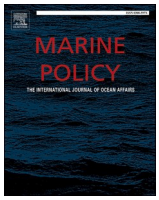
Marine Policy 172 (2025) 106507

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol



The impact of natural capital loss on blue-tourism economy: The Red Sea case study

Silvia Gallegati [a,*], Paula Masiá [a], Emanuela Fanelli [a,b], Roberto Danovaro [a,b]

[a] Università Politecnica delle Marche, Department of Life and Environmental Sciences, Via Brecce Bianche, Ancona 60131, Italy
[b] National Biodiversity Future Center, Piazza Marina 61, Palermo 90133, Italy

ARTICLE INFO

Keywords:
Blue Tourism
Marine Ecosystem Degradation
Tourism Flows
Red Sea
Environmental Policy

ABSTRACT

Global tourism growth is threatening environmental health of several destinations. While negative impacts of tourism on environmental quality are being increasingly documented, the effects of degrading environmental quality on tourists' choices have been largely neglected. Here we investigated the case study of Egyptian Red Sea, one of the world's most popular targets for blue tourism. We provide evidence that, in the North (Sharm El Sheikh), coral reefs experienced a progressive degradation (25–40 % from 1991 to 2023 in the most impacted touristic targets). We report multiple evidence that the loss of natural capital decreased the attractiveness of touristic areas: the shift of tourism flows towards the more pristine regions of the South (Marsa Alam) was unable to counterbalance the loss of Sharm El Sheikh. The significant decline in tourism flows (-23 %, 2009–2019) caused an estimated annual loss of ca. 1.77 billion USD (0.6 % of the Egyptian GDP in 2019). We conclude that, given the increasing demand of pristine environments as tourism target, an unsustainable ecosystem management can threaten local economies, particularly where nature integrity represents a key asset for destination choice. Policy makers should thus consider the convenience of protecting natural capital and/or carrying on ecosystem restoration interventions to recover their attractiveness and develop a sustainable blue-tourism economy.

1. Introduction

Tourism is a leading force in the global economy: in 2019, at the peak of sixty years of continuous growth, 1.4 billion people moved around the world for tourism [1]. In the period 2014–2019, the tourism economy contributed to more than 10.3 % of all jobs worldwide (334 million, equivalent to ca. 20 % of the new jobs created) and 10.4 % of global GDP (US$ 10 trillion; [2]).

Tourism and tourism-related income are key determinants of economic growth, employment and well-being, especially in developing countries [3-5]. In most cases, the touristic offer is based on the beauty of pristine nature and the possibility to watch endemic species and wild animals [6]. Tourism is a driving sector also in Middle East/North Africa (MENA) countries, a region that, in 2018, welcomed 87 million international tourists, equivalent to 6 % of the world's total arrivals [7]. In 2019, the travel and tourism sector accounted for 5.3 % of GDP growth and 6.7 million jobs across the MENA region [8].

Among MENA countries, Morocco, Tunisia, Lebanon, and Egypt are those for which tourism represents a highly relevant source of income [8]. Here and elsewhere, tourism also represents a strategic component in the diversification of local economies [9,10]. Egypt, in particular, is a renowned tourism destination of culture and antiquity [11], but during the last four decades, a policy for diversifying tourism attractions was elaborated by the Egyptian government (Five Year Plan in 1982), with the scope of accommodating an increasing international demand while reducing the pressure on historic locations along the Nile Valley [11]. Since 1995, international tourism, and particularly blue tourism, has remarkably increased in Egypt [12], attracting passengers through several tour operators offering a wide variety of the popular "*sun and beach package holidays*'' [13]. An increasing proportion of tourists has been attracted by the promotion of nature-based tourism on the Red Sea coasts, where the natural beauty, wilderness and unicity offered new opportunities and experiences in a previously underdeveloped area of the region [14].

Blue tourism relies on the presence of a pristine natural capital [2] and on the provision of ecosystem services (ESs), defined as the direct and indirect benefits that humans obtain from ecosystems [15]. In the last decades, tourists have been increasingly attracted by a thriving and

* Corresponding author.
E-mail addresses: s.gallegati@univpm.it (S. Gallegati), p.masia@univpm.it (P. Masiá), e.fanelli@univpm.it (E. Fanelli), r.danovaro@univpm.it (R. Danovaro).

https://doi.org/10.1016/j.marpol.2024.106507
Received 3 May 2024; Received in revised form 7 October 2024; Accepted 11 November 2024
Available online 17 November 2024

pristine biodiversity, and nature-based experiences [16]. Such kind of tourism also has positive effects in terms of tourist permanence, as the average duration of the stay has been shown to be positively linked to the biodiversity profile of a destination [17].

The main driver of tourist attraction in Sharm El Sheikh since the 1980s has been its natural capital and biodiversity associated with the colorful coral reefs [18-20]. Cesar [21] estimated that the percentage of direct users of the reef (divers and snorkelers) varies from 30 % to 100 %, depending on location. More recent analyses showed that, snorkeling, SCUBA diving and field nature experiences (e.g., dolphin watching) represent by far the strongest attraction factor for 97 % of tourists in the Red Sea [19]. Since the early 1990s, the Red Sea has been a target for massive blue tourism, leading to the exponential increase of the number of hotels and accommodation facilities. In 2000, the number of rooms along the Egyptian coasts was 10.549, equivalent to 22 % of the total hotel accommodation capacity in Egypt [22]; fifteen years later, the cities of Sharm El Sheikh, Hurghada and Marsa Alam alone accounted for over 110,000 rooms (almost 60 % of total rooming capacity of the Country; [23]). This growth was primarily due to the construction of new resorts and the expansion of the existing ones, almost exclusively located within 50–300 m from the coast [24].

With over 13 million passengers in 2019 and 12 million in 2022, Egypt is the most visited African country. This implies important economic returns as, in 2019, tourism contributed for 8.8 % of total GDP, employing 2.42 million people, equivalent to 9.5 % of total Egyptian workforce [2]. In 2019, in Egyptian tourism economy "coral-reef tourism" industry generated USD 7 billion in revenues, more than any other country in the world, and more than double the revenues of the runner-up Indonesia [20]. However, the growing popularity of this destination has progressively threatened and degraded marine ecosystems, and particularly the vulnerable coral reefs, which in some areas have significantly suffered from this increasing human pressure. For this reason, there is serious concern on the factors that might potentially jeopardize this important economic income [22].

As a downside of the numerous economic benefits, tourism can cause increased carbon emissions, habitat loss, alteration of biodiversity, acceleration of the depletion of natural resources and overuse of water resources [25,12,26]. Recent studies demonstrated that blue tourism and related activities might have negative impacts on marine environmental status [27] and can compromise the habitat integrity of marine and coastal areas [28-32].

This applies also to the Red Sea, where blue tourism is determining several direct and indirect impacts on marine ecosystems [12,21] related to tourism pressures, exploitation of marine resources, overfishing and/or fishing in illegal areas and is creating concern about the degrading environmental quality caused by tourism impacts themselves [33,34].

The impacts of coastal tourism on the local marine ecosystems can be grouped into four main categories: a) construction of buildings and facilities directly related to tourism (hotels, golf courses, marinas, canals in fringing reefs, road paving); b) litter, wastewater, dumping, desalination and sewage treatment plants, power generation plants, etc.; c) increasing ecological footprint related to the increase of resident population (due to the expansion of tourism-related jobs); d) impact of tourists and touristic activities (recreational fishing, boat tours, jet ski, snorkeling and SCUBA diving, trampling over the reef, etc.). All these activities are producing significant and negative impacts on the surrounding coral reef ecosystems, which are often overlapping with outcomes of other human activities [35] creating cumulative effects.

The effects of the degrading environmental quality and consequently reduced tourist incomes have been already documented in various places worldwide. One example is the Boracay Island (Philippines) once considered one of the world's most beautiful islands, that due to unregulated tourism and consequent environmental degradation became a "*polluted disaster*" [36]. In 2018, the Philippine government closed for six months the Boracay Island to tourism. This temporary closure resulted in a significant loss of incomes (from 7 to PHP 27.9 billion, [37]), but served as a stark reminder of the need for developing an eco-sustainable tourism [36].

Although the negative impacts of tourism on environmental quality are increasingly recognized and documented, much less is known on the effects of degrading environmental quality on tourists' choices and the consequent economic implications. The increasing tourists' attention and sensitivity towards environmental issues (e.g., marine litter and plastic, mammal conservation, etc.) can result in a lower appeal of destinations where naturalness is jeopardized or ecosystem integrity compromised [38,39]. Such attention to nature preservation is increasingly evident among the younger generations, and thus expected to orient a larger portion of the tourism in the future [40]. If so, this could cause shifts in tourists' preferences towards different localities with severe economic implications as the progressive degradation in Egyptian coral reefs is discouraging tourism and could lead to a loss of up to USD 5.6 billions out of the 7 generated by coral reef tourism by the end of the century [20].

In this study, we investigate the effects of environmental degradation of the Red Sea coral reefs on the local blue tourism economy. We also assess the economic dimensions of this effect and explore if it has the potential of affecting the economic development of the Egyptian coastal areas.

2. Materials and methods

2.1. Study area

The Red Sea is a semi-enclosed basin located between African and Arabian plates, extending for a 1932 km-long shore, [41]. Egypt shows the largest coastline development among the Red Sea countries and its coasts extend for ca 1386 km. The main Egyptian coastal cities are Sharm El Sheikh, Ras Ghareb, Hurghada, Safaga, El-Quseir and Marsa Alam [42].

The Red Sea is currently worldwide recognized for its high biodiversity and presence of endemic species [18,43]. Coral reefs are among the greatest attractions of the Red Sea, with 359 species of scleractinian corals [44], 211 species of echinoderms and >1000 species of fishes associated to the reefs [18] globally renowned from their pristine conditions and resilience to rising sea temperatures [33]. It is also habitat for endangered marine mammals, such as cetaceans, dugongs, and turtles (https://www.iucnredlist.org/regions/persian-gulf; [45]).

Sharm El Sheikh is the oldest and most iconic blue-tourism destination of the Red Sea: since 1982, the city started its expansion as a major international resort, with a high concentration on the area on Na'ama Bay, a portion of shoreline 1 km long, 10 km North of Sharm El Sheikh town [46]. Currently, resorts in Sharm El Sheikh cover a portion of shoreline approximately 30 km long. Ras Mohammed National Park, established in 1983, is the first marine protected area of Egypt and extends on the coastline of the southern tip of Sinai ca. 30 km West from Sharm El Sheikh.

Marsa Alam is a town in South-Eastern Egypt whose development began only in 1995 and strongly increased after 2003, when the airport of Marsa Alam was inaugurated. The airport of Marsa Alam, located approximately 60 km North of the homonymous town, serves resorts that span on a shoreline of over 300 km. At the southernmost end of the Marsa Alam Region, lies the Wadi El Gemal–Hamata Protected Area, designated in 2003 as a National Park under the IUCN Protected Area Category II (Fig. 1)

In this study, we consider and compare a set of variables from two areas: a) Sharm El Sheikh and surrounding coasts vs. b) the coastline around Marsa Alam, from the city of El Quseir to the marine protected area of Berenice.

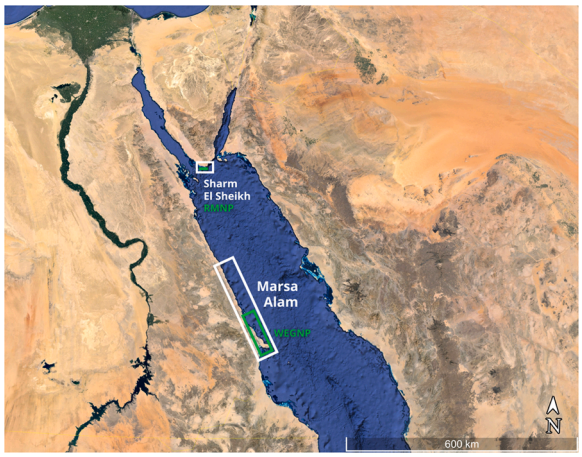


Fig. 1. Sharm El Sheikh and Marsa Alam resort areas (white), Ras Mohammed National Park and Wadi El Gemal National Park (green).

2.2. Data collection

2.2.1. Environmental quality data

We identified the changes in the concentration of phytopigments (expressed as Chlorophyll-*a* contained in the microalgae) as a measure of the phytoplankton biomass and thus as a proxy of marine eutrophication (i.e., the process of deterioration of the water quality related to the increasing release of nutrients due to sewage and/or insufficient waste-water management). Data on Chlorophyll-*a* has been retrieved from Copernicus Marine Data (https://data.marine.copernicus.eu/products; accessed in July 2023). This variable was selected as eutrophication is a recognized threat to coral health [47] and is one of the Descriptors of the Marine Strategy Framework Directive (D5, EC 56/2008). High Chlorophyll-*a* concentrations are typically associated with a decrease of water transparency (which is crucially important for coral survival, [48]), a shift in the ecosystem functioning and eventually to the rise of red tide or toxic phytoplankton blooms [49].

The second investigated variable is the change in coral coverage (i.e., the portion of the area covered by living corals, expressed as percentage). This has been investigated through extensive literature research and data mining from Scopus, Web of Science and Google Scholar, from 1991 to 2023, using the following search: "Coral Status" or "Coral health" AND "Red Sea" or "Sharm El Sheikh'' or "Marsa Alam" or "Ras Mohammed" or "Wadi El Gemal". Due to the scarcity of data in peer-reviewed articles we extended the search to grey literature (technical reports, monitoring activities). Articles relating to areas of the Red Sea other than Sharm El Sheikh and Marsa Alam, such as the Gulf of Aqaba or the Arabic coasts, were intentionally excluded by this specific analysis. We used available data to reconstruct temporal patterns in coral cover and to compare the two destinations (i.e., Sharm El Sheikh and Marsa Alam).

Within the Sharm El Sheikh area, we also compared the changes in coral cover between Sharm El Sheikh touristic area and Ras Mohammed National Park (West of Sharm El Sheikh), to assess the differences between protected and unprotected areas within the same region.

For the Marsa Alam region we acquired data from: a) North Marsa Alam (Abu Dabab), b) Central Marsa Alam, c) South Marsa Alam and d) Wadi El-Gemal-Hamata Protected Area (WEGNP). Data availability for Sharm El Sheikh started in 1991, whereas from Marsa Alam the first available information dates to 2003.

2.2.2. Index of human impact

Finally, we determined the index of "Human Impact on Marine Ecosystems", through an ecosystem-specific, multiscale spatial model that quantifies anthropogenic impact [50]. This index elaborated 17 drivers of human pressures over 20 ecosystems, among which coral reefs. The index increases as the anthropogenic impact increases. Data for this model were collected in shapefiles elaborated with QGIS to extract zonal statistics like the spatial mean value of the index in the considered areas. The HI Index was elaborated with data accessible from the portal EcoInformatics (https://knb.ecoinformatics.org/view/doi:10.5063/F12B8WBS). All data used are annual averages of the Human Impact Index elaborated by Halpern. The files were exported in "tiff" format, for the period of availability 2003–2013 and the manually overlapped with shapefiles containing the areas around the sites to be analyzed (see Fig. 1). The last step consisted in superimposing the shapefiles on the maps contained in the.tiff files to calculate the zonal statistics which specifically are an average of all the points belonging to each.tiff file, but within the area delimited by the shapefile. The model was applied to both Sharm El Sheikh and Marsa Alam regions.

2.2.3. Socio-economic data

Different databases were mined to extract data from independent sources and to assess the economic and social implications of the tourism-driven environmental degradation.

The number of passengers who traveled via Sharm El Sheikh and Marsa Alam airports was used as a proxy for the number of tourists visiting the two destinations. We retrieved tourism data from the following sources: i) UNTWO Tourism Data Dashboard, ii) CEIC Data for Egyptian Ministry of Civil Aviation and iii) Statista.com. All databases were accessed in July 2023.

The analysis of average expense per travel in 2023 was made by sampling the average cost (in USD) of a seven-day holiday with flights included in all-inclusive resorts in Sharm El Sheikh and Marsa Alam. In particular, the website of a leading Italian Tour Operator (https://www.alpitour.it/), UK Tour Operator (https://www.tui.co.uk/) and online Tour Operator (https://www.expedia.it/) were accessed in the month of July 2023 to determine the mean and median prices of a stay in hotels of 4* and 5* categories. The analysis was carried out for two distinct seasonality periods, the high-season peak of August and the low-season period of December, before Christmas Holidays.

Since Tripadvisor is a potentially relevant "text source" for investigating consumers' perceptions [51,52], we used this data source to collect the comments from the tourists [53] who visited and compared the two destinations of Sharm El Sheikh and Marsa Alam in order to analyze their impressions/perceptions and decision process based on the environmental quality and "naturalness" of the sites selected for their vacation. We used user-generated contents (UGC) from Tripadvisor reviews and Q&A sections on Egypt and Red Sea, Sharm El Sheikh and Marsa Alam and we selected all travelers' opinions when referred to coral reefs and biodiversity (expressed with identified keywords such as: fish, turtle, life, colors, natural beauty etc.) after their vacations. The selection of UGC in Trip Advisor was purposefully conducted to capture a broad and relevant spectrum of tourist opinions regarding the environmental quality of the two destinations. The "Purposeful sampling" is a well-recognized approach for qualitative data collection and analysis in mixed method implementation research, particularly useful when the researcher seeks to gain in-depth insights into a specific issue or phenomenon [54]. When the aim is to select information-rich data that can provide significant insights into the topic in analysis, purposeful sampling allows a more systematic and transparent way for decision making [55]. This method is particularly suitable when the research focus is on understanding the perceptions, experiences, or opinions of individuals within a specific context [56]. We systematically selected comments based on predefined criteria to ensure that the sample adequately represented the range of opinions expressed by tourists, including relevance (comments were selected if they directly referred to aspects of environmental quality, such as preservation of natural habitats, or pollution, making comparisons between the two destinations of interest: Marsa Alam and Sharm El Sheikh) and variety of perspectives (including both positive and negative comments on the two destinations to capture a

balanced view of the destination quality as perceived by tourists). The final sample size was determined based on the principle of data saturation, where no new insights were being gained from additional comments. This approach has been standardized to ensure that the sample is sufficiently large to capture the full range of relevant opinions without redundancy [57].

An additional analysis was conducted with Google Trends at global scale to highlight the global research interest of the keywords "Marsa Alam" and "Sharm El Sheikh'': data were filtered for the time-span January 2009-December 2019, coherently with the timespan analyzed for the tourism flows, at a global level.

3. Results

3.1. Changes in Chlorophyll-a concentration

Satellite images show an overall increase of chlorophyll concentrations over time throughout the Red Sea region, but with a stronger increase in the northern region and along coastal areas. Chlorophyll-*a* concentrations were typically very low, with average annual values ranging from 0.09 m^{-3} in Marsa Alam to 0.16 mg m^{-3} in Sharm El Sheikh (Fig. 2; for the meso-scale map and the values of environmental variables, see SOM Figure S1).

3.2. Temporal patterns in coral reef health

A total of 16 scientific articles (plus one IUCN report) were retrieved for assessing the coral coverage specifically in the two areas of interest. In both areas, we also compared the data from protected areas (Ras Mohammed National Park - RMNP for Sharm El Sheikh, Wadi El Gemal National Park WEGNP for Marsa Alam; here defined as "Control") with those of the touristic area (here defined as "Impacted").

In the 1980s, the condition of corals in Sharm El Sheikh was pristine and characterized by a relevant hard coral cover (ca 72 % at a depth of 1 m) [58]. In 1989/90, there was reported evidence of direct human impact with 1.7–4.7 broken coral colonies per square meter in diving sites compared to 0–0.5 in non-diving sites [59]. Ten years later, coral coverage decreased to 41 % or less depending on the location [60,61] and approximately ten more years after coral cover within Ras Mohammed area ranged from 23 % to 40 % [62].

In the Marsa Alam region, in early 2000's, the touristic areas exhibited a coral coverage (29–33 %) significantly lower than in pristine (now protected) areas (69 %; [63]). Approximately ten years later, impacted areas showed a coral coverage of ca. 16 % vs. 53–78 % in pristine areas [64]; Attalla et al. [65]).

3.3. Changes in coral cover in protected and unprotected areas

In the Sharm El Sheikh area, coral coverage was on average 29 % (ranging from 14 % to 40 %) in the touristic area, vs. ca. 41 % (ranging from 10 % to 86 %) in the protected area.

In the Marsa Alam region, in the northern area coral cover showed an average of 65 % (range from 38 % to 92 %), whereas in the Wadi El Gemal–Hamata Protected Area coral cover showed an average of 71 % (range from 63 % to 85 %).

In both regions, areas more affected by the presence of tourism facilities showed a lower coral coverage than in protected areas, but the decrease of coral cover in the Sharm El Sheikh area was ca 30 % vs. 8.5 % in Marsa Alam (Fig. 3, Supplementary Table S1).

3.4. Human impact on marine ecosystems

At a global level, there are few to no areas where coral reefs show an HI Index <1.5 [50]: Marsa Alam stayed below this level until 2010. Our data suggest that almost half of all coral reefs experience medium high to very high impact. The HI Index shows an increasing trend in both regions, but Sharm El Sheikh suffered from a significantly higher impact than Marsa Alam. The gap between the two indexes diminishes over time: the initial difference of nearly 50 % in the first three years gradually narrows, eventually reaching disparities of less than 20 % in the last years (Fig. 4). The yearly values for the HI Index have been reported in Table S2 of the SOM.

3.5. Tourism flows and travel preferences

The number of passengers traveling to the Egyptian coasts of Red Sea via Sharm El Sheikh and Marsa Alam airports was used as a proxy for the number of tourists visiting the two destinations (Fig. 5). Total number of passengers in Sharm El Sheikh decreased by almost 3 million (-23 %) in the decade 2009–2019, while in Marsa Alam it grew by approximately 0.8 million (+85 %). These patterns indicate that the number of passengers choosing the Egyptian coast as a destination for their holidays decreased over time and this decrease is mostly due to the drop of Sharm El Sheikh flows. Data from 2016 were omitted since they were showing a significant drop in both locations due to the terrorist attacks that occurred in 2015 and 2016 [66,67].

The analysis carried out using Google Trends for the period 2009–2019 highlighted that the research interest for Sharm El Sheikh decreased over time (Figs. 6a and 6b). Conversely, the interest in Marsa Alam as a target for vacation remains stable in the decade. It is to be noted that in 2016 Google Trends changed the modality of data

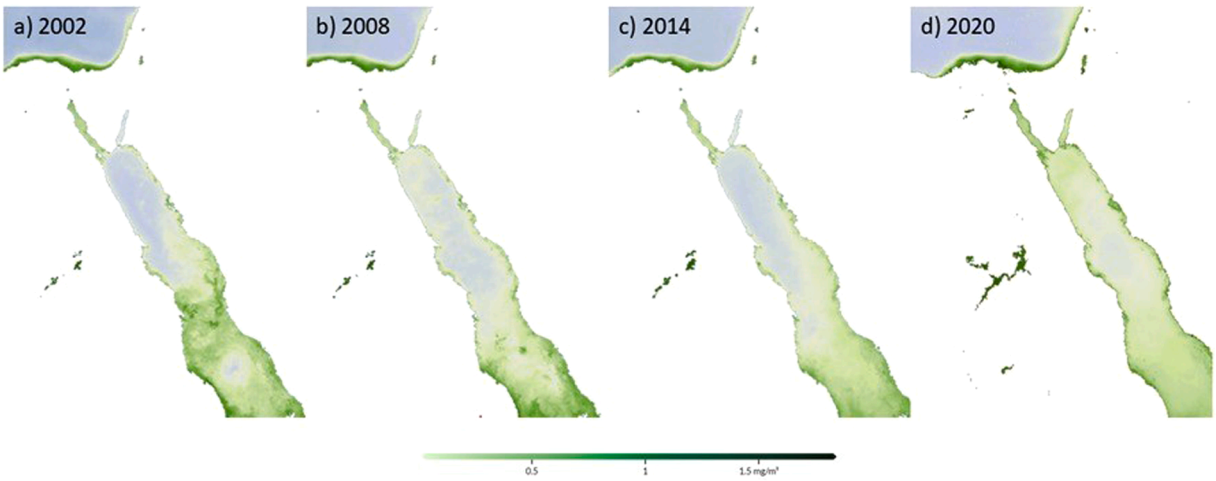


Fig. 2. Satellite images from the studied areas; a) 2002, b) 2008, c) 2014, d) 2020.

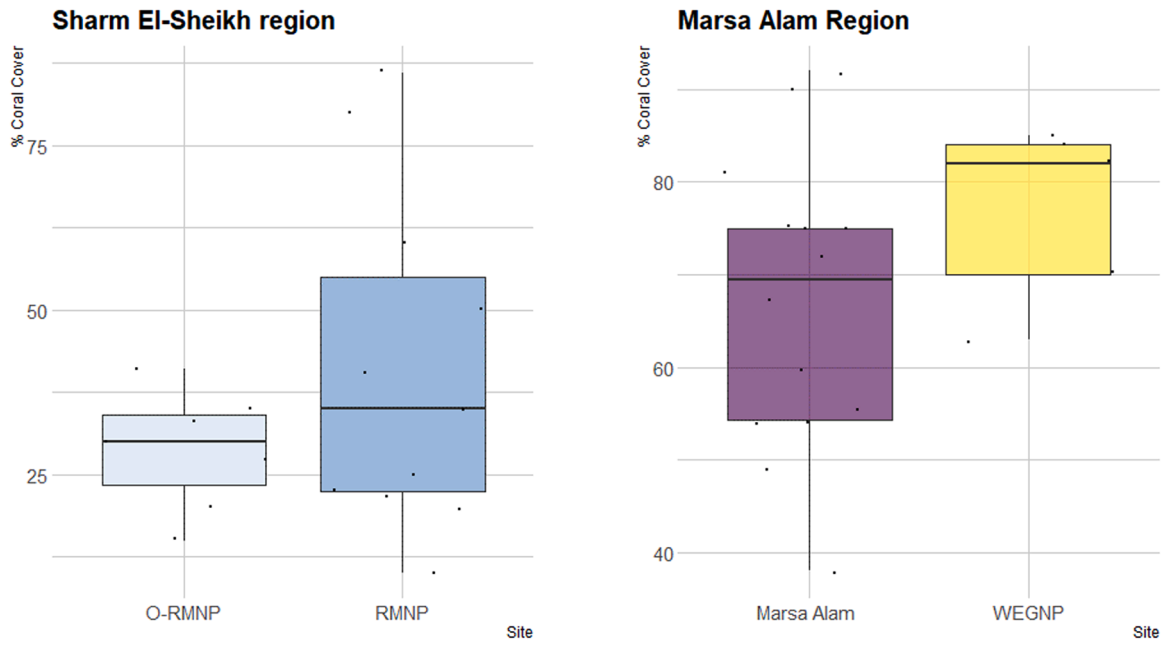


Fig. 3. Boxplot with all data over time in the two studied locations. O-RMNP: Outside Ras Mohammed National Park; RMNP: Ras Mohammed National Park; WEGNP: Wadi El Gemal National Park (Including sampling points from the border outside the park).

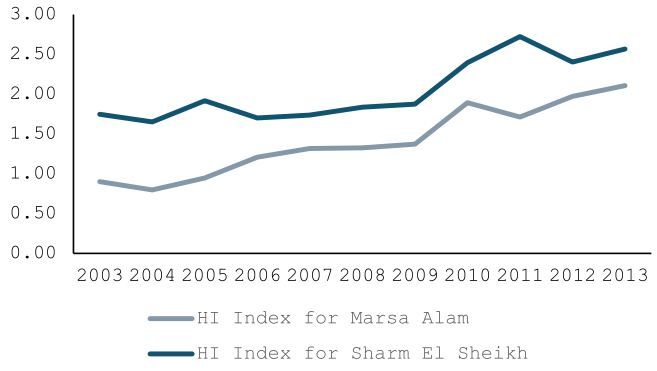


Fig. 4. Cumulative Human Impact Index in Marsa Alam and Sharm El Sheikh, from 2003 to 2013.

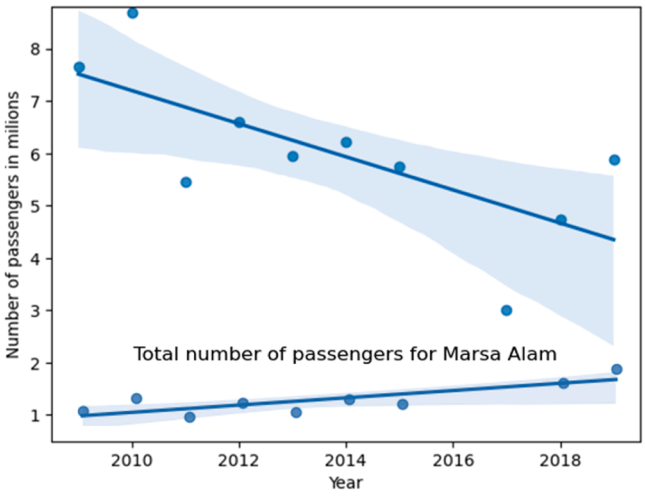


Fig. 5. Trend of tourism flow (passengers traveling to Egyptian Coasts of Red Sea) to Sharm El Sheikh and Marsa Alam airports.

acquisition causing a drop in interest scores for all searches worldwide: this might limit the data comparability with the previous years and negatively influence the trend from 2016 onwards.

3.6. *User-generated contents for social analysis*

A sample of the opinions and feedback of tourists visiting the investigated areas for holiday purposes was collected on Tripadvisor and analyzed. We selected the comments in topics where the two locations were compared and aggregated their reviews by categories of perception on which the visitors gave more emphasis (general features of the destination/Reef and coral quality-colors/Presence of wildlife). The results of this analysis are reported in Supplementary Table S3. Overall, the results of the tourists' opinion revealed a consistent higher appreciation for the marine ecosystems of the Marsa Alam coasts when compared to those of Sharm El Sheikh: this factor would lead them to choose again and/or recommend the former destination rather than the latter because of grater accessibility and more pristine conditions of natural resources. Some opinions, besides the better opportunities for a naturalistic experience (SCUBA diving, snorkeling on coral reefs, visiting dolphin, sea turtles and dugong areas), also considered the associated costs (*"even if the holiday itself is more expensive"*). Conversely, those recommending Sharm El Sheikh were basing their preference on the "*luxurious resorts*", "*entertainment*", and "*presence of a town close to the resorts*" more than on the natural beauty, integrity, and values of wilderness.

3.7. *Cost analysis*

The analysis of average costs for a seven-day vacation revealed consistent differences between Marsa Alam and Sharm El Sheikh (Fig. 7): in the high season, a seven-day holiday in Marsa Alam is on average 6.9 % more expensive than in Sharm El Sheikh, while in low season the average difference is +4.7 %. The spread of costs between Marsa Alam and Sharm El Sheikh becomes even more evident when considering median prices: +10.6 % in high season and +7.5 % in low season (see Supplementary Tables S4 and S5).

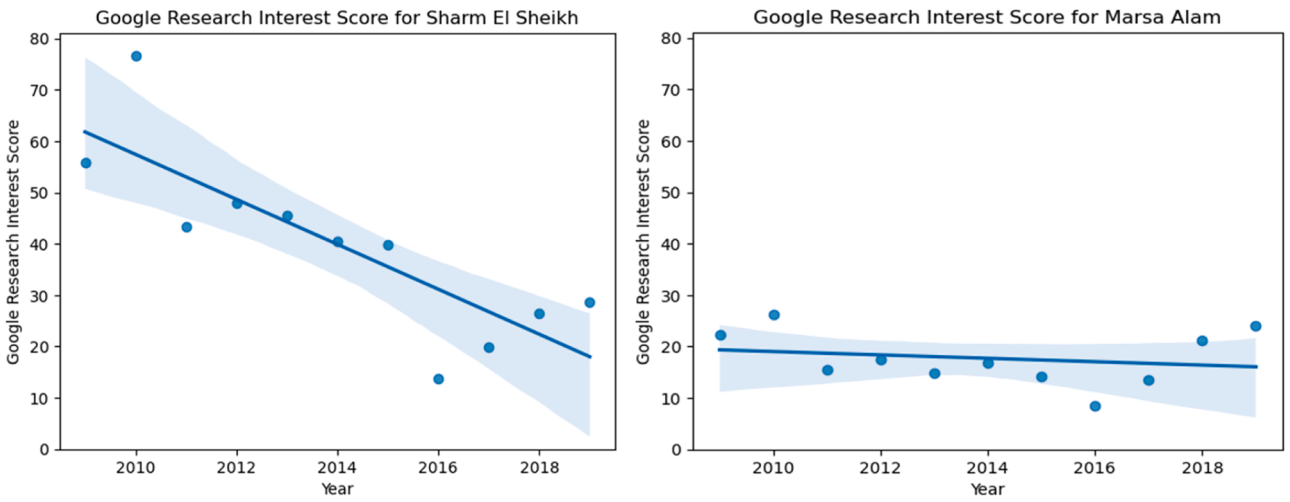


Fig. 6. Google Trend research interest for: a) Sharm El Sheikh and b) Marsa Alam.

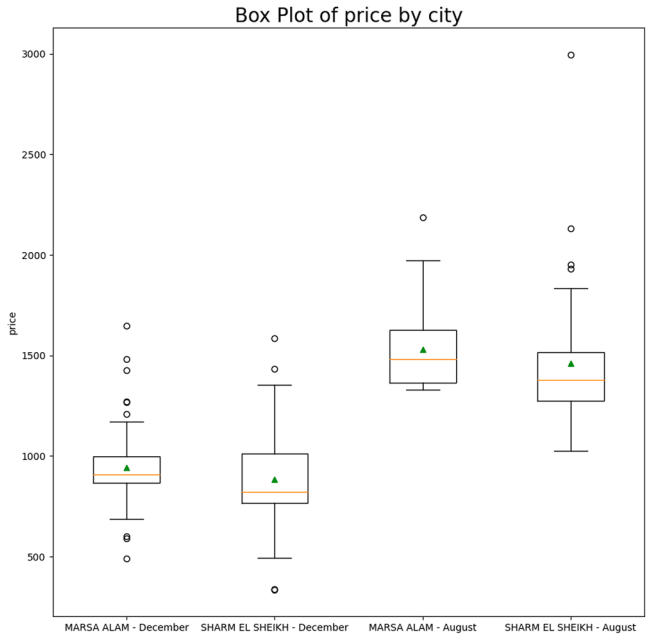


Fig. 7. Box plot of mean and median prices (in USD) of a 7-days all-inclusive holiday in Sharm El Sheikh and Marsa Alam, low and high season.

4. Discussion

4.1. Threats and trends in coral reefs' health in the Red Sea

Our results corroborate previous evidence that tourism exploitation and associated impacts (shipping, maritime and other transportation, boat accidents, increased sedimentation, pollution, waste and sludge from accommodation, infrastructures and facilities, trampling over the corals, or use of harmful sunscreen products; [68]) can explain the loss of coral cover in the investigated areas (as highlighted by the Human Impact Index; Fig. 4). The direct consequences of snorkeling and trampling on coral reefs are known since more than a decade [19] and are evident also from our analysis of coral cover data, which shows a negative trend in Sharm El Sheikh (especially in the area most exposed to intensive tourism), that led to a loss of coral coverage by approximately 40 % or more over the last 3 decades.

We conducted a comparative analysis between the protected area of the RMNP (used here as control), whose border is located at ca 3 km from tourism facilities, with the area accessible to tourists (impact). Currently, 12 % of the park is accessible to visitors, and thanks to its robust conservation initiatives, it earned a spot on the IUCN's Green List in 2018 (https://iucngreenlist.org/, accessed November 2023). The coral coverage within the park ranges from 60 % to 80 %. These values of coral coverage, similar to the coral coverage conditions in the 80's [58], are among the highest in the whole Gulf of Aqaba. Conversely, coral coverage in the touristic area outside the park's boundaries ranges from 20 % to 30 %, with lowest values in the coral reef areas facing the hotels and resorts.

Along the wider area of the Marsa Alam region (stretching for approximately 300 km), there are notable differences between the northern part (showing a higher concentration of resorts and hotel) and the southernmost part, which includes the Berenice area and protected areas such as Wadi El Gemal-Hamata National Park. Currently, hard coral coverage in the Marsa Alam area is still very high, from 55 % to 67 % [69], indicating limited impacts on coral reef health. Yet, a comparison between protected (Wadi El-Gemal National Park) and unprotected sites in the Marsa Alam area revealed that, in 2015, coral coverage within the National Park was on average 82 % (vs. 63 %, outside the park; [70]).

As also suggested by the trend of Human Impact Index on marine ecosystems, our data indicate that the environmental condition of the coral reefs is worsening in both areas, but in Marsa Alam it is consistently better than in Sharm El Sheikh. We also provide evidence of the efficacy of the protection measures in both Marsa Alam and Sharm El Sheikh areas, which are responsible for a preservation of ca 20–40 % of coral cover. The temporal trends of the decreasing coral health, along with the significant differences in coral cover between protected and unprotected marine areas, strongly support the conclusion that human impacts are the main driver of the decrease of coral cover and consequent habitat loss.

Stony corals are not just attracting the tourists for their intrinsic beauty, but are also ecosystem engineers that provide several ecosystem services, in particular food and nurseries for a large variety of species, including the famous colorful fish species of the Red Sea [71]. A decrease of coral covers means a consequent decrease in the associated biodiversity and local species loss: for instance, all butterfly fish species are crucially dependent on the coral polyps for their diet and are among the first taxa lost after coral degradation [72].

4.2. Impacts of degrading reef health on tourism attractiveness

Here we show that the expansion of the accommodation and tourism facilities in Sharm El Sheikh mirrors the flow of tourists that since the

80's have identified the Red Sea as a target for their vacations. At the same time, the deteriorating environmental conditions, which started to be evident already in the late 90's, have been driving a change in the public perception of the attractiveness of the area. This was highlighted by the feedback reported on social media, comments and reviews in TripAdvisor, the search trends from Google. It has been shown already that online social travel networking contributes to creating the destination's image and is increasingly influencing the identification of tourist targets [73]: the comments found in TripAdvisor can discourage tourism flow towards the most impacted destinations by reporting that the famous coral reefs which for decades attracted the tourists to the Red Sea are not there anymore (Hawkins, 1996), especially for what concerns coral colors, in favor of more pristine locations.

The decreasing attractiveness of the Egyptian reefs close to Sharm El Sheikh has been reported already 20 years ago, with an increasing echo and a negative trend that alarmed the local authorities that started appropriate management actions of protection of the reefs from trampling and other damaging practices: in 2019, Egypt was the 11th Country worldwide to implement UNEP's initiative "Green Fins", the only internationally recognized voluntary eco-certification offering a sustainable management approach for diving and snorkeling operators, which in Egypt are estimated to be over 500 [74]. Egyptian authorities also explored the possibility of restoring the damaged coral reefs of the northern areas, but pilot interventions are still in progress.

The decreasing environmental quality (namely the richness, integrity, biodiversity and thus beauty of the coral reefs) raises a growing concern as the results of this study provide evidence of the progressive drop of attractiveness of Sharm El Sheikh as a target for nature-oriented vacations and partial shift of tourists to Marsa Alam. Several studies have shown that there is a significant relationship between number of tourists, international tourism income and economic income [75,76] and that the negative impacts on the natural beauty, such as bleaching, can directly cause economic losses to the residents of the destination [77]. This is made evident by the loss of arrivals for about 23 % from 2009 to 2019 in Sharm El Sheikh (despite the overall increase of tourists worldwide), with a negative impact on the Egyptian tourism supply chain.

4.3. Economic implications of degrading environmental qualities and tourism flows

In 2019, tourism accounted for 8.8 % of Egyptian GDP (26,7 billion USD), providing 3.1 million jobs (9.5 % of the total Egyptian workforce, [2,78]). However, the decrease of blue tourism reported here might have had disruptive effects, particularly evident for Sharm El Sheikh that employs a great number of domestic migrant workers, whose incomes also support households in the native villages or towns [79]. Sharm El Sheikh accounts for 28.9 % of total Egyptian rooming capacity and we assume that it contributes to the tourism-related Egyptian GDP by an equal share (hence ca. 2.6 % of total GDP). In a scenario where the tourism flows decreased by 23 % as happened from 2009 to 2019, the reduced contribution of Sharm El Sheikh to the Egyptian GDP can be estimated at approximately 1.77 billion USD (-6,65 % of tourism related GDP), equivalent to a loss of 0.6 % of total GDP (2019 values).

The loss of Sharm El Sheikh is partly counterbalanced by the growth of Marsa Alam. In terms of flows, Sharm El Sheikh lost 1.76 million passengers from 2009 to 2019, Marsa Alam grew by over 800,000, with a net balance of −960,000 passengers. The two destinations together, basing on their rooming capacity, contribute to ca. 35 % of tourism-related GDP (3 % of Egyptian GDP): in the decade 2009–2019 the Red Sea experienced an overall decrease in flows of ca 11 %. The reduced flows may imply a lower contribution of 1 billion USD to the Egyptian GDP (3.75 % of tourism related GDP and 0.33 % of total GDP).

Our data support the evidence that a degraded environmental quality discourages tourists in choosing one destination and hence affects all the sectors of the local tourism supply chain. These estimates are projections of possible scenarios but must be considered with caution as tourism is known to have large multiplier effects on other sectors of the economy [80,81] and that due to difference in prices, not all destinations contribute to the national GDP proportionally to their accommodation capacity, as hypothesized above.

Ecosystem integrity and conservation is becoming a major attraction factor for tourists who are looking for wildlife and pristine destinations [38,82], for those who pay a particular attention to sustainability issues [83,84] and are willing to pay a premium to visit ecosystems with greater ecological health such as Marine Protected Areas [85,86]. This is apparently confirmed by the increasing attractiveness and growing flows of tourists towards the more pristine area of Marsa Alam and towards ecologically pristine areas, as it is for the Ras Mohammed National Park, close to Sharm El Sheikh, that passed from a few hundreds of visitors (tickets emitted) in 1988, to 444,653 in the fiscal year 2018/19, of which 400,461 (90 %) were international tourists [87]. Moreover, it is to be noted that the wider variety of attractions that go beyond the snorkeling and diving activities, expanding/orienting the attraction to nightlife, markets, food and more luxurious accommodations, which may be appealing to tourists who are not seeking for a merely "blue" experience, is mostly present in Sharm El Sheikh. Also, a monetary policy of lowering prices has been carried on in the destination, so that today, in equal accommodation conditions (e.g., a five-star hotel in the same season), Sharm El Sheikh results on average less expensive than Marsa Alam and price is a relevant variable for holiday destination choice [88]: in 2018, Sharm El Sheikh was ranked as the lowest-costing luxury holiday destination in the world [89].

4.4. Potential actions to contrast current trends

Tourist destinations of Red Sea need crucial actions towards sustainable development [90]. Local managers should work on engaging tourists in educational initiatives and in the development of environmentally responsible behaviors [91,92] that can be highly beneficial in the long term for the environment and the local economies. The study by Hannak et al. [19] highlighted that in the Red Sea the least educated tourists about reef ecology and less experienced snorkelers and divers would be the most prepared to financially support educational activities. If in fact by one side more tourists mean more consumptions, services and employment, leading to an economic growth in Egypt, on the other side an unsustainable expansion of the tourism flows, by degrading local ecosystems, might develop a boomerang effect on economic development.

At the same time, there is evidence that Sharm El Sheikh's experience is addressing the local management (even in other Red Sea regions) towards a more sustainable development and more attention is being paid to minimizing and mitigating the impacts in the construction of new facilities, in enforcing the ban of trampling, discouraging impactful behaviors and reducing the negative environmental effects of the management of new resorts in the area [93,94].

At global scale, there are several emerging issues related to the blue tourism, such as the coral bleaching caused by sunscreen products [95] which call for a change in the use of eco-sustainable personal care products and has led to the Hawaii Reef Bill to stop the use of products containing oxybenzone and other harmful chemical filters [96]. However, these measures have been not yet adopted in the Red Sea region.

Moreover, it emerges that despite some recent attempts to protect the coral-reef from direct impacts of tourism (such as trampling over the reef, which has been forbidden only very recently), continuous, coordinated initiatives to protect the Red Sea reefs close to the touristic locations have not been sufficiently enforced [33]. Local managers should increase the efforts in ecosystem protection and good practices to avoid or minimize any environmental impact.

To compensate the habitat loss, coral-reef restoration is currently carried out in several areas of the world [97-102]. In 2022, also in Egypt started the first pilot project of coral-reef restoration, based on the

creation of 100 nurseries to regenerate damaged reefs. However, restoration interventions, appropriate, long-term investments, and a specific expertise, so that the effects of these interventions require time to be fully assessed.

Future management strategies should involve destination managers, local communities, tourists and volunteers as to prevent further damage and incentivize local inhabitants to play a positive active role in tourism planning, environmental conservation, and sustainable use of resources [103-106].

5. Conclusions

The present study provides evidence that the progressive loss of coral cover covaried with the decrease of attractiveness of one of the best-known marine locations in the world: Sharm El Sheikh. Data on social perception collected in this study highlight that habitat degradation negatively influenced the tourists in the selection of their destination, ultimately contributing to a decrease of tourism flows. The significant decline in tourism flows in Sharm El Sheikh (-23 %, 2009–2019) caused an estimated annual loss of ca. 1.77 billion USD (0.6 % of the Egyptian GDP in 2019), only partly compensated by the increased tourism in Marsa Alam. Overall, the resulting annual loss is in the order of ca 1 billion USD. We also documented the increasing number of tourists' accesses in marine protected areas, which still preserve a higher biodiversity and better coral health. However, the increase of tourism in the southern region of Marsa Alam, in absence of adequate environmental management measures, can threaten the integrity of this area, as it reported for the touristic areas of Sharm El Sheikh. Protection measures, together with the local initiatives aimed at discouraging wrong behaviors damaging the coral reefs (i.e., trampling on the reef, once common and now completely forbidden, feeding on large fish, managing plastic and litter pollution etc.) can reduce the impacts and in some cases contribute to preserve the natural capital and reef integrity. Available evidence suggests that responsible behaviors and education towards environmental sustainability and protection of natural resources (e.g., marine protected areas) can be extremely relevant not only to target future targets for vacation, but also to increase the average duration of the stay and to build loyalty of the tourists to a specific area for their vacations. Protection of coral reefs is the first solution to preserve the ecosystem's attractiveness, but it might take a long time to be effective on degraded/impacted reefs. A complementary solution could be the limitation of the overtourism along with the education of the tourists to respect the reefs and avoid any impact. Finally, the development of active restoration interventions might accelerate the coral recovery and the overall ecosystem quality thus shortening the time to a new shift and orientation of the future vacations.

CRediT authorship contribution statement

Roberto Danovaro: Writing – review & editing, Validation, Supervision, Methodology, Formal analysis, Conceptualization. **Emanuela Fanelli:** Writing – review & editing, Supervision. **Paula Masià:** Writing – original draft, Formal analysis, Data curation. **Silvia Gallegati:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This study was supported by the Project DiverSea (HORIZON-CL6–2022-BIODIV-01; Grant agreement 101082004) and by the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.4—Call for tender no. 3138 of 16 December 2021, rectified by Decree no. 3175 of 18 December 2021 by the Italian Ministry of University and Research, funded by the European Union—NextGenerationEU, Award Number: project code CN_00000033, Concession Decree No. 1034, of 17 June 2022, adopted by the Italian Ministry of University and Research, Project title "National Biodiversity Future Center—NBFC".

We want to thank Alessio Giorgetti (UNIVPM) for his support in the analysis of Human impact index and Alessandra Kostantchouk (UNIVPM) for preparing Supplementary Figure S1.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2024.106507.

Data availability

Data will be made available on request.

References

[1] D. Streimikiene, B. Svagzdiene, E. Jasinskas, A. Simanavicius, Sustainable tourism development and competitiveness: the systematic literature review, Sustain. Dev. 29 (1) (2021) 259–271.
[2] WTTC. (2022), Annual Research: Key Highlights World Travel and Tourism Council (WTTC). Available from: ⟨https://wttc.org/research/economic-impact⟩.
[3] C.L. Jenkins, B.M. Henry, Government involvement in tourism in developing countries, Ann. Tour. Res. 9 (4) (1982) 499–521.
[4] M. Oppermann, Tourism space in developing countries, Ann. Tour. Res. 20 (3) (1993) 535–556.
[5] R. Saner, L. Yiu, M. Filadoro, Tourism development in least developed countries: challenges and opportunities, Sustain. Tour.: Breakthr. Res. Pract. (2019) 94–120.
[6] R. Naidoo, W.L. Adamowicz, Biodiversity and nature-based tourism at forest reserves in Uganda, Environ. Dev. Econ. 10 (2) (2005) 159–178.
[7] UNWTO, 2019, https://www.unwto.org/global/publication/tourism-mena-region accessed in August 2023.
[8] WTTC. (2021), Trending in travel: Emerging consumer trends in travel & tourism in 2021 and beyond. Retrieved from https://wttc.org/Portals/0/ Documents/ Reports/2021/Trending_In_Travel-Emerging_Consumer_Trends-231121. pdf.
[9] Huseynli, B. (2022). The Contribution of the Number of Tourists to the Economic Growth of Egypt: An Econometric Analysis. African Journal of Hospitality, Tourism and Leisure, 11(4):1350- 1361. DOI: https://doi.org/10.46222/ajhtl.19770720.295.
[10] N. Tuncay, C.C. Özcan, The effect of Dutch disease in the tourism sector: the case of Mediterranean Countries, Tour. Hosp. Manag. 26 (1) (2020) 97–114.
[11] L. Yu, Tourism in the Egyptian Red Sea area: a responsible development approach, Hosp. Rev. 12 (2) (1994) 4.
[12] W. Gladstone, B. Curley, M.R. Shokri, Environmental impacts of tourism in the Gulf and the Red Sea, Mar. Pollut. Bull. 72 (2) (2013) 375–388.
[13] P. Picazo, S. Moreno-Gil, Tour operat'rs' marketing strategies and their impact on prices of sun and beach package holidays, J. Hosp. Tour. Manag. 35 (2018) 17–28.
[14] Hilmi, N., Safa, A., & Reynaud, S. (2012). Coral reefs and tourism in Eg'pt's red sea. Topics in Middle Eastern and North African Economies, 14.
[15] Millennium Ecosystem Assessment (2005), Ecosystems and human well-being: wetlands and water. World resources institute, Washington, DC.
[16] R. Buckley, Tourism and environment, Annu. Rev. Environ. Resour. 36 (2011) 397–416.
[17] Macagno, G., Loureiro, M., Nunes, P.A., & Tol, R.S. (2009). Assessing the impact of biodiversity on tourism flows: a model for tourist behaviour and its policy implications.
[18] J.D. DiBattista, M.B. Roberts, J. Bouwmeester, B.W. Bowen, D.J. Coker, D. F. Lozano-Cortés, M.L. Berumen, A review of contemporary patterns of endemism for shallow water reef fauna in the Red Sea, J. Biogeogr. 43 (3) (2016) 423–439.
[19] J.S. Hannak, S. Kompatscher, M. Stachowitsch, J. Herler, Snorkelling and trampling in shallow-water fringing reefs: Risk assessment and proposed management strategy, J. Environ. Manag. 92 (10) (2011) 2723–2733.
[20] Lubchenco, J., & Haugan, P.M. (2023). The Expected Impacts of Climate Change on the Ocean Economy. In The Blue Compendium: From Knowledge to Action for a Sustainable Ocean Economy (pp. 15-50). Cham: Springer International Publishing.
[21] H. Cesar, Economic valuation of the Egyptian Red Sea Coral Reefs, Egypt. Environ. Policy Program (2003) 88 p..
[22] I.M. Shaalan, Sustainable tourism development in the Red Sea of Egypt threats and opportunities, J. Clean. Prod. 13 (2) (2005) 83–87.
[23] T.A. Abdelmawgoud, Analyzing the Egyptian hotel capacity: an exploratory study, Int. J. Tour. Hosp. Manag. 2 (2) (2019).

[24] K. Dewidar, Changes in the shoreline position caused by natural processes for coastline of Marsa Alam–Hamata, Red Sea, Egypt, Int. J. Geosci. 2 (04) (2011) 523.

[25] P. Chen, Y. Zhao, D. Zuo, X. Kong, Tourism, Water pollution, and waterway landscape changes in a traditional village in the Huizhou Region, China, Land 10 (8) (2021) 795.

[26] Z. Liu, J. Lan, F. Chien, M. Sadiq, M.A. Nawaz, Role of tourism development in environmental degradation: A step towards emission reduction, J. Environ. Manag. 303 (2022) 114078.

[27] K. Swangjang, P. Kornpiphat, Does ecotourism in a Mangrove area at Klong Kone, Thailand, conform to sustainable tourism? A case study using SWOT and DPSIR, Environ., Dev. Sustain. (2021) 1–26.

[28] S. Gössling, C.M. Hall, D. Scott, Coastal and ocean tourism, Handb. Mar. Environ. Prot.: Sci., Impacts Sustain. Manag. (2018) 773–790.

[29] M.B. Orams, M. Lück, Coastal and marine tourism, Wiley Black Companion Tour. (2014) 479–489.

[30] M. Papageorgiou, Coastal and marine tourism: a challenging factor in marine spatial planning, Ocean Coast. Manag. 129 (2016) 44–48.

[31] L. Wang, H. Zhang, The impact of marine tourism resources development on sustainable development of marine economy, J. Coast. Res. 94 (SI) (2019) 589–592.

[32] S. Zubair, D. Bowen, J. Elwin, Not quite paradise: Inadequacies of environmental impact assessment in the Maldives, Tour. Manag. 32 (2) (2011) 225–234.

[33] K. Kleinhaus, A. Al-Sawalmih, D.J. Barshis, A. Genin, L.N. Grace, O. Hoegh-Guldberg, M. Fine, Science, diplomacy, and the Red Sea's unique coral reef: it's time for action, Front. Mar. Sci. 7 (2020) 90.

[34] A. Shoaira, A. Maher, D. Mandour, The impact of coral reefs conservation on SCUBA diving tourism sustainability, J. Fac. Tour. Hotels-Univ. Sadat City 3 (2019) 2.

[35] S. Gedik, S. Mugan-Ertugral, The effects of marine tourism on water pollution, Fresenius Environ. Bull. 28 (2) (2019) 863–866.

[36] NUS, National University of Singapore Blog (2020) ⟨https://blog.nus.edu.sg/nomadchronicles/2020/09/11/a-troubled-paradise-boracay-islands-paradise-or-polluted-disaster/⟩, accessed in October 2024.

[37] Reyes, C.M., Albert, J.R.G., Quimba, F.M.A., Ortiz, M.K.P., & Asis, R.D. (2018). The Boracay closure: Socioeconomic consequences and resilience management (No. 2018-37). PIDS Discussion Paper Series.

[38] C. Linnes, J. Agrusa, G. Ronzoni, J. Lema, What tourists want, a sustainable paradise, Tour. Hosp. 3 (1) (2022) 164–183.

[39] L.A. Manrai, A.K. Manrai, S. Friedeborn, Environmental determinants of destination competitiveness and its Tourism Attractions-Basics-Context, ABC, indicators: a review, conceptual model and propositions, J. Econ., Financ. Adm. Sci. 25 (50) (2020) 425–449.

[40] V.M. Robinson, H.A. Schänzel, A tourism inflex: generation Z travel experiences, J. Tour. Futures 5 (2) (2019) 127–141, https://doi.org/10.1108/JTF-01-2019-0014.

[41] Edwards, A.J. (1987). Red Sea. Elsevier. ISBN: 9781483285993.

[42] Safaa A. Ghoneim, Walid A. Abdellatif, A customized indicator-based tool to assess resiliency of egyptian coastal cities: case study of red sea cities, Civ. Eng. Archit. 10 (6) (2022) 2554–2571, https://doi.org/10.13189/cea.2022.100624.

[43] Head, S.M. (1987) Corals and Coral Reefs of the Red Sea. In: Edwards, A.J. and Head, S.M., Eds., Key Environments: Red Sea, Pergamon Press, Oxford, 128-151. https://doi.org/10.1016/B978-0-08-028873-4.50012-8.

[44] M.L. Berumen, R. Arrigoni, J. Bouwmeester, T.I. Terraneo, F. Benzoni, Corals of the Red Sea, Coral reefs Red. Sea (2019) 123–155.

[45] PERSGA (2010). The Status of Coral Reefs in the Red Sea and Gulf of Aden: 2009. PERSGA Technical Series Number 16, PERSGA, Jeddah.

[46] Hawkins, J.P., & Roberts, C.M. (1996). The growth of coastal tourism in the Red Sea: present and possible future effects on coral reefs. Biological Conservation, 2 (76), 216.

[47] E.R. Hall, E.M. Muller, T. Goulet, J. Bellworthy, K.B. Ritchie, M. Fine, Eutrophication may compromise the resilience of the Red Sea coral Stylophora pistillata to global change, Mar. Pollut. Bull. 131 (2018) 701–711.

[48] C.S. Yentsch, C.M. Yentsch, J.J. Cullen, B. Lapointe, D.A. Phinney, S.W. Yentsch, Sunlight and water transparency: cornerstones in coral research, J. Exp. Mar. Biol. Ecol. 268 (2) (2002) 171–183.

[49] Z.A. Mohamed, Potentially harmful microalgae and algal blooms in the Red Sea: current knowledge and research needs, Mar. Environ. Res. 140 (2018) 234–242.

[50] B.S. Halpern, S. Walbridge, K.A. Selkoe, C.V. Kappel, F.' Micheli, C. d'Agrosa, R. Watson, A global map of human impact on marine ecosystems, Science 319 (5865) (2008) 948–952.

[51] P. O'connor, User-generated content and travel: A case study on Tripadvisor. com. Information and Communication Technologies in Tourism 2008, Springer, Vienna, 2008, pp. 47–58.

[52] A. Valdivia, M.V. Luzón, F. Herrera, Sentiment analysis in TripAdvisor, IEEE Intell. Syst. 32 (4) (2017) 72–77.

[53] A. Ćulibrk, O. Tzoraki, M.E. Portman, Adaptation of a freshwater evaluation framework to a coastal system: the case of Kamari, Santorini, J. Environ. Manag. 288 (2021) 112406.

[54] Patton, M.Q. (2014). Qualitative research & evaluation methods: Integrating theory and practice. Sage publications.

[55] C. Benoot, K. Hannes, J. Bilsen, The use of purposeful sampling in a qualitative evidence synthesis: a worked example on sexual adjustment to a cancer trajectory, BMC Med Res Method. 16 (2016) 21, https://doi.org/10.1186/s12874-016-0114-6.

[56] L.A. Palinkas, S.M. Horwitz, C.A. Green, J.P. Wisdom, N. Duan, K. Hoagwood, Purposeful sampling for qualitative data collection and analysis in mixed method implementation research, Adm. Policy Ment. Health Ment. Health Serv. Res. 42 (2015) 533–544.

[57] G. Guest, A. Bunce, L. Johnson, How many interviews are enough? An experiment with data saturation and variability, Field Methods 18 (1) (2006) 59–82.

[58] M.M.A. Kotb, R.G. Hartnoll, A.F. Ghobashy, Coral reef community structure at Ras Mohammed in the northern Red Sea, Trop. Zool. 4 (2) (1991) 269–285.

[59] J.P. Hawkins, C.M. Roberts, Effects of recreational SCUBA diving on fore-reef slope communities of coral reefs, Biol. Conserv. 62 (3) (1992) 171–178.

[60] A.H. All, A. Emara, Benthic community associated with coral reefs in the coastal area of Gulf of Aqaba, Red Scs, Egypt, Egypt. J. Aquat. Biol. Fish. 11 (4) (2007) 95–108.

[61] W. Leujak, R.F. Ormond, Quantifying acceptable levels of visitor use on Red Sea reef flats, Aquat. Conserv.: Mar. Freshw. Ecosyst. 18 (6) (2008) 930–944.

[62] M. Ammar, H.A. Madkour, Quantification of coral reef communities along the Gulf of Aqaba and Ras Mohammed, Red. Sea, Egypt. Curr. Trends Ecol. 2 (2011) 35–54.

[63] Mostafa. (2003). Assessment of Coral Reef Communities At Abu-Dabab, North of Marsa Alam Egypt.

[64] M. Hanafy, Effects of recreational scuba diving and snorkeling on coral reefs of the sheltered bays of the Red Sea, Egypt, Egypt. J. Aquat. Biol. Fish. 16 (4) (2012) 43–56.

[65] T. Attalla, M. Kotb, M. Hanafy, S. Mohammed, Status of the fringing coral reefs in the southern Egyptian coast of the Red Sea, Egypt. J. Aquat. Biol. Fish. 19 (4) (2015) 51–67.

[66] W. Okulicz-Kozaryn, The economics of tourism in Egypt: three reasons for the fall of the tourist flow, Glob. Manag. 107 (2016).

[67] Walsh, C.M. (2020). Created vulnerabilities: political economy of tourism development in Sharm El Sheikh.

[68] C. Corinaldesi, F. Marcellini, E. Nepote, E. Damiani, R. Danovaro,). Impact of inorganic UV filters contained in sunscreen products on tropical stony corals (Acropora spp.), Sci. Total Environ. 637 (2018) 1279–1285.

[69] Hussein, H.N., Ghallab, A., & Al-Hammady, M.A. (2020) Effect of Urbanization Development on Coral Reef at Marsa Alam Coast, Southern Egyptian Red Sea.

[70] A. Nassar, M. Ismail, A. Abu El-Regal, M, Resilience drivers in some coral reef sites in Wadi El-Gemal marine protected area, Southern Egyptian Red Sea, Egypt. J. Aquat. Biol. Fish. 25 (1) (2021) 699–720.

[71] {C}Voolstra, C.R., & Berumen, M.L. (Eds.){C}. (2019). Coral reefs of the Red Sea (Vol. 11). Berlin/Heidelberg, Germany: Springer.

[72] M.S. Pratchett, S.K. Wilson, M.L. Berumen, M.I. McCormick, Sublethal effects of coral bleaching on an obligate coral feeding butterflyfish, Coral Reefs 23 (2004) 352–356.

[73] J. Miguéns, R. Baggio, C. Costa, Social media and tourism destinations: TripAdvisor case study, Adv. Tour. Res. 26 (28) (2008) 1–6.

[74] UNEP (2019), ⟨https://www.unep.org/news-and-stories/story/protecting-egypts-colourful-coral-reefs-green-fins⟩, accessed in March 2024.

[75] U. Khan, Does tourism boost economic growth: an evidence from Italy, Int. J. Econ. Bus. Adm. 8 (4) (2020) 214–222.

[76] C.F. Tang, I. Ozturk, Is tourism a catalyst of growth in Egypt? Evidence from Granger non-causality and the generalised variance decomposition analysis, Anatolia 28 (2) (2017) 173–181.

[77] C. Fezzi, D.J. Ford, K.L. Oleson, The economic value of coral reefs: climate change impacts and spatial targeting of restoration measures, Ecol. Econ. 203 (2023) 107628.

[78] OECD (2020), "Egypt", in *OECD* Tourism Trends and Policies 2020, OECD Publishing, Paris, https://doi.org/10.1787/6b47b985-en.

[79] I. Elgammal, C. Wilbert, Tourism mobilities, marriages and 'mimicking': some experiences of domestic migrant tourist workers in Sharm El Sheikh, Ann. Leis. Res. 16 (4) (2013) 332–347.

[80] W.R. Eadington, M. Redman, Economics and tourism, Ann. Tour. Res. 18 (1) (1991) 41–56.

[81] D.C. Frechtling, E. Horváth, Estimating the multiplier effects of tourism expenditures on a local economy through a regional input-output model, J. Travel Res. 37 (4) (1999) 324–332.

[82] H. Perkins, D.A. Grace, Ecotourism: supply of nature or tourist demand? J. Ecotourism 8 (3) (2009) 223–236.

[83] M. Cucculelli, G. Goffi, Does sustainability enhance tourism destination competitiveness? Evidence from Italian destinations of excellence, J. Clean. Prod. 111 (2016) 370–382.

[84] G. Goffi, M. Cucculelli, L. Masiero, Fostering tourism destination competitiveness in developing countries: The role of sustainability, J. Clean. Prod. 209 (2019) 101–115.

[85] S. Grafeld, K. Oleson, M. Barnes, M. Peng, C. Chan, M. Weijerman, Div'rs' willingness to pay for improved coral reef conditions in Guam: an untapped source of funding for management and conservation? Ecol. Econ. 128 (2016) 202–213.

[86] M. Reynisdottir, H. Song, J. Agrusa, Willingness to pay entrance fees to natural attractions: an Icelandic case study, Tour. Manag. 29 (6) (2008) 1076–1083.

[87] R. Tawfik, The application of D(A)PSI(W)R(M) framework to coral reef conservation, Sustainability 15 (11) (2023) 9133, https://doi.org/10.3390/su15119133.

[88] J.L. Nicolau, F.J. Mas, The influence of distance and prices on the choice of tourist destinations: the moderating role of motivations, Tour. Manag. 27 (5) (2006) 982–996.

[89] Egypt Independent, 2018, accessed in September 2023: https://egyptindependent.com/sharm-El Sheikh-and-hurghada-ranked-lowest-costing-luxury-holiday-destinations-in-the-world/.
[90] A. Eladawy, N.C. Mitchell, T. Nakamura, M. El-Husseiny, Y.A. Takagi, N. Elhady, J.P. Walsh, Towards a combined human-natural system approach in the Northern Red Sea Region: ecological challenges, sustainable development, and community engagement, Mar. Policy 159 (2024) 105917.
[91] T.M. Cheng, H.C. Wu, How do environmental knowledge, environmental sensitivity, and place attachment affect environmentally responsible behavior? An integrated approach for sustainable island tourism, J. Sustain. Tour. 23 (4) (2015) 557–576.
[92] J. Liu, J. Li, S.S. Jang, Y. Zhao, Understanding tourists' environmentally responsible behavior at coastal tourism destinations, Mar. Policy 143 (2022) 105178.
[93] A. Gohar, G.M. Kondolf, Sustainable tourism along the red sea: still possible? eScholarship, Univ. Calif. (2016) https://doi.org/10.13189/cea.2016.040201.
[94] A. Gohar, G.M. Kondolf, How eco is eco-tourism? A systematic assessment of resorts on the Red Sea, Egypt, Sustainability 12 (23) (2020) 10139.
[95] R. Danovaro, L. Bongiorni, C. Corinaldesi, D. Giovannelli, E. Damiani, P. Astolfi, L. Greci, A. Pusceddu, Sunscreens cause coral bleaching by promoting viral infections, Environ. Health Perspect. 116 (4) (2008) 441–447.
[96] Hawaii SB2571 (2018). https://www.capitol.hawaii.gov/session2018/bills/SB2571_.HTM. Accessed November 2023.
[97] L. Bongiorni, D. Giovanelli, B. Rinkevich, A. Pusceddu, L.M. Chou, R. Danovaro, First step in the restoration of a highly degraded coral reef (Singapore) by in situ coral intensive farming, Aquaculture 322 (2011) 191–200.
[98] R. Danovaro, J. Aronson, R. Cimino, C. Gambi, P.V. Snelgrove, C. Van Dover, Marine ecosystem restoration in a changing ocean, Restor. Ecol. 29 (2021) e13432.
[99] S. Fraschetti, C. McOwen, L. Papa, N. Papadopoulou, M. Bilan, C. Boström, G. Guarnieri, Where is more important than how in coastal and marine ecosystems restoration, Front. Mar. Sci. 8 (2021) 626843.
[100] D.E. Matorres, M. Fabinyi, V. Horigue, C.T. Novilla, M.V. Baria-Rodriguez, Institutional dimensions of coral reef restoration in the Philippines, Environ. Sci. Policy 156 (2024) 103734.
[101] M. Omori, Coral restoration research and technical developments: what we have learned so far, Mar. Biol. Res. 15 (7) (2019) 377–409.
[102] B. Rinkevich, Climate change and active reef restoration—ways of constructing the "reefs of tomorrow, J. Mar. Sci. Eng. 3 (1) (2015) 111–127.
[103] A.W. Datta, C. Wyborn, B.C. Chaffin, M.L. Barnes, Imagining reef futures after mass coral bleaching events, Environ. Sci. Policy 151 (2024) 103625.
[104] S. Khalid, M.S. Ahmad, T. Ramayah, J. Hwang, I. Kim, Community empowerment and sustainable tourism development: the mediating role of community support for tourism, Sustainability 11 (22) (2019) 6248.
[105] M. Muganda, A. Sirima, P.M. Ezra, The role of local communities in tourism development: grassroots perspectives from Tanzania, J. Hum. Ecol. 41 (1) (2013) 53–66.
[106] A.I. Sulaiman, C. Chusmeru, B. Kuncoro, The educational tourism (edutourism) development through community empowerment based on local wisdom and food security, Int. Educ. Res. 2 (3) (2019) p1-p1.