Regional Studies in Marine Science 45 (2021) 101813

Contents lists available at ScienceDirect

Regional Studies in Marine Science

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

Effects of recreational SCUBA diving on coral reefs with an emphasis on tourism suitability index and carrying capacity of reefs in Kish Island, the northern Persian Gulf

Mohammad Reza Shokri [a,*], Maryam Mohammadi [b]

[a] Department of Animal Sciences and Marine Biology, Faculty of Life Sciences and Biotechnology, Shahid Beheshti University, G.C., Evin, Tehran, Iran
[b] Environment Department, Kish Free Trade Zone Organization, Kish Island, Iran

ARTICLE INFO

Article history:
Received 2 March 2021
Received in revised form 23 April 2021
Accepted 27 April 2021
Available online 29 April 2021

Keywords:
Diving tourism
Impact assessment
Coral reefs
Habitat suitability
Carrying capacity

ABSTRACT

The popularity of ecotourism in Kish Island located off the southern coast of Iran in the Persian Gulf has increased over the last 30 years with a large development of a SCUBA diving industry. The suitability and carrying capacity of seven sites were assessed and management strategies proposed. The Tourism Suitability Index (TSI) for snorkeling and SCUBA diving was determined based on some criteria. The plausible effect of SCUBA diving on reef health was assessed with the Reef Health Index. The tourism carrying capacity (TCC) was assessed based on physical and biological conditions of each site, the infrastructure, the equipment available, and the characteristics of the service providers and the administrators of the Kish Free Trade Zone Organization. The RHI index showed that, except for one reef with a fair condition, the health condition of the remaining reefs was good. TSI results showed that all reefs were categorized as suitable for snorkeling. Whereas, of seven reefs, one reef was conditionally suitable, and the remaining reefs were categorized as suitable for SCUBA diving. The TCC values ranged between 31,727 and 336,313 dives/year, with a total of 822,716 dives/year for all seven sites. Only two sites were the most visited with the TCC ranging from 61,427 to 75,116 dives/year. These numbers were lower than the actual number of recreational visitors to these two sites (273,750 dives per year) suggesting a need for adequate preventive management if these diving sites are to maintain their aesthetic appeal and biological characteristics. Such management may initially be directed towards dictating diving clubs to use less-visited sites, to use the sites based on their proposed TCC value, and to create their man-made sites. These results suggest that several reefs around Kish Island are suitable for SCUBA diving, and can be promoted as a suitable destination.

1. Introduction

The tourism sector accounts for 5% of the global economy (Buckley, 2011). With a growth rate of 6.2% per annum, the annual tourism's economic value reached US$1 trillion in 2011 and the international tourist arrivals hit 1.5 billion in 2019 confirming tourism as a leading and resilient economic sector, especially given current uncertainties (UNWTO, 2020).

In recent years, because of the development of tourism-related infrastructure in various Persian Gulf countries, especially Bahrain, Qatar, and the UAE, tourism has grown significantly in the region (Nadim et al., 2008; Burt and Bartholomew, 2019; Vaughan et al., 2019). The number of annual tourists from the Persian Gulf countries almost tripled from 8.2 million in 1995 to 22.9 million in 2010 (Gladstone et al., 2013). In some Gulf States, such as the UAE, recent development projects have revolved around the policy of economic diversification in response to the continued depletion of oil reserves (Stephenson, 2014). Coastal resorts and activities such as SCUBA diving, deep-sea fishing, and wildlife watching are expanding with the rapidly growing Persian Gulf tourism industry, especially in the warmer southern countries (Gladstone et al., 2013).

The Persian Gulf, the world's warmest sea, is home to the most tolerant coral reef species (Burt et al., 2014). Yet, considering the increasing frequency and intensity of bleaching events in this sea and the above global rates of regional warming, the capacity for recovery and the projection for the future of the reefs in this region are not optimistic (Riegl et al., 2018; Burt and Bartholomew, 2019). Superimposed on natural threats, coastal development will continue in the Persian Gulf with increased rates of landfill and dredging causing more stress to the nearshore reefs (Burt, 2014; Burt et al., 2017). Despite the paucity of specific assessments dedicated to the valuation of services provided by the Persian Gulf reef ecosystems, the countries of the region

* Corresponding author.
E-mail addresses: M_Shokri@sbu.ac.ir (M.R. Shokri), Maryam.Mohammadi@kish.ir (M. Mohammadi).

https://doi.org/10.1016/j.rsma.2021.101813
2352-4855/

earn a relatively high income from reef ecosystem services. In Abu Dhabi, for example, the amenity value of coastal beaches is estimated at US$824 million in tourism revenue for the UAE, with beach habitats valued between US$8.3 million and US$13.8 million per hectare (Blignaut et al., 2016).

The rapid growth of tourism in the Iranian coasts of the Persian Gulf reveals increased diversification of water recreational activities. The numbers of local and international tourists have been increased in coastal areas of Iran following the establishment of free trade zones e.g. Kish and Qeshm free trade zones, and Pars Special Economic Energy Zone (Gladstone et al., 2013). A comparison of the number of incoming passengers to Kish Island during different months of the years 2012 to 2018 indicates the presence of the maximum number of passengers in April followed by March and February. Accordingly, the minimum number of incoming passengers to the island is from May to September. According to the data obtained from the Tourism Affairs Deputy of the Kish Free Trade Zone Organization (KFTZO), the number of incoming passengers to Kish Island shows a relative increase in the number of passengers from the year 2012 with 1,306,189 passengers to about 2,042,357 passengers in 2018 with an average growth rate of 0.08% during this period. According to the data obtained from the Tourism Affairs Deputy of KFTZO, there are 22 water recreation centers and clubs at Kish Island providing equipment and facilities for a wide range of water sports including swimming, snorkeling, SCUBA diving, cable skiing, jet skiing, submarine scooter, and spear and hook fishing. Kish shallow reefs are suitable for SCUBA diving, even for people who do not have certified diving experience. On the other hand, sensitive coral ecosystems around this island have been directly and indirectly affected by water sports. Recreation activities in Iran and other regions across the world have been reported to cause habitat damage such as trampling of intertidal areas and shallow reefs, breakage of corals by divers and snorkelers, anchor damage to corals, and ship and land-based litter (Jameson et al., 1999; Barker and Roberts, 2004; Aghajan Pour et al., 2012; Au et al., 2014; Werner et al., 2016). Over-collecting of curios and bait for fishing and trampling by tourists have been led to the depletion of wildlife, particularly intertidal organisms (Gladstone et al., 2013). Therefore, management of coral reef-based tourism and minimizing the impact of tourism on coral reefs are essential to ensure the sustainable development of the coral reef ecosystem.

Ecological carrying capacity defined as the ability of a resource to resist recreational use without unacceptable damage to its ecological components is widely used in the management of diving tourism (Shelby and Heberlein, 1987). However, there is no global consensus on the criteria for quantifying carrying capacity at diving sites. The carrying capacity of a diving site can be expressed as the number of divers per site per year and as a measure of the number of divers a reef could tolerate without enduring significant degradation (Salm, 1986). Methods and results of previous studies determining carrying capacities for coral reefs around the world shows that ecological transport capacity is usually determined experimentally using quadrat or photoquadrat, the most widely accepted method of obtaining information about the coral status of a diving site (Dixon et al., 1993, 1995; Harriott et al., 1997; Hawkins and Roberts, 1997; Schleyer and Tomalin, 2000; Zakai and Chadwick-Furman, 2002; Barker and Roberts, 2004; Serour and Kangas, 2005; Leujak and Ormond, 2007). Other than the magic number that is the maximum number of divers/dives, a rate by which a site can sustain, the relationship between the influence of the diver and diving activity has been also considered. Hawkins and Roberts (1997) argued that this relationship as a non-linear equation may take the form of a J- or S-curve. If the curve is J, diver-induced impacts would appear minor up to a certain level of activity but would become quickly noticeable upon reaching a critical level. However, when a phase shift occurs after a period of exponential advance in damage to habitat, and habitat degradation stabilizes at an unhealthy condition, then it turns into an S curve.

So far, no study has been accomplished to assess the impact of water sports on coral reefs in Kish Island. To our knowledge, no study also has been dedicated in the Persian Gulf to assess the suitability of reefs for water sports, in particular for snorkeling and SCUBA diving. Likewise, there are no published materials in this region aiming to assess the carrying capacity of reefs for SCUBA diving as the main water sport damaging coral reefs. To bridge the gap of knowledge on the impact of SCUBA diving on coral reefs of Kish Island, and for adequate preventive management of diving sites to maintain their aesthetic appeal and biological characteristics, the present study was carried out with the followings objectives: (1) to assess the effect of SCUBA diving on coral reefs of Kish Island, and (2) measuring the suitability and carrying capacity of reefs in this island.

2. Material and methods

2.1. Study area and data collection

The present study was undertaken in Kish Island with an area of 91.5 km^2 located off the southern coast of Iran in the Persian Gulf (26° 32' N, 53° 58' E) (Fig. 1). Kish Island with a population of 40,000 and free trade zone status is a famous tourist destination, with shopping malls, tourist attractions, and leisure hotels attracting about 1 million visitors annually. Tourists from foreign countries for which Iran typically requires a visa are exempt from visas to enter this island. The island has the best and newest water and sea recreation opportunities including swimming, snorkeling, SCUBA diving, cable skiing, jet skiing, submarine scooter, and spear and hooks fishing. Of the total economic value of US$14.6 million yr^{-1}; 62% is attributed to recreational activities in Kish Island (Madani et al., 2012).

Coral reefs around this island occur as unconnected patchy reefs at a depth of 3 to 18 m and are mostly found on the east, north, and southeast (Fig. 1). Due to the proximity of major coral reefs to the beach (i.e., ≈10 m), SCUBA divers can reach the corals by shore diving. Yet, amateur divers are strongly recommended to do boat diving. Due to the existence of hotels and diving clubs in the east of the island, the coral reefs at the east of the island are highly visited by divers, thus, these reefs have been saturated by visitors. Anchoring is prohibited at the eastern side and the effect of hand-line fishing is negligible. The majority of damages recorded should be due to diving-related activities.

A total of seven coral reef patches were surveyed within two periods: (1) March 2017, during the Persian New Year, as a period with maximum visitors to coral reefs, and (2) December 2018 as a period with the lowest number of visitors to coral reefs. The benthic composition of the sea bed at each location was determined by the Line Intercept Transect survey method described in Reef Check Instruction Manual (Hodgson et al., 2006). At each location, four transects (4 × 20 m, fiberglass measuring tape) were laid out parallel to the shore at the depth of 3–6 m where the highest coral cover exists. Once the transects were laid down on the seabed, the diver swam slowly along the transect recording onto the datasheet the lifeforms encountered under the tape. At each point where the benthic lifeform changed, the diver recorded the name of lifeform and substrate type including live hard coral, recently killed coral, coral rubble, nutrient indicator algae, soft coral, sponge, non-living bottom type (rock, sand, and silt/clay), and others (e.g., sea anemone, tunicates). Finally, the percent cover of a lifeform category was calculated for each 20 m transect and each location by averaging the data of four 20 m

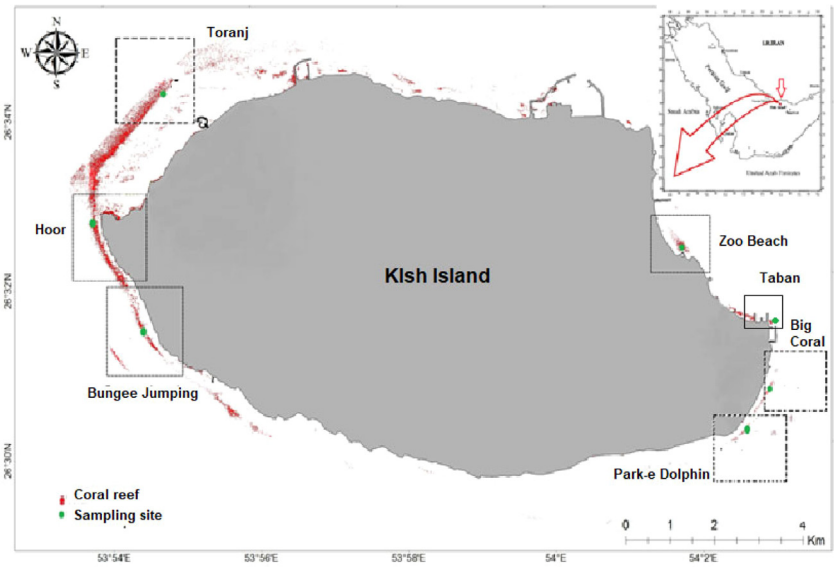

Fig. 1. Map of coral reefs of Kish Island and sampling sites (Kabiri, 2018).

transects. The possible damages caused by the anchors, fin kicks, pushing or holding coral, dragging gear, and kneeling/standing on corals were recorded in each reef. Vertical zonation at each reef was explored by swimming across a transect line being laid perpendicular to the shore starting from the 1 m depth extending to the offshore to a maximum depth of 20 m (Hill and Wilkinson, 2004).

Survey locations were chosen purposively by considering the number of tourist visits in crowded, medium, and quiet tourism locations. In doing so, three (i.e., Zoo Beach, Big Coral, Park-e Dolphin), two (i.e, Taban, Toranj), and two (i.e., Hoor, Bungee Jumping) reefs were considered as crowded, medium, and quiet tourism locations, respectively (Fig. 1). At each location, reef fish abundance and biodiversity were determined qualitatively by visual underwater observations and quantitatively by the Fish Belt Transect survey method described in Reef Check Instruction Manual (Hodgson et al., 2006). In the Fish Belt Transect survey, four 5-m-wide (centered on the transect line) by 20-m-long segments were sampled for all fish species. Unlike the Reef Check method, in which only those fish being targeted by fishermen, aquarium collectors, and others are counted, in the present study, the whole fish community was examined (Bargahi et al., 2020). Fish seen up to 5 m above the line are included.

2.2. The plausible effect of SCUBA diving activities on reef health

The plausible effect of SCUBA diving activities on reef health was assessed using the Reef Health Index developed by Healthy Reefs for Healthy People (HRI, 2021). The RHI was calculated using four indicators: (i) live coral cover; (ii) fleshy macroalgae cover; (iii) biomass of herbivorous fish (g 100 m-2), of the families Scaridae and Acanthuridae; and (iv) biomass of commercial fish (g 100 m-2), using only the families Lutjanidae and Serranidae. Scaridae and Acanthuridae were used due to their important functional role in coral reefs. As the most important grazers with the reef, Scaridae, and Acanthuridae reduce the overgrowth of fleshy macroalgae (Díaz Pérez et al., 2016). Snappers (Lutjanidae) and serranids as the most important commercial fish play an important trophic role as carnivores that exert a strong predatory influence in the coral reefs (Díaz Pérez et al., 2016). The mean value of each indicator was converted to an ordinal scale indicating five grades of health, with values of 1 (“critical”), 2 (“poor”), 3 (“fair”), 4 (“good”), and 5 (“very good”).

2.3. Tourism suitability index analysis of reefs for snorkeling and SCUBA diving

Data related to tourism suitability parameters for each surveyed reef were collected through direct on-site observation as well as systematically by online questionnaire forms. In doing so, a survey of the tourists and tour operators that come to Kish Island was conducted using questionnaires and interviews. The questionnaires (see supplementary) used in this study were adapted from the questionnaires used in carrying capacity assessment project in Pulau Payar Marine Park, Malaysia with some modifications (Ching Lim, 1998). These investigations addressed the perceptions of Kish Island's reef users with particular reference to reef status, diver satisfaction, and marine conservation awareness.

Besides, to determine the carrying capacity of the area, interviews were also conducted to investigate the perspectives of the relevant stakeholders including diving club managements, tourists/visitors.

The tourism suitability index (TSI) for snorkeling and SCUBA diving at each surveyed reef was determined based on a suit of criteria (Yulianda, 2007) with some modification as detailed in Tables 1 and 2. The rank or score assigned to each of these variables (criteria) was estimated based on the amount of that variable in each reef relative to the domains assigned to the respective variable (Tables S1, S2, 3 and 4). The reason for choosing these variables is based on the degree of satisfaction of the snorkeler and SCUBA divers from performing these activities. So that snorkel and SCUBA diving satisfaction are positively and directly related to water transparency, percentage of live coral reef cover, number of living forms, the richness of reef fish species, the width of coral reef (due to increasing in available area for more people), the distance of the coral reef front from the shore (due to the ease of access and less distance to access the coral reef), and the ease of entering the water (safe entry into the water). On the other hand, snorkel satisfaction is negatively related to flow velocity (due to high energy expenditure for swimming and maintaining buoyancy in areas with high flow velocity), and coral reef depth (due to reduced depth of vision).

Water transparency was determined from the average values recorded during the diving operation. The percentage cover of live corals and the species richness of reef fish were also calculated by Line Intercept and Fish Belt transects surveys, respectively. The

Table 1
Criteria for the TSI analysis for snorkeling.

Parameter	Weight	Category (SI)	Score	Category (S2)	Score	Category (S3)	Score	Category (N)	Score
Water visibility (m)	5	25	3	10–<25	2	5–<10	1	<5	0
Coral cover (%)	5	>50	3	20–<50	2	10–<20	1	<10	0
Lifeform no.	5	>10	3	<5–10	2	3–5	1	<3	0
Reef fish species	3	>50	3	30–50	2	10–30	1	<10	0
Current velocity (cm/sec)	1	0-50 (0-1 knots)	3	>50-100 (1-2 knots)	2	>100-150 (2-3 knots)	1	>150 (>3)	0
Reef depth (m)	1	1–3	3	>3–4	2	>4–5	1	>5	0
Reef width (m)	1	>500	3	>100–500	2	20–100	1	<20	0
Reef fore edge distance from the shore (m)	5	<100	3	<100–150	2	150–200	1	>200	0
Water accessibility	3	Very safe	3	Safe	2	Relatively safe	1	Unsafe	0

Table 2
Criteria for the TSI analysis for SCUBA diving.

Parameter	Weight	Category (SI)	Score	Category (S2)	Score	Category (S3)	Score	Category (N)	Score
Water visibility (m)	5	>20	3	10–<20	2	5–<10	1	<5	0
Coral cover (%)	5	>50	3	20–<50	2	10–<20	1	<10	0
Lifeform no.	5	>10	3	<5–10	2	3–5	1	<3	0
Reef fish species	3	>70	3	50–70	2	20–50	1	<20	0
Current velocity (cm/sec)	1	0-50 (0–1 knots)	3	>50–150 (1–3 knots)	2	>150–250 (3–5 knots)	1	>250 (>5)	0
Reef depth (m)	1	0–5	3	>5–10	2	>10–15	1	>15	0

Table 3
Ratings assigned to each snorkeling suitability variable at each reef.

Reef name	Water transparency (m)	Coral cover (%)	Lifeform no.	Coral fish species no.	Current velocity (cm/sec)	Reef depth (m)	Reef width (m)	Reef fore-edge distance from the shore (m)	Water accessibility
Park-e Dolphin	1	1	3	1	2	2	1	3	3
Big Coral	1	1	3	1	3	2	1	2	3
Taban	0	0	2	1	3	3	2	3	1
Zoo Beach	1	2	3	1	3	3	1	2	3
Toranj	1	1	3	1	3	2.5	3	0	2
Hoor	1	0	2	1	3	3	2	2	0
Bungee Jumping	1	0	2	1	3	3	2	1	1

Table 4
Ratings assigned to each SCUBA diving suitability variable at each reef in Kish Island.

Reef name	Water transparency (m)	Coral cover (%)	Lifeform no.	Coral fish species no.	Current velocity (cm/sec)	Reef depth (m)
Park-e Dolphin	1	1	3	1	2	3
Big Coral	1	1	3	1	3	3
Taban	0	0	2	1	3	3
Zoo Beach	1	2	3	1	3	3
Toranj	1	1	3	1	3	2.5
Hoor	1	0	2	1	3	3
Bungee Jumping	1	0	2	1	3	3

number of life forms in each surveyed reef was recorded based on the categories presented in the Tropical Marine Resources Survey Handbook (English et al., 1997). The reef width and the frontal distance of each reef from the shore were obtained based on the images of WorldView-2, QuickBird, and GeoEye-1 satellites (Kabiri, 2018). Given the lack of data on sea current pattern, current flow velocity in each reef was estimated based on the maximum flow velocity calculated in the Environmental Impact Assessment report of the Kish power and desalination plants of Kish Island (Yari, 2015). The depth of each reef was determined in the central section of each reef using hydrographic maps. The degree of ease of access to water was also assessed based on field observations from the shore adjacent to each reef. For example, due to the rocky nature of the Hoor reef, the rank assigned to this coral patch was considered zero.

TSI for each surveyed reef was formulated as follows (Yulianda, 2007):

$$TSI = \sum (Ni/Nmax) \times 100$$

Where TSI is tourism suitability index (%); Ni is the score for each affecting factor, and Nmax is the maximum score for tourism activities.

The results of the calculations were further classified into four classes of suitability including TSI (S1) = 83%–100% (very suitable), TSI (S2) = 50− < 83% (suitable), TSI (S3) = 17− < 50% (conditional suitable), and TSI (N) =< 17% (not suitable).

2.4. Tourism carrying capacity analysis of reefs for SCUBA diving

Tourist carrying capacity (TCC) of each reef was estimated according to the method developed by Cifuentes et al. (1999) and modified by Gallo et al. (2003). In this method, correction

factors were adjusted to match the conditions of underwater activity and probabilistic elements of threat and vulnerability of each surveyed reef. This method allows the establishment of the maximum number of visits that each reef can receive based on its physical, biological, social, and economic conditions and regulations related to service providers and administration of the Kish Free Zone Organization. In doing so, physical carrying capacity (PCC), the real carrying capacity (RCC), and finally, the TCC (expressed as the number of visitor groups per day or the number of visitors (persons) per day) are consequently calculated. It should be noted that different components of the TCC follow the consecutive sequence of PCC $\geq$ RCC $\geq$ TCC; thus, the final estimated value of carrying capacity tends to decrease as each of these calculations is performed.

The physical carrying capacity (PCC) includes a theoretical estimate of the maximum number of visits that can occur physically at a given time and place, without limitations on operational and management capacity (e.g., site access, ecosystem fragility, infrastructure, financing). PCC in each reef is calculated by the following formula:

$$PCC = (\frac{S}{SP}) \times NV$$

In this formula, S is the area available for diving (i.e., coral reef length), SP is the area occupied by each diver, and NV is the number of dives that can be repeated per reef per day, or in other words, the number of visits per day to each reef. Following international diving regulations, divers must dive in pairs, and each diver usually dives along a line and requires 2 m of space. On the other hand, each diver must be 2 m away from the other diver. Therefore, each diver occupies 4 m and therefore the SP will be equal to 4 m (Ríos-Jara et al., 2013). Given the shallow depths of surveyed reefs, so without considering the decompression models, the NV value is calculated from the following formula:

$$NV = \frac{Vt}{Tv}$$

In this formula, Vt is the potential visiting time to dive every day on each reef, which according to a survey of club managers on the island this measure is for 8 h a day (in daylight from 9 am to 4 pm in autumn and winter and from 9 am to 6 pm in spring and summer).

Tv is the time used for each visit. According to a survey of club managers, the Tv for each diving visit was set at 90 min per person per visit. Based on the above formulas, the PCC for each reef is as shown in Table 5.

To calculate the real carrying capacity (RCC), several correction factors were used for each reef. These factors were: (1) social (CFsoc), (2) fragility (CFfg), (3) damage caused by touching (CFdt), and (4) wind accessibility (CFwind). The correction factors were calculated with the following formula:

$$CFx = 1 - \frac{Lmx}{Tmx}$$

In this formula, CFx is the correction factor for the variable x, Lmx is the limiting magnitude of variable x (i.e., the occupancy limits that result from the distance between diving groups), and Tmx is the total magnitude of variable x. Correction factors are equivalent to the empirical probability of variable x, which is related to the relative frequency of variable x, and is estimated based on observations recorded during field operations to assess the physical and biological conditions of the given reef. Therefore, correction factors quantitatively express the non-occurrence probability of x (Gallo et al., 2003).

The social correction factor (CFsoc) expresses various aspects of visit quality to obtain maximum satisfaction while visiting coral reefs. Visits should be undertaken in guided groups to maintain higher safety and control visitor behavior and reduce possible impacts of divers on the environment. According to the rules set by the Recreational SCUBA Training Council (RSTC) and the Professional Association of Diving Instructors (PADI), groups of nine divers (consisting of eight visitors and one guide) should be considered. Besides, the time interval between visitor groups should be 60 min. This interval is equivalent to the time when a group of visitors occupies a diving site so as not to cause interference between divers underwater and their boats on the surface. Based on this restriction, no more than one group of divers should visit a site at a given time. Therefore, to calculate the CFsoc, the limiting size (Lm), which is equivalent to the occupancy limits of a site calculated from the distance between the diving groups, is calculated from the following formula:

$$Lm = S - (P \times Ng)$$

In this formula, S is the distance between the diving groups (equivalent to the length of each reef, taking into account that no more than one group of visitors should occupy a diving site at a given time), P is the number of people in each group (9 divers), and Ng is the number of diving groups per reef, which is considered one group here.

To calculate the number of possible dives per day, or in other words, the number of people per day, taking into account that each person will need four meters of space, first the working time of each reef (i.e., eight hours or 480 min), the time required for diving was divided into 90 min per person and the result was 5.33 people per day in every four meters. Based on the above formula, the amount of CFsoc in each reef is as estimated in Table S3.

To calculate the fragility correction factor (CFfg), the coverage of stony corals was calculated because they are relatively vulnerable to direct contact by divers and anchoring vessels (Hawkins and Roberts, 1992; Vicki et al., 1997; Nickerson-Tietze, 2000; Tratalos and Austin, 2001; Lynch et al., 2004; Uyarra and Côté, 2007).

The branching, massive, and nodular types are the primary growth forms of stony corals at Kish Island. The result of the present study revealed that there were 14 species of stony corals (i.e., *Acropora downingi*, *Dipsastraea speciose*, *D. pallida*, *D. matthai*, *Siderastrea savignyana*, *Psammocora contigua*, *Plesiastrea versipora*, *Platygyra daedalea*, *Cyphastrea serailia*, *C. microphthalma*, *Porites harrisoni*, *P. lutea*, *Turbinaria peltata*, *Pavona decussate*) belonging to the eight families at Kish Island. The distribution of coral reefs is variable, and the greatest coverage occurs in the eastern reefs of the island (Table S4). The amount of CFfg was calculated from the following formula:

$$CFfg = 1 - \frac{C(\%\ \text{fragile coverage})}{100\%}$$

In this formula, CFfg is the fragility factor, and C is the percentage of fragile cover. According to the above formula, the amount of fragility factor for each reef is as estimated in Table S4.

The correction factor of damage caused by touching (CFdt), as a limiting factor, subtracts the mathematical expectation or rate of damage caused by contact with divers. To calculate this factor, the frequency of touching with corals was estimated. According to the previous studies in the Mexican Pacific (Alonso-Domínguez, 2009), the frequency of contact of corals by divers is as shown in Table S5. Since these values have not yet been calculated for the Middle East region, the values in the same table were used to calculate the CFdt for Kish Island.

The CFdt was calculated by the following formula:

$$CFdt = 1 - (\frac{\text{Frequency of touches/diver/min}}{Divetime(\text{min})} \times 100)$$

In this formula, the frequency of contact with corals for each diver per minute in case of deduction and the duration of diving

Table 5
The values of each criterion for estimating the physical carrying capacity (PCC) for each reef in Kish Island.

Reef name	S (m)	SP (m)	NV (visits per day)	Vt (min)	Tv (min)	PCC (visitors per day for given site)
Park-e Dolphin	400	4.00	5.3	480	90	533
Big Coral	368.42	4.00	5.3	480	90	491
Taban	567.65	4.00	5.3	480	90	757
Zoo Beach	550	4.00	5.3	480	90	733
Toranj	2666.67	4.00	5.3	480	90	3556
Hoor	209.68	4.00	5.3	480	90	280
Bungee Jumping	1250	4.00	5.3	480	90	1667

in minutes is the denominator. According to the above formula, the amount of CFdt for each reef is as estimated in Table S6.

To calculate the wind accessibility correction factor (CFwind), the maximum suitable wind speed under which it is possible to dive on Kish Island was obtained from the website of the Iran Meteorological Organization. According to the managers of diving clubs on Kish Island, diving operations in the east of the island can be performed at wind speeds of less than 32 km per hour under the Shamal (north) wind and 24 km per hour under Quas (Kaus, Cowshee) wind that is a gale-force southeasterly wind.

According to 10-year (2007 to 2017) statistics of wind speed, the number of days when the wind speed is more than the above values and diving operations are not possible is 45 days a year on average in Kish Island. Similarly, the number of days when SCUBA diving is possible is equal to 320 days. The amount of CFwind is calculated by the following formula:

$$\text{CFwind} = 1 - \frac{\text{hl}}{\text{ht}}$$

In this formula, hl is the number of hours with the limited wind (suitable for SCUBA diving) per year (320 days × 8 h per day), and ht is the total number of hours per year when SCUBA diving is possible according to the hours with natural daylight (365 days × 8 h a day). Accordingly, the CFwind for each reef is as estimated in Table S7.

Using the values of each correction factor, the real carrying capacity (RCC) is calculated based on the following formula and its values for each reef are as estimated in Table 6.

$$\text{RCC} = \text{PCC} \times \text{CFsoc} \times \text{CFfg} \times \text{CFdt} \times \text{CFwind}$$

Tourism carrying capacity (TCC) for the surveyed reefs in Kish Island was calculated following the method suggested by Cifuentes et al. (1999) based on management capacity (MC) and taking into account variables such as existing tourism infrastructure, equipment, professional capacity, and availability of the environment personnel guards and service providers. Optimal management capacity is one of the most favorable conditions in which the department related to the management of coral reefs in the Kish Free Zone Organization has developed its activities to achieve the intended objectives (Cifuentes et al., 1999). For each variable, different components were considered to facilitate the estimation of management capacity. These components include: (1) infrastructure, such as an office on the island, residential housing for staff, meeting rooms, camping area, trash cans, recycling system, chairs and benches, desks, toilets, baths and showers, drainage or septic tank (wastewater treatment systems), a workshop, a warehouse, mooring pier, buoy, footpaths, road signs and symbols, site map, electricity, and drinking water; (2) equipment, such as meteorological stations, vehicles, and service ships, diving equipment, air compressors, radio communications, fire extinguishers, first aid kits, screens and projection equipment, computers, chainsaws, wheelbarrows, dollies, GPS, and compass; and (3) personnel, such as administrators, rangers, dive guides, service operators, certified boatmen, certified divers, operational protocols and instructions, safety protocols and instructions, and sites use regulations. These components were evaluated according to four criteria including quantity, state, functionality, and location: (1) quantity, which estimates the percentage of the relationship between the available value and the desired value; (2) state, which refers to the conditions of protection and use of each component, such as its maintenance, cleanliness and safety, adequate and safe use of installations, facilities or equipment; (3) location, which includes the appropriate location and spatial distribution of personnel in the area, equipment and infrastructure, and ease of access to these resources; and (4) functionality, which is the result of combining the two criteria of state and location, that is, the practical application of the relevant component to both the criteria of staff and visitors. Although these criteria do not represent the totality of options for evaluating and determining the island's management capacity, they are nevertheless sufficient to achieve a good approximation.

Finally, in order to have a more objective estimation of the island's management capacity, the qualitative criteria were converted to quantitative and percentage-based criteria, from "not satisfactory" equal to zero (>35%), "low satisfactory" equal to 1 (55%–35%), "satisfactory" equal to 2% (% 75%–55%), "high satisfactory" equal to 3% (% 90%–75%), to "very high satisfactory" equal to 4 (90% ≤). The management capacity (MC) of Kish Island was estimated by calculating the average values of infrastructure, equipment, and personnel variables (Table 7). Using the values calculated for management capacity, the tourism carrying capacity (TCC) for each reef was calculated (Table 7) from the following formula.

$$\text{TCC} = \text{RCC} \times \text{MC}$$

In this formula, TCC is the tourism carrying capacity, RCC is the real carrying capacity and MC is the management capacity. The TCC is expressed as the number of diving groups per day, and the number of dives per year, assuming that each group consists of nine visitors (one guide and eight tourists).

3. Results

3.1. The general condition of coral reefs and associated reef fish in Kish Island

The seabed in all the studied reefs mainly follows a more or less uniform morphology. So that the sea bed along the vertical section from the shore to the sea is formed by three zones with a relatively gentle slope: (1) Sand and silt area: The seabed from a depth of zero to 3 m is mainly covered by sediments consisting of sand and silt with a particle size of 0.63–1.63 mm; (2) Coral area: the seabed from a depth of 3 to 18 meters is mainly covered by sand, rocks, and coral colonies. The most turbulent areas are characterized by robust and wave-resistant corals of massive and submassive species (e.g., *Porites*, *Platygyra*, *Dipsastraea*), high surf areas by wave-resistant morphotypes of branching species (e.g., *Acropora*), intermediate depths (e.g., 5–8 m depth) by corals

Table 6
The values of each correction factor and the real carrying capacity (RCC) for each reef in Kish Island.

Station	PCC	CFsoc	CFfg	CFdt	CFwind	RCC (dives/day)	RCC (dives/day)
Park-e Dolphin	533	0.250	0.84	0.81	0.78	70.76	377.13
Big Coral	491	0.250	0.89	0.81	0.78	69.47	370.28
Taban	757	0.250	1.00	0.81	0.78	119.81	638.58
Zoo Beach	733	0.250	0.79	0.81	0.78	92.11	490.95
Toranj	3556	0.250	0.86	0.81	0.78	487.00	2595.69
Hoor	280	0.250	0.96	0.81	0.78	42.48	226.44
Bungee Jumping	1667	0.250	0.96	0.81	0.78	253.86	1353.05

Table 7
Values for calculating each of the variables used in the calculation of management capacity (MC), real carrying capacity (RCC), and tourism carrying capacity (TCC).

Variables	Facilities	Park-e Dolphin	Big Coral	Taban	Zoo Beach	Toranj	Hoor	Bungee Jumping
Infrastructure	Office	4	4	4	4	4	4	4
	Residential housing for staff	4	4	4	4	4	4	4
	Meeting rooms	4	4	4	4	4	4	4
	Trash cans	0	4	4	4	0	2	0
	Recycling system	2	2	2	2	2	2	2
	Chairs and benches	0	3	3	4	0	3	0
	Desks	0	0	0	0	0	0	0
	Baths and showers	4	4	4	4	4	4	4
	Drainage or septic tank (wastewater treatment systems)	4	4	4	4	4	4	4
	Workshop	4	4	4	4	0	0	0
	Warehouse	0	0	0	0	0	0	0
	Mooring pier	0	4	4	4	0	0	0
	Buoy	0	4	0	4	0	0	0
	Footpaths	4	4	4	4	4	4	4
	Road signs and symbols	0	0	0	0	0	0	0
	Site map	0	0	0	0	0	0	0
	Electricity	0	4	4	4	0	0	0
	Drinking water	0	4	4	4	0	4	4
	Mean	**1.6667**	**2.9444**	**2.7222**	**3.0000**	**1.4444**	**1.9444**	1.6667
Equipment	Meteorological stations	4	4	4	4	4	4	4
	Vehicles and service ships	4	4	4	4	4	4	4
	Diving equipment	4	4	4	4	4	4	4
	Air compressors	4	4	4	4	4	4	4
	Radio communications	4	4	4	4	4	4	4
	Fire extinguishers	0	0	0	0	0	0	0
	First aid kits	4	4	4	4	4	4	4
	Screens and projection equipment	4	4	4	4	4	4	4
	Computers	4	4	4	4	4	4	4
	Chainsaws	0	0	0	0	0	0	0
	Wheelbarrows	0	0	0	0	0	0	0
	Dollies	4	4	4	4	4	4	4
	GPS	4	4	4	4	4	4	4
	Compass	4	4	4	4	4	4	4
	Mean	**3.1429**	**3.1429**	**3.1429**	**3.1429**	**3.1429**	**3.1429**	3.1429
Personnel	Administrators	4	4	4	4	4	4	4
	Rangers	4	4	4	4	4	4	4
	Certified boatmen	1	1	1	1	1	1	1
	Certified divers	4	4	4	4	4	4	4
	Operational protocols and instructions	0	0	0	0	0	0	0
	Safety protocols and instructions	1	1	1	1	1	1	1
	Site use regulations	2	2	2	2	2	2	2
	Mean	**2.2857**	**2.2857**	**2.2857**	**2.2857**	**2.2857**	**2.2857**	2.2857
Management capacity (MC) (%)		**2.3651**	**2.7910**	**2.7169**	**2.8095**	**2.2910**	**2.4577**	2.3651
Real carrying capacity (RCC) (Dives/day)		**70.76**	**69.47**	**119.81**	**92.11**	**487.00**	**42.48**	253.86
Tourism carrying capacity (TCC) (Dives/day)		**167.35**	**193.90**	**325.51**	**258.79**	**1,115.71**	**104.41**	600.39
Tourism carrying capacity (TCC) (Dives/year)		**59,575**	**69,027**	**1,15,882**	**92,128**	**3,97,193**	**37,171**	2,13,738

with a wide diversity of morphologies, and greater depths (>8 m) by flattened and plating morphologies (e.g., *Turbinaria, Pavona*); and (3) Coastal alluvial area: The seabed at depths beyond 18 m is mainly covered by fine sand and silt and mostly with a grain size of 0.63 mm.

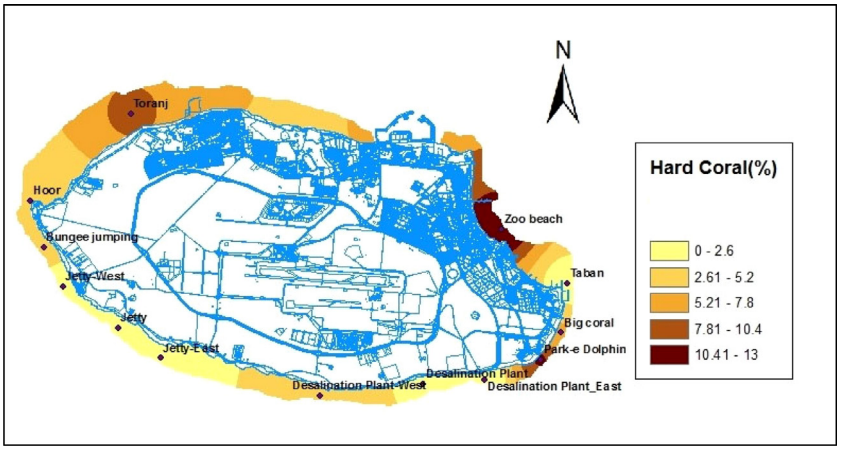

Fig. 2. Distribution pattern of hard live corals on reefs around Kish Island.

The highest percentage of live coral cover was found at Park-e Dolphin reef, followed by Big Coral and Zoo Beach (east of the island) and then at Toranj reef in the northwest of the island (Fig. 2). The highest percentage of recently dead coral cover was observed in the northwest of the island at Hoor reef, followed by Bungee Jumping and Toranj. The highest percentage of nutrient indicator algae (i.e., turf algae > 2.5 cm in length, fleshy algae, plantlike grapes like) such as brown Ulva algae, different types of green/blue algae, and algae containing air bubbles was recorded at Taban reef in the east of the island. The highest percentage of coral rubbles, the remnants of recently killed corals, were found at Big Coral reef, followed by Hoor, Bungee Jumping, and Park-e Dolphin reefs, indicating the presence of more branched corals at these stations in the past.

At the time of the present study, the hard corals in studied reefs in Kish Island were mainly dominated by submassive and massive corals consisting of 14 species of stony corals (i.e., *A. downingi*, *D. speciose*, *D. pallida*, *D. matthai*, *S. savignyana*, *P. contigua*, *P. versipora*, *P. daedalea*, *C. serailia*, *C. microphthalma*, *P. harrisoni*, *P. lutea*, *T. peltata*, *P. decussate*) belonging to the eight families. The biodiversity of stony corals was variable with the greatest diversity in the eastern reefs of the island. The highest species number was recorded in Toranj reef with 10 species and the lowest in Taban reefs with two species.

Reef fishes were represented by 33 species belonging to 30 genera and 20 families. Pomacentridae with seven species was the most diverse group. Lutjanidae followed by Pomacentridae were the most abundant families (Bargahi et al., 2020). In terms of reef fish species richness, Toranj and Big Coral reefs with 29 species were the specious reefs and Taban reef with 20 species was the poorest reef. In terms of abundance, reefs located in the east of the island were more populated by reef fish than those reefs on the western side of the island.

3.2. The effect of SCUBA diving activities on reef health

The RHI index showed that, except Taban reef with a fair condition, the health condition of the remaining reefs was good (Fig. 3). According to the RHI, except for the Taban reef, the health condition of the remaining reefs was higher in March 2017 as a period with maximum visitors to coral reefs than that of December 2018 as a period with the lowest number of visitors.

Expect Taban reef, with the RHI index above 4 which indicates a good health condition for the remaining six reefs, the RHI index for reefs in Big Coral, Park-e Dolphin, and Zoo Beach as the crowded locations and Toranj as the quiet tourism location, were generally higher than that of reefs in Hoor and Bungee Jumping as the quiet tourism locations (Fig. 3).

3.3. Tourism suitability index (TSI) of reefs for snorkeling and SCUBA diving

The results of the TSI calculation for snorkeling activity showed that all seven coral reefs were in a suitable category for this activity (Table 8, Fig. 4). The results of the TSI calculation for SCUBA diving activity showed that except for the Taban reef that was in the conditional suitable category, the remaining reefs were in the suitable category for this activity (Table 8, Fig. 5).

3.4. The tourism carrying capacity of reefs for SCUBA diving

The values for the physical (PCC), real (RCC), and tourism (TCC) carrying capacities per day and year for each reef in Kish Island are presented in Table 9. The PCC ranged from 279.7 divers per day in Hoor reef to 3555.6 divers per day in Toranj reef. The RCC ranged from 226.4 divers per day in Hoor reef to 2595.7 divers per day in Toranj reef. Similarly, the lowest and highest TCC, which indicate the number of visitors (divers) per day or year, were estimated in the Hoor reef and Toranj reef, respectively (Fig. 6).

4. Discussion

The biological diversity of the reefs of Kish Island renders it an attractive destination for water sport activities in the northern Persian Gulf. However, the fragile coral ecosystems of the island, which have been adversely affected by climate change-driven tensions and coastal development, lack the capacity to withstand any additional pressure from water sports. Therefore, it is important to develop an appropriate zoning plan and establish criteria for using ecosystem services commensurate with its carrying capacity. Thus, the approach proposed in the present study to assess the suitability and carrying capacity of reefs in Kish Island consider not only environmental concerns but also existing infrastructures, the accessibility, and security conditions for high-quality recreational diving. All of these considerations alternately reduce the potential impact of visitors and have positive consequences for the conservation of the coral reefs in Kish Island, as any change in the island's coral ecosystems could have consequences for its biodiversity.

4.1. Effects of water sports on coral reefs and associated reef fish in Kish Island

The highest percentage of live coral cover was found at Park-e Dolphin reef, followed by Big Coral and Zoo Beach (east of

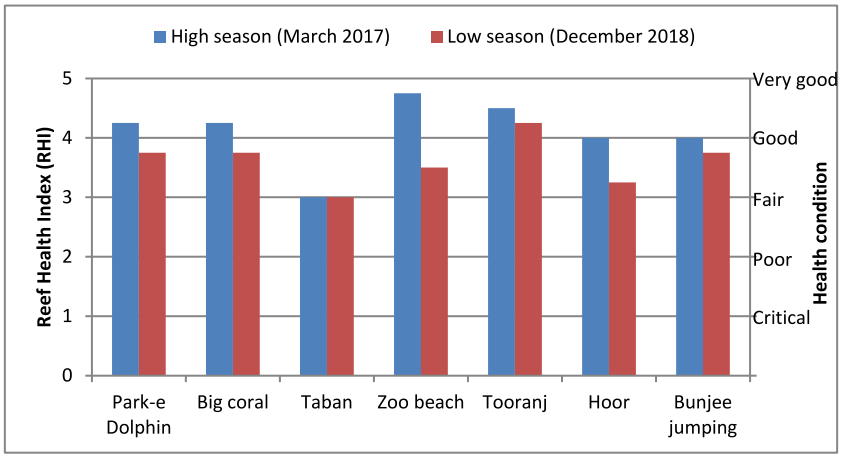

Fig. 3. The variation of the RHI index in March 2017 as a period with maximum visitors to coral reefs and December 2018 as a period with the lowest number of visitors across seven reefs in Kish Island.

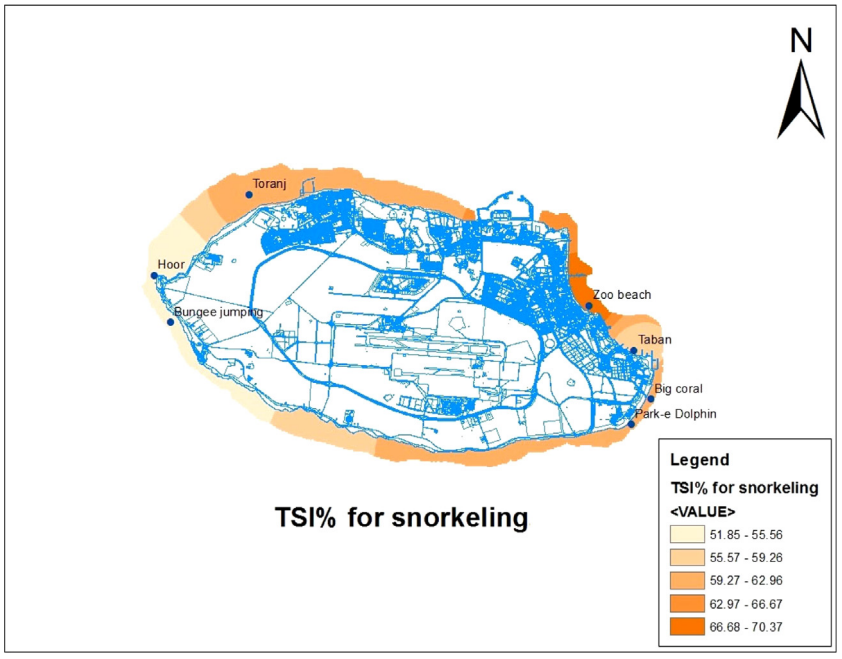

Fig. 4. Tourism suitability index (TSI) for snorkeling activity in Kish Island.

Table 8
Tourism suitability index (TSI) of reefs for snorkeling and SCUBA diving in Kish Island. TSI (S1) = 83–100% (very suitable), TSI (S2) = 50 − <83% (suitable), TSI (S3) = 17 − <50% (conditional suitable), and TSI (N) = <17% (not suitable).

Reef	TSI for snorkeling (%)	Suitability	TSI for SCUBA diving (%)	Suitability
Park-e Dolphin	62.96	Suitable	61.11	Suitable
Big Coral	62.96	Suitable	66.67	Suitable
Taban	55.56	Suitable	50.00	Conditional suitable
Zoo Beach	70.37	Suitable	72.22	Suitable
Toranj	61.11	Suitable	63.89	Suitable
Hoor	51.85	Suitable	55.56	Suitable
Bungee Jumping	51.85	Suitable	55.56	Suitable

the island) and then at Toranj reef in the northwest of the island. The highest percentage of recently dead coral cover was observed in the northwest of the island at Hoor reef, followed by Bungee Jumping and Toranj. The highest percentage of nutrient indicator algae (i.e., turf algae > 2.5 cm in length, fleshy algae, plantlike grapes like) such as brown Ulva algae, different types of green/blue algae, and algae containing air bubbles was recorded at Taban reef in the east of the island, indicating an increase in material load. It seems that the construction of a recreational breakwater at Taban reef has disrupted the natural flow of water in this area, which in turn has led to water stagnation and increased nutrient load. Increasing the percentage of algae in this reef occupies hard beds and reduces the chances of coral larvae settling. On the other hand, the water of this reef had high turbidity reducing the penetration of light required for coral reefs. It is well known that light transmission through the water

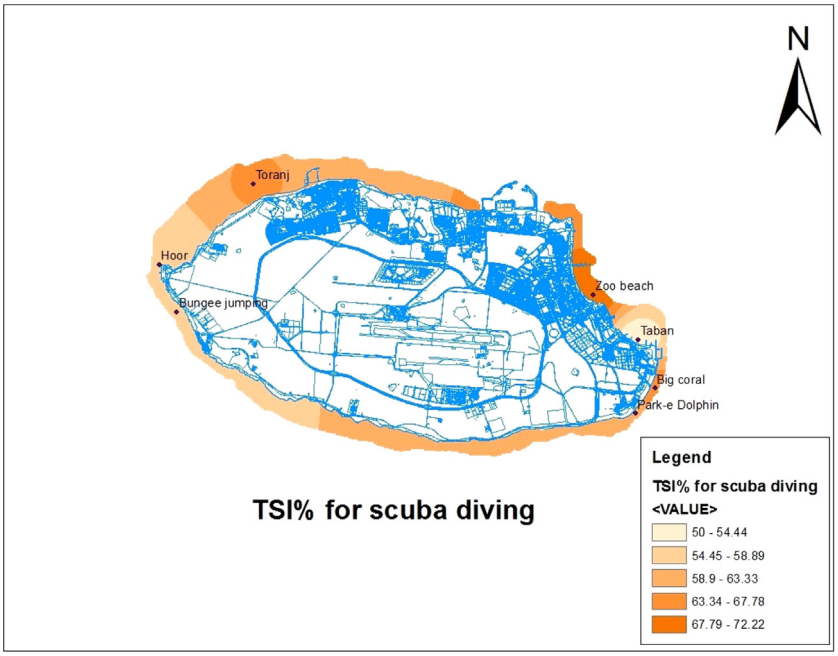

Fig. 5. Tourism suitability index (TSI) for SCUBA diving activity in Kish Island.

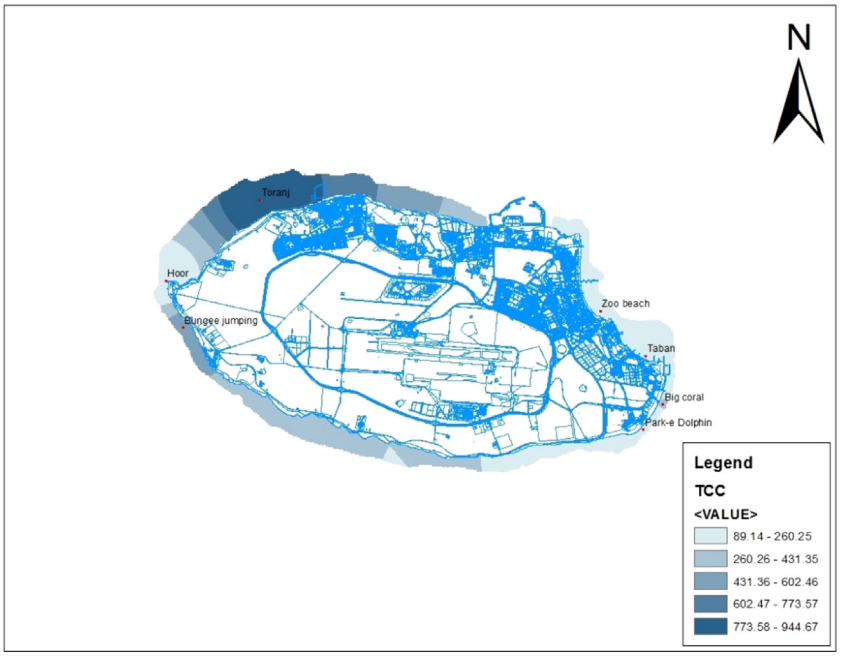

Fig. 6. Tourism carrying capacity (diver per day) for SCUBA diving activity in Kish Island.

Table 9
The values for the physical (PCC), real (RCC), and tourism (TCC) carrying capacities per day and year for each reef in Kish Island.

Reef	PCC (diver/day)	RCC (diver/day)	TCC (diver/day)	TCC (diver/year)
Park-e Dolphin	533.33	377.13	167.35	59575
Big Coral	491.23	370.28	193.90	69027
Taban	756.87	638.58	325.51	115882
Zoo Beach	733.33	490.95	258.79	92128
Toranj	3555.56	2595.69	1115.71	397193
Hoor	279.57	226.44	104.41	37171
Bungee Jumping	1666.67	1353.05	600.39	213738
The total number of divers allowed per day and year in seven reefs			2766.05	984712.51

column decreases exponentially with particle concentration and depth (Kirk, 1994). Accordingly, the probability of coral reefs returning to Taban reef is very low due to the reduction of the hard bed surface and reduced light penetration. Previous studies have documented the damaging effects of microalgae on corals in particular during their early life history stages. These include reductions in successful coral larvae settlement due to reductions in settlement space because of increased sediment trapping by algae (Birrell et al., 2005), occupied settlement space by algae overgrowth (Olsen et al., 2016), direct inhibition of settlement via allelochemicals (Paul et al., 2011; Dixson et al., 2014), reductions in light availability (Strader et al., 2015), and direct physical abrasion of newly settled and young corals (Box and Mumby, 2007; Venera Ponton et al., 2011).

The highest percentage of coral rubbles, the remnants of recently killed corals, were found at Big Coral reef, followed by Hoor, Bungee Jumping, and Park-e Dolphin reefs, indicating the presence of more branched corals at these reefs in the past. Due to the bleaching event driven by the rising water temperature in the summer of 2017, the corals in some parts of the Gulf have been suffered greatly. The bleaching was the result of an extended period of summer calm, which resulted in reef bottom temperatures reaching 37.7°C in some parts of the Gulf, with temperatures exceeding lethal thresholds for over 9 days (Paparella et al., 2019). The impact of exceeding temperature during summer 2017 appeared afterward when two-third of corals were lost to mortality between April and September 2017 (Burt and Bartholomew, 2019; Burt et al., 2019). Coral bleaching in summer 2017 also had a substantial adverse impact on reefs across the northern Persian Gulf by killing the entire shallow water *Acropora* zones. Likewise, the reefs in Kish Island experienced a 95% loss during peak bleaching in summer 2017. Mortality sustained after peak bleaching on this island, and by March 2018 coral cover averaged just 6.5%, but this was followed by a slow recovery in which by February 2019 coral cover reached 13.2% (Bargahi et al., 2020). The 2017 bleaching did not cause intense shifts in the coral community composition, because earlier events have eliminated the most sensitive taxa (Burt and Bartholomew, 2019).

At the time of the present study, the hard corals in studied reefs in Kish Island were mainly dominated by submassive and massive corals consisting of 14 species of stony corals belonging to the eight families. The biodiversity of stony corals was variable with the greatest diversity in the eastern reefs of the island. The highest species number was recorded in Toranj reef with 10 species and the lowest in Taban reefs with two species. Comparison of coral species diversity in this study with previous studies indicates a decrease in biodiversity. In 2001, for example, 21 species of stony corals were reported from Kish Island (Fatemi and Shokri, 2001). The decrease in species diversity of stony coral species in Kish Island in recent years indicates the impact of the concurrent occurrence of the bleaching phenomenon and possibly the increase in the effects of destructive human activities on Kish Island. The findings from the present study suggest that the observed extensive degradation of coral reefs in Kish Island has been due to climate phenomenon rather than diving pressure that has locally impacted some crowded reefs.

Anchors from boats can cause considerable damage to coral reefs, including breakage, fragmentation, and direct injury to the reef ecosystem ultimately reducing coral cover, reductions in the biodiversity of corals and reef fish, and also reducing the structural complexity of coral reefs (Hawkins et al., 1999). Previous studies have shown a direct and positive relationship between bed complexity and species richness and biodiversity of reef fish (Risk, 1972; Luckhurst and Luckhurst, 1978; Carpenter et al., 1981; Roberts and Ormond, 1987). The higher the complexity of the sea bed, the higher the species richness and biodiversity of reef fish. Therefore, one of the adverse effects of anchors is the breakage, fragmentation, and direct injury to the coral colonies that may lead to the reduced structural complexity of coral reefs and a decline in the species richness and biodiversity of reef fish. Mechanical contact of diving equipment and boat anchors with coral colonies may result in breakage and abrasion of the corals, thereby making the corals more susceptible to invasion by pathogens and bioeroding organisms, possibly increasing mortality (Hawkins and Roberts, 1992; Lamb et al., 2014). Previous studies have shown that the intensity of coral bioerosion observed in the Persian Gulf appears to be higher than elsewhere in the world (Jafari et al., 2016; Al-Mansoori et al., 2020), therefore, any factor that weakens corals against bioeroding organisms may exacerbate degradation of corals in this region.

To reduce the adverse effects of boat anchors on coral reefs of Kish Island, it is necessary to install floating buoys and encourage the boaters to use them. Of the seven reefs surveyed around Kish Island, only the Big Coral and Zoo Beach reefs have floating buoys. Therefore, the possibility of degradation of coral beds by anchors in other reefs is very likely.

In terms of reef fish species richness, Toranj and Big Coral reefs with 29 species were the specious reefs and Taban reef with 20 species was the poorest reef. In terms of abundance, reefs located in the east of the island were more populated by reef fish than those reefs on the western side of the island. Previous studies have shown that manual feeding of reef fish may lead to changes in the natural composition of coral communities, adversely affecting a certain group of fish while favoring others, especially snappers and moray eels (Sweatman, 1996; Hawkins et al., 1999). Manual feeding of fish may also encourage fish to behave aggressively towards divers to receive food (Hawkins et al., 1999). However, some people in favor of feeding fish believe that doing so will engage divers in the activity and cause less damage to vulnerable parts of coral reefs (Hawkins et al., 1999). In the present study, the abundance of Abudefduf also known as the sergeant-majors, which is a non-edible fish and is usually attracted to hand feeding, were higher at Big Coral and Zoo Beach reefs, which are the main destinations of visitors, indicating the effect of manual feeding on the behavior of this fish. A similar trend was observed for the moray eel in crowded reefs of Big Coral and Zoo Beach where these fish swim very close to the divers waiting for food.

The collision of the bottom of the boats with the coral colonies causes irreparable effects on the coral reefs through breakage, fragmentation, and direct injury to the coral colonies and making the coral skeleton defenseless against the entry of borers. Boring organisms such as barnacles, bivalves, bristle worms, and boring sponges dig and nest coral skeletons through mechanical and chemical tools (Hutchings, 1986; Hutchings et al., 2005). A recent study exploring the effect of ship groundings on coral reefs in the Philippines has shown a direct association between the prevalence of coral disease with ship grounding (Raymundo et al., 2018). Among the seven studied reefs on Kish Island, the effects of the boat collision in the form of breakage, fragmentation and direct injury on coral colonies were evident at Big Coral, Zoo Beach, and Park-e Dolphin reefs as crowded reefs.

Except for the Taban reef with the fair health condition, RHI index above 4 which indicates a good health condition for the remaining six reefs, reveals that the water sports have not largely affected the health condition of coral reefs in Kish Island. RHI index for reefs in Big Coral, Park-e Dolphin, and Zoo Beach as the crowded reefs and Toranj as the quiet tourism location, were generally higher than that of reefs of Hoor and Bungee Jumping as the quiet tourism locations. Unlike Taban reef, the higher RHI for the other six reefs in March 2017 as a period with maximum visitors to coral reefs than that of December 2018 as a period with

the lowest number of visitors may be due to the bleaching event in the summer of 2017. The impact of exceeding temperature during summer 2017 appeared afterward when two-third of corals were lost to mortality between April and September 2017 in some parts of the Gulf (Burt and Bartholomew, 2019). Likewise, the reefs in Kish Island experienced a 95% loss during peak bleaching in summer 2017. Mortality sustained after peak bleaching on this island, and by March 2018 coral cover averaged just 6.5%, but this was followed by a slow recovery in which by February 2019 coral cover reached 13.2% (Bargahi et al., 2020).

4.2. Tourism suitability index (TSI) of reefs for snorkeling and SCUBA diving

The results of the TSI calculation for snorkeling activity showed that all seven coral reefs were in a suitable category for this activity. Yet, snorkeling in Kish Island is not a common activity, because the visitors feel unsafe due to a large number of passing boats in the coastal area.

The results of the TSI calculation for SCUBA diving activity showed that except for the Taban reef that was in the conditional suitable category, the remaining reefs were in the suitable category for this activity. The main reason for the conditional suitable category for Taban reef is that the visitors to this reef feel unsafe due to a large amount of passing boats that is due to proximity to the recreational pier. The high water turbidity and low visibility that is driven by stagnant water and increased nutrients level in the water column are other reasons for a conditional suitable category for Taban reef. However, due to the relatively significant Tourism Carrying Capacity (TCC) of about 263 divers per day, Taban reef can be turned into a suitable diving destination and reduce the tourist pressure from the other two reefs (i.e., Big Coral, Zoo Beach).

4.3. The tourism carrying capacity of reefs for SCUBA diving

Comparison of TCC across reefs in Kish Island indicates that the total number of possible dives in all four reefs located in the east of the island (i.e., Park-e Dolphin, Big Coral, Taban, Zoo Beach) with a total capacity of 945.5 divers per day is less than the total possible diving in all three reefs located in the west of the island (i.e., Toranj, Hoor, Bungee Jumping) with a total number of 1,820.5 divers per day. Meanwhile, most of the SCUBA diving activities on the island are being practiced in the two reefs of Big Coral (28.75%) and Zoo Beach (57.14%). Taban reef with the possibility of accepting 325.5 divers per day has a significant potential compared to the two reefs of Big Coral and Zoo Beach with the possibility of accepting 193.9 and 258.8 divers per day, respectively.

Taban reef is one of the least popular destinations for divers in the east of the island. According to observations, about 10 boats each with at least 15 tourists visit each of the two reefs of Big Coral and Zoo Beach five times a day. Thus, daily about 750 divers visit each of the reefs, which is about four times above the calculated TCC for these two reefs. The current levels of diving at two reefs of Zoo Beach and Big coral as crowded locations all located on the east of Kish Island fall above the calculated tourism carrying capacity (TCC), suggesting that presently diving in these reefs is beyond sustainable limits.

Toranj and Bungee Jumping reefs, with the capacity to accept 1,115 and 600 divers per day, respectively, have good potential as new diving sites. However, according to the present study, these two reefs are one of the least popular destinations for divers on the island due to their relatively long distance from diving clubs. Given the rocky shore and the presence of relatively strong sea currents, the Hoor reef in the west of the island has less potential than Toranj and Bungee Jumping reefs as a suitable site for diving activities.

Comparison of TCC for the crowded diving sites in Kish Island (i.e., Park-e Dolphin, Big Coral, Taban, Zoo Beach) with a total capacity of 945.5 divers per day and some diving sites in Saba and Bonaire (Netherlands Antilles) and Egypt (Hawkins and Roberts, 1997) with carrying capacity of 13–16 divers per day and Tidung Island (Indonesia) (Simanjuntak and Supriharyono, 2018) with carrying capacity of 60–300 divers per day, shows that the reefs in Kish Island may support more divers.

Kish Island with substantial biological diversity and scenic beauty is the most visited destination for ecotourism activities in the northern Persian Gulf. Nevertheless, due to the small size of the island and the fragility of its coral reef ecosystems, it is important to create an appropriate zoning plan and to establish criteria for using ecosystem services following its environmental and socio–economic characteristics. Thus, the calculated TCC for the reefs in this island considers not only environmental questions but also economic and social issues, including scenic beauty and the presence of charismatic species such as stony corals, echinoderms, reef fishes, as well as the security, infrastructure, and accessibility conditions for high-quality recreational diving. If properly covered, all of these considerations will minimize the possible impact of visitors, with substantial consequences for the conservation of coral ecosystems, because any change in the island environments could impose adverse consequences on its biodiversity.

The growing number of diving exercises, on the one hand, and the major focus of diving activities on the Big Coral and Zoo Beach reefs is alarming for the urgent need to control and manage diving activities in the northeast of the island. Therefore, the primary recommendation is to stop issuing a further license to establish a diving club on the island. The second recommendation is the proportional distribution of diving activities across the four diving destinations in the northeast of the island. In this way, some visitors using the Big Coral and Zoo Beach reefs will be encouraged to use the Park-e Dolphin and Taban reefs.

5. Conclusion

In conclusion, the results of the present study revealed that SCUBA diving activities have relatively damaged coral reefs in Kish Island. Therefore, to maintain the revenue from water sports, the officials of the Kish Free Trade Organization must enforce special management measures. Since more than 90% of diving and other water sports are exercised under the vision of diving clubs, so the club managers and diving instructors play an important role in increasing the level of awareness of visitors to coral ecosystems. The level of awareness of water recreation operators, especially those whose activities are directly related to coral reefs, is generally high. Yet, it seems that the use of information tools such as signboards (e.g., Protect Coral Reefs, https://reefrelief.org/wp-content/uploads/2009/05/ProtectPoster.pdf) is not common. Another way may be instituting a diver permitting system to track (and limit) the number of divers at specific locations, and perhaps once the capacity is reached then limiting them at these locations and only allowing them to go to less pressured areas.

The establishment of Marine Protected Areas (MPAs) is a core strategy in reducing the impact of the anthropogenic stressors (e.g., overexploitation of marine resources, destructive fishing, pollution, irresponsible recreational activities) on the marine environment, leading to the conservation of marine biodiversity and populations (Green et al., 2011). Of six management categories (one with a sub-division) suggested for MPAs (i.e., Strict Nature Reserve, Wilderness Area, National Park, Natural Monument or Feature, Habitat/Species Management Area, Protected

Landscape or Seascape, Protected Areas with sustainable use of natural resources) (Day et al., 2019), assigning Kish Island as a National Park can be a strategy for conservation of coral ecosystems in this Island. The National Park is defined as "Large natural or near-natural areas protecting large-scale ecological processes with characteristic species and ecosystems, which also have environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities" (Day et al., 2019). In doing so, one strategy may be limiting all access to the heavily visited reefs on a basis of year-round, seasonal, or rotating, all of which will allow degraded corals to rehabilitate, grow and reproduce.

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.

Acknowledgments

The authors wish to thank Dr. Hamid Reza Bargahi for his assistance in field sampling and underwater survey, and Dr. Kivan Kabiri and Mr. Arshia Jafarpour Azami for their assistance in GIS mapping. We also thank Mr. Mosayeb Shirani, Mr, MohsenEsmaeili and Dr. Mostafa Khanzadi at Kish Free Zone Organization for their support. The ethical approval for this study was obtained from the local ethics committee in Kish Free Zone Organization. Kish Free Trade Zone Organization, Krish Island, Iran financially supported this study under contract number 96/314012466 in 2017.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.rsma.2021.101813.

References

Aghajan Pour, F., Shokri, M.R., Abtahi, B., 2012. Visitor impact on rocky shore communities of Qeshm Island, the Persian Gulf, Iran. Environ. Monit. Assess. 185, 1859–1871. http://dx.doi.org/10.1007/s10661-012-2673-2.

Al-Mansoori, N., McParland, D., Howells, E., Bauman, A., Burt, J., 2020. Coral bioerosion on the marginal reefs of northeastern Arabia. Aquat. Ecosyst. Health Manage. 23, 187–195. http://dx.doi.org/10.1080/14634988.2019.1677204.

Alonso-Domıńguez, A., 2009. Comportamiento de buzos en dos aŕeas naturales protegidas de Bahıá de Banderas. Islas Marietas y Los Arcos, University of Guadalajara, Jalisco-Nayarit.

Au, A.C.-s., Zhang, L., Chung, S.-s., Qiu, J.-W., 2014. Diving associated coral breakage in Hong Kong: Differential susceptibility to damage. Mar. Pollut. Bull. 85, 789–796. http://dx.doi.org/10.1016/j.marpolbul.2014.01.024.

Bargahi, H.R., Shokri, M.R., Kaymaram, F., Fatemi, M.R., 2020. Changes in reef fish assemblages following multiple bleaching events in the world's warmest sea (Kish Island, the Persian Gulf). Coral Reefs 39, 603–624. http://dx.doi.org/10.1007/s00338-020-01945-3.

Barker, N.H.L., Roberts, C.M., 2004. Scuba diver behaviour and the management of diving impacts on coral reefs. Biol. Conserv. 120, 481–489. http://dx.doi.org/10.1016/j.biocon.2004.03.021.

Birrell, C.L., McCook, L.J., Willis, B.L., 2005. Effects of algal turfs and sediment on coral settlement. Mar. Pollut. Bull. 51, 408–414. http://dx.doi.org/10.1016/j.marpolbul.2004.10.022.

Blignaut, J., Mander, M., Inglesi-Lotz, R., Glavan, J., Parr, S., 2016. The amenity value of Abu Dhabi's coastal and marine resources to its beach visitors. Ecosyst. Serv. 19, 32–41. http://dx.doi.org/10.1016/j.ecoser.2016.04.005.

Box, S., Mumby, P., 2007. Effect of macroalgal competition on growth and survival of juvenile Caribbean corals. Mar. Ecol. Prog. Ser. 342, 139–149. http://dx.doi.org/10.3354/meps342139.

Buckley, R., 2011. Tourism and environment. Annu. Rev. Environ. Resour. 36, 397–416. http://dx.doi.org/10.1146/annurev-environ-041210-132637.

Burt, J.A., 2014. The environmental costs of coastal urbanization in the Arabian Gulf. City 18, 760–770. http://dx.doi.org/10.1080/13604813.2014.962889.

Burt, J.A., Bartholomew, A., 2019. Towards more sustainable coastal development in the Arabian Gulf: Opportunities for ecological engineering in an urbanized seascape. Mar. Pollut. Bull. 142, 93–102. http://dx.doi.org/10.1016/j.marpolbul.2019.03.024.

Burt, J.A., Ben-Hamadou, R., Abdel-Moati, M.A.R., Fanning, L., Kaitibie, S., Al-Jamali, F., Range, P., Saeed, S., Warren, C.S., 2017. Improving management of future coastal development in Qatar through ecosystem-based management approaches. Ocean & Coastal Management 148, 171–181. http://dx.doi.org/10.1016/j.ocecoaman.2017.08.006.

Burt, J., van Lavieren, H., Feary, D., 2014. Persian Gulf reefs: An important asset for climate science in urgent need of protection. Ocean Chall. 20, 49–56.

Burt, J.A., Paparella, F., Al-Mansoori, N., Al-Mansoori, A., Al-Jailani, H., 2019. Causes and consequences of the 2017 coral bleaching event in the southern Persian/Arabian Gulf. Coral Reefs 38, 567–589. http://dx.doi.org/10.1007/s00338-019-01767-y.

Carpenter, K.E., Miclat, R.I., Albaladejo, V.D., Corpuz, V.T., 1981. The influence of substrate structure on the local abundance and diversity of Philippine reef fishes. In: Proceedings of Fourth International Coral Reef Symposium, Manila, pp. 497–502.

Ching Lim, L., 1998. Carrying Capacity Assessment of Pulau Payar Marine Park, Malaysia. BOBP, Madras (India), p. 129.

Cifuentes, M., Mesquita, C.A., Meńdez, J., Eugenia Morales, M., Aguilar, N., Cancino, D., Gallo, M., Jolón, M., Ramírez, C., Ribeiro, N., Sandoval, E., Turcios, M., 1999. Capacidad de carga turıśtica de las aŕeas de uso puḃlico del Monumento Nacional Guayabo, Costa Rica. WWF Centroameŕica, Turrialba, p. 60.

Day, J., Dudley, N., Hockings, M., Holmes, G., Laffoley, D., Stolton, S., Wells, S., Wenzel, L., 2019. Guidelines for Applying the IUCN Protected Area Management Categories To Marine Protected Areas, second ed. IUCN, Gland. Switzerland, p. 36.

Díaz Pérez, L., Rodriguez Zaragoza, F., Ortiz, M., Cupul-Magaña, A., Carriquiry, J., Rios-Jara, E., Rodríguez-Troncoso, A., García Rivas, C., 2016. Correction: Coral reef health indices versus the biological, ecological and functional diversity of fish and coral assemblages in the Caribbean Sea. PLoS One 11, e0167252. http://dx.doi.org/10.1371/journal.pone.0167252.

Dixon, J.A., Fallon Scura, L., van't Hof, T., 1993. Meeting ecological and economic goals: marine parks in the Caribbean. 22, 117–125.

Dixon, J.A., Scura, L.F., van't Hof, T., 1995. Ecology and microeconomics as 'joint products': The Bonaire Marine Park in the Caribbean. In: Perrings, C.A., Mäler, K.G., Folke, C., Holling, C.S., Jansson, B.O. (Eds.), Biodiversity Conservation: Problems and Policies. Springer Netherlands, Dordrecht, pp. 127–145.

Dixson, D.L., Abrego, D., Hay, M.E., 2014. Chemically mediated behavior of recruiting corals and fishes: A tipping point that may limit reef recovery. Science 345, 892–897. http://dx.doi.org/10.1126/science.1255057.

English, S., Wilkinson, C., Baker, V. (Eds.), 1997. Survey Manual for Tropical Marine Resources. Australian Institute of Marine Science.

Fatemi, S.M.R., Shokri, M.R., 2001. Iranian coral reefs status with particular reference to Kish Island, Persian Gulf. In: International Coral Reef Initiative (ICRI) Regional Workshop for the Indian Ocean, Maputo, Mozambique.

Gallo, F., Martıńez, A., Rıéos, J.I., 2003. Capacidad de carga de visitantes en aŕeas de buceo de San Andreś Isla (Colombia). Universidad Tecnoloǵica de Pereira, Pereira, p. 7.

Gladstone, W., Curley, B., Shokri, M.R., 2013. Environmental impacts of tourism in the Gulf and the Red Sea. Mar. Pollut. Bull. 72, 375–388. http://dx.doi.org/10.1016/j.marpolbul.2012.09.017.

Green, S., Meneses, A., White, A., Kilarski, S., Christie, P., 2011. Emerging marine protected area networks in the coral triangle: Lessons and way forward.

Harriott, V.J., Davis, D., Banks, S.A., 1997. Recreational diving and its impact in Marine Protected Areas in Eastern Australia. Ambio 26, 173–179.

Hawkins, J., Roberts, C., 1992. Effects of recreational SCUBA diving on fore-reef slope communities of coral reefs. Biol. Conserv. 62, 171–178. http://dx.doi.org/10.1016/0006-3207(92)91045-T.

Hawkins, J.P., Roberts, C.M., 1997. Estimating the carrying capacity of coral reefs for Scuba diving. In: Eight International Coral Reef Symposium, Panama City, pp. 1923–1926.

Hawkins, J.P., Roberts, C.M., Tom Van't, H., De Meyer, K., Tratalos, J., Aldam, C., 1999. Effects of recreational SCUBA diving on caribbean coral and fish communities. Conserv. Biol. 13, 888–897. http://dx.doi.org/10.1046/j.1523-1739.1999.97447.

Hill, J., Wilkinson, C., 2004. Methods for Ecological Monitoring of Coral Reefs. Australia Institute of Marine Science, Townsville, Australia.

Hodgson, G., Hill, J., Kiene, W., Maun, L., Mihaly, J., Liebeler, J., Shuman, C., Torres, R., 2006. Reef Check Instruction Manual: A Guide To Reef Check Coral Reef Monitoring. Reef Check Foundation, Pacific Palisades, California, USA, p. 95.

HRI, 2021. Report card for the mesoamerican reef, healthy reefs initiative.

Hutchings, P.A., 1986. Biological destruction of coral reefs. Coral Reefs 4, 239–252. http://dx.doi.org/10.1007/bf00298083.

Hutchings, P., Peyrot-Clausade, M., Osnorno, A., 2005. Influence of land runoff on rates and agents of bioerosion of coral substrates. Mar. Pollut. Bull. 51, 438–447. http://dx.doi.org/10.1016/j.marpolbul.2004.10.044.

Jafari, M.A., Seyfabadi, J., Shokri, M.R., 2016. Internal bioerosion in dead and live hard corals in intertidal zone of Hormuz Island (Persian Gulf). Mar. Pollut. Bull. 105, 586–592. http://dx.doi.org/10.1016/j.marpolbul.2015.11.048.

Jameson, S., Ammar, M.S.A., Saadalla, E., Mostafa, H.M., Riegl, B., 1999. A coral damage index and its application to diving sites in the Egyptian Red Sea. Coral Reefs 18, 333–339. http://dx.doi.org/10.1007/s003380050208.

Kabiri, K., 2018. Mapping of the Hard Corals Around Kish, Hendorabi, Farur, and Farurgan Islands in the Persian Gulf using High Spatial Resolution Satellite Images. Iran National Science Foundation, Tehran, Iran.

Kirk, J.T.O., 1994. Light and Photosynthesis in Aquatic Ecosystems. Cambridge University Press, Cambridge, UK.

Lamb, J.B., True, J.D., Piromvaragorn, S., Willis, B.L., 2014. Scuba diving damage and intensity of tourist activities increases coral disease prevalence. Biol. Conserv. 178, 88–96. http://dx.doi.org/10.1016/j.biocon.2014.06.027.

Leujak, W., Ormond, R.F.G., 2007. Visitor perceptions and the shifting social carrying capacity of South Sinai's coral reefs. J. Environ. Manage. 39, 472–489. http://dx.doi.org/10.1007/s00267-006-0040-1.

Luckhurst, B.E., Luckhurst, K., 1978. Analysis of the influence of substrate variables on coral reef fish communities. Mar. Biol. 49, 317–323. http://dx.doi.org/10.1007/BF00455026.

Lynch, T., Wilkinson, E., Melling, L., Hamilton, R., MacReady, A., Feary, S., 2004. Conflict and impacts of divers and anglers in a marine park. J. Environ. Manage. 33, 196–211. http://dx.doi.org/10.1007/s00267-003-3014-6.

Madani, S., Ahmadian, M., Khalili Araghi, M., Rahbar, F., 2012. Estimating total economic value of coral reefs of Kish Island (Persian Gulf). Int. J. Environ. Res. 6, 51–60. http://dx.doi.org/10.22059/ijer.2011.471.

Nadim, F., Bagtzoglou, A.C., Iranmahboob, J., 2008. Coastal management in the Persian Gulf region within the framework of the ROPME programme of action. Ocean & Coastal Management 51, 556–565. http://dx.doi.org/10.1016/j.ocecoaman.2008.04.007.

Nickerson-Tietze, D., 2000. Scientific characterization and monitoring: Its application to integrated coastal management in Malaysia. Ecol. Appl. 10, 386–396. http://dx.doi.org/10.2307/2641100.

Olsen, K., Sneed, J.M., Paul, V.J., 2016. Differential larval settlement responses of Porites astreoides and Acropora palmata in the presence of the green alga Halimeda opuntia. Coral Reefs 35, 521–525. http://dx.doi.org/10.1007/s00338-015-1394-8.

Paparella, F., Xu, C., Vaughan, G.O., Burt, J.A., 2019. Coral bleaching in the Persian/Arabian Gulf is modulated by summer winds. Front. Mar. Sci. 6, 1–15. http://dx.doi.org/10.3389/fmars.2019.00205.

Paul, V., Kuffner, I., Walters, L., Ritson-Williams, R., Beach, K., Becerro, M., 2011. Chemically mediated interactions between macroalgae Dictyota spp. and multiple life-history stages of the coral Porites astreoides. Mar. Ecol. Prog. Ser. 426, 161–170. http://dx.doi.org/10.3354/meps09032.

Raymundo, L., Licuanan, W., Kerr, A., 2018. Adding insult to injury: Ship groundings are associated with coral disease in a pristine reef. PLoS One 13, e0202939. http://dx.doi.org/10.1371/journal.pone.0202939.

Riegl, B., Johnston, M., Purkis, S., Howells, E., Burt, J., Steiner, S.C.C., Sheppard, C.R.C., Bauman, A., 2018. Population collapse dynamics in *Acropora downingi*, an Arabian/Persian Gulf ecosystem-engineering coral, linked to rising temperature. Global Change Biol. 24, 2447–2462. http://dx.doi.org/10.1111/gcb.14114.

Ríos-Jara, E., Galván-Villa, C.M., Rodríguez-Zaragoza, F.A., López-Uriarte, E., Muñoz Fernández, V.T., 2013. The tourism carrying capacity of underwater trails in Isabel Island National Park. Mexico. J. Environ. Manage. 52, 335–347. http://dx.doi.org/10.1007/s00267-013-0047-3.

Risk, M.J., 1972. Fish diversity on a coral reef in the Virgin Islands. Atoll Res. Bull. 193, 1–4. http://dx.doi.org/10.5479/si.00775630.153.1.

Roberts, G.M., Ormond, R.F.G., 1987. Habitat complexity and coral reef fish diversity and abundance on Red Sea fringing reefs. Mar. Ecol. Prog. Ser. 41, 1–8. http://dx.doi.org/10.3354/meps041001.

Salm, R., 1986. Coral reefs and tourist carrying capacity: The Indian Ocean experience. UNEP 9, 11–14.

Schleyer, M.H., Tomalin, B.J., 2000. Damage on South African coral reefs and an assessment of their sustainable diving capacity using a fisheries approach. Bull. Mar. Sci. 67, 1025–1042.

Serour, R.K., Kangas, P.C., 2005. An emergy-based model for diver carrying capacity on coral reefs. In: Brown, M.T., Campbell, D., Comar, V., Huang, S., Rydberg, T., Tilley, D.R., Ulgiati, S. (Eds.), Emergy Synthesis 3: Theory and Applications of the Emergy Methodology. Center for Environmental Policy, University of Florida, Gainesville.

Shelby, B., Heberlein, T.A., 1987. Carrying Capacity in Recreation Settings. Oregon State University Press.

Simanjuntak, S.W., Supriharyono, H., 2018. Analysis of suitability and carrying capacity of tourism in Tidung Island, Kepulauan Seribu, Indonesia. Russian J. Agric. Socio-Economic Sci. 6, 151–159. http://dx.doi.org/10.18551/rjoas.2018-06.16.

Stephenson, M.L., 2014. Tourism, development and 'destination Dubai': cultural dilemmas and future challenges. Curr. Issues Tour. 17, 723–738. http://dx.doi.org/10.1080/13683500.2012.754411.

Strader, M., Davies, S., Matz, M., 2015. Differential responses of coral larvae to the colour of ambient light guide them to suitable settlement microhabitat. R. Soc. Open Sci. 2, 150358. http://dx.doi.org/10.1098/rsos.150358.

Sweatman, H.P.A., 1996. Impact of Tourist Pontoons on Fish Assemblages on the Great Barrier Reef, Technical Report 5, 5, T.r. CRC Reef Research Center, Townsville, Australia, p. 54.

Tratalos, J.A., Austin, T.J., 2001. Impacts of recreational SCUBA diving on coral communities of the Caribbean island of Grand Cayman. Biol. Conserv. 102, 67–75. http://dx.doi.org/10.1016/S0006-3207(01)00085-4.

UNWTO, 2020. UNWTO World Tourism Barometer and Statistical Annex, December 2020. UNWTO World Tourism Barometer (English Version) 18. pp. 1–36. http://dx.doi.org/10.18111/wtobarometereng.2020.18.1.7.

Uyarra, M.C., Côté, I., 2007. The quest for cryptic creatures: Impacts of species-focused recreational diving on corals. Biol. Conserv. 136, 77–84. http://dx.doi.org/10.1016/j.biocon.2006.11.006.

Vaughan, G.O., Al-Mansoori, N., Burt, J.A., 2019. Chapter 1 - The Arabian Gulf. In: Sheppard, C. (Ed.), World Seas: An Environmental Evaluation (Second Edition). Academic Press, pp. 1–23.

Venera Ponton, D., Diaz-Pulido, G., McCook, L.J., Rangel-Campo, A., 2011. Macroalgae reduce growth of juvenile corals but protect them from parrotfish damage. Mar. Ecol. Prog. Ser. 421, 109–115. http://dx.doi.org/10.3354/meps08869.

Vicki, J.H., Derrin, D., Simon, A.B., 1997. Recreational diving and its impact in marine protected areas in eastern Australia. Ambio 26, 173–179.

Werner, S., Budziak, A., van Franeker, J., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused By Marine Litter. MSFD GES TG Marine Litter - Thematic Report. JRC Technical report.

Yari, S., 2015. Field Measurement Report of Physical Param and Flow Modeling for Desalination and Power Plants of Kish Island. KIsh Free Trade Zone, Kish, Iran, p. 32.

Yulianda, F., 2007. Ekowisata Bahari Sebagai Alternatif Pemanfaatan Sumberdaya Pesisir Berbasis Konservasi. Unpublished Paper Departemen Manajemen Sumberdaya Perairan, Fakultas Perikanan dan Ilmu Kelautan Institut Pertanian Bogor Bogor.

Zakai, D., Chadwick-Furman, N.E., 2002. Impacts of intensive recreational diving on reef corals at Eilat, northern Red Sea. Biol. Conserv. 105, 179–187. http://dx.doi.org/10.1016/S0006-3207(01)00181-1.