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Distribution of butterflyfishes (Chaetodontidae) along the Egyptian Red Sea coast and its relation to coral health

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ABSTRACT

1. The distribution of butterflyfishes (Chaetodontidae) and percentage cover of different benthic components of substrate was studied along the coast of the Egyptian Red Sea from 60 km north of Hurghada to Halayeb area near the Sudanese border.

2. The work was conducted during the period from 1999 to 2001 and was carried out at 130 stations along the coast including 75 representing six different coastal-fringing coral reef profiles.

3. Distribution of the 10 species of butterflyfishes found in the study area did not differ significantly across six recognized reef profiles.

4. Linear regression analyses revealed a significant correlation between the number of individuals of certain species of butterflyfishes with certain substrate components and an overall correlation with the percentage of living coral coverage.

5. These results suggest that butterflyfishes may be useful as indicators of coral health.

KEY WORDS: butterflyfishes; Red Sea; ecology; distribution; coral cover

INTRODUCTION

The complex architecture of coral reefs offers shelter to an extremely diverse fauna (Connell, 1978). In most studies, the physical complexity of the reef substratum is positively correlated with the diversity of fish community, but not with fish abundance (Luckhurst and Luckhurst, 1978; Roberts and Ormond, 1987). In some studies, the biological nature of the substratum, i.e. coral species richness and/or diversity of live coral, seem to have no influence on the diversity and abundance of fish communities (Luckhurst and Luckhurst, 1978; McManus *et al*., 1981; Bouchon *et al*., 1987; Roberts and Ormond 1987). However, in other studies (Carpenter *et al*., 1981; Sano *et al*., 1984; Reese, 1993), these fish characteristics were positively correlated with the percentage of live coral. The variability in the relationship between the fish and coral

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communities may be attributed to geomorphological, ecological and methodological factors (Chabarnet *et al*., 1997).

Much of the research on coral reef fishes in the last decade has focused on mechanisms of coexistence and a relatively fruitless argument as to whether or not reef fishes partition their resources in ways consistent with niche theory (Anderson *et al*., 1981; Sale and Williams, 1982; Sheppard *et al*., 1992; El-Elwany, 1997). Many of these studies have provided good descriptive data of patterns of distributions but have done little to increase our knowledge of factors determining the distribution and abundance of reef fishes. Reef fish assemblages of the Red Sea region are as varied as the reefs themselves (Roberts *et al*., 1992). There are marked differences among areas in species richness, assemblage composition and abundance of species (Sheppard *et al*., 1992).

Butterflyfishes (family: Chaetodontidae) are among the most easily identified fish members of the coral reef community. Reese (1981, 1993), Risk (1994), and Crosby and Reese (1996) proposed butterflyfishes as good and easily utilized indicators for coral reef health or status. It is possible to hypothesize that the abundance and distribution of butterflyfishes may be affected in general by human impacts on coral reefs, such as improper diving activity that directly or indirectly damages their habitats and reduces their preferred food density. Yossef (1996) studied the relation between reef health and the abundance of all species of butterflyfishes at 15 sites in the Red Sea from the Gulf of Suez to Safaga, and concluded that reef profile had almost no effect on fish distribution. However, she also suggested the possibility of using abundance and social behaviour of obligate corallivore butterflyfishes as indicators for assessing reef health. El-Elwany (1997) examined the link between the butterflyfish presence and coral health at the Gulf of Aqaba, but showed a non-significant relation between the fishes of this family and integrity of corals.

The objective of this work was to study the distribution of the butterflyfishes along the Egyptian coast of the Red Sea, extending from Ras Gharib south to Halayeb (excluding both Gulfs of Suez and Aqaba), and to evaluate whether substrata characteristics (such as reef profile, living coral coverage, and coral type) influence the structure of the butterflyfish communities. In addition the study also examined the relationship between the presence of butterflyfishes and coral health to verify their usefulness as bio-indicators.

MATERIALS AND METHODS

The study area

The study area included the Egyptian Red Sea coast from 50 km north of Hurghada to the coast of Halayeb (27.523810N–22.3434N), close to the Sudanese border. The area surveyed was divided into sectors, each containing a number of stations separated by 5–7 km (Figure 1). A total of 130 stations were sampled, of which 75 supported coral communities, the remainder being dominated by seagrass and mangroves.

Field study

Stations were sampled along the reef face area within a depth range of 1–5 m. Field observations were carried out by snorkelling and scuba diving. Underwater observations were recorded using waterproof papers and pencils. All butterflyfishes were counted within each 100 × 2 m wide transect running along the reef face and parallel to the reef edge. Five transects were studied at each station. The count started 15 minutes after laying the transect tape in order to minimize the disturbance to fishes (Roberts *et al*., 1992).

The percentage cover of the different substrates in the study area was estimated using line intercept transects according to the method of English *et al*. (1997). At each station, a 50-m line transect was laid parallel to the shoreline at the reef face and the percentage cover of each taxon was calculated. Substrate components were classified as hard corals, soft corals, dead corals (recognized by over-growing algae) and

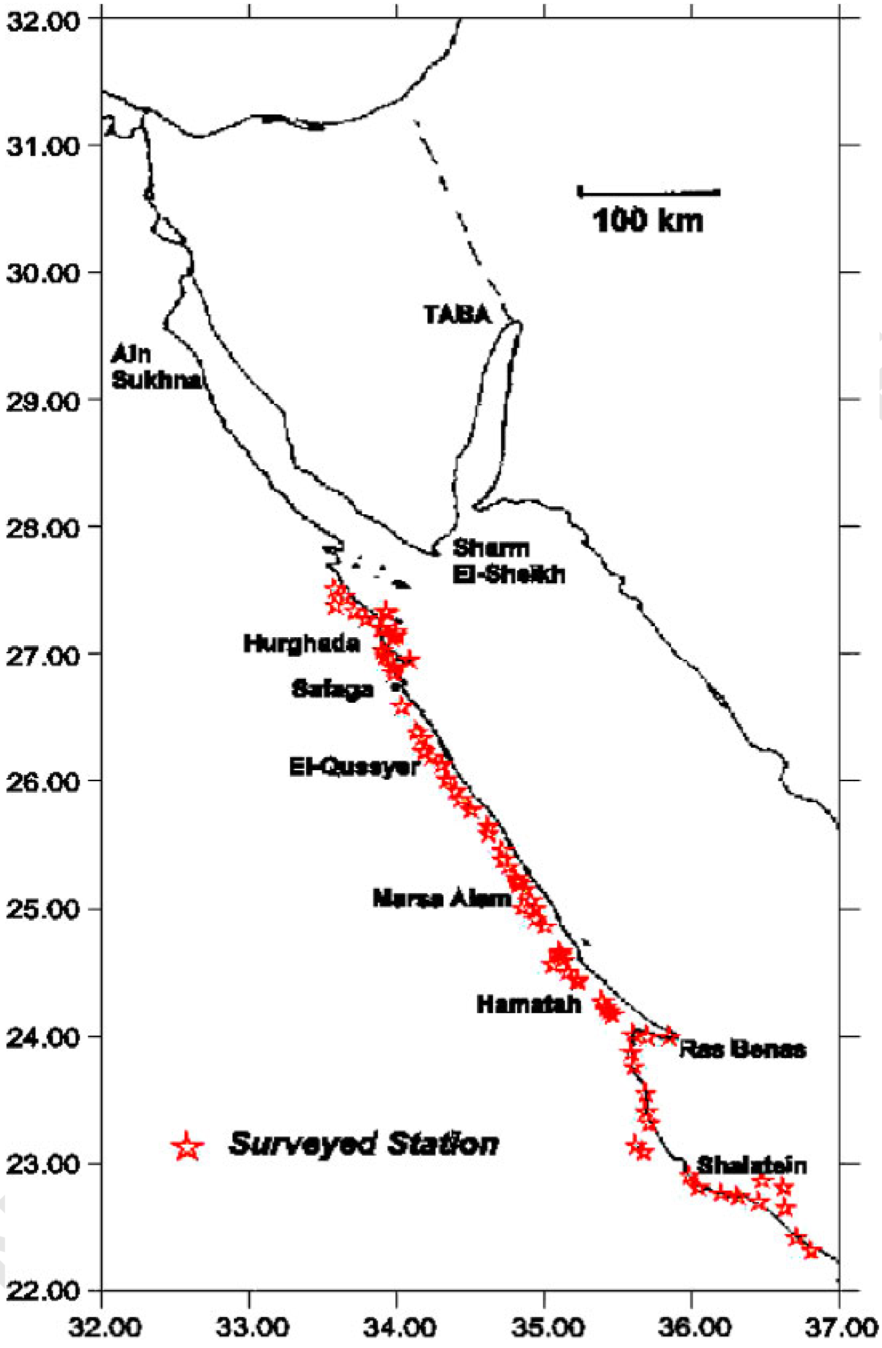

Figure 1. Red Sea map showing the surveyed stations for the butterflyfish species counts and percentage substrate cover.

others, including plants (filamentous algae, calcareous algae, fleshly algae), associated fauna (molluscs, echinoderms and sponges), in addition to the ‘dead substrate’ component (sand and rock). Three transects were studied for substrate analysis at each station after the fish census was completed.

Data analysis

Both Statistica (Version 6.0) and PRIMER (Version 5.0) statistical programs were used for regression analyses to determine the relationship between the different substrate components and the number of fishes recorded in each station. A cluster analysis of the percentage cover data for the substrate components along the surveyed stations was performed to determine similarity among these stations.

RESULTS

The butterflyfish species composition

Ten species of butterflyfishes from two genera (*Chaetodon auriga*, *Chaetodon fasciatus*, *Chaetodon lineolatus*, *Chaetodon melannotus*, *Chaetodon austriacus*, *Chaetodon paucifasciatus*, *Chaetodon semilarvatus*, *Chaetodon larvatus*, *Chaetodon trifascialis*, and *Heniochus intermedius*) were recorded along the coast of the Egyptian Red Sea. These species were recorded at almost all stations except for the *C. larvatus* which was recorded only at three stations, characterized by deteriorated coral reef, around Hurghada. On the other hand, the number of species recorded in a single station ranged from one to nine with an average of 6.9 ± SE 1.7 species per station. Four stations out of the 75 each contained either one, two, three or four species of chaetodontids. The number of stations occupied by between five and nine chaetodontid species ranged from 10 to 18 stations (Figure 2).

Regardless of the number of species at any station, the number of individual fishes seen in one station ranged between 1 and 60 individuals with an average of 27 ± 11 fish.

The reef profiles

Within the study area, six basic types of reef and bottom profiles were identified (Figure 3). The differences between these basic types were based on the type of substratum, width, depth, topography and gradient of the different reef zones. The following is a brief description of the different reef types:

- Type 1: A wide rocky reef flat (>100 m distance) with a very gentle gradient of reef face reaching <10 m depth a long distance (~ 200 m) from the reef edge which was not clearly marked. The reef slope was mostly sandy with a few scattered coral patches. The coral coverage was very low especially over the reef flat.
- Type 2: A narrow reef flat area (<50 m) with some relatively deep sandy lagoons (up to 2 m depth). This type of reef flat was mostly exposed during the low-tide periods, which probably led to the very poor condition of its marine life. The reef face had a moderate gradient which reached more than 10 m in depth after a distance of >20 m from the reef edge, which in turn was not recognizable. The reef slope was sandy with some coral patches.
- Type 3: A very wide reef flat area, reaching sometimes more than 1 km in width and interspersed with several deep sandy lagoons (<10 m depth). The reef flat was mostly covered with sand and seagrass beds, while the coral coverage started low and increased towards the reef edge. The reef edge had a high coral coverage with turf algae covering all the rocky bottom area. The reef face of this area was steep and dropped down to a depth of less than 30 m with a moderate coral coverage, and was followed by a gently graded sandy slope with scattered coral patches.
- Type 4: A very narrow reef flat less than 50 m in width, with the reef edge not clearly visible and sloping down to 2 m depth. The reef face was sloped at a steep angle to the reef flat. The reef face extended no deeper than 10 m before giving way to a gentle sandy reef slope, with no coral cover but almost total algal cover, especially turf algae, which covered the rocky substrate. The reef flat (<50 m wide) was of

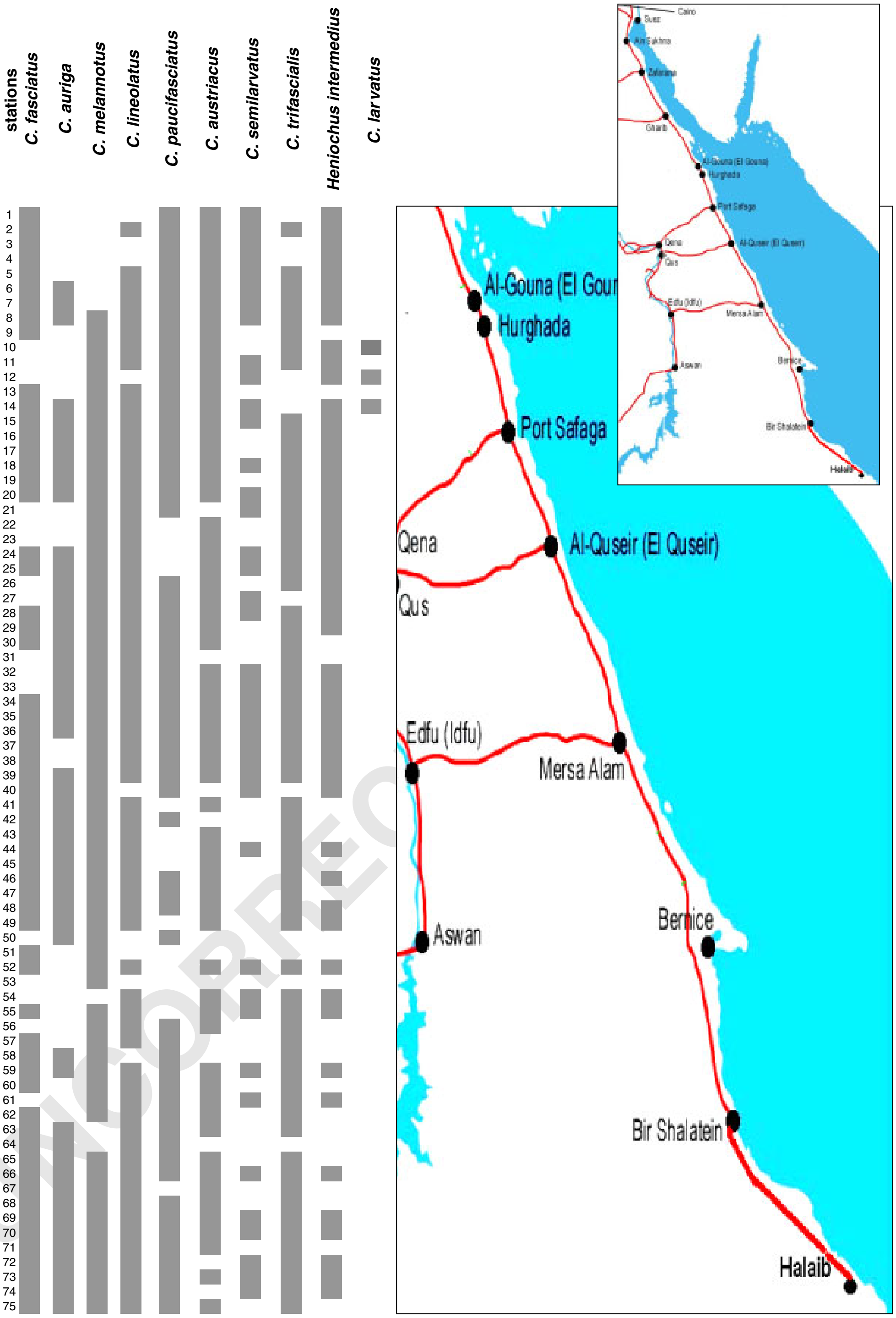

Figure 2. Map showing the distribution of the 10 recorded species of butterfly fishes along the coast of the Red Sea.

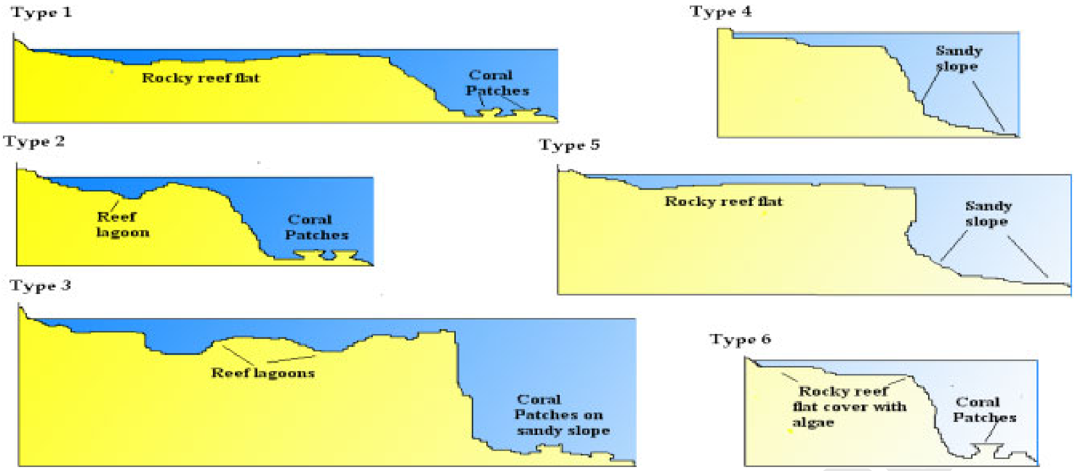

Figure 3. The different reef profiles identified during the survey.

uniform bottom coverage and substrate type, with no demarcation between the back and front of the reef flat. The input of heavy sediment from the reef flat onto the reef face was clearly obvious.

- Type 5: This reef type had a moderately wide rocky reef flat 100–200 m wide, with coral coverage increasing towards the reef edge. The reef face descended very steeply to more than 10 m depth, with high to moderate coral cover. The reef slope had a steep gradient with a sandy bottom clear of coral patches.
- Type 6: This reef type was similar to the previous type except that the reef edge was very distinct with a sharp vertical angle between the reef face and the reef flat. Besides, the sandy reef slope occupied with some coral patches and the reef edge was covered with low coral cover.

The effect of the profile shape and texture on the presence and absence of different species of butterflyfishes were found to be statistically weak or non-significant. *C. auriga*, *C. lineolatus*, *C. melannotus*, *C. austriacus*, and *C. trifascialis* showed very weak correlations with profile type (correlation coefficient ranging from 0.23 to 0.41). All other species showed no correlation at all with the profile type.

Benthic compositions of the substrate

The substrate for all the 75 surveyed stations was composed of 55.2 ± 30.02% dead substrate, of which 37.4 ± 16.9% was rocky, 21.6 ± 16.7% was sandy, while dead coral and coral rocks comprised 37.5% and 3.5% was dead corals covered with algae. The remaining 44.8 ± 30.0% of substrate was living hard and soft corals.

Stations described by major substrate type separated into two major clusters, the first included 27 stations (about 32%) which had a living coral coverage from 0 to 30% and the second included those with living coral coverage from 40% to 100%, represented in this case by 48 stations (Figure 4). The overall examination of the similarity matrix of the substrate component showed that further breakdown to the sub-cluster level was needed in order to show the status of corals at all stations.

The stations could be further classified into four major sub-clusters as follows: deteriorated stations with living coral cover of 10% or less (18 stations); degraded stations with living coral cover of 11–30% (10 stations); disturbed stations with living coral cover of 40–60% (26 stations); and non-disturbed stations with living coral cover of 70% or more (21 stations). The same type of clustering follows to some extent the classification used by previous studies in this field (Grigg, 1993; Galzin *et al*., 1994; Chabarnet *et al*., 1997). A similar variation in the living coral cover on the Egyptian coast of the Red Sea was reported by Kotb

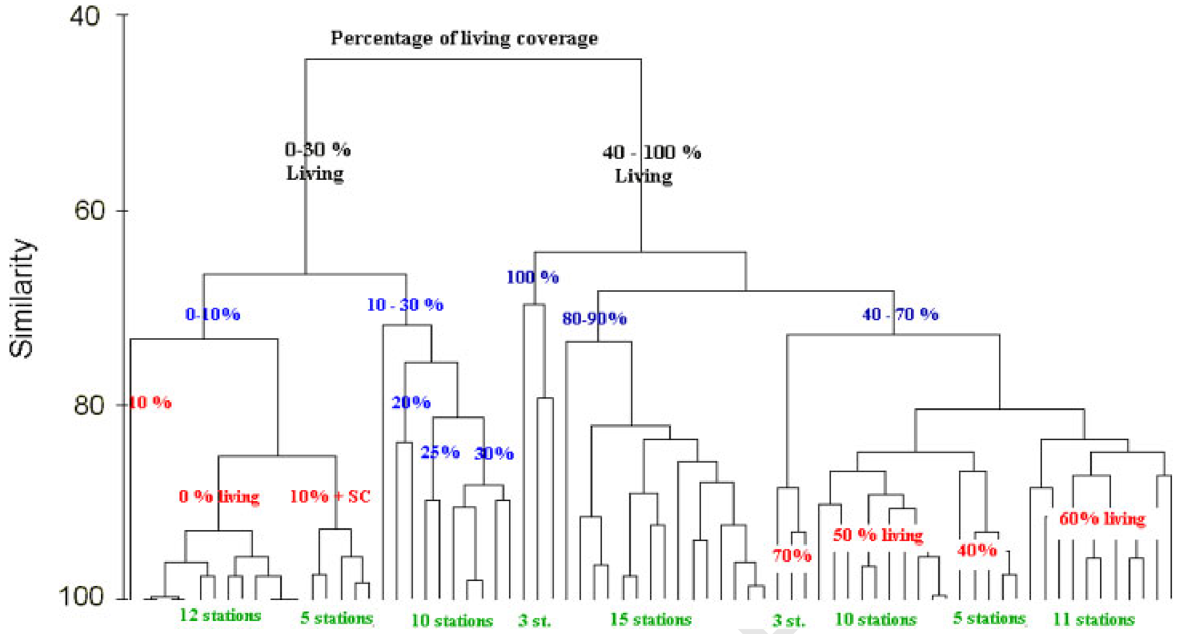

Figure 4. Cluster analysis dendrogram performed between the surveyed stations along the Red Sea coast using the percentage of living coral cover.

et al. (2001) where they found that the percentage of living corals varied all over the coast from one area to another without any significant links to geographical factors. The Egyptian coast of the Red Sea has been subjected to different types of human activities, including diving and boating, which could have resulted in different types of impacts on coral reef fishes corresponding to similar impacts on the corals themselves.

RELATIONSHIPS BETWEEN FISH AND SUBSTRATE COMPONENTS

Linear regression equations were calculated to investigate the relationships between fish community and benthic composition of the substrate. Butterflyfishes species which showed a significant relationship with living substrate were *C. lineolatus*, *C. austriacus* and *C. trifascialis*, with R values of 0.9, 0.8 and 0.9 respectively. In contrast *C. melannotus* showed a relatively weaker relationship with living substrate ($R=0.5$) and relatively higher relationship with soft coral cover ($R=0.6$). The relationship between the total number of butterflyfish individuals and the different benthic components (Table 1) also showed a positive significant correlation in the case of living substrate ($R=0.82$), and of soft and hard corals ($R=0.64$ and 0.66, respectively). However, the relationship between the number of individuals of butterflyfishes and the percentage of dead substrate (including rock and sand) was found to be strongly negative ($R=-0.82$).

DISCUSSION

The same number of species was previously recorded by many authors: Roberts *et al*. (1992) along the Red Sea; El-Elwany (1997) for the Gulf of Aqaba; and Yossef (1996) for the Gulf of Suez and south to Safaga.

Table 1. Results of correlation matrix between the butterflyfish species and different substrate components along the Egyptian coast of the Red Sea

Butterflyfish species	Profile	% Dead substrate	% Rock	% Sand	Dead coral	% Living substrate	HC cover	SC cover	Coral sp.	Others
C. fasciatus	−0.13	0.1	−0.03	0.2	−0.01	−0.1	−0.09	0.09	0.06	−0.2
C. auriga	0.23*	−0.1	0.04	−0.2	0.2	0.1	0.09	0.05	0.03	−0.03
C. melannotus	0.35*	−0.5*	−0.5*	−0.5*	−0.07	0.5*	0.37*	0.6*	0.4*	0.04
C. lineolatus	0.41*	−0.9*	−0.8*	−0.8*	0.02	0.9*	0.7*	0.6*	0.4*	0.24*
C. paucifasciatus	−0.15	0.0	−0.01	0.05	−0.1	−0.0	−0.04	0.11	0.07	−0.2
C. austriacus	0.38*	−0.8*	−0.8*	−0.7*	−0.05	0.8*	0.7*	0.5*	0.4*	0.24*
C. semilarvatus	−0.03	0.1	0.1	0.05	−0.07	−0.1	−0.08	−0.04	−0.4*	−0.04
C. trifascialis	0.34*	−0.9*	−0.8*	−0.8*	−0.02	0.9*	0.7*	0.6*	0.4*	0.27*
H. intermedius	0.15	0.0	0.03	−0.0	−0.1	−0.0	0.04	−0.07	−0.3*	−0.07
Total number of fishes	0.42*	−0.82*	−0.74*	−0.72*	−0.05	0.82*	0.66*	0.64*	0.37*	0.12

* = significant $P < 0.05$.

The only difference in the species composition occurred when a single record appeared for species associated with certain habitat types, such as *C. larvatus* where it was recorded only in three deteriorated reefs suffering from human impacts. However, all other studies conducted on the butterflyfishes reported the same nine species recorded as in this study.

The non-significant relationship between reef profile and number of butterflyfish species could be attributed to the limited depth span where the study was conducted on the reef face at 1–5 m. The previous studies on this group of fishes in the Red Sea also showed a non-significant effect of depth on the fish assemblages on the upper reef face (El-Elwany, 1997). It has been suggested that the availability of food for chaetodontids in relatively shallow water is the factor governing their presence (Harmelin-Vivien and Bouchon-Navaro, 1981; Roberts and Ormond, 1987; Chabarnet *et al.*, 1997).

Surface expression of the latitudinal variation in butterflyfish assemblages and the coral cover percentage along the Egyptian coast of the Red Sea (Figures 5 and 6) revealed that the living coral cover is not the only variable that may control the distribution of butterflyfish. These variables may include temperature, turbidity, salinity and food preference.

Species richness and diversity of fish assemblages are correlated with many coral variables, such as architectural complexity (or coverage of branching coral), diversity, species richness, abundance, size of colony, coverage of living coral, coverage of massive and encrusting coral (Chabarnet *et al.*, 1997). Other studies have also demonstrated correlations between architectural complexity of the substratum and fish populations (Luckhurst and Luckhurst, 1978; Talbot *et al.*, 1978; Gladfelter *et al.*, 1980; Carpenter *et al.*, 1981; Sano *et al.*, 1984; Roberts and Ormond 1987; Hixon and Beets, 1989; Grigg, 1993; Galzin *et al.*, 1994).

Sale and Douglas (1984), however, considered this relationship to be valid only for sedentary or territorial fish species. Nevertheless, it appears that a highly complex environment allows the habitat to be shared by many species. As a consequence, destruction of the habitat, caused by a great reduction in the coverage of branching corals (Naim, 1993) may lead to a reduction in the number of fish species (Chabarnet *et al.*, 1997).

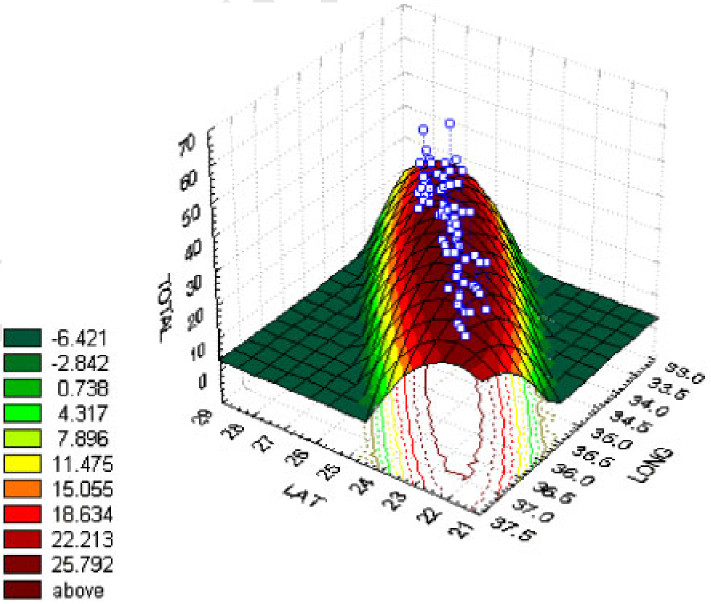

Figure 5. Surface expression of the butterflyfish species along the Egyptian coast of the Red Sea.

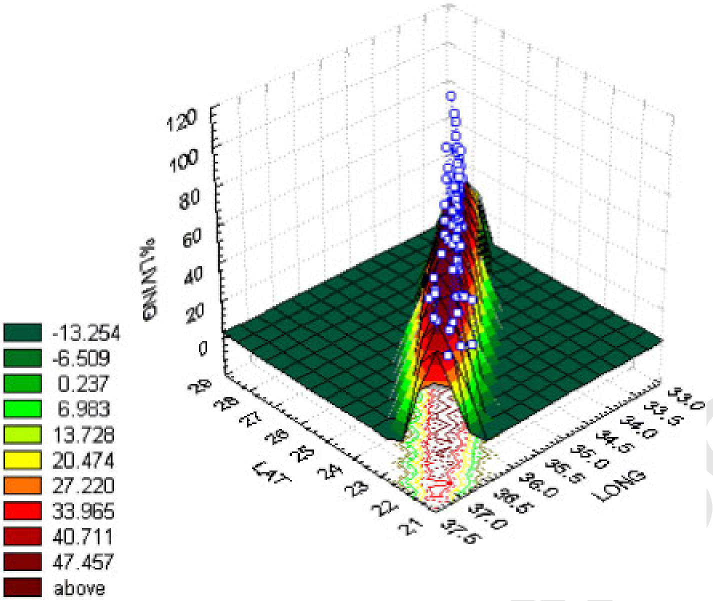

Figure 6. Surface expression of the living cover percentage (soft and hard corals) along the Egyptian coast of the Red Sea.

The relationship between species richness of the fish assemblage and the diversity and abundance of coral is less apparent in the literature than habitat complexity owing to the difficulties of coral classification. Certain authors (Sano *et al*., 1984; Williams, 1986; Galzin *et al*., 1994) consider that a large variety of living corals support more specialist fish species such as corallivore species, which agrees with our findings.

Various studies have also shown that the coverage by living coral has a positive influence on the species richness of fish (Carpenter *et al*., 1981; Sano *et al*., 1984; Bell and Galzin, 1984, 1988). However, other authors (Luckhurst and Luckhurst, 1978; McManus *et al*., 1981; Roberts and Ormond, 1987) have found no correlation. One of the reasons for this difference may be due to differences in the sampling as some authors worked in shallow waters <3 m (Carpenter *et al*., 1981), whereas others worked at greater depths, as deep as 40 m (Roberts and Ormond, 1987). It appears that the correlation between species richness of butterflyfish and the living coral coverage is greater on the shallow reefs than on the deep outer slope.

However, we support the view of Chabarnet *et al*. (1997) that data from all reef zones should be pooled to reflect the status and distribution of butterflyfishes over certain substrate. From our data we could conclude that the relationship between butterflyfishes and coral health will be not obvious if the work is conducted in an area with high average coral cover (over 60%) or low variability, where the fish abundance will be relatively more-or-less stable between sites, as in the case of the study conducted at the Gulf of Aqaba (El-Elwany, 1997). Also, the number of stations could be a factor when conducting such studies (e.g. small number of sites over a vast area), as in case of (Yossef, 1996) who studied only 17 stations along almost 600 kilometres of coastline, since fewer sites are less likely to be representative of the overall area.

Support for the use of butterflyfishes in coral health monitoring depends on individual study results which could be site-specific and not appropriate for direct use in other areas. Jameson *et al*. (2001) studied the available literature on this subject in order to decide the possibility of using chaetodontid fishes as indicators for coral monitoring. They recommended that more research was needed in order to confirm the use of this group in creating an index of biotic integrity (IBI), which in turn can be used in evaluating the impacts on coral reef. The research suggested including the measurement of fish response across a gradient of human-influenced sites, calibrating the data for specific regions and verifying the index using other sites. The current work could be considered as a baseline towards the achievement of such research.

The results of this study clearly indicate that there is a relationship between some species of butterflyfishes and the percentage of living coverage in the coral reef community surveyed, and that this relationship could be used as a tool for coral monitoring if applied in a wide area of the coast. However, data obtained from studies carried out on smaller areas are not adequate to represent the whole coral reef community with its complexities and are inevitably more site-specific. Hence, regional and sub-regional indices should be calculated for the use of butterflyfish as a coral reef monitoring tool in other regions. The sensitivity of butterflyfishes as indicators is not very high in short-term studies since the variation within the fish assemblages may not be noticeable. However, obligate corallivore butterflyfish indices can be a very useful for long-term monitoring programmes. The best butterflyfish species to be used in monitoring Egyptian Red Sea coral reefs are the three obligatory coral feeders, *C. lineolatus*, *C. austriacus* and *C. trifascialis*. Further studies would be useful to determine the pre- and post-settlement process and factors responsible for controlling the structure of the Red Sea butterflyfish assemblages where some reefs consistently receive higher recruitment levels than others. A long-term reef monitoring programme should be established for the Red Sea coast, using butterflyfishes, in addition to another international coral monitoring techniques, for comparison of results and aiming to help the authorities in decision-making about the future of Red Sea coral reef habitats.

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