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Research Article

Strandings and debris accumulation on San Lázaro Beach: insights into an effective coastal trap

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ABSTRACT. Strandings of marine fauna and the accumulation of floating debris are complex phenomena driven by interactions between oceanographic processes and human activities. San Lázaro Beach, located in the Gulf of Ulloa, Baja California Sur, Mexico, has been identified as a recurrent stranding site for sea turtles; however, the simultaneous accumulation of organic remains and marine debris in this area has not been systematically evaluated. This study aimed to characterize the composition and spatial distribution of stranded objects along 50 km of coastline during two seasons (summer and autumn), using transects oriented parallel and perpendicular to the shoreline. Marine turtle remains, other marine fauna remains, marine vegetation, and various types of solid waste were recorded. Analyses showed that accumulation was significantly higher in parallel transects, with a predominance of organic materials. Seasonal patterns of marine turtle remains abundance varied by analysis level: specific transects showed higher values in autumn, while site-level aggregation revealed greater overall abundance in summer, especially at central stranding hotspots. These results suggest that beach orientation, in combination with the direction of the California Current, promotes the formation of a coastal retention zone that favors the recurrent accumulation of animal remains and floating debris. This phenomenon has direct implications for coastal monitoring, sea turtle conservation, and marine debris management along the western coast of the Baja California peninsula.

Keywords: strandings; marine turtles; marine debris; coastal trap, California Current; Gulf of Ulloa

INTRODUCTION

Beach strandings of marine organisms and floating debris represent visible manifestations of oceanographic, ecological, and anthropogenic processes. While strandings of marine fauna such as cetaceans and turtles have traditionally been documented as resulting from natural or human-related causes, it is increasingly evident that the spatial and temporal patterns of these events are closely linked to coastal physical dynamics (Hart et al. 2006). The California Current, which flows from northwest to southeast along the western coast of Baja California, plays a key role in the distribution of floating particles, biological detritus, and carcasses of marine fauna. This current, combined with coastal orientation and local bathymetry, can create favorable conditions for coastal traps that concentrate floating objects (Critchell & Lambrechts 2016, Lebreton et al. 2018).

The Gulf of Ulloa, located in the Mexican Pacific on the western coast of the Baja California peninsula, is a biologically productive region that is critical for the conservation of marine species such as the loggerhead turtle (*Caretta caretta*), where a high incidence of strand-

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ings has been documented (Peckham et al. 2007). San Lázaro Beach has been identified as a concentration point for stranded turtles. Still, the accumulation of marine debris and other species' remains has also been observed, suggesting a more complex pattern. This phenomenon has already been partially documented in the region by Salinas-Zavala et al. (2020), who demonstrated that prolonged surface cooling events (<18°C) are closely linked to mass strandings of loggerhead turtles in the Gulf of Ulloa. This antecedent provides a relevant conceptual framework and highlights the need to expand the analysis. In this manuscript, we explore how beach orientation and the dynamics of the California Current can explain not only turtle strandings but also the systematic accumulation of other biological remains and floating debris.

To address this, we analyzed seasonal sampling data from parallel and perpendicular transects, considering the composition, abundance, and spatial distribution of stranded objects, with particular emphasis on marine turtle remains. Since San Lázaro Beach is oriented perpendicular to the average flow of the California Current and exhibits a linear morphology without transverse barriers, it is expected to act as an active coastal trap, concentrating floating debris of various types (organic and inorganic) at specific accumulation points. This concentration is not expected to be homogeneous but to display defined spatial patterns, both among sites and between seasons, revealing differences in the magnitude and composition of strandings.

MATERIALS AND METHODS

Study area

San Lázaro Beach is located on the western coast of Baja California Sur, Mexico, within the Gulf of Ulloa (approximately 24.8°-25.2°N, 112.2°-112.7°W). It extends approximately 50 km with a southwest-northeast orientation. The beach is exposed to the California Current, which flows predominantly from northwest to southeast. It is a gently sloping beach with minimal human intervention, making it suitable for coastal ecological studies (Fig. 1).

Sampling design

Two field campaigns were conducted, one in summer and another in autumn 2022. Ten sampling sites were established at 5 km intervals along ~50 km of coastline (Fig. 1, left panel). At each site, a 100×200 m (2 ha) sampling unit was defined, extending from the dune toe to the supralittoral zone. Each unit was divided into two adjacent 100×100 m sections (A and B). Within each section, two orthogonal transects (parallel and perpendicular to the shoreline) were outlined, generating four quadrants; two quadrants per section were systematically surveyed. All surveys were conducted within a single day per campaign to minimize temporal variability.

Recording and classification of stranded objects

In each transect, objects were recorded every 5 m along the transect line. For transects perpendicular to the shoreline, which ran across sections A and B, we recorded all objects within the full width of each section (100 m per section), ensuring that each section was treated independently. Objects located between the two sections were assigned to the nearest section.

All visible stranded objects were recorded, including remains of marine fauna (turtles, mammals, fish, birds), marine vegetation (seagrass, macroalgae), plastic debris (bottles, sacks, fragments), metals, glass, and fishing gear. Predefined functional categories were used for analysis: marine fauna, rigid plastics, soft plastics, nets, wood, metallic debris, and others.

Stranded objects were recorded using a semi-quantitative scale ranging from 0 to 5 (0 = absence, 1 = very low abundance, 2 = low abundance, 3 = moderate abundance, 4 = high abundance, 5 = very high abundance). All observations were conducted *in situ*, and no items were removed to avoid altering subsequent accumulation patterns.

Considerations on marine turtle remains

For marine turtle remains, it was assumed that the specimens counted corresponded to strandings that occurred within the influence zone of each sampling site. Although authorities have occasionally responded to reports of mass strandings by removing or burying carcasses, such movements are carried out mainly perpendicular to the beach (toward dunes or inland). Therefore, it was considered that marine turtle remains recorded within transects were not significantly displaced (more than 5 km) in a direction parallel to the coast, which is the spatial axis of analysis in this study. This assumption ensures that the observed distribution of marine turtle remains within each site (200 m in total length, equivalent to 2 ha of sampled area) is representative of stranding and accumulation processes on San Lázaro Beach.

Data analysis

Field data were organized in a matrix of observations by transect and stranded-object category. Each record

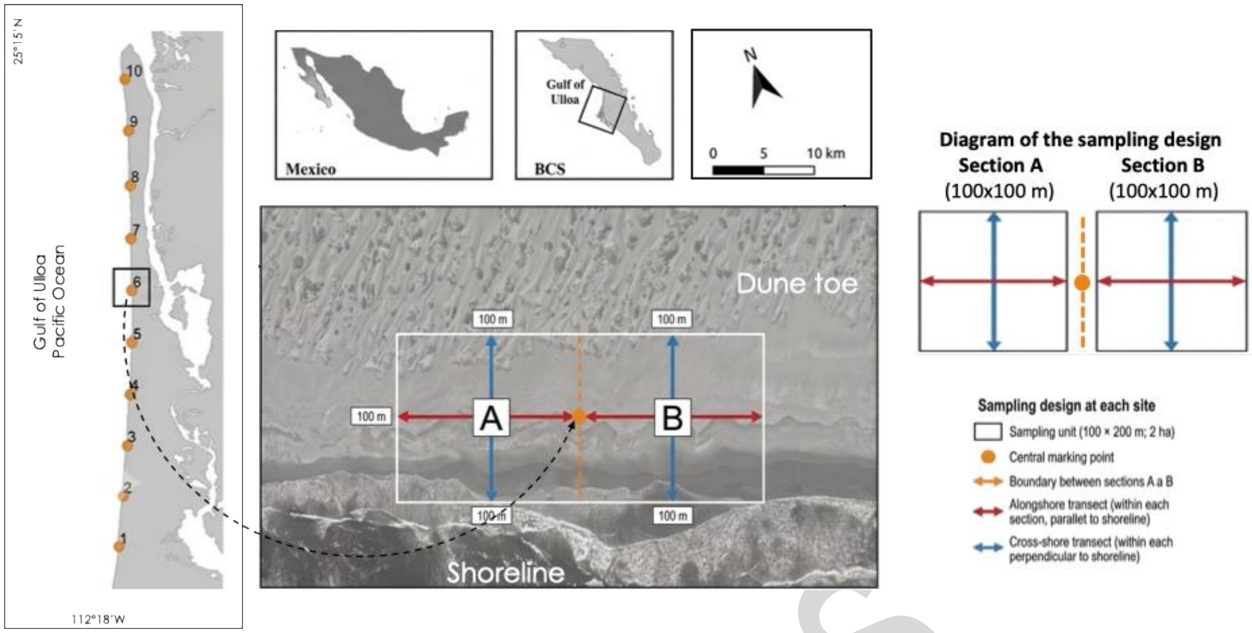

Figure 1. Study area and sampling design at San Lázaro Beach, on the western coast of Baja California Sur (BCS), Mexico, within the Gulf of Ulloa. The left panel shows the distribution of 10 sampling sites along approximately 50 km of shoreline. The upper panels show the location of the study area within Mexico and on the Baja California peninsula. The right panel presents the sampling design applied at each site. A single 100×200 m sampling unit (2 ha) was established at each site, starting at the dune toe and extending seaward across the supralittoral zone. This unit was divided into two adjacent sections (A and B), each 100×100 m. Within each section, two orthogonal transects were outlined: one parallel and one perpendicular to the shoreline. The intersection of these transects defined four quadrants per section, of which two were systematically surveyed.

was recorded on an ordinal scale from 0 to 5 (0 = absence, 1 = very little, 2 = little, 3 = medium, 4 = much, 5 = abundant), to standardize relative abundance estimates among observers. Subsequently, categories were grouped into organic residues (e.g. carapaces, skeletal remains, vegetation, macroalgae, mangrove seeds, feathers) and inorganic residues (e.g. plastics, ropes, glass, metals, styrofoam), allowing comparative analyses at both the object and functional group levels. Descriptive analyses (frequencies, means, totals per category) were applied to characterize the general composition of strandings.

Comparisons between transect orientations (parallel *vs*. perpendicular) and between seasons (summer *vs*. autumn) were performed using Mann-Whitney U tests, given the ordinal nature of the scale and the absence of normality in several categories. For global comparisons between organics and inorganics, data showed normal distribution (Shapiro-Wilk, $P > 0.05$), so paired Student's *t*-tests were applied. Differences among sampling sites were evaluated using two-way ANOVA with interaction (type×site), which allowed discrimination of the effect of residue type, spatial location, and their interaction. When relevant, Tukey HSD post hoc tests were applied to identify specific significant comparisons. Outlier detection to identify marine turtle remains accumulation hotspots was performed using Tukey's method, applied separately for each season (summer and autumn).

To analyze spatial trends, Spearman correlations were applied between site number (southwest-northeast gradient) and accumulation values. The direct relationship between organic and inorganic residues at the transect level was evaluated using Pearson and Spearman correlations. Concordance between quadrants was assessed with Fisher's exact test and Cohen's Kappa index, based on presence/absence matrices.

Finally, to identify possible accumulation hotspots, mean marine turtle remain densities per hectare were calculated for each site and season, and outliers were detected using Tukey's method. These distinguished sites have exceptionally high accumulations compared to the general pattern. All analyses were performed in Python (2023) 3.11 using the libraries: pandas, numpy, scipy, statsmodels, seaborn, and matplotlib.

RESULTS

During the summer and autumn surveys conducted along the 50 km of San Lázaro Beach, various stranded objects were recorded, including marine fauna remains, floating vegetation, and anthropogenic solid waste. A total of 4,309 items were recorded across all transects. The most abundant categories were seagrass (2,469 records), mangrove seeds (760 records), and macroalgae (663 records). Solid waste included plastics (182), styrofoam (19), and metals. Marine fauna remains were reported and classified into broad taxonomic groups, including marine turtle carapaces (102), marine turtle skeletal remains (90), and marine mammal skulls (24). Recently stranded marine vertebrates (one sea turtle, one dolphin, and one sea lion) were recorded as single, independent observation events, with no duplicate records of the same event. Due to the advanced state of decomposition, the organisms could not be reliably identified beyond their respective taxonomic groups.

Comparison between transect orientations

Parallel and perpendicular transects consistently differed in the accumulation of objects. Significant differences ($P < 0.05$) were found in 18 of 20 object classes, highlighting the strong effect of transect orientation. For organic materials, the effect was even more marked, with significance in 95% of the comparisons (19 of 20). In contrast, inorganic materials only showed differences in 45% of cases (9 of 20), reflecting a more variable distribution. Globally, considering all sites and seasons, highly significant differences were detected between parallel and perpendicular transects (Table 1).

In parallel transects, greater accumulation was recorded for both organic objects (mean = 1.997) and inorganic objects (mean = 0.257), compared to perpendicular transects (means = 0.621 and 0.084, respectively). The same pattern was observed for total objects (parallel mean = 1.377; perpendicular = 0.442). In all three cases, Mann-Whitney U tests yielded $P < 0.001$, confirming that transect orientation has a decisive effect on accumulation at San Lázaro Beach.

Temporal comparison: summer *vs.* autumn

Significant differences were found in multiple categories between summer and autumn. In autumn, higher averages of carapaces, marine turtle skeletal remains, plastic debris, and wood fragments were observed, while in summer, seagrass and dry vegetation predominated. Mann-Whitney tests confirmed that at least 15 categories showed significant differences ($P < 0.05$) between seasons.

The seasonal comparison revealed significant differences in total accumulation and inorganic content (Table 2). On average, inorganics were notably more abundant in summer (0.27) than in autumn (0.08), with a highly significant difference ($P < 0.001$). For total objects, a significant difference ($P = 0.041$) was also observed, with slightly higher values in summer (0.97) than in autumn (0.85). In contrast, organics did not show significant seasonal differences ($P = 0.738$), indicating that their accumulation depends more on orientation and littoral dynamics than seasonality.

Comparison between quadrants

To avoid observer bias associated with the quantitative 0-5 scale, where one team may have been stricter or more generous in assigning categories, data were transformed to a presence/absence (0/1) approach to eliminate magnitude bias, preserves essential information (whether an object was present or absent), and allows robust comparisons using association tests for binary data (Fisher's exact test) and concordance measures. Out of 120 quadrant comparisons, 109 cases (90.8%) showed perfect agreement in presence/absence, while only 11 cases (9.2%) showed discrepancies. Fisher's test confirmed that there were no significant differences between quadrants within each site and season ($P > 0.05$ in all cases). Complementarily, Cohen's Kappa index confirmed near-perfect concordance in most cases; disagreements yielded Kappa = 0, reflecting isolated discrepancies without a systematic pattern. These findings confirm that the two 1-ha quadrants are equivalent in detecting objects, justifying pooling their records into a combined 2-ha area per site for subsequent analyses.

Global accumulation profiles by site

Linear accumulation profiles were generated for organics and inorganics, summing values by site (Table 3). These values correspond to a relative accumulation index per hectare. Profiles along the coastal axis allow visualization of accumulation gradients and highlight priority zones for monitoring and conservation. Parallel transects recorded higher average values in nearly all categories (including carapaces, plastic debris, macroalgae, and skeletal remains). These differences were statistically significant in more than 10 categories

Table 1. Mann-Whitney U test results for mean abundance scores (0-5 scale) per transect, comparing parallel and perpendicular orientations for total, organic, and inorganic objects.

Variable	Mean parallel	Mean perpendicular	U-stat	*P*-value
Total	1.377	0.442	1,956,573	2.23×10^{-168}
Organics	1.997	0.621	1,950,781	1.59×10^{-164}
Inorganics	0.257	0.084	1,407,184	3.12×10^{-21}

Table 2. Mann-Whitney U test comparing mean abundance scores (0-5 semi-quantitative scale) per transect between summer and autumn for total, organic, and inorganic stranded objects.

Variable	Mean summer	Mean autumn	U-stat	*P*-value
Total	0.974	0.846	1,331,392	0.041*
Organics	1.410	1.208	1,273,405	0.738
Inorganics	0.266	0.075	1,437,389	<0.001*

Table 3. Accumulation index values (0-5 ha^{-1}) by site, season, and global. Org.: organic; Inorg.: inorganic.

Site	Org. summer	Org. autumn	Inorg. summer	Inorg. autumn	Org. global	Inorg. global
1	0.63	0.66	0.18	0.06	0.65	0.12
2	1.09	0.78	0.34	0.06	0.94	0.20
3	1.38	0.24	0.41	0.05	0.81	0.23
4	1.49	1.48	0.35	0.04	1.49	0.20
5	1.07	1.01	0.24	0.01	1.04	0.13
6	0.72	1.43	0.16	0.08	1.07	0.12
7	1.14	1.60	0.27	0.12	1.37	0.19
8	1.02	1.94	0.20	0.10	1.48	0.15
9	1.88	1.51	0.23	0.15	1.69	0.19
10	3.69	1.42	0.29	0.08	2.55	0.18
Global	1.41	1.21	0.27	0.07	1.31	0.17

(Mann-Whitney U test, $P < 0.05$). Overall, profiles suggest that the active stranding zone is located at the immediate coastal edge, conditioned by beach orientation relative to the California Current, reinforcing the interpretation of San Lázaro as an active coastal trap.

Organic accumulation was considerably higher than inorganic (global = 1.31 *vs.* 0.17). Site 10 emerged as a clear hotspot (global = 2.55), followed by sites 9 (1.69), 8 (1.48), and 7 (1.37). These patterns were consistent across both seasons, with notable increases in autumn at sites 6 and 8. For inorganics, the highest values were recorded at sites 2 (0.20), 3 (0.23), and 4 (0.20), exceeding the global average (0.17) (Fig. 2).

Spatial comparison between organics and inorganics by season

Combined analysis revealed differences in accumulation patterns between organic and inorganic compounds (Table 4). During summer, organic residues showed a northeastward increasing gradient, peaking at sites 9 and 10. In autumn, a similar but attenuated gradient peaked at site 8. In contrast, inorganics were highest at southwestern sites (1-4) and decreased toward the northeast.

Table 4. Spatial comparison between organics and inorganics by season. df: degrees of freedom, F: F-statistic.

Source	Sum Sq	df	F	*P*-value
Season	61.79	1	31.92	1.67e-08
Type	2075.78	1	1072.5	1.27e-217
Season × type	0.05	1	0.03	0.874
Residual	12386.97	6400	--	--

Two-way ANOVA showed both residue type ($F = 1072.5$, $P < 0.001$) and season ($F = 31.9$, $P < 0.001$) explained differences, with residue type being the dominant factor. No significant interaction ($P = 0.874$) indicated that organics consistently exceeded inorganics in both seasons. Tukey's HSD test confirmed highly significant differences among residue types ($P < 0.001$).

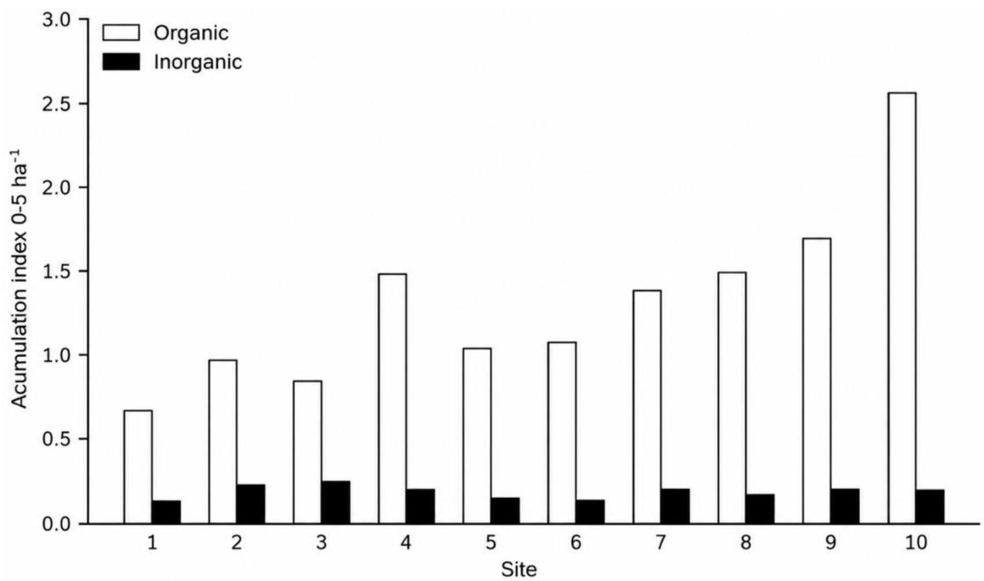

Figure 2. Accumulation index of organic and inorganic waste by sampling site.

Comparison between organic and inorganic residues by site

To test for differences along the beach, site totals (n = 10) were compared. Elements were grouped as organic (e.g. seagrass, macroalgae, vegetation, carapaces) and inorganic (e.g. plastics, glass, metal, ropes). Shapiro-Wilk tests indicated normal distributions (organics: W = 0.908, P = 0.266; inorganics: W = 0.905, P = 0.249). The paired Student's t-test showed a significant difference (t = 6.638, df = 9, P < 0.001), confirming that organics accumulate more than inorganics. Spearman's correlation showed a strong positive trend for organics (ρ = 0.867, P = 0.0012) that increased toward the northeast, whereas inorganics showed no significant trend (ρ = -0.115, P = 0.751). A two-way ANOVA (type × site) revealed highly significant differences for type (F = 1145.0, P < 0.001), site (F = 27.7, P < 0.001), and their interaction (F = 26.0, P < 0.001) (Table 5).

Seasonal analysis of marine turtle remains

Seasonal analysis of marine turtle remains was conducted using a total of 192 reports, comprising marine turtle carapaces (n = 102) and marine turtle skeletal remains (n = 90). All records were treated as a single group (sea turtle remains) due to inconsistent ability to assign them to the species level based on preservation conditions. Marine mammal remains (dolphins and sea lions) were not included in this analysis due to their low frequency (n = 24 skulls across both campaigns) and their sporadic occurrence, which did not allow robust seasonal comparisons.

Table 5. Comparison between organics and inorganics by site. Sum Sq: sum of squares, df: degrees of freedom, F: F-statistic.

Source	Sum Sq	df	F	*P*-value
Type	2075.78	1	1145.0	5.18e-231
Site	451.7	9	27.68	1.41e-47
Type × site	423.74	9	25.97	1.91e-44
Residual	11573.37	6384	--	--

Marine turtle remains were considered strandings within the influence of each site. Mann-Whitney U test showed a significant difference between campaigns (U = 1,325,599.5, P < 0.001), with higher abundance in summer, especially at central sites (3-6) (Fig. 3). Mean values were 0.053 carapaces ha^{-1} in summer *vs*. 0.013 ha^{-1} in autumn (Table 6).

Hotspots of marine turtle remains accumulation by season

To identify potential hotspots, mean densities per hectare were evaluated for each site and season, using Tukey's outlier detection. In summer, several central sites (3-6) had the highest values (0.075-0.100 carapaces ha^{-1}), suggesting a corridor of accumulation, but none exceeded Tukey's upper limit (0.136), so no statistical outliers were detected. In contrast, in autumn, accumulation was lower and more dispersed. Still, site 5 (0.038 carapaces ha^{-1}) exceeded the threshold (0.034), making it the only statistically detectable hotspot (Fig. 3, Table 7), indicating marked seasonal variability: in

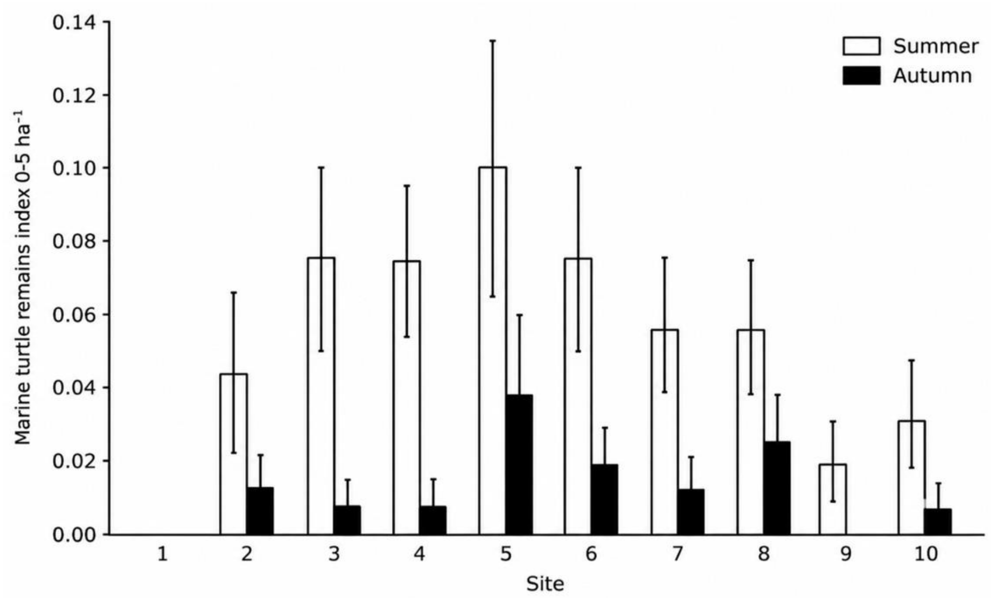

Figure 3. Marine turtle remains index (0-5) ha^{-1} per site on San Lázaro Beach, comparing summer (white bars) and autumn (black bars). Error bars represent standard error (±SE) at the transect level. Summer showed greater, broader accumulation across the central sites (3-6), whereas autumn identified a localized hotspot at site 5 using Tukey's method.

Table 6. Means of recoded index (0-5) for marine turtle remains by site and season.

Site	Summer	Autumn	Global
1	0.000	0.000	0.000
2	0.044	0.013	0.028
3	0.075	0.006	0.041
4	0.075	0.006	0.040
5	0.100	0.038	0.069
6	0.075	0.019	0.047
7	0.056	0.013	0.034
8	0.056	0.025	0.040
9	0.019	0.000	0.009
10	0.031	0.006	0.019
Global	0.053	0.013	0.033

summer, accumulation extended across several sites, while in autumn it was localized at a single site, possibly linked to microbathymetry, beach orientation, or California Current dynamics. Moreover, seasonal differences may also be influenced by natural delays in floating and stranding: after death, turtles often sink and resurface only days or weeks later, when decomposition gases allow them to float. This delay can cause strandings observed in one campaign to correspond to mortalities from previous months.

DISCUSSION

The results of this study strongly suggest that San Lázaro Beach may function as a coastal trap, that is, a coastal sector where morphology, orientation, and exposure to prevailing currents and winds favor the recurrent accumulation of floating materials, both natural and anthropogenic. Unlike sporadic deposits, an active coastal trap concentrates objects repeatedly due to persistent, predictable hydrodynamic processes (Martinez et al. 2009, Lebreton et al. 2018). Such traps are typically found on open beaches with an oblique orientation to dominant currents or in areas where longshore drift converges with irregular bathymetry (Critchell & Lambrechts 2016). In the case of San Lázaro, the southwest-northeast alignment of the coastline, combined with the northwest-southeast flow of the California Current, suggests a net drift toward shore, consistent with the observed accumulation of dead organisms, plant debris, and floating waste.

A comparative analysis of residue types showed that organic materials dominated accumulation at San Lázaro, with significantly higher values than inorganic materials. This pattern is consistent with longshore transport processes that favor the deposition of floating biological remains such as carapaces, macroalgae, or skeletal parts, in contrast to the more localized persis-

Table 7. Tukey statistical parameters for marine turtle remains densities by season. car: carapaces; SD: standard deviation.

Season	Mean (car ha^{-1})	SD	Tukey upper limit	Outlier sites
Summer	0.053	0.030	0.136	None
Autumn	0.013	0.012	0.034	5

tence of plastics, glass, or metals. Inorganic materials likely originate from multiple human sources, including coastal settlements, fishing activities, maritime transport, and land-based runoff, which contribute to debris input along the shoreline in varying degrees. Seasonal differences were also observed, though less pronounced than those linked to residue type: overall, strandings were more abundant in summer, except for localized cases such as site 5 in autumn, which acted as a hotspot of carapace accumulation.

The analysis of sea turtle carapaces revealed a clear signal of seasonal and spatial variability. Central sites (3-6) showed the highest densities during summer, suggesting the existence of an accumulation corridor linked to micro-bathymetric variations and interaction with the California Current. In autumn, by contrast, the pattern was concentrated at a single site (5), identified as a statistical outlier using Tukey's method. This result reinforces the notion that both general hydrodynamic processes and local convergence conditions may influence turtle strandings. It is also important to consider the natural delay in carcass flotation: after death, turtles often sink and reappear only days or weeks later, when decomposition gases enable buoyancy (Schultz et al. 2022). This lag may explain some of the differences between seasonal campaigns, as strandings observed at one time may reflect mortalities that occurred months earlier.

Correlation analyses at the transect level showed that organics and inorganics do not necessarily accumulate in the same places, suggesting that they respond to different processes. Organic residues showed a gradient increasing toward the northeast, consistent with longshore transport. In contrast, inorganics displayed a more irregular pattern, likely associated with local input sources or stochastic processes such as wind, rip currents, or microtopography.

Similar selective accumulation phenomena have been documented in other regions, such as the northern coast of Chile, where north-facing beaches concentrate debris transported by the Humboldt Current (Thiel et al. 2003), or in remote islands of the South Pacific, where coastal orientation and trade winds turn certain sectors into persistent sinks of oceanic debris (Lavers & Bond 2017). These parallels reinforce the interpretation of San Lázaro as a convergence system comparable to other high-accumulation environments.

In the ecological context of the Gulf of Ulloa, this coastal trap function is particularly relevant given the high density of vulnerable marine fauna, particularly marine turtles. Among these, the loggerhead turtle (*C. caretta*) has been frequently reported in stranding records and fisheries-interaction data for the region and is considered a key species in the area (Peckham et al. 2007, Salinas-Zavala et al. 2020). Whilst this study did not identify marine turtle remains at a species level, the detection of those remains on the shoreline does not necessarily reflect the cause or location of death, as drift processes can displace animal remains by tens of kilometers (Hart et al. 2006). Wind direction, current intensity, and carcass condition (buoyancy, integrity) may lead to over- or underestimation of mortality detected onshore. Additionally, many carcasses never reach the coast and sink or remain trapped in inaccessible intertidal zones, which can bias sample availability. Not all lethal interaction events leave visible marks on carapaces, further complicating post-mortem diagnosis (Stacy et al. 2016).

Given these limitations, strandings in coastal traps should be interpreted as indicators of physical accumulation in convergence zones, rather than as direct estimators of mortality rates or specific causes. Their primary value lies in identifying critical monitoring points, which can be integrated with other sources of evidence (fishing effort, necropsies, tissue analyses, satellite data) to construct a more comprehensive picture (Parga 2015). This integrated approach is key for adaptive management and marine conservation.

CONCLUSIONS

San Lázaro Beach serves as an effective coastal trap, where physical conditions, such as coastal orientation and the direction of the California Current, converge to favor the systematic accumulation of biological remains and floating debris.

Marine turtle remains were more abundant in summer and in transects parallel to the shoreline, indicating direct accumulation along the active tidal fringe.

Specific sites in the central portion of the 50 km stretch of San Lázaro Beach functioned as stranding hotspots, concentrating higher numbers of marine turtle remains. These sites should be considered priorities for monitoring and conservation actions.

The observed spatial and seasonal patterns highlight the need to incorporate physical oceanography into coastal conservation and management programs and to integrate measures to mitigate marine debris.

San Lázaro is a key site not only for studying sea turtle strandings but also for evaluating the combined impacts of natural and anthropogenic factors on coastal ecosystems of the Mexican Pacific.

Credit author contribution

C.A. Salinas-Zavala: funding acquisition, project administration, supervision, conceptualization, methodology, formal analysis and writing-original draft; M.V. Morales-Zárate: conceptualization, methodology, validation, writing-original draft, review and editing; J.Z. Retana-Arellano: fieldwork, data collection, review and editing; J.A. López-Ramírez: fieldwork, data collection and review.

Conflict of interest

The authors declare no conflict of interest

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