


Research

Contrasts in ecological assessment and tourism sector perceptions of coral reefs: a case study at Islas Marietas National Park

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Abstract

Understanding and incorporating stakeholders' perceptions is fundamental to effectively managing marine protected areas (MPAs). Islas Marietas National Park (IMNP), an ecologically important coral reef ecosystem in the Central Mexican Pacific (CMP), has experienced major fluctuations in tourism pressures, environmental health, and regulatory changes in the past decade, which has led to efforts in its monitoring and restoration; however, limited research has been conducted to understand stakeholders' perceptions of the social-ecological system. The present study integrates ecological attributes of the park, primarily changes in live coral cover (LCC), and stakeholders' perceptions of the coral reef ecosystem to determine how users and tourism operators perceive the ecological changes in the area. It employs a mixed-methods approach, including ecological markers such as changes in live coral cover from 2012 to 2022 and recent surveys collected from tourism stakeholders. The results show that while live coral cover increased from $12.11 \pm 6.21\%$ in 2012 to $25.29 \pm 15.00\%$, tourists and tourism operators perceive a decrease and degradation of the natural environment. In addition, tourists perceive a major ecological decline than tourism operators, and this perception is not correlated with their age range. Perceptions of environmental health do not align with the health status assessed by ecological monitoring, and the lack of awareness of ecological recovery at IMNP may hinder management efforts' continued and expanded success. Therefore, developing more effective communication initiatives, citizen involvement, and education is important for conserving and managing coral communities in the park.

Keywords Tourism · Stakeholder perceptions · Marine protected areas · Islas Marietas National Park · Coral reef communities

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1 Introduction

Coral reef ecosystems are important to ecological health and coastal communities, with high biodiversity and many services directly or indirectly derived from them [1]. They are also threatened by anthropogenic pressures and environmental changes, including natural stressors enhanced by climate change, such as more frequent and intense storms and El Niño–Southern Oscillation (ENSO) events [1–3]. One approach to protecting coral reefs or mitigating the stress from anthropogenic threats is through the establishment of marine protected areas (MPAs), which, depending on their type of protection, allow for lower-impact uses of natural resources and incorporate different active and passive management strategies to avoid their degradation [4]. Achieving effective management of a protected area may require a balance between protecting species and ecosystems and allowing for sustainable resource use that economically benefits local communities [5].

Marine protected areas (MPAs) have been increasingly implemented as a tool to conserve and restore coral reefs and their associated biodiversity [3, 5]. Management actions within the designated area may include limiting over-fishing, regulating the extraction of organisms, and controlling local threats associated with tourism and shipping [6, 7]. Because resource use can cause a degradation of the natural system, it may be useful to establish a limit of acceptable change (LAC), which is a threshold of acceptable ecological degradation in response to the fluctuation of environmental conditions and the pressure of economic activities. By selecting key indicators and quantitative standards to maintain environmental quality over time [8, 9], the LAC works as a regulatory system to prevent or mitigate biodiversity loss [5], and a planning or monitoring tool [9]. Marine eco-tourism is one economic activity connected to marine protected areas, where tourism activities such as scuba diving and snorkeling have become important economically in the past few decades, with more use pressure in tropical marine regions, which, depending on the regulations, may cause a minimum or a major degradation of the ecosystem [10]. Their relevance can be quantified in economic benefits, resulting in US \$36 billion in tourism services worldwide [11].

Islas Marietas National Park, located in the Central Mexican Pacific, harbors an ecologically important coral reef ecosystem and is considered a tourism hotspot [12]. In the past decade, the coral reef at IMNP has undergone several bleaching events and degradation associated with both global and localized anthropogenic pressures; these include the effects of ENSO (El Niño Southern Oscillation) events, which caused massive mortalities during the last four decades [13, 14], as well as the impact of major increases in visitation, which caused degradation to the coral reef ecosystem [15]. In response, new regulations were introduced at IMNP in 2016, including carrying capacity restrictions [12], extensive ecological monitoring, and coral restoration activities [16], which have contributed to maintaining the ecosystem's health through active management. However, limited research has investigated social perceptions of the environment at IMNP, and social perceptions have not been incorporated in management actions.

Past studies specific to IMNP have identified that more detailed research on the economic and social elements of the national park is necessary [12, 17]. Very few studies have recognized or evaluated these social components, possibly because these indicators can be difficult to measure or are not prioritized [17]; however, accounting for these types of social dimensions in protected area management is critical to the development of just and ethical management practices [18]. A past survey-based study conducted within the park investigated tourists' perceptions of climate change more broadly, but prior research has not specifically addressed perceptions of the ecosystem and management within Islas Marietas National Park [19].

The establishment of marine protected areas and related tourism can have positive and negative impacts on social-ecological systems. While sustainable and low-impact tourism in protected areas is often a critical part of management, it can also lead to over-exploitation and degradation [9, 20]. Similarly, while the MPA-linked tourism industries can benefit adjacent communities economically, regulations can limit historical resource uses, and tourism development can negatively affect residents. Because these potential impacts determine the success of the protected area for both conservation and socioeconomic value, understanding stakeholders' perceptions is imperative and can affect the outcomes of the MPA's management and the entire social-ecological system. The present study represents a multi-disciplinary approach to address this gap in knowledge at Islas Marietas National Park by investigating changes in live coral cover (LCC) from 2012 to 2022 and whether tourists' and tourism operators' perceptions of the natural environment coincide with the results of ecological monitoring. Live coral cover was selected as a commonly used metric of reef health that can also serve as a proxy for other ecological variables, including the presence of key organisms such as reef fish [21]. Insights about the natural environment from those who work at, visit, or otherwise interact with protected areas are also necessary to understand gaps in understanding and awareness, which can inform management actions and education initiatives.

2 Methods

2.1 Study area and ecological data

Islas Marietas National Park (Fig. 1) is located in the Central Mexican Pacific region (20°41'55.21"N, 105°34'34.20"W). The park was declared a Natural Protected Area (NPA) in 2015 and is guided by a management plan outlining the permitted programs and activities and the strategies to conserve and manage the area's natural resources [22].

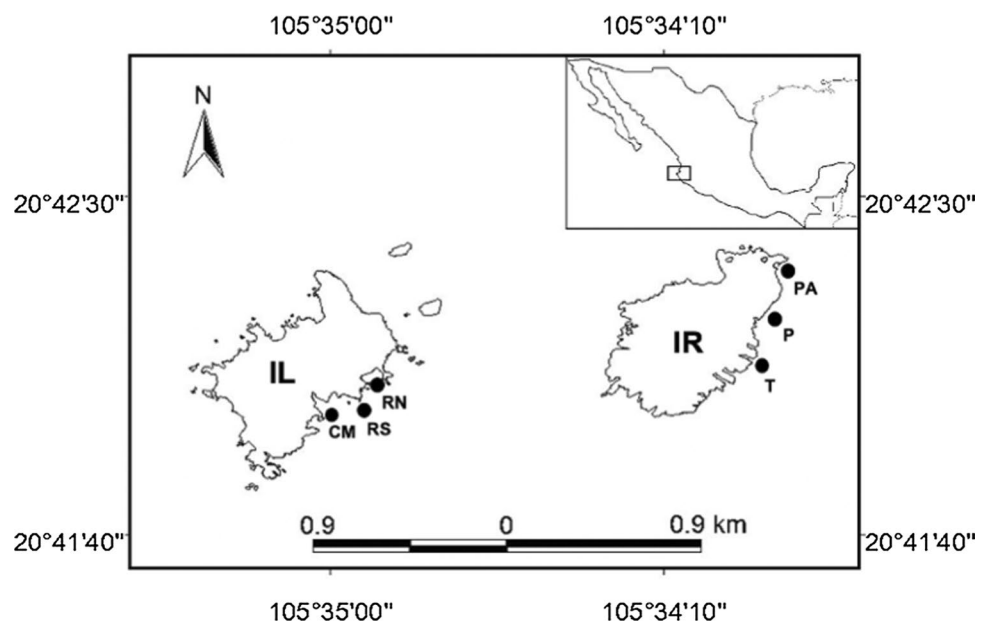
Ecological monitoring to determine changes in live coral cover was conducted at six sites within Islas Marietas: (1) three at Isla Larga: Cueva del Muerto, Área de Restauración/Restoration North, Área de Restauración Sur/Restoration South; and (2) three at Isla Redonda: Túnel/Amarradero, Pavonas and Playa del Amor (Fig. 1). Each site differs in use and intensity of use, primarily due to the implementation of additional regulations in 2016: Cueva del Muerto, which is the most visited and high-pressure site for snorkeling, as it is suitable for both new and experienced snorkelers; the Restoration North and Restoration South sites, which are entirely closed to tourism activities; Túnel/Amarradero, which is primarily a dive site with low snorkeling use; Pavonas, which is also a dive site with low snorkeling use, and Playa del Amor, which is a "swim-through" only site where groups swim across to enter a cave and access the beach during a 15-min period, but do not linger to snorkel. Under current regulations at Playa del Amor, tourists are not permitted to wear fins, the number of visitors is limited to 210 per day, and the site can only be visited from Wednesday to Sunday. For all sites, tourists are required to wear life jackets to discourage diving down and other actions that disturb the reef. Additionally, coral restoration efforts by direct coral transplantation occur at all sites except Túnel [16].

Live coral cover was assessed in the same season every two years from 2012 to 2022, except for 2020, due to the Covid-19 pandemic. Five 25-m-long belt transects were laid out parallel to the coast at each of the six sites. An estimate of percent coverage was recorded using a square frame (1 m²) with six evenly distributed, equidistant replicates on each transect. The corals were identified in situ at the species level and then by groups: branching coral (*Pocillopora* spp.), massive corals (*Pavona* spp. and *Porites* spp.), and cup coral (*Tubastrea coccinea*). Data were tested for normality using the Anderson–Darling test, and a paired t-test ($p > 0.05$) was used to determine if there are significant differences in coral cover between 2012 and 2022. Ecological data were analyzed statistically using Excel 16.66.1 and MiniTab 21.1.0.

2.2 Analysis of trends in tourism and surveys

Comisión Nacional de Áreas Naturales Protegidas (CONANP) authorities provided monthly tourism census data from 2012 to 2022. A survey was selected as the primary means of collecting social data based on the ability to collect information about perceptions in the tourism setting, including both qualitative and quantitative data [23]. Several

Fig. 1 Study area, Islas Marietas National Park (IMNP), located in the Central Mexican Pacific. Ecological monitoring occurred at six study sites at Isla Larga (IL) and Isla Redonda (IR): Cueva del Muerto (CM), Restoration South (RS), Restoration North (RN), Túnel (T), Pavonas (P), and Playa del Amor (PA)



basic objectives were established to maximize participation, accuracy, and ability to collect the data of interest. The questions were developed for the specific context of the study area. The ecological indicators were selected based on their significance at IMNP, past ecological monitoring data, and their visibility to tourists. The questionnaires contained Likert scale, closed-ended, and multiple-choice questions with a consistent format and no technical or complex language. There were three different survey questionnaires, depending on the individual's role (tourist, tourism operator, and park managers/rangers), but with the same primary survey questions, order, and format for comparison across the entire population (Table S1). Park managers/rangers were surveyed to add additional context for tourist and tourism operator survey results. The primary differences between surveys were in background and demographic information specific to each sector (e.g., 'How many years have you been working as a tourism service provider at Islas Marietas?').

The survey target number was developed from a theoretical population calculated from IMNP permit and census numbers. Based on the number of permitted operators (120, as estimated by CONANP staff), the size of management staff (10), and the number of tourists at IMNP in 2022 (172,208), the population is estimated as 172,338. Using this population estimation, to achieve a confidence level of 90%, with a 5% margin of error, between 173 and 270 responses would be needed depending on the skew of results [24]. For tourism operators, the representation of different strata was considered, including respondents who offer services to small groups (3 to 8 visitors) and large groups (50+ visitors). This set a target for a minimum of 173 responses, which is also reasonably acceptable based on diminishing returns in survey responses, and the sample size ($n = 181$) is considered representative.

All potential respondents were approached and asked for consent to participate in the survey. Each survey was conducted individually, and respondents were encouraged to focus on individual surveys, avoiding a "third party present effect" or respondents influencing each other. Surveys were distributed to visitors and tourism operators on the boat after snorkeling or other park activities had occurred. Additionally, some tourism operators were surveyed at their offices/shops to reach a higher number of operators. Surveys were offered to all participants in Spanish or English, and all approached participants were comfortable using one of those languages.

Demographic and background information was collected and reported descriptively (Table S2). Age group was investigated in conjunction with 'perceptions of change,' as described below. Survey results were analyzed statistically using Excel 16.66.1 and MiniTab 21.1.0. The "then vs. now" perception questions were transformed into quantitative indices for statistical analysis and data visualization. In the questionnaire, respondents select their perception of the current status of each indicator (coral, reef fish, tourists) as more, less, or the same as ten years ago. The time frame was set at ten years to include the growth in popularity of Playa del Amor, which caused an abrupt increase in visitation to the park, the regulatory changes when IMNP was declared an NPA in 2015 [22], the establishment of the coral restoration program, and the current management and conservation strategy of the area. The perceptions responses were converted into a 3-point scale, labeled the Relative Perceptions Index (RPI): -1 (less), 0 (the same), and 1 (more); converting to the RPI allows for data visualization, and a 3-point scale is sufficient to capture the range of possible responses for this question type. This also enabled further quantitative analysis of the data, including calculating the average RPI for age groups or sectors to understand the average perceptions of a particular group. A Spearman's correlation was calculated to determine relationship between coral RPIs and age group.

3 Results

3.1 Ecological results

Results show that live coral cover (LCC) for all study sites at Islas Marietas National Park increased from $12.11 \pm 6.21\%$ in 2012 to $25.29 \pm 15.00\%$ in 2022, with a significant difference over the decade ($t = 3.35$, $p = 0.020$). The North and South Restoration areas had the highest increases of at least twofold in live coral cover from 2012 to 2022. Both sites have ongoing coral restoration projects and are closed to tourism activities. Túnel, primarily a dive site and does not have ongoing restoration activities, had the lowest relative increase in LCC (21%) (Fig. 2).

During the ten years of the study, the average LCC at Isla Larga was lowest in 2012 (15.43%); at Isla Redonda the lowest LCC was recorded in 2016 (5.64%), which was also the year with the lowest live coral cover (11.49%) across all study sites (Cueva del Muerto, North Restoration, South Restoration, Pavonas, Túnel, and Playa del Amor) (Fig. 3).

Fig. 2 Percent live coral cover (% LCC) by site at Islas Marietas National Park for 2012 and 2022. Error bars represent standard errors of the mean

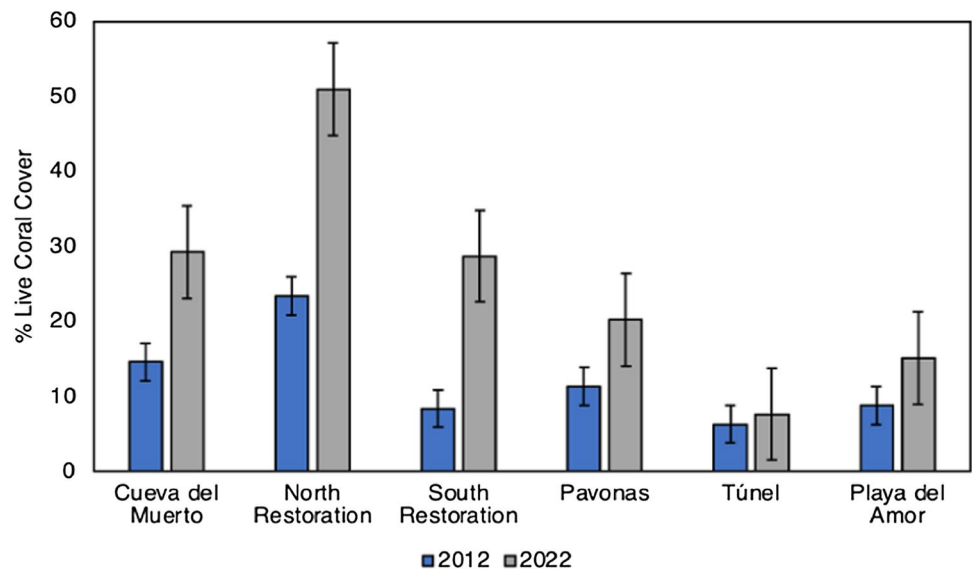
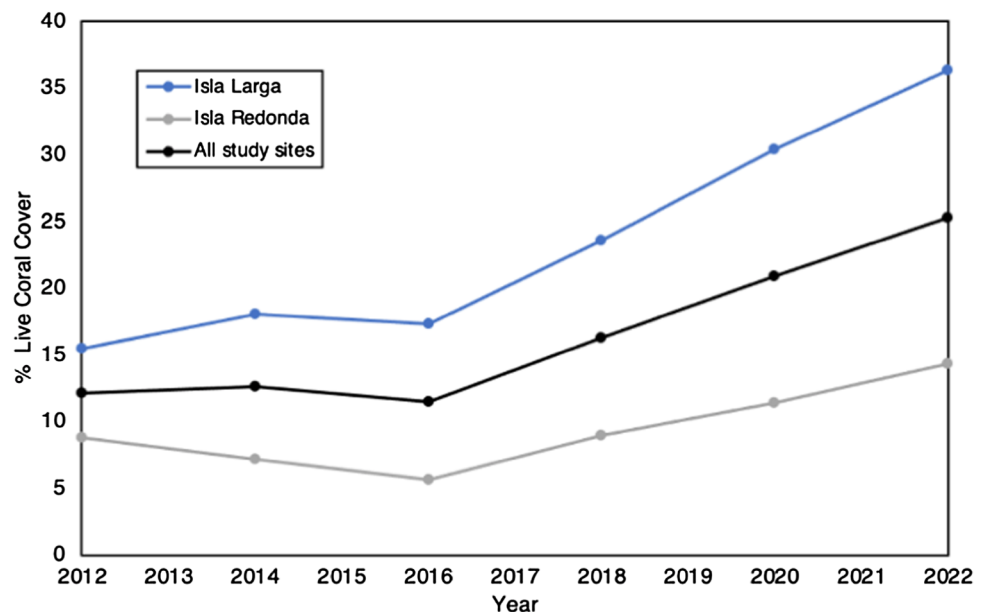


Fig. 3 Average percent live coral cover (% LCC) at Isla Larga, Isla Redonda, and all study sites at Islas Marietas National Park from 2012 to 2022



3.2 Annual visitors

The census data provided by CONANP showed a total visitation of 1,634,939 people from 2012 to 2021 (S3). The lowest annual visitor numbers were in 2012 and 2013; after this period, visitors per year rose rapidly, reaching the highest annual visitation in 2015 with 322,535 people. After reaching this peak, the number of visitors dropped each year, with a more considerable decrease in 2020, when values closer to those in 2013 were recorded. The number of visitors increased annually from 2020 to 2022 (Fig. 4).

3.3 Survey results

A total of 181 respondents (excluding insufficiently complete surveys) participated in the survey from September–November 2022. By sector, there were a total of 126 tourists and 52 tourism operators. Also, three CONANP

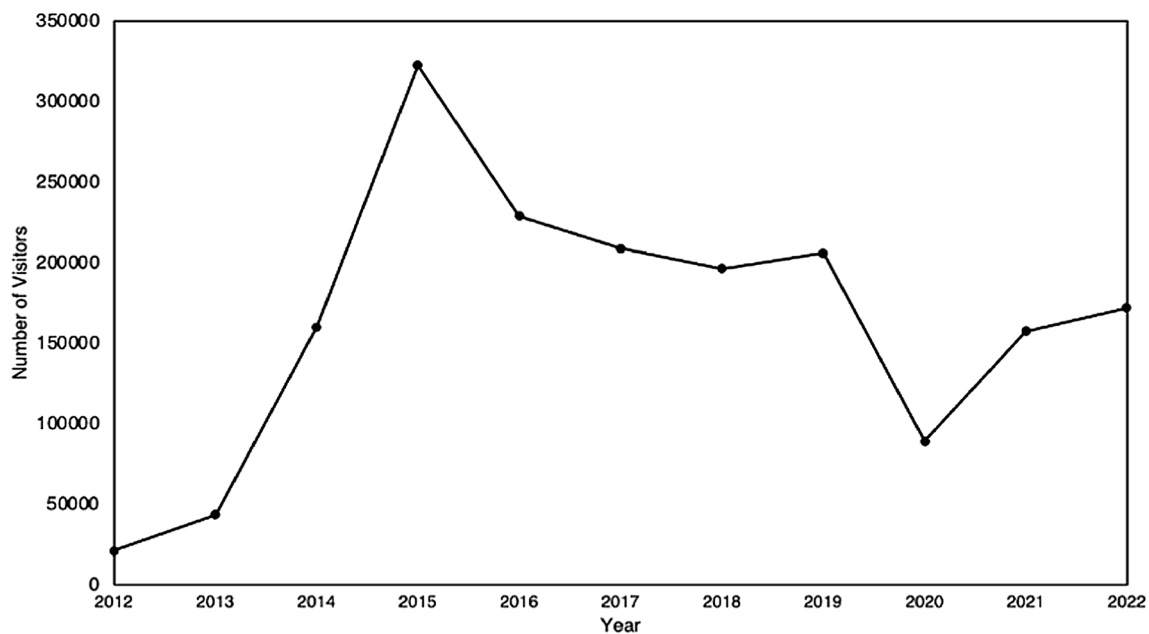


Fig. 4 Total number of annual tourists to Islas Marietas National Park, per year, from 2012 to 2022

managers or park rangers completed a version of the survey. The largest survey respondent age group across all sectors was 25–34, followed by 35–44; across all sectors, Mexican was the most represented nationality (49.7%), followed by American (39.2%) and Canadian (5.5%; Table S2).

Respondents in the tourism operator category represent all sectors of tourism operators at Islas Marietas National Park, including large boats, catamarans, and small boats, as well as both lower- and higher-budget tours. Respondents ranged from those who had worked there for less than one year (13.5%), to 21–30 years (7.7%), with the majority (73.1%) having worked there for less than ten years, reflecting a high turnover among operators. Tourist survey respondents (126), engaged in at least one of the three permitted activities in the area, and often in multiple different activities as part of the same tour. Because of this, the same individual may represent a response for more than one activity. The most common activity was snorkeling ($n = 103$), followed by visiting beaches ($n = 33$) and scuba diving ($n = 17$) (Figure S1).

Tourists and tourism operators provided their perceptions of the natural environment (fish, coral) and their perceptions of the number of tourists visiting IMNP via survey. The responses show an average perception of decreased fish and coral and an increase in tourists. The average relative perception for tourists' responses is more extreme than tourism operators'; they had lower average Relative Perceptions Indices for ecological indicators (fish and coral) and a higher average RPI for perceived tourists than operators did. Both sectors perceive a decline in the abundance of coral and fish and an increase in tourism (Fig. 5).

Spearman's correlation was used to understand if there is a relationship between Relative Perceptions Indices for coral and age group. There was a non-significant, moderately weak positive correlation between age group and perception of coral cover ($r = 0.486$, $p = 0.329$). Additionally, only the age groups 45–54 and over 65 years have a positive or neutral perception of the health of the coral community (Fig. 6).

This study also explored the economic value of the coral reef to provide additional context. Most of the tourists (60.3%) and tourist operators (76.2%) perceive that the reef provides "a lot" of economic value, and only 4% of the respondents describe the economic value of the coral reef as "little" or "none". According to tourism operators, this economic benefit is partly related to the regulations (66.7%), and only a few perceive some or a big negative impact (8.3%). The regulations are also considered positive for maintaining the natural environment (86.0% of tourists and 87.2% of tourist operators), and less than 7.4% of the respondents believe that regulations cause a negative impact on the environment.

Finally, in response to a question about the impact of tourists on the natural environment, 50.0% of tourism operators perceive tourism as a factor that causes a big positive or some positive impact on the natural environment; in contrast, only 18.0% of tourists responded that tourists had some positive or a big positive impact and 76.2% selected that tourists have a big negative or some negative impact. Only a small fraction of tourism operators (4.0%) and tourists (5.7%) selected "no impact".

Fig. 5 Average Relative Perceptions Indices of tourism operators and tourists for coral, fish, and tourists at Islas Marietas National Park. “More than ten years ago” is represented by a value of 1, “The same as ten years ago” is represented by a value of 0, and “Less than ten years ago” is represented by a value of - 1

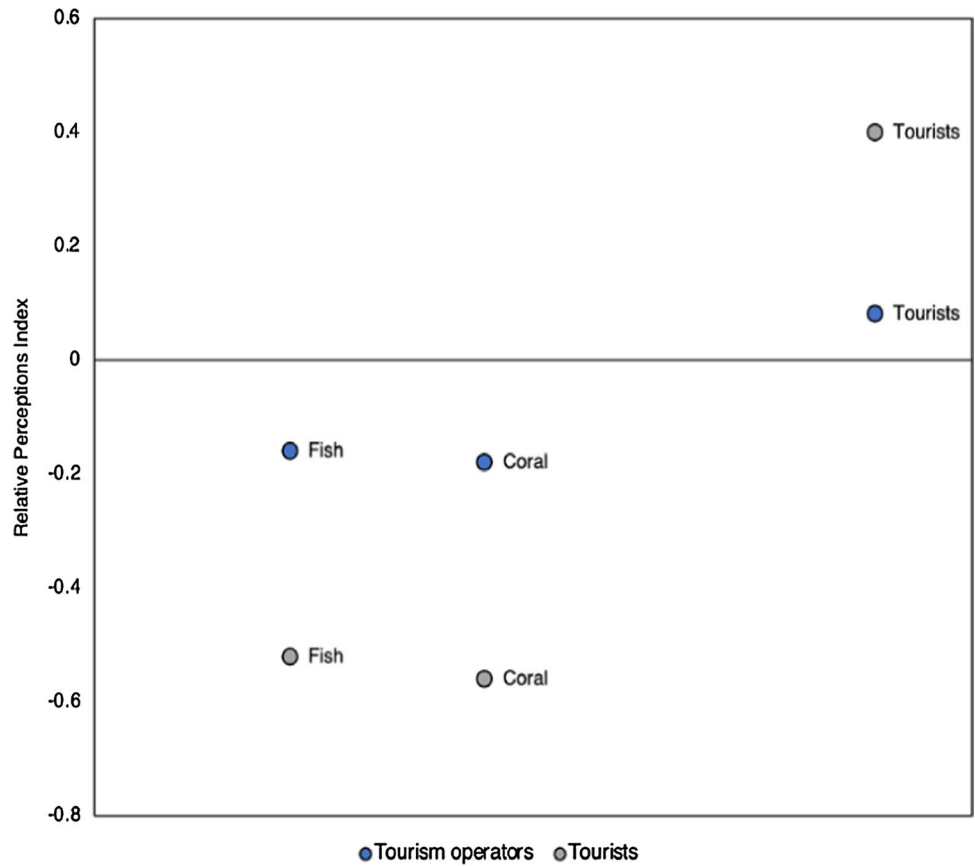
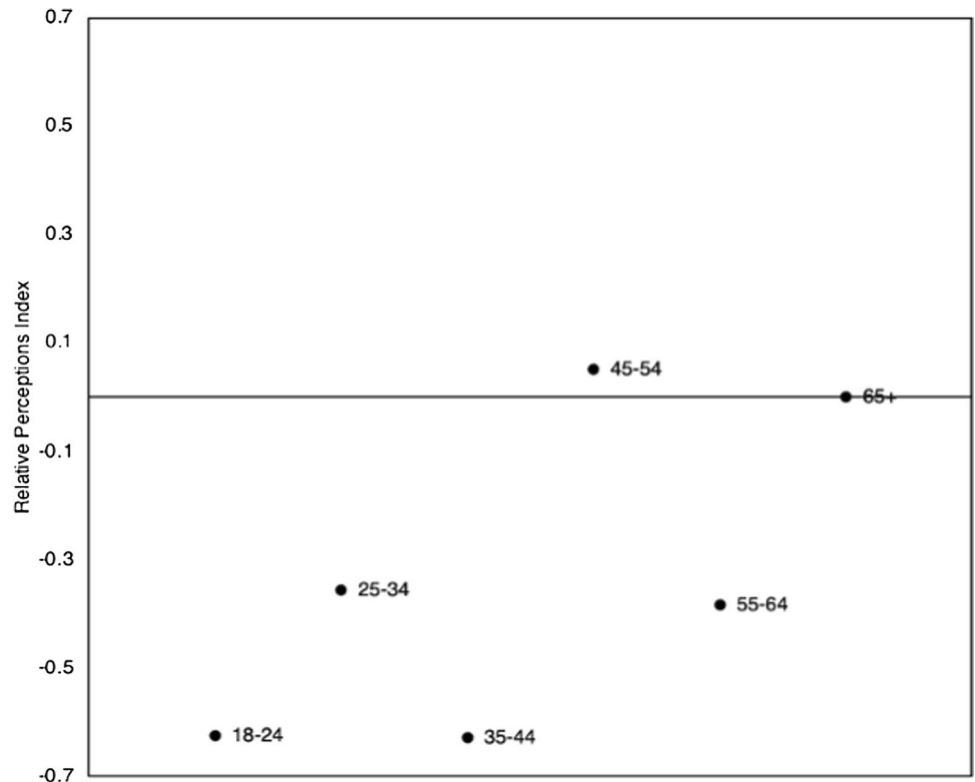


Fig. 6 Average Relative Perceptions Indices of all survey respondents for coral cover, by age group, at Islas Marietas National Park. “More than ten years ago” is represented by a value of 1, “The same as ten years ago” is represented by a value of 0, and “Less than ten years ago” is represented by a value of - 1



4 Discussion

4.1 Increased coral cover at IMNP

Coral reefs are considered one of the most threatened ecosystems globally due to the cumulative effects of multiple natural and anthropogenic stressors, which have led to massive bleaching and mortality events worldwide [25, 26]. In the last 30 years, it's estimated that over 50% of the world's coral reefs have died or severely degraded [1, 2, 11]. Contrary to global trends, the results show an improvement in the coral reef ecosystem at Islas Marietas National Park over the decade analyzed in this study. Live coral cover increased significantly between 2012 and 2022 (Fig. 2), which may also provide evidence of changes in associated organisms, such as reef fish biomass [21]. Increases in coral cover at IMNP may have resulted from two processes: the natural recovery, which has also been recorded in other sites along the region, and the implementation of active management actions, including the implementation of regulations for the use of the sites, the coral restoration program and the carrying capacity [15, 16]. The results also show a decrease in coral cover in 2016 (Fig. 3), which may be partially attributed to the thermal stress caused by the strong El Niño event, considered the most intense in the last three decades [27]. This event caused a bleaching response, but not massive mortality [28], as recorded 20 years earlier [13]. Therefore, through natural and assisted recovery, coral cover in the NPA shows a constant recovery through 2022.

In addition to natural stressors contributing to the decrease in LCC in 2016, coral cover may be influenced by the annual visitation to IMNP. As previously described, the Central Mexican Pacific region, and in particular Islas Marietas National Park, suffered a bleaching event and massive coral mortality caused by the 1997–98 El Niño event [13], and showed a slow but constant recovery [15, 28], until 2016, coinciding with a year after the peak of park visitation (Figs. 3, 4). After the authorities recognized the damage caused by tourism to the ecosystem, a temporary closure of the area and new regulations were put into place [12]. The effect of the prohibition of tourism for four months, the implementation of new visitor regulations with specifics according to the site, the constant surveillance by park rangers to enforce regulations (e.g. restricting visits to two restoration sites), and the implementation of the coral restoration program may all be contributing factors to the increase in LCC from 2016 to 2022. While all these factors and natural recovery must be considered, the temporal trend shows that as visitation decreased, LCC increased. The sites with the highest recovery of LCC are North and South Restoration (Fig. 2). Besides being coral restoration sites (along with all other study sites except Túnel), these are two sites entirely closed to tourism activities and are only accessed for research or management activities; all other sites experience use by divers and snorkelers [22].

Although additional variables contributed to changes in the natural environment from 2012 to 2022, the correlation between the introduction of regulations and restoration projects and the increase in LCC indicates that the ecological elements of this case study warrant future research and that aspects of management at IMNP may have the potential to serve as a “success story” for other marine protected areas in Mexico and more broadly. These results also suggest that effective conservation of coral reef ecosystems may require active restoration actions, such as coral outplanting, to be combined with other management actions, such as carrying capacity limits, closures during specific days or seasons, regular training workshops for tourism service providers, and other strategies. The assessment of carrying capacity in the park in 2016 and its continued use as an active management tool to respond to changes in vulnerability should also be further explored, and could more broadly inform the management of tourism-impacted coral reef ecosystems [12].

4.2 Social perceptions

To understand if tourism stakeholders' perceptions of the natural environment coincide with the state of health assessed in ecological monitoring, average Relative Perceptions Indices were analyzed; RPIs establish if an individual perceives that there is more, less, or the same cover/abundance of an indicator in the present versus the past. Survey results show that tourism operators and tourists perceive a decline in the abundance of coral cover and fish associated with the coral community. Overall average RPI for coral was -0.43 , while the overall average RPI for fish was -0.40 ; individuals across both sectors believe that coral cover and fish abundance have declined at IMNP in the last decade. This demonstrates a gap between the perceived state of ecological health and ecological monitoring results, as live coral cover is higher in 2022 than in 2012 (Figs. 2, 5).

One important consideration when investigating the gap between stakeholder perceptions and the status of coral reefs at IMNP is the variation in reef health among sites. While all sites had higher LCC in 2022 compared to 2012, the two sites with the most significant improvements, Restoration North and Restoration South, are closed to tourism. The sites that are open to tourism and thus observed by visitors and operators (Cueva del Muerto, Pavona, Túnel, Playa del Amor) have experienced smaller improvements in LCC. This considered, those sites also experienced substantial improvements from 2012 to 2022, and the variation among sites does not account for the disconnect between ecological monitoring and stakeholder perceptions. It is also important to consider that all tourism sites except for Túnel have ongoing restoration activities, so that variable is not exclusive to Restoration North and Restoration South. A final consideration is that most visitors (83.3%) were visiting IMNP for the first time, and rather than having firsthand perceptions of the past, they may be influenced by other variables. While some research suggests that those who invest their time and money to visit coral reefs are more likely to recognize a healthy versus a degraded reef [29, 30], perceptions of coral reef quality may result from many factors, including (1) the scenic value and the weather conditions of the site, (2) the experience and quality of the tourism operator, and (3) previously obtained information (e.g. social media, television, etc.). These factors or a combination may affect perceptions regardless of the environmental conditions [29, 31]. Previous research has also shown a disconnect between diver perceptions and reality in the opposite ecological scenario of this study, with divers perceiving the coral to be healthy when it is fact highly degraded [32].

It is documented that media coverage strongly impacts public beliefs about climate change and environmental impacts [33, 34], which could be a factor that contributes to a perception of ecological degradation at Islas Marietas. In recent years, mass media coverage of coral reefs, including many of the most well-known reefs, tends towards portraying degradation and loss, and some studies have found that these data are sensationalized [35]. While drawing attention to the global decline of coral reefs is important, misleading and sensational reporting can negatively impact conservation and management. One issue is that adverse environmental reporting without discussion of actions for improvement can cause a maladaptive response; individuals feel helpless and are less likely to support proposed actions [35, 36]. Additionally, the public may tend to overgeneralize media reports, particularly in the case of highly sensationalized news. Stakeholders at Islas Marietas may be generalizing the broader media coverage of coral reefs, resulting in misconceptions that the ecosystem at IMNP has also declined in recent years. Furthermore, at Islas Marietas, there was a lot of publicity in 2016 surrounding the damage to the park and the reasons for the closure in local and national media, but there wasn't significant follow-up on recovery efforts and results. This could benefit the management of the NPA since visitors may recognize before arrival that they are at a vulnerable site, or it may mask the actual conservation status of the site and the interventions that have been taken. Further research should investigate the role of media or other sources of respondents' perceptions at IMNP. There is an urgent need to inform users and change their perceptions, as these may cause them to believe that restoration and regulatory measures are ineffective, inhibiting future policy and regulatory development at Islas Marietas and other protected areas. The findings suggest that management strategies must address these results, including enhanced educational strategy and stakeholder engagement, as well as the standardization of education tools for tourists during the visitation to the park.

Another consideration at IMNP is the importance of co-management, which refers to partnerships between managers and stakeholders and may encourage cooperation and compliance with rules and help create a relationship of trust with governmental institutions [38]. The regulation of natural protected areas in Mexico dictates different conservation classifications, which restrict or allow activities such as tourism, fishing, extraction, and even small-scale urbanization [37]. IMNP's status as a National Park means that restricted use subzones may be established, as well as zones allowing the sustainable use of natural resources as part of the management plan [12, 37]. The enforcement of the regulations in IMNP is the responsibility of park rangers [12, 16], however, effective regulations require the "buy-in" and cooperation of local users and must balance social and conservation benefits. During the closure of the area in 2016, the tourism operators initiated a cooperative strategy with the formation of a civil association, Bahía Unida. This association enables collaboration between operators and authorities, facilitates financial donations, and enforces self-regulation [39], to promote compliance and avoid another closure. This type of cooperative also generates a sense of involvement [30, 38] and may help to promote responsibility for direct and indirect anthropogenic impacts on the marine environment [30].

In addition to their importance for biodiversity, coral reefs have an estimated economic value of \$10 trillion annually due to all the ecosystem services they provide [40]. Coral reef-related tourism represents more than a third of this value [11] and is an opportunity for social development that may benefit local populations [41], but also may cause degradation. This degradation includes both direct use impacts and indirect impacts such as non-planned urbanization, changes in land use, and increases in waste or pollution that may affect the coral reef [32, 42]. Recreation and tourism are consistently

viewed as valuable cultural services within IMNP [17], and this study suggests that tourists and tour operators recognize the economic benefits. Based on current visitation, the minimum national economic spillover from the entrance to the area is approximately \$400,000 USD per year, and there is an extra \$2 USD per visitor charged by Bahía Unida, which is used directly for the conservation of the area [38]. This valuation does not but should also consider the indirect economic benefits such as hotels, restaurants, transportation, and other services used by visitors and ecosystem services. While most users recognize the important economic benefits of the coral reef ecosystem at IMNP, this concept should be reinforced in management strategies to increase the effectiveness of any conservation effort.

Research incorporating a system's biological and social aspects, including establishing baseline social perceptions from different stakeholders, is crucial for effectively managing protected areas and promoting ecosystem recovery. This study investigated changes in the natural environment at Islas Marietas National Park, analyzed stakeholder perceptions of changes and if they coincide with ecological monitoring results, and explored the factors that may influence these perceptions, such as age. There were several key results: the natural environment at Islas Marietas National Park changed from 2012 to 2022, with a significant increase in live coral cover; however, tourists and tourism operators perceive the ecosystem health to have declined. Also, perceptions of ecological change are not correlated significantly with age group.

This study on social perceptions at IMNP fills a gap in the current research and develops a basis for future social-ecological research in coral reef systems with protection or non-protection status. By confirming the ecological recovery seen in previous studies and illuminating stakeholders' perspectives, this study reveals both the successes of protected area management at IMNP and the opportunities to integrate and educate stakeholders more effectively. Understanding and incorporating the values and views of stakeholders is necessary for effective management and provides significant insight to guide future research and the strategies of managers at Islas Marietas National Park and in marine protected or highly vulnerable areas more broadly.

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Data availability The authors confirm that data analyzed during this study are included in this published article.

Code availability Not applicable.

Declarations

Ethics approval and consent to participate Verbal informed consent to conduct the interviews were obtained before being interviewed. The present study does not contradict the ethical standards in the 1964 Declaration of Helsinki, as it does not involve any medical data or information that could be used to identify any participant.

Competing interests The authors have no competing interests to declare relevant to this article's content.

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