Environmental and Human Health
https://ojs.ukscip.com/index.php/ehh

Article

Heavy Metal Toxicity and the Literacy-Awareness Paradox: A Socio-Behavioral Model of Bushmeat Consumption in Akwa Ibom State, Nigeria

Daniel Etim Jacob [1,*], Gideon Efiakedoho [1], Ogaga Dean Efenakpo [2], Imaobong Daniel Jacob [1,3], Koko Sunday Daniel [1], Francis Muyorkem Akor [1] and Angela Nwanneka Okeke [3]

[1] Department of Forestry and Wildlife, University of Uyo, Uyo 520003, Nigeria

[2] Department of Forestry and Wildlife Management, University of Port Harcourt, Port Harcourt 500004, Nigeria

[3] Department of Forestry and Wildlife Technology, Federal University of Technology, Owerri 460114, Nigeria

[*] Correspondence: danieljacob@uniuyo.edu.ng

Received: 28 July 2025; **Revised:** 7 October 2025; **Accepted:** 17 November 2025; **Published:** 21 December 2025

Abstract: Food safety in Sub-Saharan Africa is increasingly compromised by invisible chemical contaminants in wild-sourced proteins, often referred to as bushmeat. This study provides a novel integration of toxicological risk assessment and socio-behavioral modeling by analyzing 60 consumers and meat samples of the Greater Cane Rat (*Thryonomys swinderianus*) across Akwa Ibom State, Nigeria. Chemical analysis revealed severe heavy metal contamination. Zinc (385 mg/kg) and Chromium (2.5 mg/kg) significantly exceeded World Health Organization (WHO) permissible thresholds by 7.6 and 2.5 times, respectively. Health risk assessments demonstrated a cumulative Hazard Index (HI) of 2.440, indicating significant non-carcinogenic health risks for consumers. Furthermore, the Incremental Lifetime Cancer Risk (ILCR) for Chromium reached 3.82×10^{-4}, dangerously exceeding the globally acceptable threshold. Socio-behaviorally, a stark literacy-awareness paradox emerged. Despite 60.71% of respondents holding a tertiary education, 57.14% were entirely unaware of the causes of chemical contamination, and 60.71% were unfamiliar with safety or risk-reduction practices. Binary logistic regression confirmed that education level ($p < 0.05$) and specific toxin awareness ($p < 0.01$) are critical predictors of consumer behavior. Notably, toxicologically aware individuals were 7.28 times more likely to pay for safety-certified bushmeat. These findings imply that standard educational campaigns are insufficient. Public health interventions must shift from general literacy to localized, evidence-based risk communication to mitigate chronic toxicity and protect urban food systems.

Keywords: Bushmeat; Heavy Metals; Food Safety; Akwa Ibom; Risk Assessment; Literacy-Awareness Paradox; Willingness to Pay; Consumer Behavior

1. Introduction

Global public health is shifting from a traditional focus on microbial pathogens toward the silent pandemic of chronic chemical contamination. While acute diarrheal diseases dominate headlines, Elbehiry et al. [1] argue that long-term toxicological exposure is now a primary determinant of epidemiological risk as industrial pollutants saturate global food supplies. In Sub-Saharan Africa, where contaminated food causes millions of annual illnesses [2], heavy metals and pesticide residues threaten regional life expectancy on a scale exceeding publicized infectious outbreaks [3]. Despite this, regulatory efforts remain concentrated on formal exports, leaving the shadow economy of wild-sourced protein (bushmeat) largely unmonitored [4,5]. Jacob et al. [6,7] highlight that these informal markets bypass veterinary inspections, exposing consumers to invisible hazards as wild animals act as biological sponges for industrial discharge.

In Nigeria's Niger Delta, the Greater Cane Rat (*Thryonomys swinderianus*), or grasscutter, is a cultural and nutritional staple prized for its perceived natural purity. However, the anthropogenic stress in the region driven by petroleum exploration and rapid urbanization has compromised this purity. Recent studies [8,9] confirm that the region's soil-water-biota pathway is increasingly leaking industrial waste into wild foragers. Consumers face a twofold risk of environmental bioaccumulation and toxic processing. Grasscutters accumulate Zinc (Zn) and Chromium (Cr) from polluted forage, and even though Zn is essential, its concentration in industrial runoff often crosses the narrow threshold into systemic toxicity [10]. Furthermore, hexavalent Chromium is a potent carcinogen. Because grasscutters are non-migratory, their tissues provide a high-definition record of localized pollution [11]. This hazard is compounded by the common practice of singeing animal hair with scrap tires and spent oil which is a tertiary contamination source of Lead (Pb) and Polycyclic Aromatic Hydrocarbons (PAHs) that creates a permanent toxic cocktail in the meat's fatty tissues [12].

Despite these documented threats, a literacy-awareness paradox persists in Akwa Ibom State, Nigeria. While general education levels are high, consumers remain safety-illiterate regarding invisible chemical risks. Many rely on mental shortcuts, assuming natural origin equates to healthiness [13,14], or disregard chemical hazards because the meat appears fresh [15,16]. Paradoxically, higher education often increases purchasing power, thereby increasing exposure frequency without a corresponding increase in toxin-specific knowledge.

Addressing this gap, this study integrates chemical risk assessment with socio-behavioral modeling, a rare synthesis in Nigerian literature. By utilizing binary logistic regression and Principal Component Analysis (PCA), we identify the drivers of risk perception and Willingness to Pay (WTP) for certified safe meat. Moving beyond ineffective bans, we build on the argument that market-based safety certifications are more culturally viable in the Niger Delta [17]. Ultimately, this research provides the numeric foundation for policy packages designed to transition the grasscutter trade from an unregulated market into a safe, controlled value chain [18].

2. Methodology

2.1. Study Area

The research was conducted in Akwa Ibom State, Nigeria, located between latitudes 4°32′ and 5°33′ North. The region covers approximately 7,249 km^2 and is characterized by a tropical climate with high humidity and significant annual rainfall [19,20]. The study area was stratified into three primary senatorial districts to reflect different anthropogenic pressures: Uyo (The administrative capital, characterized by high population density and municipal solid waste intensity), Eket (The industrial hub, dominated by oil and gas processing and gas flaring activities), and Ikot Ekpene (An agricultural center with significant wetland resources and fertilizer usage).

2.2. Sampling and Data Collection Protocol

A multistage sampling technique was employed to bridge the gap between laboratory-verified toxicity and consumer behavior. Following the initial stratification of the state, one major bushmeat market was purposively selected from each Senatorial District to serve as the primary sampling unit. The selection of these specific markets namely the Uyo, Eket, and Ikot Ekpene central markets was intentional, as they represent the highest volume of bushmeat trade and diversity of supply chains in their respective districts. This ensured that the study captured the most significant points of human-animal interaction and environmental exposure [21].

Within these markets, sixty (60) consumers were purposively selected for the administration of pre-tested structured questionnaires. This non-probability sampling approach was necessary because a definitive sampling frame of bushmeat consumers does not exist. By targeting individuals at the point of purchase, the researchers ensured that the respondents were active participants in the bushmeat value chain, rather than the general public. This expert-user targeting is essential for investigating the literacy-awareness paradox, as it focuses specifically on the demographic actually making the high-risk dietary choices [22].

Importantly, fresh carcasses of the Greater Cane Rat (*Thryonomys swinderianus*) were obtained directly from these same markets at the time of the surveys. This triangulation allowed for a direct, site-specific link between the laboratory-verified heavy metal levels and the psychological drivers of the individuals purchasing from those exact sources [23,24]. Samples of muscle tissue were neatly dressed and transported in sterile plastic bags on ice to the laboratory, where they were maintained at −20 °C to prevent enzymatic degradation or external contamination as prescribed by Ogungbile et al. [25].

2.3. Laboratory Determination of Heavy Metal Concentration

To achieve the highest analytical rigor and reproducibility, the procedures of the Association of Official Analytical Chemists (AOAC) were strictly followed, supplemented by refined methods for biological matrices as described by Ogungbile et al. [25]. The mineralization process followed a structured four-stage procedure designed to minimize cross-contamination and maximize trace element recovery [26]. Initially, tissue samples were oven-dried at 103 °C until a constant weight was achieved for precise dry-weight determinations, followed by pulverization in an acid-washed porcelain mortar to eliminate exogenous metal contamination. The samples then underwent ashing in a muffle furnace at 550 °C for two hours; this high-temperature mineralization is vital for removing organic matter that might interfere with spectrophotometric signals [27]. Throughout this stage, temperature was strictly monitored to prevent the volatilization of elements like Cadmium [28].

The resulting inorganic ash was dissolved in a 1:1 mixture of Hydrochloric Acid (HCl) on a thermostat hot plate until the digest reached a clear, translucent state, signifying complete dissolution. The solution was quantitatively transferred to a 100 mL volumetric flask and diluted with double-distilled water for analysis. Quantitative determination was performed using an xplorAA GBC Atomic Absorption Spectrophotometer (AAS), where concentrations of Fe, Pb, Cr, As, Cd, and Zn were measured at element-specific wavelengths. To ensure statistical reliability and account for matrix effects, every sample was analyzed in triplicate, and mean values were utilized for subsequent risk assessments in accordance with the quality assurance frameworks of Olomo et al. [26] and Olaoye et al. [29].

2.4. Statistical Analysis

The study utilized a mixed-method statistical framework to integrate empirical laboratory data with consumer survey results. Descriptive statistics, including frequencies and percentages, were first applied to summarize the socio-demographic profiles and consumption drivers of the respondents. To evaluate the health implications of heavy metal ingestion, the Estimated Daily Intake (EDI) was calculated using the following model:

$$\mathrm{EDI} = \frac{\mathrm{C} \times \mathrm{IR} \times \mathrm{EF} \times \mathrm{ED}}{\mathrm{BW} \times \mathrm{AT}} \tag{1}$$

Where C represents the heavy metal concentration in the meat (mg/kg), IR is the ingestion rate, EF is exposure frequency, ED is exposure duration, BW is average body weight, and AT is the averaging time. Non-carcinogenic health risk was then determined via the Target Hazard Quotient (THQ) and the cumulative Hazard Index (HI), which is the sum of THQs for all metals studied ($\mathrm{HI} = \sum \mathrm{THQ}$). An $\mathrm{HI} > 1.0$ indicates a significant non-carcinogenic risk to the consumer. Furthermore, the Incremental Lifetime Cancer Risk (ILCR) was calculated for carcinogenic metals (Cr, As, Pb) using the formula:

$$\mathrm{ILCR} = \mathrm{EDI} \times \mathrm{CSF} \tag{2}$$

where CSF is the Cancer Slope Factor.

To identify the specific predictors of Willingness to Pay (WTP) for safety-certified meat, a Binary Logistic Regression (Logit) model was employed. The model was structured to determine the probability (P) that a consumer would be willing to pay for certified safe meat based on a set of independent variables (X_1, X_2, ... X_n) such as education, income, and risk awareness. The logit transformation is expressed as:

$$\mathrm{Logit(P)} = \ln\left(\frac{\mathrm{P}}{1-\mathrm{P}}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon \tag{3}$$

Where β_0 is the intercept, $\beta_1 ... \beta_n$ are the regression coefficients, and ϵ is the error term. The strength and direction of these relationships were evaluated using Wald chi-square tests and Odds Ratios (OR). Finally, Principal Component Analysis (PCA) was performed to reduce the dimensionality of consumption drivers (e.g., taste, cultural value, and availability), identifying the primary factors that explain the variance in consumer choices. All inferential tests were conducted at a $p < 0.05$ significance level using SPSS v.26, effectively establishing a coherent link between empirical chemical toxicity and consumer behavioral intent.

3. Results

3.1. Demographic Profile

The demographic data in **Table 1** shows that the consumer base in Akwa Ibom is predominantly male (69.64%) and falls within the most economically active age range of 31–40 years (46.46%). This indicates that the Greater Cane Rat (*Thryonomys swinderianus*) is a primary protein choice for the region's core workforce. A significant finding is the high level of formal education, with 60.71% of respondents holding tertiary degrees. This high baseline of general literacy is a vital technical parameter for this study, as it establishes the starting point for the Literacy-Awareness Paradox analyzed in later sections. Occupationally, the dominance of self-employed individuals (42.86%) and civil servants (28.57%) shows that these consumers possess the stable purchasing power required to afford bushmeat, which often commands a higher market price than farmed livestock in urban centers. Furthermore, the prevalence of households with 4–6 members (30.36%) suggests that the chemical risks identified in the laboratory analysis are not isolated to individual purchasers but are distributed across family units. Since 100% of the sample identified as Christian, it is evident that there are no religious dietary restrictions limiting the exposure to this meat within the study area.

Table 1. Demographic Characteristics of Respondents in the Study Area.

Variable	Category	Frequency	Percentage (%)
Gender	Male	39	69.64
	Female	15	30.36
Age	20–30	20	35.71
	31–40	26	46.46
	41–50	7	12.50
	51–60	2	3.57
	61–70	1	1.79
Education	FLSC	7	12.50
	SSCE	12	21.43
	Tertiary institution	34	60.71
	No formal education	3	5.36
Marital Status	Married	31	55.36
	Single	24	42.86
	Separated	1	1.79
Religion	Christianity	56	100
Household Size	1–3	8	14.29
	4–6	17	30.36
	7 and above	13	23.21
	No response	18	32.14
Occupation	Civil servant/public servant	16	28.57
	Student	3	5.36
	Self-employed	24	42.86
	Farming/fishing	4	7.14
	Trading	6	10.71
	Teaching	3	5.36
	Total	56	100.00

3.2. Preferred Bushmeat Species and Selection Patterns

The dietary profile of respondents in Akwa Ibom exhibits a highly specialized preference for specific wildlife, with the Greater Cane Rat (Thryonomys swinderianus) and various Antelope species dominating the market (**Table 2**). Collectively, these two taxa account for 44.64% of primary consumption. While a segment of the consumer base maintains a narrow preference for a single species, a majority (55.36%) engages in mixed-species consumption, often rotating between Antelope, Grasscutter, and Monkey depending on seasonal availability and market pricing. Notably, 37.31% of respondents consumed a broad spectrum of other species, including snakes and alligators, indicating a high level of dietary diversity within the bushmeat trade.

3.3. Regulatory Compliance and Toxicological Assessment

The state mean concentrations were compared against the permissible limits established by the World Health Organization (WHO) to determine the safety status of the meat for human consumption as indicated in **Table 3**.

While Iron and Lead concentrations were found to be within safe limits, both Zinc, Cadmium and Chromium significantly exceeded the permissible thresholds (**Table 2**). Chromium, detected at 2.49 mg/kg, is more than double the WHO permissible limit of 1.0 mg/kg. Zinc, although an essential cofactor for over 300 enzymes, exhibited a concentration of 384.75 mg/kg, more than seven times the limit of 50.0 mg/kg indicating a significant toxicological burden in the regional food chain, transforming a primary protein source into a vector for chronic chemical exposure.

Table 2. Preferred Bushmeat Species among Respondents.

Preferred Species	Frequency	Percentage (%)
Antelope	13	23.21
Grasscutter	12	21.43
Antelope and Grasscutter (Mixed)	6	10.71
Antelope and Monkey	4	7.14
Antelope, Monkey, Grasscutter, and Other species	12	21.23
Other (Snakes, Alligator, Duiker, etc.)	9	16.08
Total	56	100.00

Table 3. Some Heavy Metal Levels in Grasscutter Consumed in Akwa Ibom State, Nigeria.

Metal	Measured Value (mg/L)	WHO Limit (mg/L)	Toxicological Remark
Iron (Fe)	243.44 ± 95.13	5.00–100.00	Nutritional; potential overload.
Arsenic (As)	ND	0.10	Safe (Not Detected).
Cadmium (Cd)	0.72 ± 0.24	0.05	Unsafe; significantly exceeds limit (14×).
Lead (Pb)	ND	0.10	Safe (Not Detected).
Chromium (Cr)	2.49 ± 0.77	1.00	Unsafe; exceeds limit (2.5×).
Zinc (Zn)	384.75 ± 174.08	50.00	Toxic; exceeds limit (7.6×).

3.4. Health Risk Assessment

The health risk parameters calculated for metal exposure via grasscutter consumption are summarized in **Table 4**. The Estimated Daily Intake (EDI) for Iron (0.187 mg/kg/day) and Zinc (0.295 mg/kg/day) represented the highest mass transfers per kilogram of body weight. Conversely, Cadmium and Chromium exhibited lower mass intake but significantly higher toxicological potency per unit. While individual Target Hazard Quotients (THQ) for most metals remained below the unity threshold (<1.0), the THQ for Zinc (0.984) approached the critical safety limit. Most importantly, the cumulative Hazard Index (HI) was calculated at 2.440, and the Incremental Lifetime Cancer Risk (ILCR) for Chromium reached 3.82×10^{-4}.

Table 4. Health risk parameters for metal exposure via grasscutter consumption.

Metal	EDI (mg/kg/Day)	THQ	ILCR	Safety Limit (HQ/HI)
Iron (Fe)	0.187	0.267	-	<1.0
Zinc (Zn)	0.295	0.984	-	<1.0
Cadmium (Cd)	0.00055	0.552	-	<1.0
Chromium (Cr)	0.00191	0.637	3.82×10^{-4}	<1.0
Hazard Index (HI)	-	2.440	-	<1.0

3.5. Consumption and Preparation Methods of Bushmeat

The behavioral profile of respondents in Akwa Ibom indicates that bushmeat is primarily an occasional dietary component rather than a daily staple (**Table 5**). Three-quarters of the sample (75.00%) reported rare or occasional consumption (monthly to yearly), while 25.00% are regular consumers. Regarding culinary processing, boiling (21.43%) and roasting (19.64%) were the most common standalone methods. However, the most significant finding was the prevalence of multi-modal preparation (46.43%), where consumers utilize a combination of boiling, frying, and roasting, often within the same meal or household cycle.

Table 5. Integrated Profile of Consumption Habits, Species, and Drivers.

Variable Category	Primary Indicator/Metric	Frequency	Percentage (%)
Consumption Frequency	Rare (Yearly)/Occasional (Monthly)	42	75.00
	Regular (Several times a month)	14	25.00
	Total	56	100.00
Preparation Methods	Grilled	2	3.57
	Boiled	12	21.43
	Fried	3	5.36
	Roasted	11	19.64
	Stewed	2	3.57
	Combined (Boiled, Fried, Roasted and Stewed	26	46.43
	Total	56	100.00

3.6. Consumption Drivers and Principal Component Analysis (PCA)

The factors influencing bushmeat consumption in Akwa Ibom are characterized by a multi-dimensional motivational structure (**Table 6**). Nearly half of the respondents (48.21%) identified a combination of two or more factors, such as taste, nutrition, and social utility, as their primary drivers. Among single-factor motivations, taste preference and perceived nutritional value were the most prominent with 12.50% respectively. Notably, price and health concerns were entirely absent as influencing factors (0%), indicating that for this demographic, the decision to consume bushmeat is decoupled from economic cost or perceived medical risk.

Table 6. Factors Influencing Bushmeat Consumption.

Factor Category	Frequency	Percentage (%)
Single Factor: Availability	5	8.93
Single Factor: Tradition/Culture	3	5.38
Single Factor: Taste Preference	7	12.50
Single Factor: Nutritional Value	7	12.50
Single Factor: Social Gatherings	5	8.93
Multiple Factors (any combination of two or more factors)	27	48.21
Price	0	0
Health Concerns	0	0

To understand the deeper psychological structure of these choices, a Principal Component Analysis (PCA) was conducted on the influencing factors (**Figure 1**). The analysis revealed a two-dimensional structure explaining 65.2% of the total variance, indicating a high degree of internal consistency in consumer motivations. The first principal component (PC1) illustrates a contrast between intrinsic motivations (Taste and Nutritional Value) and logistical motivations (Availability and Social gatherings). The second principal component (PC2) distinguishes between sensory preference and functional utility (the practical role of the meat in a social or dietary context). This mapping suggests that while taste is the leading individual driver, consumer behavior is divided between those driven by the inherent qualities of the meat and those driven by environmental convenience.

3.7. Awareness, Experience, Risk Reduction, and Health-Seeking Behaviour

The survey data reveals a significant deficit in specialized health literacy regarding heavy metal exposure (**Table 7**). While nearly 40% of respondents (38.46%) claimed awareness of symptoms associated with contaminated bushmeat, a dominant majority (61.54%) remained entirely unaware of the specific risks posed by bioaccumulative toxins. This lack of awareness is mirrored in the reported health history, where 87.50% of the sample stated they had never experienced issues related to bushmeat consumption, while a small subset (10.71%) reported suspected symptoms. Furthermore, knowledge of protective preparation methods was found to be insufficient; only 35.71% of respondents were familiar with risk-reduction practices, compared to 60.71% who possessed no such knowledge. Regarding medical intervention, 42.86% indicated they were very likely to seek professional help for suspected contamination. However, the preferred pathways for care were highly fragmented, with 46.43% choosing general hospitals, while the remainder relied on a pluralistic mix of local health centres (14.29%), traditional healers (5.36%), and self-medication (3.57%).

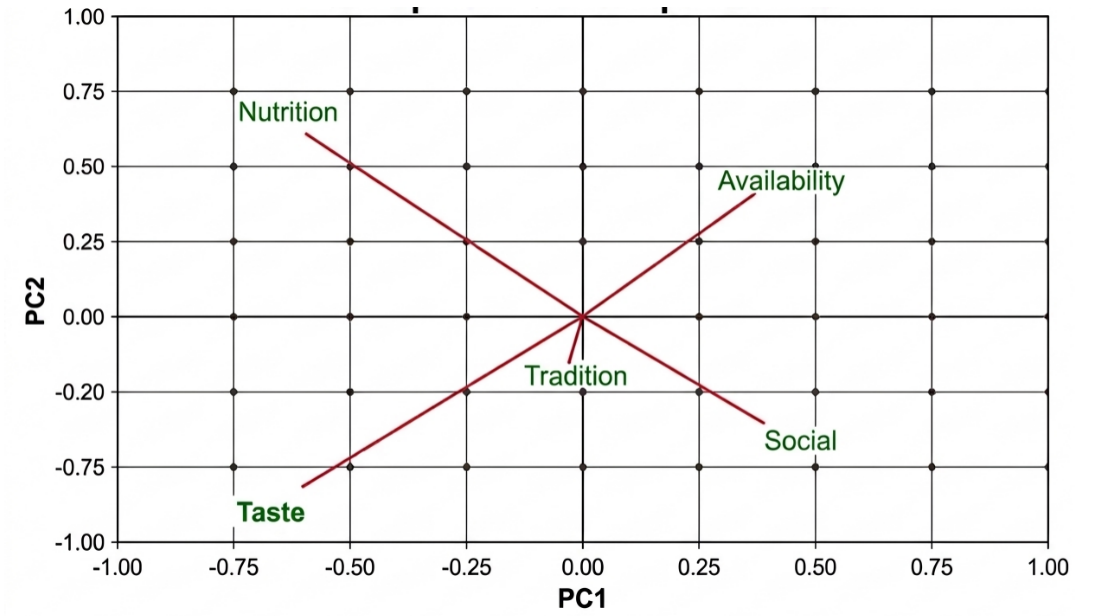

Figure 1. Two-dimensional mapping of consumption determinants using principal component analysis.
Note: The PCA plot illustrates the relationship between various consumption drivers. PC1 represents the first and PC2 the second principal components. Vector length indicates the strength of the variable's influence on the component, and the angle between vectors indicates their correlation.

Table 7. Awareness, Experience, Risk Reduction, and Health-Seeking Behaviour Related to Bushmeat Consumption.

Indicator Category	Variable/Response Option	Frequency	Percentage (%)
Awareness of Health Symptoms	Yes	20	38.46
	No	32	61.54
	No Response	4	7.14
Experience of Health Problems	Yes	6	10.71
	No	49	87.50
	No Response	1	1.79
Awareness of Methods to Reduce Contamination	Yes	20	35.71
	No	34	60.71
	No Response	2	3.57
Likelihood to Consult a Medical Professional	Very Likely	24	42.86
	Somewhat Likely	8	14.29
	Neutral	11	19.64
	Not Very Likely	9	16.07
	Not Likely at All	4	7.14
Medical Advice/Treatment Option(s)	Local Health Center	8	14.29
	General Hospital	26	46.43
	Traditional Healer	3	5.36
	Self-Medication	2	3.57
	None of the Above	1	1.79
	Local Health Center and General Hospital	5	8.93
	Local Health Center and Self-Medication	5	8.93
	Local Health Center, General Hospital, and Traditional Healer	5	8.93
	Local Health Center, General Hospital, and Self-Medication	5	8.93
Total		56	100.00

3.8. Economic Receptivity and Logit Regression Analysis

The population demonstrates a high latent receptivity to safety regulations and evidence-based information. Approximately 62.50% of respondents were willing to pay (WTP) a premium for bushmeat certified as safe from heavy metals, and 67.86% would change their consumption habits if presented with scientific evidence of high contamination. To identify the determinants of this willingness to pay, a binary logistic regression (logit) model was applied (**Table 8**). The analysis indicates that education level ($\beta = 1.245$, $p < 0.05$) and prior awareness of toxins ($\beta = 1.986$, $p < 0.01$) were the most significant predictors of behavioral intent. Individuals with tertiary education were 3.47 times more likely to pay for safety certification, while those already aware of poisonous materials in meat were 7.28 times more likely to do so. Factors such as gender, age, and prior health issues did not reach statistical significance ($p > 0.05$).

Table 8. Predictors of Willingness to Pay (WTP) for Certified Safe Bushmeat.

Predictor Variable	Coefficient (β)	Std. Error	Wald χ^2	*p*-Value	Odds Ratio (Exp(β))
Constant	−2.431	1.120	4.708	0.030	0.088
Gender (Male = 1)	0.512	0.380	1.815	0.178	1.669
Age (Continuous)	0.108	0.065	2.756	0.097	1.114
Education (Tertiary = 1)	1.245	0.512	5.912	0.015*	3.473
Occupation (Income-Stable = 1)	0.824	0.443	3.459	0.063	2.279
Awareness of Toxins (Yes = 1)	1.986	0.621	10.228	0.001**	7.286
Prior Health Issue (Yes = 1)	0.415	0.502	0.683	0.409	1.514

Note: *. Significant at $*p < 0.05$, $**p < 0.01$.

4. Discussion

4.1. Socio-Demographic Determinants and the Cultural Habitus of Consumption

The demographic profile of grasscutter (*Thryonomys swinderianus*) consumers in Akwa Ibom reveals a distinct social stratification, characterized by a predominantly male, middle-aged, and highly educated consumer base. This gendered pattern reflects the joint culture prevalent in Nigerian urban centers, where bushmeat serves as a primary tool for social interaction and professional bonding in informal bars [6,30,31]. These findings align with Alarape et al. [32] and Osazuwa-Peters [33], who argue that bushmeat consumption in West African cities is a symbolic act linked to masculinity and social status. This contrasts with broader protein consumption trends in neighboring regions where gender distributions are often more balanced, suggesting that in Akwa Ibom, the bushmeat joint remains a masculine-dominated cultural space.

Furthermore, our results indicate that bushmeat has transitioned into a luxury signaling good for the middle class. Unlike rural subsistence hunting, where wild meat is a necessary protein source, the Akwa Ibom market is sustained by civil servants and self-employed professionals with stable incomes. This shift is consistent with the observations of McNamara et al. [34] and Adebowale et al. [35], who opined that urbanization decouples bushmeat demand from economic lack, reframing it as a product of cultural nostalgia and a preference for perceived superior taste [36,37]. Ebewore et al. [38] and recent studies by Ndlovu et al. [18] highlight that the high market price of grasscutter meat, though often exceeding that of domestic livestock serves as a mechanism for the middle class to reflect economic success and cultural authenticity.

A critical mechanistic finding of this research is the primacy of sensory pleasure over health risk perception. The preference for grasscutter meat represents a cultural habitus that is significantly resistant to the health-conscious trends seen in Western markets. For instance, while European consumers are increasingly influenced by traceability and strict safety labeling [39], the Akwa Ibom consumer operates within a semantic field where wild is instinctively equated with organic. Olunusi [40] and Schoofs et al. [10] argue that this nature-is-safe mental shortcut creates a blockage in public health communication as consumers assume wild animals are free from the growth hormones and antibiotics found in intensive livestock, while remaining oblivious to the invisible chemical bioaccumulation caused by industrial runoff from the Niger Delta's oil and gas activities.

The stability of income and the prevalence of mid-sized households in our sample further support the argument by Akinsorotan et al. [41] that cultural preference often supersedes economic rationality in the African bushmeat trade. The ritualistic nature of this consumption acting as a link to ancestral roots in a modernizing environment [42], explains why demand persists even as prices rise. Consequently, typical health warnings are likely to fail unless they address the specific sensory and cultural prestige of the meat. As noted by Gbogbo et al. [43] and Ogungbile et al. [25], revealing the hidden chemical contamination (such as lead or cadmium) through localized scientific data may be the only effective tool to dismantle the purity narrative and influence the decisions of the highly educated consumer class that currently dominates the market. This group possesses the cognitive capacity to interpret scientific risk data but requires a shift in the food safety health literacy framework to move beyond the aesthetic evaluation of meat quality.

4.2. Species Preference and the Mechanistic Risk of Bioaccumulation

The overwhelming preference for grasscutter and antelope identified in this study aligns with regional trends across West Africa, where these species are favored for their high protein content and perceived wild flavor [44].

However, from a toxicological perspective, this preference represents a significant mechanistic pathway for human exposure to environmental contaminants. Unlike wider-ranging migratory animals, the grasscutter is a non-migratory herbivore that grazes on grasses and tubers in proximity to human settlements and industrial zones. As noted by Schoofs et al. [10] and Ogungbile et al. [25], such species act as sentinel organisms that bioaccumulate heavy metals from contaminated soil and water through the soil-water-biota pathway. In the Niger Delta, where gas flaring and oil spills are prevalent, the high consumption rate of these specific animals would ensure a consistent, chronic intake of toxins like Lead (Pb) and Chromium (Cr) for the human consumer [45,46].

The mixed-species consumption pattern observed in our results further complicates the risk profile. While some researchers suggest that dietary diversification can reduce exposure to a single toxin, Ndlovu et al. [18] argue that in contaminated ecosystems, multi-species diets often lead to a cocktail effect. Consumers eating a mix of grasscutter (grazers), antelope (browsers), and monkeys (frugivores) are likely exposed to a broader array of synergistic toxins, ranging from heavy metals to polycyclic aromatic hydrocarbons (PAHs) and pesticides. These findings contrast with studies in more pristine environments [41], where species selection was driven purely by availability, whereas in Akwa Ibom State, selection is a deliberate cultural preference that inadvertently maximizes the toxicological load on the consumer. Furthermore, the inclusion of other species like snakes introduces a trophic level risk. As apex predators, snakes undergo biomagnification, concentrating toxins found in their smaller prey. The consumption of such species, even at lower frequencies, can result in acute exposure levels that exceed safety thresholds. These results support the argument by Gbogbo et al. [43] that public health interventions must be species-specific. Rather than general warnings against bushmeat, communication should highlight the specific bioaccumulative risks associated with the grasscutter and antelope, as the purity narrative of these animals must be scientifically dismantled to alter the high-risk selection patterns of the affluent urban demographic.

4.3. Environmental Bioaccumulation and the Industrial-Cultural Hybrid Threat

The detection of Zinc and Chromium at levels higher than the WHO and FAO safety limits shows that we need to change how we think about food safety in the Niger Delta. The toxic buildup in the grasscutter (*Thryonomys swinderianus*) is a double-layered threat. It comes from two places: the pollution the animal absorbs from the environment while alive, and the extra chemicals added by humans during butchering and cooking. Because grasscutters stay in a small area throughout their lives, their bodies act like a biological mirror of the local environment. In Akwa Ibom State, this habitat is under constant stress from oil drilling, gas flaring, and city waste. Studies by Jacob et al. [47,48] and Amadi et al. [49] confirm that small animals in the Niger Delta soak up much higher levels of metals than those living in cleaner areas. This shows a direct link where industrial poison moves from the soil into the plants the animals eat, eventually sticking to their muscle tissue.

These facts challenge the common belief that bushmeat is purer or more organic than meat from a farm. While cows or goats are usually raised in fenced areas with specific feed, wild grasscutters are exposed to whatever toxins are in the air and water. This purity myth is debunked by Okoro et al. [50] and Evivie and Olanrewaju [51], who found that wild-caught meat in Nigeria often has more metal residue than farmed meat. Nkosi et al. [52] also point out that because these animals do not have a controlled diet, they experience higher levels of biomagnification as they move up the food chain, especially in areas where farm chemicals and industrial waste mix. A large part of the Chromium found in the meat likely comes from the common habit of burning off the animal's fur using old car tires. This is done because it is cheap and gives the meat a smoky taste, but it acts as a direct delivery system for poison. Burning rubber releases a dangerous mix of heavy metals and chemicals called Polycyclic Aromatic Hydrocarbons (PAHs) [53].

Researchers like Njoga et al. [54] and Adesola et al. [55] have warned that these invisible chemical risks are often ignored because people are more worried about germs. However, Essuman and Duah [56] argue that once the skin is burned with tires, the heat opens up pores that allow these toxins to sink deep into the meat. Once inside, you cannot simply wash or boil the chemicals away. This risk is very different from what is seen in Europe or North America. In those regions, the main concern with wild meat is Lead (Pb) from hunters' bullets, as noted by Cromie et al. [57] and Gerofke et al. [58]. In the Niger Delta, the problem is a mix of oil pollution and dangerous cooking traditions. While Western countries focus on tracking where meat comes from, West Africa needs to focus on cleaning the soil and banning the use of tires for cooking. As Leite et al. [59] observed, there is a dangerous false sense of safety here. While heat kills bacteria, it actually makes heavy metals more concentrated because the water in the meat evaporates during cooking. This creates a silent danger that does not smell or look bad like rotten meat does, leading people to unknowingly risk organ failure and cancer over many years, as shown by the high Hazard Index and Cancer Risk scores found in this study.

4.4. The Literacy-Awareness Paradox and Economic Pathways to Safety

The research revealed a remarkable literacy-awareness paradox among the consumers, where a highly educated demographic lacks specific, practical knowledge regarding chemical food safety. Although the vast majority of respondents hold tertiary degrees, a large proportion remain unaware of the routes by which heavy metals get into the food chain or how to avoid these risks. This demonstrates that academic success, which is a measure of general intelligence, does not automatically translate into food safety literacy. These findings are in line with socio-cognitive theories of Bearth and Siegrist [14], who argue that consumers struggle to understand the risks of products that do not have sensory cues, such as a bad smell or visible signs of deterioration. In Akwa Ibom State, education provides the financial means to buy grasscutter meat as a luxury, but fails to provide the specialized knowledge for checking the chemical safety of the meat. Consequently, high-incomes professionals unknowingly consuming high-risk delicacies.

In agreement with this scenario, Bishoge et al. [60] pointed out that in many sub-Saharan African countries, food safety in educational curricula is largely limited to basic microbial hygiene such as handwashing. This narrow focus hardly prepares students for the complexities of chemical pollutants like heavy metals or pesticide residues. This invisible risk is further compounded by the naturalness bias. As reported by Adenuga and Montowska [61], educated consumers often mistakenly equate wild-caught with organic purity. They assume that because the animal lived away from industrial farms, it is a safer product, and this mentality makes it hard for even the most knowledgeable consumers to accept that their luxury meal is actually contaminated with Chromium or Zinc.

Based on the results of the binary logistic regression, market-driven safety interventions show great potential. The study reveals a strong link between formal education, prior knowledge of toxins, and a Willingness to Pay (WTP) a premium for safety-certified meat. The high WTP recorded among middle-to-high-income professionals suggests this group is willing to bear the costs of safety if they are provided with credible, transparent information. This is in line with general trends in developed economies like China, where higher incomes have resulted in an increased demand for green food and certified labels, as documented by Wei et al. [62]. Similarly, in Nigeria, such consumer behavior has been observed in the case of poultry and smoked fish, where regular income earners prioritize hygiene once they are made aware of the underlying risks [63,64].

Prior awareness is a very strong predictor in this study as individuals who are aware of the toxins are significantly more likely to pay for safety. This proves that information is the most powerful tool for behavioral change. This approach differs from typical public health efforts that focus on total prohibition and thus unintentionally pushes the bushmeat trade even deeper into the unregulated shadow economy where there are no safety standards. Instead, the results indicate that a nudging strategy [65], would be more effective. By exposing the hidden risk of tire-singeing through targeted risk communication, policymakers can change the current literacy-awareness paradox into a market demand for safer meat.

Ekanem et al. [16] assert that when the health risks of traditional processing are measured and shared with the public, demand for safer alternatives like gas-singed or mechanically de-haired will increase rapidly. Essentially, a certification system backed by local toxicological data would not only be the public health initiative but also an economic force, encouraging vendors to adopt safer, non-toxic preparation methods. This represents a shift from a purely regulatory framework to a socio-economic one that preserves cultural tastes, while on the other hand, reduces health risks from long-term exposure. As Nordhagen et al. [66] suggest, the ultimate goal of food safety in the Niger Delta should be brandable safety, where vendors are rewarded for using stainless steel processing and clean energy with higher prices. This act will turn consumer wealth into a tool for public health reform, cleverly utilizing the social stratification that drives the trade to eventually improve it.

5. Conclusions

This study identifies a critical intersection between environmental pollution, traditional food processing, and consumer psychology in the Niger Delta's informal bushmeat market. The findings reveal that heavy metal concentrations in grasscutter meat significantly exceed international safety limits, presenting a severe, invisible toxicological threat to a productive and well-educated demographic. The study's primary contribution is the identification of the Literacy-Awareness Paradox. This phenomenon demonstrates that high academic achievement does not equate to food safety literacy. Because chemical contamination lacks sensory cues like foul odors or visible rot, even highly educated consumers rely on their senses and mistakenly equate wild-caught with organic and safe.

Practical implications for public health are twofold. First, there is an urgent need to ban the use of scrap tires for singeing, which is a major source of Chromium and other hazardous compounds. Second, the data shows that specific awareness of toxins rather than general education is the strongest driver of a consumer's Willingness to Pay (WTP) for safer meat. This makes market-based interventions, such as safety certifications, a highly viable policy option. Also, rather than relying on broad prohibitions that may drive the trade underground, authorities should implement localized risk communication campaigns. Translating toxicological data into practical consumer knowledge will empower the public to demand safer standards, shifting the market toward non-toxic processing methods.

The study recommends that future research should focus on the long-term clinical outcomes of populations consuming singed meat and the feasibility of decentralized, stainless-steel processing hubs. Ultimately, transitioning from culturally trusted to scientifically certified products will preserve the cultural value of the bushmeat chain while protecting the population from chronic risks like organ failure and malignancy.

Author Contributions

Conceptualized and designed the study, coordinated data collection, and wrote the original draft, D.E.J.; conducted fieldwork, sampling, and administered surveys to consumers in Akwa Ibom markets, G.E., I.D.J., K.S.D., and F.M.A.; contributed to the laboratory analysis and statistical modeling, including Principal Component Analysis (PCA) and binary logistic regression, I.D.J., K.S.D., O.E.D. and A.N.O. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Institutional Review Board Statement

Ethical review and approval were waived for this study due to the fact that all tested bushmeat specimens were retrieved posthumously from commercial open-market channels, eliminating animal welfare concerns, while the associated human consumer modeling was completely risk-free, utilizing anonymous questionnaires that protected participant identities in strict accordance with national institutional frameworks.

Informed Consent Statement

Survey respondents provided informed consent prior to participating, and anonymity was maintained.

Data Availability Statement

All data generated or analyzed during this study are included in this published article. Raw laboratory data and survey responses are available from the corresponding author upon reasonable request.

Acknowledgments

The authors acknowledge the technical support provided by the laboratory staff at the University of Uyo and the cooperation of the bushmeat vendors and consumers in Akwa Ibom State who participated in the study.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

AI Use Statement

AI was solely used for language editing.

References

1. Elbehiry, A.; Marzouk, E.; Abalkhail, A.; et al. Microbial food safety and antimicrobial resistance in foods: A dual threat to public health. *Microorganisms* **2025**, *13*, 1592.
2. World Health Organization. WHO guiding principles for pathogen genome data sharing. Available online: https://www.who.int/publications/i/item/9789240061743 (accessed on 28 April 2025).
3. Rilwanu, M.M. Assessment of Public Health Risk of Heavy Metals from Contaminated Water, Soil and Edible Vegetables in Selected Areas of Nasarawa State, Nigeria. Master's Thesis, Kwara State University, Ilorin, Nigeria, 2021.
4. Sackey, H.N.; McNamara, J.; Milner-Gulland, E.J.; et al. Bushmeat consumption frequency and preferences among rural households in a West African savanna landscape: Implications for food security and conservation. *People Nat.* 2025, *in press*. [CrossRef]
5. Sackey, H.N.; McNamara, J.; Milner-Gulland, E.J.; et al. The bushmeat trade in northern Ghana: Market dynamics, drivers of trade and implications for conservation. *Oryx* **2023**, *57*, 216–227.
6. Jacob, D.E.; Ukpong, E.E.; Umoh, U.A.; et al. Determinants of bushmeat traders' income in Itu, Akwa Ibom State, Nigeria. *Management* **2018**, *2*, 103–116.
7. Jacob, D.E.; Etuk, I.M.; Nelson, I.U. Assessment of anti-poaching effectiveness in Old Oyo National Park, Nigeria. In Proceedings of the 6th NSCB Biodiversity Conference, Uyo, Nigeria, 6–10 May 2018; pp. 422–429.
8. Akani, G.C.; Amuzie, C.C.; Alawa, G.N.; et al. Factors militating against biodiversity conservation in the Niger Delta, Nigeria: The way out. In *Biodiversity in Africa: Potentials, Threats and Conservation*; Springer Nature Singapore: Singapore, 2022; pp. 573–600.
9. Numbere, A.O.; Gbarakoro, T.N.; Babatunde, B.B. Environmental degradation in the Niger Delta ecosystem: The role of anthropogenic pollution. In *Sustainable Utilization and Conservation of Africa's Biological Resources and Environment*; Springer Nature Singapore: Singapore, 2023; pp. 411–439.
10. Schoofs, H.; Schmit, J.; Rink, L. Zinc toxicity: Understanding the limits. *Molecules* **2024**, *29*, 3130.
11. Igene, J.O.; Okoro, K.I.; Ebabhamiegbebho, P.A.; et al. A study assessing some metal elements contamination levels in grasscutter meat. *Int. J. Biotechnol. Food Sci.* **2015**, *3*, 63–69.
12. Das, S.; Sultana, K.W.; Ndhlala, A.R.; et al. Heavy metal pollution in the environment and its impact on health: Exploring green technology for remediation. *Environ. Health Insights* **2023**, *17*, 11786302231201259.
13. Veflen, N.; Andersen, V.; Lelieveld, H. Misinformation about food safety. In *Food Safety Management*; Academic Press: Cambridge, MA, USA, 2023; pp. 1073–1080.
14. Bearth, A.; Siegrist, M. Are risk or benefit perceptions more important for public acceptance of innovative food technologies: A meta-analysis. *Trends Food Sci. Technol.* **2016**, *49*, 14–23.
15. Sogore, T.; Guo, M.; Sun, N.; et al. Microbiological and chemical hazards in cultured meat and methods for their detection. *Compr. Rev. Food Sci. Food Saf.* **2024**, *23*, e13392.
16. Ekanem, A.M.; Ijezie, A.E.; Udo, I.A.; et al. Meat singeing practices and knowledge of its effects on health and environment among butchers in Uyo, Nigeria. *J. Adv. Med. Pharm. Sci.* **2020**, *22*, 23–33.
17. Sievert, K.; Lawrence, M.; Parker, C.; et al. Understanding the political challenge of red and processed meat reduction for healthy and sustainable food systems: A narrative review of the literature. *Int. J. Health Policy Manag.* **2020**, *10*, 793–808.
18. Ndlovu, W.; Karonga, S.; Vorhies, F. Wild meat value chain integration systems: Opportunities for value chain formalisation and scaling in Africa. *Afr. J. Ecol.* **2025**, *63*, e70017.
19. Nelson, I.U.; Jacob, D.E. Differentials in forecast modeling of target and generated forest revenue in Akwa Ibom State, Nigeria. *Biomed. J. Sci. Tech. Res.* **2024**, *58*. [CrossRef]
20. Jacob, D.E.; Eniang, E.A. Threats and conservation status of Cercopithecus sclateri in Akwa Ibom State, Nigeria. In *Sustainable Utilization and Conservation of Africa's Biological Resources and Environment*; Springer: Singapore, 2023. [CrossRef]
21. Jenkins, J.; Lawundeh, W.; Hanson, T.; et al. Human-animal entanglements in bushmeat trading in Sierra Leone: An ethnographic assessment of a potential zoonotic interface. *PLoS ONE* **2024**, *19*, e0298929.
22. Lin, S.-H.; Sah, A.K.; Hong, Y.-M. Environmental literacy among the general public in Chiayi County, Taiwan. *Sustainability* **2025**, *17*, 3108.
23. Irenge, C.A.; Bushenyula, P.K.; Irenge, E.B.; et al. Participative epidemiology and prevention pathway of health

risks associated with artisanal mines in Luhihi area, DR Congo. *BMC Public Health* **2023**, *23*, 121.

24. Manning, L. Triangulation: Effective verification of food safety and quality management systems and associated organisational culture. *Worldw. Hosp. Tour. Themes* **2018**, *10*, 297–312.
25. Ogungbile, P.; Ajibare, A.; Akinola, O.M.; et al. Health risk assessment of heavy metals in the consumption of bushmeat obtained from Epe, Southwest Nigeria. *Polytechnica* **2024**, *7*, 8. [CrossRef]
26. Olomo, K.O.; Asubiojo, M.T.; Olaleye, O.K. Elemental trace enrichment and contamination assessment in an active mining site of Itagunmodi Area, Southwestern Nigeria. *Int. J. Environ. Sci. Technol.* **2024**, *21*, 6357–6372.
27. Wang, B.; Sun, X.; Yang, Z.; et al. Substrate chemistry trumps mineral protection in governing temperature sensitivity of organic carbon mineralization in saline lake sediments. *Geochim. Cosmochim. Acta* **2025**, *407*, 81–90.
28. Zhang, J.; Wu, S.; Xu, J.; et al. Comparison of ashing and pyrolysis treatment on cadmium/zinc hyperaccumulator plant: Effects on bioavailability and metal speciation in solid residues and risk assessment. *Environ. Pollut.* **2021**, *272*, 116039.
29. Olaoye, J.; Bakare-Abidola, T.; Adeiza, A.A. Assessment of selected trace metal levels (Pb, Zn, Cu) in wild and domesticated grasscutter tissues. *Int. J. Sci. Archit. Technol. Environ.* **2024**, *1*, 109–118.
30. Jacob, D.E.; Eniang, E.A.; Ubo, M.O.; et al. A survey of hunting practices in Ikot Ubo, Nigeria. *For. Agric. Rev.* **2020**, *1*, 39–53.
31. Jacob, D.E.; Udoakpan, U.I.; Ufot, I.N. The potential benefits of wildlife in food security in Nigeria. In *Contemporary Issues in Sustainable Tropical Agriculture*; Etim, L., Udoh, J.P., Etim, N., et al., Eds.; University of Uyo: Uyo, Nigeria, 2013; pp. 174–192.
32. Alarape, A.A.; Ijose, O.A.; Ayodele, I.A. Assessing the relationship between socioeconomic factors of bushmeat consumers and pattern of consumption in Owo, Ondo State, Nigeria. *Niger. J. Wildl. Manag.* **2017**, *1*, 128–136.
33. Osazuwa-Peters, M. The local contexts of meat consumption: Analyzing meatification in Nigeria. *Food Cult. Soc.* **2021**, *24*, 712–730.
34. McNamara, J.; Fa, J.E.; Ntiamoa-Baidu, Y. Understanding drivers of urban bushmeat demand in a Ghanaian market. *Biol. Conserv.* **2019**, *239*, 108291.
35. Adebowale, T.; Ibiyomi, B.B.; Akintunde, O.A.; et al. Assessing preference and perception of bushmeat consumers among households in Ibadan, Oyo State. *Fudma J. Sci.* **2024**, *8*, 233–237.
36. Emelue, G.U.; Jacob, D.E.; Godwin, O.S. Assessment of indigenous wildlife conservation practices in Ika North East Local Government Area of Delta State, Nigeria. *Niger. J. Agric. Food Environ.* **2014**, *10*, 11–17.
37. Jacob, D.E.; Nelson, I.U.; Udoakpan, U.I.; et al. Wildlife poaching in Nigeria National Parks: A case study of Cross River National Park. *Int. J. Mol. Ecol. Conserv.* **2015**, *5*, 1–7.
38. Ebewore, S.O.; Ovharhe, O.J.; Emaziye, P.O. Acceptability of bush meat as a source of animal protein in Delta State, Nigeria: Implication for extension services. *J. Northeast Agric. Univ.* **2015**, *22*, 67–78.
39. Niewiadomska, K.; Kosicka-Gębska, M.; Gębski, J.; et al. Game meat consumption—Conscious choice or just a game? *Foods* **2020**, *9*, 1357.
40. Olunusi, B.O. Wildlife trade dynamics: exploring bushmeat market with a view toward social and ecological justice in Ibadan Metropolis Nigeria. *Front. Conserv. Sci.* **2024**, *5*, 1401308.
41. Akinsorotan, O.A.; Olaniyi, O.E.; Oguntuase, B.G.; et al. Dynamics and socioeconomic drivers of illegal hunting of wildlife animal for consumption in Oba Hills Forest Reserve in southwest Nigeria. *J. Appl. Sci. Environ. Manage.* **2020**, *24*, 287–298.
42. Tokede, A.M. Cultural beliefs on grasscutter consumption and willingness to adopt its domestication technology among urban dwellers in Southwest, Nigeria. *Niger. Agric. J.* **2020**, *51*, 10–15.
43. Gbogbo, F.; Rainhill, J.E.; Koranteng, S.S.; et al. Health risk assessment for human exposure to trace metals via bushmeat in Ghana. *Biol. Trace Elem. Res.* **2020**, *196*, 419–429.
44. Andong, F.A.; Ossai, N.I.; Echude, D.; et al. Motives, other meat sources and socioeconomic status predict number of consumers with preference for two antelope species served in Enugu-Nigeria. *Glob. Ecol. Conserv.* **2023**, *42*, e02387.
45. Efenakpo, O.D.; Jacob, D.E.; Goodnews, N.N. Population status and anthropogenic threats to the African dwarf crocodile (Osteolaemus tetraspis) in the Niger Delta, Nigeria. *J. Sustain. Environ. Manag.* **2025**, *4*, 1–8.
46. Onyena, A.P.; Folorunso, O.M.; Nwanganga, N.; et al. Engaging One Health in heavy metal pollution in some selected Nigerian Niger Delta cities: A systematic review of pervasiveness, bioaccumulation and subduing environmental health challenges. *Biol. Trace Elem. Res.* **2024**, *202*, 1356–1389.
47. Jacob, D.E.; Nelson, I.U.; Efenakpo, O.D.; et al. Reptiles as environmental sentinels: Exploring their signifi-

cance. In *Biomonitoring of Pollutants in the Global South*; Izah, S.C., Ogwu, M.C., Hamidifar, H., Eds.; Springer: Singapore, 2024. [CrossRef]
48. Jacob, D.E.; Nelson, I.U.; Okweche, S.I.; et al. Suitability of mammals indigenous to the Global South as bioindicator species for assessing environmental health. In *Biomonitoring of Pollutants in the Global South*; Izah, S.C., Ogwu, M.C., Hamidifar, H., Eds.; Springer: Singapore, 2024. [CrossRef]
49. Amadi, C.N.; Frazzoli, C.; Orisakwe, O.E. Sentinel species for biomonitoring and biosurveillance of environmental heavy metals in Nigeria. *J. Environ. Sci. Health C* **2022**, *38*, 21–60.
50. Okoro, E.E.; Okolie, A.G.; Sanni, S.E.; et al. Toxicology of heavy metals to subsurface lithofacies and drillers during drilling of hydrocarbon wells. *Sci. Rep.* **2020**, *10*, 6152.
51. Evivie, S.E.; Olanrewaju, A.O. Heavy metal analysis in smoked and fresh bushmeat from selected markets in Nigeria. *Afr. J. Biotechnol.* **2015**, *14*, 2532–2540.
52. Nkosi, D.V.; Bekker, J.L.; Hoffman, L.C. Toxic metals in wild ungulates and domestic meat animals slaughtered for food purposes: A systemic review. *Foods* **2021**, *10*, 2853.
53. Archibong, F.N.; Orakwe, L.C.; Ubah, J.I.; et al. Menace of waste rubber contamination in public health and environment around world of automobile industrialization: A review. *Int. J. Environ. Sci. Technol.* **2025**, *22*, 16261–16278.
54. Njoga, E.O.; Ezenduka, E.V.; Ogbodo, C.G.; et al. Detection, distribution and health risk assessment of toxic heavy metals/metalloids, arsenic, cadmium, and lead in goat carcasses processed for human consumption in South-Eastern Nigeria. *Foods* **2021**, *10*, 798.
55. Adesola, R.O.; Hossain, D.; Ogundijo, O.A.; et al. Challenges, health risks and recommendations on meat handling practices in Africa: A comprehensive review. *Environ. Health Insights* **2024**, *18*.
56. Essuman, E.K.; Duah, K.K. Poisonous substances used to capture and kill the greater cane rat (Thryonomys swinderianus). *Vet. Med. Sci.* **2020**, *6*, 617–622.
57. Cromie, R.; Newth, J.; Reeves, J.; et al. The sociological and political aspects of reducing lead poisoning from ammunition in the UK: Why the transition to non-toxic ammunition is so difficult. In Proceedings of the Oxford Lead Symposium, Oxford, UK, 10 December 2014; pp. 104–124.
58. Gerofke, A.; Martin, A.; Schlichting, D.; et al. Heavy metals in game meat. In *Chemical Hazards in Foods of Animal Origin*; Wageningen Academic: Wageningen, The Netherlands, 2019; pp. 585–609.
59. Leite, L.C.; Melo, E.S.D.P.; Arakaki, D.G.; et al. Human health risk assessment through roasted meats consumption. *Int. J. Environ. Res. Public Health* **2020**, *17*, 6737.
60. Bishoge, O.K.; Omary, M.; Liheluka, E.; et al. Hand hygiene practices among primary and secondary school students in sub-Saharan Africa: A systematic review. *J. Water Sanit. Hyg. Dev.* **2023**, *13*, 1018–1035.
61. Adenuga, B.M.; Montowska, M. The Nigerian meat industry: An overview of products' market, fraud situations, and potential ways out. *Acta Sci. Pol. Technol. Aliment.* **2023**, *22*, 305–329.
62. Wei, P.; Liu, H.; Xu, C.; et al. Does Green Food Certification promote agri-food export quality? Evidence from China. *J. Integr. Agric.* **2024**, *23*, 1061–1074.
63. Ayodeji, O.O.; Oni, T.S.; Sanyaolu, V.A. Consumer awareness of polycyclic aromatic hydrocarbon (PAHS) contaminants in smoked fish and factors influencing smoked fish consumption in Ado-Odo/Ota Local Government area of Ogun State. *Ghana J. Agric. Sci.* **2023**, *58*, 1–13.
64. Ghali-Mohammed, I.; Isola, T.O.; Adeyemo, I.A.; et al. Food safety knowledge and attitudes among fish vendors in informal markets in Ilorin, Nigeria: A cross-sectional study. *Discover Food* **2024**, *4*, 161.
65. Graf, R. Nudging before the nudge? Behavioural traffic safety regulation and the rise of behavioural economics. In *Handbook of Behavioural Change and Public Policy*; Edward Elgar Publishing: Cheltenham, UK, 2019; pp. 23–37.
66. Nordhagen, S.; Lee, J.; Onuigbo-Chatta, N.; et al. What is safe and how much does it matter? Food vendors' and consumers' views on food safety in urban Nigeria. *Foods* **2022**, *11*, 225.