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Efficiency of Coral Reef Bio-Indicators in the Northern Part of the Persian Gulf

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Abstract: The purpose of this study was to determine efficiency of coral reef indicators proposed by Reef Check for the Persian Gulf. Data were collected in the Northern part of the Persian Gulf, using Reef Cheek standard methodology, statistical analyses carried out were spearman correlation, redundancy analysis and indicator species analysis. According to the results of this study: (1) dark butterfly fish (*Chaetodon nigropunctatus*), Arabian butterfly fish (*Chaetodon melapterus*) and total butterfly fish (sum of both species) show consistent positive correlation with live coral and negative correlation with macroalgae coverage and have high, consistent and significant indicator values for high coral/low macroalgae habitats and are good indicators of healthy reefs in the region, (2) parrotfish >20 cm (sum of all species) show consistent positive correlation with live coral and negative correlation with macroalgae cover but don't show high significant and consistent indicator value for high coral/low macroalgae habitats and are considered as weak bio-indicators for healthy reefs in the areas and (3) none of invertebrate species show consistent significant correlation with substrate types (live coral and macroalgae) or high consistent and significant indicator values for habitat types and therefore they can't be used as reef health indicator in the region. It is concluded that only above-mentioned butterfly fish and to lower extent parrot fish can be pointed out as reef health indicators and efficiency of other fishes and invertebrates proposed by Reef Check, need to be revised as indicator of harvest types and other anthropogenic impacts in the region.

Key words: Coral reefs, bio-indicators, efficiency, Northern Persian Gulf

INTRODUCTION

Using bio-indicators in environmental monitoring programs is becoming increasingly popular because of their easiness, cost-effectiveness and because bio-indicators reduce complex environmental stresses to simple measurable responses. It is very important to choose appropriate bio-indicators in monitoring programs. In other words selection of effective indicators is key to the overall success of any monitoring program (Beyeler and Dale, 2001).

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In reef monitoring programs definition of healthy reef is very important. Census methods such as live coral index [(percentage of live coral/(percentage of live coral + percentage of dead coral)] or only percentage of live coral cover are the most popular reef monitoring parameters. Macroalgae cover is also used as a negative indicator of coral health because it often out-competes stressed corals (Linton and Warner, 2003). However, census methods do not provide early warning signals or give reasons for coral mortality, which is why bio-indicators are crucial.

Coral species richness and functional aspects such as coral growth rates, productivity, calcification, fecundity and recruitment (Peters *et al*., 1997; Richmond, 1993) are other parameters used as coral health monitoring parameters. High coral species richness does not necessarily reflect maximum health because some reef stresses result in decreased fish or invertebrate numbers rather than loss of coral. In addition, many non-coral bio-indicators have been proposed for inclusion into reef monitoring programs worldwide. The most widely discussed non-coral bio-indicators of environmental stress on coral reefs are the chaetodontids or butterfly fish which have now been incorporated into a number of reef monitoring programs in the Indo-Pacific (White, 1989; Crosby and Reese, 1996). A number of studies have shown a positive correlation between chaetodontid diversity and abundance and percent live coral cover or coral species richness (Bell and Galzin, 1984; White, 1989; Shokri *et al*., 2005). Reese (1981) first gave a detailed definition of the butterfly fish bio-indicator hypothesis, which has been re-stated again in Reese (1994) and Crosby and Reese (1996).

For this study reef, percentage live coral cover vs. percentage macroalgae cover defines health and healthy reefs are those with high live coral and low macroalgae cover vise versa.

Reef Check (RC), as the largest and most widespread global organization dedicated to monitoring reefs proposes some fish and invertebrate indicators for coral reef monitoring program in the Persian Gulf region (Hodgson *et al*., 2004).

The purpose of this study was to determine potential and effectiveness of these fishes and invertebrates as coral reef health indicators in the Northern part of the Persian Gulf using data collected using standard RC methodology (Hodgson *et al*., 2004).

MATERIALS AND METHODS

Study Area

Persian Gulf coral communities exist in a harsh environment with respect to salinities, sea temperatures and extreme low tides (Coles and Fadlallah, 1991). These factors have a profound influence on community structure by restricting the number of species in the area and by causing recurrent mortality among the dominant species (Coles and Fadlallah, 1991; Fadlallah *et al*., 1995; Riegl, 1999). In recent years, coral bleaching has occurred throughout the world resulting in mass mortality of corals mainly due to the elevated temperature (Wilkinson, 2000). This has also been the case in the Persian Gulf over the last decade (Pilcher *et al*., 2000).

Data for this study were collected from the coral reefs at Khark, Kharku, Hendorabi, Kish, Farur and Farurgan Islands and Nayband bay in 2007. All the studied islands and the bay are located in the Northern part of the Persian Gulf. Data collected from some of the mentioned islands and from Lavan and Larak Islands during 2002, 2003 were also used in the present study (Fig. 1).

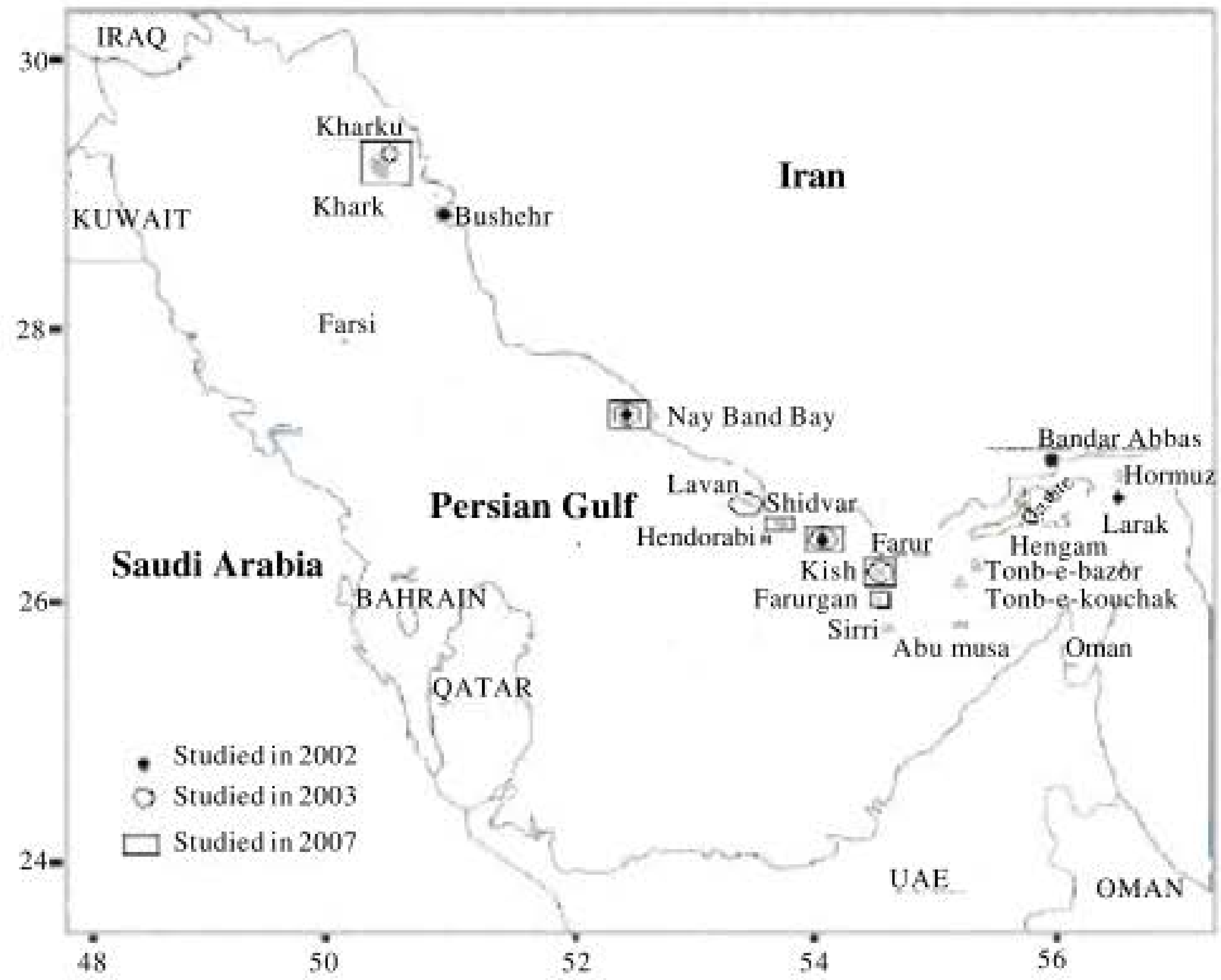

Fig. 1: Study area in the Northern part of the Persian Gulf, showing the sampled reefs locations in 2002, 2003 and 2007

Sampling Techniques

Survey sites were chosen using manta tow surveys and reconnaissance dives. They were popular diving areas, the best reefs in the area or the worst reefs in the area and they reflect a wide range of habitats.

At each site, data were collected along 2 depth contours at shallow (3-6 m) and intermediate (6-12 m) depths (If the reef was too shallow, the 6-12 m depth transect was not completed). Along each depth contour a 100 m transect was placed and along it four 20 m replicate transects were surveyed. The start and end points of 20 m transects were 5 m apart.

Along each transect at each depth a belt transect (5 m wide centered on each 20 m transect line) was sampled for commercially important fish favored by fishers and aquarium and invertebrate taxa typically targeted for curios and food (Hodgson *et al*., 2004). A line-point intercept sampling method was used to study the nature of the substrate (Hodgson *et al*., 2004), with substrate type recorded at 0.5 m intervals along the transect. RC's standard categories are hard (live) coral, soft coral, recently killed coral, fleshy seaweed, sponge, rock, rubble, sand, silt/clay and other.

Statistical Methods

Detrended Correspondence Analysis (DCA) were run on the fish and invertebrate data sets using Canoco 4.0 to determine the unimodality of the data. Detrending was done by segments, species were square root transformed and rare species were down-weighted. Following Chi-squared measure distance and one standard deviation cutoff, Outliers were identified and removed from the data set using PC-ORD 4.17.

Redundancy Analysis (RDA) were run using Canoco 4.0 to determine correlations between fish and invertebrate vs. substrate types because all DCA axis 1 gradients were below 2.5 because RDA is useful where gradients are shorter (Palmer, 2004). Once RDA's were performed, collinear environmental variables, those with Variance Inflation Factors (VIF) over 10, were deleted (Coker and Kent, 1992), also all data were checked for normality using the Anderson-Darling test in Minitab 13.20, in cases where p values were below 0.05 (Non-normal distribution), data were log transformed using x = Log (x+1).

In addition, spearman correlation analyses were used to show the relationships between fish and invertebrate species/taxa and environmental variables using Minitab 13.20.

Indicator species were identified for each habitat type using the method introduced by Dufrene and Legendre (1997) based on an indicator value index (IndVal) as follows:

$$\text{IndVal} = A_{ij} \times B_{ji} \times 100$$

where, A_{ij} is a measure of specificity (A_{ij} = $\text{Nindividual}_{ij}/\text{Nindividual}_{i}$) and B_{ji} is a measure of fidelity (B_{ji} = $\text{Nsites}_{ji}/\text{Nsites}_{j}$).

In our case Nindividual_{ij} is the mean number of species i across transects of group j and Nindividual_{i} is the sum of the mean numbers of individuals of species i over all groups, Nsites_{ji} is the number of transects in cluster j where species i is present and Nsites_{j} is the total number of transects in that cluster.

The final indicator value assigned to a species for a certain habitat topology is the highest value found over all groups of that type. For maximum A_{ij}, species i is only present in cluster j. B_{ji} is highest when species i is present in all transects of cluster j. indicator value is thus highest (100%) when species i is present in all transects of only one habitat group. The significance of the indicator values were tested using a random reallocation of transects among transects groups using Monte Carlo randomization test (1000 permutations).

The calculations of indicator values and the associated Monte Carlo (randomization) test were performed using the PC-ORD 4.17.

The sites hierarchy component of Dufrene and Legendre (1997) method to select transects clusters was preformed using Minitab 13.20. Clustering was hierarchical with standardized variables (to allow for different units), Euclidean distances and Ward linkages.

Transects were clustered into groups based on substrate types (using live coral cover and macroalgae cover as the determining variables).

RESULTS

Abundance of Indicators and Substrate Types

Average abundance of indicator fish and invertebrates within belt transects and average percentage cover of substrate line transects in 2002, 2003 and 2007 are respectively presented in Table 1 to 3.

Correlation Between Proposed Indicators and Environmental Variables

In redundancy analysis for fish vs. substrate types in 2002, dark butterfly fish and Arabian butterfly fish and to some extent, other groupers and parrotfish exhibited positive correlation and orange-spotted grouper showed negative correlation with live coral coverage (Fig. 2), for invertebrates vs. substrate types short-spine urchin exhibited positive correlation with both live coral and macroalgae coverage (Fig. 3).

In redundancy analysis for fish vs. substate types in 2003, dark butterfly fish, long-fin butterfly fish, grey grunt, Arabian butterfly fish, parrotfish, orange-spotted grouper, other groupers and to some extent snappers demonstrated positive correlation with live coral and

Table 1: Average fish/invertebrate density (individual/100 m^2) and percentage cover of substrate types in 2002 transects

	Kish 1		Kish 2		Larak	
	3-6	6-12	3-6	6-12	3-6	6-12
Fish/invertebrate	(m)					
Orange-spotted grouper>30 cm	0.00	0.25	0.00	0.00	0.00	0.00
Other groupers>30 cm	0.00	0.00	0.25	0.00	0.50	0.25
Hump-head wrasse	1.00	0.00	0.00	0.00	0.00	0.00
Dark butterfly	0.50	1.00	0.00	0.50	14.50	0.00
Arabian butterfly	0.25	0.00	0.00	0.00	0.50	0.00
Long-fin butterfly	0.00	1.00	0.75	0.00	0.00	0.00
Parrotfish >20 cm	0.00	0.25	1.75	0.25	2.00	0.00
Moray eel	0.00	0.00	0.00	0.25	0.00	0.00
Short-spine urchin	1.50	16.00	5.25	41.75	3.25	0.00
Pencil urchin	0.00	3.00	0.00	0.00	0.00	0.00
Sea cucumber	0.00	3.00	0.50	0.00	0.50	0.00
Lobster	0.00	0.00	0.25	0.00	0.00	0.00
Live coral	15.00	8.13	10.00	6.88	42.50	2.50
Fleshy algae	3.75	3.75	26.25	1.88	9.38	2.50
Others	3.13	1.25	8.13	3.13	3.13	0.63
Rubble	3.13	40.63	3.13	0.00	15.63	1.88
Rock	33.13	0.00	11.88	4.38	10.00	1.25
Recently killed coral	0.00	1.25	3.13	0.00	0.63	0.00
Soft coral	0.00	0.00	0.00	0.00	0.00	1.88
Sand	37.50	40.00	28.75	80.63	17.50	86.25
Sponge	4.38	5.00	8.75	3.13	1.25	3.13

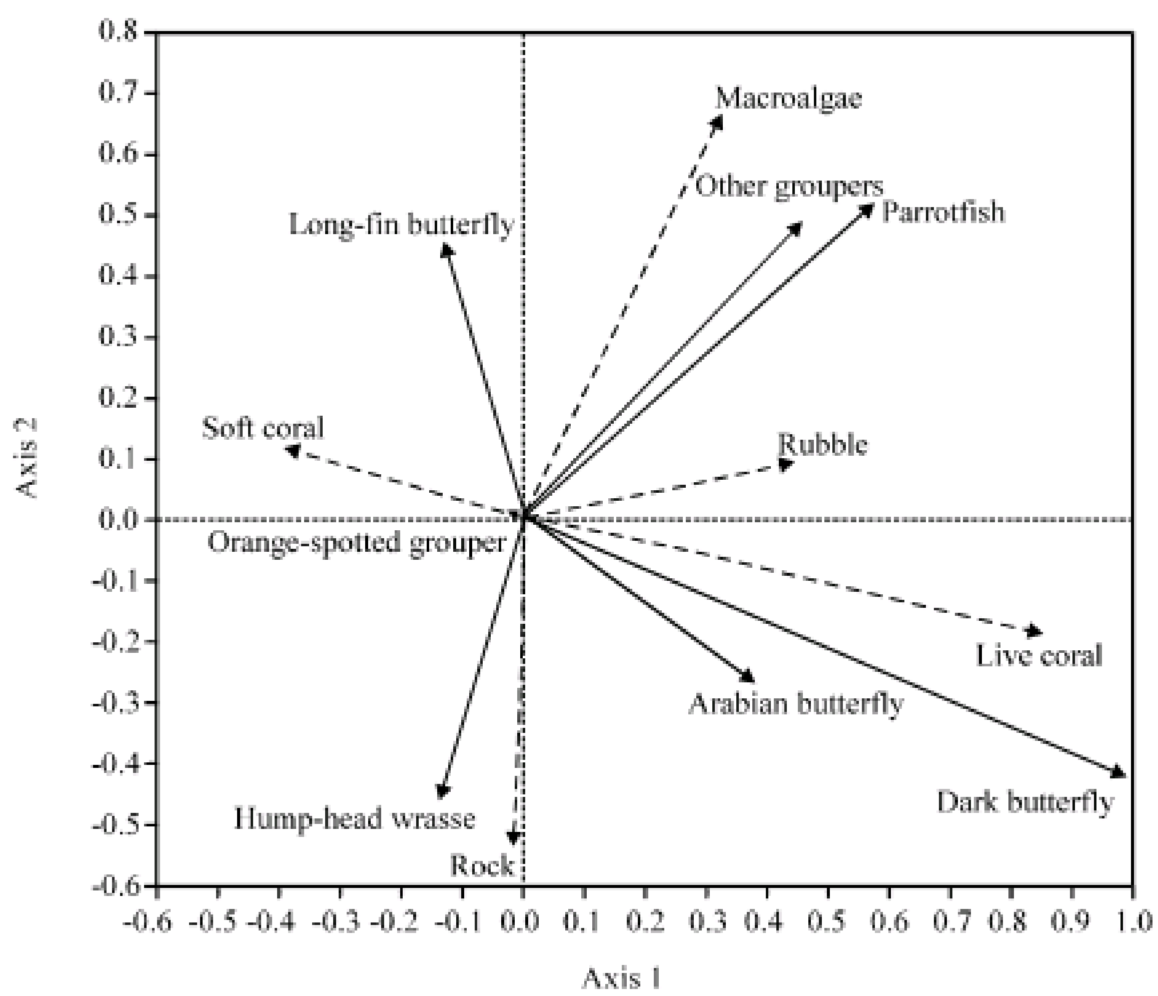

Fig. 2: Redundancy anlysis for fish vs. substrate types data in 2002

negative correlation with macroalgae coverage (Fig. 4), for invertebrates vs. substate types, triton sells and pencil urchin showed positive correlation with live coral, sea cucumbers showed negative correlation with live coral and short-spine urchin exhibited negative correlation with macroalgae and litle positive corelation with live coral coverage (Fig. 5).

In redundancy analsis for fish vs. substrat types in 2007, parrotfish, dark butterfly fish and to some extent Arabian butterfly fish exhibited positive correlation with live coral and

Table 2: Average fish/invertebrate density (individual/100 m^2) and percentage cover of substrate types in 2003 transects

	Nayband 1		Kharku		Lavan		Kish 1	
	3-6	6-12	3-6	6-12	3-6	6-12	3-6	6-12
Fish invertebrate substrate	(m)							
Orange-spotted grouper >30 cm	1.00	2.80	3.00	2.30	4.50	2.80	4.00	1.75
Other groupers >30 cm	0.00	0.50	1.50	0.00	0.50	0.80	1.25	0.75
Spotted grunt	0.50	0.00	0.00	0.00	3.50	0.00	0.00	0.25
Arabian butterfly	0.00	0.00	3.00	0.50	0.50	0.00	0.50	1.25
Dark butterfly	6.50	10.75	17.00	7.30	5.50	3.00	4.50	11.25
Parrotfish >20 cm	0.50	3.50	3.50	0.00	0.00	1.50	0.50	5.50
Snapper	28.80	1.30	57.50	7.50	13.80	2.30	10.25	4.50
Long-fin butterfly	0.00	0.00	0.00	2.80	0.00	0.00	0.00	0.00
Grey grunt	0.00	0.00	0.00	2.50	0.00	0.00	0.00	0.00
Black-spotted grunt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Short-spine urchin	462.25	0.00	145.50	30.75	96.00	59.25	3.25	5.00
Long-spin urchin	0.00	123.50	38.00	75.75	2.25	0.50	12.50	8.50
Pencil urchin	0.00	0.00	13.25	32.00	0.00	0.00	0.50	2.25
Cowry shell	1.50	1.25	0.00	0.00	2.00	1.75	0.75	2.25
Sea cucumber	0.50	1.75	0.00	0.00	2.75	2.25	0.75	3.00
Triton shell	0.00	0.75	7.00	7.25	0.00	0.00	0.00	0.00
Live coral	31.25	25.63	50.00	44.38	35.00	21.25	15.00	5.00
Fleshy algae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Others	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63
Rubble	5.00	9.38	5.00	5.63	3.75	6.25	8.13	3.75
Rock	58.13	21.88	19.38	18.13	46.88	38.75	38.75	45.00
Recently killed coral	1.88	2.50	0.00	12.50	5.00	16.25	15.00	21.88
Soft coral	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00
Sand	3.75	31.88	22.50	18.13	9.38	5.00	21.88	23.75
Sponge	0.00	5.00	3.13	1.25	0.00	11.88	1.25	0.00

	Kish 2	Farur		Nayband 2	
	3-6	3-6	6-12	3-6	6-12
Fish invertebrate substrate	(m)				
Orange-spotted grouper >30 cm	1.50	1.25	5.00	0.00	0.00
Other groupers >30 cm	0.00	0.00	17.00	0.25	0.00
Spotted grunt	0.00	0.00	0.00	0.00	0.00
Arabian butterfly	2.00	5.25	5.25	0.00	0.00
Dark butterfly	8.50	7.50	10.25	1.00	2.50
Parrotfish >20 cm	2.00	6.75	9.75	0.00	1.25
Snapper	58.25	39.00	10.25	0.00	0.00
Long-fin butterfly	0.00	0.00	1.25	0.00	0.00
Grey grunt	0.00	0.00	1.50	0.00	0.00
Black-spotted grunt	0.00	0.00	0.00	0.00	0.25
Short-spine urchin	8.00	2.50	1.75	411.75	114.50
Long-spin urchin	3.00	3.25	1.25	0.00	0.00
Pencil urchin	0.00	0.00	0.00	0.00	0.00
Cowry shell	0.00	1.00	1.50	0.00	0.00
Sea cucumber	0.50	0.00	0.50	0.00	2.25
Triton shell	0.50	0.75	0.00	0.00	0.00
Live coral	27.50	37.50	58.13	30.00	28.13
Fleshy algae	2.50	0.00	0.00	0.63	1.88
Others	0.00	0.00	0.00	1.25	9.38
Rubble	7.50	0.63	15.00	22.50	3.13
Rock	11.88	3.13	11.25	31.88	14.38
Recently killed coral	33.13	25.63	5.63	1.88	0.63
Soft coral	0.00	0.00	3.75	0.00	0.00
Sand	0.00	28.13	5.63	11.88	35.63
Sponge	17.50	0.63	0.63	0.00	6.88

negative correlation with macroalgae coverage. Orange-spotted groupers, other groupers and also snappers showed lower positive correlation and spotted grunt showed negative correlation with live coral (Fig. 6), for invertebrates vs. substrat types sea cucumbers and to lower extent short-spine urchin demonstrated negative correlation with live coral and litle correlation with macroalgae coverage (Fig. 7).

Table 3: Average fish/invertebrate density (individual/100 m^2) and percentage cover of substrate types in 2007 transects.

	Hendorabi	Nayband 1	Nayband 2	Kharku		Khark	
	3-6	3-6	3-6	3-6	6-12	3-6	6-12
Fish invertebrate substrate	(m)						
Orange-spotted grouper >30 cm	0.50	0.50	0.00	0.00	0.25	0.00	0.25
Other groupers >30 cm	1.50	0.75	0.75	0.25	0.25	0.00	0.00
Spotted grant	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arabian butterfly	0.50	0.00	0.00	0.00	0.25	0.00	0.00
Dark butterfly	5.50	6.50	5.25	13.00	4.75	5.75	6.00
Parrotfish >20 cm	5.50	0.50	0.25	0.00	0.00	0.00	1.25
Moray	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Snapper	0.75	25.75	1.75	0.00	0.50	0.00	0.00
Short-spine urchin	1.25	0.00	700.75	270.75	155.50	60.75	0.00
Long-pine urchin	0.00	0.00	0.00	13.25	62.50	0.00	58.75
Pencil urchin	0.00	0.00	0.00	0.50	1.50	0.00	0.00
Cowry shell	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Sea cucumber	0.50	0.00	0.00	0.25	0.00	0.00	0.00
Live coral	21.25	56.88	42.50	63.75	47.50	45.63	67.50
Algae	14.38	0.00	0.00	0.63	0.00	0.63	0.00
Others	0.63	0.00	0.00	0.00	0.00	0.00	0.00
Rubble	9.38	8.75	14.38	8.75	24.38	6.88	15.00
Rock	23.13	17.50	41.25	5.63	5.63	41.25	11.88
Recently killed coral	0.00	5.00	0.63	6.25	4.38	0.00	2.50
Soft coral	2.50	0.00	0.00	0.00	0.00	0.00	0.00
Sand	28.13	11.88	1.25	15.00	18.13	5.63	3.13
Sponge	0.63	0.00	0.00	0.00	0.00	0.00	0.00
	Kish 1		Kish 2	Farur		Farurgan	
	3-6	6-12	3-6	3-6	6-12	3-6	6-12
Fish invertebrate substrate	(m)						
Orange-spotted grouper >30 cm	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other groupers >30 cm	0.50	0.00	0.00	0.00	0.50	0.25	0.25
Spotted grant	0.00	0.00	0.00	0.00	0.00	0.25	0.25
Arabian butterfly	5.50	0.00	0.00	2.50	0.00	0.50	0.50
Dark butterfly	7.75	0.00	0.00	10.75	0.25	2.25	2.25
Parrotfish >20 cm	0.00	0.00	0.00	1.00	0.00	3.50	3.50
Moray	0.00	0.00	0.00	0.00	0.25	0.00	0.00
Snapper	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Short-spine urchin	0.00	0.00	65.50	0.00	22.75	1.00	0.00
Long-pine urchin	0.00	2.25	13.00	58.75	18.50	0.00	0.00
Pencil urchin	0.00	0.50	0.00	0.00	0.00	0.00	0.00
Cowry shell	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sea cucumber	0.00	0.25	0.00	0.00	0.00	0.25	0.00
Live coral	74.38	1.25	2.50	68.75	11.25	22.50	30.63
Algae	0.00	2.50	1.88	0.00	0.00	0.00	0.00
Others	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rubble	11.88	22.50	13.13	5.00	18.75	7.50	1.88
Rock	5.00	1.25	5.63	20.63	5.63	46.88	30.63
Recently killed coral	1.88	0.00	0.00	0.63	0.00	0.00	0.00
Soft coral	0.00	0.00	0.00	0.00	0.00	0.63	13.75
Sand	6.88	72.50	76.25	5.00	64.38	22.50	23.13
Sponge	0.00	0.00	0.63	0.00	0.00	0.00	0.00

According to the results of spearman correlation analysis in 2002, dark butterfly fish ($r = 0.962$, $p<0.01$), Arabian butterfly fish ($r = 0.950$, $p<0.01$) and total butterfly fish ($r = 0.964$, $p<0.05$) exhibited high positive and significant correlation with percent live coral cover and sea cucumbers ($r = -0.576$, $p<0.05$) showed significant negative correlation with percent live coral cover. In 2003 Arabian butterfly fish ($r = 0.568$, $p<0.05$) showed positive and significant correlation with live coral cover. In 2007 total butterfly fish ($r = 0.877$, $p<0.001$) and dark butterfly fish ($r = 0.858$, $p<0.001$) showed high positive and significant correlation with live

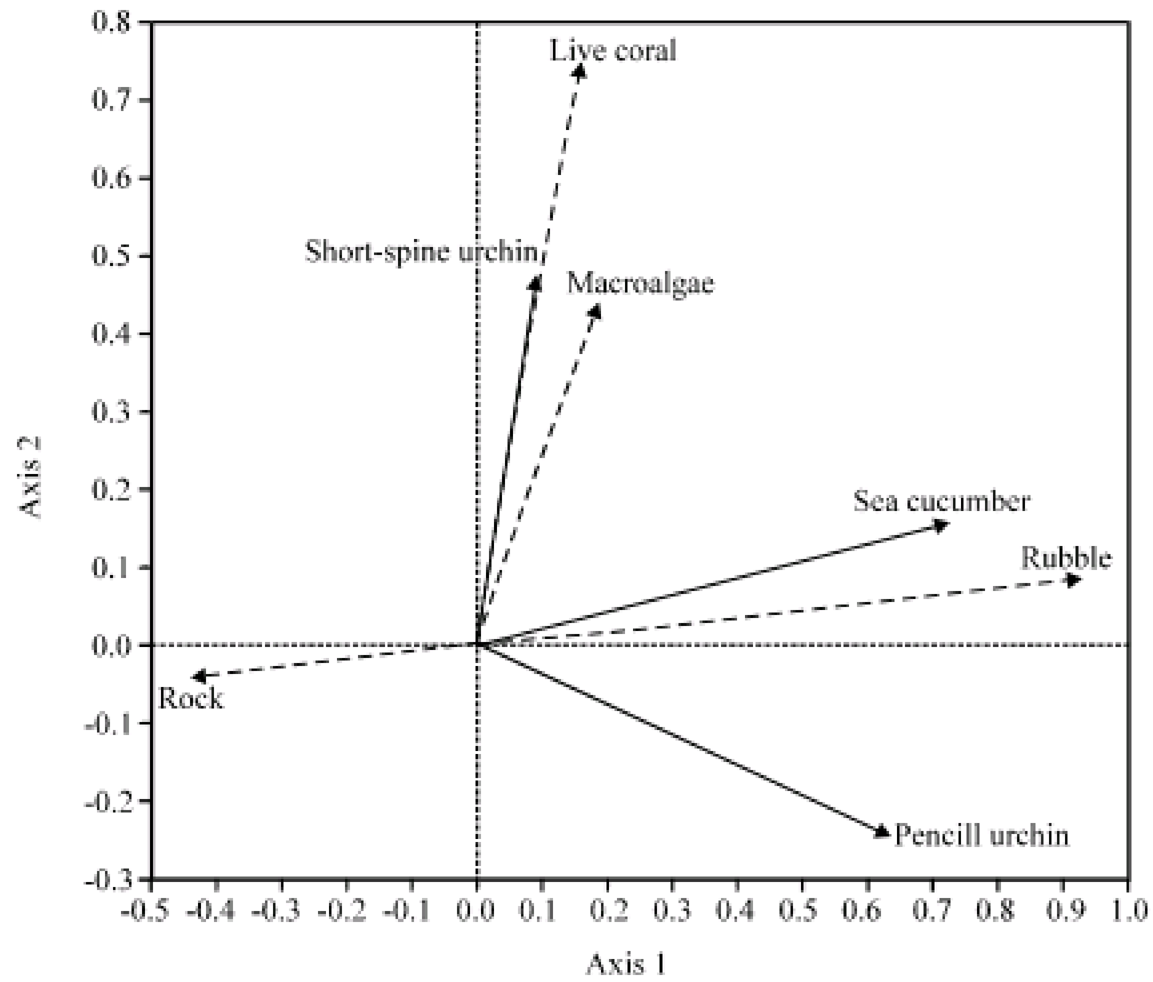

Fig. 3: Redundancy anlysis for invertebrate vs. substrate types data in 2002

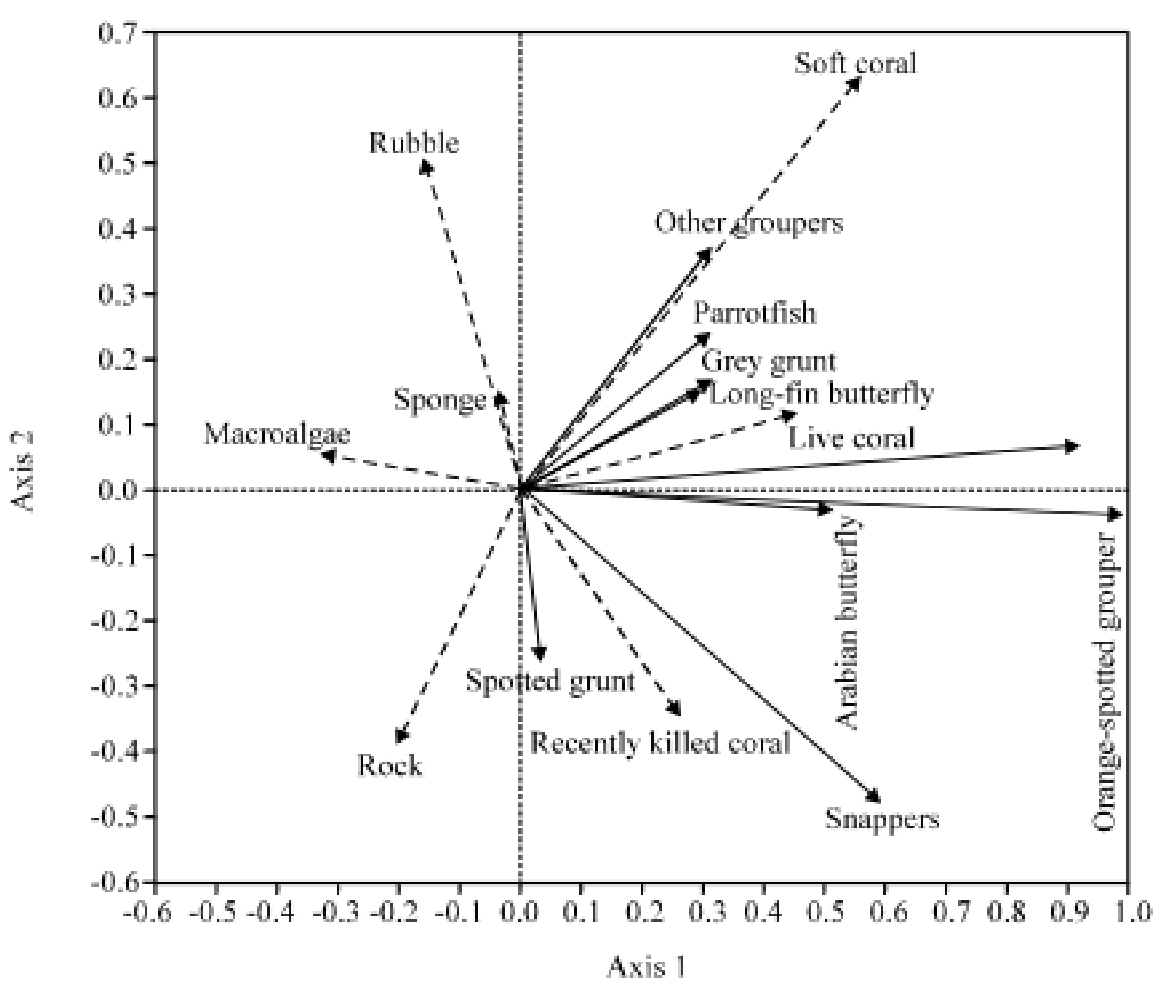

Fig. 4: Redundancy anlysis for fish vs. substrate types data in 2003

coral cover. Also in 2002 lobester ($r = 0.959$, $p<0.005$) and in 2007 orange-spotted grouper ($r = 0.539$, $p<0.05$), other groupers ($r = 0.694$, $p<0.01$), parrot fish ($r = 0.651$, $p<0.05$) and sea cucumber ($r = 0.789$, $p<0.005$) demonstrated positive significant correlation with macroalgae cover.

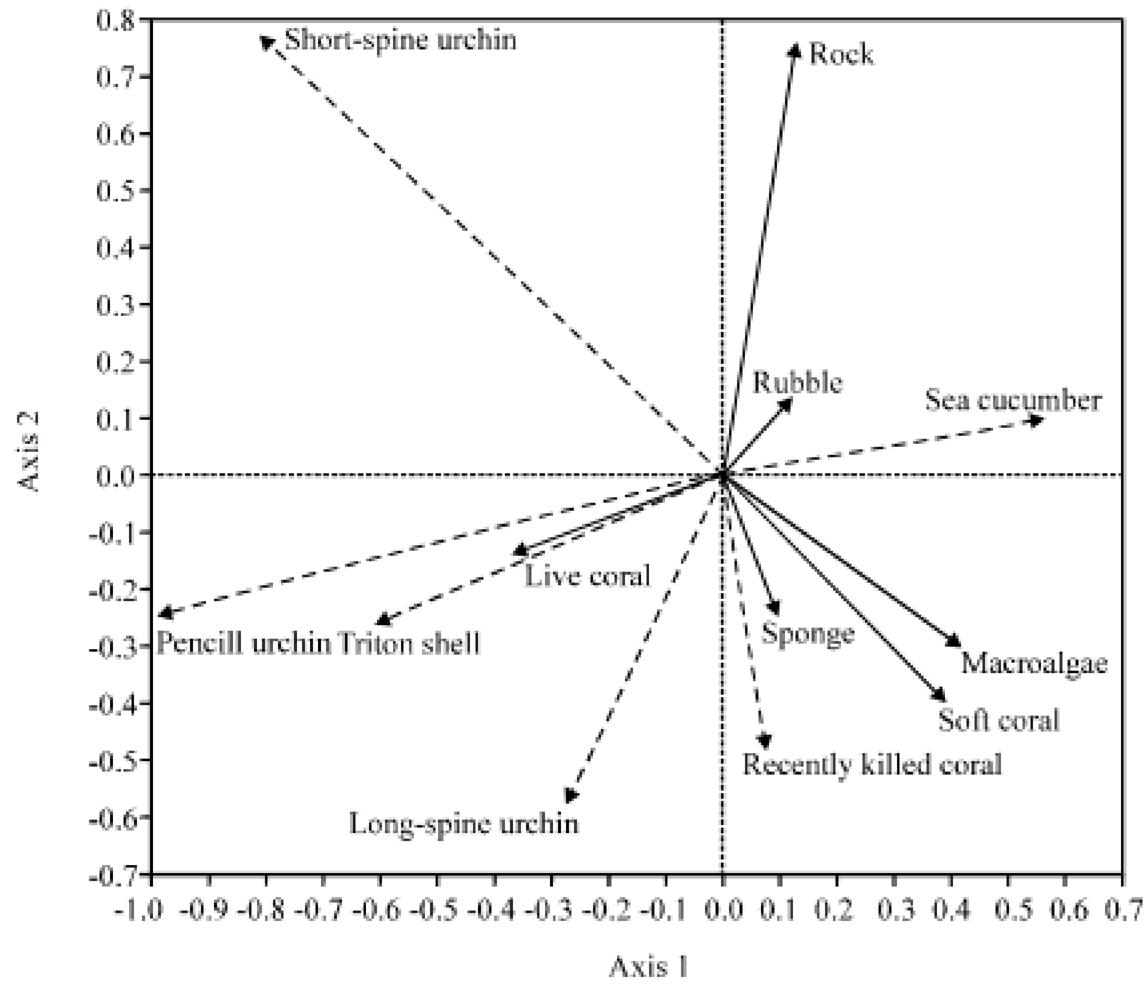

Fig. 5: Redundancy anlysis for invertebrate vs. substrate types data in 2003

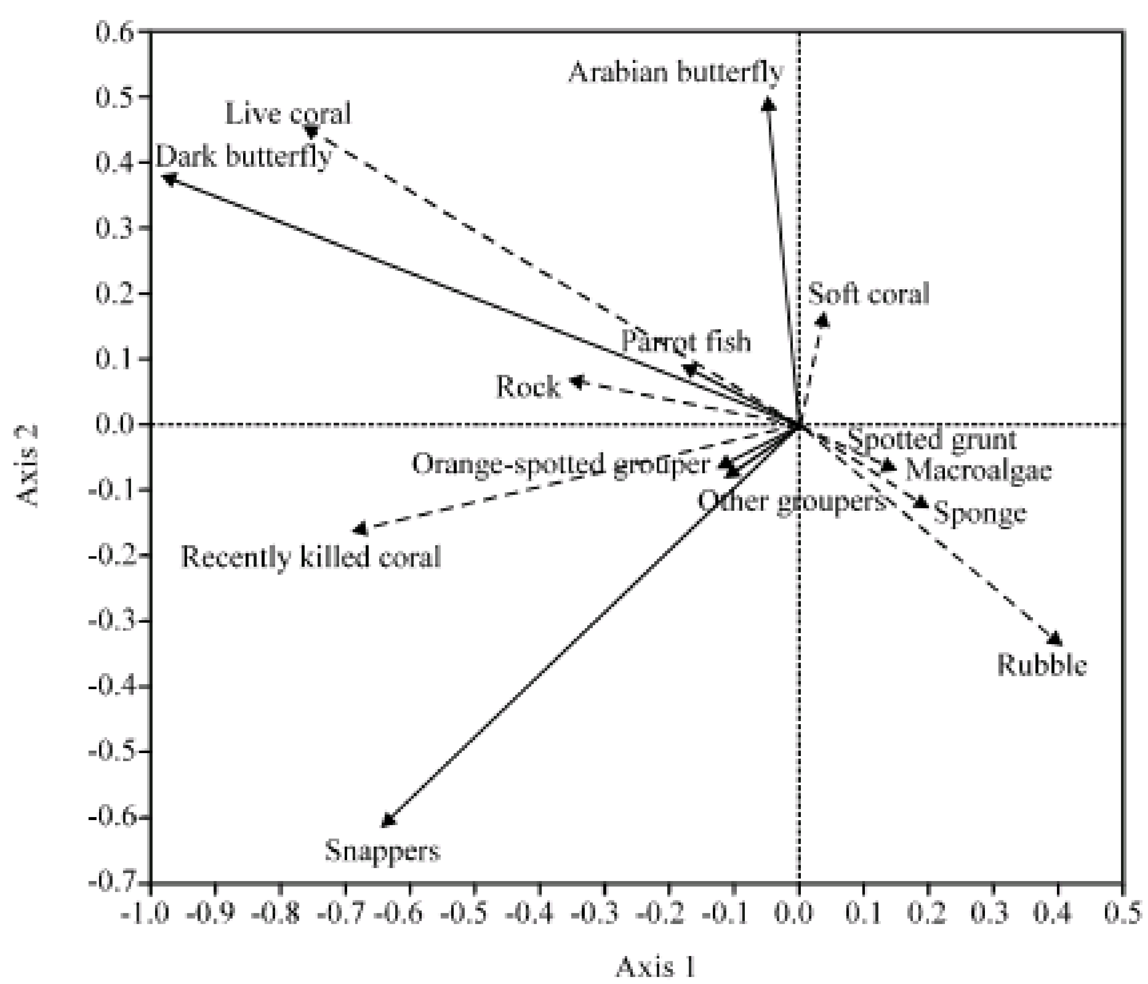

Fig. 6: Redundancy anlysis for fish vs. substrate types data in 2007

Indicator Values of Proposed Indicators for Different Habitat Groups

Studied transects were clustered into groups based on percentage live coral and macroalgae cover of substrate. For both live coral and macroalgae cover the following criteria were used: High cover = more than 31%, medium cover = 11-30%, low cover = 1-10%, very low cover = less than 1%.

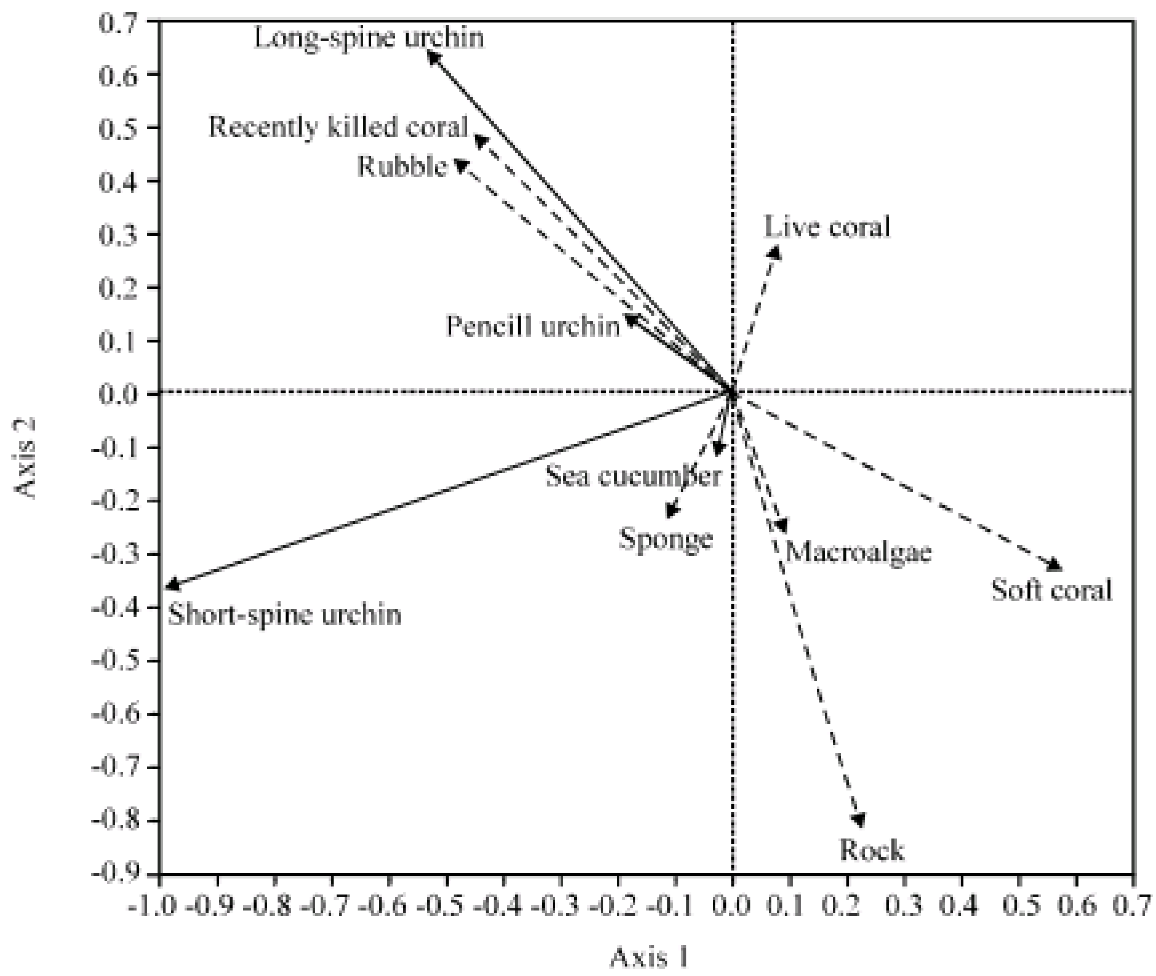

Fig. 7: Redundancy anlysis for invertebrate vs. substrate types data in 2007

Table 4: Indicator Values (IV) for characteristic species/taxa of different habitat groups

Species/taxa	IV	*P	Transect group	Year
All butterfly	90.6	0.3790	Medium to high coral/low macroalgae	2002
Dark butterfly	95.2	0.2380		
Arabian butterfly	100.0	0.0630		
Hump-head wrasse	50.0	0.3310		
Long-fin butterfly	50.0	0.4760	Low coral/low to medium macroalgae	
Short-spine urchin	62.5	0.5310		
Orange-spotted grouper	43.7	0.3870	High coral/very low macroalgae	2003
Other groupers	56.5	0.4490		
Arabian butterfly	63.3	0.1090		
Dark butterfly	48.4	0.1360		
Snappers	49.2	0.4140		
Long-fin butterfly	66.7	0.0750		
Grey grunt	66.7	0.0750		
All butterfly fishes	53.0	0.0360		
Long-spine urchin	59.6	0.3500		
Pencil urchin	62.8	0.0860		
Triton shells	62.9	0.0840		
Short-spine urchin	56.3	0.4540	Medium coral/very low to low macroalgae	
Cowries	54.5	0.1160	Low coral/very low macroalgae	
Sea cucumbers	61.1	0.0730		
Dark butterfly	81.4	0.0010	High coral/ very low macroalgae	2007
All butterfly	81.3	0.0020		
Short-spine urchin	45.4	0.4910		
Long-spine urchin	40.6	0.4020		
Parrotfish	42.4	0.3580	Low to medium coral/very low to medium macroalgae	
Sea cucumbers	42.1	0.1780		

*Proportion of monte carlo test randomized trials with indicator value equal to or exceeding the observed indicator value. p = (1 + number of runs$\geq$observed)/(1 + number of randomized runs)

Caculated indicator values for characteristic species/taxa of habitat groups recognized in the survey area in different years are shown in Table 4.

DISCUSSION

Several studies (Chabanet *et al*., 1997; Zekeria and Videler, 2000; Adjeroud *et al*., 2002; Bozec *et al*., 2005) suggested that the abundance of butterfly fish is positively influenced by the density of live coral. Relationship between temporal variation of butterfly fish and the corals as the only taxon directly affected by natural disturbances was reported by Adjeroud *et al*. (2002). Crosby and Reese (1996) have suggested that corallivore butterfly fish could be used as indicator species for changing conditions of coral reefs. Shokri *et al*. (2005) have suggested that *Chaetodon nigropunctatus* may be an excellent candidate for coral health indicator in Iranian waters of the Northern Persian Gulf.

However, it appears that dark butterfly fish (*Chaetodon nigropunctatus*), arabian butterfly fish (*Chaetodon melapterus*) and totall butterfly fish (sum of dark butterfly fish and arabian butterfly fish) are good indicators for high coral, low macroalgae habitats and therefore healthy reefs. Total butterfly fishes exhibited high and significant indicator values in 2003 (53.0, $p<0.05$) and 2007 (81.3, $p<0.01$) for high coral/very low macroalgae habitats. They also showed high significant positive correlation with live coral in 2002 ($r = 0.964$, $p<0.05$) and 2007 ($r = 0.877$, $p<0.001$). Arabian butterfly fish showed high indicator value in 2002 (100.0) for Medium to high coral/low macroalgae habitats and in 2003 (63.3) for high coral/very low macroalgae habitats and this is further illustrated by the RDAs where they demonstrated positive correlation with live coral in 2002, 2003 and 2007 and also by spearman corellation where they showed high positive and signifiant correlation with live coral in 2002 ($r = 0.950$, $p<0.01$) and positive signifiant correlation in 2003 ($r = 0.568$, $p<0.05$). Dark butterfly fish showed high indicator value in 2002 (95.2), 2003 (48.4) and high significant indicator value in 2007 (81.4, $p<0.005$) for high coral/very low macroalgae habitats, this is further illustrated by the RDA's where they exhibited positive correlation with live coral in 2002, 2003 and 2007 and negatively correlated with macroalgae in 2003 and 2007. Furthermore dark butteflyfish showed high significant positive correlation with live coral cover in 2002 ($r = 0.962$, $p<0.01$) and 2007 ($r = 0.858$, $p<0.001$).

Although, parrotfish are large herbivores crucial to the existence of coral by browsing algae (Hughes, 1994; Bellwood *et al*., 2004; Rotjan and Lewis, 2006), relatively easy to count and potentially good bio-indicators for reef health, however, the results obtained in the present study indicate that they are weak indicators for the helthy coral reefs in the region, being positively correlated with macroalgae in 2002, negatively correlated in 2003 and 2007 and positively correlated with live coral in 2002, 2003 and 2007 but they didn't show high significant coorrelation with live coral or low macroalgae or high indicator value for high coral/low macroalgae habitats, except in 2007 that they demonstrated positive significant correlation ($r = 0.651$, $p<0.05$) with macroalgae cover.

Concerning invertebrates, none of the species proposed by RC for the Persian Gulf can be discerned as bio-indicator for reef health in the region. For example, short spine urchins (*Echinometra mathaei*) showed high indicator values for low live coral/low to medium macroalgae habitats in 2002, for high to medium live coral/low to very low macroalgae areas in 2003 and for high live coral/very low macroalgae areas in 2007. Lack of consistent correlation is further illustrated by the lack of consistency in RDA graphs, they were positively correlated with live coral and macroalgae in 2002, indicating little correlation with live coral and negatively correlated with macroalgae in 2003, negatively correlated with live coral and indicating little correlation with macroalgae in 2007.

Based on the results of this study it can be concluded that:

- Arabian butterfly fish (*Chaetodon melapterus*), dark Butterfly fish (*Chaetodon nigropunctatus*) and totall butterfly fish (sum of both species) show positive correlation with live coral and negative correlation with macroalgae coverage and have high, consistent and statistically significant indicator values for high coral/low macroalgae cover and are good indicators of healthy coral reefs in the survey area
- Parrotfish show consistent positive correlation with live coral and negative correlation with macroalgae cover but don't show high significant and consisitent indicator value for high coral/low maco-algae habitats and are considered as weak bio-indicators for healthy reef areas
- None of invertebrate species show consistent significant correlation with substrate types (live coral and macroalgae) or high consistent and significant indicator values for habitate types and therefor they can't be used as reef health indicators in the region

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