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Marine biodiversity survey in the Northern Red Sea: a large-scale monitoring carried out in collaboration with volunteer divers

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Abstract

Coral reefs, the most biodiverse ecosystems of the ocean, are facing grave peril. Concerns over global change and its effect on coral reef survivorship have highlighted the need for long-term datasets and proxy records, to interpret environmental trends and inform policymakers. Citizen science programs have showed to be a valid method for collecting data, significantly reducing financial and time costs for scientific institutions. The study is based on the elaboration of data collected by recreational divers and its main purpose is to evaluate changes in the state of coral reef biodiversity in the Red Sea over a long term period, and validate the volunteer-based monitoring method. Volunteers recreational divers completed a questionnaire after each dive, recording the presence of 72 animal taxa and negative reef conditions. Comparisons were made between records from volunteers and independent records from a marine biologist who performed the same dive at the same time. A total of 500 different volunteers were tested in 78 validation trials. Relative values of accuracy, reliability and similarity seem to be comparable to those performed by conservation volunteer divers on precise transects in other projects, or in community-based terrestrial monitoring. A total of 9301 volunteer recreational divers participated in the monitoring program, completing 23,059 survey questionnaires in a 5-year period. The volunteer-sightings-based index showed significant differences between the main geographical areas. The area of Hurghada is distinguished by a medium-low biodiversity index, heavily damaged by a not controlled anthropic exploitation. Coral reefs along the Ras Mohammed National Park at Sharm el Sheikh, conversely showed a high biodiversity index. The detected pattern seems to be correlated with the different conservation measures adopted in the area. In our experience and that of other research institutes, *citizen science* can integrate conventional methods and significantly reduce costs and time. Involving recreational divers we were able to build a large data set, covering a wide geographic area. The main limitation remains the difficulty of obtaining an homogeneous spatial sampling distribution.

1. Introduction

1.1 Biodiversity

The term "biological diversity", often shortened to "biodiversity" is an umbrella term to collectively describe the variety and variability of nature. Biodiversity also embraces the entire "Life on Earth" (Maclaurin et al. 2008). When speaking of biodiversity we must distinguish the meaning of the term, depending on whether it is applied: to biological sciences, policies of conservation or environmental protection. The concept of biodiversity cannot be reduced to a numerical value, and this explains the difficulty of its use in the context of environmental policies. Hence, it is important to develop a relevant definition for the environmental policy, which characterizes the biodiversity by reflecting its social value as well as the scientific soundness; a new definition could allow communication about what to do, also encouraging shared actions (Norton 2008).

In biological terms, biodiversity has several definitions, depending on the level of analysis performed. Diversity is a property of any biological system: there is a diversity among genes, populations, species, communities, and then a diversity in ecosystems. The ecological definition is used at the community level: a set consisting of populations of species that persist in the same area (Massa and Ingegnoli 1999). The meaning of this type of diversity is the concept of species richness (Baltanás 1992; May 1995; Bianchi and Morri 2000), defined as the number of species living in a particular habitat, region or ecosystem. Ecologists usually measure the diversity through a series of indices that, more or less directly, relate the number of species with their abundance and / or numerical dominance (Magurran 1988).

In the fields of policy management and conservation, the first attempt to define the term biodiversity was advanced in 1992 in Nairobi (Kenya), during the Convention on Biological Diversity (CBD), where guidelines for the management of biodiversity were drawn up. In Article 2 of CBD, biodiversity is defined as "the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; it includes diversity within species, between species, and of ecosystems". The CBD is considered the first truly global agreement on biodiversity, since it refers to all living species on the planet without distinguishing specific lists of organisms at risk or particular habitats to be protected. The strategy for the conservation of biological diversity of the Convention provides a conscious use of natural elements and the appropriate value of the benefits derived from their exploitation. Consequently, the actions for the protection of biodiversity must not be limited to the conservation of species and habitats, but must provide a network of partnerships involving social and economic policies, science and technology.

Biodiversity holds an important ecological value as an indicator of the health of the environment (Culotta 1996; Bengtsson et al. 1997; Grime 1997) and services produced by ecological systems are identified as primary aspects of human welfare, representing a portion of the economic value the entire planet. The future is identified in the term "sustainability", applied to all the aspects of the society. The environmental sustainability becomes a cornerstone for management of resources, funding research for new technologies and raise awareness, of professionals and not, about preservation problems. This approach is based on the concept that man is not a disturbing element for the planet ecosystem, but an integral part of it.

Costanza et al. (1997), estimated that the economic value of ecosystem services of the entire biosphere ranges, with a conservative estimation, between 16 and 54 trillion dollars per year. The growing interest in biological diversity therefore derives from the belief that loss of biodiversity would result in the loss of ecosystem functions and a consequent loss of "services" for humanity. These services encompass a number of functions dependent on both chemical and physical interactions of organisms with the environment, and the value that these organizations have as source of food or raw material (Duarte 2000).

The connection between biodiversity, ecosystem functions and services has been described, for example, in Tilman et al. (1996), Naeem et al. (1997), Schläpfer and Schmid (1999) for terrestrial environments, and in Duarte (2000) for marine environments, providing suitable reasons for the preservation of biodiversity as a whole, rather than the conservation of only model species or "nice" ones (the so-called "Walt Disney effect " described in Bianchi and Morri 2000). Efforts to ensure adequate monitoring of biodiversity and describe connections with services to society are increasing and they became priorities in international research programs (Tilman 1997; Noss 1999; Danielsen et al. 2000: Duarte 2000; Sheil 2001).

From 1992 to 2010, (which was the first deadline for the main objectives of the Convention on Biological Diversity), an attempt was made to involve the community in biodiversity conservation, especially through information and dissemination. The various parties that have signed the Convention and the new Strategic Plan 2011-2020, are working now in this direction, with actions summarized in four rules: identify, monitor, control and maintain. The work of each state should focus on identifying the relevant components of biological diversity for the conservation and sustainable use, their monitoring, control activities and processes that could have negative impacts on the identified components and the maintenance of the whole system.

The identification and quantification of threats enable managers to take effective measures (Goffredo et al. 2010). Major threats to global biodiversity include: (1) alteration of the areas caused by man, due, for example, to the increase of the areas used for agriculture or farming, the massive deforestation, the development of urban and commercial areas; (2) loss, degradation and fragmentation of habitats in small portions partially or completely separated from each other, due to the construction of physical barriers preventing free movement of species; (3) introduction of non-indigenous species; (4) hunting and fishing, potential threats of extinction if practiced excessively; (5) pollution from industrial discharges, urban and agricultural activities contribute to profoundly alter soil and water; (6) climate change (Zwick 1992; Bax et al. 2003).

A preliminary analysis of the threats and of the status of biodiversity in a specific environment is the essential step to implement effective conservation and restoration measures. A monitoring program is, therefore, one of the tools for a realistic framework of the problem, before any recovery activity.

1.1.1 The importance of monitoring and the involvement of citizens

The term "monitoring" is used to describe many types of activities. The goals of a monitoring program can be categorized into two classes: scientific and management. The scientific goals are focused entirely on the knowledge development about behavior and dynamics of the monitored system, while monitoring programs designed to help the management, provide useful information to make informed management/administration decisions. Biodiversity monitoring allows to determine the status of biological diversity of one or more ecological levels and to record any changes in space and time. The obtained information can be used to create useful guidelines to orient decisions concerning the management of biological diversity in terms of production and conservation (Niemelä 2000).

Unfortunately, governmental agencies, which are responsible for the conservation of biodiversity, are often severely underfunded and are not able to sustain the necessary spatial and temporal large-scale monitoring, that requires a large number of operators (Inamdar et al. 1999; Au et al. 2000; Bennun 2001; Sheil 2001; Balmford et al. 2005; Sharpe and Conrad 2006; Devictor et al. 2010). To overcome the economic impediment, in some cases we can implement a workaround that involves volunteers in environmental monitoring, resorting to “citizen science” (Evans et al. 2005; Goffredo et al. 2010). Volunteers can be an important resource for monitoring schemes requiring many observers, such as those designed to estimate the status of local resources, establish basic ecological measures or identify the impacts of human activities on environmental quality (Rees and Pond 1995; Altizer et al. 2004). The United Nations Development Programme emphasizes how the public involvement is essential in environmental management and monitoring (Sharpe and Conrad 2006).

For terrestrial environments a wide range of environmental projects that are based on the active involvement of the public have been carried out for several years since the end of the nineties, including, studies of macroinvertebrates and water quality in streams, lakes, estuaries and marshes (USEPA 1997; Fore et al. 2001) or fauna censuses (Newman et al. 2003). Ornithology is an area that widely and successfully uses the citizens science (Bhattacharjee 2005). Over the past decade, Cornell University has harnessed the enthusiasm of non-specialist volunteers to explore questions such as the dynamics of infectious disease in bird populations and the impact of acid rain on their reproductive success. (Hames 2002; 2006).

For the marine environment, instead, the involvement of significant numbers of volunteers is more difficult, due to the special diving skills required (a license is needed to be enable to dive underwater). Since the nineties, with the explosion of interest by citizens for diving as a recreational activity (RSTC 1997) it was possible to plan some research programs in the marine environment which attempted the involvement of recreational divers as volunteers, by using their interest in marine diversity (Evans et al. 2005; Goffredo et al. 2004; 2010). Among the research projects developing the use of non-specialist volunteers in marine monitoring, Fish Survey Project, conducted in Florida and the Caribbean (Pattengill-Semmens and Semmens 2003), and Reef Check, on a global scale (Hodgson 1999) are two significant examples. The Fish Survey Project assesses volunteers on fish species identification skills and classifies recruits as “beginners” or “experts” according to test results. Reef Check enrolls volunteers who pass a training course involving survey techniques and diving skills. Participants perform successive surveys (fish, invertebrates, and substratum) at specific reef sites, transects and depths, following a strict protocol, and collect biophysical and socioeconomic data on that site under the guidance of professional scientists. This method provide certain guarantees about the quality of collected data, but limits the attractiveness of the research projects and the number of volunteers willing to participate. Collectively these projects are able to involve few hundreds of recreational divers every year.

In monitoring programs conducted by volunteers, whether terrestrial or marine, an appropriate training, which clearly explain the methodology and limitations of the project, is required (Goffredo et al. 2010). As proposed by Greenwood (1994), Pattengill-Semmens and Semmens (2003), citizen volunteers can effectively contribute to the collection of data as part of monitoring activities and the work of Schmitt and Sullivan (1996), Fore et al. (2001), Newman et al. (2003) Goffredo et al. (2004; 2010) confirm that adequately trained volunteers can collect reliable data and perform assessments comparable to those performed by professionals.

This kind of research offers some benefits because:

- the involvement and training of volunteers ensure the availability of motivated operators and a lot of information which is hard to collect in a short time by a single researcher;
- economically speaking, a survey carried out with volunteers, does not involves expenses for their work, and should drastically lower the costs, often prohibitive, of censuses carried out on a large scale in time and space;
- it improves the scientific literacy and environmental awareness and education amongst all age groups of the community. Maximizing the number of volunteers involved allows to exploit the educational potential of these projects.

Koss and Kingsley (2010) have also demonstrated that volunteers participating in monitoring programs feel gratified by the improvement of their scientific knowledge, with consequent increased interest in the entire ecosystem. Medio et al. (1997), Bryskle (2002) and Goffredo et al. (2004; 2010) have pointed out that the involvement of citizens has an important educational value, by increasing sensitivity to the conservation problems and reducing the impact on the environment. For example, Medio et al. (1997) in a work carried out at the National Park of Ras Mohammed, has shown that a pre-dive briefing, explaining the delicate nature of the coral ecosystem and buoyancy control techniques, can improve the behavior of divers and reduce by 93% their impacts on the fragile coral reef.

The main limitation in collaboration with volunteers, however, is the uneven spatial distribution of samples (Fore et al. 2001; Goffredo et al. 2010).

1.1.2 Our experience

In order to maximize the participation of recreational divers in marine biodiversity monitoring programs, since 1999 my research group has tested a new citizen science model for biodiversity monitoring. This method ensures the reliability of the collected data and the education of citizens, without requiring extensive taxonomic knowledge and without diminishing, the pleasure arising from recreational activities (Goffredo et al. 2004; 2010). Our goal was to unite research with the recreational activity, making citizens active participants in management and conservation efforts, through their data collection. This approach has allowed the participation of thousands of citizens in marine conservation monitoring.

The first project completed by our research group, "Mediterranean *Hippocampus* Mission" (Goffredo et al. 2004), which ended in 2001 focused on the seahorse. This fish was chosen for some key features: 1) it is a well-known organism, since childhood, and it is part of the cultural heritage. It represents a "precious thing" that makes his search exciting and fun, which are essential aspects in a project that involves citizens, 2) it is interesting from the point of view of conservation (it prefers climax Mediterranean environments and it is considered at risk of extinction), and 3) data available in the scientific literature on its biology, ecology and taxonomy were extremely scarce in the middle of 90s. The volunteers were involved in the first census of the two species of seahorses found in Italian waters, and reported sightings on a very simple questionnaire. It was then possible to map the distribution of seahorses in the Italian Mediterranean Sea.

The project underlined the interest of recreational divers to take part in monitoring projects. The success of "Mediterranean *Hippocampus* Mission" has allowed us to design a more ambitious project "Divers for the Environment: Mediterranean Underwater Biodiversity Project" (www.progettosubambiente.org; Goffredo et al., 2010). Project objectives were: 1) to test the effectiveness of non-professionals in the simultaneous detection of several marine taxa along different coastal areas, thus reducing the time and costs of research, 2) to develop an index assessing the status of marine biodiversity based on volunteer sightings, 3) to validate this method by comparing the results of volunteers with the ones of professional researchers. With this model, the monitoring of biodiversity, or of individual species at risk, can be carried on for long periods at low cost, both inside and outside marine protected areas, to estimate the effectiveness of conservation actions.

1.2 Coral reefs

The first traces of coral reefs date back more than 500 million years. Their distribution is remarkably varied over time, with phases of great geographic expansion and contraction following climatic changes that occurred during the different geologic eras. Today, the distribution of reefs is limited to tropical seas, where they extend over a total area of nearly 600,000 square kilometers. Coral reefs develop primarily between the surface and a depth of 30 m but in waters whose average winter temperature stays above 20°C. Other factors that limit the development of coral reefs are water salinity, which must be constant, and the intensity of ambient light. (Ferrari et al. 1999).

Although coral reefs cover less than 0.2% of the ocean's area, they are the marine ecosystem with the highest biodiversity, "the rainforests of the sea". Coral reefs are the most biodiverse ecosystems of the ocean, estimated to harbour around one third of all described marine species (Reaka-Kudla, 1997, 2001), most of which are found nowhere else.

They are important biogenic habitat and, thanks to their intricate three-dimensional structure, they favor heterogeneous adaptations and rich complexes of interdependent species, creating a unique habitat. They play a key role for human activities, providing essential goods and services that are important to more than 500 million people around the world, such as:

1) recreational opportunities for diving, snorkeling and viewing (direct use values), thus supporting the tourism industry which is the main economic resource for many third world countries;

2) coastal protection and habitat/nursery functions for commercial and recreational fisheries (indirect use values);

3) welfare associated with the diverse natural ecosystems (preservation values).

Despite the many services provided, coral reefs suffer a lot of threats by humans, including invasive fishing practices, pollution, mining, dredging activities and unsustainable tourism. Also the global environmental changes (such as oceans warming and acidification) are a great threat to coral reef survival. Corals are particularly susceptible to rapid climate change: exposure to water temperatures just a few degrees higher than the average can cause them stress, bleaching and death (Hoegh-Guldberg 1999).

More than 30% of the CO_2 emitted into the atmosphere by human activities is dissolved in the oceans, causing a decrease of pH (Caldeira and Wickett 2003, Sabine et al. 2004). The resulting ocean acidification may compromise the coral skeletal formation. The consequences of coral reefs degradation were not limited only to the loss of the goods and services they provide, but would mean of a significant portion of Earth’s biodiversity, probably something never experienced before in human history.

Coral reefs are present along the coastline of 109 countries in the world, but they have been damaged or destroyed by human activities in 93 of these 109 countries. (Ferrari et al. 2006). Monitoring becomes necessary in places where coral reefs are subjected to strong human pressure. Coral reefs could be able to report in a timely manner ecological changes taking place, highlighting early warning signals (Guttal and Jayaprakash 2009; Schefferl et al. 2009). Quickly predicting ecosystem changes could enable the timely and effective implementation of protective actions.

2. Research objective

This thesis is focused on "STE - Scuba Tourism for the Environment – Red Sea Biodiversity Monitoring Program", a research project primarily aimed at obtaining information on the status of the Egyptian Red Sea biodiversity, by collaborating with volunteer scuba divers. The project started in 2007 and will end in 2014.

The main goals of this research are:

1. validate the monitoring method, based on the involvement of volunteer recreational divers and compare the results with professional investigations;

2. develop an index based on volunteer observations to assess the biodiversity of the marine environment.

3. Materials and methods

3.1 The survey questionnaire

The research project, started in 2007, involved recreational scuba divers in the collection of data on marine biodiversity of coastal areas of the Red Sea area. Schmitt and Sullivan (1996), Pattengill-Semmens and Semmens (2003), and Goffredo et al. (2010) are examples of monitoring projects that involved volunteer scuba divers and describe the features of scuba diving activity.

A specific survey questionnaire was created, representing the reference tool of the research (Figs. A1 - A5, in the Appendix). It was composed by 3 sections: the first part informed the tourist about the sustainable behavior when approaching coral reefs (Fig. A2, in the Appendix), the second part, with the help of high definition pictures, was useful for the identification of the organisms to be censused (Fig. A3, in the Appendix), the third part was a form for data recording (Fig. A4, in the Appendix).

The 72 taxa, chosen from 7 different animal phyla, the following principal features:

- previously well known by volunteer recreational divers or easily recognizable;
- historically expected to be commonly found throughout the entire Red Sea.

These characteristics were necessary in order that:

1) the method is suitable for amateurs and tasks are realistic and achievable ("method calibration" in Newman et al. 2003; Goffredo et al. 2004; Bell 2007; Cohn 2008)

2) the variation in biodiversity composition and the estimated level of biodiversity detected among geographic areas is related to local conditions (Richards e Bohnsack 1990; Leppäkoski et al. 1999; Niemelä 2000; Therriault e Kolasa 2000).

The relevance of each taxon in revealing variation in diversity among sites was quantified using the ‘‘global BEST test’’ (Bio-Env + STepwise; PRIMER-E version 6 software, PRIMER-E, Ltd., Ivybridge, UK; Clarke et al. 2008). Using this software it is possible to determine the minimum subset of taxa which would generate the same multivariate sample pattern as the full assemblage.

As in previous works (Schmitt and Sullivan 1996, Pattengill-Semmens and Semmens 2003, Goffredo et al. 2004), for each recorded questionnaire the following data were required: generalities of volunteers (name, surname, address, e-mail), level of diving qualification, diving agency that issued the license, technical information about the dive (place, date, time of day, depth, length of time), type of habitat explored (coral reef, sandy bottom, or other habitat), and an estimate of the abundance of surveyed organisms. The presence of dead, bleached, broken, sediment covered corals and the presence of litter were been considered as negative environmental conditions. The number of divers presents on the dive site and the number of contacts with the reef were other diver behaviour features recorded. For each taxon we defined the scale of abundance as ‘‘rare’’ ‘‘frequent,’’ or ‘‘abundant’’ based on the frequency at which the taxon is normally encountered. This frequency was estimated using scientific databases, literature, and personal observations. As an example, the coral *Seriatopora histrix* (porcupine coral, identified in the questionnaire with the number 10), was classed as “rare” until 5 colonies seen, “frequent” until 15 colonies, “abundant” when more then 15 colonies were seen; the fish *Balistoides viridescens* (titan triggerfish, identified in the questionnaire with the number 44), was classed as “rare” until 2 individuals seen, “frequent” until 4 individuals, “abundant” when more then 4 individuals were seen.

Completed questionnaires were sent to the University of Bologna by some collection points in Sharm el Sheikh and Hurgada, thanks to collaboration with NEOS Airline, that took care of the transportation, or were sent directly by the volunteers.

The diving certification level of volunteers ranged from open water divers (at least 6 recorded dives), to instructors (at least 100 recorded dives). The diving certification level was ranked on an ordinal scale, based on international standards (WRSTC, www.wrstc.com, or CMAS, www.cmas2000.org): open water diver (level 1), advanced diver (level 2), rescue diver (level 3), divemaster (level 4), instructor (level 5).

No sampling scheme was used (i.e. volunteer divers were not forced; they performed survey dives when and where they decided). Also the recreational dive profile (dive depth, time, path, and safe diving practices) was not modified for the surveys: divers performed the dive as they normally do during recreational dives (after Goffredo et al. 2004). This was done: 1) because the aim of the study was to test the validity of data from recreational dives for marine monitoring, 2) to maximize volunteer participation uniting the research activity with what citizens normally do for fun.

During the survey dive each diver was responsible for corals, invertebrates, fishes, reptiles, mammals, as well as litter. Soon after the dive, each participant completed a recording questionnaire (i.e. number of recorded questionnaires = number of dives performed).

Immediately after the dive volunteers completed the questionnaires, assisted by trained professional divers (see below). Since divers eagerly tend to discuss what they saw with each other, volunteers were convincingly asked to make their records without colluding with other members of the group, in order that records were made individually (during data elaboration, it was assumed that records were made independently). During data questionnaire recording the trained professional divers were available for consultation in the event of difficulties with recording or taxa identification.

3.2 Involvement of volunteers

The role of diving agencies is fundamental in involving recreational divers in marine environmental education projects (Goffredo et al. 2004; 2010). STE project is supported by the main international diving agencies working in the Red Sea. Diving agencies had both a logistical role, by printing and distributing questionnaires in their diving centers, and an active role in the dissemination of the project and related issues. With their collaboration the research team held training courses for professional divers, which were organized at diving centers and schools or hobby fairs (for example during international tourism expositions as BIT- International Tourism Exchange or at the European Dive Show). The research team trained professional divers on the overarching project objectives and methods, including taxa identification and data recording (the training program comprised lectures, video, and slideshows). Topics such as biodiversity and its change caused by natural and anthropogenic pressures were covered. The training courses were efficient because they reached a large number of diving professionals, who in turn involved recreational divers.

In addition, the diving center staff involved in the project is supported by an operator of the University of Bologna (student or researcher) who helped during the pre-and post-dive briefing and accompanied the group underwater without interfering with the dive. From May to November 2012 I was in Marsa Alam, Egypt, where I was able to directly involve a huge number of volunteers, snorkelers and divers, in data collection. Thanks to the collaboration with the resort Settemari Floriana Lagoon, every day I presented the project to about 20-25 people, with an accurate explanation of the project goals and methods. I gave them the questionnaires trying to focus their attention on the morphological and ecological features of the taxa to be censused, and then I accompanied them during snorkeling or dives in different sites in the Marsa Alam area. After each dive I assisted volunteers with the questionnaire recording. When possible questionnaire recording was performed directly on the diving boat as soon as the volunteers returned, avoiding to postpone data recording after docking. Every week, thanks to the collaboration with local diving center, I organized educational seminars on the Red Sea marine environment and focusing on project goals and methods. In this occasion I informed and involved volunteers, showing them slides of the taxa to be surveyed, and giving them information on the correct behavior to adopt when approaching reefs. I also conducted specific environmental education classes for children every week with the aim of increasing their naturalistic awareness and environmental education. The questionnaires I collected in this six-month period will be elaborated during the next months and data are not presented in this thesis.

According to Day and Monroe (2000), who highlighted the valuable role of the media in environmental education and the involvement of citizens, I contacted about 500 journalists of national and international magazines, newspapers, radio and television programs, thus disseminating project information, giving the participants feedbacks and updates, and contacting new volunteers.

The media responded positively, (more than 50 million of contacts, readers and radio audience, based on official audience ratings: http://www.audipress.it/, http://www.audiradio.it/,; press review on http://www.STEproject.org, since 2005), reporting project aims and methods and inviting divers to contact the research laboratory and diving centers affiliated with the project.

We set up an official partnership with the popular scientific magazine "Tuttoturismo and the airline NEOS, who inserted the questionnaires its on board magazine.

To update volunteers on the progress of research and related initiatives (events and training courses, conferences) I also created the website www.STEproject.org.

3.3 The financial support to research and patronage

Medio et al. (1997), Suter (1998) and Sheil (2001) suggest that monitoring and conservation projects should be based on interdisciplinary relationships that involve, for example, parks, industry, research and politics. STE - Scuba Tourism for the Environment was supported financially in different years by the Ministry of Tourism of the Arabic Republic of Egypt - ETA (Egyptian Tourist Authority, 2007-2012), by ASTOI (Association of Italian Tour Operator 2007-2010), by Settemari SpA tour operator (2011-2012) , by the diving agencies SNSI (Scuba Nitrox Safety International, 2007-2012) and SSI (Scuba Schools International, 2007-2010), by the environmental association Project Aware Foundation (2007-2010), by the diving center Viaggio nel Blu (2011-

2012), and was patronaged by the Italian Ministry for the Environment, Land and Sea Protection (Fig. A1 and A5 Appendix).

3.4 The survey station parameters

Incomplete or illegible questionnaires were discarded, as were those that demonstrated misunderstanding of the methods (for examples multiple dives recorded on the same questionnaire).

Data were aggregated according to type of habitat explored: coral reef, sandy bottom or other habitat (for example wreck or blue). We calculated the volunteers marine biodiversity index (V.MBI) only for coral reef sites, since this habitat was recorded in the highest number of survey questionnaires, thus enabling spatio-temporal comparison of results (see paragraphs below for V.MBI calculation). Data from sites without coral reefs were not used ses in this thesis. The questionnaires from coral reefs habitats were aggregated by dive site. We used the term "survey station" to define a dive site that produced at least ten valid questionnaires over one year. Questionnaires from the survey stations were defined as "useful questionnaires" and were statistically analyzed. Dive sites that failed to reach the quorum of ten valid questionnaires over one year were defined as "sparse sites" and their questionnaires, defined as "sparse questionnaires", were not elaborated.

As in previous studies (Schmitt and Sullivan, 1996; Pattengill-Semmens and Semmens, 2003; Goffredo et al. 2004), we performed a statistical analysis for each survey station by calculating the following parameters:

- number of useful questionnaires recorded in one year;
- mean date, hour and depth of survey;
- number of taxa (aggregated over all questionnaires);
- sighting frequency of each taxon (%SF; expressed as percentage of dives in which the taxon was sighted);

- Density score = [(*R* × 1) + (*F* × 2) + (*A* × 3)]/*n* where *R*, *F*, and *A* are the number of times the taxon was signaled respectively as “rare”, “frequent” or “abundant”, 1, 2 and 3 are normalized abundance values assigned respectively to the classes “rare”, “frequent” and “abundant”, and *n* = (*R* + *F* + *A*) (for statistical characteristics and rationale see Schmitt and Sullivan, 1996; Pattengill-Semmens and Semmens, 2003),
- Abundance score = Density score × %SF (for statistical characteristics and rationale see Schmitt and Sullivan, 1996; Pattengill-Semmens and Semmens, 2003);
- biodiversity value, calculated by the Shannon-Wiener index (observed biodiversity H_{SH}, maximum biodiversity L(S), equipartition index E_{SH}; Magurran, 1988) using the relative abundance of each taxon (Abundance score) to calculate the parameter p_i of the Shannon-Wiener index (p_i = proportion of individuals of the taxon *i*; Magurran, 1988);
- totally or partially dead corals sighting frequency ((%DCS) expressed as percentage of dives where totally or partially dead corals was observed.
- bleached corals sighting frequency (%BlCS) expressed as percentage of dives where bleached corals was observed.
- broken corals sighting frequency (%BrCS) expressed as percentage of dives where broken corals was observed.
- sediment covered corals sighting frequency (%CCS) expressed as percentage of dives where sediment covered corals was observed.
- litter sighting frequency (%LF) expressed as percentage of dives where litter was observed.
- snorkelers and scuba divers sighting frequency (%DiS) expressed as percentage of dives where snorkelers and scuba divers present on the dive site was observed.
- snorkelers and scuba divers contacts sighting frequency (%ImS) expressed as percentage of dives where snorkelers and scuba divers contacts with the reef was observed.

3.5 Assessment of the validity of data

Comparisons were made between records from trained volunteers and independent records from a marine biologist (over 2000 hours of marine surveying experience), hereafter referred to as the "control diver". The explanations for the experimental design comparing volunteers to the control diver are after Mumby et al. (1995) and Darwall and Dulvy (1996):

- the control diver dove simultaneously with 3 or more trained volunteers without interfering with them;
- validation dive sites were not selected prior to the assessment; the control diver dove where the diving center officer planned the dive for that day, accordingly to safe conditions (weather, currents, divers experience);
- "Depth where you spent most of your dive" recorded in the questionnaire, had to be between 11 and 20 meters. The depth range is considered as representative of all collected data;
- "Depth where you spent most of your dive" and "Actual bottom time" of the control diver had to be inside the 95% confidence limits of the mean values of the group of divers.

For each trial the inventory of taxa (with abundance rating) was generated by the control diver, and this was compared with the inventory generated by each volunteer surveyor to identify data accuracy.

3.5.1 Description of analyses

Correlation analyses between the records of the control diver and the records of the volunteers were performed to assess their agreement (Darwall and Dulvy 1996; Evans et al. 2000). This comparison was performed each year at different survey stations with different volunteers, to constantly monitor the validity of collected data and the effectiveness and consistency of the annual training workshops. A variety of non-parametric statistical tests were used to analyze the survey data:

- Spearman rank correlation coefficients (ρ_s) were calculated and results displayed in terms of mean value and 95% confidence limit. Several terms were used to describe sources of inaccuracy, error and variation in survey data (Table 1).

- Cronbach's alpha (α) correlation was used to analyze the reliability of survey data (Hughey et al. 2004). α coefficient is a calculated value (ranging between 0 and 1, and expressed as percentage in the text) based on the average correlation of items within a test if the response categories are standardized (Coakes and Steed, 1997). Values above 0.5 are considered acceptable as evidence of a relationship (Nunnally, 1967; Hair et al. 1995), an α above 0.6 is considered an effective reliability level (Flynn et al. 1994), while values above 0.7 are more definitive (Peterson, 1994). α coefficient was calculated for each volunteer taxa inventory against the control diver inventory. The results were displayed in terms of mean value and 95% confidence limit.

- Czekanowki's proportional similarity index "SI" was used to obtain a measure of similarity between each volunteer and the control diver ratings (as for Sale and Douglas, 1981, and Darwall and Dulvy,1996):

$$SI_{ij}=1-\frac{1}{2}\sum_{n=1}^{s}\left[p_{in}-p_{jn}\right],$$

where there are *s* taxa, and p_{in} and p_{jn} represent the proportions of individuals in census *i* and *j* respectively belonging to the n^{th} species. The value $p_{in}-p_{jn}$ is taken as the absolute difference between the two proportions. The index ranges from 0 when two censuses have no taxa in common to 1 when the distribution of abundance ratings across species is identical. Values above 0.5 are considered as indication of sufficient levels of precision, while values above 0.75 are considered as high levels of precision (Darwall and Dulvy, 1996). The results were displayed in terms of mean value and 95% confidence limit.

Table 1: Definition and derivation of terms used to describe components of the accuracy and consistency of volunteers data. Modified from Mumby et al. (1995).

	Definition and derivation of parameter
Accuracy	Similarity of volunteer-generated data to reference values from a control diver measured as rank correlation coefficient and expressed as a percentage in the text. This measure of accuracy is assumed to encompass all component sources of error.
Consistency	Similarity of data collected by separate volunteers during the same dive. This was measured as rank correlation coefficient and expressed as percentage in the text. This measure of consistency is assumed to encompass all component source of error.
% Identification	The percentage of the total number of taxa present that were recorded by the volunteer diver. The total number of taxa present was derived from the control diver data (i.e. we assumed as taxa present the ones recorded by the control diver).
Correct identification	The percentage of volunteers that correctly identified individual taxa when the taxon was present.
Correctness of abundance ratings (CAR)	This analysis quantified the correctness in abundance ratings made by the volunteer. It has been expressed as the percentage of the 62 surveyed taxa whose abundance has been correctly rated by the volunteer (i.e. the value of the rating indicated by the volunteer was equal to the reference value recorded by the control diver).

To develop eligibility criteria for future surveys, we identified independent variables (diving certification level and group size of participants) to examine their effect on the precision of volunteers. The possible influence of dive time and depth on volunteer precision was also assessed. For all of these analyses the Spearman rank correlation was tested. In this kind of analysis N indicates the sample size and P the probability value.

An evaluation of the reliability of the entire group of volunteers was performed in each trial. For this purpose, for each trial in the five years (2007-2011) an Overall Questionnaire was calculated, that summarizes the individual questionnaires of all volunteers present in the trial. The Overall Questionnaire was obtained by the mean of the abundances of sighted taxa, of the negative conditions and of the behavioral aspects recorded by individual volunteers. The Overall Questionnaire thus calculated was compared with the reference using the same statistical analyses previously described (Table 1; excluding the consistency that, by definition, represents the comparison between individual volunteers). Statistical analyses were conducted using SPSS 12.0 for Windows. (Coakes and Steed 1997).

3.6 Construction of the biodiversity evaluation model

3.6.1 Preliminary remarks

In our model the measure of biodiversity at a single survey station derives from the overall recorded information on censused taxa; single taxa by themselves are not considered indicators of general patterns (Grime, 1997; Therriault and Kolasa, 2000). The observed marine biodiversity has been synthesized into components of the Shannon-Wiener index (Magurran, 1988; Lohrer et al. 2004).

To evaluate the biodiversity level at each survey station we made a comparison between the parameters for each station and those calculated for a virtual "Reference Station". The parameters were: S_A, H_{SH}, E_{SH}, %DCS, %BlCS, %BrCS, %CCS, %DiS, %ImS and %LF, defined as "main parameters", and sighting frequencies of individual taxa, defined as "special parameters".

It was assumed that the virtual Reference Station represented the best current condition for a station on coral reef (i.e. its parameters were calculated from the actual stations having the best parameter conditions – higher biodiversity, lowest presence of negative conditions, lowest presence of divers and contacts with the reef; see below for parameter calculation of the virtual Reference Station). The parameter values of each individual station were expected to match those of the virtual Reference Station; otherwise they were considered as "penalties". The number of penalties resulting in the individual station determined the biodiversity index value.

3.6.2 Parameter calculation of the virtual Reference Station

I calculated the virtual Reference Station parameter values as follows:

I. I calculated the “main” and “special” parameters of each survey station from the total number of useful questionnaires obtained during the years;

II. For each of the main parameters, S_A, H_{SH}, E_{SH}, %LF, %ImS and for the special parameters I calculated the mean value of the stations and the lower 95% confidence limit. For the main parameters %DCS, %BlCS, %BrCS, %CCS, %DiS we calculated the mean value of the stations and the upper 95% confidence limit;

III. I compared the parameter values of each station with the confidence limits obtained. If a value was below (above, for %DCS, %BlCS, %BrCS, %CCS, %LF, %DiS, %ImS), this counted as a “non-matching point” for the station. We summed the number of non-matching points for the station;

IV. I calculated the mean number of non-matching points per station and the 95% upper confidence limit. I rejected the stations with more non-matching points than the confidence limit;

V. For the stations remaining after the rejection we returned to step (2). The (2), (3), and (4) cycle was repeated until all the remaining stations had a number of non-matching points less than or equal to the upper confidence limit.

I assumed the lower 95% confidence limits of the means for the remaining stations (upper 95% limit for %DCS, %BlCS, %BrCS, %CCS, %DiS) as the values of the virtual Reference Station.

3.6.3 Volunteers. Marine Biodiversity Index (V.MBI)

For each year, we compared the values of the parameters of each station with the values of the virtual Reference Station.

The parameters that did not reach the minimum requirements were considered as penalties (for S_A, H_{SH}, E_{SH} and the special parameters, the value had to be equal or higher than that of the virtual Reference Station; for %DCS, %BlCS, %BrCS, %CCS, %LF, %DiS, %ImS the value had to be equal or lower than that of the virtual Reference Station). Each penalty was assigned a value calculated according to the frequency with which the penalty itself occurred in the totality of the stations: penalty value = 100 – penalty frequency (i. e. the percentage of stations in which the penalty was present). The sum of the penalty values was calculated for the main parameters and for the special parameters (we got two sums). Each sum was normalized on a scale from 0 to -1, where 0 indicated the absence of penalties, and -1 indicated all penalties. We calculated the V.MBI for each individual station as the mean of the two normalized sums.

The index was reduced to five classes: very good (for values between 0 and -0.200), good (-0.201 to -0.400), mediocre (-0.401 to -0.600), low (-0.601 to -0.800), and very low (-0.801 to -1).

The differences between V.MBI detected along the Red Sea coasts were analyzed using ANOVA - Tukey's post hoc.

4. Results

4.1 Validation trials

The overall trends of accuracy, consistency, reliability and similarity were described, including an inspection of the individual components of accuracy (defined in Table A1 in the Appendix) and species level analysis.

Seventy-eight validation trials were performed (Table A1 in the Appendix). A total of 500 different volunteers were tested, with a mean number of volunteers per trial of 6.4 (95% CI = 5.7-7.2). Mean diving certification level of volunteers varied significantly among trials from 1.3 to 5.0 (from open water diver to instructor).

There was significant variability in the accuracy of validation trials. The mean accuracy of each trial ranged from 40% to greater than 77.9%, with the majority of trials (67.9%) with a mean accuracy between 45% and 60% (Table 2). Intra-group variation (coefficient of variation, CV) was approximately 40% per trial. Accuracy was not correlated with:

- number of participants in the trial group ($\rho_S = 0.115$, N = 78, $P = 0.314$);
- volunteer diving certification level ($\rho_S = 0.186$, N = 78, $P = 0.101$);
- depth of the trial ($\rho_S = 0.003$, N = 78, $P = 0.977$);
- dive time of the trial ($\rho_S = 0.017$, N = 78, $P = 0.879$);
- date of the trial ($\rho_S = 0.071$, N = 78, $P = 0.540$).

The accuracy of the Overall Questionnaire was significantly higher than the mean accuracy of each team in 68 trials (87.2%). The accuracy of the Overall Questionnaire was positively correlated ($\rho_S = 0.382$, N = 78, $P = 0.001$) with the number of participants in the trial group (Table A1 in the Appendix and Table 2).

The mean consistency of each trial ranged from 33.5% to 77.2%, with the majority of trails (66.7%) with a mean consistency between 40% and 55% (Table 2). Intra-group variation (CV) was approximately 24% per team. Consistency was not correlated with:

- number of participants in the trial group (ρ_S = -0.061, N = 78, P = 0.595);
- volunteer diving certification level (ρ_S = 0.039, N = 78, P = 0.729);
- depth of the trial (ρ_S = -0.135, N = 78, P = 0.237);
- dive time of the trial (ρ_S = -0.043, N = 78, P = 0.703).
- date of the trial (ρ_S = -0.026, N = 78, P = 0.820

Percent of identified ranged from 39.0% to 82.0%, with the majority of trials (52.6%) performing with a mean percentage of identified between 55% and 70% (Table 2). Intra-group variation (CV) was approximately 24% per trial. Percent of identified was not correlated with:

- number of participants in the trial group (ρ_S = 0.077, N = 78, P = 0.502);
- volunteers diving certification level (ρ_S = 0.140, N = 78, P = 0.221);
- depth of the trial (ρ_S = 0.055, N = 78, P = 0.630);
- dive time of the trial (ρ_S = 0.054, N = 78, P = 0.634).
- date of the trial (ρ_S = -0.182, N = 78, P = 0.110).

Percent of identified of the Overall Questionnaire was significantly higher than the mean percentage of identified of each team in 74 trials (94.9%). Percent of identified of the Overall Questionnaire was positively correlated (ρ_S = 0.594, N = 78, P < 0.001) with the number of participants in the trial group (Table A1 in the Appendix and e Table 2).

The correctness of abundance ratings, CAR, ranged from 44.6% to 77.7%, with the majority of trials (71.8%) performing with a mean CAR between 50% and 65% (Table 2). Intra-group variation (CV) was at approximately 10% per trial. Percent of identified was not correlated with:

- number of participants in the trial group (ρ_S = -0.063, N =78, *P* = 0.580);
- volunteers diving certification level (ρ_S = 0.015, N = 78, *P* = 0.893);
- depth of the trial (ρ_S = -0.078, N = 78, *P* = 0.495);
- dive time of the trial (ρ_S = 0.036, N = 78, *P* = 0.750).
- date of the trial (ρ_S = -0.201, N = 78, *P* = 0.077).

The correctness of abundance ratings of the Overall Questionnaire was significantly higher than the mean correctness of abundance ratings of each team in 47 trials (60.3%). CAR of the Overall Questionnaire was negatively correlated (ρ_S = -0.625, N = 78, *P* = 0.000) with the number of participants in the trial group (Table A1 in the Appendix and Table 2).

According to the α correlation test, 14 trials (17.9%) performed with an insufficient level of reliability (α, 95% CL lower bound ≤ 50%); 41 trials (52.6%) scored acceptable relationship with the control diver census (α, 50% < 95% CL lower bound ≤60%), 17 trials (21.8%) scored an effective reliability level (α, 60% < 95% CL lower bound ≤70%), and 6 trials (7.7%) performed from definitive to very high levels of reliability (α, 70% < 95% CL lower bound ≤100%; Table 2). Intra-group variation (CV) was approximately 14% per trial. α correlation coefficient was not correlated with:

- number of participants in the trial group (ρ_S = 0.161, N = 78, *P* = 0.157);
- volunteers diving certification level (ρ_S = 0.197, N = 78, *P* = 0.082);
- depth of the trial (ρ_S = 0.121, N = 78, *P* = 0.287);
- dive time of the trial (ρ_S = 0.074, N = 78, *P* = 0.509).
- date of the trial (ρ_S = -0.009, N = 78, *P* = 0.935).

The α correlation test of the Overall Questionnaire was significantly higher than the mean α of each team in 38 trials (48.7%). Reliability of the Overall Questionnaire was significantly and negatively related (ρ_S = 0.345, N = 78, *P* = 0.002) with the number of participants in the trial group (Table A1 in the Appendix and Table 2).

According to the Czekanowki's proportional similarity index "SI", 9 teams (11.5%) performed with levels of precision below the sufficiency threshold (SI, 95% CL lower bound ≤ 50%); 68 teams (87.2%) scored a sufficient level of precision (SI, 50% < 95% CL lower bound ≤75%), and 1 teams (1.3%) scored high levels of precision (SI, 75% < 95% CL lower bound ≤100%; Table 2). Intra-group variation (CV) was approximately 17% per team. The similarity index was not correlated with:

- number of participants in the trial group (ρ_S = 0.127, N = 78, *P* = 0.266);
- depth of the trial (ρ_S = 0.077, N = 78, *P* = 0.500);
- dive time of the trial (ρ_S = 0.025, N = 78, *P* = 0.823);
- date of the trial (ρ_S = 0.057, N = 78, *P* = 0.622).

The similarity index was positively correlated with the volunteers diving certification level (ρ_S = 0.245, N = 78, *P* = 0.030).

The similarity index of the Overall Questionnaire was significantly higher than the mean similarity index of each team in 60 trials (76.9%). The similarity index of the Overall Questionnaire was positively correlated (ρ_S = 0.234, N = 78, *P* = 0.039), with the number of participants in the trial group (Table A1 in the Appendix and Table 2).

The correct identification of taxa ranged from a maximum value of 93.2% for the fire coral (*Millepora* sp.) to the minimum value of 0% for the pencil urchin (*Phyllacanthus* sp., Table A2 in the Appendix). Forty-two taxa (57.5%) showed a level of correct identification of more than 50.0%. The correct identification of taxa was positively correlated with the number of dives in which the taxon was present (ρS = 0733 N = 73, P <0.01). Six taxa were not present in any of the 78 trials, then it was not possible to calculate their correct identification (Table A2 in the Appendix).

In 68 trials (86.1%) the lower 95% confidence limit of the mean correct identification value of the Overall Questionnaire was higher than upper 95% confidence limit of the mean correct identification of each volunteers' questionnaire.

Table 2: Summary table showing the weighted mean of the parameters calculated on the questionnaire of individual volunteers and on the Overall Questionnaire with their standard deviations. " Overall-Individual " represents the difference between the the Overall Questionnaire and questionnaire of individual volunteers. The Student's t-analysis was done between the questionnaire of individual volunteers and the Overall Questionnaire, represented in absolute value.

	Individual volunteer	Standard Dev.	Overall Questionnaires	Standard Dev.	Overall - Individual	Student's t
Accuracy	54.3	6.9	71.9	8.2	17.6	14.5
% of identified	64.5	8.6	95.2	6	30.7	25.9
CAR	59.3	6.4	63.9	9.8	4.6	3.5
Alpha	68.1	6.4	78.4	6.8	10.3	9.7
Similarity index	58.1	6.1	70.1	5.9	12.0	12.5

4.2 The survey distribution

Over five years (2007-2011), a total of 9301 volunteer recreational divers participated in the monitoring program. They spent a total of 18 666 hours underwater and completed 23 059 valid survey questionnaires (Table 3). The geographic distribution of coral reef habitat surveys was not homogenous among the five years (ρS = 0.951, ES = 0.019). Most surveys were made in the Sharm el-Sheikh area, accounting for 68.5% of the total number of valid recorded questionnaires, and distributed in various sub-areas: Ras Mohammed Peninsula (24.0%), Tiran (20.7%), Local Dives (19.0%), Gubal (3.8 %), Nabq (1.2%; Fig. 1).

The great majority of questionnaires (89.8%) involved coral reef (Table 3). The low number of useful questionnaires from sandy habitats and other habitats did not allow spatio-temporal analyses of results. Conversely, for rocky habitats, most questionnaires were useful (96% of coral reef recorded questionnaires).

For the coral reef 114 survey stations located in various areas of the Red Sea were identified: 40 survey stations in Sharm el-Sheikh (3 in Nabq, 6 in Tiran, 18 in Local Dives, 8 in Ras Mohammed, 5 in Gubal), 18 survey station in Hurghada, 31 in Marsa Alam, 2 in Quseir, 2 in Dahab, 2 in Yambu al Bahr, 2 in Rabigh, 2 in Hamata, 4 in Port Sudan, 2 in Shalatin and 9 in Berenice (Table A3 in the Appendix).

Table 3 - Distribution of survey effort performed by volunteer recreational divers in the five years of research; only useful questionnaires were elaborated. See the Material and methods section 3.4. for details.

Year	Volunteer divers	Hours of diving	Total recorded questionnaires	Coral reef questionnaires		Sandy bottom questionnaries		Other habitat questionnaires	
				Recorded	%Useful	Recorded	%Useful	Recorded	% Useful
2007	1154	2516	3248	2975	96.7	129	20.9	144	94.4
2008	1760	3955	4870	4656	96.9	109	53.2	105	78.1
2009	1926	3473	4120	3031	92.5	928	94.2	161	88.8
2010	2598	4543	5667	5133	96.4	358	69.3	176	82.4
2011	2234	4180	5154	4913	97.2	127	41.7	114	82.5
Totale	**9301**	**18 666**	**23 059**	**20 708**	**89.8**	**1651**	**7.2**	**700**	**3.0**

Mean depth of the surveys performed at the stations was homogeneous among years ($\alpha = 0.916$, ES = 0.021; $\rho_S = 0.916$ ES = 0.047); the most commonly surveyed depth range was between 10 and 25 m (59.0% of the stations, Table A3 in the Appendix). Also the mean time (date and hour) of the surveys performed at the stations was homogeneous among years (for the date: $\alpha = 0.870$, ES = 0.048; $\rho_S = 0.737$, ES = 0.048; for the hour: $\alpha = 0.649$, ES = 0.207; $\rho_S = 0.727$, ES = 0.032); the surveys was distributed during the all seasons with a pick in the summer period (50.2% of the stations had mean sampling date between July and September) and in the late morning (63.3% of the stations had a mean sampling time between 10:00 and 12:00, Table A3 in the Appendix).

Also the mean temperature of in the different stations was homogeneous among the years (α = 0847, ES = 0067; $\rho S = 0.746$, ES = 0.041). The water temperature ranged from a minimum of 23.9°C to a maximum of 29.7°C with a majority of surveys in the range 25.0 - 28.0 °C (67.6% of surveys; Table A3 in the Appendix).

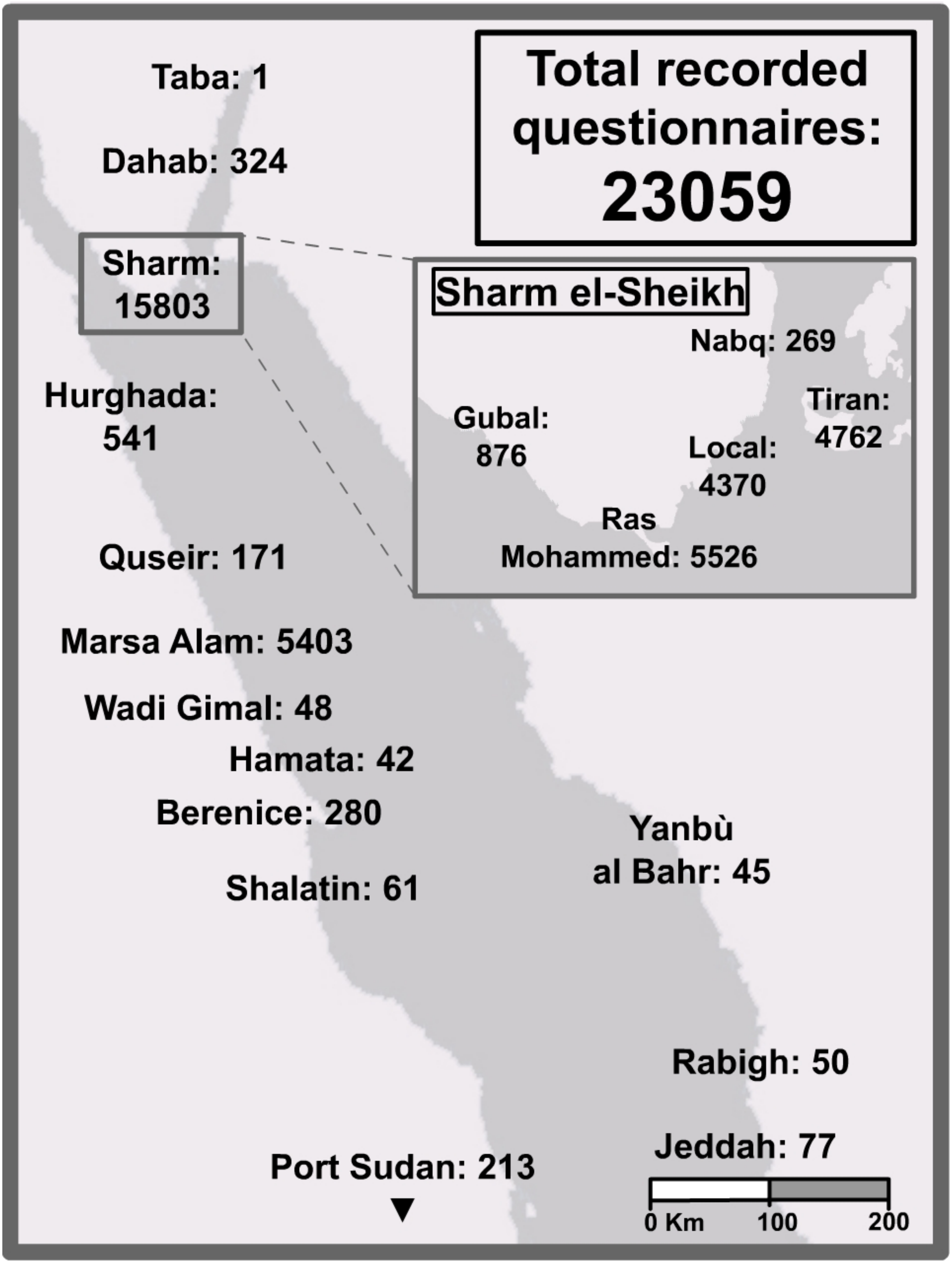


Figure 1 - Geographic distribution of the survey effort over the five years of research (2007-2011). The figure represents the distribution of the total number of registered questionnaires. The peninsula of Sinai area (Sharm el-Sheikh) has been divided into 5 areas: Gubal, Ras Mohammed, Local, Tiran and Nabq

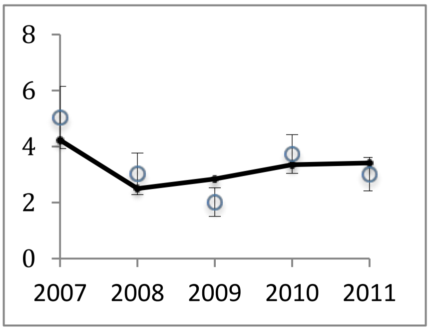
4.3 Volunteers Marine Biodiversity Index on coral reef

Of the 72 surveyed organismal taxa, 41.7% (30 taxa) were not common, with a sighting frequency (%SF, calculated on the total number of surveys over the four years) ⩽ 20%, 51.4% (37 taxa) were common (20% < %SF < 70%), and only 6.9% (5 taxa) were very common (%SF ⩽ 70%; taxa ranking according to sighting frequency is after Schmitt and Sullivan, 1996, and Darwall and Dulvy, Goffredo et al. 2010; Table A4 in the Appendix).

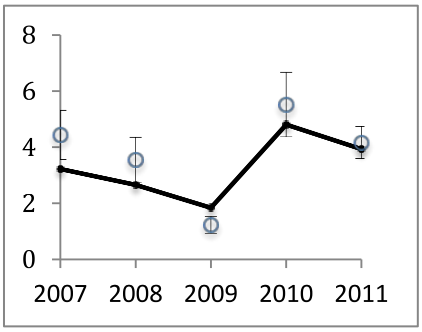
Most of the taxa (56, 91.8%) had homogeneous sighting frequencies among the five years α = 0.915, ES = 0.004; ρ_S = 0.811, ES = 0.008). The sighting frequency of five taxa was not homogeneous among the years (Fig. 2). Of these, the Spanish dancer (*Hexabranchus sanguineus*) and the hermit crabs (Diogenidae) did not show a particular trend. Instead, the map angelfish (*Pomacanthus maculosus*) showed a negative trend among the years (Jonckheere - Terpstra test, P = 0.002), while Sohal surgeon fish (*Acanthurus sohal*) and sharks (Squaliformes) showed a positive trend (Jonckheere - Terpstra test, P = 0.007, P = 0.007; Fig. 2).

Regarding the negative conditions, the sighting frequencies were homogeneous among years for totally or partially dead corals (α = 0.791, ES = 0.075; ρS = 0.691, ES = 0.062), for corals covered with sediment (α = 0.774, ES = 0.038; ρS = 0699, ES = 0.041) and for litter (% LF, α = 0.861, ES = 0.032; ρS = 0.722, ES = 0.046). We found significantly different sighting frequencies among the years both for broken corals, showing no particular trend, and for the bleached corals with a positive trend (Jonckheere - Terpstra test, P = 0.031; Fig. 2).

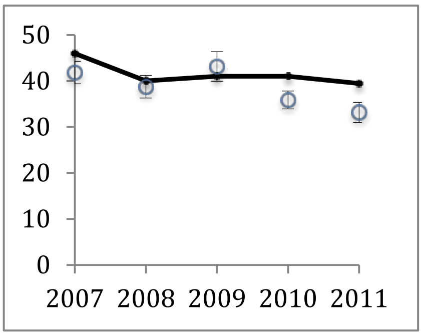
Sighting frequency, %SF



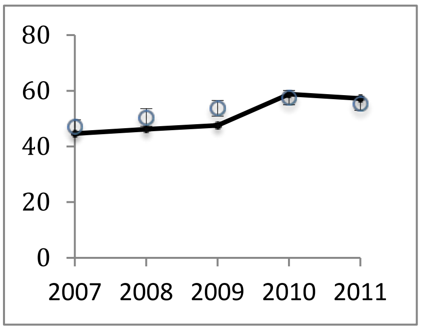
Spanish dancer



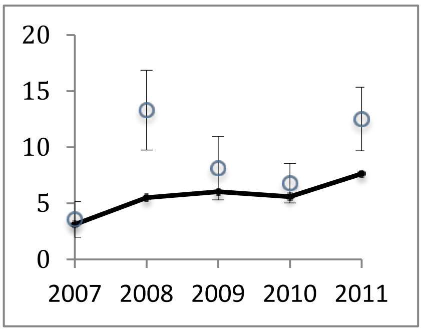
Hermit crabs



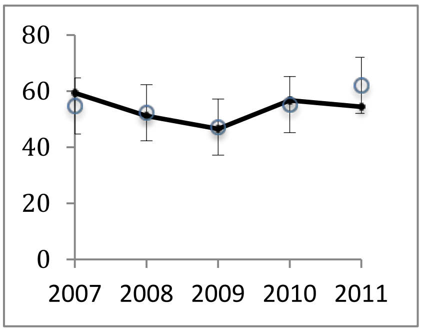
Map angel*



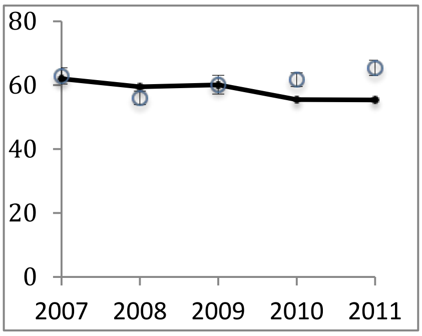
Sohal surgeon fish*



Sharks*



Bleached corals*



Broken corals

Figure 2 – Taxa with not homogeneous sighting frequencies among the years 2007-2011. For these taxa the sighting frequency (%SF, percentage of dives where the taxon was sighted) is represented over the five-year study. * Taxa showing a trend. Dove:

Mean sighting frequency (± standard error) among the stations surveyed in the year;

Sighting frequency on the total number of dives performed in the year.

Sighting frequencies of snorkelers and scuba divers (%DiS) and of voluntary or involuntary contacts (%ImS) were homogeneous among years (%DiS: α = 0.881, ES =0.019; ρ_S = 0.769, ES =0.028; %ImS: α = 0.902, ES = 0.026; ρ_S = 0.736, ES =0.067).

Regarding the main parameters of V.MBI, there were no significant differences among the years (SA α = 0857, ES = 0.025; ρS = 0701, ES = 0.026; HSH α = 0809, ES = 0.022; ρS = 0631, ES = 0.049; ESH α = 0853, ES = 0.046; ρS = 0.775, ES = 0.019). The values of V.MBI in each survey station among years were homogeneous (α = 0.827, ES = 0.010; ρS = 0668, ES = 0.019, Fig 3).

Table 4 – Results of the homogeneity test for the taxa that were not homogeneous in the five years of analysis; * represents significant values

	2007			2008			2009			2010			2011		
	alpha	*rho*	*P*	*alpha*	*rho*	*P*	*alpha*	*rho*	*P*	*alpha*	*rho*	*P*	*alpha*	*rho*	*P*
Spanish dancer	0.761*	0.739*	0.000	0.958*	0.691*	0.000	0.665	0.480*	0.003	0.943*	0.783*	0.000	0.816*	0.715*	0.000
Hermit crabs	0.778*	0.710*	0.000	0.959*	0.776*	0.000	0.572	0.416*	0.011	0.979*	0.823*	0.000	0.847*	0.651*	0.000
Map angel	0.683	0.525*	0.001	0.936*	0.903*	0.000	0.954*	0.910*	0.000	0.969*	0.927*	0.000	0.927*	0.887	0.000
Sohal surgeon fish	0.528	0.423*	0.009	0.099	0.067	0.654	0.188	0.090	0.598	0.959*	0.918*	0.000	0.890*	0.816*	0.000
Sharks	0.500	0.712*	0.000	0.974*	0.823*	0.000	0.973*	0.790*	0.000	0.971*	0.817*	0.000	0.968*	0.896*	0.000
%BICS	0.054	0.072	0.674	0.893*	0.763*	0.000	0.234	0.147	0.384	0.876*	0.730*	0.000	0.829*	0.811*	0.000
%BrCS	0.139	0.160	0.343	0.786*	0.662*	0.000	0.092	0.105	0.537	0.840*	0.624*	0.000	0.794*	0.741*	0.000

The marine biodiversity index (V.MBI) calculated according to the parameters described in Chapter 3, showed that fifty-seven stations (50.0%) had a “mediocre” value of biodiversity (values from - 0.4 to - 0.6). Sixteen stations (14.0%; “El Aruk Gigi” and “Yellowfish Reef” in Hurghada, “Radisson Hotel House Reef”, “Ulysses”, "Kingston" "House Reef - Tiran Beach" and "White Knight" "in Sharm el-Sheikh, "Big Brother" in Quseir, "Gota el Sharm" in Marsa Alam, "Precontinente II" and "Angarosh" in Port Sudan, "Sha'ab Aid", "Umm el Karim", "Umm el Arouk", "Lahami Bay House Reef" and "Sha'ab Faragi" in Berenice; Fig. 3) presented a “low” value of V.MBI, ranged between - 0.6 and - 0.8. Thirty-nine stations (34.2%) had a “good” value of V.MBQI (values from - 0.2 to - 0.4), while only 2 stations (1.7%; "Elphinstone," and "Marsa Mikky", in Marsa Alam, Fig. 3) showed a “very good” marine biodiversity, with a V.MBI between 0 and - 0.2 (Fig. 3).

Five areas presented a sufficient number of survey stations to allow spatial analysis on the status of biodiversity Marsa Alam (MA), Hurghada HRG) and the three main areas of Sharm el-Sheikh, the peninsula of Ras Mohamed (SSH-RM), the island of Tiran (SSH-T) and coastal reef (SSH-L, see Table A3 in the Appendix).

An initial analysis showed that the five areas were significantly different in the V.MBI (ANOVA, P = 0.007). Subsequently I performed an analysis of variance between the individual areas, showing the Hurghada area to be different from the area of Ras Mohammed in V.MBI (ANOVA, Tuckey post-hoc P = 0.003). The Hurghada area (18 survey stations), on the western coast of the Red Sea, had a medium-low biodiversity with 72.2% of the stations (13) showing V.MBI values between -0.4 and -0.6 and 11.1% of the stations (2) with V.MBI values of less than -0.6 (Fig. A6 in the Appendix). The peninsula of Ras Mohammed (8 survey stations), generally had a high biodiversity, showing 87.5% of stations (7) with good biodiversity (Fig. A7 in the Appendix).

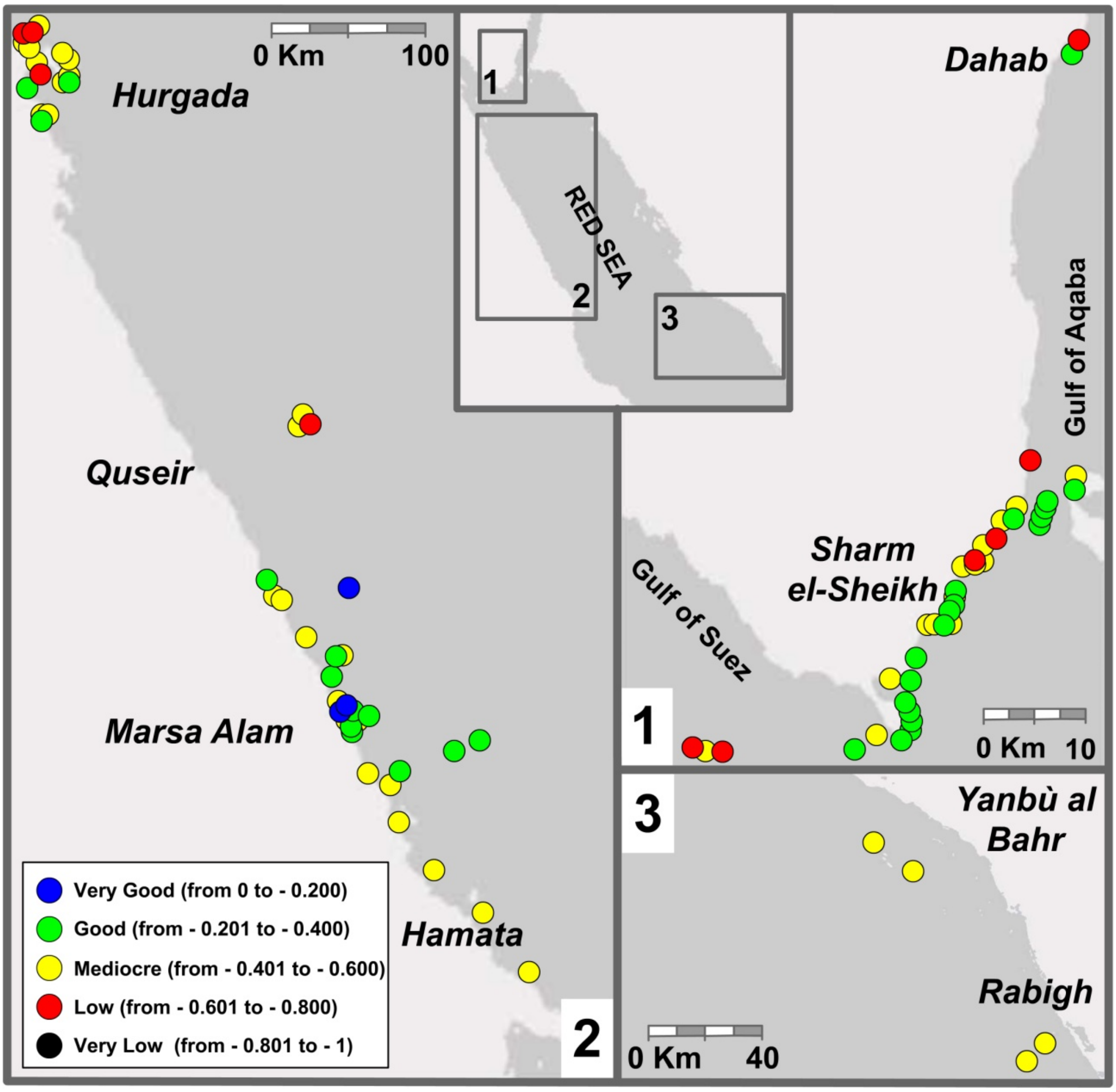


Figure 3 - Marine Biodiversity Index in survey stations on coral reefs in over the period 2007-2011.

With the intention to critically evaluate the rationalization of survey effort requested to volunteers divers, the "best" match between the similarity matrix among-survey-stations deriving from the full assemblage of taxa listed in the survey questionnaire, and that deriving from random subsets of taxa was determined. The taxa which generated the same multivariate pattern as the full list turned out to be a subset of 21 organismal taxa (29.2% of the original list; $\rho_S = 0.951$, $P < 0.01$; Table A2 in the Appendix).

5. Discussion

5.1 Quality of recreational volunteer-generated data

The lack of trends in the V.MBI of survey stations among the five years of project allowed to make a comparison between the results of all trials without taking into account the time factor.

Accuracy, reliability and similarities were encouraging, given the number of species surveyed and the unmodified recreational dive profile. These values were higher than 50% in most of the validation trials (69.3% of the trials for the accuracy, reliability and 82.1% to 88.5% for the similarity index) and therefore indicate an acceptable level of accuracy (Peterson, 1994; Mumby et al. 1995; Darwall and Dulvy 1996). Relative values of the three analysis seem comparable to those performed by conservation volunteer divers on precise transects in other projects, (Mumby et al. 1995; Darwall e Dulvy 1996), or in community-based terrestrial monitoring (Evans et al. 2000). However, in STE project, volunteers carry out normal recreational dive, not subject to specific behavioral constraints, with a training which is limited to the pre-dive briefing (as opposed to Mumby et al. 1995; Hodgson 1999; Pattengill-Semmens and Semmens 2003).

Only in 42.3% of validation trials the consistency have exceeded 50%. This indicates a lack of homogeneity among operators in the sightings recorded at the end of the same dive. This could be explained by two factors.

1) Each volunteer seems to record only a part of the taxa sighted by the reference diver, probably according to different interests or activities during the dive. For instance, while one diver may be more interested in corals (for example a macro-photography amateur) and pay more attention to the benthic environment, another one might be more interested in the “extraordinary encounter” (such as sharks) and pay more attention to the pelagic environment.

2) The particular type of seabed in each survey station can be responsible for different similarity of the sightings recorded in each dive.

For example a horizontal seabed, helps divers to stay at the same depth and then to follow a more homogeneous path, thus increasing the degree of correlation of individual sightings; on the contrary, along a vertical wall, divers easily perform the dive at different levels of depth, by increasing the differences between the individual observations. This lack of homogeneity among volunteers is also observed in the Overall Questionnaire, whose reliability is significantly higher than the one of individual volunteers. The sum of the observations of individual volunteers enriches the total information, confirming the complementary observation of volunteers probably due to different interests or activities. This possible bias did not affect project results, since the sampling method appositely required a minimum threshold of 10 recorded questionnaires collected in one year to define a diving site as “survey station” and calculate its biodiversity index (Goffredo et al. 2010).

The obtained results suggest that this method of data collection using volunteers can be realized regardless of the number of volunteers in the group, depth and the dive time. In fact, there is no significant correlation between these factors and reliability analysis. There is a positive correlation between the level of experience of the volunteers and the similarity index, contrary to what is observed in Goffredo et al. 2010, in which an inverse correlation between the level of certification of the volunteers and consistency was explained by greater diligence of the less experienced divers than advanced level. The positive correlation detected between the level of experience of the volunteers and the similarity index can be justified by the fact that diving in the Red Sea are relatively more difficult to manage than those in the Mediterranean, because of strong currents and frequent dives into the blue . For this reason, even the most experienced divers tend to follow more closely the path of the dive guide. In addition, the Red Sea marine environments have a greater homogeneity than the Mediterranean Sea.

Similarly to conservation volunteers on precise transects (Mumby et al. 1995; Bell 2007), the positive correlation between correct identification and the taxa presence frequency in the validation trials indicated that recreational volunteers were more accurate in recording the most frequent/straightforward taxa, while they were less accurate with rare/cryptic taxa, even if the identification of these of taxa was specifically addressed in the training program. The taxon with the highest value of correct identification was the fire coral. This organism is a dominant species in semi-exposed habitat (Riegl et al. 2009) and is also described and reported during the pre-dive briefing as highly stinging.

According to the BEST test of searching over subsets of variables for a combination that optimizes the survey effort, 21 out of 72 taxa (29.2% of the original assemblage) were sufficient to generate the same multivariate sample pattern as the full set. For future monitoring research, limitation of items to the most necessary could, reduce the effort during both volunteer training and field work, but on the other hand, it could strongly limit the appeal of the project to potential volunteers. Removing attractive species from the questionnaire such as sharks or turtles would likely decreased volunteers' enjoinment and loyalty, and also the educational potential of the project. Adding charismatic organisms that citizen volunteers are likely to see to the survey in order to give them something to report with satisfaction is an approach successfully experimented in ornithological studies (Greenwood, 2007).

5.2 The surveys

The distribution of the surveys was not homogenous over the spatial scale. Most of the questionnaires, in fact, is from the Sharm el-Sheikh area (Fig. 1). This was expected, since the project, was operatively born in the southern part of the Sinai Peninsula, where the first collaborationg diving centers are located. Despite this, there has been an increasing number of survey stations in Marsa Alam area and some isolated stations in the most southern part of Egyptian territory (Hamata), in Sudan and Saudi Arabia (Yambu al Bahr, Rabigh; Fig. 1).

The presence of isolated survey stations along the eastern and western coasts is due to the collaboration with several diving schools involved in the project. These schools autonomously organize diving cruises in those areas and give an important contribution to research, providing spot information about areas which would otherwise be difficult to be monitored, because they are not in the path of mass touristic routes.

The higher number of collected questionnaires for the coral reef, compared to those collected for the other habitats (Table 3), is attributable to a recreational divers preference this habitat, which is the most biodiverse and therefore more fun to visit (Goffredo et al. 2004; 2010). This is an expected consequence of project methods, which specifically avoids to interfere in the volunteer's selection of the dive site, with the result of involving thousands of enthusiastic data collectors with very low costs for the project (Goffredo et al. 2004; 2010).

Bathymetric and temporal survey distribution reflected the typical pattern of recreational diver activity. Normally, international diving school agencies recommend 30 m as the maximum depth (WRSTC, 2006) and the preferred period for diving is the warm season during the daytime (only advanced divers perform night dives).

5.3 Volunteers Marine Biodiversity Index (V.MBI)

Given that our study lasted only five years, it is not surprising that sighting frequencies of most taxa were consistent over the years. Only seven taxa showed significant temporal trends. The sighting frequency of bleached corals increases during the five years of the project. This finding is consistent with studies related to global warming and acidification that cause the expulsion of zooxanthellae and the resulting coral bleaching (Sobel and Camargo 2010; Bernhard et al. 2012). The significant increase in the sightings frequency of Sohal surgeon fish (*Acanthurus sohal*) could be related to the increasing number of snorkelers involved in the last years of the project. In fact, the Sohal surgeon fish live in the earliest depth meters, so its observation could be easier by groups of snorkelers rather than by divers who stop near the surface only for short periods at the beginning and at the end of the dive. The positive trend of sharks (Squaliformes) could be related with 1) the improvement of fishing techniques, less invasive a highly selective for the target species and sizes (Carlson et al. 2012) and 2) the strict regulations that prohibit the fishing in all the Red Sea protected areas (Samy et al. 2011). The Egyptian legislation allows, however, the local fishing industry by the Bedouins even within marine protected areas. This fishing is carried out with small boats which are used to capture only fish of small size. This could explain the significant decrease of the sighting frequency of map angelfish (*Pomacanthus maculosus*) among the years (Grandcourt et al. 2010).

The findings obtained in the Hurghada area (Fig. A6 in the Appendix) are in agreement with literature and personal observations: this area was severely damaged due to a not controlled anthropic exploitation. The safeguard and management measures mentioned above, were extremely important here. The establishment of the Protectorate of Elba (Egyptian Environment Affairs Agency) in 1995, and the installation program for the mooring buoys released in 1997, are allowing a gradual improvement in the area (Jameson et al. 2007).

The high biodiversity in the peninsula of Ras Mohammed (Fig. A7 in the Appendix) is attributable to the presence of the marine protected area. The control measures of recreational and commercial activities implemented by the Egyptian government could be good to protect environmental resources. Examples of such measures are the provision of regulations on new buildings (the prohibition of dumping overboard sediment produced by construction, causing serious damage to coral reefs) and the creation of access points to the sea by docks (to avoid the tourists to walk onto the reef).

Finally, the area of Marsa Alam has been characterized by a less harmful development of tourist activities. With the data that I collected during my stay in Marsa Alam, the mass of data on this area will be increased, allowing a wider view of the environmental status of this area. I expect to find some significant differences between the area of Marsa Alam and the near area of Hurghada, due to the recent damage that has occurred in the latter, where a good level of biodiversity hasn’t yet been restored, and due to a more intense tourism pressure on the coasts.

6. Conclusion

The results of the project not only provide preliminary considerations about the environmental condition of the Red Sea, but may also can be used for implementation of recovery or conservation programs in the area by local institutions. The Egyptian Government, the Ministry of Tourism and the Egyptian Tourism Authority (ETA), have demonstrated consistent interest in obtaining continuously updated data on the marine and coastal environments, which are the primary component of the tourism industry. Results of the STE project may be useful in the design, expansion and improved management the network of protectorates, identification of areas to be protected and direction of tourism towards increased sustainability. The Egyptian Government is developing programs to defend the natural heritage of the country, with particular attention to the protection of marine biodiversity through the creation of zones with limited human impact.

As shown by previous studies (Carr and Reed 1992; Botsford et al. 2003; Bell et al. 2006; Lipcius et al. 2008), the creation of "recruitment zones" as marine protected areas that, regulate their access and activities, may be effective in promoting the restoration and recovery of degraded areas.

The homogeneity of the data over five years along with the absence of temporal trends, indicates that monitoring frequency could possibly be reduced in order to optimize survey effort. For this purpose we suggest two potential strategies:

• annual rotation of the monitored areas, to convey effort on a single area. In this way the collection of data in the same area would be carried out at regular intervals (eg every 3-4 years);

• continuously monitoring the whole area but collecting data every two years or with longer intervals.

The first strategy is not feasible, as a key characteristic of this kind of project is not imposing any changes to the recreational activity of divers (as opposed to Mumby et al. 1995; Hodgson 1999; Pattengill-Semmens and Semmens 2003), including the dive site. Previously, we have adopted different types of incentives to direct volunteers in certain areas or habitats with limited success (Goffredo et al. 2010). Therefore, it is not possible to plan what the area will be monitored for each year.

The second strategy is also not feasible, because the reduced effort would be ineffective in gaining the loyalty of individual volunteers and involvement of sponsors, diving centers and diving schools. The ongoing maintenance of these relationships has proven extremely useful in enabling data collection. It is too expensive in terms of time and money to re-establish contacts and relationships that will inevitably be lost by stopping the project. Carrying out research in a discontinuous manner during the years also reduces the effectiveness of environmental education and awareness of tourists. For these reasons, we believe it is essential to maintain continuous monitoring effort.

The continuous collection of data in this area of the Red Sea, subjected to increasing human impact, could be able to indicate, in a timely manner, ecological changes taking place, highlighting those that can be defined as *early warning signals* (Guttal and Jayaprakash 2009; Scheffer1 et al. 2009).

In addition, results obtained from the STE project can be integrated with existing projects, such as the current project lead by the Department of Biological, Geological and Environmental Sciences of this University, that aims to predict the effects of global warming and ocean acidification in the Red Sea (CoralWarm; www.coralwarm.eu). Likewise, studies based on long-term monitoring data allow for examinations of variation in biodiversity and analysis of the possible role of seawater temperature and acidity in ecosystem changes.

This project successfully involved citizens that use the sea for recreational purposes (such as tourist divers and snorkelers) in the collection of data.

The monitoring carried out with the involvement of volunteers inevitably has some limits. The STE project, using the collaboration of divers and not wanting to interfere with their usual behavior on holiday, is limited in the spatial and temporal homogeneity of the surveys (geographical regions and habitat). The main advantages are: the huge mass of data obtained in a short time and from a wide geographical area and the reliability of satisfactory results, relevant to make this method applicable in other environmental projects, both in the sea but also on land: birdwatchers and mountain hikers could be other possible types of suitable volunteers. In our experience, and of other institutes (Darwall and Dulvy 1996; EPA 1997; Evans et al. 2000; Foster-Smith and Evans 2003; Bhattacharjee 2005; Sharpe and Conrad 2006; Bell 2007), “citizen science” can complement and augment conventional methods, and it can be a key solution to personnel needed to carry out research. Given the scarce government resources for the continuous generation of the basic data necessary to identify complex environmental issues (Au et al. 2000; Sharpe and Conrad 2006), the role of citizens in monitoring is particularly important, even when volunteers need to have special skills, such as those needed for the exploration of the marine environment. The results, therefore, suggest that the monitoring conducted by previously trained volunteers, can become a viable alternative (Au et al. 2000; Sharpe and Conrad 2006, Devictor et al. 2010).

Finally, citizen involvement as ecological research operators improves scientific literacy and environmental awareness and education amongst all age groups in the community (Evans et al. 2005), and determines a more sustainable approach to the environment (Medio et al. 1997) and leads them to have more attention to the environment surrounding, a higher awareness of the fragility of ecosystems and a greater interest in the protection and preservation of natural heritage (Medio 1997; Trumbull et al. 2000; Brewer 2002; Evans et al. 2005; Koss and Kingsley 2010). Close cooperation between this kind of research and dive centers certainly makes more effective and immediate awareness and environmental education of the individual divers.

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APPENDIX

TABLES

Table A1 – Quality of volunteers generated data. Results of the 78 validation trials performed during the 5-year research project (2007-2011). The column "Overall Questionnaire" shows the values obtained from the comparison between the reference and the Overall Questionnaire (described in Chapter 3.5.1), and the values in bold indicate that it is significantly greater than the value calculated on the individual questionnaires. Parameter definitions are in Table 1 and in the Materials and methods section .

Year	Station name	Code	Date	Team size	Certif. level	Depth (m)	Dive time (min)	Accuracy	CV	Overall Questionna	Consistecy	CV	Percent Identified	CV	Overall Questionna	CAR	CV	Overall Questionna	Reliability	CV	Overall Questionna	Similarity Index	CV	Overall Questionna
2007	Ras Nasrani	RNS	3-lug	3	3.0 (1.0 - 5.0)	26.7 (23.4 - 29.9)	48.3 (35.3 - 61.4)	45.0 (42.8 - 47.2)	4	**56.5**	35.4 (30.6 - 40.1)	12	59.7 (36.0 - 83.5)	35	**91.7**	65.0 (57.6 - 72.3)	10	**79.7**	65.0 (60.2 - 69.8)	5	**73.3**	48.7 (41.8 - 55.6)	13	**58.9**
	Ras Katy	RKT	3-set	5	2.0 (1.4 - 2.6)	14.0	53.0	77.9 (70.6 - 85.1)	11	**86.0**	76.2 (71.3 - 81.1)	10	78.7 (67.3 - 90.1)	17	**96.8**	77.7 (74.3 - 81.1)	5	81.0	88.3 (83.3 - 93.3)	4	93.2	75.6 (69.6 - 81.6)	9	81.5
	Ras Nasrani	RNS	11-set	5	2.0 (1.1 - 2.9)	10.5 (8.0 - 12.9)	49.3 (47.9 - 50.7)	62.1 (59.0 - 65.2)	6	**74.5**	62.6 (54.0 - 71.2)	22	73.2 (67.9 - 78.4)	8	**92.1**	65.3 (63.5 - 67.2)	3	**77.2**	76.2 (74.2 - 78.1)	2	**83.3**	65.8 (62.8 - 68.9)	5	**75.5**
	Shark & Yolanda Reef	SYR	12-set	5	2.6 (1.6 - 3.6)	14.3 (12.4 - 16.3)	45.2 (39.1 - 51.3)	43.2 (40.1 - 46.3)	8	**54.8**	47.8 (44.0 - 51.5)	13	53.6 (39.5 - 67.7)	30	**87.2**	48.6 (44.8 - 52.4)	9	**53.2**	61.3 (55.8 - 66.7)	7	65.3	50.3 (40.3 - 60.3)	23	**66.3**
	Ras Ghozlani	RGZ	20-set	3	1.3 (0.7 - 2.0)	18.2 (14.5 - 21.8)	50.0	59.1 (49.3 - 69.0)	15	**71.7**	55.0 (40.8 - 69.2)	23	74.2 (66.8 - 81.7)	9	**95.5**	57.4 (55.7 - 59.0)	3	**72.2**	73.8 (61.3 - 86.3)	10	79.9	66.6 (63.3 - 69.9)	4	**74.1**
	Ras Katy	RKT	24-set	5	2.2 (0.8 - 3.6)	9.5 (8.6 - 10.4)	43.2 (36.9 - 49.5)	52.1 (44.5 - 59.6)	16	**71.8**	45.5 (41.3 - 49.7)	15	61.9 (41.1 - 82.7)	38	**100.0**	60.8 (57.9 - 63.6)	5	**70.9**	64.7 (50.4 - 78.9)	18	71.4	52.1 (42.1 - 62.2)	22	**67.8**
	Ras Umm Sid	RUS	24-set	3	2.7 (0.3 - 5.0)	19.1 (15.3 - 23.0)	42.7 (39.0 - 46.3)	53.5 (37.9 - 69.0)	26	67.3	54.5 (50.3 - 58.8)	7	73.0 (49.8 - 96.2)	28	95.2	54.9 (49.1 - 60.6)	9	**70.9**	67.7 (46.1 - 89.2)	20	72.6	62.3 (49.5 - 75.2)	18	70.9
	Jackson Reef	JKR	16-ott	5	3.2 (1.8 - 4.6)	14.0 (12.0 - 16.0)	44.2 (41.4 - 47.0)	62.3 (53.6 - 70.9)	16	70.7	64.8 (53.2 - 76.5)	29	80.8 (67.3 - 94.3)	19	**100.0**	71.4 (69.5 - 73.2)	3	**77.2**	69.4 (57.4 - 81.4)	14	77.4	58.6 (52.6 - 64.6)	12	61.4
2008	Ras Za' Atar	RZA	18-giu	7	3.3 (3.3 - 3.3)	12.7 (8.5 - 17.0)	49.1 (45.9 - 52.3)	45.6 (41.9 - 49.3)	11	**58.7**	43.9 (36.9 - 50.9)	37	53.2 (43.4 - 62.9)	25	**88.9**	58.6 (54.8 - 62.3)	9	**75.9**	61.1 (54.6 - 67.7)	10	**73.7**	49.8 (45.2 - 54.4)	13	**65.1**
	Shark & Yolanda Reef	SYR	18-giu	5	3.1 (2.5 - 3.6)	17.8 (16.2 - 19.4)	44.8 (43.2 - 46.4)	50.3 (42.1 - 58.5)	19	**71.9**	35.1 (29.4 - 40.9)	26	52.7 (34.5 - 70.9)	39	**95.1**	55.7 (51.2 - 60.2)	9	68.4	63.6 (53.7 - 73.5)	12	72.8	50.9 (37.5 - 64.4)	30	**68.9**
	Shark & Yolanda Reef	SYR	9-lug	8	2.4 (1.6 - 3.2)	17.4 (14.7 - 20.1)	48.6 (45.6 - 51.7)	54.4 (49.8 - 59.0)	12	**66.8**	43.3 (38.1 - 48.5)	32	72.5 (62.2 - 82.8)	21	**100.0**	68.0 (62.7 - 73.4)	11	68.4	71.3 (64.8 - 77.9)	9	**83.0**	54.6 (50.6 - 58.6)	11	**58.7**
	Shark Observatory	SOB	25-lug	6	4.2 (3.2 - 5.1)	17.5 (13.9 - 21.1)	53.3 (46.9 - 59.7)	59.8 (47.7 - 71.9)	25	**74.6**	59.1 (53.6 - 64.5)	18	76.8 (66.9 - 86.6)	16	**100.0**	55.9 (47.7 - 64.1)	18	59.5	72.9 (58.6 - 87.1)	17	81.5	66.2 (59.7 - 72.7)	12	**73.4**
	Shark & Yolanda Reef	SYR	30-lug	10	2.5 (1.8 - 3.3)	16.3 (14.4 - 18.1)	52.2 (48.9 - 55.5)	52.2 (47.6 - 56.8)	14	**69.8**	52.2 (48.9 - 55.4)	21	75.1 (67.2 - 83.1)	17	**100.0**	53.3 (49.1 - 57.4)	13	51.9	67.5 (64.3 - 70.7)	8	**77.5**	60.5 (56.7 - 64.3)	10	**68.6**
	Temple	TMP	11-ago	6	3.7 (2.5 - 4.9)	14.1 (12.9 - 15.3)	53.2 (47.9 - 58.4)	49.4 (47.4 - 51.5)	5	**60.1**	48.9 (43.5 - 54.2)	22	65.4 (60.6 - 70.2)	9	**88.5**	65.8 (63.3 - 68.4)	5	65.8	63.9 (57.4 - 70.5)	9	**72.4**	54.4 (51.3 - 57.5)	7	**60.6**
	Jackson Reef	JKR	14-ago	11	2.8 (2.2 - 3.5)	15.6 (12.6 - 18.5)	57.8 (52.9 - 62.7)	50.9 (46.1 - 55.7)	16	**69.0**	45.7 (42.5 - 48.8)	26	68.2 (58.7 - 77.7)	24	**100.0**	57.9 (53.8 - 62.0)	12	53.2	65.8 (60.4 - 71.1)	10	**74.7**	56.7 (52.6 - 60.9)	12	**65.4**
	Jackson Reef	JKR	16-ago	6	2.5 (1.8 - 3.2)	20.3 (15.8 - 24.8)	61.0 (58.0 - 64.0)	53.7 (48.0 - 59.4)	13	**65.8**	52.8 (49.1 - 56.6)	14	74.1 (63.5 - 84.7)	18	**92.6**	62.0 (58.5 - 65.5)	7	**68.4**	70.9 (63.2 - 78.6)	9	**81.4**	57.2 (54.0 - 60.5)	7	**62.9**
	Ras Katy	RKT	12-set	6	3.0 (1.7 - 4.3)	14.6 (12.9 - 16.3)	59.7 (57.8 - 61.5)	49.2 (44.0 - 54.3)	13	**61.4**	54.6 (47.1 - 62.0)	27	68.1 (60.6 - 75.6)	14	**100.0**	67.7 (63.6 - 71.8)	8	70.9	61.5 (54.3 - 68.8)	10	**69.8**	51.5 (47.2 - 55.8)	10	**56.9**
	Shark & Yolanda Reef	SYR	12-set	12	2.8 (1.9 - 3.6)	16.9 (14.7 - 19.0)	42.0 (41.0 - 43.0)	70.5 (64.5 - 76.6)	15	**84.2**	65.4 (62.5 - 68.2)	18	78.9 (74.8 - 83.0)	9	**100.0**	68.0 (62.9 - 73.2)	13	58.2	84.0 (77.6 - 90.5)	9	**91.6**	72.7 (68.4 - 76.9)	10	**78.3**
	Temple	TMP	6-ott	5	3.0 (1.4 - 4.6)	14.6 (14.1 - 15.1)	45.9 (42.8 - 49.0)	50.1 (44.1 - 56.1)	14	**62.3**	57.8 (51.8 - 63.8)	17	58.6 (45.0 - 72.1)	26	**92.9**	64.1 (57.8 - 70.3)	11	68.4	67.1 (58.8 - 75.4)	10	73.7	51.8 (44.4 - 59.1)	16	58.8
	Shark Observatory	SOB	9-ott	9	3.2 (1.8 - 4.6)	18.8 (15.8 - 21.8)	48.9 (45.3 - 52.4)	53.4 (47.0 - 59.8)	18	**78.3**	43.1 (38.4 - 47.8)	33	61.1 (52.0 - 70.2)	23	**100.0**	64.4 (61.9 - 67.0)	6	**69.6**	67.2 (57.9 - 76.5)	15	**79.2**	55.9 (49.3 - 62.5)	18	**72.8**
	Shark & Yolanda Reef	SYR	9-ott	5	3.3 (2.4 - 4.3)	16.8 (14.1 - 19.5)	45.0 (43.2 - 46.8)	56.5 (42.9 - 70.0)	27	**76.1**	57.1 (47.0 - 67.2)	29	67.8 (53.5 - 82.0)	24	**94.4**	61.3 (55.7 - 66.8)	10	**68.4**	71.1 (55.2 - 87.0)	18	80.8	60.9 (50.0 - 71.9)	21	**72.2**
2009	Marsa Abu Dabab	MAD	28-lug	9	2.0 (1.4 - 2.6)	15.4 (14.8 - 16.1)	53.0 (50.2 - 55.8)	67.8 (61.8 - 73.7)	14	**75.9**	65.5 (62.5 - 68.4)	14	79.4 (74.4 - 84.4)	10	**100.0**	76.7 (70.7 - 82.6)	12	72.2	83.7 (76.9 - 90.5)	9	**91.2**	70.1 (64.3 - 75.9)	13	73.2
	Shark & Yolanda Reef	SYR	19-ago	7	2.7 (1.6 - 3.7)	16.1 (13.7 - 18.5)	46.1 (39.8 - 52.4)	52.8 (44.7 - 60.9)	21	**73.5**	42.0 (37.1 - 46.9)	27	69.9 (62.3 - 77.5)	15	**97.9**	54.6 (51.1 - 58.1)	9	**72.2**	65.2 (55.0 - 75.4)	15	**78.6**	61.6 (57.8 - 65.4)	8	**77.0**
	Shark & Yolanda Reef	SYR	27-ago	8	2.9 (2.0 - 3.8)	17.2 (14.8 - 19.6)	54.3 (51.8 - 56.9)	49.1 (40.4 - 57.7)	19	**67.2**	50.6 (44.7 - 56.5)	29	60.2 (50.2 - 70.2)	28	**94.7**	58.1 (55.1 - 61.1)	3	**65.8**	64.8 (51.4 - 78.1)	11	77.0	55.4 (48.7 - 62.1)	19	**67.5**
	Jackfish Alley	JAL	27-ago	9	3.1 (2.2 - 4.1)	17.0 (15.3 - 18.6)	54.2 (51.8 - 56.5)	50.0 (43.9 - 56.2)	26	**73.8**	43.4 (39.3 - 47.5)	31	59.8 (49.0 - 70.7)	24	**100.0**	57.1 (55.8 - 58.4)	7	50.6	67.1 (60.1 - 74.1)	21	**75.7**	56.0 (49.0 - 63.0)	17	**72.3**
	Eel Garden	EGR	3-set	5	2.4 (1.6 - 3.2)	14.9 (8.3 - 21.6)	51.2 (46.6 - 55.8)	40.4 (36.6 - 44.1)	11	**56.6**	37.7 (30.8 - 44.5)	29	46.5 (34.3 - 58.8)	30	**84.8**	49.6 (46.7 - 52.5)	7	**62.0**	56.6 (50.6 - 62.5)	8	**64.1**	48.1 (37.9 - 58.4)	24	**66.4**
	Shark & Yolanda Reef	SYR	3-set	6	3.1 (1.9 - 4.4)	14.2 (10.9 - 17.4)	53.3 (48.5 - 58.2)	46.0 (39.4 - 52.6)	18	**69.2**	39.4 (33.1 - 45.7)	32	54.8 (45.0 - 64.6)	22	**95.6**	54.0 (50.5 - 57.5)	8	**69.6**	59.6 (50.8 - 68.4)	13	**69.8**	51.2 (44.3 - 58.1)	17	**70.0**
	Woodhouse Reef	WDR	28-set	6	2.3 (1.2 - 3.4)	20.1 (16.6 - 23.6)	47.1 (43.9 - 50.3)	53.4 (43.4 - 63.3)	23	**72.8**	48.8 (43.5 - 54.1)	21	58.6 (41.0 - 76.2)	38	**97.0**	63.9 (61.2 - 66.7)	5	64.6	67.4 (56.5 - 78.3)	14	74.1	53.0 (41.2 - 64.9)	28	**70.6**
	Jackson Reef	JKR	29-set	13	2.9 (2.1 - 3.8)	18.0 (16.0 - 20.1)	49.1 (45.9 - 52.3)	48.3 (44.0 - 52.7)	17	**74.6**	39.7 (36.8 - 42.6)	33	54.4 (46.0 - 62.7)	28	**95.5**	55.6 (53.1 - 58.1)	8	54.4	62.7 (56.0 - 69.4)	14	**75.7**	52.8 (46.0 - 59.6)	24	**69.8**
	Shark Observatory	SOB	4-nov	18	3.8 (3.2 - 4.4)	17.6 (16.2 - 18.9)	47.6 (45.7 - 49.4)	55.6 (49.4 - 61.7)	24	**73.5**	51.4 (49.1 - 53.8)	29	66.9 (58.5 - 75.2)	27	**96.7**	64.3 (61.8 - 66.8)	9	60.8	68.3 (59.7 - 76.9)	19	**83.7**	57.7 (52.1 - 63.4)	21	**69.1**
	Jackson Reef	JKR	12-nov	3	4.0 (2.0 - 6.0)	17.0 (15.0 - 18.9)	58.3 (49.5 - 67.0)	58.7 (41.1 - 76.4)	27	76.3	42.6 (21.5 - 63.6)	44	64.8 (34.2 - 95.3)	42	91.4	63.3 (54.7 - 71.9)	12	**79.7**	71.7 (50.0 - 93.4)	19	81.3	58.3 (36.7 - 80.0)	33	77.6
2010	Torfa Mikky	TMK	17-apr	3	3.0 (1.0 - 5.0)	13.3 (10.7 - 15.9)	48.0 (48.0 - 48.0)	49.9 (20.1 - 79.8)	53	61.4	51.5 (44.9 - 58.1)	11	71.3 (57.1 - 85.5)	18	**94.4**	59.9 (54.0 - 65.9)	9	**70.9**	67.5 (54.9 - 80.0)	11	76.8	62.1 (55.7 - 68.4)	9	67.0
	Dolphin House	DLH	15-mag	5	2.5 (1.7 - 3.3)	10.2 (7.9 - 12.4)	44.0 (36.7 - 51.2)	58.3 (46.7 - 69.9)	23	**75.8**	49.9 (41.6 - 58.3)	27	82.0 (73.6 - 90.4)	12	**100.0**	55.9 (45.0 - 66.9)	22	**68.4**	71.2 (53.2 - 89.1)	20	82.3	63.2 (55.5 - 70.9)	14	68.6
	Marsa Samadai	MSA	24-mag	4	2.0 (2.0 - 2.0)	13.8 (11.2 - 16.4)	48.7 (44.5 - 52.8)	55.7 (43.9 - 67.4)	21	**67.4**	54.8 (43.6 - 66.0)	26	63.8 (52.9 - 74.6)	17	**82.5**	58.2 (54.7 - 61.7)	6	**70.9**	69.5 (53.8 - 85.2)	16	77.8	59.1 (48.8 - 69.3)	18	**69.4**
	Abu Ghusun (relitto Hamata	AGH	28-mag	3	4.0 (4.0 - 4.0)	16.3 (14.6 - 18.1)	46.7 (44.3 - 49.0)	51.1 (45.7 - 56.5)	9	**61.9**	48.1 (39.7 - 56.5)	15	61.0 (48.7 - 73.2)	18	**82.9**	59.1 (55.8 - 62.4)	5	**68.4**	60.4 (49.7 - 71.2)	11	66.1	56.6 (46.8 - 66.3)	15	66.3
	Elphinstone Reef	ELR	16-giu	3	3.0 (1.0 - 5.0)	18.8 (12.6 - 25.0)	48.7 (43.6 - 53.8)	59.1 (27.4 - 90.8)	47	83.0	43.5 (35.5 - 51.6)	16	61.8 (31.3 - 92.3)	44	91.2	67.9 (48.7 - 87.2)	25	82.3	66.3 (25.2 - 107.3)	38	82.6	60.0 (29.9 - 90.1)	44	76.0
	Marsa Shagra	MSG	16-giu	4	3.3 (1.8 - 4.7)	13.9 (10.1 - 17.7)	51.0 (44.9 - 57.1)	54.7 (42.2 - 67.1)	23	**74.3**	49.4 (44.8 - 54.0)	12	57.1 (38.2 - 75.9)	34	**89.7**	58.9 (52.3 - 65.4)	11	**69.6**	66.2 (46.5 - 85.9)	21	77.4	57.3 (42.3 - 72.3)	27	**73.7**

Table A1 – Continuation.

Year	Station name	Code	Date	Team size	ertification lev	Depth (m)	Dive time (min)	Accuracy			Consistecy		Percent Identified			CAR			Reliability			Similarity Index		
									CV	Overall Questionna		CV		CV	Overall Questionna		CV	Overall Questionna		CV	Overall Questionna		CV	Overall Questionna
	Temple	TMP	5-lug	4	1.8 (1.3 - 2.2)	14.6 (11.1 - 18.2)	52.5 (44.6 - 60.4)	57.5 (35.3 - 79.6)	39	78.7	45.2 (27.6 - 62.7)	48	60.0 (30.3 - 89.7)	51	**90.0**	58.9 (55.9 - 61.8)	5	**87.3**	68.8 (39.3 - 98.2)	31	86.5	55.3 (33.2 - 77.4)	41	76.2
	Woodhouse Reef	WDR	8-lug	5	2.6 (1.7 - 3.4)	16.1 (14.2 - 18.0)	56.0 (50.6 - 61.4)	54.9 (46.9 - 62.9)	17	**67.1**	54.5 (47.5 - 61.6)	21	72.4 (57.6 - 87.2)	23	**100.0**	57.0 (50.4 - 63.5)	13	**69.6**	69.5 (59.0 - 80.0)	12	79.8	56.3 (50.8 - 61.9)	11	**63.7**
	Ras Umm Sid	RUS	19-lug	5	5.0	18.2 (11.6 - 24.8)	45.7 (42.4 - 49.1)	51.6 (46.3 - 57.0)	12	**67.6**	51.4 (47.3 - 55.6)	13	72.2 (62.3 - 82.1)	16	**94.4**	53.6 (47.6 - 59.6)	10	**75.9**	66.5 (56.3 - 76.8)	12	**78.3**	58.8 (53.4 - 64.3)	11	**66.9**
	Shark & Yolanda Reef	SYR	21-lug	9	4.0 (3.2 - 4.8)	15.8 (13.9 - 17.7)	46.4 (42.7 - 50.1)	63.3 (54.0 - 72.5)	22	**85.3**	50.6 (46.8 - 54.4)	23	74.6 (64.0 - 85.3)	22	**100.0**	59.5 (55.8 - 63.2)	7	59.5	76.0 (63.8 - 88.2)	17	**88.3**	66.6 (59.5 - 73.7)	16	**78.2**
	Ras Za' Atar	RZA	28-lug	7	3.0 (1.8 - 4.2)	16.2 (15.0 - 17.5)	52.9 (50.6 - 55.1)	51.0 (40.7 - 61.4)	27	**70.4**	42.8 (37.3 - 48.3)	25	60.2 (45.8 - 74.7)	32	**94.6**	60.2 (55.4 - 65.0)	11	**77.2**	62.3 (50.2 - 74.4)	18	**76.5**	55.8 (47.1 - 64.5)	21	**70.4**
	Jackson Reef	JKR	5-ago	5	2.8 (1.5 - 4.0)	15.4 (12.7 - 18.1)	46.4 (42.8 - 49.9)	47.0 (43.7 - 50.2)	8	**67.6**	36.2 (28.0 - 44.4)	37	55.7 (44.7 - 66.6)	22	**91.9**	57.7 (53.8 - 61.7)	8	**73.4**	65.9 (61.2 - 70.6)	6	**77.5**	52.3 (49.2 - 55.3)	7	**69.0**
	Gordon Reef	GRR	10-ago	5	3.0 (1.6 - 4.4)	12.4 (8.7 - 16.2)	50.2 (47.1 - 53.3)	57.0 (46.4 - 67.5)	21	**73.8**	46.6 (41.2 - 52.0)	19	75.0 (65.7 - 84.3)	14	**100.0**	62.3 (55.2 - 69.4)	13	**79.7**	68.1 (53.6 - 82.5)	17	80.7	60.6 (54.5 - 66.6)	11	**68.2**
	Ras Ghozlani	RGZ	11-ago	4	2.0 (0.6 - 3.4)	10.8 (4.1 - 17.5)	50.7 (43.1 - 58.2)	46.1 (39.5 - 52.7)	15	**62.2**	41.2 (35.7 - 46.8)	17	54.8 (47.1 - 62.5)	14	**87.2**	46.2 (42.0 - 50.4)	9	**64.6**	59.5 (42.6 - 76.4)	20	69.7	55.4 (49.6 - 61.1)	11	**69.5**
	Ras Za' Atar	RZA	15-ago	6	4.2 (3.2 - 5.1)	12.2 (8.7 - 15.7)	55.7 (49.2 - 62.1)	52.8 (46.4 - 59.2)	15	**69.8**	48.6 (43.4 - 53.8)	21	62.5 (51.5 - 73.5)	22	**94.4**	59.5 (49.2 - 69.8)	22	62.0	67.5 (58.8 - 76.3)	11	73.4	56.6 (51.0 - 62.2)	12	**69.9**
	Ras Umm Sid	RUS	#####	3	2.7 (0.9 - 4.4)	14.9 (11.5 - 18.3)	39.0 (37.0 - 41.0)	43.4 (40.0 - 46.8)	7	**60.0**	33.5 (26.6 - 40.4)	18	49.2 (32.1 - 66.3)	31	**83.3**	57.0 (53.2 - 60.8)	6	**70.9**	59.2 (47.0 - 71.5)	13	69.1	47.7 (33.5 - 61.8)	26	**67.6**
	Woodhouse Reef	WDR	#####	3	1.5 (0.9 - 2.1)	15.6 (12.6 - 18.6)	50.3 (46.5 - 54.0)	42.1 (34.6 - 49.5)	16	**54.4**	40.4 (33.7 - 47.2)	15	54.7 (27.3 - 82.1)	44	**87.2**	57.0 (47.6 - 66.4)	15	**75.9**	52.6 (41.3 - 63.9)	13	60.9	45.5 (30.6 - 60.4)	29	**61.3**
	Shark & Yolanda Reef	SYR	#####	4	1.3 (0.7 - 2.0)	14.5 (8.9 - 20.0)	41.5 (34.6 - 48.4)	44.9 (40.6 - 49.2)	10	**55.2**	41.6 (33.8 - 49.4)	23	51.6 (37.8 - 65.4)	27	**81.3**	60.8 (55.3 - 66.2)	9	**74.7**	58.2 (51.3 - 65.2)	8	**67.5**	47.6 (40.3 - 55.0)	16	**60.8**
	Jackson Reef	JKR	#####	4	3.0 (2.2 - 3.8)	15.0 (6.5 - 23.4)	48.8 (46.3 - 51.2)	42.9 (33.0 - 52.9)	12	**56.8**	40.0 (26.2 - 53.8)	30	69.1 (48.8 - 89.4)	27	**94.1**	51.3 (40.4 - 62.1)	4	**77.2**	54.5 (33.7 - 75.3)	14	69.0	50.9 (43.1 - 58.7)	24	**60.8**
	Gordon Reef	GRR	#####	3	1.5 (0.5 - 2.5)	13.9 (11.8 - 16.0)	46.7 (40.1 - 53.2)	40.8 (35.2 - 46.4)	24	44.2	62.8 (41.5 - 84.1)	43	39.0 (27.0 - 51.1)	30	**51.2**	54.9 (52.7 - 57.0)	22	**60.8**	53.3 (41.4 - 65.1)	27	57.9	40.9 (29.9 - 51.9)	16	49.8
	Gordon Reef	GRR	31-ago	11	3.4 (2.5 - 4.3)	13.5 (10.9 - 16.0)	45.5 (44.8 - 46.2)	47.9 (38.2 - 57.7)	34	**69.9**	45.3 (40.9 - 49.6)	36	56.1 (50.0 - 62.3)	19	**97.5**	66.4 (56.7 - 76.1)	25	57.0	62.8 (58.2 - 67.5)	9	**72.8**	52.5 (48.8 - 56.2)	12	**66.2**
	Temple	TMP	3-ott	4	2.8 (1.1 - 4.4)	12.9 (10.4 - 15.3)	49.0 (47.9 - 50.1)	64.0 (55.9 - 72.2)	13	**77.6**	65.8 (53.3 - 78.3)	24	65.0 (50.4 - 79.6)	23	**90.0**	65.5 (57.7 - 73.3)	12	**77.2**	72.6 (60.5 - 84.7)	12	80.3	61.8 (50.6 - 72.9)	18	72.0
	Canyon	CNY	8-ott	3	3.7 (1.9 - 5.4)	16.5 (11.1 - 22.0)	47.7 (40.1 - 55.2)	63.3 (49.2 - 77.4)	20	68.6	73.7 (49.5 - 97.9)	29	81.8 (72.7 - 90.9)	10	**90.9**	62.0 (57.1 - 67.0)	7	**74.7**	73.0 (58.1 - 88.0)	13	80.3	64.3 (56.7 - 71.9)	10	68.3
	Blue Hole - El Bells	BHL	8-ott	3	3.7 (1.9 - 5.4)	17.2 (16.0 - 18.5)	43.7 (37.4 - 49.9)	60.6 (59.8 - 61.4)	1	**68.0**	77.2 (60.5 - 94.0)	19	79.4 (72.8 - 86.1)	7	**91.2**	59.1 (54.5 - 63.7)	7	**68.4**	72.7 (70.6 - 74.8)	2	**77.5**	64.7 (64.3 - 65.1)	59	**68.3**
	Ras Umm Sid	RUS	1-nov	7	3.7 (2.7 - 4.7)	20.1 (17.4 - 22.7)	46.3 (40.7 - 51.8)	44.1 (40.2 - 47.9)	12	**63.8**	42.1 (37.9 - 46.4)	24	57.5 (43.4 - 71.6)	33	**100.0**	49.7 (44.9 - 54.6)	13	**63.3**	62.9 (56.9 - 69.0)	9	**71.4**	52.7 (47.5 - 57.9)	13	57.9
	Ras Za' Atar	RZA	5-nov	15	3.5 (2.7 - 4.2)	16.5 (14.5 - 18.5)	49.1 (46.1 - 52.0)	55.6 (47.9 - 63.4)	28	**82.5**	43.4 (41.1 - 45.6)	27	62.4 (52.4 - 72.4)	32	**100.0**	56.3 (53.3 - 59.3)	10	50.6	69.3 (60.0 - 78.6)	18	**82.9**	58.3 (51.1 - 65.5)	24	**74.6**
	Shark & Yolanda Reef	SYR	5-nov	10	3.2 (2.4 - 4.0)	15.7 (12.7 - 18.7)	50.2 (45.9 - 54.5)	55.8 (49.0 - 62.7)	20	**73.7**	51.1 (47.9 - 54.2)	21	74.4 (65.9 - 82.9)	18	**100.0**	49.5 (44.0 - 55.0)	18	53.2	69.4 (60.0 - 78.8)	15	78.2	63.7 (60.0 - 67.4)	9	**72.2**
	Jackson Reef	JKR	11-nov	11	3.5 (2.8 - 4.1)	17.5 (15.8 - 19.3)	48.4 (45.5 - 51.3)	58.8 (51.3 - 66.3)	22	**85.2**	45.3 (41.5 - 49.0)	32	62.3 (51.7 - 72.9)	29	**100.0**	56.0 (52.0 - 60.1)	12	57.0	72.6 (63.9 - 81.4)	14	**85.2**	60.8 (52.8 - 68.8)	22	**77.8**
	Thomas Reef	TMR	11-nov	9	3.4 (2.6 - 4.3)	17.1 (11.4 - 22.8)	61.9 (56.1 - 67.7)	52.6 (45.1 - 60.1)	22	**71.7**	47.0 (43.4 - 50.7)	24	55.8 (47.1 - 64.5)	24	**93.3**	54.0 (49.7 - 58.4)	12	46.8	71.1 (61.1 - 81.1)	15	**82.8**	58.6 (50.9 - 66.2)	20	**75.4**
	Shark & Yolanda Reef	SYR	12-nov	7	3.7 (2.7 - 4.6)	17.0 (13.7 - 20.4)	44.6 (37.7 - 51.5)	52.4 (45.1 - 59.7)	19	**68.2**	50.4 (45.1 - 55.7)	25	57.1 (45.3 - 68.9)	28	**85.4**	47.4 (45.0 - 49.7)	7	**54.4**	68.0 (58.3 - 77.7)	13	76.4	57.1 (49.0 - 65.2)	19	**70.4**
2011	Dolphin House	DLH	22-giu	4	2.0	8.8 (-0.1 - 17.6)	45.3 (41.2 - 49.3)	45.7 (38.6 - 52.8)	16	**53.8**	48.7 (35.0 - 62.3)	35	62.0 (43.8 - 80.2)	30	**88.0**	66.8 (63.1 - 70.5)	6	**81.0**	59.6 (54.0 - 65.1)	7	**70.1**	51.0 (45.2 - 56.8)	12	55.4
	Marsa Samadai	MAS	26-giu	3	4.3 (3.0 - 5.6)	15.0 (12.7 - 17.3)	51.7 (48.4 - 54.9)	67.8 (34.9 - 100.7)	43	85.1	47.9 (35.8 - 60.0)	22	74.2 (40.7 - 107.6)	40	100.0	77.2 (54.7 - 99.7)	26	91.1	81.1 (54.6 - 107.6)	20	88.8	69.4 (37.1 - 101.7)	41	76.9
	Tower	TWR	18-lug	10	4.2 (3.5 - 4.9)	16.1 (12.9 - 19.3)	46.4 (43.4 - 49.4)	56.8 (51.2 - 62.4)	16	**76.0**	47.2 (43.7 - 50.8)	25	62.0 (52.9 - 71.1)	24	**97.5**	60.0 (56.2 - 63.8)	10	60.8	69.0 (58.2 - 79.9)	18	**84.8**	60.6 (54.6 - 66.7)	16	**73.5**
	Jackfish Alley	JAL	19-lug	8	4.0 (2.7 - 5.3)	16.8 (10.9 - 22.7)	44.2 (40.9 - 47.5)	57.1 (50.5 - 63.8)	17	**72.4**	52.4 (48.3 - 56.4)	24	70.6 (64.1 - 77.1)	13	**97.3**	61.2 (57.7 - 64.8)	8	63.3	71.7 (61.1 - 82.3)	15	**85.1**	65.0 (61.2 - 68.7)	8	**70.7**
	Ras Za' Atar	RZA	20-lug	6	2.8 (1.8 - 3.9)	12.7 (7.9 - 17.4)	44.4 (38.0 - 50.9)	59.2 (53.6 - 64.9)	12	**77.4**	58.4 (52.6 - 64.2)	20	57.4 (50.3 - 64.6)	16	**91.5**	54.9 (50.2 - 59.5)	10	**59.5**	71.0 (62.8 - 79.3)	10	**80.5**	58.6 (52.1 - 65.1)	14	**72.0**
	Gordon Reef	GRR	23-lug	6	4.0 (2.8 - 5.2)	19.3 (14.0 - 24.5)	52.3 (48.6 - 56.1)	67.7 (60.4 - 75.0)	14	**80.5**	63.2 (60.1 - 66.4)	10	77.2 (70.2 - 84.3)	11	**97.6**	63.5 (57.1 - 69.9)	13	**72.2**	79.8 (72.3 - 87.2)	8	**88.1**	71.2 (65.6 - 76.7)	10	**79.5**
	Jackson Reef	JKR	26-lug	10	2.9 (2.1 - 3.6)	12.9 (8.8 - 16.9)	45.3 (41.6 - 49.1)	57.4 (48.5 - 66.3)	25	**84.8**	44.8 (40.7 - 48.9)	31	61.3 (47.7 - 74.9)	36	**100.0**	53.9 (46.8 - 61.1)	21	55.7	67.7 (55.2 - 80.3)	21	**81.0**	57.9 (48.0 - 67.8)	27	**80.0**
	Laguna Reef	LGR	26-lug	3	2.7 (1.4 - 4.0)	11.7 (1.2 - 22.2)	50.5 (48.6 - 52.5)	62.8 (43.6 - 82.0)	27	77.3	56.9 (42.9 - 70.8)	22	66.7 (42.9 - 90.4)	31	**93.2**	60.8 (44.2 - 77.3)	24	69.6	73.5 (51.0 - 96.0)	19	81.2	63.8 (45.7 - 81.9)	25	76.3
	Jackfish Alley	JAL	10-ago	4	3.3 (2.0 - 4.6)	10.0 (-0.2 - 20.2)	45.2 (35.2 - 55.2)	45.2 (41.3 - 49.2)	9	**59.7**	48.1 (42.1 - 54.1)	16	51.3 (35.2 - 67.3)	32	**85.0**	55.7 (54.3 - 57.1)	3	**68.4**	60.0 (48.9 - 71.1)	13	68.5	49.8 (40.8 - 58.8)	18	**61.9**
	Shark & Yolanda Reef	SYR	14-ago	6	3.0 (1.4 - 4.6)	17.4 (14.3 - 20.5)	47.6 (44.9 - 50.3)	52.3 (43.2 - 61.4)	22	**73.0**	47.0 (43.2 - 50.9)	16	66.7 (47.6 - 85.7)	36	**100.0**	48.9 (42.8 - 55.0)	16	51.9	63.2 (51.6 - 74.8)	16	71.2	58.7 (47.3 - 70.1)	24	**72.8**
	Near Garden	NGR	15-ago	3	3.0	22.0 (19.7 - 24.3)	55.7 (48.1 - 63.2)	44.5 (37.0 - 51.9)	15	**54.7**	47.5 (36.0 - 59.1)	21	55.2 (38.5 - 71.9)	27	**81.3**	61.2 (56.6 - 65.8)	7	**73.4**	61.5 (47.7 - 75.3)	14	67.5	52.2 (48.1 - 56.4)	7	**65.7**
	Gordon Reef	GRR	16-ago	5	2.5 (1.7 - 3.4)	18.0 (15.0 - 21.0)	55.6 (49.8 - 61.4)	40.6 (37.2 - 44.0)	9	**57.1**	35.3 (29.6 - 41.0)	26	46.5 (33.2 - 59.8)	33	**87.0**	44.6 (42.6 - 46.5)	5	**49.4**	51.7 (42.6 - 60.8)	14	59.6	47.4 (38.7 - 56.1)	21	**66.5**
	Temple	TMP	5-set	7	2.3 (1.5 - 3.2)	12.4 (11.2 - 13.6)	46.0 (40.7 - 51.3)	55.7 (48.6 - 62.8)	17	**66.1**	59.2 (50.5 - 68.0)	35	65.0 (59.6 - 70.4)	11	**89.7**	68.0 (64.5 - 71.5)	7	**74.7**	64.8 (50.2 - 79.3)	21	74.9	57.9 (53.0 - 62.9)	11	**67.4**
	Shark & Yolanda Reef	SYR	14-set	19	3.3 (2.7 - 3.9)	16.4 (14.4 - 18.4)	47.3 (43.9 - 50.6)	55.5 (49.4 - 61.6)	24	**78.7**	46.5 (44.3 - 48.8)	32	61.4 (53.0 - 69.7)	30	**100.0**	58.3 (56.1 - 60.5)	8	48.1	70.2 (62.6 - 77.9)	17	**82.5**	58.5 (52.4 - 64.7)	23	**73.4**
	Woodhouse Reef	WDR	15-set	8	2.8 (1.9 - 3.6)	16.9 (14.8 - 19.0)	52.1 (47.0 - 57.2)	53.6 (47.9 - 59.2)	15	**74.3**	46.2 (41.0 - 51.3)	30	57.1 (48.3 - 65.8)	22	**91.9**	60.3 (57.8 - 62.8)	6	**67.1**	68.7 (61.5 - 75.9)	11	**78.3**	54.7 (48.4 - 61.1)	17	**71.1**
	Shark & Yolanda Reef	SYR	16-set	10	3.1 (2.4 - 3.8)	14.5 (12.8 - 16.2)	53.0 (51.8 - 54.2)	60.8 (54.4 - 67.1)	17	**78.9**	52.4 (48.5 - 56.4)	26	70.7 (61.6 - 79.9)	21	**97.6**	58.2 (54.1 - 62.4)	11	59.5	71.2 (61.1 - 81.3)	16	**83.5**	63.3 (57.2 - 69.3)	15	**75.7**
	Jackson Reef	JKR	17-set	5	3.4 (2.1 - 4.7)	15.9 (13.8 - 18.0)	50.4 (47.6 - 53.2)	62.4 (51.9 - 72.9)	19	**78.6**	58.4 (50.7 - 66.1)	21	65.4 (52.8 - 78.0)	22	**95.1**	55.9 (48.5 - 63.4)	15	58.2	70.5 (53.9 - 87.1)	19	79.0	64.5 (53.6 - 75.4)	19	**76.0**

Table A2 – Taxon level analyses. Correct identifications were generated from a maximum sample size of 78 validation trials performed at the stations listed in Table A1, from July 03, 2007 to September 17, 2011. N: actual sample size for each taxon (i.e. presence frequency: number of validation trials in which the taxon was present). Refer to Table 1 for definition of "Correct identification". The column "Overall Questionnaire" shows the values obtained from the comparison between the reference and the Overall Questionnaire (described in Chapter 3.5.1), and the values in bold indicate that it is significantly greater than the value calculated on the individual questionnaires. Best subset of taxa: the BEST test was performed on the total sample size of useful questionnaires collected over the 5-year of research. Twenty one taxa constituted the minimum subset which generated the same multivariate sample pattern derived from the full taxa assemblage and represented in Fig. 2.

Taxon		Correct identification							
						Overall Questionnaire			
Common name	Scientific name	Mean	N	95% CI		Media	95% CI		Best taxon
2 - fire coral	*Millepora sp.*	93,2	77,0	89,8	96,5	**100,0**	-	-	
5 - sea fan	*Subergorgia hicksoni*	91,3	64,0	87,3	95,3	**100,0**	-	-	
46 - parrotfishes	Scaridae	87,0	69,0	83,5	90,5	**100,0**	-	-	X
42 - butterflyfishes	Chaetodontidae	87,0	74,0	82,5	91,5	**98,6**	96,0	101,3	
4 - soft tree coral	*Dendronephythya sp.*	84,4	75,0	79,7	89,1	**98,7**	96,1	101,3	
9 - plating acropora	*Acropora sp.*	83,4	62,0	78,5	88,3	**96,8**	92,5	101,2	
How many snorkelers/divers were present?		82,4	76,0	78,5	86,3	**100,0**	-	-	
44 - Red Sea clownfish	*Amphiprion bicinctus*	82,3	63,0	77,8	86,8	**100,0**	-	-	
35 - groupers	Ephinephelinae	80,2	74,0	76,0	84,4	**98,7**	96,1	101,3	
1 - tube sponge	*Siphonochalina sp.*	79,2	68,0	73,7	84,7	**98,5**	95,6	101,4	
3 - leather coral	*Sarcophyton sp.*	77,3	76,0	72,2	82,4	**98,7**	96,1	101,3	
20 - tridacnae	*Tridacna sp.*	76,5	69,0	71,6	81,5	**98,6**	95,7	101,4	X
• - broken corals		75,6	72,0	70,2	81,0	**97,2**	93,4	101,0	X
13 - lettuce coral	*Turbinaria sp.*	73,7	42,0	68,3	79,1	**97,7**	93,1	102,2	
12 - mushroom corals	Fungiidae	72,4	75,0	67,0	77,9	**98,7**	96,1	101,3	X
37 - humpback batfish	*Platax sp.*	70,1	26,0	59,6	80,6	**100,0**	-	-	X
62 - totally or partially dead corals		69,7	66,0	63,4	76,0	**97,0**	92,8	101,1	X
8 - sea carpet host anemones	Stichodactylidae	69,6	68,0	64,3	74,9	**100,0**	-	-	X
32 - giant moray	*Gymnothorax javanicus*	69,2	34,0	58,9	79,6	**97,1**	91,3	102,8	
63 - bleached corals		68,5	44,0	61,5	75,6	**97,7**	93,3	102,2	
49 - caranxes	Carangidae	67,8	68,0	60,2	75,5	**89,7**	82,4	97,0	X
57 - blue-spotted stingray	*Taeniura lymma*	67,3	44,0	58,7	75,9	**95,6**	89,5	101,6	
10 - porcupine coral	*Seriatopora hystrix*	66,9	63,0	60,5	73,3	**98,4**	95,3	101,5	
45 - humphead wrasse - Napoleon fish	*Chelinus undulatus*	66,9	25,0	56,8	77,0	**96,0**	88,2	103,8	X
54 - blowfishes	Tetradontidae	66,7	69,0	60,9	72,5	**98,6**	95,7	101,4	
Other sponges		65,3	66,0	59,3	71,2	**93,9**	88,1	99,7	X
7 - sea whips	Ellisellidae	63,6	51,0	56,4	70,8	**94,2**	87,8	100,6	X
Other cephalopods		63,3	2,0	56,8	69,9	**100,0**	-	-	
14 - pineapple corals	Faviidae	61,6	54,0	55,5	67,8	**98,2**	94,6	101,7	
50 - lionfish	*Pterois sp.*	61,6	58,0	54,5	68,7	**100,0**	-	-	
47 - barracuda	*Sphyraena sp.*	60,5	17,0	43,7	77,4	88,2	72,4	104,0	
41 - map angel	*Pomacanthus maculosus*	60,4	44,0	52,0	68,8	**93,2**	85,6	100,7	
11 - bubble coral	*Plerogyra sp.*	60,4	53,0	53,9	66,9	**94,4**	88,3	100,6	
60 - turtles	Cheloniidae	58,9	13,0	42,1	75,8	**92,3**	77,2	107,4	
52 - titan triggerfish	*Balistroides viridiscens*	55,6	27,0	46,1	65,2	**92,6**	82,5	102,7	
19 - coriacea	*Chromodoris quadricolor*	54,6	6,0	40,9	68,4	**100,0**	-	-	
40 - goatfishes	Mullidae	54,2	54,0	46,6	61,7	**94,4**	88,3	100,6	X
39 - glassfishes	Pempheridae	53,7	24,0	40,2	67,1	**87,5**	74,0	101,0	

Table A2 – Continuation

Taxon		Correct identification							
						Overall Questionnaire			
Common name	Scientific name	Mean	N	95% CI		Media	95% CI		Best taxon
How many contacts did you see ?		53,6	50,0	46,2	60,9	**98,0**	94,1	101,9	
6 - red sea fans	Melithaeidae	51,7	41,0	44,0	59,4	**92,7**	84,6	100,8	X
38 - red bass	*Lutjanus bohar*	51,3	42,0	43,8	58,8	**97,6**	93,0	102,3	
48 - Sohal surgeon fish	*Acanthurus sohal*	50,9	29,0	39,6	62,1	**93,1**	83,7	102,5	
51 - spotted flatheads	Platycephalidae	49,9	14,0	33,1	66,8	85,7	66,7	104,7	
• - sediment covered corals		49,5	53,0	42,2	56,7	**94,3**	88,1	100,6	
36 - blackspotted rubberlip	*Plectorhinchus gaterinus*	49,4	15,0	37,9	60,9	**93,3**	80,3	106,4	
Other rays and torpedos		48,3	3,0	-2,4	99,0	**100,0**	-	-	
Other corals		47,5	72,0	40,7	54,4	**86,3**	78,4	94,2	
15 - black coral	*Antipathes sp.*	46,7	43,0	38,7	54,7	**90,7**	81,9	99,5	
• - litter		46,3	44,0	37,2	55,3	**93,2**	85,6	100,7	
34 - squirrelfish	*Sargocentron sp.*	45,9	55,0	40,3	51,6	**94,5**	88,5	100,6	X
33 - needlefishes	Syngnathidae	45,4	14,0	27,7	63,1	78,6	56,3	100,9	
Other bony fishes		44,0	68,0	37,3	50,8	**83,8**	75,0	92,6	
53 - boxfishes	Ostraciidae	43,4	22,0	30,2	56,5	72,0	54,0	90,0	X
27 - sea cucumbers	Holothuroidea	40,7	16,0	26,5	54,8	**87,5**	70,8	104,2	
18 - spanish dancer	*Hexabranchus sanguineus*	33,3	1,0	-	-	**100,0**	-	-	
29 - spiny starfish	*Acanthaster planci*	33,3	1,0	-	-	**100,0**	-	-	
30 - fire urchin	*Asthenosoma sp.*	33,3	1,0	-	-	**100,0**	-	-	
21 - wing oyster	*Pteria sp.*	30,6	35,0	23,7	37,6	**77,1**	63,0	91,3	
56 - sharks	Squaliformes	30,5	2,0	12,0	49,1	**100,0**	-	-	
28 - pearl red star	*Fromia sp.*	30,2	3,0	-2,3	62,6	66,7	1,3	132,0	X
26 - sea lilies	Crinoidea	28,5	41,0	21,5	35,5	**78,0**	65,2	90,9	
16 - Christmas tree worm	*Spirobranchus sp.*	25,5	38,0	17,8	33,2	**74,4**	60,5	88,2	
55 - porcupinefishes	Diodontidae	25,0	10,0	12,1	37,9	**70,0**	40,1	99,9	X
43 - longnose hawkfish	*Oxycirrhites typus*	24,4	9,0	8,6	40,3	66,7	34,0	99,3	
Other sea slugs		23,0	15,0	11,1	34,9	60,0	34,3	85,7	X
61 - dolphins	Delphinidae	20,0	1,0	-	-	**100,0**	-	-	
Other sea urchins		17,3	49,0	11,3	23,3	**55,1**	41,0	69,2	
Other sedentary worms		13,5	11,0	1,3	25,8	40,0	8,0	72,0	X
Other bivalves		13,2	31,0	8,2	18,3	**61,3**	43,9	78,7	
Other starfishes		13,2	8,0	2,7	23,7	50,0	13,0	87,0	X
Other decapods		9,7	8,0	-2,4	21,8	37,5	1,6	73,4	
24 - banded boxer shrimp	*Stenopus hispidus*	5,6	2,0	-5,3	16,4	50,0	-48,0	148,0	X
31 - pencil urchin	*Phyllacanthus sp.*	0,0	1,0	-	-	**0,0**	-	-	
17 - cowries	Cypraedae	-	0,0	-	-	**-**	-	-	
22 - squids	Seepidae	-	0,0	-	-	**-**	-	-	
23 - bigfin reef squid	*Sepioteuthis sp.*	-	0,0	-	-	**-**	-	-	
25 - hermit crabs	Diogenidae	-	0,0	-	-	**-**	-	-	
58 - manta	*Manta sp.*	-	0,0	-	-	**-**	-	-	
59 - torpedo	*Torpedo sp.*	-	0,0	-	-	**-**	-	-	

Table A3 - Geographic coordinates, number of useful questionnaires, bathymetry of survey, moment of survey in the survey stations on rocky bottom. BE (Berenice), D (Dahab), SSH (Sharm el-Sheikh; SSH-N – Nabq, SSh-T – Tiran; SSH-L – Local, SSH-RM – Ras Mohammed, SSH-G – Gubal), HRG (Hurgada), Q (Quseir), MA (Marsa Alam), H (Hamata), RAB (Rabigh), YAB(Yambù al Bahr), SHA (Shalatin), PS (Port Sudan).

	No of useful questionnaires						Bathymetry of survey		Moment of survey				Temperature	
Survey Stations	**2007**	**2008**	**2009**	**2010**	**2011**	**Tot**	**Mean Depth (m)**	**S.E.**	**Mean date (yearly fraction)**	**S.E.**	**Mean hour (daily fraction)**	**E.S.**	**Mean Temperature (°C)**	**S.E.**
Abili Gafar (BE)	-	-	-	14	-	14	20.29	0.7	0.84	0.0	0.29	0.0	29.00	0.2
Lahami Bay House Reef (BE)	-	-	-	-	61	61	3.92	0.5	0.86	0.0	0.53	0.0	26.64	0.1
Sha'ab Aid (BE)	-	-	-	10	-	10	16.40	0.9	0.84	0.0	0.65	0.0	28.40	0.5
Sha'ab Aiman (BE)	-	-	-	15	-	15	18.17	0.9	0.84	0.0	0.50	0.0	29.47	0.2
Sha'ab Faragi (BE)	-	-	-	-	16	16	16.08	1.9	0.75	0.0	0.36	0.0	28.83	0.2
Sha'ab Mahrous (BE)	-	-	-	22	16	38	19.44	1.1	0.82	0.0	0.44	0.0	28.98	0.2
Sha'ab Maksur (BE)	-	-	-	16	-	16	18.68	0.5	0.85	0.0	0.31	0.0	28.05	0.1
Umm el Arouk (BE)	-	-	-	-	22	22	14.29	1.4	0.80	0.0	0.57	0.0	29.06	0.1
Umm el Karim (BE)	-	-	-	-	10	10	9.99	1.5	0.80	0.0	0.66	0.0	29.00	0.0
Blue Hole - El Bells (D)	57	34	26	34	15	166	17.70	0.4	0.68	0.0	0.47	0.0	26.20	0.2
Canyon (D)	51	35	16	22	-	124	17.38	0.4	0.69	0.0	0.53	0.0	26.23	0.2
Abu Galawi Soraya (H)	-	-	-	14	-	14	10.65	1.0	0.69	0.1	0.46	0.0	29.14	0.6
Sataya reef (H)	-	-	10	-	-	10	10.50	1.3	0.32	0.0	0.60	0.0	24.20	0.1
Abu Ramada Cave (HRG)	21	-	-	-	-	21	12.96	0.7	0.60	0.0	0.47	0.0	25.75	0.3
Abu Ramada Sud (HRG)	13	-	-	-	-	13	12.84	0.7	0.49	0.0	0.45	0.0	25.95	0.3
Aida (Big Brother) (HRG)	-	-	12	-	-	12	19.30	1.3	0.84	0.0	0.49	0.0	26.17	0.3
El Aruk Broken (HRG)	-	-	14	-	-	14	9.79	0.2	0.84	0.0	0.58	0.0	27.57	0.1
El Aruk Gigi (HRG)	18	-	-	-	-	18	8.21	0.5	0.46	0.0	0.58	0.0	26.24	0.3
Erg Somaya (HRG)	-	-	15	-	-	15	17.27	0.4	0.85	0.0	0.44	0.0	27.60	0.1
Fanadir (HRG)	13	-	-	-	-	13	13.21	1.3	0.47	0.0	0.43	0.0	25.82	0.2
Fanus (HRG)	16	-	-	-	-	16	12.06	0.6	0.46	0.0	0.53	0.0	25.79	0.3
Gota Abu Ramada (HRG)	31	-	25	-	-	56	9.26	0.3	0.66	0.0	0.51	0.0	26.90	0.1
Halg Disha (HRG)	18	-	-	-	-	18	13.68	1.2	0.47	0.0	0.45	0.0	25.51	0.4
House Reef Makadi Bay (HRG)	-	29	-	-	-	29	12.51	0.9	0.38	0.0	0.52	0.0	25.41	0.3
Numidia (Big Brother) (HRG)	-	-	14	-	-	14	18.79	1.4	0.84	0.0	0.39	0.0	26.79	0.2
Ras Disha (Ergs) (HRG)	16	-	-	-	-	16	9.16	1.0	0.46	0.0	0.54	0.0	26.15	0.3
Sha'ab El Erg (HRG)	-	-	-	12	-	12	8.75	1.2	0.78	0.0	0.48	0.0	28.08	0.2
Sha'ab Sabina (HRG)	-	-	15	-	-	15	9.57	0.1	0.85	0.0	0.56	0.0	27.20	0.1
Small Giftun (Giftun Soraya) (HRG)	-	-	31	-	-	31	11.66	0.4	0.84	0.0	0.58	0.0	27.26	0.1
Umm Gamar (HRG)	-	10	-	12	-	22	13.86	1.8	0.71	0.0	0.46	0.0	28.33	0.1
Yellowfish Reef (HRG)	-	-	-	17	-	17	12.97	1.2	0.79	0.0	0.67	0.0	27.94	0.5
Abu Dabbab (MA)	15	330	-	-	-	345	1.53	0.1	0.72	0.0	0.41	0.0	26.70	0.0
Abu Ghusun (relitto Hamata) (MA)	-	-	-	50	28	78	9.81	0.6	0.46	0.0	0.45	0.0	26.46	0.2
Aquarius (MA)	-	-	-	23	19	42	5.15	0.6	0.48	0.0	0.51	0.0	26.42	0.2
Baia delle Tartarughe (Patty) (MA)	-	146	-	-	-	146	1.03	0.0	0.66	0.0	0.62	0.0	27.48	0.1
Check Point (MA)	-	-	-	12	-	12	12.29	1.1	0.50	0.0	0.49	0.0	27.80	0.7
Daedalus (MA)	-	11	-	-	-	11	23.66	2.3	0.64	0.0	0.50	0.0	29.15	0.6
Dolphin House (MA)	-	-	97	141	76	314	7.06	0.4	0.53	0.0	0.49	0.0	27.02	0.1
El Qulan (MA)	-	-	-	19	21	40	1.07	0.1	0.54	0.0	0.52	0.0	26.86	0.4
Elphinstone Reef (MA)	15	10	-	39	28	92	20.99	0.6	0.64	0.0	0.42	0.0	27.26	0.2
Erg Torfa (MA)	-	-	-	34	35	69	15.03	0.4	0.44	0.0	0.48	0.0	26.38	0.2
Erg Tunduba (MA)	-	-	-	27	12	39	15.04	0.8	0.41	0.0	0.49	0.0	25.90	0.3
Gota el Sharm (MA)	-	-	-	10	29	39	17.01	1.0	0.81	0.0	0.52	0.0	28.23	0.1

Table A3 - Continuation.

	No of useful questionnaires						Bathymetry of survey		Moment of survey				Temperature	
Survey Stations	**2007**	**2008**	**2009**	**2010**	**2011**	**Tot**	**Mean Depth (m)**	**S.E.**	**Mean date (yearly fraction**	**S.E.**	**Mean hour (daily fraction)**	**S.E.**	**Mean Temperature (°C)**	**S.E.**
Habili Marsa Alam (MA)	-	-	-	21	15	36	15.61	0.5	0.48	0.0	0.56	0.0	26.38	0.3
Habili Nakary (MA)	-	-	-	-	13	13	20.57	0.8	0.26	0.0	0.42	0.0	23.92	0.5
House Reef BL (MA)	-	-	-	10	12	22	13.85	0.8	0.42	0.0	0.45	0.0	25.58	0.5
Lagoon (MA)	-	-	-	441	415	856	1.15	0.0	0.53	0.0	0.57	0.0	27.24	0.1
Marsa Abu Dabab (MA)	-	-	332	144	-	476	4.71	0.3	0.66	0.0	0.44	0.0	27.45	0.1
Marsa Asalaya (MA)	-	-	-	29	-	29	12.57	0.8	0.51	0.0	0.53	0.0	26.98	0.4
Marsa Ghadeira (MA)	-	-	-	-	19	19	14.18	0.8	0.32	0.0	0.46	0.0	25.56	0.4
Marsa Ghamal (MA)	-	-	-	45	42	87	15.61	0.5	0.40	0.0	0.48	0.0	25.58	0.2
Marsa Mikky (MA)	-	-	-	16	12	28	13.40	1.0	0.42	0.0	0.49	0.0	26.53	0.4
Marsa Naizak (MA)	-	-	-	18	-	18	15.64	0.8	0.46	0.0	0.49	0.0	25.93	0.4
Marsa Samadai (MA)	-	-	-	145	106	251	12.61	0.3	0.47	0.0	0.62	0.0	26.91	0.1
Marsa Shona (MA)	12	-	29	-	-	41	14.36	0.7	0.84	0.0	0.53	0.0	27.35	0.1
Sha'ab Claudia (MA)	-	-	-	14	-	14	9.93	0.5	0.81	0.0	0.48	0.0	27.71	0.3
Sha'ab Marsa Alam (MA)	-	15	59	119	68	261	8.92	0.5	0.57	0.0	0.48	0.0	27.18	0.1
Sha'ab Nakary (MA)	-	-	-	26	22	48	17.71	0.6	0.46	0.0	0.44	0.0	26.29	0.3
Sharm el-Luli (MA)	-	156	66	204	139	565	1.24	0.1	0.55	0.0	0.47	0.0	26.64	0.1
Torfa Mikky (MA)	-	-	-	11	-	11	12.32	0.6	0.33	0.0	0.41	0.0	24.98	0.3
Torfa Tunduba (MA)	-	-	-	83	34	117	15.45	0.4	0.43	0.0	0.51	0.0	26.32	0.2
Erg Wadi Gimal (MA)	-	-	-	11	-	11	14.91	0.4	0.84	0.0	0.64	0.0	27.82	0.2
Angarosh (PS)	-	-	-	-	92	92	16.51	0.2	0.05	0.0	0.54	0.0	26.03	0.1
Precontinente II (Sha'ab Rumi) (PS)	-	-	-	-	15	15	11.47	0.7	0.03	0.0	0.68	0.0	26.27	0.2
Sha'ab Rumi Nord (PS)	-	-	-	-	12	12	16.90	0.9	0.04	0.0	0.44	0.0	26.50	0.2
Sha'ab Rumi Sud (PS)	-	-	-	-	35	35	19.08	0.7	0.04	0.0	0.49	0.0	26.65	0.3
Big Brother (Q)	-	10	47	-	-	57	19.55	0.9	0.81	0.82	0.47	0.0	26.60	0.9
Small Brother (Q)	-	12	53	-	-	65	18.84	0.7	0.81	0.0	0.43	0.0	26.74	0.7
Maria's Reef (RAB)	-	11	-	-	-	11	24.88	3.5	0.75	0.0	0.46	0.0	29.27	0.4
Noura Reef (Mary Joy) (RAB)	-	12	-	-	-	12	16.36	1.9	0.75	0.0	0.65	0.0	29.23	0.5
Abili Ali (SHA)	-	-	-	30	-	30	18.40	0.7	0.84	0.0	0.39	0.0	28.90	0.2
Dangerous Reef (SHA)	-	-	-	21	-	21	13.94	0.5	0.84	0.0	0.72	0.0	28.90	0.3
Alternatives (SSH-G)	15	31	19	30	-	95	6.50	0.7	0.57	0.0	0.50	0.0	26.74	0.2
Bluff Point (SSH-G)	-	-	-	14	-	14	20.00	2.3	0.79	0.0	0.30	0.0	28.00	0.2
Dunraven ((SSH-G)	24	40	16	41	19	140	16.41	0.4	0.65	0.0	0.52	0.0	26.57	0.2
Kingston (SSH-G)	-	-	-	13	-	13	9.85	1.6	0.78	0.0	0.68	0.0	28.08	0.1
Ulysses (SSH-G)	-	-	-	11	-	11	11.09	2.9	0.79	0.0	0.49	0.0	28.07	0.3
Club Reef house reef (SSH-L)	104	63	-	-	-	167	1.40	0.2	0.59	0.0	0.51	0.0	25.97	0.1
Coral Bay House Reef (SSH-L)	-	-	-	-	18	18	10.30	0.6	0.52	0.0	0.60	0.0	26.89	0.4
Far Garden (SSH-L)	-	35	-	-	-	41	16.41	0.7	0.60	0.0	0.55	0.0	25.68	0.3
Middle Garden (SSH-L)	-	14	-	-	-	14	14.41	0.9	0.45	0.0	0.51	0.0	25.06	0.4
Near Garden (SSH-L)	41	47	16	20	31	155	15.76	0.3	0.58	0.0	0.53	0.0	25.77	0.2
Paradise (SSH-L)	-	39	-	-	16	55	17.11	0.7	0.70	0.0	0.54	0.0	27.65	0.2
Ras Bob (SSH-L)	18	39	12	68	99	236	7.35	0.4	0.54	0.0	0.46	0.0	26.32	0.1
Ras Ghamila (SSH-L)	88	35	-	-	14	137	15.23	0.5	0.57	0.0	0.56	0.0	26.48	0.2
Ras Katy (SSH-L)	109	110	41	72	131	463	11.10	0.3	0.60	0.0	0.50	0.0	26.51	0.1
Ras Nasrani (SSH-L)	127	115	66	243	135	686	10.20	0.3	0.65	0.0	0.47	0.0	27.00	0.1
Ras Umm Sid (SSH-L)	175	249	156	186	191	957	15.64	0.2	0.63	0.0	0.55	0.0	26.73	0.1
Sinai Grand Resort HR (SSH-L)	-	-	-	10	-	10	14.55	2.2	0.59	0.0	0.78	0.1	28.78	0.4
Sodfa (SSH-L)	-	11	-	-	45	56	9.61	1.1	0.38	0.0	0.51	0.0	25.42	0.2
Naama Bay Beach (SSH-L)	21	14	-	10	11	56	7.95	0.6	0.38	0.0	0.64	0.0	25.39	0.4
Temple (SSH-L)	55	202	136	128	146	667	13.54	0.2	0.64	0.0	0.49	0.0	26.41	0.1
Torfa El Karuf (SSH-L)	122	69	10	-	13	214	14.02	0.3	0.53	0.0	0.51	0.0	26.30	0.2
Tower (SSH-L)	-	13	-	27	29	69	17.55	0.7	0.48	0.0	0.56	0.0	26.67	0.2
White Knight (SSH-L)	-	17	-	-	-	17	17.89	1.7	0.64	0.0	0.47	0.0	27.52	0.5
House Reef - Tiran Beach (SSH-N)	-	-	-	-	26	26	7.53	0.5	0.56	0.0	0.51	0.0	27.15	0.2
Radisson Hotel House Reef (SSH-N)	10	19	-	-	-	29	2.41	0.4	0.65	0.0	0.54	0.0	26.02	0.5
Tamra Beach (SSH-N)	-	-	-	-	53	53	1.08	0.1	0.39	0.0	0.53	0.0	26.41	0.2

Table A3 - Continuation.

Survey Stations	No of useful questionnaires						Bathymetry of survey		Moment of survey				Temperature	
	2007	2008	2009	2010	2011	Tot	Mean Depth (m))	S.E.	Mean date (yearly fraction	S.E.	Mean hour (daily fraction)	S.E.	Mean Temperature (°C)	S.E.
Eel Garden (SSH-RM)	-	78	21	25	-	124	12.36	1.2	0.53	0.0	0.60	0.1	27.26	0.1
Jackfish Alley (SSH-RM)	120	222	152	227	268	989	14.50	0.6	0.57	0.0	0.46	0.0	26.93	0.1
Marsa Bareika (SSH-RM)	-	-	-	15	-	15	11.07	0.3	0.60	0.0	0.48	0.0	26.45	0.3
Marsa Ghozlani (SSH-RM)	75	69	-	-	-	144	1.59	0.2	0.64	0.0	0.57	0.0	26.96	0.1
Ras Ghozlani (SSH-RM)	119	192	116	159	213	799	12.19	0.3	0.62	0.0	0.51	0.0	26.76	0.1
Ras Za' Atar (SSH-RM)	151	133	78	114	189	665	14.22	0.3	0.56	0.0	0.49	0.0	26.45	0.1
Shark & Yolanda Reef (SSH-RM)	422	582	268	374	359	2004	16.05	0.1	0.60	0.0	0.48	0.0	26.72	0.0
Shark Observatory (SSH-RM)	48	170	147	110	141	616	10.14	0.3	0.60	0.0	0.46	0.0	27.08	0.1
Gordon Reef (SSH-T)	83	199	99	399	391	1171	8.51	0.2	0.62	0.0	0.48	0.0	27.27	0.0
Jackson Reef (SSH-T)	318	483	253	272	373	1699	3.18	0.8	0.55	0.0	0.53	0.0	26.78	0.0
Kormoran (SSH-T)	-	-	-	13	-	13	14.74	0.2	0.62	0.0	0.48	0.0	28.68	0.2
Laguna Reef (SSH-T)	13	21	36	76	106	252	6.08	0.1	0.66	0.0	0.57	0.0	26.95	0.1
Thomas Reef (SSH-T)	106	124	70	126	163	589	16.62	0.3	0.61	0.0	0.50	0.0	26.48	0.1
Woodhouse Reef (SSH-T)	218	224	232	232	154	1060	16.23	0.2	0.61	0.0	0.49	0.0	26.57	0.1
Abu Galawa (YAB)	-	13	-	-	-	13	25.08	3.6	0.74	0.0	0.59	0.0	29.69	0.3
Sha'ab Suflani (marker 44) (YAB)	-	18	-	-	-	18	33.57	2.6	0.75	0.0	0.55	0.0	29.06	0.3

Table A4 – Taxa sighting frequencies (SF%). Taxa were divided in “non commmon” (SF%≤20); “common” (20>SF%≥70); “very common” (SF%>70).

CODE	TAXON	SIGHTING FREQUENCY%	
Other cephalopods	Other cephalopods	2,6	NOT COMMON
59	torpedo	2,6	
23	bigfin reef squid	2,8	
58	manta	3,1	
18	spanish dancer	3,4	
22	squids	3,8	
25	hermit crabs	3,9	
29	spiny starfish	4,9	
61	dolphins	5,4	
17	cowries	5,5	
Other rays and torpedos	Other rays and torpedos	5,6	
Other decapods	Other decapods	5,9	
Other starfishes	Other starfishes	6,0	
28	pearl red star	7,2	
24	banded boxer shrimp	7,4	
Other sea slugs	Other sea slugs	7,5	
56	sharks	7,6	
19	coriacea	7,9	
30	fire urchin	7,9	
31	pencil urchin	8,3	
Other sedentary worms	Other sedentary worms	8,7	
Other bivalves	Other bivalves	9,5	
43	longnose hawkfish	12,3	
51	spotted flatheads	13,7	
Other sea urchins	Other sea urchins	14,4	
21	wing oyster	16,4	
26	sea lilies	17,0	
16	Christmas tree worm	18,2	
60	turtles	19,0	
33	needlefishes	19,4	
55	porcupinefishes	20,7	COMMON
47	barracuda	22,2	
27	sea cucumbers	23,8	
15	black coral	27,4	
6	red sea fans	27,5	
39	glassfishes	29,1	
53	boxfishes	29,8	

Table A4 – Continuation.

CODE	TAXON	SIGHTING FREQUENCY%	
38	red bass	31,2	COMMON
37	humpback batfish	31,9	
Other bony fishes	Other bony fishes	32,9	
32	giant moray	33,3	
36	blackspotted rubberlip	33,6	
11	bubble coral	34,9	
34	squirrelfish	34,9	
Other corals	Other corals	37,9	
7	sea whips	38,4	
45	humphead wrasse	39,3	
41	map angel	39,4	
57	blue	40,5	
Other sponges	Other sponges	41,0	
50	lionfish	42,8	
52	titan triggerfish	44,6	
40	goatfishes	46,9	
13	lettuce coral	50,7	
10	porcupine coral	51,4	
49	caranxes	51,7	
5	sea fan	52,1	
14	pineapple corals	53,3	
48	Sohal surgeon fish	57,3	
1	tube sponge	57,4	
8	sea carpet host anemones	57,9	
12	mushroom corals	58,1	
4	soft tree coral	62,9	
35	groupers	63,0	
3	leather coral	64,0	
54	blowfishes	64,3	
9	plating acropora	69,4	
44	Red Sea clownfish	72,1	VERY COMMON
20	tridacnae	73,0	
42	butterflyfishes	75,2	
46	parrotfishes	81,1	
2	fire coral	91,2	

Table A5 - Taxa sighting frequency, observed biodiversity, negative conditions and behavioral sighting frequency , marine biodiversity index in the survey stations on coral reef. In blue shows the parameters that failed to meet the expectations of the virtual Reference Station.

	Abili Gafar (BE)	Lahami Bay House Reef (BE)	Sha'ab Aid (BE)
1 - tube sponge	57.1	29.5	50.0
Other sponges	71.4	62.3	30.0
2 - fire coral	71.4	100.0	90.0
3 - leather coral	78.6	88.5	80.0
4 - soft tree coral	85.7	86.9	70.0
5 - sea fan	21.4	1.6	30.0
6 - red sea fans	7.1	0.0	10.0
7 - sea whips	28.6	3.3	30.0
8 - sea carpet host anemones	21.4	59.0	40.0
9 - plating acropora	78.6	96.7	60.0
10 - porcupine coral	35.7	65.6	40.0
11 - bubble coral	14.3	13.1	0.0
12 - mushroom corals	50.0	91.8	70.0
13 - lettuce coral	21.4	29.5	30.0
14 - pineapple corals	35.7	88.5	30.0
15 - black coral	14.3	4.9	0.0
Other corals	35.7	85.2	0.0
16 - Christmas tree worm	0.0	19.7	10.0
Other sedentary worms	0.0	32.8	0.0
17 - cowries	14.3	0.0	0.0
18 - spanish dancer	0.0	0.0	0.0
19 - coriacea	0.0	3.3	0.0
Other sea slugs	0.0	6.6	0.0
20 - tridacnae	14.3	95.1	50.0
21 - wing oyster	0.0	4.9	0.0
Other bivalves	0.0	24.6	0.0
22 - squids	0.0	0.0	0.0
23 - bigfin reef squid	0.0	4.9	0.0
Other cephalopods	0.0	1.6	0.0
24 - banded boxer shrimp	0.0	13.1	0.0
25 - hermit crabs	0.0	1.6	0.0
Other decapods	0.0	26.2	0.0
26 - sea lilies	0.0	9.8	0.0
27 - sea cucumbers	0.0	27.9	40.0
28 - pearl red star	0.0	6.6	0.0
29 - spiny starfish	0.0	9.8	0.0
Other starfishes	0.0	13.1	0.0
30 - fire urchin	0.0	3.3	0.0
31 - pencil urchin	0.0	3.3	0.0
Other sea urchins	0.0	27.9	0.0
32 - giant moray	85.7	13.1	70.0
33 - needlefishes	7.1	3.3	20.0
34 - squirrelfish	78.6	52.5	90.0
35 - groupers	78.6	82.0	50.0
36 - blackspotted rubberlip	21.4	42.6	20.0
37 - humpback batfish	0.0	27.9	0.0
38 - red bass	14.3	31.1	10.0
39 - glassfishes	0.0	11.5	10.0
40 - goatfishes	35.7	82.0	60.0
41 - map angel	0.0	13.1	20.0
42 - butterflyfishes	85.7	98.4	90.0
43 - longnose hawkfish	0.0	0.0	0.0
44 - Red Sea clownfish	35.7	55.7	70.0
45 - Napoleon fish	85.7	19.7	70.0
46 - parrotfishes	64.3	90.2	70.0
47 - barracuda	64.3	9.8	0.0
48 - Sohal surgeon fish	50.0	57.4	20.0
49 - caranxes	92.9	90.2	30.0
50 - lionfish	42.9	52.5	30.0
51 - spotted flatheads	7.1	0.0	0.0
52 - titan triggerfish	64.3	62.3	30.0
53 - boxfishes	0.0	37.7	0.0
54 - blowfishes	7.1	77.0	40.0
55 - porcupinefishes	0.0	18.0	0.0
Other bony fishes	42.9	83.6	20.0
56 - sharks	14.3	8.2	0.0
57 - blue-spotted stingray	0.0	59.0	80.0
58 - manta	0.0	0.0	0.0
59 - torpedo	0.0	0.0	0.0
Other rays and torpedos	0.0	11.5	0.0
60 - turtles	0.0	16.4	0.0
61 - dolphins	42.9	0.0	0.0
SA	40.0	63.0	37.0
HSHA	5.0	5.3	4.9
ESHA	93.1	87.9	93.9
%DCS	21.4	91.8	60.0
%BlCS	14.3	83.6	60.0
%BrCS	57.1	91.8	70.0
%CCS	21.4	62.3	50.0
%LF	14.3	55.7	50.0
%DiS	85.7	96.7	70.0
%ImS	64.3	9.8	40.0
V.MBQI	-0.580	-0.617	-0.744

FIGURES

Figure A1 - Survey questionnaires. Cover.

Figure A2 - Survey questionnaires. Section with environmental education suggestions.

Figure A3 - Survey questionnaires. Section with photographs to identify the surveyed taxa..

Please, send this questionnaire to: STE project, Marine Science Group - Department of Evolutionary and Experimental Biology, University of Bologna, Via F. Selmi 3, I-40126 Bologna Italy
www.STEproject.org

Surname	Name
Complete address	
E-mail	Dive Certification (level and training organization)
Dive site	Nearest town
Diving Center	
Dive date	Maximum depth (m)
Depth where yuo spent most of your dive (m)	Water temperature (°C)
Actual bottom time (minutes)	Dive starting time (0-24)

Environment where yuo spent most of your dive (choose one) ❒ coral reef ❒ sandy bottom ❒ other__________

Please select the organisms you have seen in the checklist below estimating the frequency of their occurrence. Your instructor can help you!

	RARE	FREQUENT	VERY FREQUENT
SPONGES			
1 - tube sponge (*Siphonochalina* sp., Demospongiae)	❒ 1-2	❒ 3-10	❒ more than 10
Other sponges	❒ 1-2	❒ 3-10	❒ more than 10
COELENTERATES, CORALS			
2 - fire coral (*Millepora* sp., Milleporina, Hydrozoa)	❒ 1-10	❒ 11-100	❒ more than 100
3 - leather coral (*Sarcophyton* sp., Alcyonacea, Anthozoa)	❒ 1-5	❒ 6-15	❒ more than 15
4 - soft tree coral (*Dendronephthya* sp., Alcyonacea, Anthozoa)	❒ 1-10	❒ 11-100	❒ more than 100
5 - sea fan (*Subergorgia hicksoni*, Gorgonacea, Anthozoa)	❒ 1-3	❒ 4-10	❒ more than 10
6 - red sea fans (Melithaeidae, Gorgonacea, Anthozoa)	❒ 1-5	❒ 6-15	❒ more than 15
7 - sea whips (Ellisellidae, Gorgonacea, Anthozoa)	❒ 1-2	❒ 3-6	❒ more than 6
8 - sea carpet host anemones (Stichodactylidae, Actiniaria, Anthozoa)	❒ 1-3	❒ 4-10	❒ more than 10
9 - plating acropora (*Acropora* sp., Scleractinia, Anthozoa)	❒ 1-2	❒ 3-6	❒ more than 6
10 - porcupine coral (*Seriatopora hystrix*, Scleractinia, Anthozoa)	❒ 1-5	❒ 6-15	❒ more than 15
11 - bubble coral (*Plerogyra* sp., Scleractinia, Anthozoa)	❒ 1-5	❒ 6-15	❒ more than 15
12 - mushroom corals (Fungiidae, Scleractinia, Anthozoa)	❒ 1-5	❒ 6-15	❒ more than 15
13 - lettuce coral (*Turbinaria* sp., Scleractinia, Anthozoa)	❒ 1-5	❒ 6-15	❒ more than 15
14 - pineapple corals (Faviidae, Scleractinia, Anthozoa)	❒ 1-2	❒ 3-6	❒ more than 6
15 - black coral (*Antipathes* sp., Antipatharia, Anthozoa)	❒ 1-2	❒ 3-6	❒ more than 6
Other corals	❒ 1-5	❒ 6-25	❒ more than 25
ANELLIDA, SEDENTARY WORMS			
16 - Christmas tree worm (*Spirobranchus* sp., Polychaeta)	❒ 1-5	❒ 6-15	❒ more than 15
Other sedentary worms	❒ 1-5	❒ 6-15	❒ more than 15
MOLLUSCS, GASTROPODS (SEA SLUGS)			
17 - cowries (Cypraeidae, Prosobranchia)	❒ 1	❒ 2-3	❒ more than 3
18 - spanish dancer (*Hexabranchus sanguineus*, Opisthobranchia)	❒ 1	❒ 2-3	❒ more than 3
19 - coriacea (*Chromodoris quadricolor*, Opisthobranchia)	❒ 1-2	❒ 3-4	❒ more than 4
Other sea slugs	❒ 1	❒ 2-3	❒ more than 3
MOLLUSCS, BIVALVES			
20 - tridacnae (*Tridacna* sp.)	❒ 1-2	❒ 3-6	❒ more than 6
21 - wing oyster (*Pteria* sp.)	❒ 1-5	❒ 6-15	❒ more than 15
Other bivalves	❒ 1-4	❒ 5-10	❒ more than 10
MOLLUSCS, CEPHALOPODS			
22 - squids (Sepiidae)	❒ 1-2	❒ 3-4	❒ more than 4
23 - bigfin reef squid (*Sepioteuthis* sp.)	❒ 1	❒ 2-3	❒ more than 3
Other cephalopods	❒ 1-2	❒ 3-4	❒ more than 4
ARTHROPODS, CRUSTACEANS, DECAPODS			
24 - banded boxer shrimp (*Stenopus hispidus*)	❒ 1	❒ 2-3	❒ more than 3
25 - hermit crabs (Diogenidae)	❒ 1	❒ 2-3	❒ more than 3
Other decapods	❒ 1	❒ 2-3	❒ more than 3

	RARE	FREQUENT	VERY FREQUENT
ECHINODERMS, CRINOIDS (SEA LILIES)			
26 - sea lilies (Crinoidea)	❒ 1-5	❒ 6-15	❒ more than 15
ECHINODERMS, HOLOTHURIANS (SEA CUCUMBERS)			
27 - sea cucumbers (Holothuroidea)	❒ 1-2	❒ 3-10	❒ more than 10
ECHINODERMS, ASTEROIDS (STARFISHES)			
28 - pearl red star (*Fromia* sp.)	❒ 1	❒ 2-3	❒ more than 3
29 - spiny starfish (*Acanthaster planci*)	❒ 1-2	❒ 3-6	❒ more than 6
Other starfishes	❒ 1-2	❒ 3-5	❒ more than 5
ECHINODERMS, ECHINOIDS (SEA URCHINS)			
30 - fire urchin (*Asthenosoma* sp.)	❒ 1-2	❒ 3-4	❒ more than 4
31 - pencil urchin (*Phyllacanthus* sp.)	❒ 1-3	❒ 4-10	❒ more than 10
Other sea urchins	❒ 1-3	❒ 4-7	❒ more than 7
VERTEBRATES, BONY FISHES			
32 - giant moray (*Gymnothorax javanicus*, Anguilliformes)	❒ 1	❒ 2-3	❒ more than 3
33 - needlefishes (Syngnathidae, Syngnathiformes)	❒ 1-2	❒ 3-4	❒ more than 4
34 - squirrelfish (*Sargocentron* sp., Beryciformes)	❒ 1-5	❒ 6-15	❒ more than 15
35 - groupers (Epinephelinae, Perciformes)	❒ 1-5	❒ 6-15	❒ more than 15
36 - blackspotted rubberlip (*Plectorhinchus gaterinus*, Perciformes)	❒ 1-3	❒ 4-10	❒ more than 10
37 - humpback batfish (*Platax* sp., Perciformes)	❒ 1-10	❒ 11-100	❒ more than 100
38 - red bass (*Lutjanus bohar*, Perciformes)	❒ 1-10	❒ 11-100	❒ more than 100
39 - glassfishes (Pempheridae, Perciformes)	❒ 1-100	❒ 101-1000	❒ more than 1000
40 - goatfishes (Mullidae, Perciformes)	❒ 1-10	❒ 11-100	❒ more than 100
41 - map angel (*Pomacanthus maculosus*, Perciformes)	❒ 1	❒ 2-3	❒ more than 3
42 - butterflyfishes (Chaetodontidae, Perciformes)	❒ 1-5	❒ 6-15	❒ more than 15
43 - longnose hawkfish (*Oxycirrhites typus*, Perciformes)	❒ 1	❒ 2-3	❒ more than 3
44 - Red Sea clownfish (*Amphiprion bicinctus*, Perciformes)	❒ 1-3	❒ 4-15	❒ more than 15
45 - humphead wrasse - Napoleon fish (*Cheilinus undulatus*, Perciformes)	❒ 1	❒ 2-3	❒ more than 3
46 - parrotfishes (Scaridae, Perciformes)	❒ 1-5	❒ 6-25	❒ more than 25
47 - barracuda (*Sphyraena* sp., Perciformes)	❒ 1-5	❒ 6-25	❒ more than 25
48 - Sohal surgeonfish (*Acanthurus sohal*, Perciformes)	❒ 1-5	❒ 6-15	❒ more than 15
49 - caranxes (Carangidae, Perciformes)	❒ 1-5	❒ 6-15	❒ more than 15
50 - lionfish (*Pterois* sp., Scorpaeniformes)	❒ 1-5	❒ 6-15	❒ more than 15
51 - spotted flatheads (Platycephalidae, Scorpaeniformes)	❒ 1-2	❒ 3-4	❒ more than 4
52 - titan triggerfish (*Balistoides viridescens*, Tetraodontiformes)	❒ 1-2	❒ 3-4	❒ more than 4
53 - boxfishes (Ostraciidae, Tetraodontiformes)	❒ 1-2	❒ 3-4	❒ more than 4
54 - blowfishes (Tetraodontidae, Tetraodontiformes)	❒ 1-3	❒ 4-10	❒ more than 10
55 - porcupinefishes (Diodontidae, Tetraodontiformes)	❒ 1	❒ 2-3	❒ more than 3
Other bony fishes	❒ 1-10	❒ 11-65	❒ more than 65
VERTEBRATES, CARTILAGE FISHES, SHARKS			
56 - sharks (Squaliformes)	❒ 1	❒ 2-3	❒ more than 3
VERTEBRATES, CARTILAGE FISHES, RAYS AND TORPEDOS			
57 - blue-spotted stingray (*Taeniura lymma*)	❒ 1-2	❒ 3-6	❒ more than 6
58 - manta (*Manta* sp.)	❒ 1	❒ 2-3	❒ more than 3
59 - torpedo (*Torpedo* sp.)	❒ 1	❒ 2	❒ more than 2
Other rays and torpedos	❒ 1	❒ 2-4	❒ more than 4
VERTEBRATES, REPTILES, TURTLES			
60 - turtles (Cheloniidae)	❒ 1	❒ 2-3	❒ more than 3
VERTEBRATES, MAMMALS, CETACEANS			
61 - dolphins (Delphinidae)	❒ 1-2	❒ 3-6	❒ more than 6

Attention: please indicate the possible presence of the following negative conditions

62 - PARTIALLY OR TOTALLY DEAD CORALS	❒ 1-10	❒ 11-100	❒ more than 100
63 - BLEACHED CORALS	❒ 1-10	❒ 11-100	❒ more than 100
• - BROKEN CORALS	❒ 1-10	❒ 11-100	❒ more than 100
• - SEDIMENT COVERED CORALS	❒ 1-10	❒ 11-100	❒ more than 100
• - LITTER	❒ 1	❒ 2-10	❒ more than 10

Attention: please give information about snorkelers and scuba divers behaviour

How many snorkelers and scuba divers were present on the dive site?	❒ 1-25	❒ 26-50	❒ more than 50
How many snorkelers and scuba divers contacts with the reef did you see during your dive? (both voluntary or involuntary contacts)	❒ 1-5	❒ 6-10	❒ more than 10

gure A4 - Survey questionnaires. Section with a form to record data.

Figure A5 - Survey questionnaires. Supporting partners.

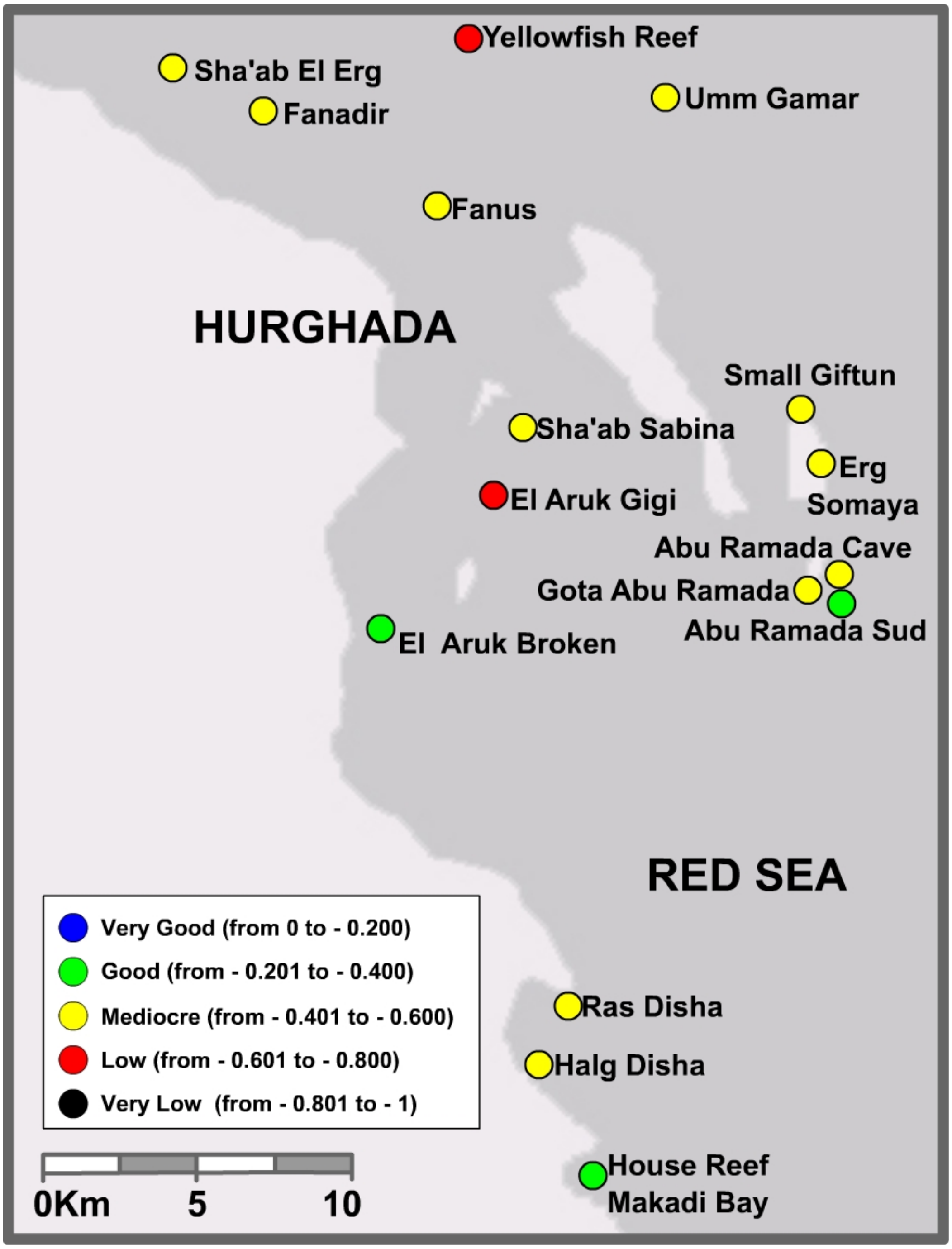

Figure A6 - Marine Biodiversity Index in survey stations on coral reefs in the Hurghada area over the period 2007-2011.

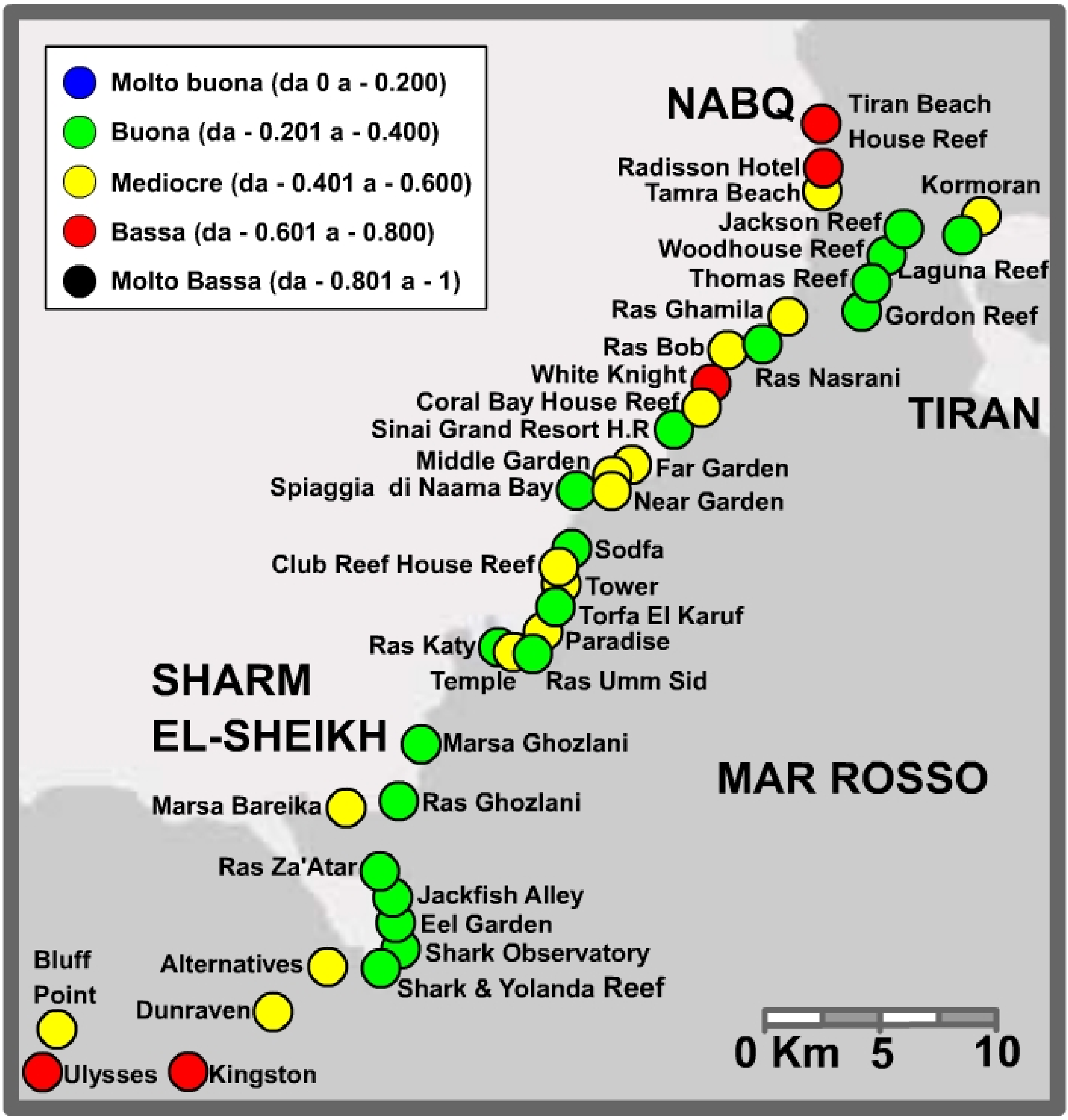

Figure A7 - Marine Biodiversity Index in survey stations on coral reefs in the Sharm el Sheikh area over the period 2007-2011.

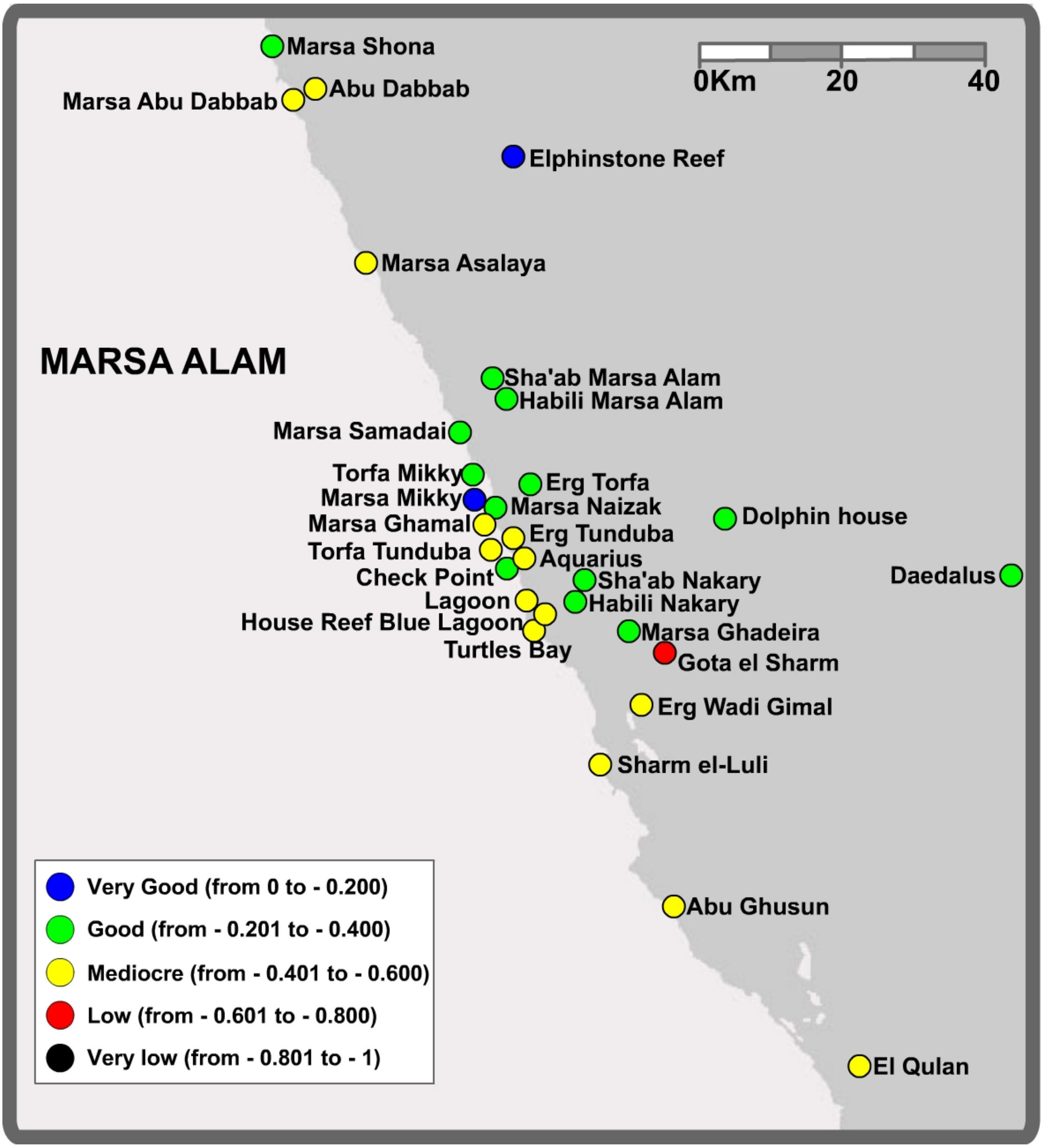

Figure A8- Marine Biodiversity Index in survey stations on coral reefs in the Marsa Alam area over the period 2007-2011.