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Feeding Ecology and Seasonal Shifts in Diet of the Daisy Stingray *Fontitrygon margarita* (Günther, 1870) off Lagos Coastal Waters, Nigeria

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ABSTRACT

A total of 360 specimens of the daisy stingray (*Fontitrygon margarita*), ranging in disc width from 12.5 to 41.8 cm, were collected from February 2023 to July 2024 off the Lagos Coastal Waters, Nigeria, to examine their feeding ecology and dietary variation. The proportion of empty stomachs ranged between 23.33% and 28.57%, with an overall mean of 26.23%, suggesting consistent feeding activity throughout the study period. Stomach content analysis revealed that *F. margarita* is an opportunistic carnivore, preying mainly on benthic organisms. Crustaceans were the dominant food item across all size groups, accounting for the highest numerical (49.9%), volumetric (50.8%), and occurrence (33.8%) values, with an Index of Relative Importance (IRI) of 72.4%. Fish and annelids were secondary prey, contributing 20.1% and 20.6% numerically, with corresponding IRI values of 12.7% and 11.6%, while molluscs were least important (IRI = 3.3%). Ontogenetic dietary shifts were observed, with larger individuals consuming more fish, whereas smaller stingrays relied predominantly on crustaceans and annelids. The observed stability in feeding pattern indicates favourable environmental conditions and prey availability. These findings highlight the trophic adaptability of *F. margarita* and its ecological significance as a benthic predator within the Lagos coastal ecosystem, providing baseline information for effective management and conservation.

INTRODUCTION

Understanding the feeding ecology of elasmobranchs is essential to assessing their ecological roles, population dynamics, and conservation status (Bornatowski et al., 2023). Among these cartilaginous fishes, stingrays play a crucial role as benthic predators, contributing significantly to energy transfer within coastal ecosystems (Flowers et al., 2021). Their diet provides essential nutrients for growth, reproduction, and overall health (Machovsky-Capuska & Raubenheimer, 2020).

However, information on the trophic ecology of many stingray species, particularly those inhabiting the eastern tropical Atlantic, remains limited. The daisy stingray (*Fontitrygon margarita*), once classified under the genus *Dasyatis*, is a demersal species distributed in shallow coastal waters of West Africa, often occurring in estuaries and muddy substrates (Last et al., 2016). Despite its ecological importance and increasing susceptibility to artisanal and commercial fisheries, little is known about its feeding habits and dietary adaptability.

Like many elasmobranchs, *F. margarita* exhibits opportunistic feeding strategies, preying on a range of benthic invertebrates and small teleosts (Last et al., 2016). Variability in prey availability due to habitat conditions and seasonal fluctuations significantly influences stingray dietary composition. Seasonal changes, particularly in tropical environments, can alter the structure and abundance of benthic invertebrate and fish populations, leading to notable shifts in predator feeding patterns (Vettorazzi et al., 2022). Habitat characteristics such as substrate type and complexity also play a role in prey distribution and foraging success (Crook et al., 2022). Investigating these seasonal dietary changes is key to understanding the species' ecological niche and potential trophic plasticity, especially in regions where environmental conditions and anthropogenic pressures are dynamic.

The analysis of stomach contents, including the frequency of empty stomachs, remains a foundational method in diet studies of elasmobranchs (Soyinka et al., 2022). Empty stomach frequency can provide insights into feeding periodicity, prey availability, and potential stressors affecting foraging success (Moruf & Lawal-Are, 2017). Moreover, identifying dominant food items across seasons helps reveal shifts in foraging strategies and prey selectivity. In the case of *F. margarita*, such data are scarce, which impedes efforts to evaluate its trophic role and manage its populations sustainably.

Given its restricted habitat preferences and susceptibility to coastal fisheries, *F. margarita* is vulnerable to habitat degradation and overexploitation (Linardich et al., 2021). By studying its feeding ecology and seasonal dietary shifts, we can better understand how environmental and anthropogenic variables affect its foraging behaviour. This knowledge is critical for informing ecosystem-based management strategies and conservation policies, particularly as coastal habitats in West Africa face increasing pressure from development, pollution, and climate change. This study aims to investigate the feeding ecology of *F. margarita*, focusing on stomach content analysis to identify food items and determine the frequency of empty stomachs. Additionally, the study examined how dietary composition varies between wet and dry seasons to understand seasonal foraging adaptations. The findings will enhance ecological understanding of this species and provide valuable data for fisheries management and conservation planning.

MATERIAL AND METHODS

Study Area

The study area which is off Lagos coast extends from Ibeju Lekki Local Government Area to Apapa Local government Area of Lagos State, Nigeria. The study area is located between longitude 6°26′N to 6°27′N and latitude 3°23′E to 3°58′N (Figure 1). The climate is made up of rainforest, tropical coastal waters with prolonged wet season (May to October) and short dry season (November to April). The most insulation received is modified by absorption, selective scattering, cloud cover, rainfall and harmattan haze. The mean daily temperature is about 28°C throughout the year. The vegetation is made up of red mangrove (*Rhizophora* sp.) and white mangrove (*Avicennia* sp.). The most common vegetation on the southern edges close to the sea are coconut (*Cocos nucifera*), giant reeds (*Paspalam vaginatum*) and *Spore bolus virginucus.*

Sampling and Sample Preparation

A total of 360 specimens of *F. margarita* (Figure 2) were collected from February 2023 to July 2024. Sampling was conducted between 6:30 am and 8:30 using 4-m industrial trawl nets with a stretched mesh size of 60 mm in the main body and 44 mm mesh size at the cod-end. Each trawl lasted 15 minutes, performed during daylight and low tides. Specimens were immediately preserved in ice chests onboard and later transferred to a deep freezer at −20°C in the Nigerian Institute for Oceanography and Marine Research, where they were stored until further analysis.

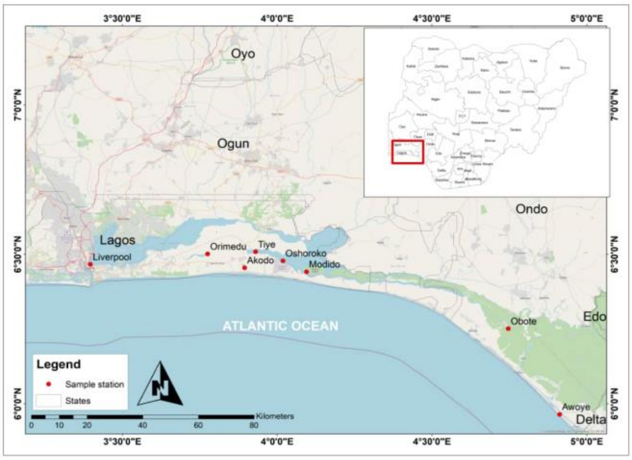

Figure 1. Map of Lagos coastal water showing sampling stations

Figure 2. Dorsal view of Daisy Stingray (*Fontitrygon margarita*)

Laboratory Analysis

In the laboratory, each ray specimen was dissected to expose the gastrointestinal tract. Stomachs were carefully excised and preserved in 10% buffered formalin for 24–48 hours before further examination under a dissecting microscope. Stomach contents were sorted and identified to the lowest possible taxonomic level using standard identification keys (Fischer et al., 1981). Each stomach was classified as either empty or containing food, and the frequency of empty stomachs was recorded to determine feeding intensity across seasons. Stomach contents were analysed under a stereomicroscope and quantified according to major prey categories, with data grouped by size classes based on disc width: Small (≤20 cm), Medium (21–30 cm), and Large (>30 cm).

Food items were grouped into major categories such as crustaceans, molluscs, fishes, and Annelida. The occurrence, numerical composition, and volume contribution of each food category were calculated following Hyslop (1980), with wet weights measured using a digital top-loading balance to the nearest 0.01 g. To assess seasonal variation, specimens were grouped by season—dry (November–April) and wet (May–October)—and analysed separately. Comparative analysis of food composition between seasons was conducted to detect shifts in dietary patterns, possibly linked to prey availability or reproductive cycles. The Index of Relative Importance (IRI) was also computed to integrate multiple feeding indices and rank dominant prey types across seasons (Hart et al., 2002).

Data Analysis

Data on gut contents were assessed for normality and homogeneity of variance using the Chi-square test to ensure assumptions of statistical tests were met. Variations in the contribution of each food item across size classes and seasons were analysed using a quadratic fit model to explore non-linear relationships between these variables and dietary composition. A significance level of $p < 0.05$ was used for all statistical tests.

RESULTS AND DISCUSSION

Empty Stomach Analysis

The monthly variation in empty stomachs of the daisy stingray off Lagos coastal waters from February 2023 to July 2024 indicates a relatively stable pattern of feeding activity, with the percentage of empty stomachs ranging from 23.33% (September 2023 and March 2024) to 28.57% (July 2023) (Table 1). The overall percentage of empty stomachs across all months is 26.23%, suggesting that roughly one in four stingrays examined had an empty stomach at the time of capture. There are no significant monthly fluctuations, implying a relatively consistent feeding behaviour throughout the study period. However, slight variations may reflect environmental factors, prey availability, or changes in feeding intensity across months.

This consistency in this result suggests continuous foraging activity with minimal seasonal influence. Similar observations were reported by Ndome & Udo (2018) in the study of Chrysichthys species in Nigerian coastal waters, where feeding was shown to occur year-round, albeit with minor fluctuations linked to prey availability. Comparable findings were also noted by Yogi et al. (2023), for elasmobranchs along the Indian coast, where only slight monthly variations in empty stomach frequency were attributed to localized changes in prey distribution rather than seasonal shifts.

Table 1. Monthly variation in empty stomachs of the daisy stingray, *Fontitrygon margarita* off Lagos coastal waters, Nigeria (February, 2023 – July, 2024)

Year	Month	No of fish examined	No of fish with Feed	No of fish with empty stomach	% Empty Stomach
2023	Feb	23	17	6	26.09
	Mar	39	29	10	25.64
	Apr	36	26	10	27.78
	May	30	22	8	26.67
	Jun	29	21	8	27.59
	Jul	28	20	8	28.57
	Aug	30	22	8	26.67
	Sept	30	23	7	23.33
	Oct	29	21	8	27.59
	Nov	28	21	7	25.00
	Dec	25	19	6	24.00
2024	Jan.	29	21	8	27.59
	Feb	30	22	8	26.67
	Mar	30	23	7	23.33
	Apr	29	21	8	27.59
	May	29	21	8	27.59
	Jun	29	22	7	24.14
	Jul	27	20	7	25.93
	Total	530	391	139	26.23

Table 2. Food items and feeding indices of the daisy stingray, *Fontitrygon margarita* off Lagos coastal waters, Nigeria (February, 2023 – July, 2024)

Type of Organism	Numerical Percentage		Volumetric Percentage		Frequency of Occurrence			
	Number (N)	*N%*	*Volume (V)*	*V%*	*Frequency (F)*	*F%*	*IRI*	*IRI%*
Annelida	325	20.6	172.48	15.5	59	15.1	545.2	11.6
Crustacea	785	49.9	565.52	50.8	132	33.8	3397.2	72.4
Fish	316	20.1	266.49	23.9	53	13.6	596.3	12.7
Mollusc	148	9.4	109.72	9.8	28	7.2	137.9	3.3
Total	**1574**	**100**	**1114.21**	**100**	-	-		**100**

Food Items of Daisy Stingray

Table 2 presented the food items and feeding indices of the daisy stingray. The analysis, based on the numerical method (N%), volumetric method (V%), frequency of occurrence (F%), and the index of relative importance (IRI), revealed that crustaceans formed the dominant dietary component. Crustaceans (crabs, shrimps, and prawns) accounted for the highest numerical percentage (49.9%), the greatest volumetric percentage (50.8%), and the highest frequency of occurrence (33.8%), resulting in an overwhelmingly high IRI value of 3397.2. This indicated that crustaceans were the most important prey group in the diet of *F. margarita* during the study period.

This finding aligns with the work of Orose et al. (2021), who also reported crustaceans as the primary diet component of *Dasyatis margarita* in the Niger Delta estuaries, with similar dominance in IRI values. Likewise, Palma et al. (2024) documented a crustacean-based diet in *Dasyatis garouaensis* from the Lake Chad Basin, suggesting a common trophic trend among benthic stingray species in West African waters. Annelids ranked second in importance, contributing 20.6% numerically and 15.5% volumetrically, with a frequency of occurrence of 15.1%, and an IRI of 545.2. This is consistent with the observations of Queiroz et al. (2023), who noted annelids as secondary prey for stingrays off the Brazilian north-eastern coast, indicating their availability in soft-bottom habitats where these rays forage.

Fish were also a significant dietary item, comprising 20.1% by number and 23.9% by volume, although they appeared less frequently (13.6%) in the stomachs examined, yielding an IRI of 596.3. This reflects the ray's ability to prey on more mobile organisms when available. A similar pattern was observed by Mensah et al. (2019) in their study of *Dasyatis margarita* in Ghanaian coastal waters, where fish were a substantial but less frequent diet component due to seasonal fluctuations in prey availability.

Molluscs were the least important prey group, representing only 9.4% numerically, 9.8% volumetrically, and 7.2% by frequency of occurrence, with the lowest IRI value of 137.9. Although molluscs formed a minor part of the diet in this study, Demeke-Admassu & Tadesse (2015) recorded similar molluscan presence in the diet of *Gymnura altavela* from the Lagos Lagoon, suggesting occasional consumption based on encounter rates rather than preference.

Table 3 presented the stomach content analysis of the Daisy Stingray categorized by size groups based on disc width (Small: ≤20 cm, Medium: 21–30 cm, and Large: >30 cm). In all size groups, crustaceans emerged as the dominant prey item, with the highest numerical percentages: 49.8% in small individuals, 49.9% in medium individuals, and 49.8% in large individuals, respectively. This dominance was further emphasized in the occurrence method, where crustaceans appeared in 66.7%, 22.3%, and 72.4% of stomachs for the small, medium, and large size groups respectively, indicating their critical role in the diet throughout growth stages. These findings align closely with those of Queiroz et al. (2023), who reported crustaceans as the primary dietary component in several Dasyatidae rays, including *Dasyatis spp*., particularly in juveniles and subadults.

Fish were the second most important prey group, contributing approximately 20.0–20.1% numerically across all sizes and appearing frequently in the occurrence method, especially in larger stingrays (69.0%). This increasing reliance on fish with size may suggest a gradual shift toward more energetically profitable prey as the rays mature. The observed ontogenetic shift toward increased fish consumption in larger *F. margarita* may be attributed to enhanced swimming ability and greater mouth gape, which facilitate the capture of more mobile prey. Additionally, higher energetic demands during growth likely favour prey with superior nutritional value, as fish generally provide higher protein and lipid content than crustaceans, annelids, and molluscs, making them more profitable dietary resources (Mihalitsis & Bellwood, 2017). Annelids also contributed notably, maintaining about 20.6–20.7% numerically but showing slightly lower occurrence percentages, particularly in medium-sized individuals (14.9%). This pattern is consistent with the findings of Branco-Nunes et al. (2019) in *Dasyatis spp*, where annelids were recorded as secondary prey, more prominent in smaller specimens. Their soft-bodied nature may make them suitable prey for developing stingrays.

Molluscs, while present, represented the least proportion across all size classes, with numerical contributions ranging between 9.4% and 9.5% and occurrence rates comparatively low (4.5%–31.0%). This aligns with the dietary profiles reported for *F. margarita* and related species by Averbuj et al. (2021), who noted molluscs as occasional prey, likely opportunistically consumed due to their relative availability and handling complexity.

Seasonal Food Items of Daisy Stingray

Tables 4 summarized the seasonal variation in the diet composition of the studied fish species, based on both the numerical method (N%) and the occurrence method during the dry season (November–April) and wet season (May–October). In the dry season, crustacea were the most dominant prey item, representing 42.3% of the total number of food items consumed (numerical method) and appearing in 33.7% of the stomachs examined (occurrence method). This dominance is consistent with the findings of Orose et al. (2021), who reported a high prevalence of crustaceans in the diet of estuarine and coastal fish species in Nigerian waters during low-flow periods when benthic invertebrates are more accessible.

Annelids were the second most abundant prey group, accounting for 27.2% numerically and occurring in 14.6% of the stomachs. The relatively high annelid consumption during the dry season aligns with Branco-Nunes et al. (2019), who noted their seasonal abundance in sediment-rich substrates during dry months.

Table 3. Stomach content of the daisy stingray, *Fontitrygon margarita* (by size groups/ disc width) off Lagos coastal waters, Nigeria (February, 2023 – July, 2024)

Type of Organism	Small (≤ 20 cm)				Medium (21–30 cm)				Large (>30 cm)			
	Numerical Method		*Frequency of Occurrence*		*Numerical Method*		*Frequency of Occurrence*		*Numerical Method*		*Frequency of Occurrence*	
	No	*N%*	*F*	*F%*	*No*	*N%*	*F*	*F%*	*No*	*N%*	*F*	*F%*
Annelida	98	20.7	18	24.0	163	20.7	30	14.9	65	20.6	12	41.4
Crustacea	236	49.8	50	66.7	393	49.9	45	22.3	157	49.8	21	72.4
Fish	95	20.0	20	26.7	158	20.1	20	9.9	63	20.0	20	69.0
Mollusca	45	9.5	9	12.0	74	9.4	9	4.5	30	9.5	9	31.0

Table 4. Seasonal variation in stomach contents of the daisy stingray, *Fontitrygon margarita* off Lagos coastal waters, Nigeria (February, 2023 – July, 2024)

Type of Organism	Dry Season (November – April)				Wet Season (May – October)			
	Numerical Method		*Frequency of Occurrence*		*Numerical Method*		*Frequency of Occurrence*	
	No	*N%*	*F*	*F%*	*No*	*N%*	*F*	*F%*
Annelida	274	27.2	38	14.6	51	9.0	21	16.2
Crustacea	426	42.3	88	33.7	359	63.4	44	33.8
Fish	203	20.1	35	13.4	113	20.0	18	13.8
Mollusca	105	10.4	17	6.5	43	7.6	11	8.5

Fish prey formed 20.1% of the diet by number and occurred in 13.4% of stomachs, reflecting a carnivorous tendency consistent with findings by Mihalitsis & Bellwood (2017), which also showed increased piscivory during resource-scarce periods. Molluscs were the least represented, contributing 10.4% numerically and appearing in 6.5% of the stomachs—similar to observations by Demeke-Admassu & Tadesse (2015) in *Clarias gariepinus*, which reported low mollusc ingestion due to their hard shells and limited availability in some benthic environments.

During the wet season, crustacea remained the dominant prey group, with an even higher numerical contribution of 63.4% and occurrence in 33.8% of stomachs. This indicated an increased reliance on crustacean prey during periods of higher rainfall, possibly due to increased runoff and nutrient input enhancing crustacean productivity, a pattern also reported by Orose et al. (2021). However, the contribution of annelids decreased notably, forming only 9.0% of the diet numerically and occurring in 16.2% of stomachs, although the frequency of occurrence was slightly higher than in the dry season. This decline mirrors seasonal availability patterns described by Queiroz et al. (2023), who observed that annelid populations often decline in oxygen-deficient or flood-prone benthic zones during the rainy season.

During the wet season, crustaceans may dominate the diet of *F. margarita* due to elevated primary productivity driven by nutrient runoff from rivers and increased surface mixing, boosting availability of crustacean prey. Enhanced freshwater flow also alters salinity and oxygen levels, increases sediment disturbance, and reduces habitat suitability for annelids and molluscs, likely causing their observed seasonal decline (Machovsky-Capuska & Raubenheimer, 2020). These seasonal shifts probably affect *F. margarita*'s energy intake and nutritional balancing, since crustaceans are relatively protein-rich and energetically valuable, helping compensate for lower contributions from softer, less mobile prey.

The proportion of fish prey remained relatively stable, constituting 20.0% numerically and 13.8% by occurrence, confirming the consistency of piscivory regardless of season, as also documented by Neves et al. (2021) in estuarine fish species. Similarly, molluscs continued to contribute the least to the diet, accounting for 7.6% numerically and 8.5% by occurrence, likely due to limited accessibility during flooding and sediment transport.

CONCLUSION

This study provides insights into the feeding behaviour of the daisy stingray (*F. margarita*) in Lagos coastal waters, highlighting temporal, seasonal, and ontogenetic patterns. The consistent proportion of empty stomachs (26.23%) indicates stable year-round feeding, suggesting favourable environmental conditions and prey availability. Crustaceans were the dominant prey across seasons, while annelids, fish, and molluscs served as secondary items, with wet-season declines in annelid and mollusc consumption reflecting hydrological influences. Ontogenetic shifts were evident, as larger individuals expanded dietary breadth and consumed more mobile prey such as fish, consistent with enhanced predatory capability. Continued long-term monitoring is strongly recommended to track dietary responses of *F. margarita* to both natural ecological shifts and anthropogenic disturbances, such as pollution, habitat destruction, and fishing pressure. This information is crucial to support the development and implementation of effective and sustainable management strategies for this ecologically important species. The findings of this study can inform fisheries management practices by providing a better understanding of the trophic dependencies of *F. margarita* and the potential impacts of environmental change on its food resources.

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Compliance with Ethical Standards

Authors' Contributions

ANI: Conceptualization, Investigation, Writing – review & editing

OOS: Conceptualization, Investigation, Supervision

MOS: Investigation, Methodology, Formal analysis

All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

This study was carried out with strict recommendation and approval of the health research ethics committee of the college of medicine, university of Lagos, Nigeria. Registration number: CMUL/ACUREC/08/23/1255.

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Data Availability

The authors confirm that the data supporting the findings of this study are available within the article.

AI Disclosure

The authors confirm that no generative AI was used in writing this manuscript or creating images, tables, or graphics.

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