

# **Coral Reefs and Tourism in Egypt's Red Sea**

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## **1. Introduction**

The Sinai Peninsula is one of the most important tourists' magnets for the sacred Shrines (St Katherine Monastery) and ecologically-valued landmarks (the coral of Aqaba). The most interesting flora and fauna are not terrestrial, but aquatic.

The Red Sea has unique marine habitats as coral reefs, mangroves and sea grass beds. They provide key resources for coastal populations: food, shoreline protection and stabilization, and economic benefits from tourism (Barrania Ahmed, 2010). The location is in a developing country that is highly dependent on tourism as a source of foreign income (Ibrahim and Ibrahim 2003). Also, Red Sea tourism is largely dependent on the surrounding environment such as sand and water quality, and especially coral reefs, which are sensitive to tourist activity, with low government control in the area and growth in private investments.

Much has occurred in the past twenty years in development of the tourism industry in Egypt. Various new destinations in Egypt have been promoted for tourism including the Mediterranean coast, the Red Sea coast, the Gulf of Aqaba, Upper Egypt, and the Western Desert area (Daher 2007). This diversification of tourism in the country has been undertaken

in hope that it will result in an increase in much-needed tourism revenue, economic growth and employment opportunities.

Unfortunately, the relationship between tourism and the environment is unbalanced: tourism is environmentally dependent and the environment is vulnerable to the impact of tourism (Wong 1993). Our study aims at understanding how to balance this relationship. Yet it's not easy to achieve sustainable development in developing countries that rely heavily on tourism income, particularly in ecologically sensitive areas. In this sense, ecotourism along the coral reefs of the Egyptian Red Sea represents a challenge to sustainability. Not only are coral reefs sensitive to environmental changes and anthropogenic pressure, they are also a tourist attraction and Egypt is a developing country that relies on tourism income.

## **2. Biodiversity in the Egypt's Red Sea**

### **2.1. What are coral reefs?**

The National Oceanic and Atmospheric Administration defines coral reefs as “unique (e.g., the largest structures on Earth of biological origin) and complex systems”<sup>1</sup>. Coral reefs are indeed a major marine ecosystem because their species diversity greatly exceeds that of any other marine environment. They are generally known as the rainforest of the oceans. It is assumed that, while their total area is less than 0.2% of the sea surface (Smith 1978), coral reefs host almost 30% of all the marine biodiversity (i.e. 93,000 described coral reef plants or animals on a total of 274,000 described marine species, Porter and Tougas 2001).

Living animals, mainly coral colonies, produce coral reefs. These “reef-building corals” (= hard corals) secrete a hard skeleton made of aragonite, a form of calcium carbonate (limestone). This external skeleton then creates a 3D framework that forms a complex habitat, increasing species abundance and total productivity. Such limestone structures may reach 1.3 km thick and up to 2,000 km long. Following their shape, they are classified as fringing reefs (parallel to the coastline at a distance < 1 km from shore), barrier reefs (parallel to the coastline at a distance > 5 km from shore) or atoll reefs (Porter and Tougas 2001).

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<sup>1</sup> [http://coris.noaa.gov/about/what\\_are/](http://coris.noaa.gov/about/what_are/)

Coral reefs thrive in the inter-tropical zone and require warm (usually in the range of 22 to 26°C) salt water (salinity: 32 – 38), high ambient light levels, high water clarity and extremely low nutrient concentration (Porter and Tougas 2001). The success of coral reefs flourishing in poor nutrient waters, true oasis in an unproductive environment, is due to the presence within coral cells of unicellular algae, called zooxanthellae. Through a process called symbiosis, these algae used solar energy and CO<sub>2</sub> to photosynthesized sugars that are transferred to their host, providing up to 90% of their food (see for a general review on coral biology Dubinsky and Stambler 2011).

## **2.2. Egyptian reefs**

Egypt coastline possesses a significant proportion and considerable range of the coral reefs found in the Red Sea with about 3800 Km<sup>2</sup> of reef area (Spalding et al. 2001) and 1,800 km long (Persga 2010). Among the about 300 hard coral species found in the Red Sea, 2/3 are found in the Egyptian reefs, including some endemic species (Kotb et al. 2008). These numbers are higher than those recorded for the Caribbean and equal to Indian Ocean. Egyptian reefs are fringing reefs alongside the coastline. The reefs extent in the North to the Gulfs of Suez and Aqaba to Ras Hedarba in the South at the border of Sudan. They are however not continuous because of periodic flooding from wadies created gaps within reef system. The northern part of the Red Sea has the highest coral diversity and number of islands while the south has the highest terrestrial biodiversity for the whole country (Shaalán 2005).

PERSGA (Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden), an intergovernmental organization dedicated to the conservation of the coastal and marine environments in the region, perform a permanent survey of reefs (Kotb et al. 2008, Persga 2010). Live coral cover of Egyptian reefs averages 48%. Major fishes are the butterflyfish (Chaetodontidae) with 7.2/500 m<sup>3</sup>, parrotfish (2.2/500 m<sup>3</sup>), snapper and grouper (0.8/500 m<sup>3</sup>) (see [Table 1](#)). Some population of the marine mammals dugong (*Dugong dugon*) are present in different area (Tiran Islands, Nabq and Abu Galum Marine Park in the North, El Quseir in the South) as well as marine turtles (hawksbill, green turtle, leatherback and logger-head) or sharks.

**Table 1:** Key-species abundance during reef checks of 2002 and 2008 made by PERSGA (Persga 2010).

| Abundance (fish number/100 m <sup>2</sup> reef) | 2002        | 2008        |
|---|-------------|-------------|
| Butterflyfish                                   | 6.8 ± 0.36  | 6.10 ± 0.07 |
| <i>Diadema</i> (sea urchin)                     | < 5         | < 1         |
| Giant clam                                      | 2.2 ± 2     | 3 ± 1.4     |
| Grouper   | 0.77 ± 1.0  | 0.74 ± 0.03 |
| Lobster   | 0.02 ± 0.08 | -           |
| Parrotfish                                      | 2.0 ± 1.6   | 2.0 ± 0.4   |
| Sea cucumber                                    | < 1         | Nearly 0    |
| Snapper   | 5 ± 5       | 11 ± 10     |
| Sweetlips                                       | 0.4 ± 0.1   | 0.8 ± 0.05  |
| Triton  | < 1         | -           |

### **2.3. Role of coral reefs in tourism**

As in other countries, the environment is the main base for the natural and cultural resources for attracting tourists worldwide (Eraqi 2007). Coral reefs are therefore an important component of nature-based tourism and sustainable tourism is a crucial component of tourism strategy in Egypt. Almost 75% of tourism activity in Egypt was leisure orientated and mostly concentrated on the Sinai and Red Sea (Smits et al. 1998). Red Sea is considered to be one of the best scuba diving locations (Ibrahim and Ibrahim 2003). The web site "Scubatravel"<sup>2</sup> classifies 13 Egyptian diving sites among the 100 best dive sites of the World.

The coral reefs and their biodiversity in the Gulf of Aqaba (Nuweiba, Taba), South Sinai (Sharm el-Sheik within the Ras Mohammed National Park), the North (Hurghada, Safaga and Quseir) and South (Marsa Alam) Red Sea coast have made these two areas a world-privileged destination for diving tourists (Shaalán 2003). Water temperatures lie from 20°C in winter to 27-32°C in summer.

In a survey made in 2004 to determine the top motivations for foreigners to travel to South Sinai, the Support for Environmental Assessment and Management of Egypt, snorkelling and water sports came at the third place (with 33%) after Climate (82%) and

<sup>2</sup> <http://www.scubatravel.co.uk>

Beaches (44%) and before good value for money (27%) and travel time (23%). Surprisingly diving came sixth and cultural and religious tourism (Ste Katherine Monastery) and desert safaris all came down to the list (Jobbins 2006). Interestingly however, tourists ranked coral reefs at the first place (73%) when asked about the most enjoyed aspects of their holidays, before climate (58%), beauty of landscape (35%), beaches (31%) and accommodation, services and food (26%) (Jobbins 2006).

#### ***2.4. Local threats to the Egyptian coral reefs***

Uncontrolled tourism constitutes a major threat for coral reefs in two ways: directly, damage caused by tourist use of the reefs and indirectly, by anthropogenic impacts. If some reefs are highly impacted, some remain relatively remote and inaccessible and therefore unimpacted by human activities, but the demand of “virgin” spots for tourism accelerates the urban and coastal development.

Among the direct impacts, there are trampling, coral breaking by divers or snorkelers, damages from recreational boat anchoring and boat grounding. Riegl and Velimerov (1991) found that coral breakage was the most common damage, especially on highly frequented reefs. Also, all observed damage was most frequent within the first ten meters depth, suggesting that major threats on coral reefs are produced by inexperienced divers and snorkelers rather than by experienced divers who practise a more eco-friendly tourism (Jobbins 2006).

**The number of hotels** in the Gulf of Aqaba has increased from 5 in 1989 to 141 in 2006 while the number of hotel rooms increased from 565 to more than 48,000. Similarly around Hurghada the number of hotel rooms increased from a few hundreds in 1989 to 35,000 in 2004 (Kotb et al. 2008).

**The number of tourism boats** has increased sharply over the last 20 years leading to increased damage from anchoring and boat groundings. In Sharm El Sheik dive boat numbers rose from 23 in 1989 to 350 in 2006 and in Hurghada the number of boats increased was from less than 50 to more than 1200 boats.

Beaches are prime attractants for resort developers, but as there are few natural beaches, some coastal resorts have created artificial beaches on rocky shores. This concerns not only reef habitats, but also the sand transported down current causing **sedimentation and increasing water turbidity**.

Among indirect impact there are sewage run-off, sedimentation following urban construction, dredging, coastal alteration, over-fishing (including sharks as well as invertebrates like sea cucumbers) and destructive fishing (blast fishing), pollution, discharge of chemicals (chlorine, copper...) from desalination plants... For example, coastal modification around Hurghada for touristic land reclamation has been the prime cause of reef degradation through the discharge of increasing quantities of fine sediment (El-Gamily et al. 2001). Holden (2000) estimated that 73% of the coral along the Egyptian coast has been damaged as a result of construction.

The last report "Reefs at Risks revisited" (Burke et al. 2011) classified overfishing as the major local threat affecting 55% of reefs, through an increase in commercial fishing and heavy trawling (particularly in the Gulf of Aqaba, Kotb et al. 2008). For example, sharks represent the main attraction for divers, they are caught for their fins. A study on Zaki Reef, a shallow fringing reef at 55 km south of the Suez Canal showed that between 2004 and 2007, dead coral cover increased by 50%, sea urchin counts increased by 58% and fish abundance decreased (Moustafa et al. 2008).

### **3. Evaluation of Economic and Environmental Impacts of Coastal Tourism on the Red Sea.**

Although tourism development in Hurghada started in the late 1980s, an integrated coastal management system has been investigated only a decade later (Jameson et al. 2007). As a result, there has been substantial stress and damage of the natural resources in the region. Coral reefs, in particular, are an attractive tourism asset: they are the second most biologically diverse ecosystem after tropical rainforests, and can offer an enjoyable experience to tourists. Although the tourism movement in the Red Sea of Egypt has financially benefited to the economy, this has unfortunately been accompanied by degeneration in the coral reefs of the Red Sea. A study by Jameson et al. (2007) that

compares four coral sites exposed to extensive tourism with a site that is fairly unexposed (all located near Hurghada) finds that all four of the tourism-exposed sites suffered from physical damage reflected in consistently having a lower frequency of hard coral (especially *Acropora* coral), higher percent of soft coral, and a higher percentage of algae. This coral reef damage was primarily a result of anchor and diver damage and dynamite fishing (Jameson et al. 2007; El Gamily et al. 2001)

The 50 genera of corals in the Red Sea are threatened by mismanagement of human activity in the area. Loss of biodiversity has resulted in numerous impacts including social, economic, cultural, managerial and scientific consequences (Crosby et al. 2000). In terms of environmental impacts, coral deterioration disturbs the coastal ecosystem, resulting in coral death, loss of the complex habitat structure and decrease of associated invertebrates as well as fish reduction, an increase in algal growth, planktivores, herbivores and detritivores (Khalaf and Kochzius 2002). Environmental impacts of tourism in Hurghada are not limited to coral reefs. Urban expansion and landfilling are the leading cause of shoreline environmental degradation (El Gamily et al. 2001).

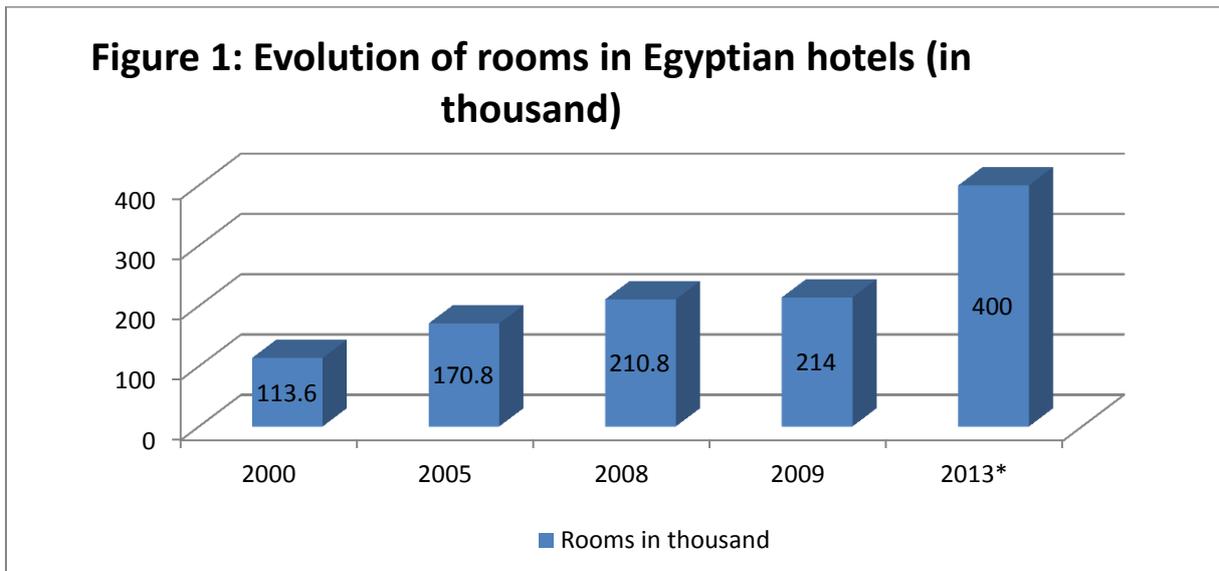
As a result of the open door policy, the past twenty years have been a period of considerable tourism growth in Egypt. Specifically, the Mediterranean coast, the Red Sea coast, the Gulf of Aqaba, Upper Egypt, and the Western Desert area have been targeted for tourism development (Daher 2007). This diversification of tourism areas in the country has occurred with the objective of increasing much-needed tourism revenue, in addition to contributing to economic growth and employment opportunities (Shaalan 2005).

### **3.1. The economic importance of tourism in Egypt.**

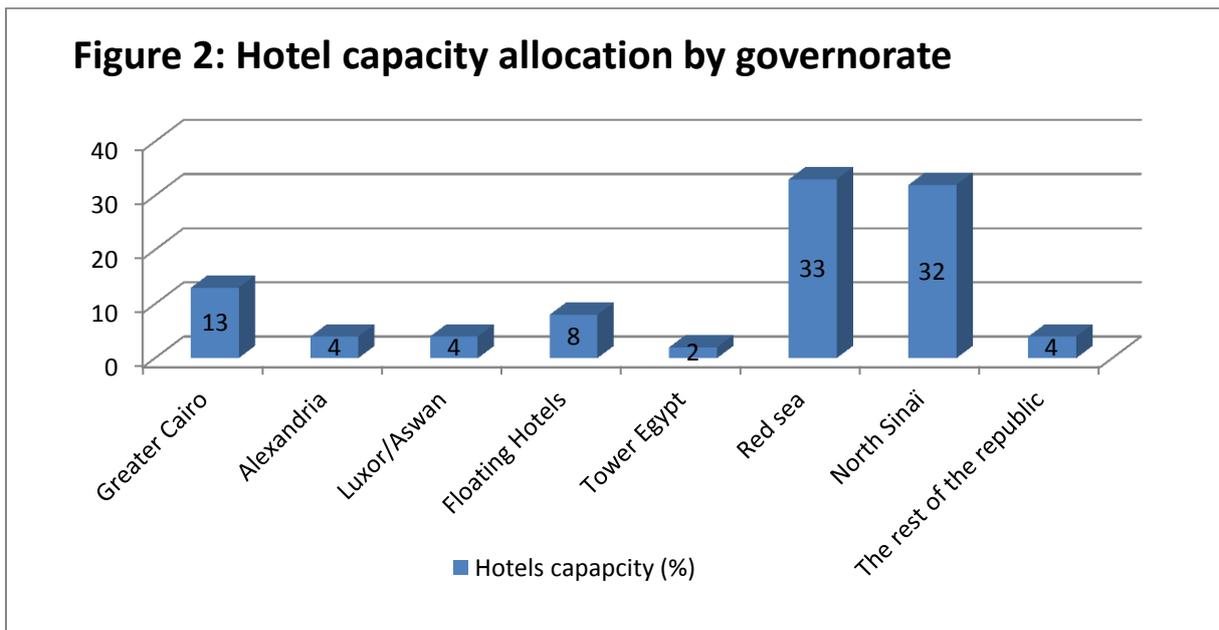
Tourism in Egypt is considered as one of the main sources of the national income as well as one of the major pillars of comprehensive development. It is associated with about 70 feeder and complementary services and industries. It is one important factor of economic growth as it represents about 40% of the Egyptian non-commodity exports in 2007/2008. The tourism sector represents the main source of foreign currency. Also, it is one of the main labour-intensive activities as the total employment provided by this sector is estimated at about 4.5 millions jobs which is equivalent to about 13% of the total labour force. Moreover,

the contribution of the tourism sector in GDP in 2008/2009 reached about 3.6%. (EGYPT yearbook 2009)

The past years witnessed an expansion of hotels and tourist villages which amounted up to 1486 hotels in 2009 with an accommodation capacity that reached about 213 thousand rooms. Also, the number of hotels under construction reached about 624 hotels with an accommodation capacity that exceeded 190 thousand rooms (see figure 1)



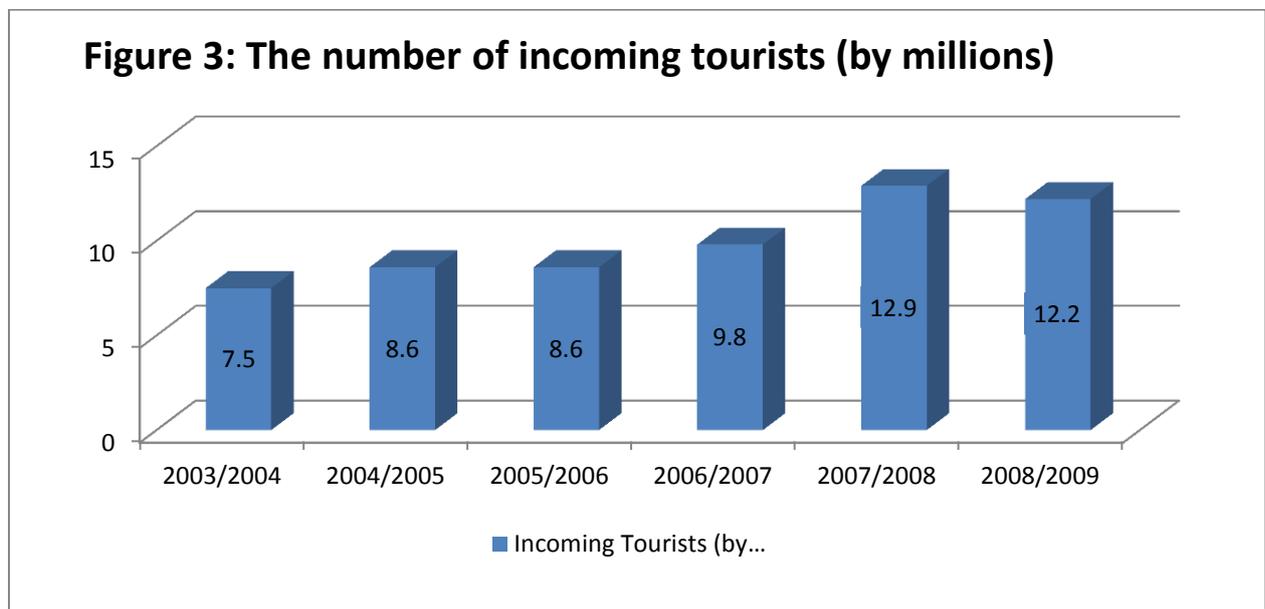
Source: The ministry of Tourism, 2008/2009



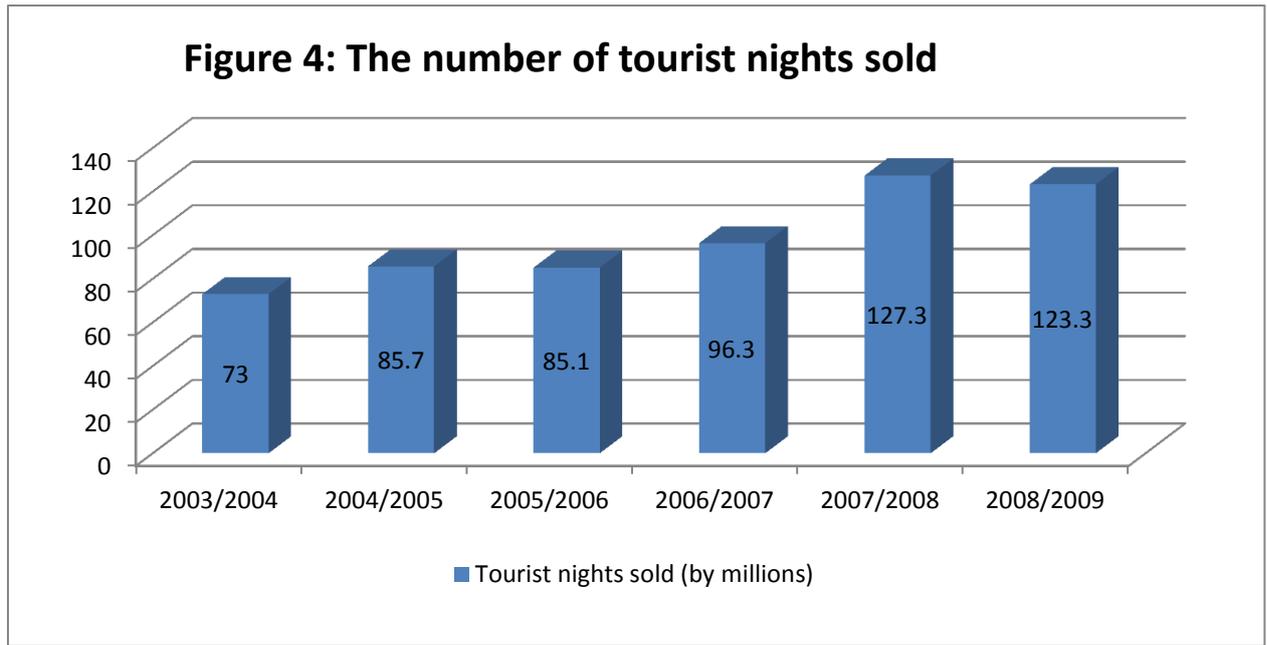
Source: ministry of tourism 2009

The Red Sea governorate represents about 33% of the total capacity, followed by south governorate (North Sinai) at about 32%, the Greater Cairo governorates at about 13%, the governorates of Luxor and Aswan at about 4%, and the Floating hotels at about 8% of the total hotel capacity (See Figure 2).

The number of incoming tourists to Egypt during the year 2008/2009 reached about 12,3 million tourists (compared to 7,5 million tourists during the year 2003/2004) spending about 123,4 million tourist nights, slight decrease due to the global crisis (See Figures 3 and 4).

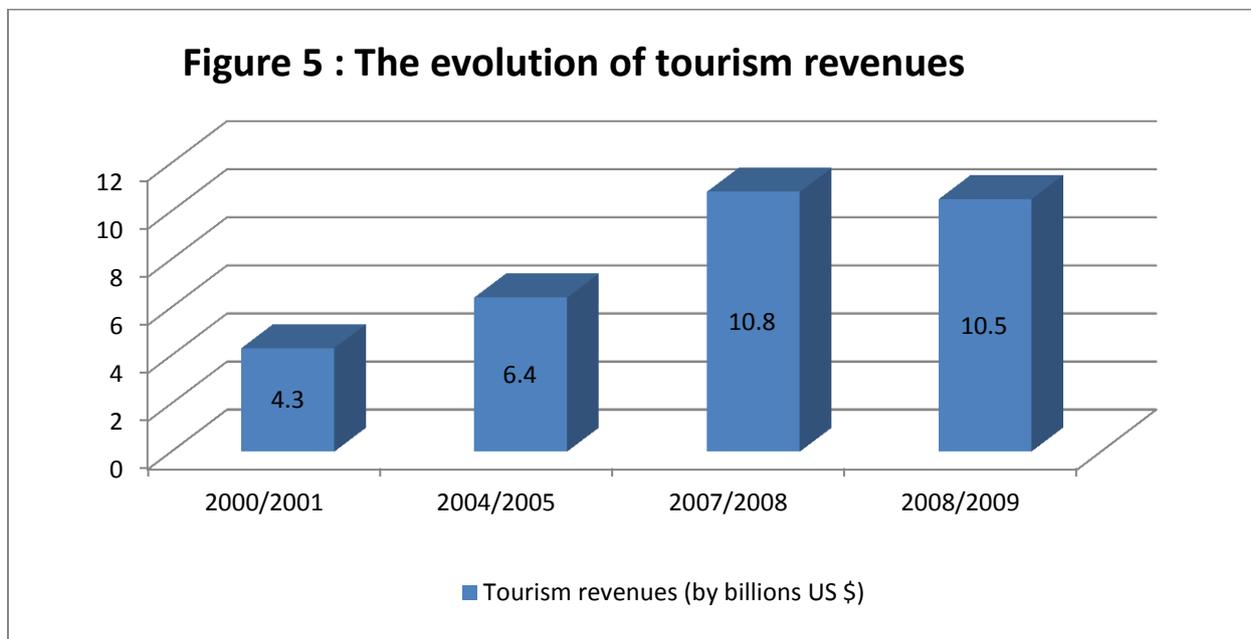


Source: ministry of tourism 2009



Source: ministry of tourism 2009

The tourism revenues increased up to about 69% during the period from 2004/2005 to 2007/2008 since the revenues rose from 6.4 billion US dollar up to 10.8 billion US dollar. These revenues were affected by the financial crisis as they decreased to 10.5 billion in 2008/2009 (See Figure 5).



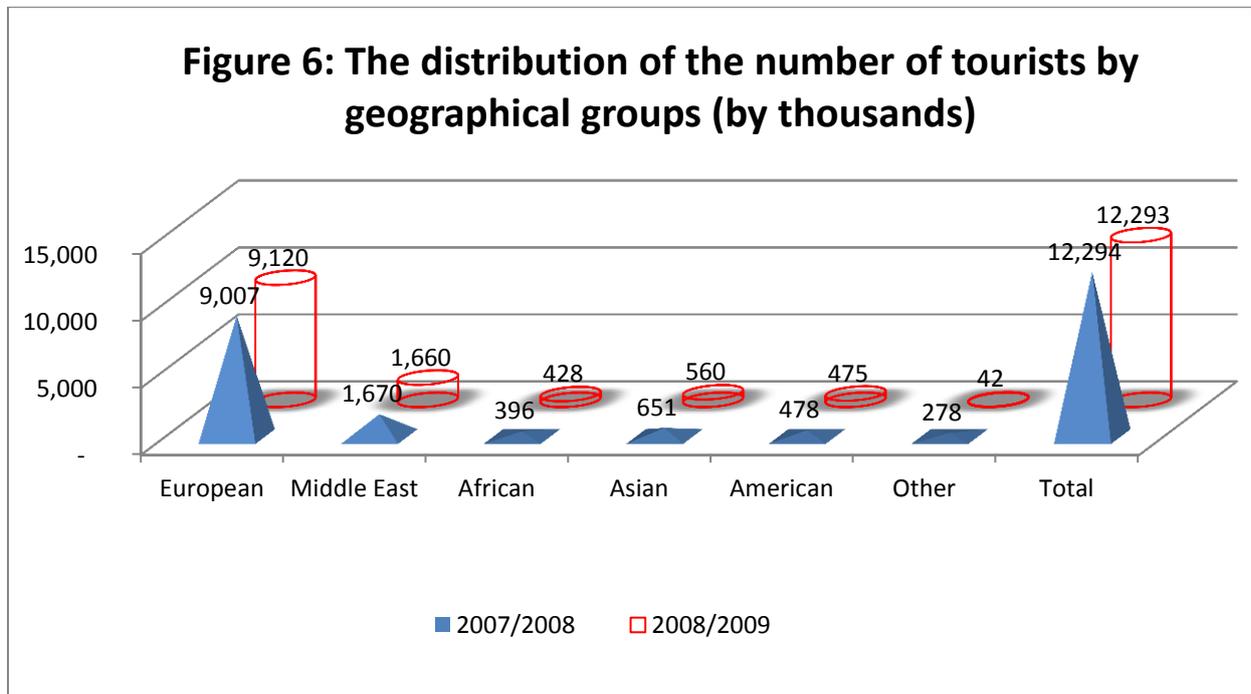
Source: ministry of tourism 2009

In 1999, 90% of Egypt's tourism investment was concentrated in coastal resorts or southern Sinai, with a large concentration on dive tourism and beach holidays around the

Red Sea Gulf of Aqaba (Shackley 1999). As a result, tourism revenue in Egypt increased by 53% from 1988 to 1992 (Alavi and Yasin 2000). This is one of the world's fastest-growing resort areas, resulting in environmental concern for the coral reefs and the desert hinterland (Shackley 1999).

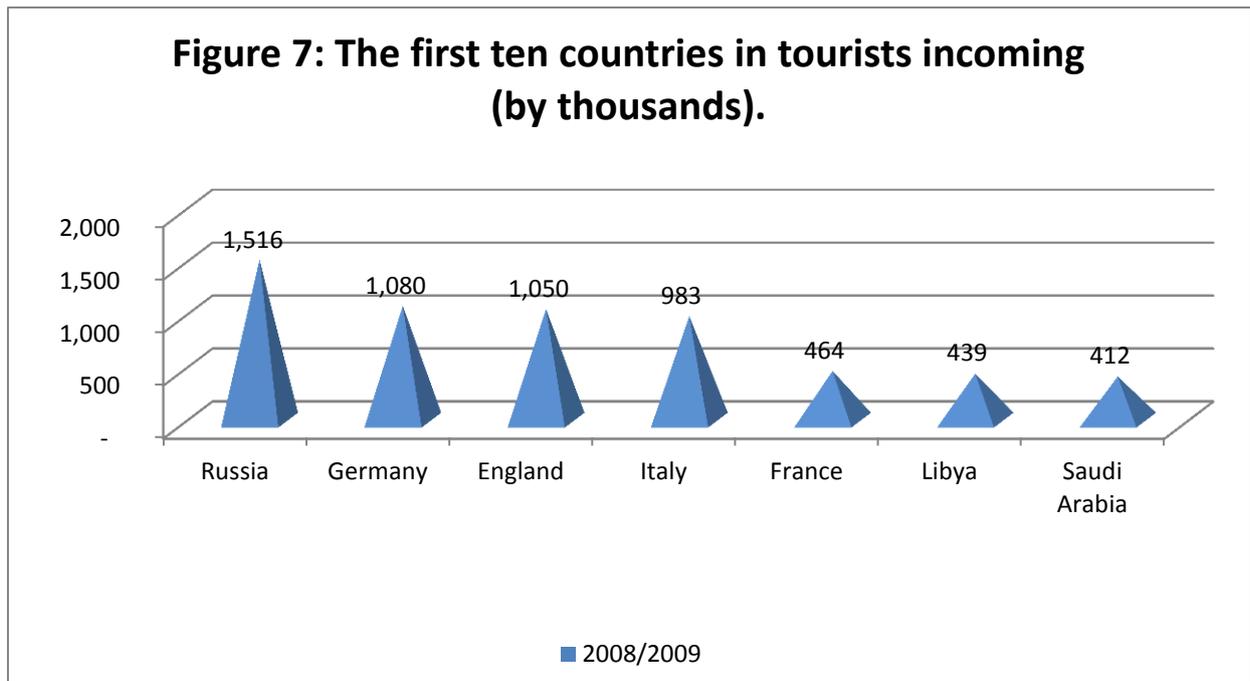
So the development of tourism sector has provoked a great progress of investment rate. It rose about 38.7% between 2006/2007 and 2007/2008. The private sector contributed to about 84% of these investments.

European countries are the main source of incoming tourism for Egypt since they constitute about 74.2% of the total number of tourists followed by the Middle East countries at 13.6% (See Figure 6).



Source: ministry of tourism 2009

In terms of the distribution percentage of the incoming tourism to Egypt among the countries, 10 main countries constitute 64% of the total incoming tourists. In 2008/2009 Russia comes ahead with a total number of about 1.5 million tourists following by Germany, England, Italy and France (See Figure 7).



Source: ministry of tourism 2009

Today, the Egyptian touristic products have evolved and diversified since new patterns of tourism showed up, such as yacht, marine environmental and sport tourism. “Diving centers tourism” represents nowadays a very popular touristic activity.

### 3.2. Economic links with Egyptian coral reefs

As we wrote before, Hurghada became the first tourist resort on the Egyptian Red Sea. Its coast extends to about 62 km along the Red Sea, and it is mainly supported by tourism from water-based sports and activities (Frihy et al. 1996). Hurghada and Safaga (50 km to the south) became an attractive destination. Both cities attract scuba divers because of abundance of coral reefs, white sandy beaches, exotic fish, clear water and year-round warm climate and boast some of the best diving sites in the world (Ibrahim and Ibrahim 2003; Gray 2000).

However, the success and sustainability of tourism in the Red Sea is threatened by the industry which supports it. Today Hurghada has been completely transformed into one of Egypt’s premiere destinations and is home to over 35,000 residents, sprawls over approximately 60 km, and houses over 170 hotels and resorts, and approximately 60 dive centers (Serour, 2004). Over one hundred major recreational projects have been constructed

in Hurghada. Uncontrolled tourism development threatens the marine and coastal environments and has become a source of national concern.

Tourism generates important economic activity globally and is a major source of foreign exchange income in many countries (Simpson et al. 2008). As we mentioned earlier, tourism in Egypt generates an estimated US\$ 10.8 billion annually (equivalent to approximately 6% of national GDP if we consider the direct and indirect activities related to tourism), as well as it provides employment for 12% of the national work force (AFP, 2007). Much of the revenue from tourism in Egypt is derived from the Red Sea region (IUCN-USAID, 2007).

The Red Sea has a number of unique marine habitats, including coral reefs, mangroves, and sea grass beds. They provide key resources for coastal populations: food, shoreline protection and stabilization as well as economic benefits from tourism.

So, the coral reefs are considered a natural capital. The total economic value (TEV) of this natural capital can be derived from the value of all goods and services provided by marine ecosystems. The TEV can be broken up to obtain the value of different components of the ecosystems use (i.e. tourism, fishery and shoreline protection). The main advantage of calculating the TEV is to highlight the importance of the conservation of the reef ecosystem.

According to global estimates (World Bank, 2002), counting only the economic value of coral reef fisheries, tourism, and shoreline protection, the costs of destroying 1 km of coral reefs ranges between US\$137,000 and 1,200,000 over a 25-year period and the properly managed coral reefs can yield an average of 15 tons of fish and other seafood per square kilometer each year. This means that the total economic value of Egypt's Red Sea reefs is estimated at US\$ 205.5 million to 1800 million, and can yield about 1400 tones of seafood.

Assessment of the cost of degradation has been estimated through two steps: (I) The quantification of the physical losses of natural capital (coral reefs habitats) as well as goods and services generated from the reefs ecosystem owing to unregulated tourism activities; (ii) The monetary valuation of the physical losses.

The cost of coral reefs and fisheries degradation in the Egyptian Red Sea area caused by unregulated tourism activities was estimated between US\$ 2626 to 2673 million per year. These include:

1- The loss of natural capital: available estimates (Jameson and al, 1999) indicate that the replacement value of one square meter of coral reefs is US\$ 3000. Based on an estimate of 4 million square meters (Institute of National planning, 2003) of coral reef damaged as a result of tourism projects within the studied area, the total value of the loss of the natural capital is about 12 billion US dollars.

2- The loss of income from marine recreational activities: as far the reef close to Hurghada becomes more congested, the more experienced divers are seeking alternative sites that led to considerable decrease in diver's payments. According to available estimations of World Bank (World Bank, 2002), the losses of income from marine recreational activities in Hurghada Area alone ranged between US\$ 110 to 157 million. Moreover, Cesar (2003) gave a value of US\$ 9.6 billion/year globally for coral reefs contribution to tourism, i.e. Egyptian reefs represent only 1% of the total reef tourism incomes.

3- The cost of shoreline protection: the cost to build an artificial barrier replacing a damaged reefs along the coast is estimated at 12.5 million US\$ per km. Based on the fact that the length of the coast in the studied area that has been affected by tourism developments and has been subject to dredging and land filling is estimated at 105 km. (north of Hurghada-Safaga) the cost of the coast protection would amount to 1313 million US dollars.

4- The cost of loss of fisheries resources: Based on the above mentioned estimates (one square kilometer yields 15 tones of sea food products and 4 million square meter of reefs were damaged), the losses of fish production was estimated at 60 tons with a value of US\$ 0.556 million at 2007 market prices.

At this stage, we reach the heart of our problem. Apart from the complications that climate change could cause, most of coral reefs damages came from tourism activity in this

region of the Red Sea. At the same time, Egypt needs economic, financial and social resources from this coastal and marine area. How can we reconcile this double bind?

### **3.3. Management programs**

As we showed in the previous part, the majority of tourists come from European countries which are very sensitive to the themes of environmental protection in general and of the marine environment in particular.

Egypt became aware very early of the need to protect its coral reefs. The Tourism Development Authority is developing the concepts of ecotourism and eco-lodging and **PERSGA**, an official regional organization formally established in September 1996 and based in Jeddah (Saudi Arabia) is responsible for the development and implementation of regional programs for the protection and conservation of the marine environment of the Red Sea and Gulf of Aden.

Management programs include reef protection and specific laws and regulations (reduction of navigational risks, controlling sources of pollution, restriction of sewage discharge, monitoring programs... Persga 2010). Among these programs, establishment of regional network of **marine protected areas** (MPAs) are important. At present, about 50% of Egypt's reefs are inside MPAs and all of these MPAs are considered at least partially effective, maintaining healthy reefs and reducing the impact of burgeoning tourism industry.

The creation of the **Environmental Protection Law and Environmental Affairs Agency** (EEAA) is the Egyptian government's response to a need for increased environmental consideration. The EEAA is the main coordinator and executor of the Environmental Law. The main objective of the Environmental Law is to protect the environment from human-induced deterioration by industry, construction, tourism and waste disposal, and other factors. In order to achieve this, the environment is divided into three categories: land, water and air.

**The South Development** project is a large proactive conservation project that has become a priority. The government plans to develop the entire southern Red Sea coastline from El Quiseir to the Sudanese border for tourism, which is very largely undeveloped for

the moment. This is an ecologically valuable area and home to hundreds of endangered and endemic species of animals and coral reefs. The Egyptian government is in the process of campaigning for a change in the development plan, so that hotel facilities, like beaches, are centralized and the buildings are constructed away from the coastline. The government aims to increase tourism in other cities that do not receive as much tourism attention. This dispersal strategy is commonly used to overcome problems of environmental degradation of tourism in developing countries, and has been used in the Maldives and Nepal (Brown et al., 1997).

Recent development in this segment includes the **formation of a cluster** that comprises 90% of all **dive centers** in Egypt. Together they have formed an alliance with ISO and have created a code of ethics and regulations to limit the environmental impacts of diving on the coastal environment. This code includes regulations on the types of equipment used, such as motors, and the performance of diving boats; the usage of equipment, such as using diving boats for fishing, and anchoring on coral reefs, among other restrictions regarding the treatment of corals during dives.

#### **4. Recommendations**

From these conclusions, the following recommendations are made to improve environmental protection in Egyptian tourism:

1. Egypt should focus on tourism quality rather than quantity.
2. The private sector should be encouraged to undertake large-scale tourism development projects. Serious attention needs to be given to the management of recreational activities and environmental policies to ensure protection of the coral reefs
3. Governmental institutions should assume a more active and less symbolic role and, in order to do so, should employ experts and knowledgeable professionals as decision makers.

4. The development of Regional Action Plans (RAPs), issued by PERSGA, for conservation of coral reefs, marine turtles, mangroves, and seabirds in the Red Sea and Gulf of Aden Region. These RAPs contain priority actions with these major objectives:

- Integrated Coastal Zone Management
- Education and awareness Status of Coral.
- Marine Protected Areas (MPAs).
- Ecological Sustainable Reef Fisheries.
- Impact of Shipping and Marine Pollution
- Research, Monitoring and Economic Valuation

Therefore, international agencies and donors are requested to assist in overcoming these constraints. Furthermore, in 2005 PERSGA member states formulated a regional agreement for biodiversity conservation and establishment of a regional MPA network. In addition, potential climate change impacts on the marine and coastal environment have been included in regional monitoring programs. Related topics such as sea level rise, coral bleaching, coastal environment degradation will be emphasised in national scientific research plans.

Since reefs, directly and indirectly, contribute to the economy of Egypt, it is important that they are not degraded so they can function to their full ecological capacity, which in turn helps people through provision of services such as recreational activities, fisheries and shoreline protection.

Until now, there had been little evidence of climate change impacts on Egyptian coral reefs except two bleaching events<sup>3</sup> which occurred in 2007. However, thermal stress and ocean acidification are projected to increase threat levels in the Middle East to nearly 90% of the reefs by 2030 while by 2050, these climate change impacts combined with current local impacts will push all Egyptian reefs to threatened status (Burke et al. 2011). Consequently, in order to sustain tourism, coral reefs need in the future more and more suitable management programs.

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<sup>3</sup> A bleaching event leads to the rupture of the symbiotic association between coral and zooxanthellae, followed by the death of the coral and destruction of coral reefs.

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