Coppejans, 1996). This species was reported by Basson (1979a) from Saudi Arabia and recorded by Basson, et al. (1989) from Bahrain (as *Pocockiella variegata*). *Sargassum* species were morphologically very variable and nearly 150 to 200 species have been described (Womersley, 1987). Five *Sargassum* species (*S. angustifolium, S. binderi, S. boveanum, S. decurrens* and *S. latifolium)* has been reported from the Saudi Arabian Gulf coast (De Clerck and Coppejans, 1996). *Sargassum latifllium* was the most common *Sargassum* species reported from the study area (Basson, 1979a; KFUPM/RI, 2001). Large areas of the infralittoral reef platform from the study area were covered with *S. latifllium* together with *S. angustifllium* and *S. boveanum* during late winter (from end of February onwards) and the spring (KFUPM/RI, 2001; KFUPM/RI, 2008; KFUPM/RI, 2013).

Invertebrates

Within the Gulf many of the reef-associated non-coral invertebrate groups (especially soft bodied groups) are poorly known for want of a dedicated survey and studies. Most of the information available on non-coral invertebrate groups was limited to reef associated fishes. A large number of invertebrate species, comprising groups of cryptic, boring or commensal organisms were reported from the Saudi Arabian Gulf reefs (KFUPM/RI, 2001; KFUPM/RI, 2003; KFUPM/RI, 2008; KFUPM/RI, 2013). These include several species of bivalves, of which *Lopha cristagalli* and *Chama pacifica* were the most abundant; and cryptic hermit crabs and commensal crabs living among the branches of the corals *Stylophora pistillata* and *Acropora clathrata*. The benthic communities associated with coral reefs usually play a major role in the removal of plant biomass by feeding (herbivory). For example, grazing by macroherbivores (notably sea urchins and fish) has profound effects on the distribution and abundance of coral reef algae and corals, by clearing substrates for the re-colonization of coral recruits following disturbances (Glynn, 1990; Hay, 1997).

The most widely distributed and abundant macroinvertebrates observed from the study area on all reefs was the echinoid *Echinometra mathaei*. This sea urchin occurred on *Porites*-dominated as well as *Acropora*-dominated reefs from Safaniyah to Tarut Bay, Figure 3.97. The spiny urchin *Diadema setosum* and the pencil urchin *Prionocidaris baculosa* was also recorded from the base and slope transects on Manifa and Tarut Bay reefs (KFUPM/RI, 2001; KFUPM/RI, 2003; KFUPM/RI, 2008; KFUPM/RI, 2013). Sea urchins are important herbivores on coral reefs, and in some ecosystems they play a critical role in maintaining the balance between coral and algae. The densities of this species were significantly higher on the reef flats of nearshore reefs. Sea urchins are important consumers of benthic algae on coral reefs (Bak, 1990; McClanahan, et al., 1996; Mills, et al., 2000; Peyrot-Clausade, et al., 2000), and as such mediate competition for space between corals and algae (Edmunds and Carpenter, 2001).

FIGURE 3.97. *Some of the macro invertebrates recorded from the study area. (a) Orange sponge; (b) Brown sponge; (c) Jellyfish; (d) Pearl oyster (Pinctada radiate); (e) Close up view of Pearl oyster; (f) Bivalve Chama sp.; (g) The most abundant sea urchin (Echinometra mathaei); (h) The less abundant sea urchin (Diadema setosum); (i) Black sea cucumber (Holothuria leucosphilota); (j) Sea cucumber (Stichopus variegatus); (k) The pharaoh cuttlefish (Sepia pharaonis); (l) Star fish (Pentaceraster mammillatus); (m) Star fish (Linckia multifora); (n) Crab (Carpilius convexus); (o) The flat head lobster (Thenus orientalis).*

In addition to their role as herbivores, sea urchins contribute to the bioerosion of the reef substratum (Bak, 1994; Downing and El-Zahar, 1987) and the production and reworking of sediments (McClanahan and Muthiga, 2001). Despite playing an important role on coral reefs, uncontrolled population growth of urchins (i.e., outbreaks) can severely reduce reef topography as rates of bioerosion exceed rates of reef accretion (Glynn, et al., 1979; Uthicke, et al., 2009).

Several other invertebrate species belonging to Porifera (sponges), Scyphozoa (jellyfish), Anthozoa (sea anemones and corals), and Hydrozoa (includes hydroids), flat worms, Nemertea (ribbon worms), Sipuncula (peanut worms), Polychaeta (bristleworms), molluscs, crustaceans, Bryozoa (often known as sea-mats) and Echinoderms were also reported from the western Arabian Gulf reefs (Basson, et al., 1977); however, detailed information on their species diversity, abundance and distribution are lacking.

Reef Associated Fishes

The reef fish diversity in the study area was much less than elsewhere in the Indo-Pacific due to the extreme environmental conditions and consequent constraints on larval supply (Coles and Tarr, 1990). Based on the survey conducted during 1985 to 2012, 147 reef fish species belonging to 43 families were recorded from the Saudi Arabian Gulf reefs, Table 3.31 and Figure 3.98. The fishes associated with offshore reefs were more diverse compared to the nearshore reef fishes, Figure 3.91. Previous studies reported 71 species of reef fishes from Bahrain (Smith, et al., 1987), 106 species on reefs off the Gulf coast of Saudi Arabia (McCain, et al., 1984), 103 species off the coast of Dubai (Riegl, 2002) and 85 species off the coast of Kuwait (Downing, 1985). A general decline in the species number and fish diversity was observed after the 1996 and 1998 mass coral bleaching in the study area (KFUPM/RI, 2001), as reported from other parts of the Gulf (Grandcourt, 2012).

Seasonal changes in the abundance of reef fishes were observed from the nearshore and offshore reefs, Figures 3.94 to 3.96. Coles and Tarr (1990) reported the seasonal changes in the abundance of reef fishes in the coral reefs off the Gulf coast of Saudi Arabia, apparently related to the winter migration of nearshore reef fishes to the offshore reefs. They have also reported a significant negative relationship between the macroalgae cover and the abundance of reef fishes. McCain, et al. (1984) attributed the seasonal changes in the abundance of reef fishes to the increase in the number of herbivorous fish in association with algal blooms during March to April. The large, fleshy algae were the preferred food source of several grazing herbivore fishes (Basson, et al., 1977).

Fish species most commonly observed on the inshore reefs were *Diplodus sargus, Chaetodon nigropunctatus, Acanthopagrus bifasciatus, Plectorhynchus schotaf, Pseudochromis persicus, Neopomacentrus sindensis, Epinephelus suillus* and *Siganus canaliculatus* (KFUPM/RI, 2001; KFUPM/RI, 2003; KFUPM/RI, 2008; KFUPM/RI, 2013). Offshore reef fish communities were more diverse. The most common species encountered on offshore reefs were *Chromis weberi, Caesio variolineatus, Abudefduf saxatilis, Chromis ternatensis, Cephalopholis hemistiktos, Halicoeres marginatus, Pomacentrus trichourus, Scarus ghobban, Thalassoma lunare* and *Acanthurus sohal* (Coles and Tarr, 1990). The data from the present study (1985 to 2012) also showed a similar reef fish community pattern (KFUPM/RI, 2001; KFUPM/RI, 2003; KFUPM/RI, 2008; KFUPM/RI, 2013).

FIGURE 3.98. *Reef fishes recorded from the study area. (a) Cheilodipterus persicus; (b)* Amphiprion bicinthus*; (c)* Chaetodon melapterus*; (d)* Pomacanthus maculosus*; (e)* Acanthurus sohal*; (f)* Scarus sordidus*; (g)* Chaetodon nigropunctatus*; (h)* Diplodus sargus kotschyi*; (i)* Plectorhincus gaterinus*; (j)* Acanthopagrus bifasciatus*; (k)* Coral fish*; (l)* Cephalopholis hemistiktos*; (m)* Pterois volitans*; (n)* Plectorhincus sordidus*; (o)* Carangoides ferdau*; (p)* Heniochus acuminatus*; (q)* Platax teira*; and (r)* Parupeneus margaritatus.

Natural and Anthropogenic Threats

Most of the natural and anthropogenic disturbances causing the decline of coral reefs are likely to directly or indirectly impact the reef associated communities. The mass coral bleaching events reported in 1996 and 1998, which were associated with the elevated seawater temperature from the region, had a major adverse impact on the reef associated communities (Riegl and Purkis, 2012). The potential impacts associated with climate change were also might have affected the abundance, distribution and diversity of reef associated communities, especially reef fishes in the Gulf (Munday, et al., 2009).

Unhealthy fishing practices such as over fishing, selective fishing and destructive fishing on coral reefs are likely to adversely impact the reef communities, especially reef fishes (Bellwood, et al., 2004). A wide variety of fishing gear such as traps, nets and handlines are used in reef fisheries in the Gulf. One of the fishing related impacts, *ghost fishing* due to the abandoned fish traps and nets, was apparently killing several reef fishes and mobile invertebrates from the region, Figure 3.99.

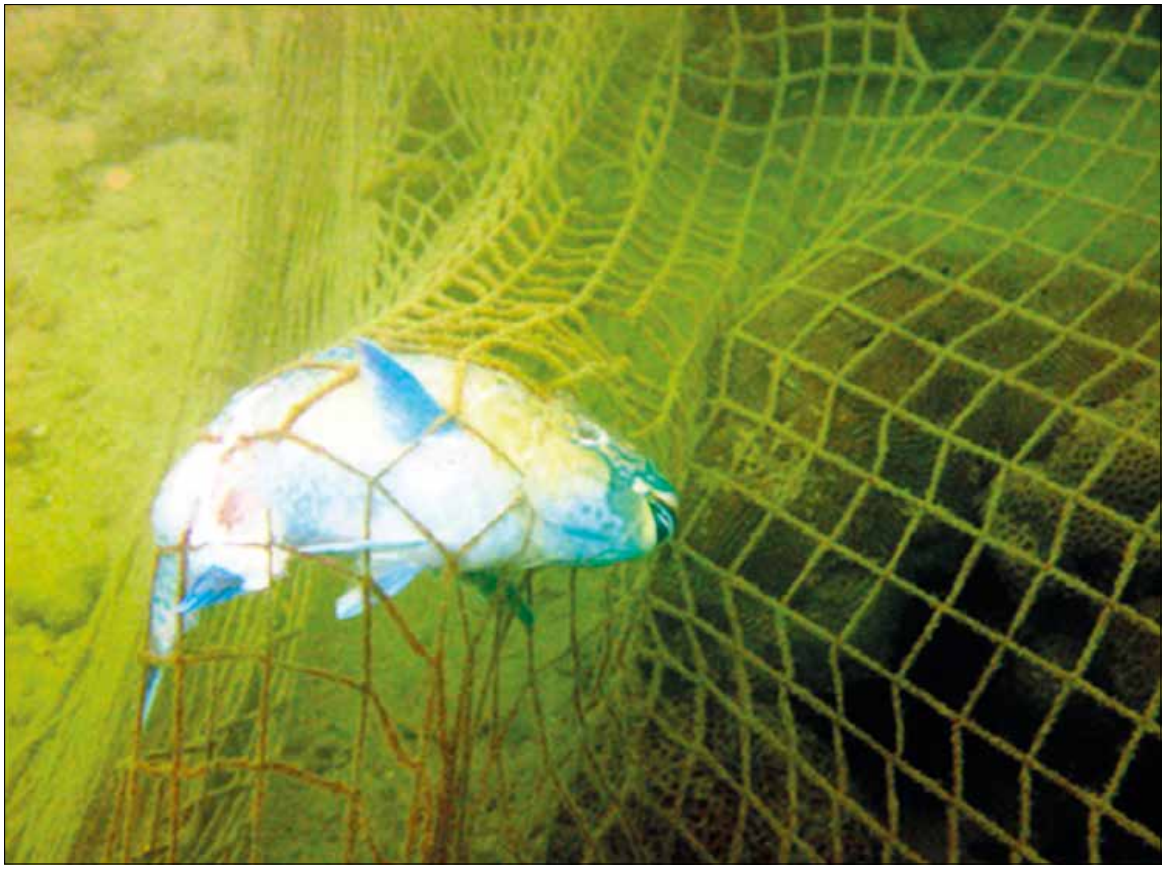

FIGURE 3.99. *A fishing net stranded on GOSP-4 Reef with a parrot fish (*Scarus ghobban*) entangled and killed (KFUPM/RI, 2003).*

The rapid industrialization happened along the Gulf coast has impacted the coastal environmental quality leading to the decline of sensitive habitats such as mangrove, seagrass and coral reefs (Sheppard, et al., 2010). The unprecedented coastal modification activities such as landfilling, reclamation, dredging and spoil disposal occurring along the Gulf region (Loughland, et al., 2012) resulted in rapid habitat loss and various secondary effects such as smothering by sediment and a loss in illumination. The cumulative impacts of anthropogenic activities in the region has impacted the coral and non-coral communities in the Gulf (Riegl and Purkis, 2012) and if the same trend is continued, several sensitive reef communities will permanently disappear from the region. Therefore, a focused coral reef management and conservation program should be implemented in the region to protect the unique coral and non-coral communities surviving in the extreme environment, compared to their counterparts from other parts of the globe.