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Ecology and Taxonomy of the mesophotic coral ecosystems in Eilat, Red-Sea

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Introduction

Coral reefs are among the most biologically diverse and economically important ecosystems on the planet, providing ecosystem services that are vital to human societies and industries thorough fisheries, coastal protection, building materials, new biochemical compounds and tourism (Veron 2000, Hoegh-Guldberg et al. 2007, Carpenter et al. 2008). Yet, in the last several decades, we are witnessing an unfortunate reality of coral reef degradation because of poorly managed anthropogenic activities (Khalaf & Kochzius 2002, Loya 2004).

The coral reefs along the Gulf of Aqaba/Eilat are among the most diverse in the world. The unique geographic structure of the gulf alongside extreme oceanographic conditions resulted in the evolution of a high proportion of endemic species typical of the Red-Sea fauna and flora (Loya 2004). The towns of Aqaba and Eilat that inhabit the northernmost part of the Gulf of Aqaba/Eilat are both involved in an infrastructures development that strongly affect the fragile coral ecosystem. The reef in Eilat that once was a flourished natural ecosystem is influenced a lot by human activities (Wilhelmsson et al. 1998). The 14 kilometers of shoreline is a major tourist attraction for hundreds of thousands visitors every year. In the last three decades, with the development of tourism and industrialization combined with harmful fisheries, that marvelous shore has become polluted and the unique underwater world that typified the northern tip of the Red-Sea have been damaged (Loya 2004, 2007, Walker & Ormond 2003). Significant decrease in living coral cover has been observed and extensive parts of the reef were destroyed as a result of inexperienced divers activity (Wilhelmsson et al. 1998, Walker & Ormond 2003), sewage spillages, oil spills (Loya & Rinkevich 1980) and natural disturbances such as severe southern storms (Eyal et al. 2011) and extreme low tides (Loya 1976). In addition, the corals seemed to be effected by global warming and new diseases have been discovered (Rosenberg & Ben-Haim 2002).

Recently, as a result of the well-documented decline of coral cover among reefs around the world (Menza et al. 2008, Lesser et al. 2009, Kahng et al. 2010, 2012) scientists began to realize the importance of the 'mesophotic coral ecosystems' which are located at greater depths (30-150 m) then the near-shore coral reefs (0-30 m). This "hidden" zone that has been scientifically neglected, mainly due to logistical constrains (Pyle 2000) is gaining increasing attention because it appears to be different in its coral community structure, exhibiting relatively stable environmental conditions (compared with shallow reef) and because it is physically and biologically linked to its shallow water counterparts (Bak et al. 2005, Lesser et al. 2009). Mesophotic reefs may harbor high number of endemic species of fishes, invertebrates, and corals (Brokovich et al. 2008, Bare et al. 2010, Hinderstein et al. 2010) and can serve as deep reef refugia for shallow and mid-depth coral propagates , as well as to provide a potential reproductive source for stressed shallow-reefs (Bongaerts et al. 2010, Kahng et al. 2010).

Mesophotic reefs are warm water, light-dependent coral reef communities starting at 30-40 m to the bottom of the photic zone, which varies by location and extend over 150 m in some regions (Hinderstein et al. 2010, Kahng et al. 2010). Often, those reefs are exposed to different physical conditions than the shallower reefs: limited light penetration, cool upwelling conditions, negligible wave effect, different concentration of nutrients, etc. which create new habitat with different ecological conditions (Menza et al. 2007, Lesser et al. 2009, Bongaerts et al. 2010). Considering the paucity of data on deep reefs, there is a critical need to map and monitor their conditions and to survey the community structure and the biodiversity in order to achieve accurate ecological forecasting and consequently, conservation decisions.

Being very small, the coral reef of Eilat is one of the most monitored reefs around the world (monitored continuously by Israel's National Monitoring of the Gulf of Eilat program). However, nothing had been done to survey the deep reef and there is no data available on the mesophotic area. That lack of knowledge is inconsistent with the growing need of extending our knowledge on this significant reef zones, especially in view of the development and availability of advanced technologies of deep diving permitting efficient research of that area. I am certain that widening our understanding of this special habitat and the species that populate it can lead us to better management decisions. Protecting mesophotic reefs may help in maintaining local and regional biodiversity and prevent potential extinction of less abundant species in danger of extinction and endemic species, which are likely to be more vulnerable due to their limited geographic ranges.

In my study, I am survey the mesophotic area of Eilat, Taxonomically identify the most abounded corals of this area and check the survival of mesophotic corals of Eilat. In addition, I examine the community structure of the mesophotic reef (40, 65m) by conducting photographed benthic survey. Part of the survey is dedicated to taxonomic identification of main scleractinian corals in key points along the mesophotic reefs of Eilat (Fig.1).

I find these themes very interesting and important and believe that exploring them is a milestone in our common way to have a better overview of the coral reefs situation around the world.

Mesophotic Coral Reef Survey objectives

1. Taxonomically identify the most abounded corals of the mesophotic area in Eilat.
2. Create a species list of the corals in the mesophotic reef of Eilat, including ID guide of *In-situ* & microscopically pictures (Fig. 3).
3. Estimate the coral cover and community structure of the mesophotic reefs of Eilat.
4. Comparisons between habitats will enable evaluation of the extent of anthropogenic perturbations and environmental stresses.
5. Test the survival and resilience of abundant mesophotic corals *in-vivo* with different physical parameters (Fig. 2)
6. The results of this research will be integrated into monitoring and research programs and will be provided to the conservation authority in order to support management and rehabilitation policies. In addition, all the samples that collected during the surveys will be given to Tel-Aviv University nature collections museum.

Methodology

The work begun in October 2010. Six different sites along the Israeli coast of the Gulf of Aqaba/Eilat (Red-Sea) were chosen according to mesophotic preliminary survey results and multibeam data of the gulf. The widest variety and diversity were found at depth of 45 m; therefore, most of the corals collected from this depth.

Study Sites

Site 1 - Ayla Reef (AR) as a suspected submerge fringing reef (i.e. - old coastline along the north beach) with knoll like structure of coral rocks in 60-65 m depth and sand/seagrass up to the shore.

Site 2 - Dekel Beach (DB) as the most northern mesophotic reef in the gulf with a massive coral reef from 20 m down to 75 m and sand/seagrass patches with coral knolls up to the shore.

Site 3 - Eilat Port (EP) as an area with the deepest reef structures in Eilat with massive reef wall up to 90 m and knoll like reef up to 130 m.

Site 4 - The Oil Jetty (OJ) of Eilat as none disturbed by diving activities reef but which exposed to anthropogenic disturbances (e.g., oil leakage, phosphate enrichment, port contamination & pollution, etc...).

Site 5 - Nature Reserve (NR) as the only protected area along the coast, with fringing reef near the shore and massive coral reef down to 50 m.

Site 6 - The Interuniversity Instituted for Marine Sciences in Eilat (IUI) as the most affected by diving and research activities site, with poor fringing reef down to 5 m, sediment slope to 30 m and massive mesophotic reef from 30 m down to 65 m depth.

The sites are approximately 1-2 km apart. Following Zvuloni et al (2010) we assume that those distances will give us the regional species pool of Eilat coral reefs.

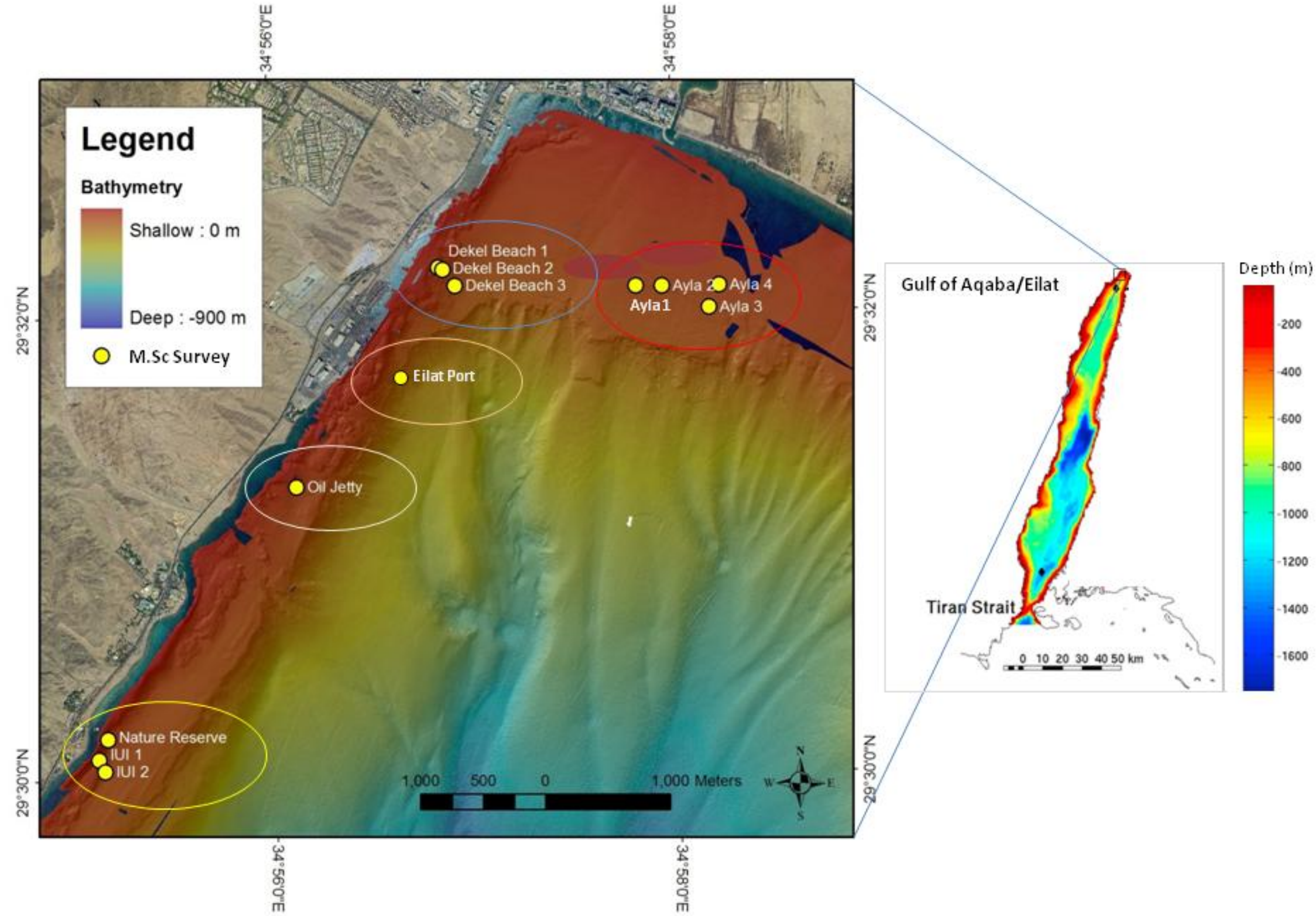

Fig. 1: Bathymetric map of the northern Gulf of Eilat. Colored ellipse represent the six sampled sites, while yellow dots represent different depth stations of mesophotic reefs surveyed (30-130m depths). Background images after Sade *et al.* (2008) and Biton & Gildor (2011).

Photography Techniques

Both In-Situ regular and fluorescence still pictures are taken for the purpose of corals & corals recruitments identification. The Images are shot with DSLR diving system stills camera (Nikon D-90) with underwater housing (Hugyfot) adapted to 100 m depth, high quality wide-angle lens and macro lens (Tokina - AT-X DX 10-17mm f/3.5-4.5 Fisheye, Nikkor – AF 105mm f/2.8D), strobe system (2 * Ikelite Digital Substrobe DS160) and light system (2 * UK Light Cannon Dive Light HID 12.5W). The whole system attached to a quadrate-pod for fix distance from the bottom. Blue excitation filters and yellow barrier filters are used to detect the corals fluorescence pigments.

Diving Techniques

In the last year I finished my CCR (Megladon™ CCR) advanced Trimix certification and obtained approximately 100 hours on the CCR. Using this technique I conducted several exploration dives to deeper depth (30-80m) in order to find new mesophotic reefs in Eilat and to Identify new coral species (e.g Ayla, DB, OJ on Fig.1).
Since the mesophotic reefs of Eilat are very close to shore we manage to work on few sites (mesophotic and shallow area) at the same dive, using underwater propulsion vehicles (Cuda 650).

R.O.V Survey Techniques

For survey and sampling in greater depths then 80m we test the "Vampyro" ROV, it is not the best vehicle for this job, but it confirm our supposition of deeper mesophotic reefs in EP and succeed to sample few corals from 110-115m depth.

Data Analysis

The pictures are processing by CPCe 4.1 software. The data will be combined with the annual data and be tested with nested ANOVA and nMDS plots (R statistics). The identification pictures and samples are processing by me according to my **1)** previous knowledge, **2)** Tel-Aviv University coral collection, **3)** expert consultants and **4)** expert coral taxonomists in case of need.

Results

In-vivo Experiment

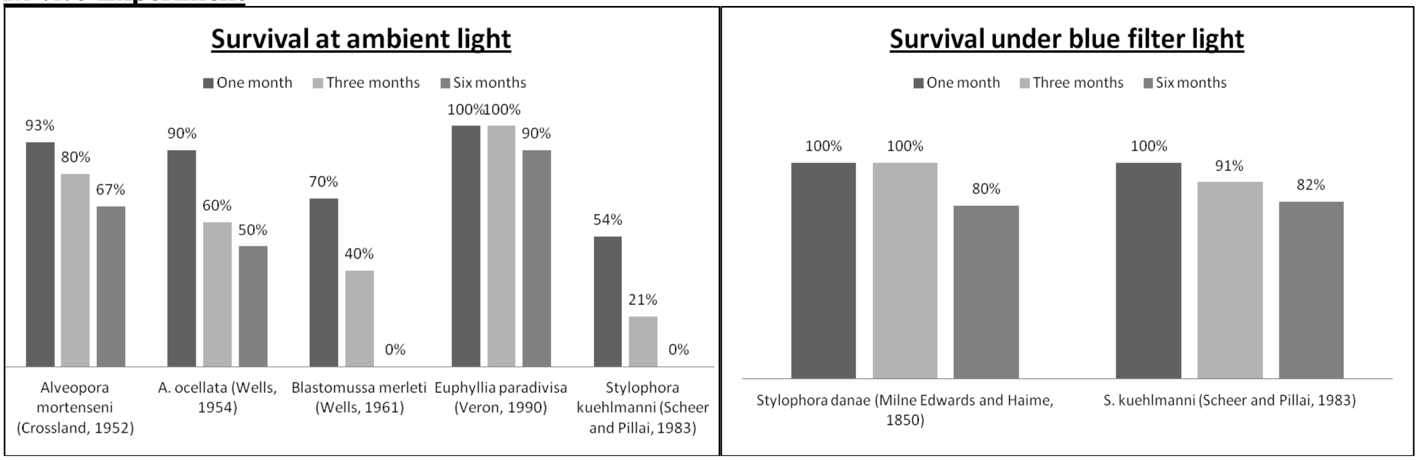

Fig. 2: Survivals of six species of mesophotic corals was tested at water tables in the IUI for six months, the five most abounded mesophotic corals checked for survival at ambient light and two *Stylophora* spp. was checked under blue light filter to resemble the light in the mesophotic area.

Taxonomic Survey

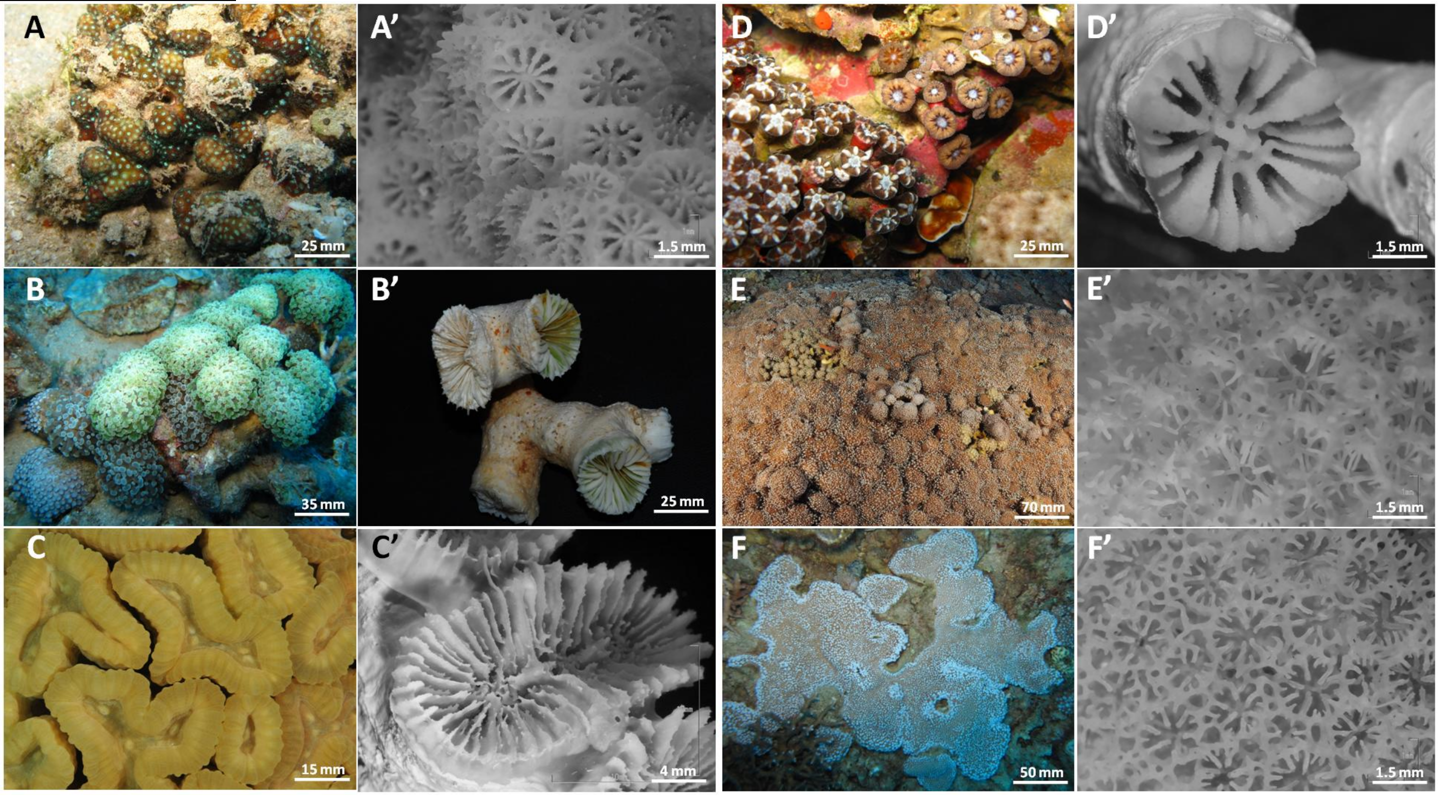

Fig. 3: Photographs of selected coral species from the mesophotic reefs, (**A, A'**) *Madracis kirbyi*, (**B, B'**) *Euphyllia paradivisa*, (**C, C'**) *Erythrastrea flabellate*, (**D, D'**) *Blastomussa merleti*, (**E, E'**) *Alveopora mortenseni* (**F, F'**) *A. ocellata*. *In-situ* photos (A-F), dissecting scope photos of coral skeletons (A'-F').

Table 1: List of mesophotic corals sampled from the Gulf of Aqaba/Eilat, ID following Veron (2000), Wallace (1999) and Hoeksema (1989).

Species/Genus	Family	Site	Depth range	Comments
***Montipora* sp.**	Acroporidae	Dekel	40-65m	possibly new record
Leptoseris scabra (Vaughan,1907)	Agariciidae	IUI, Dekel	20-72m	
***Leptoseris* sp.**	Agariciidae	Oil-Jetty	40-65m	possibly new species
Pavona cactus (Forskål, 1775)	Agariciidae	Oil-Jetty	30-50m	
Madracis kirbyi (Veron and Pichon, 1976)	Astrocoeniidae	IUI, Dekel	40-65m	possibly new record
***Dendrophyllia* sp.**	Dendrophylliidae	Ayla	65m	
Euphyllia paradivisa (Veron, 1990)	Euphyllidae	Dekel	40-65m	possibly new record
Plerogyra sinuosa (Dana, 1846)	Euphyllidae	Dekel	0-50m	
***Echinopora* sp.**	Faviidae	Oil-Jetty	45-60m	possibly new species
Erythrastrea flabellata (Scheer and Pillai, 1983)	Faviidae	IUI, Dekel	0-45m	
***Favia* sp.1**	Faviidae	Oil-Jetty	45m	possibly new species
***Favia* sp.2**	Faviidae	IUI	0-65m	
Blastomussa merleti (Wells, 1961)	Mussidae	IUI, Dekel, Ayla	5-65m	few forms (possibly new species)
Lobophyllia hemprichii (Ehrenberg, 1834)	Mussidae	Oil-Jetty, Dekel	0-50m	
Galaxea fascicularis (Linnaeus, 1767)	Oculinidae	Dekel	0-65m	
Seriatopora hystrix (Dana, 1846)	Pocilloporidae	IUI	0-65m	
Stylophora danae (Milne Edwards and Haime, 1850)	Pocilloporidae	IUI	40-65m	
S. kuehlmanni (Scheer and Pillai, 1983)	Pocilloporidae	IUI	30-65m	
Alveopora mortenseni (Crossland, 1952)	Poritidae	IUI	20-72m	
A. ocellata (Wells, 1954)	Poritidae	IUI	30-65m	
***Goniopora* sp.1**	Poritidae	Dekel, Ayla	40-65m	possibly new species
***Goniopora* sp.2**	Poritidae	Oil-Jetty	40-50m	possibly new species

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