Exploring the demography and conservation needs of hawksbill sea turtles *Eretmochelys imbricata* in north-west Mexico

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Abstract The hawksbill sea turtle *Eretmochelys imbricata* is categorized as Critically Endangered on the IUCN Red List and its population has declined by over 80% in the last century. The Eastern Pacific population is one of the most threatened hawksbill populations globally. Western Mexico is the northern distribution limit for hawksbill sea turtles in the Eastern Pacific and recent research indicates that the Mexican Pacific portion of the population is a separate management unit because of the restricted movements of these turtles. Here we use the most complete database of sighting records in the north-west Pacific of Mexico to identify sites where hawksbill turtles are present. We also develop a conservation index to determine the conservation status of hawksbill turtle sites. Our results demonstrate the importance of this region for juveniles and the relevance of rocky reefs and mangrove estuaries as habitats for hawksbill turtles. We identified 52 sites with records of hawksbill turtles. Most of these sites (71%) are not protected; however, sites with high conservation value included islands and coastal sites along the Baja California peninsula that are established as marine protected areas. Reefs and mangrove estuaries relevant for hawksbill turtles are probably also significant fish nursery areas that are important for local fishing communities, creating opportunities for conservation strategies that combine science, local engagement and policy to benefit both local fishing communities and hawksbill sea turtle conservation.

Keywords Critically Endangered species, Eastern Pacific, *Eretmochelys imbricata*, foraging grounds, Gulf of California, hawksbill sea turtle, Mexican Pacific, turtle foraging grounds

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Introduction

Overexploitation and habitat destruction have resulted in the decline and extirpation of numerous wildlife populations around the globe (McCauley et al., 2015; Ceballos et al., 2020). Long-lived species with delayed sexual maturity and long generation times, including many marine

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mammals, seabirds and sea turtles, are particularly sensitive to anthropogenic impacts, and their populations can be slow to recover even when impacts are mitigated (Lotze et al., 2011).

Sea turtles typically disperse widely from their natal beaches and transition through various geographical locations and foraging habitats as they age (Musick & Limpus, 1997). For at least a portion of their lives, they depend on coastal habitats, where they are often exposed to concentrated human activities and threats, including fisheries, pollution, habitat modification and harvesting of eggs and individuals (Peckham et al., 2007; Nelms et al., 2016). Hawksbill sea turtles *Eretmochelys imbricata* are of particular conservation concern because of the harvesting of millions of individuals for the international tortoiseshell trade (Miller et al., 2019). Hawksbill turtles are categorized globally as Critically Endangered on the IUCN Red List (Meylan & Donnelly, 1999; Mortimer & Donnelly, 2008), and the Eastern Pacific population is believed to be amongst the most threatened, with estimates of fewer than 700 nesting females remaining (Wallace et al., 2011; Gaos et al., 2017).

Along the Eastern Pacific Rim, Mexico is one of several countries that host a relatively large number of foraging hawksbill turtles, particularly juveniles (Gaos et al., 2010; Chacón-Chaverri et al., 2015; Liles et al., 2017; Llamas et al., 2017; Martínez-Estévez et al., 2021). The Mexican Pacific represents the northern limit of the hawksbill turtles' distribution, and their abundance has been reported as scarce compared to green *Chelonia mydas* and olive ridley *Lepidochelys olivacea* sea turtles (Márquez et al., 1982). During the first half of the 20th century, several hundred hawksbill turtles nested annually along the Pacific coast of Mexico (Nayarit, Islas Marías and Isla Clarión (Revillagigedo Archipelago); Márquez, 1976), which is an order of magnitude greater than current nesting numbers in the region (Gaos et al., 2017). From the late 1950s to the 1980s, the hawksbill population declined because of intensive harvesting for the shell trade, for meat trade in local markets and for stuffed souvenirs (Cliffton et al., 1982; Seminoff et al., 2003; Supplementary Plate 1). The national production of turtle shell scutes in 1973 was close to 5 t (c. 5,000 individuals; Márquez, 1976, 1996; Mortimer & Donnelly, 2008).

Several studies have reported high site fidelity and restricted foraging ranges of hawksbill turtles in the Eastern Pacific (Gaos et al., 2012; Carrión-Cortez et al., 2013; Martínez-Estévez et al., 2021). Genetic studies have also demonstrated that the Eastern Pacific population is not only differentiated from other populations but that individuals in El Salvador, Nicaragua, Costa Rica, Ecuador and Mexico constitute distinct genetic subpopulations (Gaos et al., 2016, 2018). Eastern Pacific hawksbill turtles often inhabit coastal reef ecosystems (Carrión-Cortez et al., 2013; Llamas et al., 2017). However, this population also often utilizes mangrove estuarine habitats for both nesting and foraging (Liles et al., 2011; Gaos et al., 2012; Chacón et al., 2015; Martínez-Estévez et al., 2022). The Mexican Pacific represents the northern limit of the mangrove distribution in the Eastern Pacific, and the states of Baja California, Baja California Sur, Sonora, Sinaloa and Nayarit have the highest cover of mangrove estuaries in the region (181,036 ha in 2020; Velázquez-Salazar et al., 2021). Similarly, rocky reefs are the most expansive marine habitat in north-west Mexico, covering an area of 1,025,420 ha in the Gulf of California alone (Johnson et al., 2016). Both habitat types are important nurseries for commercially important fish species and therefore support numerous small-scale fisheries, which creates additional challenges for hawksbill turtle conservation (Aburto-Oropeza et al., 2008; Liles et al., 2017).

Examining the spatial distribution of hawksbill turtles provides an opportunity to determine whether these turtles could benefit from spatial conservation strategies such as marine reserves because of their preference for restricted coastal habitats (Gaos et al., 2016; Martínez-Estévez et al., 2021). Here we use a comprehensive dataset of hawksbill turtle captures and sightings to describe the distribution of the species in north-west Mexico. We also develop a conservation index to determine the conservation value of sites with hawksbill turtle records and highlight areas that will be important for protecting this Critically Endangered species and its habitats.

Study area

The north-west Mexican Pacific comprises the Baja California peninsula (including both the Pacific and Gulf of California coasts) and the mainland coast (limited by the states of Sonora, Sinaloa, Nayarit and Jalisco; Fig. 1). The north-west Mexican Pacific is the most productive fishing region in Mexico and is the source of $>$ 70% of the annual fish landings in the country (Jiménez Esquivel et al., 2018). The region also includes a wide variety of marine habitats such as rock and coral reefs, seagrass meadows, *Sargassum* beds, terraces and mangrove estuaries, and hosts many endemic species (Lluch-Cota et al., 2007).

Methods

Hawksbill turtle captures and growth

Hawksbill turtle capture records were provided by a regional network of scientists, local communities and conservationists that have worked collaboratively for over 20 years as members of the NGO Grupo Tortuguero de las Californias A.C. (Supplementary Table 1) to document the presence and distribution of sea turtles in north-west Mexico. Records were collected using three methods:

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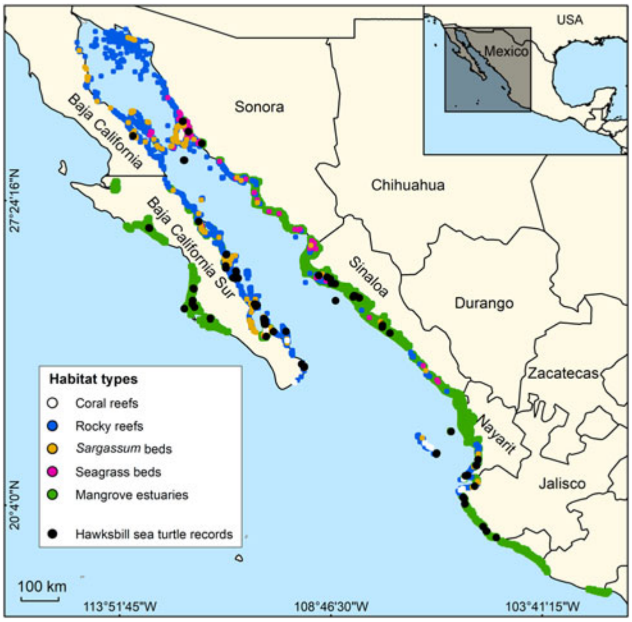

FIG. 1 Hawksbill sea turtle *Eretmochelys imbricata* records and marine habitat types in north-west Mexico. (Readers of the printed journal are referred to the online article for a colour version of this figure.)

(1) entanglement nets designed for capturing sea turtles (100–200 m long, 5–10 m deep and 25 cm mesh size) checked at regular intervals (c. every 60 min) for a recorded period of time, (2) strike netting where a net (the same as used in entanglement captures) was deployed from a small skiff to surround and capture an individual, and (3) hand capture by free diving. In addition, we also considered records of nesting females and incidental captures or strandings reported by fishers during regular fishing activities, if taking turtle body measurements was feasible.

All captured turtles were measured for straight carapace length (notch to tip), curved carapace length (CCL; notch to tip), straight carapace width (at the widest point), curved carapace width (at the widest point), body depth, plastron length, total tail length and body mass (Bolten, 1999). Individuals were categorized by life stage (i.e. juvenile or adult) based on their recorded size and on the mean nesting size of individuals from the nearest hawksbill turtle rookeries in Mexico, at Punta Mita (Nayarit) and Costa Careyes (Jalisco). The mean CCL of nesting turtles in these rookeries was 78.5 ± SD 4.2 cm, n = 6 (Grupo Tortuguero de las Californias A.C. database; data not publicly available). All individuals smaller than the mean nesting size were considered juveniles, whereas those equal to or larger than this threshold were classified as putative adults. To determine the sex of putative adult turtles, individuals that possessed a long tail extending ≥ 5 cm beyond the carapace were classified as males, whereas all other adults were classified as females. Confirmed nesting females and males (> 50 cm CCL) with long tails were categorized as putative adults regardless of body size (Wibbels, 1999). Whenever feasible, Inconel tags (Style 681, National Band and Tag Company, Newport, USA) were applied to the trailing edges of each rear flipper. Mean growth rate (cm/year) was calculated as the difference in CCL recorded at first capture and last recapture of each recaptured individual, divided by the residency time in years:

$$\text{Mean annual growth rate} = \frac{\text{CCL of first capture} - \text{CCL of last recapture}}{\text{residency in years}}$$

We used only recapture intervals ≥ 1 year and we also included negative growth values in the analysis.

Hawksbill turtle distribution and conservation index We determined the marine habitat types associated with the geographical location of hawksbill turtle records by overlapping hawksbill turtle locations and the geographical information system (GIS) layer of marine habitats compiled by The Nature Conservancy (Supplementary Table 2). We also calculated a conservation index as a proxy of the current state of hawksbill turtle sites (Halmy & Salem, 2015) using four factors: (1) isolation, (2) designated spatial protection status, (3) presence of local engagement and (4) fishing pressure. We calculated the conservation index of each site as the sum of the scores assigned to these factors (Supplementary Table 3) and then scaled the values to range from 0 to 1 for comparison. We applied a colour scale to visualize sites with high conservation index (dark) and those with low conservation index (light).

Isolation Proximity to continental land influences the success of conservation initiatives as there is an increased probability of successful protection with increased distance from the mainland and decreased human presence (Edgar et al., 2014). For hawksbill turtles, it has been demonstrated that islands harbour important foraging sites (Llamas et al., 2017; Martínez-Estévez et al., 2021). Here we assigned scores of 1–3 to the sites depending on their location: mainland coast, peninsula coast or islands, respectively.

Spatial protection status Well-enforced no-take marine protected areas have proved to be effective for the recovery of habitats and species, including sea turtles (Scott et al., 2012; Edgar et al., 2014). Here we categorized sites based on their protection status: (1) national marine protected areas established by the National Commission of Protected Areas of Mexico, (2) no-take marine protected areas established by the National Commission of Fisheries (CONAPESCA) in collaboration with fishing communities and local non-profits (Niparaja, 2015; Diario Oficial de la

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Federación, 2017), or (3) no spatial protection. We assigned a score of 1 to those sites within marine protected areas and a score of 0 to those without protection.

Local engagement Stakeholder engagement is a key factor influencing the success of marine protected areas (Giakoumi et al., 2018). For hawksbill turtles, local surveillance and engagement of fishing communities, environmental organizations, scientists and conservationists can serve to mitigate threats such as bycatch and high-impact tourism. We categorized sites based on active local engagement or a lack thereof. Local engagement was defined as one of the following activities: (1) ongoing sea turtle monitoring using the capture methods detailed above, (2) ongoing environmental education activities and training of local communities in sea turtle monitoring activities, and (3) presence of a sea turtle research or conservation organization that acts to recover entangled or injured hawksbill turtles reported by local communities. We also recorded which local group was conducting the local engagement (i.e. fishing communities or research groups/local environmental organizations). We considered the presence of any of these factors as active local engagement and assigned a score of 1 to sites with local engagement and a score of 0 to those without.

Fishing pressure North-west Mexico supports numerous small-scale fisheries dependent fully or partially on reef and mangrove systems where hawksbill turtles are also known to occur (Aburto-Oropeza et al., 2008). With increasing fishing activity (as defined by number of fishing boats per area and time) in hawksbill turtle coastal habitats, there is a greater probability of targeted catch, bycatch or collisions with boats (Wright et al., 2020). Using the best information available on the predicted small-scale fishing effort in the Gulf of California subregion, we used the number of boats/500 km^2/day as a proxy of fishing effort within areas where hawksbill turtles are present (Johnson et al., 2017). We classified sites based on four categories: 5–10, 11–20, 21–40, and 41–60 boats/500 km^2/day. For subregions for which reliable information on the level of fishing pressure was not available (i.e. the Pacific coast of the Baja California peninsula and the coast of Jalisco), we assigned conservative values of 11–20 and 21–40 boats/500 km^2/day, respectively, based on the best available information (Bravo-Olivas et al., 2014; Narchi et al., 2018).

Results

Hawksbill turtle captures and growth

The hawksbill turtle database included 718 records during 1996–2019. The records corresponded to 448 individual turtles captured, with 92 individuals recaptured a total of 124 times. The remaining 146 records corresponded to recaptures that occurred over periods of less than 1 year (Supplementary Table 4). The size range of the turtles was 31.5–96.0 cm CCL (mean = 50.6 ± SD 12.6 cm) and their weight range was 2.2–91.0 kg (mean = 17.2 ± SD 12.9 kg). Most individuals (94%, n = 420) were juveniles based on CCL. The most common size classes were 35.0–39.9 cm CCL (n = 70), 40.0–44.9 cm CCL (n = 98) and 45.0–49.9 cm CCL (n = 71), which together constituted 53% of the records (Fig. 2). We determined the sex of the putative adults (6%, n = 28) as 19 females (six of them confirmed nesting, CCL range = 78.6–96.0 cm, mean tail length = 15.2 ± SD 1.6 cm) and nine males (CCL range = 53.7–79.6 cm, mean tail length = 20.2 ± SD 9.2 cm).

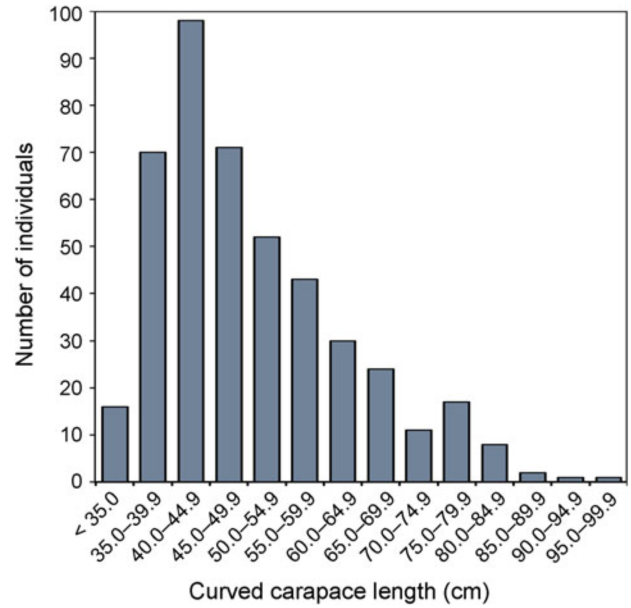

FIG. 2 Size distribution of hawksbill turtles (n = 448) in the north-west Pacific of Mexico (Fig. 1) during 1996–2019.

Of the 92 turtles that were recaptured, 61 individuals were recaptured once, 30 twice and one turtle three times. The range of the recapture interval was 1–3 years (Supplementary Table 5). All but 11 individuals were recaptured at the site of first capture. Three recaptured individuals moved 53 km between the mangrove estuary of Isla San José to the rocky reefs of Archipiélago de Espíritu Santo off the Baja California peninsula, one individual travelled 252 km across the Gulf of California from the mangrove estuary of Isla San José to the mangrove lagoon of Santa María La Reforma in Sinaloa, and one individual moved 41 km between the rocky reef habitats of Bahía de Jaltemba and Punta Mita in Nayarit. Using data from recaptured individuals, we found an overall mean growth rate in CCL of 3.6 ± SD 2.9 cm/year (Supplementary Fig. 1).

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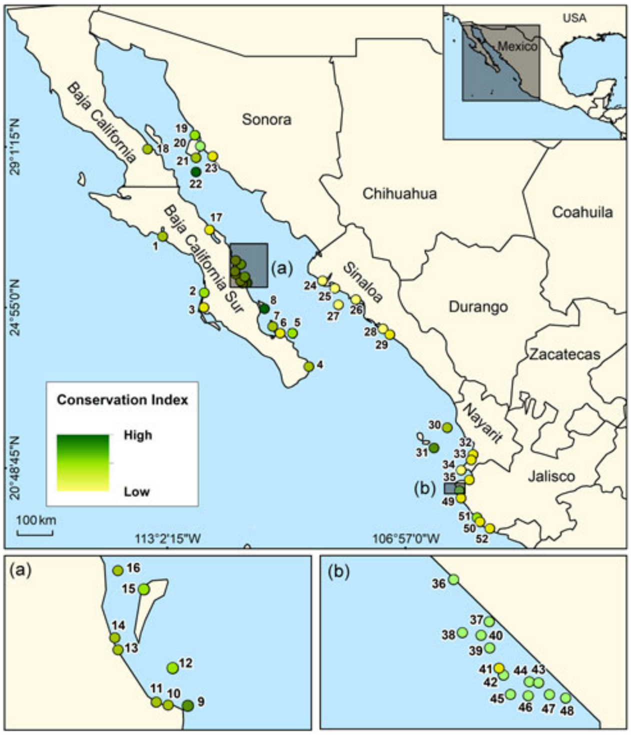

FIG. 3 Sites with hawksbill turtle records in north-west Mexico. The colour scale represents the conservation status of the sites based on the conservation index: darker colours indicate a higher conservation index and lighter colours a lower conservation index. We calculated the conservation index from each site's degree of isolation, designated spatial protection status, level of fishing pressure and presence of local engagement. Parts (a) and (b) provide detail on areas with several sites in Baja California Sur and Jalisco, respectively. Site-specific information is available in Supplementary Tables 4 and 6. (Readers of the printed journal are referred to the online article for a colour version of this figure.)

Hawksbill turtle distribution and conservation index

Hawksbill turtles were only found in two main habitat types: mangrove-dominated and reef-dominated habitats. In total, 168 hawksbill turtles were captured in mangrove-dominated habitats and 280 along open-coast areas, mainly in rocky/coral reef habitats. Although seagrass and *Sargassum* beds were present in some of the hawksbill turtle locations, hawksbill turtles were not captured in them (Fig. 1).

We recorded hawksbill turtles at 52 sites in the region, including 18 on the Baja California peninsula and 34 on the mainland coast (Fig. 3, Supplementary Table 6). Most hawksbill turtle records were from Baja California Sur (284 individuals), followed by Jalisco (94 individuals), Sinaloa (28 individuals), Nayarit (25 individuals), Sonora (11 individuals) and Baja California (six stranded or by-caught individuals). Overall, 29 sites (56%) were located on the mainland coast, 12 sites (23%) on islands (seven of them off the Baja California Peninsula and five off the mainland coast) and 11 sites (21%) on the Baja California peninsula coast. In particular, 212 (73%) of 290 individuals recorded off the Baja California peninsula were from Isla San José and the Archipiélago de Espiritu Santo, and 31% (49 of 158) of the individuals on the mainland coast were from Torrecillas, Bahia de Tlalpichichi and Piedra Partida in Jalisco.

Twelve sites (23%) fell within Mexican national marine protected areas (the biosphere reserves of El Vizcaíno, Isla San Pedro Mártir and Islas Marías and the national parks of Cabo Pulmo, Archipiélago de Espíritu Santo and Bahía de Loreto), three sites (6%) within no-take marine protected areas off the Baja California peninsula (Isla San José–Isla El Pardito, Isla San Marcial and Agua Verde), and 37 sites (71%) were not protected (Supplementary Table 6). Nearly two-thirds of the sites (65%, 34 of 52) had local engagement, mainly in the form of sea turtle monitoring and education/research activities. Seven of these sites were within protected areas and the remaining 27 without protection. Local engagement programmes led by local fishing communities and by research groups and local environmental organizations were spread evenly amongst the sites. The sites with the greatest fishing pressure (41–60 boats/500 km^2/day; five sites, 10%) were in the Mexican states of Sinaloa (n = 4) and Nayarit (n = 1). There were 12 sites (23%) with a fishing pressure of 21–40 boats/500 km^2/day, 26 sites (50%) with a fishing pressure of 11–20 boats/500 km^2/day and nine sites (17%) with a fishing pressure of 5–10 boats/500 km^2/day (Supplementary Table 6). The sites with the lowest fishing pressure corresponded to islands, sites on the coast of the Baja California Peninsula and one site on the mainland coast (Estero El Sargento) that belongs to the Comcáac Indigenous people who control access to it. Of the 15 protected sites, 12 fell within the fishing pressure categories of 5–20 boats/500 km^2/day and only three had a fishing pressure of 21–40 boats/500 km^2/day. By contrast, of the 37 unprotected sites, 31 fell within the fishing pressure categories of 10–40 boats/500 km^2/day, five had fishing pressure of 41–60 boats/500 km^2/day and only one had a fishing pressure of 5–10 boats/500 km^2/day.

In terms of the conservation index, 15 sites (29%) had the highest conservation status (scores of 0.71–1.00), corresponding to nine islands (Isla San José–Isla El Pardito, San Pedro Mártir, San Marcial, Cleofas, Archipiélago de Espíritu Santo, Montserrat, Coronados, Choyudo and Isabel) and six sites along the Baja California Peninsula (Bahía de los Ángeles, Puerto Escondido, Cabo Pulmo, Agua Verde, Laguna de San Ignacio and La Pila; Fig. 3). Isla San José–Isla El Pardito and Isla San Pedro Mártir were the top two sites overall in terms of the conservation index, both having official protection status as marine protected areas and local engagement. Thirty-one sites (60%) fell within mid-range scores (0.29–0.57) and corresponded to areas with higher fishing pressure and either not being protected or without local engagement (Fig. 3).

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All but seven of these sites are on the mainland coast. Finally, the six sites (12%) with the lowest conservation index (scores of 0–0.14) were mainland sites with high fishing pressure and no official protection (Fig. 3, Supplementary Table 6).

Discussion

This study provides the first regional analysis of the distribution of hawksbill turtles in the north-west Pacific of Mexico. Over a period of 23 years, 448 individual hawksbill turtles were recorded, constituting more than six times the previously documented numbers in the Mexican Pacific Ocean (68 individuals; Gaos et al., 2010). Most individuals (94%) were juveniles, indicating that this region is particularly important as a foraging area for turtles at earlier life history stages, corroborating previous studies in the region (Seminoff et al., 2003; Gaos et al., 2010; Martínez-Estévez et al., 2021). This is particularly relevant as juveniles of some populations are particularly vulnerable and more affected by anthropogenic threats than others (Heppell, 1998; Wallace et al., 2010). Along the Pacific coast of Mexico, the states of Nayarit and Jalisco represent the northern nesting limit for Eastern Pacific hawksbill turtles (Hart, 2016). The three main nesting areas include Costa Careyes (Jalisco), and Punta Mita and Bahia de Jaltemba (Nayarit), with 13 nests/year on average (Hart, 2016). Of the 28 adults identified, only six were nesting females, with a size range of 73–81 cm CCL. We used mean nesting size as a threshold to distinguish adults from juveniles, but it should be noted that this could underestimate the total number of adults, as nesting females < 78.5 cm CCL have been identified in the Eastern Pacific in previous studies (Liles et al., 2011) and in this study. Based on the identified males, tail length can be used to distinguish the sexes in individuals as small as 53.7 cm CCL. However, tail length is not a perfectly reliable indicator, and the sex of some individuals could be misidentified with this method (Wibbels et al., 2000). Further investigation using hormone assessment techniques would improve our knowledge regarding the sex ratio of immature sea turtles in the region (Allen et al., 2015).

The size at which sea turtles recruit from pelagic to neritic environments varies amongst sea turtle species and populations. For instance, the recruitment sizes of hawksbill turtles in some regions of the Pacific Ocean are larger than in the Caribbean, where individuals as small as 20 cm straight carapace length enter neritic habitats (Hirth et al., 1992; Hawkes et al., 2014). Several individuals in this study ($n = 16$, 4%) were smaller than 35 cm CCL but all were larger than 30 cm CCL, with the smallest recorded individual measuring 31.5 cm CCL. These findings mirror previous studies in the Baja California Peninsula and the Eastern Pacific, where recruitment sizes were reported as 34.4 cm straight carapace length and 30.0–37.0 cm CCL, respectively (Seminoff et al., 2003; Llamas et al., 2017; Wedemeyer-Strombel et al., 2021). The most frequently recorded size in our study (40.0–44.9 cm CCL, 22% of records) corresponds with that reported in Coiba National Park in Panama, a major foraging ground for Eastern Pacific hawksbill turtles (Llamas et al., 2017). Almost all of the recaptured individuals were found in the same sites where they were initially caught, and 50% of them (46 of 92) were recaptured after periods longer than 2 years. These findings demonstrate high foraging site fidelity of hawksbill turtles in north-west Mexico and corroborate studies in the Eastern Pacific and other parts of the world (Gaos et al., 2012; Shimada et al., 2019). A subset of individuals moved between foraging grounds in the Gulf of California. This could be because of natal homing, where larger juveniles tend to shift between foraging grounds, or because of displacement caused by intraspecific competition or limited availability of resources (Bowen et al., 2004; Fukuoka et al., 2015). Studying juvenile movements and interactions at foraging grounds will help us to better understand hawksbill turtle population dynamics and provide adequate protection for the species in this region.

Similar to the preferred habitats in other regions of the Eastern Pacific (Gaos et al., 2012; Llamas et al., 2017; Wedemeyer-Strombel et al., 2021), rocky/coral reefs and mangrove estuaries are the primary habitats for hawksbill turtles in north-west Mexico. In addition, we found that some anthropogenic factors (fishing pressure and spatial protection strategies) play important roles in hawksbill turtle presence, probably related to reduced bycatch mortality (at sites with low fishing pressure) or improved habitat quality (at protected sites). Our data did not allow us to quantify the search effort necessary to survey for hawksbill turtle presence in unexplored areas, so they reflect only areas known to be used by hawksbill turtles; however, the number of captured individuals was greater on the Baja California Peninsula than on the mainland coast, in part because of limited sampling effort on the mainland coast, but probably also because of habitats being less degraded along the Baja California Peninsula. Human development and greater fishing pressure along the Mexican mainland coast have significantly degraded mangrove habitats (Escobedo-Urias, 2010; Manzano-Sarabia et al., 2018). Most of the sites with a low conservation index had high fishing pressure, whereas the sites with high conservation index were either national marine protected areas or local no-take marine protected areas with strong local engagement. It seems clear that long-term protection could promote the presence of high-use areas for the species.

Of the 52 sites we identified, we consider Archipiélago de Espíritu Santo and Isla San José as foraging hotspots because of the number of individuals recorded and their persistent presence over the years. Archipiélago de Espíritu Santo has been monitored every month over the last 20 years and on

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Isla San José hawksbill turtle monitoring has been conducted every year over the last 7 years, in addition to monthly sea turtle monitoring activities. We are confident that the high number of individuals observed is influenced by these monitoring efforts and also by the official protection status and local community engagement at both sites. A regional census of hawksbill turtles should be established by conducting in-water monitoring, focused specifically on hawksbill turtles, in coastal foraging areas. This should also be expanded to unsampled or poorly sampled areas such as the mangrove habitats in Sonora, Sinaloa and Nayarit (Complejo Lagunar Bahia Guásimas–Estero Lobos, Humedales de Yavaros–Moroncarit, Sistema Lagunar Agiabampo–Bacorehuis–Río Fuerte Antiguo, Marismas Nacionales and La Tovara) and to areas with historical reports and anecdotal observations of hawksbill turtles by fishermen (e.g. Santa Rosalia, Bahía de los Ángeles and Isla San Diego in Baja California Sur, and Archipiélago de Revillagigedo and Islas Marías in the Pacific Ocean). Such census data will help us to determine the relative abundance of individuals in the region and potentially identify other foraging hotspots for the species. In addition, it is important to improve our knowledge of individual movement patterns and the genetic structure of the population. Continuing the conservation efforts with local communities, and increasing the enforcement of environmental and fisheries laws to reduce threats in the identified hawksbill turtle sites, are important steps to protect this species in north-west Mexico.

Current hawksbill turtle numbers in north-west Mexico remain relatively low after more than 20 years of protection. This could reflect a combination of continued human impacts, the relatively recent colonization of this region by the species (Gaos et al., 2016) or insufficient hawksbill turtle-focused monitoring. Nevertheless, we highlight sites where spatial protection and other conservation management strategies should be prioritized. Because hawksbill turtle core areas of use in the south-west Gulf of California are highly restricted, being no larger than 3.8 km^2 (Martínez-Estévez et al., 2021), it would be feasible to set aside areas for hawksbill turtle conservation without significantly affecting current human use. The implementation of spatial conservation strategies that consider local realities and community participation in their design and enforcement has been effective in the recovery of other hawksbill turtle populations, such as the Arnavos population (Hamilton et al., 2015). The last 2 decades of hawksbill turtle research and conservation in the Eastern Pacific have contributed to the recovery of this population. This and future studies, along with increasing political will and local community participation, will continue this endeavour over the long term.

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Conflicts of interest None.

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