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Factors Affecting the Size Structure and Life Stage Classes of *Eretmochelys imbricata* (Testudines: Cheloniidae) in the Gulf of California, Mexico

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***Abstract.*—Hawksbill Sea Turtles (*Eretmochelys imbricata*) are listed as a critically endangered species due to low population numbers worldwide. For species like this, adequate monitoring and assessments of the size structure of populations are essential. Sea turtle capture methods, including the type of fishing gear, vary widely, causing biases in the size structure of the captured individuals and hindering comparisons between studies and populations. We analyzed the effect of heterogeneity in capture methods and the statistical treatment of data across four studies of these turtles in the Gulf of California, Mexico. Normality tests indicated that only two datasets had normal distributions. Modal groups were closely associated with the gear and methods employed. Studies with the smallest size classes encompassed individuals captured by free-diving; intermediate size classes involved the use of nets and combined methods (gillnets with 25- and 50-cm stretched mesh size checked at regular intervals, strike-netting, stranded carcasses), while studies with the largest size classes were caught using gillnets (50-cm stretched mesh) and strike-netting. The frequency distribution of the life stages (juveniles, subadults, adults) varied considerably across studies, with juveniles ranging from 37–100% and subadults from 0–56% of the total numbers. Given the challenges of standardizing methods (whose use and effectiveness depend on local conditions), we recommend that explicit capture details be reported for each individual, morphometric variables be homogenized, and *a priori* statistical tests be performed to guide the choice of appropriate analyses.**

Key Words.—*a priori* data tests; Baja California peninsula; frequency distribution; Hawksbill Sea Turtle; nets

Introduction

The Hawksbill Sea Turtle (*Eretmochelys imbricata*) is distributed pantropically across the Atlantic, Indian, and Pacific Oceans. Global populations are small, primarily due to harmful anthropogenic impacts (Miller et al. 2019). In the Eastern Pacific Ocean, the impacts primarily include incidental capture in gillnet fisheries, habitat degradation of coral and rocky reefs, and illegal poaching for tortoiseshell or meat (Gaos et al. 2017). These stressors do not affect all life stages equally; juvenile and subadult turtles, which are the dominant stages in the study area, are particularly vulnerable to coastal gillnets and habitat loss due to their high site fidelity and prolonged residency in shallow, nearshore foraging grounds (Martinez-Estevez et al. 2022). Consequently, the species is currently protected under national and international laws and regulations (Secretaría de Medio Ambiente y Recursos Naturales 2020; Mortimer and Donnelly 2008).

Within the Eastern Pacific Ocean, Hawksbill Sea Turtles range from Mexico to Peru (Martínez-Estévez 2021; Martínez-Estévez et al. 2021, 2022, 2023). Recent assessments indicate a demographic viability improvement for Hawksbill Sea Turtles primarily as result of increased nesting abundance at key rookeries and improved survival estimates for specific cohorts, but with threats that worsened over the last decade (Wallace et al. 2025). These escalating threats, such as intensified coastal development, which leads to nesting beach loss and sea surface temperature anomalies that disrupt prey availability, highlight the urgent need to reduce these pressures through targeted monitoring and research efforts.

In Mexico, the coasts of the Baja California Peninsula represent the northern limit of the distribution of this species (Martínez-Estévez et al. 2022; Briggs et al. 2024). Research conducted along these coasts has striven to identify foraging and recruitment sites, establishing the region as a critical developmental area for post-pelagic juveniles (Martínez-Estévez 2021; Martínez-Estévez et al. 2021, 2022, 2023). Individuals recorded along the Baja California Peninsula likely recruit from the nearest known rookeries in the Mexican Central Pacific: Punta Mita (Nayarit), Costa Careyes (Jalisco), and Isla Ixtapa (Guerrero), although the presence of undiscovered, low-density nesting sites along the peninsula remains a plausible hypothesis (Gaos et al. 2017; 2018). Size structure analyses from both sides of the peninsula (i.e., Pacific Ocean and Gulf of California) have shown a predominance of juvenile individuals (Martínez-Estévez 2021; Martínez-Estévez et al. 2021, 2022, 2023; Reynolds et al. 2023). This categorization is based on the mean nesting size of individuals recorded at the nearest Hawksbill Turtle rookeries in Punta Mita and Costa Careyes, both on the mainland (Curved Carapace Length = 78.5 ± (standard deviation) 4.2 cm; Martínez-Estévez et al. 2022). Individuals smaller than 78.5 cm are considered juveniles where those equal or larger than 78.5 cm are considered adults (Witzel 1983; Martínez-Estevez et al. 2022). Given the slow growth rates of Hawksbill Sea Turtles in the region (3.6 ± 2.9 cm/year; Martínez-Estévez et al. 2022) individuals may spend decades in these coastal foraging grounds before reaching sexual maturity. Consequently, even slight variations in size-class reporting can lead to vastly different estimations of the time-to-maturity and the overall reproductive potential of the population. In fact, there is no consensus among the published figures on proportions by life stage as reports of juveniles range from 37–100% and subadults from 0–56% (Ramos-Ávila et al. 2019; López-Fuerte et al. 2025). Furthermore, recruitment dynamics in the Gulf of California and the Mexican Pacific Ocean may be influenced by environmental stochasticity. Climate-driven lag associations, such as sea temperature anomalies affecting the hatchling phase or food availability during the growing phase, can result in pulses of specific size cohorts years later (Bjorndal et al. 2016; Ricoy-Martinez et al. 2025). These types of associations have been reported for Hawksbill Sea Turtles in the Atlantic Ocean (Flores-Aguirre et al. 2020; López-Castro et al. 2022) and when combined with unstandardized capture efforts, the risk of misinterpreting population trends becomes even more pronounced, highlighting the relevance of this research and further analysis of the topic.

Reliable and robust biological and ecological data are crucial for developing effective conservation and management plans for this endangered species. Size structure analyses allow researchers to infer aspects of population dynamics and reproductive potential that can serve as proxies for population health (Iniciativa Carey del Pacífico Oriental 2008). Therefore, standardized protocols designed to generate such information should be implemented. Information on capture methods and protocols for non-nesting sea turtle populations is generally limited to a series of recommendations for capture methods, fishing gear type, and mesh size (Ehrhart and Ogren 2000; Gallegos-Fernández et al. 2014). In practice, gear type and capture method depend on multiple factors, such as distance from shore, depth, and substrate type, so achieving standardization is a daunting task, although the failure to account for the potential effects of these two factors on size distributions can generate unreliable numerical comparisons (Trono and Salm 2000), especially when studies fail to specify these details (Kobayashi 2004).

Although no formal studies have yet examined the effects of fishing gear on the sizes of captured sea turtles, evidence from commercial fisheries shows a positive relationship between gillnet mesh size (including nets similar to those used for turtles) and the size of captured fish (Rojo-Vázquez et al. 1999; Lorán-Núñez et al. 2008; Beltrán-Álvarez et al. 2017). Larger mesh sizes typically yield larger individuals, while smaller ones yield smaller individuals. This effect likely applies to sea turtles as well, as suggested by Ehrhart and Ogren (2000), though it has not been analyzed explicitly in sea turtle studies.

For Hawksbill Sea Turtles in the Gulf of California, two additional factors complicate comparisons and the integration of results: distinct morphometric variables, as some studies report straight carapace length (SCL, e.g., Seminoff et al. 2003), versus curved carapace length (CCL, e.g., Ramos-Ávila et al. 2019); and deficient statistical treatment of data, specifically the lack of *a priori* normality tests and tests of variances, implicit in the use of parametric tests. Many authors summarize their data with means and standard deviations but fail to confirm representativeness (Seminoff et al. 2003; Ramos-Ávila et al. 2019). This can lead to misinterpretations (Zar 2016). We assessed how fishing gear, capture methods, and *a priori* data tests affect the heterogeneity of the morphometric data used to determine the size structure and life stage distribution of Hawksbill Turtles in the Gulf of California. To this

Figure 1. Study area and data collection sites of Hawksbill Turtles (*Eretmochelys imbricata*) in the Gulf of California: site 1 = Cabo Pulmo[A,C], 2 = Isla Espíritu Santo[B,C], 3 = Isla San José[C], 4 = Agua Verde[C], 5 = Isla Monserrat[C], 6 = Isla Carmen[C], 7 = Santa Rosalía[D], 8 = Bahía Los Ángeles[A], and 9 = Canal Infiernillo[A]. Superscripts indicate the data source: A, Seminoff et al. (2003); B, Ramos-Ávila et al. (2019); C, Martínez-Estévez (2021); and D, López-Fuerte et al. (2025).

end, we compared results from four studies based on distinct gears and capture methods.

Materials and Methods

Data collection and analysis.—We conducted a comprehensive literature review of studies that reported the size structure of Hawksbill Sea Turtles in the Gulf of California. Eight publications were identified between 2003 and 2025. Four studies: Martínez-Estévez et al. (2021, 2022, 2023) and Reynolds et al. (2023) were based on the same information originally presented in Martínez-Estévez's doctoral dissertation (2021). For this reason, we used only the information presented in the dissertation for our work. Although the dissertation (Martínez-Estévez 2021) does not include the raw data, we had access to them because ME is a co-author of this study. Thus, we cite statements or analyses as Martínez-Estévez (2021) and the raw data as Martínez-Estévez (unpubl. data). In addition, we include data from Seminoff et al. (2003), Ramos-Ávila et al. (2019), and López-Fuerte et al. (2025). Data on Hawksbill Sea Turtles were collected at nine sites, ranging from Bahía de Los Angeles (28°56′50.9”N) to Cabo Pulmo (23°26′N; Fig. 1), covering the northwestern Mexican Pacific region (Martínez-Estévez et al. 2022). Seminoff et al. (2003) also reported data from the Pacific coast of the Baja California Peninsula, but those records were not considered in our analysis because this study was not conducted within the Gulf of California.

Regarding the morphometric data, Seminoff et al. (2003) reported straight carapace length (SCL), while Ramos-Ávila et al. (2019), Martínez-Estévez (2021), and López-Fuerte et al. (2025) reported the curved carapace length (CCL). To homogenize the datasets, SCL values from Seminoff et al. (2003) were converted to CCL using the regression derived from López-Fuerte et al. (2025); CCL = 0.443 + 1.015 × SCL ($F_{1,28}$ = 667.48, r = 0.98, P < 0.01; 30 turtles captured at Santa Rosalía, Mexico). While SCL measurements using calipers are considered more precise, the use of flexible tape for CCL is more common in recent regional studies due to its portability in field conditions. The use of a standardized regression ensures that these different measuring techniques do not introduce systematic bias into the comparison.

Although all four studies summarized the size data using parametric descriptors, only López-Fuerte et al. (2025) conducted *a priori* normality tests to validate the use of these statistics. For the other three datasets, we tested normality using the Chi-square Goodness-of-fit Test (Zar 2016; α = 0.05) and compared all four sets using Chi-square Tests of Independence (Zar 2016). When independence was rejected, the study that contributed most strongly to the difference was excluded, and the procedure was repeated (Carmona et al. 2004). Thus, three independence tests were performed to compare the four studies. Modal skalize groups were then associated with the gear type and capture methods employed in each one.

Capture methods varied among the studies. López-Fuerte et al. (2025) relied exclusively on semi-autonomous diving (hookah). Ramos-Ávila et al. (2019) used only gillnets with 50-cm stretched mesh. Lourdes Martínez-Estévez (unpubl. report) used gillnets, strike netting (25-cm stretched mesh), and free-diving.

For each data group (sizes of turtles captured using gillnets, free diving, and strike netting) from Lourdes Martínez-Estévez (unpubl. report), we performed the required normality tests and additionally assessed

Table 1. Chi-square normality test output for studies of Hawksbill Sea Turtles (*Eretmochelys imbricata*) curved carapace length (CCL, cm) datasets. Symbols are n = sample size, X^2 = Chi-square statistic, df = degrees of freedom, and *P*-value = probability level. An asterisk (*) indicates that data had non-normal distributions.

Study	n	X^2	df	*P*-value
Seminoff et al. (2003)	13	17.97	8	0.020*
Ramos-Ávila et al. (2019)	78	6.33	9	0.710
Martínez-Estévez (2021)	97	42.18	11	< 0.01*
López-Fuerte et al. (2025)	31	12.88	11	0.300
Martínez-Estévez (unpubl.) Gillnet	41	17.63	18	0.480
Martínez-Estévez (unpubl.) Diving	16	9.76	7	0.200
Martínez-Estévez (unpubl.) Strike netting	40	17.39	11	0.100

homogeneity of variances using Bartlett's test (Zar 2016). Although all three groups followed normal distributions (Table 1), their variances could not be considered equal (χ^2 = 8.52, df = 2, *P* = 0.014). Therefore, we used the non-parametric Kruskal–Wallis test to determine whether there were significant differences among the median turtle sizes of the three groups, followed by Nemenyi's *post hoc* test for pairwise comparisons (Zar 2016).

Based on published data, we constructed frequency histograms using 5-cm CCL intervals. We assigned life stages (juveniles, subadults, adults) following the size thresholds proposed by Witzel (1983). Including both continuous size distributions and discrete life-stage bins is important because continuous data allow for fine-scale analyses of gear selectivity while discrete bins provide a biologically relevant framework for assessing reproductive potential and population health. When combined with tagging data, these classifications can also inform recruitment, growth dynamics, site fidelity, and residency patterns (Llamas et al. 2017; Pilcher et al. 2025). Frequency distributions were then compared by Chi-square Tests of Independence, with study and life stage as the classification criteria (Zar 2016). This exercise (comparison of frequency by life-stage group) was repeated for the specimens captured by the different capture methods in the unpublished data collected by Lourdes Martínez-Estévez.

In parallel with the analyses described above, the spatial and temporal effects (capture site and year) were evaluated using the only dataset that allowed such comparisons (i.e., Lourdes Martínez-Estévez, unpubl. data; Appendix Table 3). The data did not meet the assumption of homogeneity of variances either among capture sites (χ^2 = 6.458, df = 2, *P* = 0.039) or among years (χ^2 = 15.32, df = 5, *P* = 0.009). Therefore, we used the non-parametric Kruskal–Wallis test (Zar 2016) to determine whether median turtle sizes differed significantly among groups in both analyses. Neither capture site (*H* = 4.45, df = 2, *P* = 0.107) nor year (*H* = 6.26, df = 5, *P* = 0.282) showed significant differences in the sizes of captured turtles.

Results

Datasets from Ramos-Ávila et al. (2019) and López-Fuerte et al. (2025) had normal distributions, but those by Seminoff et al. (2003) and Martínez-Estévez (2021) did not (Table 1). Crucially, when the latter two were subdivided by capture method, all resulting data groups (gillnet, diving, and strike netting) were found to be consistent with samples drawn from normally distributed populations; however, the lack of homogeneity of variances among groups (gillnet, diving, and strike netting) precluded the use of parametric statistical tests. Modal groups were associated with the gear type and capture methods used (Table 2). The smallest turtles corresponded to captures by hand by semi-autonomous diving (López-Fuerte et al. 2025). Intermediate size groups were recorded significantly more often with nets of two mesh sizes (25- and 50-cm), and combined methods such as gillnets checked at regular intervals and strike netting (Seminoff et al. 2003; Lourdes Martínez-Estévez, unpubl. data). The largest group (65–70 cm) was reported by Ramos-Ávila et al. (2019) using 50-cm mesh set nets (Table 2). These differences were also notable in the unpublished data from Lourdes Martínez-Estévez when analyzed separately, as the smallest sizes corresponded to specimens captured significantly more often via free diving, and the largest turtles captured via strike netting.

Comparison of size frequency distributions showed significant differences among the four studies (Table 3). The smallest turtles were reported significantly more often by López-Fuerte et al. (2025), followed by Seminoff et al. (2003), Martínez-Estévez (2021), and Ramos-Ávila et al. (2019; Fig. 2). Although the sample sizes were small (seven and six individuals, respectively), the data from Seminoff et al. (2003) showed distinct size structures between live captures (modal group 35–40 cm SCL) and stranded carcasses (45–50 cm SCL), which were significant (*D* = 30, df = 7,6, *P* = 0.012). The comparison of unpublished data from Lourdes Martínez-Estévez, taking into account the capture methods, also revealed significant

Table 2. Descriptive statistics for studies of curved carapace length (CCL, cm) of Hawksbill Turtles (*Eretmochelys imbricata*) across the four datasets. Abbreviation SD = standard deviation. The data from the Lourdes Martínez-Estévez study (unpubl. data) are detailed by capture method: A = gillnet, B = free diving, and C = strike netting.

Reference	Mean	SD	Modal groups	Range	Capture method
Seminoff et al. (2003)	–	–	35–40	34.4–74.2	Gillnets and stranded individuals (50 cm mesh size)
Martínez-Estévez (2021) General	–	–	45–50	31.0–90.3	Three methods together (25 cm mesh size)
Lourdes Martínez-Estévez (unpubl. data)[A]	52.27	9.14	40–60	34.8–68.0	Gillnet
Lourdes Martínez-Estévez (unpubl. data)[B]	46.66	7.46	45–50	35.0–64.9	Free diving
Lourdes Martínez-Estévez (unpubl. data)[C]	56.10	13.13	50–55	37.5–90.3	Strike netting
Ramos-Ávila et al. (2019)	60.1	10.76	65–70	39.3–86.8	Gillnet (50 cm mesh size)
López-Fuerte et al. (2025)	38.7	6.66	30–35 and 35–40	29.5–59.5	Semiautonomous diving

differences (X^2 = 7.08, df = 2, P = 0.028; Fig. 3). The sizes of organisms captured by free diving (the smallest) differed significantly from those caught by strike netting (q = 0.020, $P < 0.050$). Turtles captured with gillnets constituted an intermediate group, which did not differ significantly from the other capture methods (entanglement net versus strike netting: q = 0.967, $P > 0.050$; free diving versus strike netting; q = 0.143 $P > 0.05$).

Life-stage frequency also differed markedly among the studies (Table 4), as juvenile proportions ranged from 37–100%, while subadults ranged from 0–56%. Life stage frequency were dependent on the study (X^2 = 50.28, df = 6, $P < 0.001$). The equivalent comparison for the unpublished data from Lourdes Martínez-Estévez, based on the capture method, also

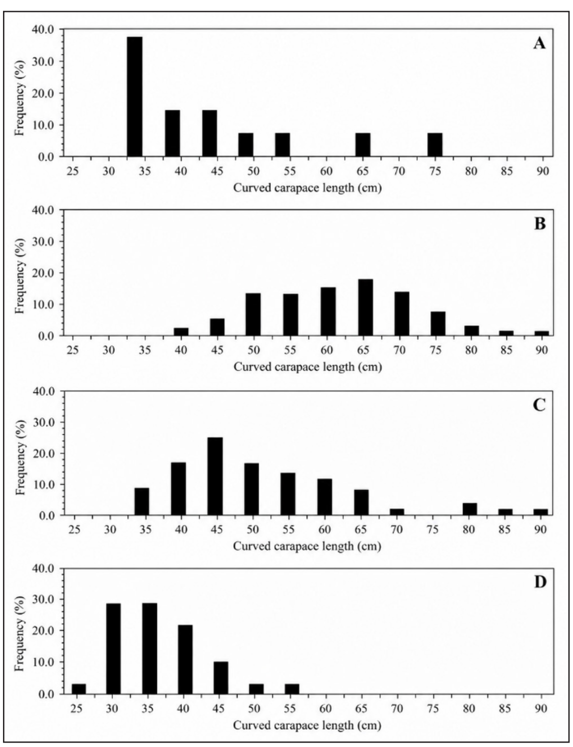

Figure 2. Size-frequency distribution (%) of Hawksbill Turtles (*Eretmochelys imbricata*) in the Gulf of California. Data from (A) Seminoff et al. (2003), (B) Ramos-Ávila et al. (2019), (C) Martínez-Estévez (2021), and (D) López-Fuerte et al. (2025).

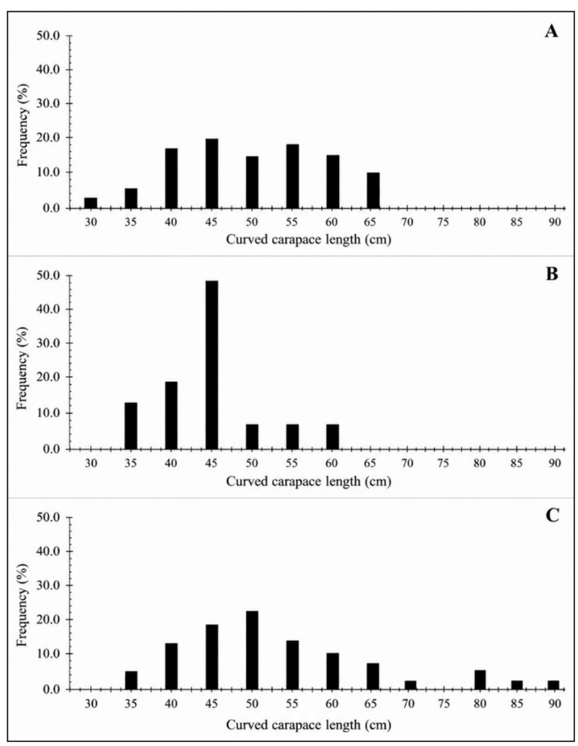

Figure 3. Percentile distribution of size frequency for the Lourdes Martínez-Estévez study (unpubl. data), separated by capture method: (A) Gillnet; (B) Free diving; and (C) Strike netting.

Table 3. Comparison of differences in size frequency distributions across studies of Hawksbill Turtles (*Eretmochelys imbricata*) across the four datasets using Chi-square tests. Abbreviations are LF = López-Fuerte et al. (2025), SE = Seminoff et al. (2003), ME = Martinez-Estévez (2021), RA = Ramos-Ávila et al. (2019), X^2 = Chi square values, df = degrees of freedom, *P* = probability level, MDS = most divergent study, and PC = percentage contribution.

Study Groups	X^2	*P*	df	MDS	PC
LF-SE-ME-RA	163.67	< 0.010	39	LF	50.5
SE-ME-RA	71.79	< 0.010	24	RA	40.2
SE-ME	21.12	0.030	11	–	–

indicated significant differences in the frequency of captures per life stage group (Table 5). The most evident differences were the smaller-sized turtles captured by free diving and the larger-sized turtles captured by strike netting (Table 5).

Discussion

We are concerned with understanding the size structure and, therefore, the life stage structure of Hawksbill Turtles in the Gulf of California. Three factors must be considered chronologically: (1) fishing gear and capture method; (2) the carapace length measurement applied; and (3) the statistical treatment of the data. First, because the ultimate aim of fieldwork is to maximize capture efficiency (Zavala-Armenta 2020), efforts to standardize fishing gear and methods are difficult to implement, as their effectiveness depends on local environmental conditions (e.g., distance from the coast, depth, substrate type), making uniformity among studies unlikely, particularly in the Baja California Peninsula (López-Castro et al. 2010).

Our literature review identified four main methods of capturing individual turtles: gillnets checked at regular intervals, strike netting, diving to capture them by hand, and using stranded or taxidermized specimens (e.g., León and Diez 1999; Ehrhart and Ogren 2000; Seminoff et al. 2003; Martínez-Estévez 2021; López-Fuerte et al. 2025). For captures by hand, three types of diving are common, free (snorkel), semi-autonomous (hookah), and scuba,

Table 5. Frequency and percentage (in parenthesis) of juvenile (< 55 cm CCL), subadult (55–70 cm CCL), and adult (> 70 cm CCL) Hawksbill Turtles (*Eretmochelys imbricata*) caught by three methods from an unpublished Lourdes Martínez-Estévez study. The abbreviation n = sample size.

Capture method	n	Juveniles	Subadults	Adults
Gillnet	41	24 (58.5%)	17 (41.5%)	0
Free diving	16	14 (87.5%)	2 (12.5%)	0
Strike netting	40	23 (57.5%)	12 (30.0%)	5 (12.5%)

Table 4. Frequency and percentage (in parentheses) of juvenile (< 55 cm CCL), subadult (55–70 cm CCL), and adult (> 70 cm CCL) Hawksbill Turtles (*Eretmochelys imbricata*) from four studies of curved carapace lengths (CCL).

Study	Juveniles	Subadults	Adults
Seminoff et al. (2003)	10 (76.9)	2 (15.3)	1 (7.58)
Ramos-Ávila et al. (2019)	29 (37.2)	44 (56.4)	5 (6.4)
Martínez-Estévez (2021)	73 (75.2)	20 (20.6)	4 (4.2)
López-Fuerte et al. (2025)	31 (100)	0	0

all of which can be practiced during the day or at night (León and Diez 1999; Ehrhart and Ogren 2000; Zavala-Armenta 2020; López-Fuerte et al. 2025). For stranded carcasses, the distinction lies in whether searches are systematic, occasional, or opportunistic (Gardner and Nichols 2001; Seminoff et al. 2003).

Nets with 25-cm (Martínez-Estévez 2021), 30-cm (Ehrhart and Ogren 2000), 40-cm (Lara-Uc et al. 2022), and 50-cm mesh (Seminoff et al. 2003; Ramos-Ávila et al. 2019) have been used in the Gulf of California. While no formal analyses have significantly linked mesh size to turtle size, this relationship is well-established in finfish fisheries (Rojo-Vázquez et al. 1999; Lorán-Núñez et al. 2008; Beltrán-Álvarez et al. 2017). Ehrhart and Ogren (2000) emphasized that selecting the appropriate mesh requires prior knowledge of size distributions in the study area based on the assumption that mesh size determines size of turtles captured. While this generalization holds for many fish species, at least one study reported the opposite for Hawksbill Sea Turtles; that is, that smaller turtles were caught with larger mesh, and *vice versa* (Moncada et al. 2011).

This discrepancy highlights the need to consider species-specific characteristics when selecting mesh size. A mesh suitable for Green Turtles (*Chelonia mydas*), for instance, may fail to retain smaller Hawksbill Sea Turtles, leading to underrepresentation in the size structure data. It is important to stress that if information of this kind is lacking, the assumption of random sampling may be violated (Zar 2016) and interpretations of size structure could be biased. Ideally, comparative studies using multiple mesh sizes should be conducted, yet the potential influence of mesh size has been largely overlooked. In fact, in some cases this information is not even reported (Kobayashi 2004).

A particularly striking example comes from two studies in the Gulf of California that shared authorship and stated that gear specifications followed guidelines from the Mexican National Commission of Natural Protected Areas. One reported 50-cm mesh (Ramos-

Ávila et al. 2019), but the other indicated 40-cm (Lara-Uc et al. 2022). Inconsistencies like this suggest that the influence of mesh size on size structure of Hawksbill Sea Turtles has been underestimated and has likely contributed to the divergent results seen across studies (Seminoff et al. 2003; Ramos-Ávila et al. 2019; Martínez-Estévez 2021).

In the studies where capture methods were reported explicitly (e.g., Seminoff et al. 2003) turtles captured alive were significantly smaller than stranded carcasses, demonstrating how gear type, location, and methods can magnify bias in estimates of size structure. Beyond methodological bias, this discrepancy may also reflect the differential vulnerability of life stages to lethal anthropogenic pressures. For instance, larger subadults and adults may be more prone to vessel strikes or entanglement in heavy commercial fishing gear, leading to their overrepresentation in stranding records. Conversely, live-capture efforts using coastal gillnets or diving often focus on shallower foraging grounds dominated by juveniles. Consequently, stranding data may provide a window into the mortality of larger size classes that are otherwise under-sampled by standard research gear. Because Hawksbill Sea Turtles are known to have long resting periods on the seafloor, they may be captured more effectively with strike netting than with nets checked regularly (unpubl. data). By exploiting species-specific behavior, this approach could yield more representative samples of the size structure of a population.

Another source of uncertainty relates to morphometric measurements. Carapace length can be reported as CCL or SCL, and each form has at least three variants: (1) minimum length, (2) nuchal-to-supracaudal straight length; and (3) maximum straight length (Bolten 2000). The fact that many authors do not specify the measurement used further impedes comparisons. Of the four studies analyzed here, Seminoff et al. (2003) and López-Fuerte et al. (2025) explicitly reported their measurement method, but Martínez-Estévez (2021) and Ramos-Ávila et al. (2019) did not.

In addition to variability in capture and measurement methods, statistical treatment has often been inconsistent. The most critical issue here is the lack of *a priori* normality tests, which have often been omitted from sea turtle studies (e.g., Moncada et al. 2011; Martínez-Estévez et al. 2022). Of these four studies, only López-Fuerte et al. (2025) applied such tests. When data are not normally distributed and variances are not tested for equality, as in Seminoff et al. (2003) and Martínez-Estévez (2021), applying parametric tests is invalid. Martínez-Estévez et al. (2022), for example, compiled over 400 measurements of Hawksbill Sea Turtles in northwestern Mexico, determining that 60% of the values fell below the mean. Summarizing such skewed data using means and measures of dispersion (standard deviation, standard error, or confidence intervals) implicitly assumes normality (Wonnacott and Wonnacott 1990). Without prior testing, inappropriate use of parametric analyses like ANOVA (Seminoff et al. 2003) or regression (Moncada et al. 2011) may occur, further compounding interpretation errors.

We can only conclude that the answer depends on the gear type and capture methods used, the type of measurements made, and the application of correct statistical tests. As a result, it is impossible to determine which of the four studies analyzed provides the most accurate reflection of reality. This is by no means a trivial issue because conclusions differ dramatically from one report to the next. For instance, in López-Fuerte et al. (2025), the proportion of juveniles was 100% compared to just 37% in Ramos-Ávila et al. (2019), yet no mention of mesh size of the gear used to catch turtles was given.

Recommendations.—Given this heterogeneity among studies, we now propose a series of recommendations to improve the comparability of future studies of size structure of Hawksbill Sea Turtles in the Gulf of California, which could be easily applied to other sea turtle species studies around the globe: (1) Capture methods: because gear type and capture methods cannot be standardized, they must be reported in detail. For gillnets, this includes length, mesh size, and how it was measured (square or stretch), and whether they were set, or the strike netting method was used. For diving, authors must specify whether the free, semi-autonomous, or scuba form was used, and if captures occurred during the day or at night. For carcass use, authors must indicate whether searches were systematic, occasional, or opportunistic; (2) Capture site: a detailed description of the capture site is also recommended, including at least the depth, distance from the shore, and substrate type, as these characteristics can influence the size of the turtles encountered. Alternatively, the geographic coordinates of each captured specimen should be provided, accurate to at least a tenth of a second; (3) Morphometric data: the measurement(s) used must be specified clearly (see Bolten 2000). We recommend using curved carapace length (CCL), as it can be measured with a flexible tape that facilitates obtaining accurate results; and (4) Data reporting: researchers should report size structure in 5-cm intervals. Finally, all raw data must be reported, including the capture method and carapace measurements for each individual, if not in the body of the article (Seminoff et al. 2003), then as an appendix (López-Fuerte et al. 2025), or supplementary material.

Accurately determining the size structure of Hawksbill Sea Turtles or any other sea turtle population is critical for their conservation and management in the Gulf of California and elsewhere. Data from comparative monitoring is crucial for building a strong baseline of population dynamics; however, as discussed here, heterogeneity in capture methods and data analysis can compromise reliability. Overcoming this challenge requires active collaboration and methodological standardization among research groups. Initiatives like the *Grupo Tortuguero de las Californias A.C*., which applies standardized methods, provide valuable models. Expanding networks like these through workshops, agreements, and the adoption of new technologies for data collection, storage, and analysis will improve data quality and enhance our understanding of populations of Hawksbill Sea Turtles; thus, enabling more effective conservation strategies to ensure the species' long-term recovery and maintenance.

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Appendix

Appendix Table 1. Morphometric data (cm), captured method and site of Hawksbill Turtles (*Eretmochelys imbricata*) presented in Seminoff et al. (2003). Straight Carapace Length (SCL); Curved Carapace Length (CCL) obtained from the equation CCL=0.443+1.015×SCL.

Turtle no.	SCL	CCL	Capture Method	Site
1	56.4	57.7	Dead	Cabo Pulmo
2	52.2	53.4		
3	36.4	37.4		
4	34.4	35.4		
5	38	39.0	Entanglement net	Bahía Los Ángeles
6	37.6	38.6		
7	35.9	36.9		
8	74.2	75.8		
9	64.5	65.9		
10	45	46.1		
11	45.1	46.2	Dead	Canal Infiernillo
12	48	49.2		
13	42.5	43.6		

Appendix Table 2. Catch frequency (cm) of Hawksbill Turtles (*Eretmochelys imbricata*) by size group presented in Ramos-Ávila et al. (2019), captured method and site. Interval Curved Carapace Length (ICCL).

ICCL	Frequency	Capture Method	Site
40–44.9	2		
45–49.9	5		
50–54.9	11		
55–59.9	11		
60–64.9	13		
65–69.9	14	Entanglement net	Espíritu Santo Island
70–74.9	11		
75–79.9	6		
80–84.9	1		
85–89.9	3		
90–94.9	1		

Appendix Table 3. Morphometric data (cm) used by Martínez-Estévez (2021) (but not published) of Hawksbill Turtles (*Eretmochelys imbricata*), capture method and site. Straight Carapace Length (SCL); Curved Carapace Length (CCL); Straight Carapace Width (SCW); Curved Carapace Width (CCW); Plastron Length (PL).

Site	Turtle no.	SCL	CCL	SCW	CCW	PL	Capture Method	Capture date
San José Island	1	46.8	49	36.4	42	24.6	Entanglement net	14 March 2020
	2	38.6	41.5	28.2	33.5	29.1		22 March 2014
	3	50.6	53.6	37.9	44.8	38.1		25 March 2014
	4	49.4	53.0	38.1	45.3	36.0		25 March 2014
	5	54.1	57.5	41.2	49.1	41.3		20 June 2014
	6	47.0	49.6	35.0	49.4	35.1		23 June 2014
	7	41.2	44.7	31.4	32.7	31.1		23 June 2014
	8	51.8	56	40.3	47	39		27 June 2014
	9	38.5	40.5	30.5	35.4	29.1		17 June 2014
	10	57.6	61.2	44.4	51.7	42.1		19 June 2014
	11	43.6	46.6	33.6	39.0	33.6		19 June 2014
	12	47.8	50.5	35.8	43.0	36.7		22 June 2014
	13	63.3	68.0	45.7	54.9	50.7		22 June 2014
	14	47.4	53.0	36.7	43.0	35.1		22 June 2014
	15	53.3	57.3	40.3	48.2	39.5		31 March 2016
	16	60.0	65.3	43.4	52.2	45.9		31 March 2016
	17	57.7	63.9	40.6	49.2	41.4		4 April 2016
	18	45.5	34.8	48.6	39.8	15.3		12 May 2016
	19	52.8	59.2	39.2	46.0	38.7		16-May 2016
	20	59.2	63.5	44.7	52	43.5		18 June 2016
	21	43.5	45.8	34.1	41.2	32.9		21 June 2016
	22	39.6	41.6	29.9	35.4	28.7		21 June 2016
	23	53.4	57.6	39.9	48	40.6		23 June 2016
	24	36.8	38.7	28.2	33.7	26.6		23 June 2016
	25	42	43.6	31.4	36	30.1		16 May 2017
	26	37.2	39	30.5	75.5	27.8		12 June 2017
	27	39.1	42	29.8	35.5	29.5		13 June 2019
	28	51.4	55.5	39	45.4	38.2		14 June 2019

Appendix Table 3, continued

Site	Turtle no.	SCL	CCL	SCW	CCW	PL	Capture Method	Capture date
	29	44.5	48.3	34.6	40.5	33.7	Entanglement net	19 June 2019
San Jose Island	30	43.9	46	32.2	37.5	32.6	Free diving	24 June 2019
	31	38.5	40.7	30.2	35.2	28.9		17 June 2019
	32	42.7	47.1	32.7	38.8	33.5		18 June 2019
	33	45.0	48.4	32.1	37.9	33.7		19 June 2019
	34	33.8	35	26.6	30	26		24 March 2017
	35	42.6	45.5	30	36	31		15 June 2017
	36	38.7	41	28.3	33.9	28		15 June 2017
	37	59	64.9	45.3	54.7	45.2		17 June 2017
	38	45	48.1	35.1	41	33.1		17 June 2017
	39	43.3	47.4	33.1	40.8	33.7		13 June 2017
San José Island	40	44.8	47.5	33.6	40.5	34.3	Strike netting	17 June 2015
	41	76.6	81.8	55.3	66.5	58.6		22 June 2015
	42	62.0	66.0	47.0	55.0	46.0		22 June 2015
	43	55.5	58.6	40.6	48.5	42.6		31 March 2016
	44	53.2	40.5	56.8	46.4	16.7		4 April 2016
	45	40.7	43.4	32.6	38.0	30.3		15 May 2016
	46	45.1	46.7	34.8	40.2	34.7		15 May 2016
	47	82.6	90.3	62.9	75.6	60.2		15 June 2016
	48	46.3	50.6	36.7	43.1	34.1		24 June 2016
	49	58.3	63.1	41	49	42.1		24 June 2016
	50	45.6	50.1	36.3	42.6	34.6		25 June 2016
	51	45.3	47.6	35.9	42	33.6		25 June 2016
	52	49	53	36.1	43.3	36.2		10 May 2017
	53	45.5	48.8	34.9	45.5	34.2		11 May 2017
	54	40.2	44.1	30.6	36.2	30.9		12 May 2017
	55	54.1	50.6	59.0	42.1	18.3		18 May 2019
	56	38.2	45.8	31.4	42.8	31		11 May 2019
	57	51.5	54.5	39.7	47.5	38.6		18 May 2019
	58	53.2	59	43.1	52	41.7		11 June 2019
	59	53.9	58.1	41.6	50.7	40.2		12 June 2019
	60	42.1	45.3	34.1	39	31.3		12 June 2019
	61	36.5	39.3	29.3	34	27.3		12 June 2019
	62	41.6	43.9	32.2	37.8	30.5		12 June 2019
	63	38.3	41	29.2	34.9	28.1		12 June 2019
	64	60.9	66.8	45.3	54.2	44.9		12 June 2019
Carmen Island	65	43.2	45.6	31.6	37	32.2	Entanglement net	1 July 2017
	66	48.9	52.7	37.4	42.8	36.7		1 July 2017
	67	55.3	59.4	39.6	48.3	41.9		1 July 2017
	68	55.9	61.3	40	47	41.9		1 July 2017
	69	43.1	46.1	32.9	38	32.7		2 July 2017
Montserrat Island	70	46.3	50	34.3	41.2	36.2	Entanglement net	4 July 2017

Appendix Table 3, continued

Site	Turtle no.	SCL	CCL	SCW	CCW	PL	Capture Method	Capture date
	71	42.8	46.6	31.3	36.5	31.3		4 July 2017
	72	38.9	40.9	28.4	32.7	28.8		4 July 2017
	73	60.2	65.4	44.8	53	45.6		4 July 2017
Montserrat Island	74	47.5	51.2	35.7	43.2	38.3	Strike netting	4 July 2017
	75	49.1	53.3	35.5	43	37		4 July 2017
Puerto Escondido	76	63.2	68	45.7	56	48.5	Entanglement net	3 July 2017
	77	57.3	61.9	42.6	52	44.8		3 July 2017
Agua Verde	78	43.3	46.1	30.9	37.2	32.9	Strike netting	30 May 2017
	79	59.1	63	45.4	53.1	45.5		31 May 2017
Cabo Pulmo	80	38.3	41.2	29.2	34.7	27.9	Free diving	8 July 2016
	81	43.4	46.2	32.5	36.9	33		8 July 2016
	82	36.1	37.5	26.4	30.6	26.4		8 July 2016
	83	45.3	47.4	32.8	39.1	33.8		8 July 2016
	84	48.6	51.1	35.2	41.2	36		8 July 2016
	85	56	59.2	39.1	46.1	41.7		9 July 2016
Espíritu Santo Island	86	60.8	64.5	45.4	54.3	44.6	Entanglement net	23 June 2016
	87	61.6	64.6	48.5	57.2	44.8	Strike netting	25 June 2017
	88	59.3	63.3	46.3	54.2	44.2		25 June 2017
	89	64.1	69.2	47.7	57.7	47.8		25 June 2017
	90	53.9	57.3	40.8	48.3	39.9		26 June 2017
	91	50.4	53.9	39.1	47.8	38		9 April 2018
	92	53.2	56.3	42.3	50	40.9		9 April 2018
	93	48	51.5	35.5	41.5	36.9		9 April 2018
	94	70	81.4	57	75.5	57.1		9 April 2018
	95	68.3	72	50	59	35.2		9 April 2018
	96	36.3	37.5	28	32.5	27.9		10 April 2018
	97	82	88.5	87.9	74	61.3		23 April 2018

Appendix Table 4. Morphometric data (cm) of examined Hawksbill Turtles (*Eretmochelys imbricata*) presented in López-Fuerte et al (2025), capture method and site. Straight Carapace Length (SCL); Curved Carapace Length (CCL); Straight Carapace Width (SCW); Curved Carapace Width (CCW); Plastron Length (PL); Plastron Width (PW). Semi-autonomous diving (SAD).

Turtle no.	SCL	CCL	SCW	CCW	PL	PW	Capture Method	Site
1	37.9	41	28.0	35	29.4	26.8	SAD	Santa Rosalía
2	38.6	40	29.7	36	28.4	26.9		
3	39.6	42	30.2	36	31.7	28.8		
4	28.3	31	21.0	25	22.4	19.3		
5	37.8	38	29.4	35	28.7	27.0		
6	43.7	44	32.9	39	32.7	30.5		
7	32.9	33	24.9	30	24.5	22.5		
8	33.4	34	24.8	30	25.5	22.7		
9	33.7	35	24.9	29	25.7	22.6		
10	31.4	32	23.1	27	23.7	21.1		

Appendix Table 4, continued

Turtle no.	SCL	CCL	SCW	CCW	PL	PW	Capture Method	Site
11	35.9	37	26.8	32	26.5	25.1	SAD	Santa Rosalia
12	35.1	36	25.6	32	26.2	24.1		
13	35.0	35	26.5	33	25.7	24.0		
14	41.2	44	30.6	38	25.5	24.3		
15	27.4	30	23.3	28	23.9	21.5		
16	40.1	41	30.0	37	29.6	27.7		
17	35.7	35	25.3	31	26.3	24.0		
18	49.9	49	35.3	40	36.9	35.2		
19	47.2	52	35.7	44	41.6	39.6		
20	38.7	41	27.3	34	29.0	29.6		
21	35.7	35	27.4	31	25.8	24.3		
22	34.7	37	25.4	31	28.9	21.3		
23	34.2	33	24.3	28	24.9	20.0		
24	32.3	34	23.0	29	24.8	20.8		
25	35.9	35	28.2	32	27.2	26.2		
26	58.8	60	41.2	52	47.6	41.2		
27	43.5	45	33.3	40	32.2	31.3		
28	43.5	45	30.9	39	31.3	29.6		
29	38.1	38	28.1	32	28.3	25.4		
30	29.8	31	24.2	27	23.6	22.2		
31	39.2	42	31.0	36	ND	ND		

Appendix Table 5. Sample sizes from Martínez Estévez (unpublished data), grouped by year and region. Data from sites within the same region were pooled: Carmen and Monserrat islands; Puerto Escondido and Agua Verde (north); Espíritu Santo and Cabo Pulmo (south); or from a single island in the case of San José Island. One-way analyses of variance were conducted using totals by zone and by year.

	Region			
Year	North	Isla San José	South	Total/year
2014	0	12	0	12
2015	0	9	0	9
2016	0	19	7	26
2017	15	10	4	29
2018	0	0	7	7
2019	0	14	0	14
Total/region	15	64	18	97