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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 understood. This study investigates the spatial and seasonal distribution of elasmobranchs in the Komo Estuary (Kango, Gabon) using Local Ecological Knowledge (LEK) collected through semi-structured interviews with 30 artisanal fishers, complemented by participatory mapping and GIS analyses. Four focal species were identified: *Fontitrygon ukpam*, *F. margaritella*, *Carcharhinus leucas*, and *Sphyrna lewini*. Among them, *F. ukpam* was the most widespread and abundant, extending from estuarine to upstream freshwater zones, whereas *C. leucas* and *F. margaritella* were concentrated in hot, saline lower-estuary waters. *S. lewini* was rarely reported. No statistically significant differences were detected between wet- and dry-season assemblages, although the data suggest a descriptive tendency toward slightly higher richness during the dry season. Temperature and salinity emerged as primary abiotic drivers, while prey availability, turbidity, and fishing pressure likely modulated these patterns. Spatial analyses (Kernel Density Estimation, Moran's I, LISA, Getis-Ord Gi*) revealed localized hotspots and species aggregations not detectable through conventional surveys, underscoring the potential of LEK as a robust spatial dataset. Beyond documenting ecological distributions, fisher knowledge reflects lived territorialities, linking species ecology with social appropriation of aquatic environments. This research demonstrates the dual ecological and geographical value of LEK, contributing to biogeography by clarifying species–environment relationships, and to environmental geography by showing how local practices shape spatial perceptions of biodiversity. It also identifies priority estuarine sectors for monitoring and co-management in data-poor tropical systems.

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, 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 the estuarine systems (such as the Komo Estuary, the largest in the country) 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 our 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. 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. 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 (Estuaire Province, Gabon), this research seeks to document the spatial and seasonal distribution of elasmobranchs by mobilizing the knowledge of local fishing communities. It analyzes the environmental factors associated with reported distributions and discusses how Local Ecological Knowledge (LEK), as a form of spatial and territorial knowledge, can enrich 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.

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, 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: a major rainy season from September to May, interrupted by a minor dry season (December–February), followed by a minor rainy season (March–May), and a major dry season (June–August) (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.

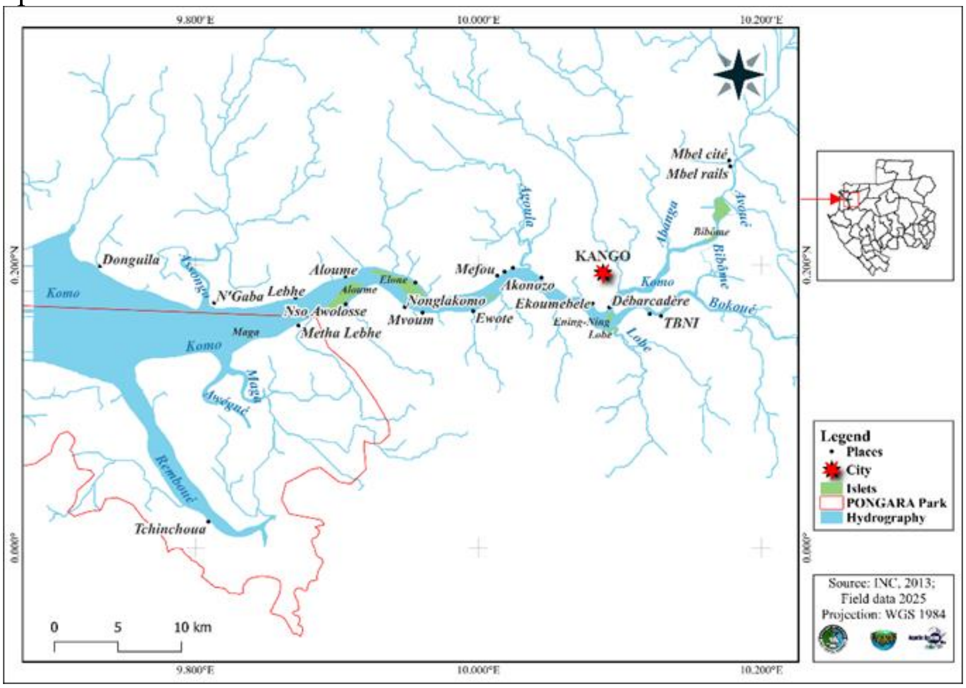


Figure 1: Map showing the location of the study area

Study participants

To gain insights into local perceptions of elasmobranch distribution, we conducted semi-structured interviews with 30 artisanal fishermen 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. The selection criteria required that fishers:

- have at least five years of fishing experience,
- were regularly active in the study zone,
- demonstrated strong familiarity with local aquatic environments through their daily fishing activities.

Given the absence of an official registry of artisanal fishers in Kango, we applied the principle of data saturation (Guest *et al.*, 2006) to determine the adequate sample size. Initial respondents were identified and recruited via the Cooperative of Fishers of Kango (CPMK), which served as a reliable entry point to 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, focusing on four main themes: socio-demographic and fishing characteristics of respondents (e.g., age, education, cooperative membership, fishing gear), composition of elasmobranchs observed or captured using a species identification guide, period of catches, geographic zones of elasmobranch observations and fishing activity, perceptions of habitat characteristics (e.g., temperature, salinity). In order to mitigate the uncertainty in fishermen's reports regarding intermediate or atypical seasons, we adopted a dichotomous approach. The data were grouped into two main categories: the great dry Season and the great rainy season (including all periods not strictly defined in these two regimes).

Interviews were conducted in French and local Gabonese languages to ensure clarity and cultural appropriateness. The survey was administered via KoboCollect on mobile devices, which facilitated standardized data entry and reduced transcription errors.

Mapping and georeferencing

To complement the qualitative data from interviews, we integrated a participatory mapping exercise designed to document the spatial distribution of elasmobranch sightings. Each fisher was invited to identify locations of observed or captured elasmobranchs on a large-scale paper map of the

Kango area. The map was subdivided into a grid of 3 × 3 km cells, enabling precise localization of reported fishing grounds and sighting areas.

During the exercise, respondents were asked to indicate: i) the exact sites of sightings or captures, ii) the approximate abundance and size of elasmobranchs observed, iii) the species identity (when recognizable), iv) and the environmental conditions at the time of observation (e.g., water salinity, temperature).

The annotated maps were subsequently digitized and georeferenced using Geographic Information Systems (GIS) tools. This process allowed the translation of local knowledge into spatial datasets that could be integrated with environmental layers. The resulting spatial database enabled the generation of species distribution maps and density surfaces through Kernel Density Estimation (KDE), highlighting areas of high concentration ("hotspots") and identifying spatial overlaps between species (Fleming & Calabrese, 2016).

To ensure comparability, all respondents used the same reference map and grid system. This standardization minimized spatial bias and enhanced the robustness of the data (Skidmore *et al.*, 2011). The combination of participatory mapping and GIS thus provided a powerful, community-informed approach for visualizing the spatial ecology of elasmobranchs in the Komo River system.

Data Analysis

All datasets were compiled and analyzed using R (v4.2.2) to investigate elasmobranch diversity, species composition, and spatial–seasonal distribution patterns. Prior to inferential testing, the homogeneity of variances was assessed with Levene's test. Since this assumption was not consistently met and the sample size remained relatively small ($n = 30$), non-parametric tests (*Kruskal–Wallis* and *Wilcoxon rank-sum*) were applied to compare species richness and occurrence frequencies between seasons.

To ensure comparability with local hydro-climatic conditions, the year was divided into two major seasons: a wet season (September–May) and a dry season (June–August), following the climatic framework established by Maloba Makanga (2010) and consistent with local fishers' perception of seasonal cycles in the Komo Basin.

Species richness was computed for each respondent and fishing zone using the *vegan* package (Oksanen *et al.*, 2022). A rarefaction curve based on 200 random permutations was produced to evaluate sampling completeness and to determine whether cumulative richness approached an asymptotic level. Cumulative species richness values and confidence intervals were plotted to visualize sample representativeness.

The species composition of elasmobranchs was described using the relative frequency of each species, calculated as the proportion of respondents reporting its occurrence within the Komo Estuary. These frequencies, expressed as percentages with 95% confidence intervals, were used to characterize overall community structure and to assess the consistency of fishers' Local Ecological Knowledge (LEK) across respondents.

Fishers' environmental perceptions of temperature and salinity were examined through cross-tabulations and visualized as grouped barplots with standard-error bars. These plots, generated using the *ggplot2* package (Wickham, 2016), highlight contrasts between the dry and wet seasons and were complemented by the aforementioned non-parametric tests to assess the significance of observed differences.

Spatial data obtained through participatory mapping were digitized and processed in QGIS and *R* (packages *sf* and *ggplot2*). Kernel Density Estimation (KDE) was applied to produce spatial density maps showing hotspots of *Fontitrygon margaritella*, *F. ukpam*, and *Carcharhinus leucas*, thereby identifying key concentration zones.

Local spatial clustering of fisher-reported occurrences was assessed using the Getis–Ord Gi* statistic (Getis & Ord, 1992), which identifies statistically significant hotspots (clusters of high values) and coldspots (clusters of low values). For each species and fishing zone, the Gi* statistic was standardized as a Z-score, calculated as:

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

Under the null hypothesis of spatial randomness, the standardized Gi* follows approximately a normal distribution with a mean of 0 and a standard deviation of 1. Following conventional thresholds of the standard normal distribution, results were interpreted as:

$|Z| \leq 1.96$: not significant ($p > 0.05$)
$Z > +1.96$: significant hotspot ($p < 0.05$)
$Z < -1.96$: significant coldspot ($p < 0.05$)

Higher thresholds ($|Z| > 2.58$ and $|Z| > 3.29$) correspond to significance levels of 1% and 0.1%, respectively. This approach allows identification of areas where species reports were more (or less) spatially concentrated than expected under a random distribution.

All descriptive, inferential, and spatial analyses were performed within a reproducible analytical framework combining the *vegan*, *sf*, *ggplot2*, and *dplyr* packages in R, and complemented by spatial visualization 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 practice, while 43% had less than 10 years; none exceeded 25 years. This reflects an overall long-term familiarity with the Komo Estuary.

Fishers reported using five main fishing gears (Table 1). Mixed surface-/bottom gillnets were the most common (40%), followed by surface drifting gill-nets (23.3%), hook-and-gillnet combinations (20%), hook only (longline/handline variants) (13.3%), and bottom-drifting gill-nets (3.3%). These practices are consistent with fishing methods most likely to generate 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

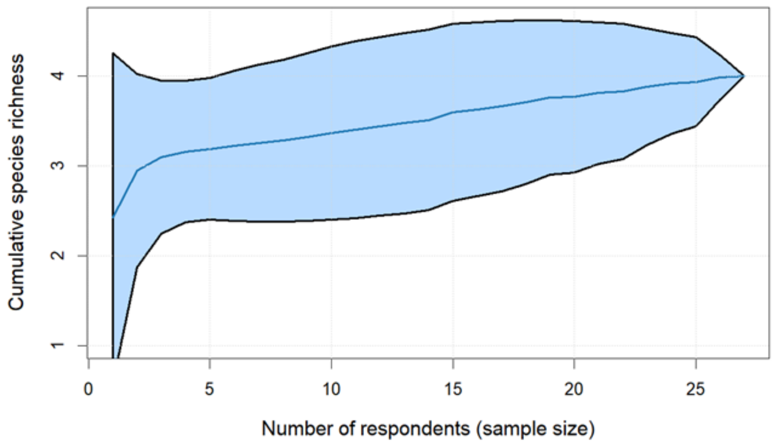
Reported elasmobranch diversity

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. Reports further highlighted a strong co-occurrence between *F. ukpam* and *F. margaritella*, with 18 respondents 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. Observed values ranged from 1 to 4 species (SD ≈ 0.8–1.0), indicating moderate inter-respondent variability.

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



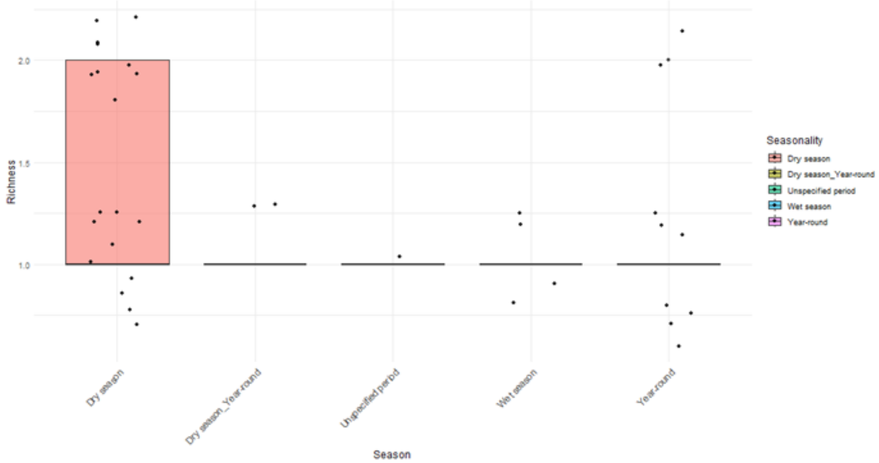
Source: The field data from Kango survey, 2025

Seasonal diversity patterns

Species richness per fishing zone ranged from one to three, with a few sites reaching up to four species. Boxplot analyses (Figure 3) indicated slightly higher richness during the dry season, although seasonal overlaps were substantial.

Non-parametric tests (Kruskal–Wallis followed by pairwise Wilcoxon comparisons) revealed no statistically significant differences between wet- and dry-season assemblages ($p > 0.05$), although dry-season reports suggested somewhat greater heterogeneity across fishing zones.

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 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).

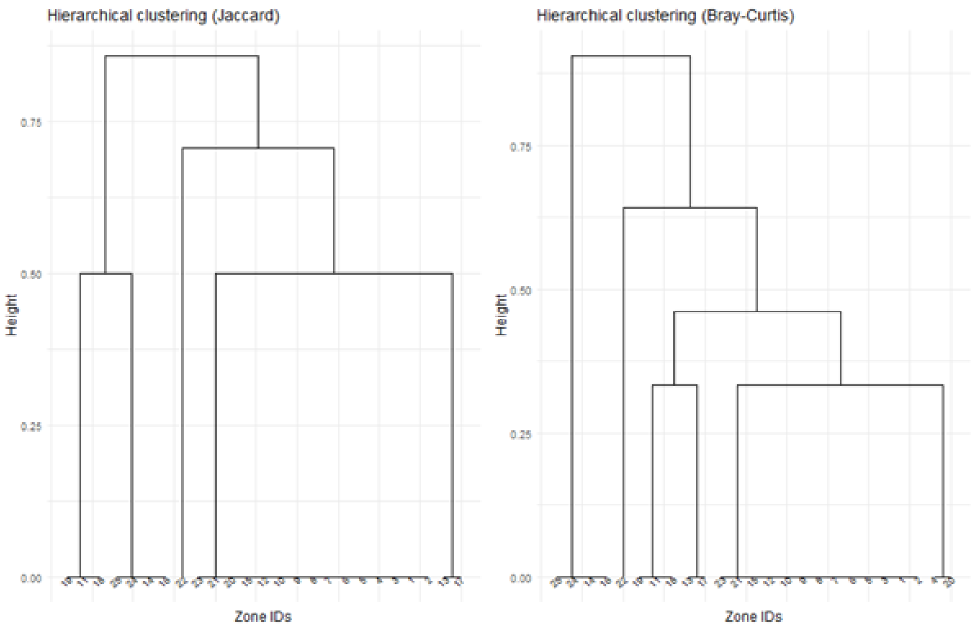
Table 2: Correspondence between fishing zone identifiers and full zone names reported by fishers in the Komo Estuary (Gabon)

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

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

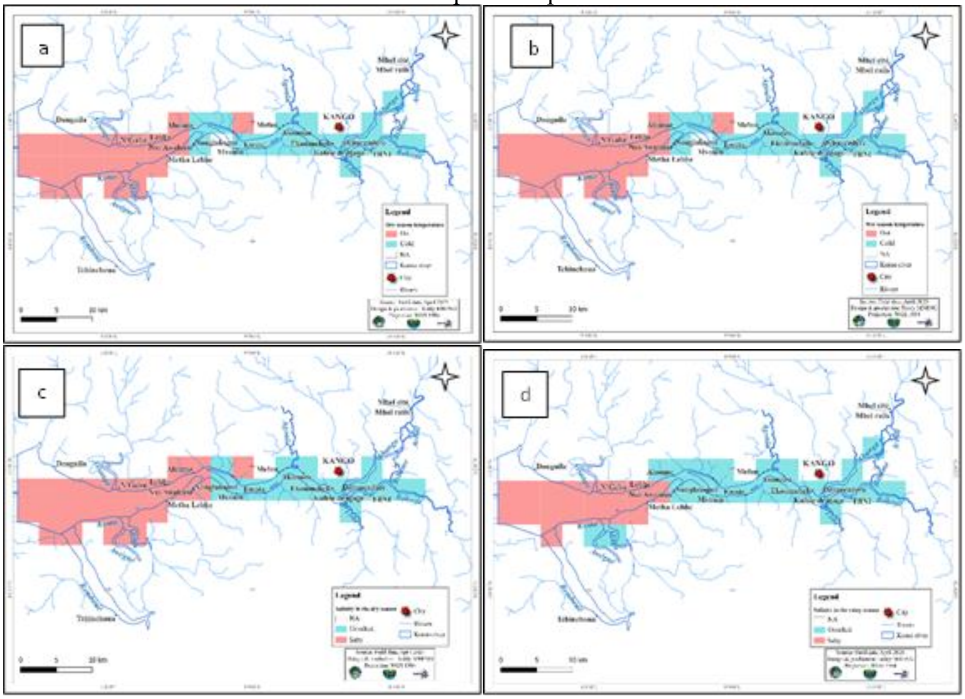


Source: Field data from Kango survey, 2025

Environmental gradients and species distributions

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

Figure 5: Environmental gradients in the Komo Estuary showing (a) temperature in dry season, (b) temperature in wet season, (c) salinity in dry season and (d) salinity in wet season. Warm and saline waters dominate the lower estuary, whereas cooler and unsalted conditions prevail upstream

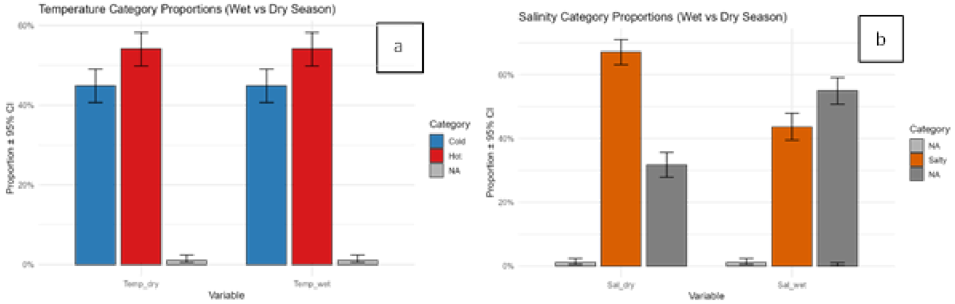


Source: Field data from Kango survey, 2025

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)

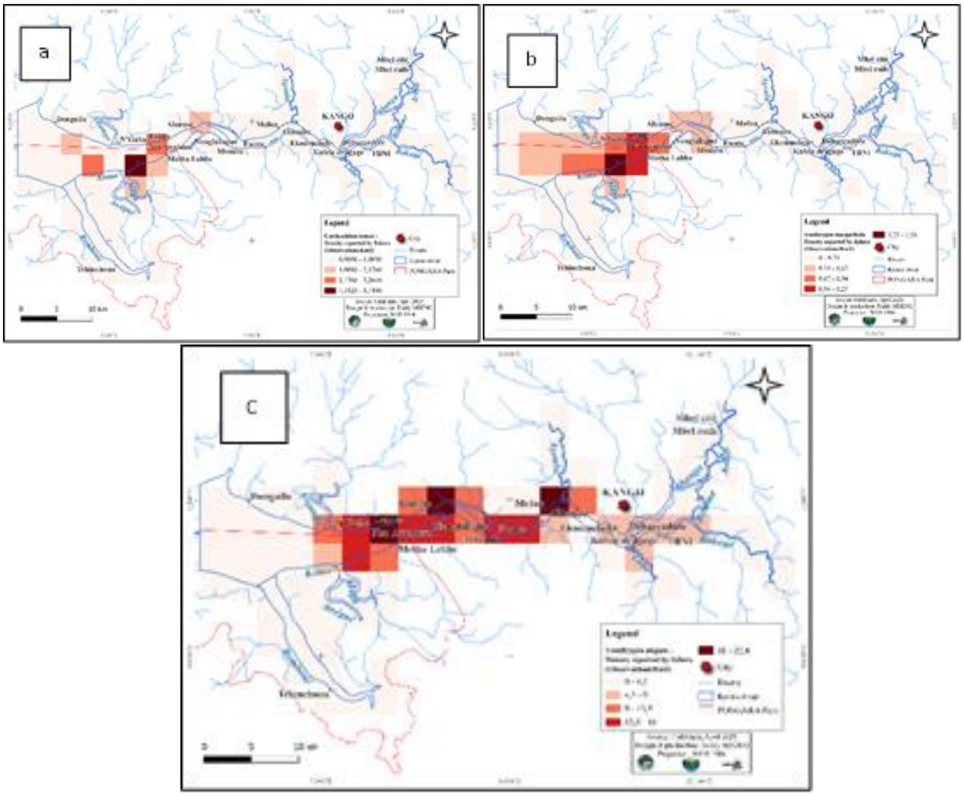


Source: Field data from Kango survey, 2025

Environmental gradients structured the reported distribution of elasmobranch species in the Komo Estuary (Figure 7). Temperature was predominantly warm in the lower estuary, especially around N'Gaba and Metha Lebhe (near Kango town), while cooler conditions were consistently reported upstream at Aloume, Mefou, and Ekoumbele along the Maga River and its tributaries. Salinity patterns showed a similar gradient, with saline waters near the Komo mouth and non-saline freshwater conditions upstream. Seasonal differences were minor and mainly 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.

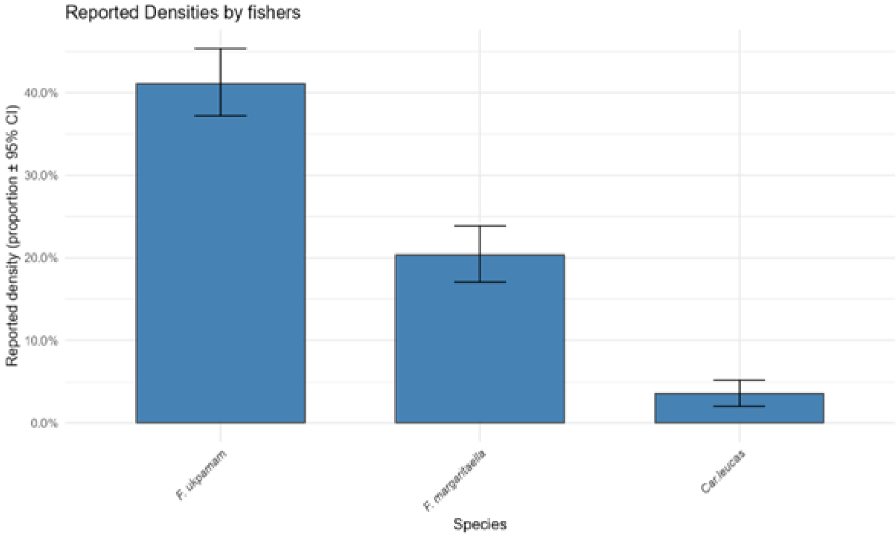
Figure 7: Spatial distribution and kernel density maps of the main elasmobranch species reported by fishers in the Komo Estuary:(a) Carcharhinus leucas, (b) Fontitrygon margaritella, (c) Fontitrygon ukpam. Density is expressed as the number of occurrences per km²



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, 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

This study provides new insights into the distribution of elasmobranchs in a poorly documented Central African estuarine system, while also demonstrating the potential of Local Ecological Knowledge (LEK) as a tool for spatial analysis. 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. Four focal species were identified : *Fontitrygon ukpam*, *Fontitrygon margaritella*, *Carcharhinus leucas*, and *Sphyrna lewini*. Seasonal differences were modest, with slightly higher richness and diversity during the dry season, but substantial spatial structuring emerged along the estuary–freshwater gradient.

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.

Such patterns mirror previous observations across West and Central Africa, where estuarine and riverine rays (notably *F. ukpam* and *F. margaritella*) dominate artisanal catches in brackish and freshwater zones (Bonfil & Abdallah, 2004). *C. leucas*, an euryhaline species, is well known for its ability to exploit estuarine corridors and penetrate rivers, often associated with warm and saline waters (Simpfendorfer *et al.*, 2005; Gausmann, 2021). By contrast, *S. lewini* was only sporadically reported, reflecting its rarity in riverine habitats and stronger association with coastal and oceanic environments (Dulvy *et al.*, 2017; Leeney *et al.*, 2015).

The apparent increase in richness during the dry season may relate to hydrological cycles: reduced rainfall and lower river discharge create broader brackish zones, favoring estuarine-tolerant taxa (Whitfield, 1999; Barletta *et al.*, 2005). Similar fluctuations have been observed in other tropical systems, where elasmobranch assemblages vary along salinity, temperature, and river discharge gradients, reflecting behavioral and trophic adaptations to seasonal cycles (Constance *et al.*, 2024).

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, 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).

The absence of major seasonal temperature shifts confirms the thermal stability of the Komo system, suggesting that salinity, rather than temperature, is the dominant seasonal driver of species distribution. These associations align with studies from Brazil, South Africa and Siberia, where salinity and temperature gradients have been identified as primary filters structuring fish assemblages in estuaries (Whitfield, 1999; Barletta *et al.*, 2010, Chikina *et al.*, 2023).

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-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., 2000; 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. 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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Ethical statement

All interviews were conducted with prior informed consent and in accordance with national ethical standards for social research in Gabon.

Conflict of Interest: The authors reported no conflict of interest.

Data Availability: All data are included in the content of the paper.

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