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Territorializing Aquatic Biodiversity: Local Ecological Knowledge (LEK) and Elasmobranch Distribution in the Kango Estuary (Gabon)

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Abstract

Elasmobranchs (sharks and rays) are ecologically and socio-economically important, yet their distribution in Central African estuarine systems remains poorly documented. This study investigated the spatial and seasonal distribution of elasmobranchs in the Komo Estuary (Kango, Gabon) using Local Ecological Knowledge (LEK) derived from semi-structured interviews with 30 artisanal fishers, complemented by participatory mapping and GIS analyses. Four species consistently reported by fishers, *Fontitrygon ukpam (F. ukpam)*, *Fontitrygon margaritella (F. margaritella)*, *Carcharhinus leucas (C. leucas)*, and *Sphyrna lewini (S. lewini)*, were treated as focal because they represented all elasmobranch taxa detected in the system and accounted for 100% of observations. Among them, *F. ukpam* was the most widespread and frequently cited (40 ± 5% of all mentions, CI: 95%), occurring from the estuary to upstream freshwater zones. *F. margaritella* represented 20 ± 7% (CI: 95%) of reports and, together with C. leucas (≈10 ± 3%, CI: 95%), was concentrated in warm, saline lower-estuary waters. *S. lewini* was rarely reported (<5% of occurrences). Although no statistically significant differences were detected between wet- and dry-season assemblages, the dry season exhibited a descriptive tendency toward slightly higher richness. Temperature and salinity emerged as key abiotic drivers, while prey availability, turbidity, and fishing pressure likely modulated species distributions. Spatial analyses highlighted localized aggregation zones not detectable through conventional surveys, demonstrating the value of LEK as a robust spatial dataset. Beyond documenting ecological patterns, fisher knowledge also reflected lived territorialities, linking species ecology to the social appropriation of aquatic environments. This study underscores the dual ecological and geographical relevance of LEK, clarifies species–environment relationships in a data-poor estuarine system, and identifies priority sectors for future monitoring and co-management.

Keywords: Elasmobranchs; Local Ecological Knowledge (LEK); Komo Estuary; Gabon; environmental geography

Introduction

Elasmobranchs (sharks and rays) occupy a central place in aquatic socio-ecosystems, functioning both as structuring predators and as essential fishery resources for coastal and riverine communities (Dedman *et al.*, 2024). Their vulnerability to anthropogenic pressures (overfishing, habitat degradation, and climate change) is now well established (Pacoureau *et al.*, 2021; Dulvy *et al.*, 2017). Despite their ecological and social importance, research on elasmobranchs in Central Africa remains limited and uneven,

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concentrated almost exclusively along the marine coast. Yet, estuarine and riverine habitats are critical interfaces where ecological processes and social dynamics converge. These spaces are not only biological corridors for species reproduction, feeding, and migration, but also sites of intense human activity and local resource governance (Khojasteh *et al.*, 2025).

In Gabon, most available data concern marine environments, while estuarine systems, such as the Komo Estuary (the largest in the country), the Noya Estuary near Cocobeach and the Ogooué delta around Port-Gentil, remain poorly documented. Recent studies in southern Gabon (Mvomo Minko *et al.*, 2025) have described artisanal shark and ray catches and their biological traits, but little is known about how elasmobranchs use the transitional gradient linking the river, estuary, and marine zones. This lack of knowledge limits the understanding of their ecological role and of the socio-territorial processes through which local communities interact with these species. Addressing this gap requires an approach that simultaneously accounts for ecological distributions and spatial practices, thereby linking biogeography to the lived geography of aquatic environments.

This study draws on the conceptual triad of territorialization (Raffestin, 1986), production of space (Lefebvre, 1974), and lived space (Tuan, 1974) to interpret how species, environments, and societies co-produce estuarine territories. Within this framework, Local Ecological Knowledge (LEK) emerges as a crucial epistemic resource. It provides spatial and temporal insights derived from the daily experience of fishers, insights expressed through landmarks, concentration zones, and seasonal rhythms (Berkström *et al.*, 2019). Far from being merely anecdotal, LEK constitutes a vernacular geography of the aquatic world, which, when translated into cartographic and analytical forms, can complement and challenge conventional scientific representations (Rudlle & Davis, 2013). Integrating LEK into spatial analyses thus allows geography to bridge sensitive and embodied knowledge with quantitative and spatial methods.

Focusing on the case of Kango, town located upstream along the Komo River, (Estuaire Province, Gabon), this research seeks to document the spatial and seasonal distribution of elasmobranchs by mobilizing the knowledge of local fishing communities. It analyzed the environmental factors associated with the reported distributions and discussed how Local Ecological Knowledge (LEK), as a form of spatial and territorial knowledge, enriched the geographical analysis of socio-ecosystems. By combining the study of species distributions with the spatialization of local perceptions, this article situates itself at the crossroads of biogeography, concerned with the ecological patterns and gradients shaping species distributions, and environmental geography, attentive to the social appropriation, governance, and lived experience of aquatic environments.

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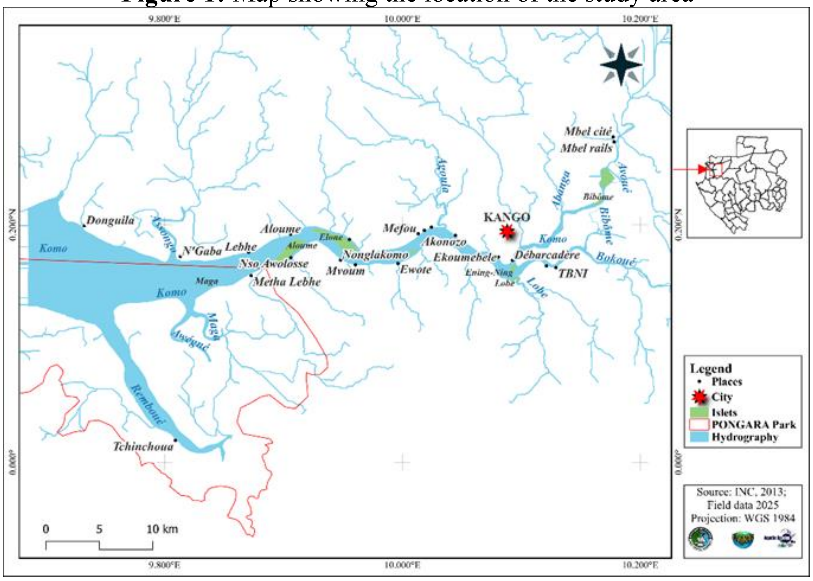
Methodology

Study area

The study was conducted in the Kango region, along the Komo River in Gabon's Estuaire Province, Komo-Kango Department (Figure 1). The Komo river, about 200 km long with a catchment of ~5,000 km², flows east–west into the Libreville Estuary and receives inputs from major tributaries such as the Mbéi and Remboué, as well as smaller streams (Avome, Abanga, Agoula, Elobé). The river is subject to semi-diurnal tides extending up to 120 km inland (Lerique, 1965). The Kango area is characterized by floodplains and swamp forests forming a mosaic of freshwater and brackish habitats, strongly influenced by tidal and salinity dynamics. Local soils, mainly ferrallitic and hydromorphic with marked acidity and low fertility (Delhumeau, 1969; Ndzengboro-Endamane *et al.*, 2023), limit agricultural potential, reinforcing communities' reliance on riverine and estuarine fisheries.

The hydro-climatic regime of Kango is characterized by a bimodal rainfall pattern: The region experiences a bimodal rainfall pattern characterized by two distinct rainy seasons, one major rainy season from September to November and a minor rainy season from March to May, alternating with two dry seasons, namely the major dry season from June to August and the minor dry season from December to February. (Maloba Makanga, 2010). Annual precipitation ranges between 2,000 and 3,000 mm. This combination of freshwater inputs, tidal intrusion, and high rainfall creates a dynamic environment particularly favorable for elasmobranchs, which exploit both riverine and brackish habitats.

Figure 1: Map showing the location of the study area



Study participants

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

Local perceptions of elasmobranch distribution were documented through semi-structured interviews with 30 artisanal fishers from the Kango area. Participants were selected using a combination of purposive and snowball sampling to ensure diversity in age, fishing experience, and fishing practices, and to capture a broad range of local ecological knowledge. Selection criteria required that fishers had at least five years of fishing experience, were regularly active within the study area, and demonstrated strong familiarity with local aquatic environments through their daily fishing activities.

Given the absence of an official registry of artisanal fishers in Kango, the principle of data saturation (Guest *et al.*, 2006) was applied to determine an adequate sample size. Initial respondents were identified and recruited through the Cooperative of Fishers of Kango (CPMK), which served as a reliable entry point into the community.

Semi-structured interviews

Semi-structured interviews were chosen as the primary method of data collection, as they allow flexibility to explore individual perceptions while maintaining comparability across respondents. A pre-designed questionnaire guided the interviews and focused on four main themes: (1) the socio-demographic and fishing characteristics of respondents (e.g., age, education level, cooperative membership, fishing gear); (2) the composition of elasmobranchs observed or captured, using a species identification guide; (3) the periods during which catches occurred; and (4) the geographic zones of elasmobranch observations and fishing activity, together with perceptions of habitat characteristics (e.g., temperature, salinity). To mitigate the uncertainty in fishers' reports regarding intermediate or atypical seasons, a dichotomous approach was adopted. Minor dry and rainy seasons were not treated separately because fishers' reports for these transitional periods lacked consistency, often overlapping in naming and timing. For analytical clarity, these intermediate periods were merged into the two dominant climatic regimes (major dry and major rainy seasons).

Interviews were conducted in French and local languages, with KoboCollect used only as a researcher-entered data-collection tool. Fishers did not interact with the application themselves; the enumerator entered responses during the interview, allowing full participation from respondents with limited literacy or no experience with digital devices. No administrative personnel intervened-the survey was entirely interviewer-administered.

Mapping and georeferencing

To complement qualitative interview data, a participatory mapping exercise was used to document the spatial distribution of elasmobranch

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

sightings. Fishers located observations and captures on a large-scale paper map of the Kango area that included major geographical landmarks, which facilitated spatial orientation and accurate reporting. Their long-standing familiarity with the Komo–Kango system, acquired through years of daily fishing activity, allowed reliable identification of fishing sites. Fishing practices were also recorded; activity was dominated by active gear, particularly gillnets, while passive gears were used less frequently.

To ensure spatial consistency, the reference map was divided into 3 × 3 km grid cells. Before beginning the mapping exercise, the map layout and grid were explained using familiar landmarks so that respondents could orient themselves without requiring formal cartographic skills. This standardization minimized spatial bias and strengthened the robustness of the spatial dataset (Skidmore et al., 2011).

As commonly described in participatory mapping research, fishers tended to report spatial information in the form of zones or fishing grounds rather than exact point locations, orienting themselves through landmarks, river channels, and environmental cues (Aswani & Lauer, 2006). Accordingly, the information collected included: (i) the specific zones or approximate areas where sightings or captures occurred, (ii) species identity when recognizable, and (iii) environmental conditions at the time of observation (salinity and water temperature). The annotated maps were then digitized and georeferenced in a Geographic Information System (GIS), producing a spatially explicit dataset suitable for integration with environmental layers.

Spatial data on fishing zones were derived directly from this participatory mapping process. Overlapping or adjacent areas reported by different respondents were grouped to form standardized fishing grounds, resulting in 25 distinct fishing zones across the Komo–Kango system. Because fishers often operate across several grounds, a single respondent could contribute information to multiple zones; zone-level datasets therefore represent the cumulative species reports from all fishers who referenced a given zone. The number of mentions per zone was used as a measure of sampling intensity, and zones supported by few reports were retained but interpreted cautiously in subsequent spatial similarity analyses. Zone identification was entirely derived from participatory mapping. Each zone name reflects the combination of rivers, channels, villages, or landmarks cited together by fishers when describing a single fishing ground. Overlapping or adjacent areas reported by different respondents were merged, resulting in 25 consolidated fishing zones representing the spatial units recognized locally by artisanal fishers.

Thermal and salinity patterns were not derived from in-situ measurements or remote-sensing data. Instead, they were based exclusively on fishers' qualitative perceptions collected during interviews. Respondents

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were asked to classify the water conditions in each fishing zone they frequented as “hot”, “cold”, “salty”, or “unsalted”, according to their experiential knowledge of the Komo–Kango system. These categorical responses were then transferred to the participatory maps and digitized in QGIS. For each of the 25 fishing zones, the dominant category reported by the majority of respondents was assigned to the corresponding polygon.

Data Analysis

All datasets were compiled and analyzed using R (v4.2.2) to examine elasmobranch diversity, species composition, and spatial–seasonal distribution patterns. Prior to inferential testing, the homogeneity of variances was assessed using Levene’s test. Since this assumption was not consistently met and the sample size remained relatively small (n = 30), non-parametric procedures were used throughout. Kruskal–Wallis tests, followed by pairwise Wilcoxon rank-sum comparisons with Bonferroni correction, were applied to assess seasonal differences in richness and occurrence frequencies.

Species Richness and Sampling Completeness

Species richness was calculated for each respondent and for each fishing zone using functions in the vegan package (Oksanen *et al.*, 2022). A sample-based rarefaction curve (200 random permutations) was generated to evaluate sampling completeness and to verify whether cumulative richness approached an asymptote. The resulting curve and associated 95% confidence intervals were used to assess whether the 30 interviews captured most of the LEK-reported diversity.

Species Composition and Relative Frequencies

The species composition of elasmobranchs was characterized using the relative frequency of each species defined as the percentage of respondents mentioning its occurrence within the Komo Estuary. Ninety-five percent confidence intervals were calculated to evaluate the internal consistency of fishers’ reports and to describe the structure of the elasmobranch community as inferred through Local Ecological Knowledge (LEK).

Perceptions of Environmental Conditions

Fishers’ perceptions of seasonal variation in temperature and salinity were analyzed through cross-tabulations and visualized using grouped barplots with standard-error bars (ggplot2; Wickham, 2016). These descriptive patterns were evaluated using the same non-parametric tests described above to determine whether perceived differences between seasons were statistically meaningful. Environmental maps of temperature and salinity (Figures 5a–d) were generated from LEK-derived categorical data using simple thematic

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

mapping in QGIS, without any numerical interpolation or instrumental measurements.

Spatial Data Processing and Fishing Zones

Spatial information obtained through participatory mapping was digitized and processed in QGIS and R (packages sf, dplyr, ggplot2). All mapped points were georeferenced and harmonized by grouping overlapping or adjacent areas into unique fishing grounds. This procedure yielded 25 distinct fishing zones, each representing a spatial unit used in subsequent analyses.

For each zone, all elasmobranch species reported by any respondent were aggregated. The number of independent mentions per species was used as an indicator of sampling intensity. Zones with limited reporting effort were retained but interpreted cautiously in spatial analyses.

Kernel Density Estimation (KDE) and Spatial Hotspots

Kernel Density Estimation (KDE) was applied to the georeferenced reports of *Fontitrygon margaritella*, *F. ukpam*, and *Carcharhinus leucas* to visualize areas of high concentration (Fleming & Calabrese, 2016). KDE surfaces were generated in R and QGIS to identify spatial hotspots and to highlight potential areas of species overlap.

Local spatial clustering was quantified using the Getis–Ord Gi* statistic (Getis & Ord, 1992). For each fishing zone and species, the Gi* statistic was standardized as a Z-score:

$$Z(G_i^*) = \frac{G_i^* - E(G_i^*)}{\sqrt{Var(G_i^*)}}$$

Under the null hypothesis of spatial randomness, $Z(G_i^*)$approximates a standard normal distribution. Significance thresholds were interpreted as follows:

- $|Z| \leq 1.96$: not significant (p > 0.05)
- $Z > +1.96$: significant hotspot (p < 0.05)
- $Z < -1.96$: significant coldspot (p < 0.05) Stricter thresholds (|Z| > 2.58 and |Z| > 3.29) corresponded to p < 0.01 and p < 0.001.

Similarity Among Fishing Zones

To assess similarity in species assemblages across the 25 fishing zones, a zone-by-species matrix was constructed from the participatory mapping outputs. Two forms of this matrix were generated: a presence–absence version, from which Jaccard distances were computed, and a frequency version, based on the number of mentions per species, used to calculate Bray–

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Curtis dissimilarities. Hierarchical clustering was then performed using the UPGMA algorithm ("average" linkage) for both distance metrics, producing dendrograms that allowed the identification of fishing zones sharing similar species compositions. All similarity analyses were conducted using the *vegdist* and *hclust* functions of the vegan package, while dendrogram visualization relied on ggdendro and ggplot2. Overall, all descriptive, inferential, and spatial analyses were integrated into a fully reproducible R workflow combining vegan, dplyr, sf, ggplot2, and patchwork, complemented by spatial processing and map rendering in QGIS.

Ethical and operational considerations

To guarantee methodological consistency, all interviews were conducted by the same investigator. Respondents were free to express their views without external influence or prompting. Where questions were left unanswered, the response was recorded as "Undetermined," while inapplicable questions were marked as "NA" (Not Applicable). Any hesitation or uncertainty expressed by participants was systematically noted.

Prior to data collection, informed consent was obtained from each participant. The objectives of the study, the voluntary nature of participation, and the anonymity of responses were clearly explained. This ethical framework ensured compliance with good practices for research involving local communities and strengthened the validity and reliability of the information collected.

Results

Overview of fisher survey data

A total of 30 artisanal fishers from the Komo Estuary (Gabon) were interviewed. All respondents were men, with 93% being Gabonese and 7% Equatorial Guinean. More than half (53%) were members of the Kango Fishers' Cooperative (CPMK).

Regarding education, 70% had completed secondary school, 20% had only primary education, and 10% reported post-secondary (higher) education. Fishing experience ranged from less than 10 years to over 25 years. Most respondents (57%) reported 10–25 years of fishing practice, while 43% had less than 10 years; none exceeded 25 years. This reflects the long-term familiarity resulting from the many years during which fishers have practiced daily or near-daily fishing within the Komo Estuary.

Fishers reported using five main fishing gears (Table 1): mixed surface–bottom gillnets (40%), surface drifting gillnets (23.3%), hook-and-gillnet combinations (20%), hook-only gear such as longlines or handlines (13.3%), and bottom-drifting gillnets (3.3%). These fishing gears, particularly the various gillnet types and the hook-and-gillnet combinations, operate across

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both the surface and bottom layers of the estuary, where elasmobranchs frequently move or rest. Their mode of operation, which involves encircling or intercepting mobile species in shallow and turbid waters, makes them especially prone to generating elasmobranch bycatch in estuarine and riverine habitats.

Table 1: Fishing gear types used by artisanal fishers interviewed in the Komo Estuary.

Gear type	N	%
Mixed surface-drifting/bottom gillnets	12	40.0
Surface drifting gill-nets	7	23.3
Hook-and-gill-net combinations	6	20.0
Hook only (longline/handline)	4	13.3
Bottom-gill-nets	1	3.3

Source: Field data from Kango survey, 2025

Elasmobranch species richness reported by fishers

Across the 30 interviewed fishers, four elasmobranch species were reported: *Fontitrygon ukpam*, *Fontitrygon margaritella*, *Carcharhinus leucas*, and, more rarely, *Sphyrna lewini*. The majority of respondents mentioned *F. ukpam* (83%) and *C. leucas* (77%), while *S. lewini* was cited by only one fisher (3%). Reports further highlighted a strong co-occurrence between *F. ukpam* and *F. margaritella*, with 18 respondents (60%) indicating that both species occurred in the same fishing grounds. Species richness per respondent was comparable across gear types (median ≈ 3 species), although bottom-set gillnets and hook-and-line gear showed slightly higher central tendencies than surface-drifting gillnets (Table 2). Observed values ranged from 1 to 4 species (SD ≈ 0.8–1.0), indicating moderate inter-respondent variability.

Table 2: Summarizes the species richness reported by fishers. Richness per respondent ranged from one to four species, with a median of approximately three species.

Metric / Category	Value
Total number of species reported	4
Respondents reporting F. ukpam	83% (25/30)
Respondents reporting C. leucas	77% (23/30)
Respondents reporting F. margaritella	60% (18/30)
Respondents reporting S. lewini	3% (1/30)
Co-occurrence F. ukpam + F. margaritella	18 respondents (60%)
Range of species richness per respondent	1 – 4 species
Median species richness	≈ 3 species
Mean species richness (± SD)	≈ 2.4 ± 0.8–1.0
Richness by gear type	
Bottom-set gillnets	2 – 4 species
Hook-and-line	2 – 4 species
Surface-drifting gillnets	1 – 2 species

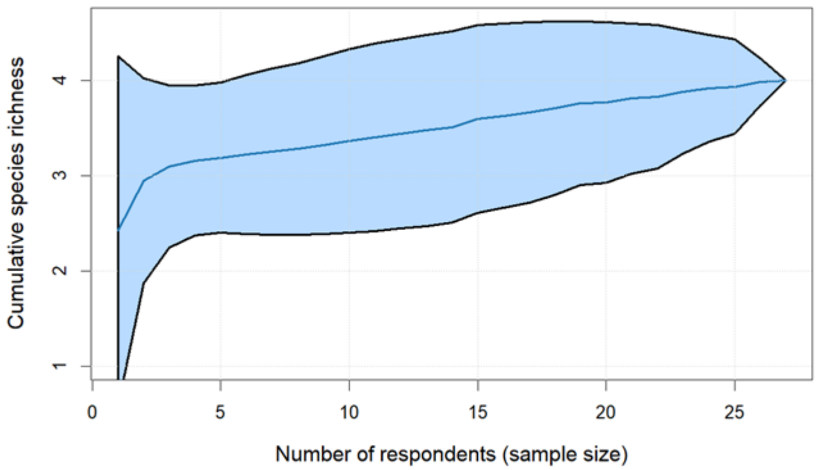
Source: Field data from Kango survey, 2025

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

The rarefaction curve (Figure 2) summarizes the cumulative species richness of elasmobranchs reported by fishers in the Komo Estuary. The curve increases steeply during the first interviews, then gradually levels off after approximately 10–15 respondents, reaching a plateau around four species. The shaded blue area represents the 95 % confidence interval based on 200 random permutations, indicating variability among random resampling iterations.

This clear asymptotic pattern suggests that the sample of 30 respondents was sufficient to capture nearly the entire range of elasmobranch diversity known through Local Ecological Knowledge (LEK) in the study area. Beyond 15 respondents, additional interviews contributed little new information, confirming the saturation of species knowledge and the representativeness of the sample. The narrow confidence interval toward the end of the curve indicates high convergence and consistency of responses among fishers, reinforcing the robustness of the LEK dataset as a proxy for observed species richness in the Komo River system.

Figure 2: Rarefaction curve showing the cumulative specific richness of elasmobranchs reported by respondents in the Komo Estuary (n = 30). The curve approaches an asymptote after approximately 15 respondents, indicating sampling completeness



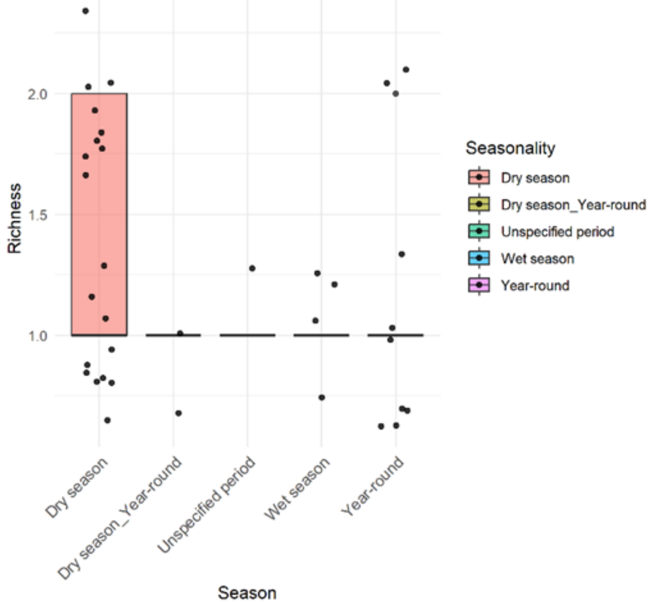
Source: The field data from Kango survey, 2025

Seasonal diversity patterns

Species richness per fishing zone ranged from one to three, with a few sites reaching up to four species across the study area. Boxplot analyses (Figure 3) showed a slight increase in richness during the dry season, although substantial overlap among seasons indicates that seasonal differences were limited. Non-parametric tests (Kruskal–Wallis followed by pairwise Wilcoxon comparisons) showed no statistically significant differences between wet- and dry-season assemblages ($p > 0.05$), although dry-season reports exhibited slightly greater variability across fishing zones.

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

Figure 3: Boxplot comparing species richness reported per respondent between wet and dry seasons. Median richness was slightly higher during the dry season. Boxes show interquartile ranges, and whiskers represent minimum–maximum values



Source: Field data from Kango survey, 2025

Spatial similarity among fishing zones

Hierarchical clustering revealed consistent patterns of similarity across fishing zones (Figure 4, table 2). Using the Jaccard index (presence/absence), most zones clustered closely, indicating relatively homogeneous assemblages across the Komo Estuary. For example, zones Lebhe_Maga_Aloume (ID 21), Lebhe_Maga_Assango (ID 22), and Maga_Lebhe_Aloume_Remboue (ID 23) grouped together. These sites are located in the central Komo corridor, east of Kango and along the confluence with the Maga River, an area where fishing effort is particularly concentrated.

In contrast, Bray–Curtis clustering (abundance-weighted) revealed stronger differentiation among zones, suggesting that some areas contribute disproportionately to overall species composition and diversity. For instance, Suceuce_petite.ile_Aloume (ID 25) and Enieng.nieng_petite.ile (ID 14), both situated downstream and west of Kango, appeared more distinct from the central cluster, reflecting localized differences in abundance. Similarly, the Undetermined zone (ID 16), positioned in peripheral fishing grounds not clearly associated with Kango or the Maga, separated early in the dendrogram, consistent with its limited and less representative catch information.

These patterns highlight that while the estuary as a whole supports broadly similar assemblages, abundance differences among fishing zones generate distinct ecological profiles depending on their location relative to

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Kango town and the Maga River system. For clarity, fishing zones were assigned numerical identifiers in the dendrograms, with their full names provided in Table 2 (legend of Zone IDs).

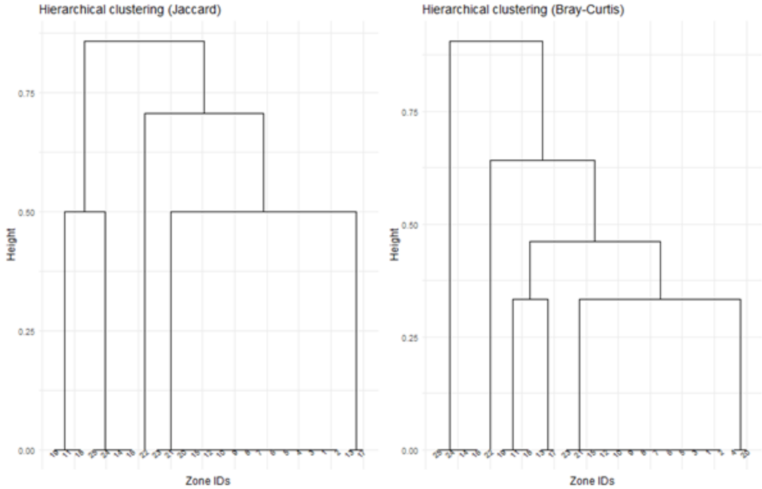
Table 2: Correspondence between fishing zone identifiers and full zone names reported by fishers in the Komo Estuary (Gabon)

id	zone
1	Aloume_Etone
2	Aloume_Lebhe_Maga_Donguila
3	Aloume_Lebhe_Maga_Remboue
4	Aloume_Lebhe_maga
5	Aloume_TBNI
6	Assango_Maga_Bas.komo_Haut.komo
7	Bas.komo_Aloume_Mefou_Lebhe_Maga_Remboue
8	Bas.komo_Haut.Komo_Bokoue_Lebhe
9	Bas.komo_Haut.komo
10	Bokoue_Agoula_Abanga_Bas.komo_Haut.komo
11	Bokoue_Haut.komo_Mefou_Elone_Aloume
12	Debarcadere_Akonozo_Mefou_Mvoum_Aloume_Lebhe_maga
13	Enieng.nieng_Bokoue_Mefou_Aloume
14	Enieng.nieng_petite.ile
15	Haut.komo_Bokoue_la.sef
16	Undetermined
17	Lebhe.Aloume_Maga_Elone_Bekheme_Ewote_Toxol
18	Lebhe_Aloume_Nonlankomo
19	Lebhe_Ekoumebele
20	Lebhe_Maga
21	Lebhe_Maga_Aloume
22	Lebhe_Maga_Assango
23	Maga_Lebhe_Aloume_Remboue
24	Maga_Tchintchoua
25	Suceuce_petite.ile_Aloume

Source: Field data from Kango survey, 2025

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

Figure 4: Cluster analysis of elasmobranch assemblages based on fisher-reported occurrences using Jaccard (a) and Bray–Curtis (b) similarity indices. Two main clusters indicate spatial differentiation between estuarine and upstream freshwater zones.

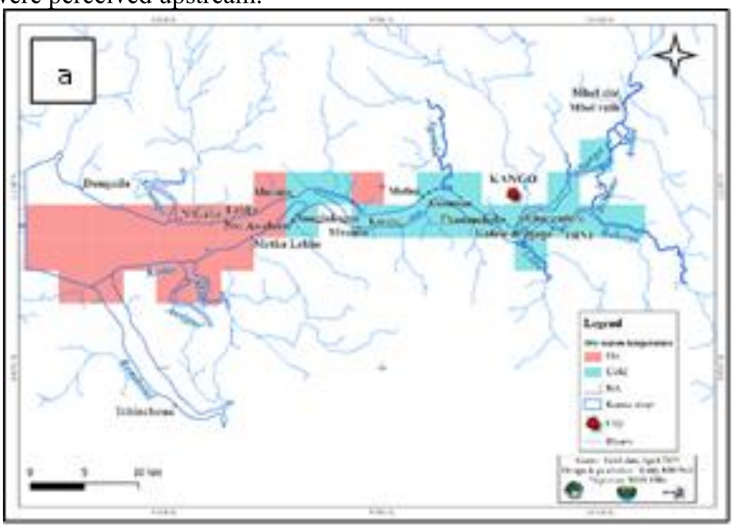


Source: Field data from Kango survey, 2025

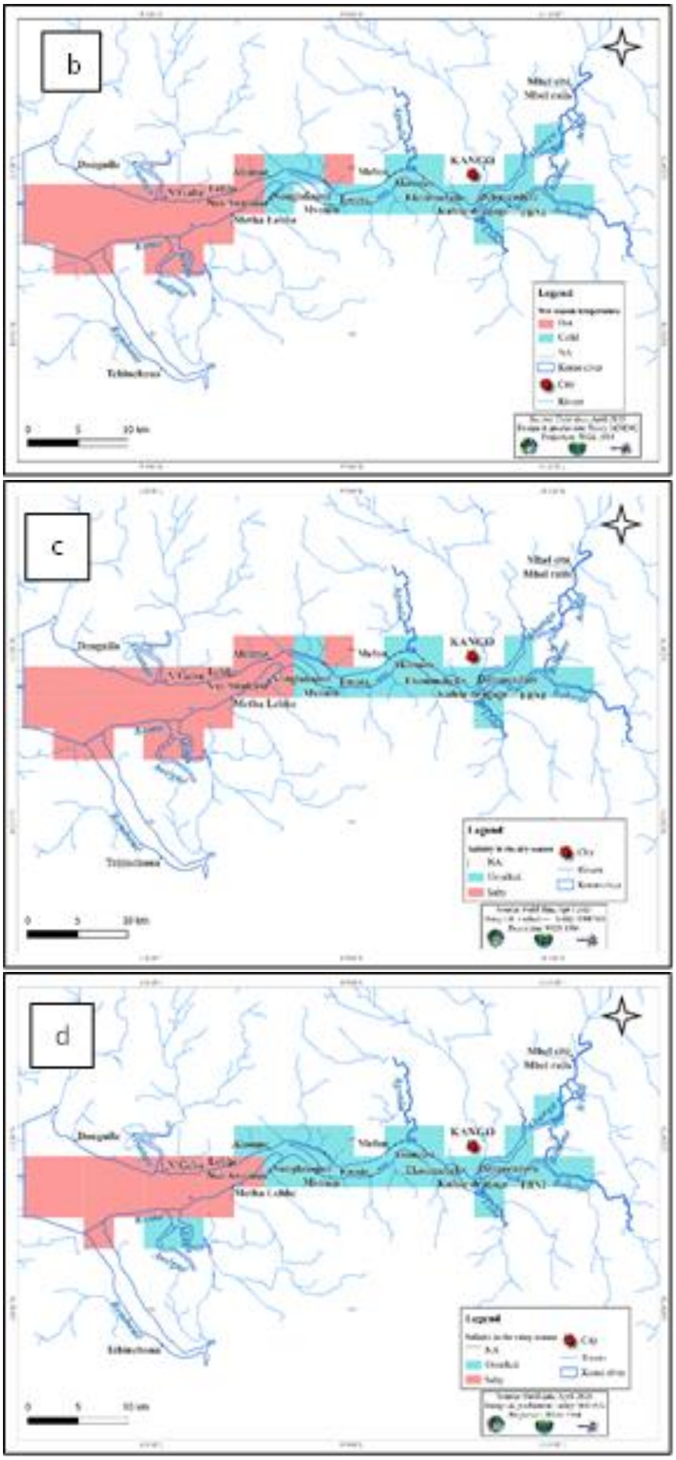
Environmental gradients and species distributions

Fisher-reported data revealed clear thermal and salinity gradients structuring the Komo River system (Figures 5a–d).

Figure 5. Local Ecological Knowledge (LEK)-based classifications of environmental conditions in the Komo Estuary, showing (a) perceived temperature in the dry season, (b) perceived temperature in the wet season, (c) perceived salinity in the dry season, and (d) perceived salinity in the wet season. These maps represent fishers' qualitative assessments ("hot/cold", "salty/unsalted") rather than instrumentally measured parameters. Warm and saline waters were perceived as dominant in the lower estuary, whereas cooler and less saline conditions were perceived upstream.



ISSN: 1857-7881 (Print) e - ISSN 1857-7431



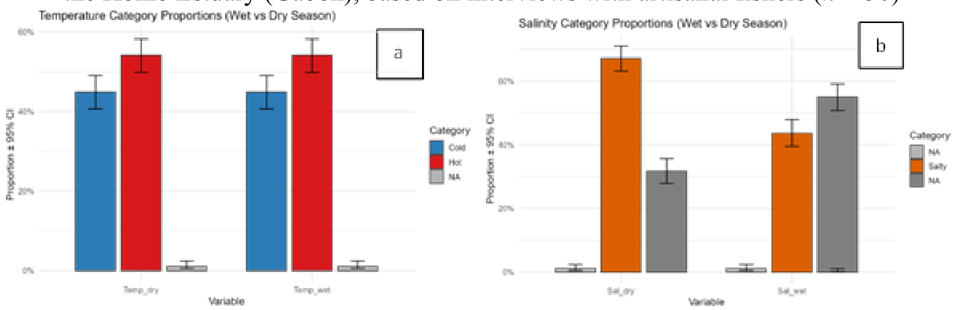
Source: Field data from Kango survey, 2025

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

Perceptions of temperature were consistent between seasons, with a dominance of "hot" waters across both the dry and wet seasons. During the dry season (Figure 6a), 56% ± 5% (95% CI) of respondents described waters as *hot*, compared with 44% ± 5% as *cold*. Similar proportions were observed in the wet season (55% ± 5% hot vs. 45% ± 5% cold). The wide overlap of confidence intervals indicates no significant seasonal difference, suggesting thermally stable conditions throughout the year. This stability supports the existence of a spatial rather than seasonal thermal gradient, with warmer waters consistently reported in the lower estuary (N'Gaba, Metha Lebhe) and cooler conditions upstream along the Maga and its tributaries.

Perceived salinity showed clearer seasonal variation. During the dry season (Figure 7), 68% ± 6% (95% CI) of respondents described waters as *salty*, compared with 32% ± 5% as *no salty*. In contrast, during the wet season, *no salty* waters dominated (55% ± 5%) over *salty* conditions (45% ± 5%). The partial overlap of confidence intervals indicates genuine seasonal differences, confirming that rainfall and river discharge strongly influence estuarine salinity. These patterns are consistent with typical tropical hydro-climatic dynamics: reduced river flow and evaporation during the dry season promote saline intrusion, whereas increased runoff in the wet season pushes the saline front downstream.

Figure 6: Seasonal variation in (a) perceived water temperature and (b) perceived salinity in the Komo Estuary (Gabon), based on interviews with artisanal fishers (n = 30)



Source: Field data from Kango survey, 2025

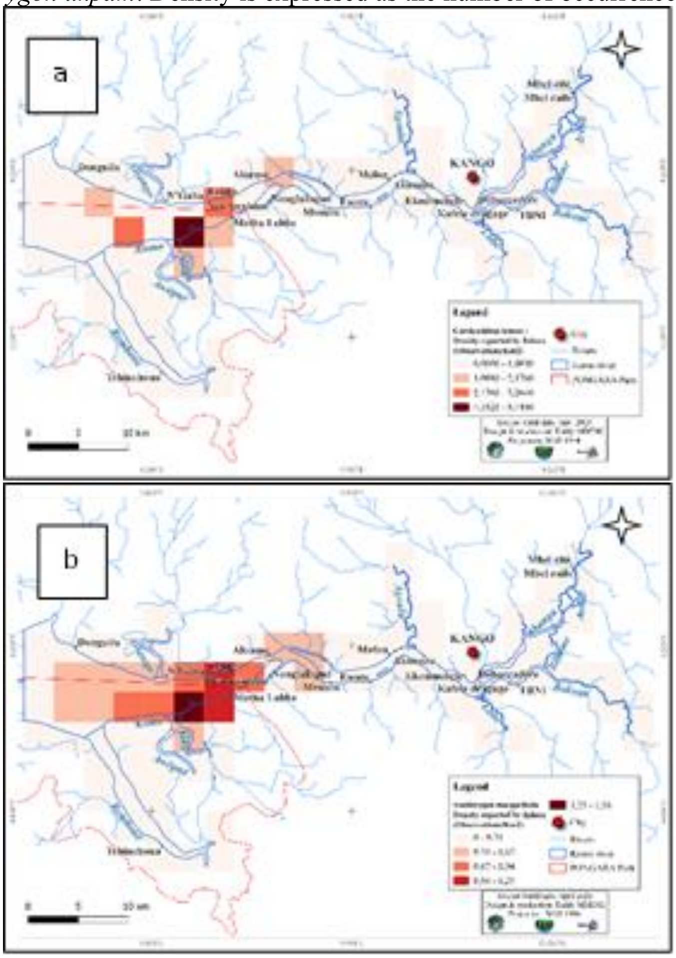
Environmental gradients structured the reported distribution of elasmobranch species in the Komo Estuary (Figure 7Perceptions of environmental conditions reported by fishers revealed consistent qualitative gradients in both temperature and salinity across the Komo Estuary (Figure 5). According to respondents, water temperature was perceived as predominantly "warm" in the lower estuary, particularly around N'Gaba and Métha Lebhe near Kango town, whereas "cold" conditions were consistently reported upstream at Aloume, Mefou, and Ekoumbele along the Maga River and its tributaries. Similar patterns emerged for salinity: fishers described the lower Komo as "salty," transitioning progressively to "unsalted" freshwater

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

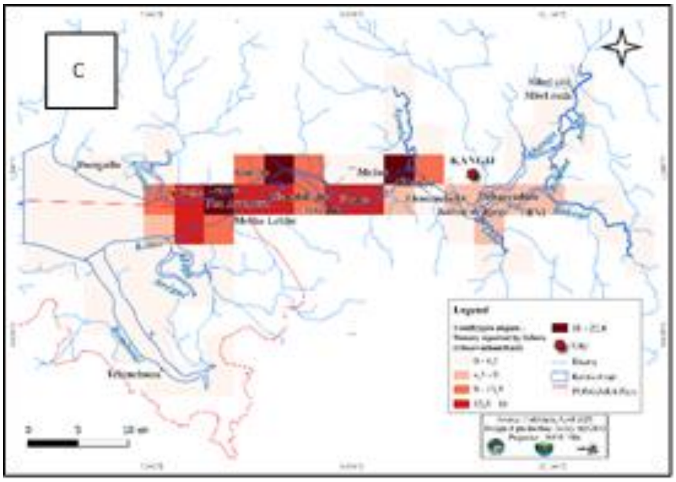
conditions upstream. These patterns reflect experiential knowledge rather than instrumentally measured values, and seasonal differences were perceived as minor, primarily associated with rainfall and river discharge.

Species-specific kernel density maps indicated distinct spatial distributions. *Carcharhinus leucas* occurred mainly in the lower and middle Komo, overlapping with warm and saline waters. *Fontitrygon margaritella* formed localized hotspots in estuarine fishing grounds near N'Gaba and downstream of Kango. *Fontitrygon ukpam* was the most widespread species, extending from the estuary into upstream freshwater reaches of the Maga River.

Figure 7: Spatial distribution and kernel density maps of the main elasmobranch species reported by fishers in the Komo Estuary:(a) *Carcharhinus leucas*, (b) *Fontitrygon margaritella*,
(c) *Fontitrygon ukpam*. Density is expressed as the number of occurrences per km².



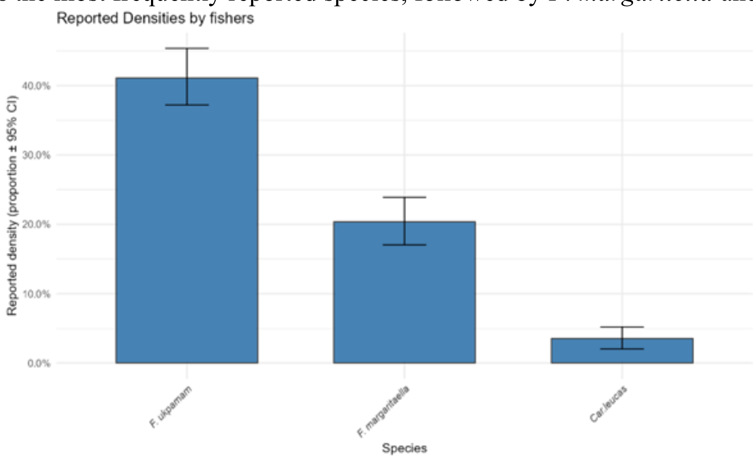
 ISSN: 1857-7881 (Print) e - ISSN 1857-7431



Source: Field data from Kango survey, 2025

The relative frequency of elasmobranch species reported by fishers (Figure 8) showed marked differences among taxa. *Fontitrygon ukpam* accounted for approximately 40 ± 5 % (95 % CI) of all reports, followed by *F. margaritella* (20 ± 7 %), while *Carcharhinus leucas* represented less than 10 ± 3 %.

Figure 8: Relative frequency of elasmobranch species reported by fishers (n = 30) in the Komo Estuary. Bars represent mean occurrence percentages ± 95% confidence intervals. *F. ukpam* was the most frequently reported species, followed by *F. margaritella* and *C. leucas*.



Source: Field data from Kango survey, 2025

Spatial autocorrelation

Global Moran's I statistics did not reveal significant spatial autocorrelation for any of the four focal species (*Fontitrygon ukpam*, *F. margaritella*, *Carcharhinus leucas*, *Sphyrna lewini*), with all *p*-values exceeding 0.70. This indicates that, at the scale of the Komo River system,

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

fisher-reported occurrences were not more clustered than expected under a random distribution.

Similarly, local indicators of spatial association (LISA) and Getis–Ord Gi* analyses did not detect any statistically significant hotspots ($Gi^* > 1.96$) or coldspots ($Gi^* < -1.96$) for any species (Table 3).

Mean Gi^* values ranged from −0.12 (*C. leucas*) to +0.34 (*F. ukpam*), with minimum and maximum values remaining below the 95% confidence threshold.

These results suggest spatial randomness at the global and local scales, although slight positive deviations in *F. ukpam* and *F. margaritella* (maximum *Gi* ≈ 1.3) may reflect weak, non-significant concentration tendencies in the lower estuary.

Discussions

The discussion addresses three complementary dimensions: the spatial and seasonal distribution of species, the environmental factors underlying these patterns, and the value of LEK as a form of spatial and territorial knowledge.

Spatial and seasonal distribution

The reported patterns of elasmobranch distribution in the Komo Estuary are consistent with ecological expectations for tropical river–estuary systems. Seasonal differences in elasmobranch richness were modest, with only slightly higher values during the dry season. This limited seasonality likely reflects the inherent stability of tropical estuarine systems such as the Komo–Kango estuary, where continuous freshwater discharge, strong tidal mixing, and the absence of marked thermal seasonality buffer short-term environmental fluctuations. As highlighted by Cloern *et al.* (2017), tropical estuaries are shaped more by persistent hydrological gradients than by seasonal cycles, resulting in relatively stable physical conditions across seasons.

Within this framework, the pronounced spatial structuring observed along the longitudinal estuary–freshwater gradient suggests that salinity regimes, turbidity, and prey availability exert a stronger influence on elasmobranch occurrence than climatic seasonality. This interpretation aligns with broader estuarine ecology findings: classical studies of estuarine and plume systems (Laprise & Dodson, 1994) show that biological assemblages follow stable upstream–downstream successions driven primarily by salinity and hydrodynamic mixing, whereas seasonal variability plays a comparatively minor role. Similarly, Blaber (2013) emphasizes that tropical estuarine fish communities are organized predominantly along salinity and river-discharge gradients, with limited seasonal restructuring.

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

From a management perspective, these results indicate that elasmobranchs in the Komo–Kango system respond more strongly to persistent habitat gradients than to seasonal change. Conservation and monitoring strategies should therefore prioritize stable ecological units, such as lower-estuary brackish hotspots versus upper-river freshwater corridors, rather than seasonal windows.

The asymptotic rarefaction curve confirmed that reported diversity reached saturation after approximately 15 respondents, indicating that the sample of 30 fishers captured nearly the complete range of elasmobranchs known through LEK in the Komo system. This strengthens the reliability of fisher-derived data as a proxy for observed diversity.

These patterns particularly the dominance of *Fontitrygon* species across the estuary, freshwater continuum, the weak influence of seasonality, and the clear salinity-driven ecological zonation, are consistent with broader estuarine ecology. Plumlee et al., (2018) demonstrated that elasmobranch assemblages in subtropical estuaries segregate along stable longitudinal salinity gradients, with salinity emerging as the strongest predictor of species distributions. Similarly, Every et al., (2019) showed that estuarine food-web structure is governed primarily by persistent hydrological and spatial gradients rather than short-term seasonal variability.

The species-specific patterns observed in this study are also consistent with known ecological traits. *C. leucas*, an euryhaline shark, is well recognized for its capacity to exploit estuarine corridors and move far upriver, typically associated with warm and saline to brackish habitats (Simpfendorfer *et al.*, 2005; Gausmann, 2021). By contrast, *S. lewini* was only sporadically reported, reflecting its rarity in riverine systems and its stronger association with coastal and oceanic environments (Dulvy *et al.*, 2017; Leeney & Downing, 2015).

The slight increase in elasmobranch richness during the dry season likely reflects seasonal hydrological dynamics in the Komo–Kango system. Reduced rainfall and lower river discharge expand brackish zones that favor estuarine-tolerant species (Whitfield, 1999; Barletta *et al.*, 2005), while similar responses to salinity and discharge gradients have been reported in other tropical estuaries (Constance *et al.*, 2024). In addition, the reduced water volume characteristic of the dry season concentrates fish and elasmobranchs into narrower, shallower channels, increasing encounter and capture probabilities, a mechanism consistent with studies showing that depth and spatial confinement strongly influence estuarine elasmobranch distributions (Swift & Portnoy, 2020).

Spatial partitioning between downstream estuarine sectors (N'Gaba, Metha Lebhe) and upstream freshwater reaches along the Maga River is particularly striking. *F. ukpam*, reported as the most widespread species,

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

appears capable of exploiting both environments, confirming its ecological plasticity (Jabado *et al.*, 2021). This distributional breadth contrasts with *F. margaritella*, which formed localized hotspots, and with *C. leucas*, whose presence was concentrated in the lower estuary.

The clustering of most fishing zones based on species composition (Jaccard and Bray–Curtis indices) revealed relatively homogeneous assemblages across the estuary, with localized differences reflecting ecological or fishing-effort heterogeneity. These findings underscore the ecological complementarity of elasmobranchs within the Komo socio-ecosystem and highlight the value of fisher knowledge for capturing fine-scale spatio-seasonal heterogeneity (Silvano & Valbo-Jørgensen, 2008; Leeney & Downing, 2015).

Although density patterns derived from LEK data were generally consistent across respondents, confidence intervals around reported frequencies indicated moderate variability, suggesting that fisher observations captured robust yet locally heterogeneous signals.

Environmental factors associated with distribution

The distributional patterns observed in the Komo River system can largely be explained by abiotic gradients, with temperature and salinity emerging as major drivers of species occurrence. *C. leucas* and *F. margaritella* were closely associated with hot, saline estuarine waters, whereas *F. ukpam* dominated upstream freshwater reaches, consistent with its known ecological plasticity (Leeney & Downing, 2015, Jabado *et al.*, 2021). These LEK-derived patterns are consistent with broader ecological knowledge showing that elasmobranch use of estuarine and freshwater systems is primarily structured by longitudinal environmental gradients rather than seasonal change (Grant *et al.*, 2019).

The LEK-derived environmental information gathered in this study indicates that fishers perceive broadly similar thermal conditions across seasons, while reporting clearer contrasts along the estuary–freshwater gradient. Because temperature and salinity classifications were qualitative (“hot”, “cold”, “salty”, “unsalted”) and not based on instrumental measurements, no quantitative assessment of seasonal thermal variation was possible. Nevertheless, the high consistency of responses across all 25 fishing zones suggests that temperature is regarded as relatively stable throughout the year, whereas salinity exhibits a more pronounced longitudinal gradient. Such perceptions are consistent with the physical dynamics of tropical estuaries, where continuous freshwater discharge and strong tidal mixing dampen seasonal thermal fluctuations, while salinity remains the dominant structuring factor influencing fish and elasmobranch assemblages (Whitfield, 1999; Barletta *et al.*, 2005; Chikina *et al.*, 2023). Although no statistical tests were

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

performed on thermal variables, the LEK-based patterns documented here align closely with established ecological expectations for comparable estuarine systems (Cloern *et al.*, 2017; Every *et al.*, 2019).

However, such abiotic explanations may not capture the full complexity of elasmobranch distributions. Several studies have emphasized that food availability and prey distributions can be equally influential, particularly for opportunistic predators such as *C. leucas* (Heupel *et al.*, 2014). In addition, factors such as turbidity and sediment load, which shape habitat suitability in tropical estuaries, have been shown to affect ray occurrence (Barletta *et al.*, 2005). Local anthropogenic pressures, including gillnet intensity and habitat degradation, may also confound environmental patterns, as suggested by Cross (2015), Cardiec *et al.* (2020).

In this light, the relatively restricted distribution of *F. margaritella* in the Komo system may not only reflect physiological limits in osmoregulation but also the species' sensitivity to fishing pressure or competition with *F. ukpam*. Similarly, the concentration of *C. leucas* in lower estuarine reaches might be reinforced by prey density or avoidance of highly turbid upstream zones rather than by abiotic conditions alone.

So, the Komo Estuary results highlight the central role of temperature and salinity in structuring species distributions but also suggest that ecological interactions and human pressures may modulate these patterns. This nuance aligns with recent calls to adopt an integrative perspective in estuarine ecology, recognizing the interplay between abiotic, biotic, and social drivers of species distributions (Kennish, 2021).

The types of fishing gear used by respondents also help contextualize the patterns documented through LEK. The predominance of mixed surface- and bottom gillnets, capable of intercepting both demersal and pelagic species, reflects a polyvalent strategy adapted to the mosaic of habitats in the Komo Estuary. From a geographical perspective, the diversity of gear types illustrates the socio-territorial structuring of fishing practices in Kango. These combinations of gears demonstrate a flexible and adaptive appropriation of aquatic environments in a context of strong hydrological and ecological variability. Considering these technical and cultural dimensions strengthens the interpretative power of LEK by emphasizing that the reported species distributions also mirror the territorialization of fishing practices and the spatialization of situated empirical knowledge.

LEK as spatial and territorial knowledge

Although global spatial autocorrelation (Moran's I) and local clustering analyses (LISA and Getis–Ord Gi*) did not reveal statistically significant hotspots or coldspots, slight positive deviations observed for *F. ukpam* and *F. margaritella* (maximum Gi* ≈ 1.3) suggest weak, non-

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

significant tendencies toward spatial concentration in the lower estuary. These patterns, although below conventional significance thresholds, illustrate how LEK can reveal emerging ecological structures and fine-scale heterogeneity that may not yet be detectable through conventional sampling. This highlights the interpretative value of LEK as a complementary spatial dataset, capable of identifying zones of ecological relevance even in the absence of strong statistical clustering.

Importantly, the lower Komo sector, where these weak concentration tendencies were observed, lies along the eastern ecological interface of the Pongara National Park (PNP). This spatial overlap suggests that Pongara's estuarine and mangrove areas function as extensions of critical habitats for elasmobranchs, particularly *F. ukpam* and *C. leucas*. Although no statistically significant hotspots were detected, the recurrence of reports around Donguila, N'Gaba, and Métha Lebhe indicates that areas near the Komo mouth and around Kango emerge as priority sites for future ecological monitoring, acoustic surveys, or co-managed fishing initiatives, reinforcing Pongara's ecological role within the Komo basin.

These results collectively illustrate that LEK, when spatialized, provides fine-scale insights into ecological patterns while also reflecting the lived territorialities of fishing communities, linking ecological processes with social appropriation of space (Tuan, 1974; Silvano & Valbo-Jørgensen, 2008). Yet, the use of LEK as spatial evidence requires a degree of caution. Reports are shaped by fishers' mobility, gear selectivity, and cultural framings of space, which may lead to overrepresentation of accessible or frequently used zones (Seidu *et al.*, 2022). In the Komo case, the concentration of reports near Kango may reflect both genuine ecological aggregations and the centrality of this town as a fishing hub. Similarly, upstream sites along the Maga were less frequently reported, which could result from lower fishing effort rather than lower species presence. These potential biases underline the importance of combining LEK with systematic ecological surveys to validate and refine spatial inferences (Johannes *et al.*, 2008; Aswani & Hamilton, 2004).

Despite these limitations, the integration of LEK into spatial analyses offers a significant contribution to geography. Beyond mapping species occurrences, it captures the territorial dimension of aquatic environments, the way fishers perceive, name, and use specific places. This dual ecological and cultural reading of space situates LEK at the crossroads of biogeography and environmental geography, where distributions are understood not only as ecological responses to abiotic gradients but also as socio-territorial constructions linked to protected-area dynamics such as those of the Pongara National Park (Benett *et al.*, 2017).

These findings underscore the value of integrating spatialized Local Ecological Knowledge into estuarine research and conservation frameworks.

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

By linking ecological patterns, territorial practices, and protected-area interfaces such as Pongara, this study highlights the need for interdisciplinary and participatory approaches that bridge scientific monitoring and community-based knowledge in managing tropical aquatic ecosystems.

Conclusion

This study provides the first integrated analysis of elasmobranch diversity and distribution in the Komo Estuary, Gabon, based on the Local Ecological Knowledge of artisanal fishers. Four focal species were identified, with *Fontitrygon ukpam* emerging as the most widespread and abundant, while *Carcharhinus leucas* and *F. margaritella* showed more restricted estuarine associations, and *Sphyrna lewini* was only sporadically reported. Spatial and seasonal patterns reveal modest fluctuations in richness but strong structuring along environmental gradients, with temperature and salinity acting as key filters shaping species distributions.

By mobilizing fisher knowledge and translating it into spatial datasets, this research demonstrates that LEK can serve as a reliable source of ecological information, capturing local aggregations and territorialities that conventional surveys often overlook. Beyond documenting species occurrences, it highlights the socio-ecological dimension of aquatic environments, linking ecological partitioning with the lived geographies of fishing communities.

These findings contribute to both biogeography, by clarifying how ecological gradients structure species distributions, and environmental geography, by situating these dynamics within human territorial practices. They also carry applied relevance, underscoring priority areas in the lower Komo for monitoring and conservation, while emphasizing the value of participatory approaches in data-poor tropical systems. Future research should combine LEK with systematic ecological surveys to refine species distribution models, assess temporal changes, and guide co-management strategies for the sustainable use of estuarine ecosystems.

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