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Original Article

Gut content analysis of snake mackerel *Gempylus serpens* (Cuvier, 1892) in Iligan Bay, Northern Mindanao, Philippines

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Abstract: Gut content analysis of the snake mackerel, *Gempylus serpens* (Cuvier, 1829), a commercially important fish in Iligan Bay, Philippines, is critical for understanding its ecological role in marine ecosystems. From July 2022 to March 2023, 58 individuals (total length 64.3 to 100.7 cm) were collected from Barangay Tambacan, Iligan City, a coastal city along Iligan Bay in Northern Mindanao, Philippines. Fish were the dominant prey, indicated by mean weight, frequency of occurrence, and index of relative importance. Cannibalism was documented, as two specimens contained remains of *G. serpens*. The species is a generalist predator, and significant positive correlations were found between gut length and total length, and between body weight and stomach weight with contents. Prey items were mostly in advanced stages of digestion, suggesting rapid digestion. This study highlights the ecological significance of *G. serpens* in Iligan Bay. Understanding the feeding ecology of *G. serpens* enriches our knowledge of marine food webs and supports the development of sustainable fishing practices, ensuring the long-term health of marine ecosystems.

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Introduction

Gempylus serpens (Cuvier, 1829), commonly known as the snake mackerel, is the sole representative of the genus *Gempylus*, one of 16 genera within the family Gempylidae (Nakamura and Parin, 1993; Nelson, 2006; Froese and Pauly, 2009). This species is cosmopolitan, inhabiting tropical and subtropical waters worldwide, including Iligan Bay in Northern Mindanao, Philippines. Typically found at mesopelagic to bathypelagic depths of up to 600 meters, *G. serpens* is a solitary, mid-level predator that exhibits diel vertical migration, moving toward surface waters at night to feed (Nakamura, 1990; Da Silva and Kerstetter, 2010).

Characterized by its elongated body, sharp dentition, and distinctive coloration, *G. serpens* preys primarily on myctophids, sauries, exocoetids, scombrids, cephalopods, and crustaceans, often employing an ambush strategy (Da Silva and Kerstetter, 2010; Choy et al., 2013). Although not targeted in commercial fisheries, the species is frequently encountered as bycatch, particularly in longline tuna operations (Nakamura and Parin, 1993). Ecologically, its predatory role helps structure midwater food webs, making it a species of interest for understanding marine ecosystem dynamics (Polovina and Woodworth-Jefcoats, 2013).

Iligan Bay is a biologically rich marine ecosystem that supports diverse coastal habitats, including coral reefs, seagrass beds, and mangrove forests. These habitats sustain high species diversity, including various fish, invertebrates, and marine plants (Recamara and De Guzman, 2015; Quiñones et al., 2020). The bay plays a significant role in the socio-economic well-being of surrounding communities, supporting both artisanal and commercial fisheries (Magsayo and Lacuna, 2018). Understanding the feeding ecology of species like *G. serpens* is essential for assessing trophic interactions and the sustainability of the bay's fisheries.

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Figure 1. A representative image of snake mackerel, *Gempylus serpens*, collected from Iligan Bay, Philippines.

Diet and gut content analyses are vital for elucidating the trophic roles of marine species. These methods provide insights into feeding habits and ecological functions, informing the structure and dynamics of aquatic food webs (Baker et al., 2014). Such information is crucial for implementing Ecosystem-Based Fisheries Management (EBFM), which emphasizes holistic management strategies that account for species interactions and environmental contexts (Hornborg et al., 2019). Dietary patterns are influenced by both extrinsic factors, such as habitat and prey availability, and intrinsic traits, including species-specific behaviors, morphology, and ontogeny (Peck et al., 2012). Therefore, understanding the feeding ecology of *G. serpens* not only advances knowledge of its biology but also supports ecosystem-wide conservation and sustainable fisheries management in regions such as Iligan Bay. Here, we investigated the feeding habits of snake mackerel from Iligan Bay, Northern Mindanao, by identifying preferred prey items through gut content analysis, determining whether the species exhibits dietary specialization, and analyzing the relationship between gut content and body length and weight.

Materials and Methods

Sample collection: Snake mackerel samples (Fig. 1) were collected from three stations in Barangay Tambacan (8°15.412'N, 124°11.732'E, 8°16.351'N, 124°11.872'E, 8°14.650'N, 124°13.247'E), Iligan City (Fig. 2), in July 2022, and October 2022 to March 2023. The hook-and-line method was used by the fishermen to capture the specimens.

Before dissection, the following morphometric measurements were obtained for each sample: Total Length (TL), Fork Length (FL), and Standard Length (SL). The length was measured to the nearest centimeter (cm), and the weight to the nearest gram (g). The stomach contents of the dissected fish samples were removed, and their weight was determined.

Dietary composition: The weight of each food item was measured using a sensitive digital balance. The stomach contents were placed in a petri dish and classified into various food categories. For each stomach, the weight of the preserved specimens of each prey taxon was recorded. Visual identification of prey was performed. In addition, photographs were obtained by spreading the prey on a whiteboard.

The digestive tract of fish samples was extracted from adult fish samples by cutting from the most anterior part of the esophagus to the most posterior end of the intestine. Using a digital weighing scale, each stomach sample will be weighed to within 0.1 grams. The stomach samples were weighed and placed in a freezer overnight. The contents of the stomach samples were properly flushed into clean plastic containers and stored in 70% ethanol. After the stomach samples' contents are removed, they will be reweighed (to within 0.1 grams) on a digital weighing scale. Each preserved prey item was categorized into groups such as fish, cephalopods, and other items.

The simplest way to assess the dietary composition of a fish population and determine the relative importance of various food items was to collect presence-absence data for each food item across all individuals. The significance was estimated from the percentage of all intestines that each dietary product occupies (Baker et al., 2014): $\%O_i = N_i/N \times 100$, where $\%O_i$ = frequency of occurrence of given food I, N_i =

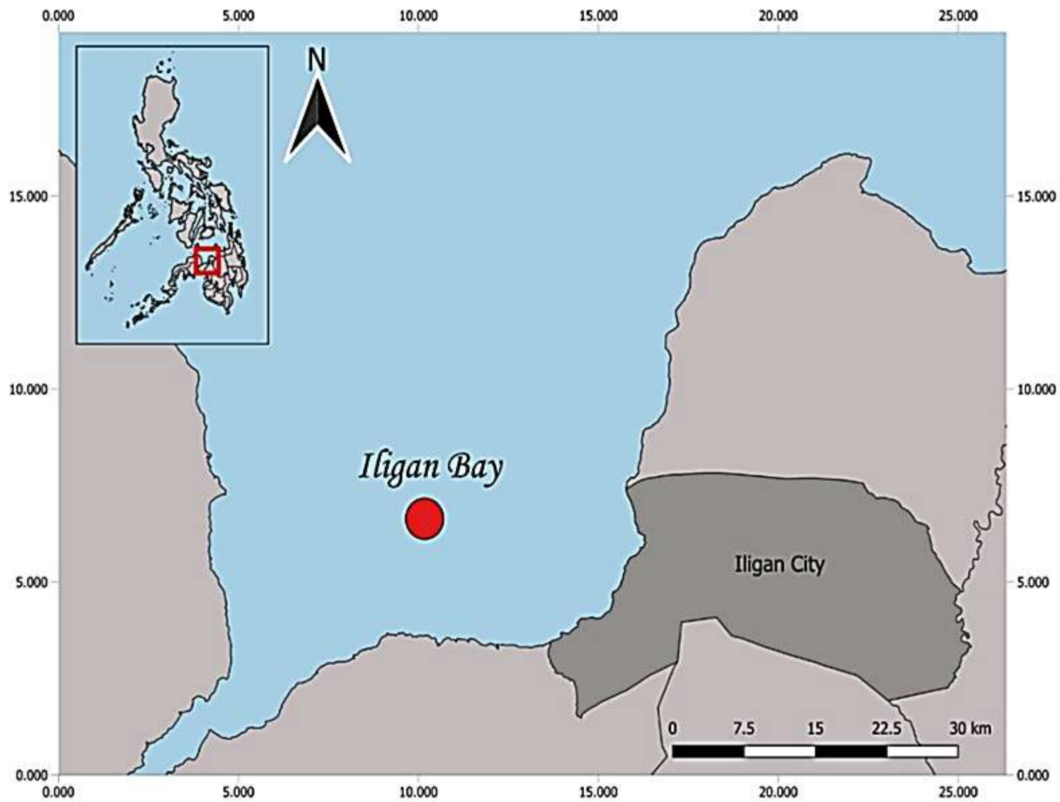

Figure 2. Map of Iligan Bay, Northern Mindanao, Philippines, where *Gempylus serpens* were collected.

number of stomachs containing food item *I*, and N =total number of stomachs with content.

In addition, the percentage of the total number of food items in all the examined fish stomachs and the number of individuals of each food group in each stomach were calculated using the formula of (Sagar and Eldon, 1983) $\%Ni = Ni/Nt$ x100, where, %N = percentage of food item *I*, N_i = number of particular food item *I*, and N_t = total number of food (gut content) items. Utilizing the percentage of the total weight of the gut contents that the particular food item occupies, its weight was calculated using the formula of $\%Wi = Wi/Wt$ x 100, where $\%W_i$ = ratio of the food item *I*, W_i = weight of food item *I*, and W_t = total weight of food (gut content).

The meal weight-to-body weight ratio was expressed as the Index of Fullness. This index is widely used and can be applied to food in the stomach or throughout the digestive tract. Generally, it is expressed as parts per 10,000 (%00, or parts per decimal) and is calculated using a formula (Edo et al., 2005) of $ISF=Wg / Wf$ x100, where W_g = weight of the stomach contents (in grams), and W_f = fish body weight.

The Index of Relative Importance measures the relation between the different food items found in the stomach by multiplying the percentage of frequency of occurrence of each food item (%O) by the total percentage by weight (%W) and percentage by number (%N). IRI is a composite index used to characterise fish diets and determine the relative importance of common dietary groups (Pinkas, 1971) and calculated as $IRI = (\%N + \%W) * \%O$, where, %N = percentage of the specific food category by number, %W = the percentage by weight, and %O = frequency of occurrence percentage of each food item

Feeding strategy determination: The method of Costello (Lima-Junior, 2001; Eya et al., 2011) was used to determine whether the species are generalists or specialists. A scatter plot of percentage weight values on the y-axis and occurrence frequency on the x-axis is used. Points near 1% of occurrence and 1% of weight indicated that the predator devoured a variety of prey in small quantities. In contrast, points

Table 1. Mean weight (MW%), frequency of occurrence (%O), percentage by number (%N), percentage by weight (%W), index of relative importance (IRI), and % IRI for each food item.

Food item	MW%	%O	%N	%W	IRI	%IRI
Fish	56.74	67.57	39.29	36.97	5152.52	78.51
Cephalopod	15.92	32.43	16.96	18.89	1162.76	17.72
Unidentified	13.96	13.51	8.93	8.93	241.31	3.68
Other (Squid jig/lure)	13.38	2.70	0.89	1.28	5.88	0.09

near 100% occurrence and 100% weight indicate that the predator is a specialist on a particular prey species. To determine whether the fish in this study are generalists or specialists, their prey items were graphed (Amundsen et al., 1996).

The body and gut length measurements, as well as the body and gut weight measurements, were analyzed using the Pearson correlation coefficient (r) to assess the relationship between length and weight. If the coefficient of determination (R2) is greater than 0.5 or close to 1.0, there is a correlation; if it is below 0.5, there is no correlation. In Microsoft Excel, the body length, gut length, body weight, and gut weight were also plotted. Length and weight of the body were plotted on the x-axis, while the length and weight of the stomach were plotted on the y-axis.

Ethical statements: This statement is made to ensure that the research study followed ethical guidelines in accordance with the U.K. Animals (Scientific Procedures) Act, 1986, and associated guidelines, EU Directive 2010/63/EU for animal experiments, and the National Institutes of Health guide for the care and use of Laboratory animals (NIH Publications No. 8023, revised 1978).

Results

Dietary composition: A total of 58 individual *G. serpens* ranging from 64.3 to 100.7 cm in total length (TL) were collected. Out of the 58 fish examined, 19 (33%) were with empty stomachs. Seasonal changes in fish are not a factor in the empty stomachs, since the percentage of snake mackerels with contents was similar every month. Food items of *G. serpens* were categorized into four main groups (Table 1; Fig. 3): fish, cephalopods, unidentified prey items, and others. Unidentified prey items were in advanced stages of digestion. A squid lure found in the stomach is categorized as 'other'.

Fish made up most of the overall stomach content by mean weight, at 56.74%, followed by cephalopods (mainly squid), at 15.92%; unidentified digested food items were third at 13.96%, and other items were last at 13.38% by mean weight. 67.57% of the stomachs that have contents contain fish, followed by cephalopods, which are present with 32.43% of the total number of stomachs that have contents.

Most of the snake mackerel's diet (39.29%N) consisted of fish, followed by cephalopods, unidentified prey items, and other items, with 16.96%N, 8.93%N, and 0.89%N, respectively. By weight, *G. serpens* fed dominantly on fishes (36.97%W), and secondarily on cephalopod (18.89%W), followed by unidentified prey items with 8.93%W and others with 1.28%W (Table 1).

The index of relative importance (IRI) of the various dietary items found in the stomachs of all the examined fish, based on the weight percentage (%W), numerical percentage (%N), and frequency of occurrence (%O), is presented in Table 1. IRI was also applied to interpret the recorded data, as it has been shown to reduce bias in descriptions of animal dietary data (Hart et al., 2002). The IRI has fish at 5152.52, cephalopods at 1162.76, unidentified prey at 241.31, and others at 5.88.

Feeding strategy: The scatter plot consists of percentage weight values on the y-axis and frequency of occurrence on the x-axis. The points (in symbols) show that fish has 68% frequency of occurrence with 37% of weight, while cephalopod has 32% of frequency of occurrence with 19% of weight, unidentified prey items have 14% of weight and 13% of frequency of occurrence, and lastly, other food prey has 1% weight and 3% frequency of occurrence. Although the fish has a frequency of occurrence above

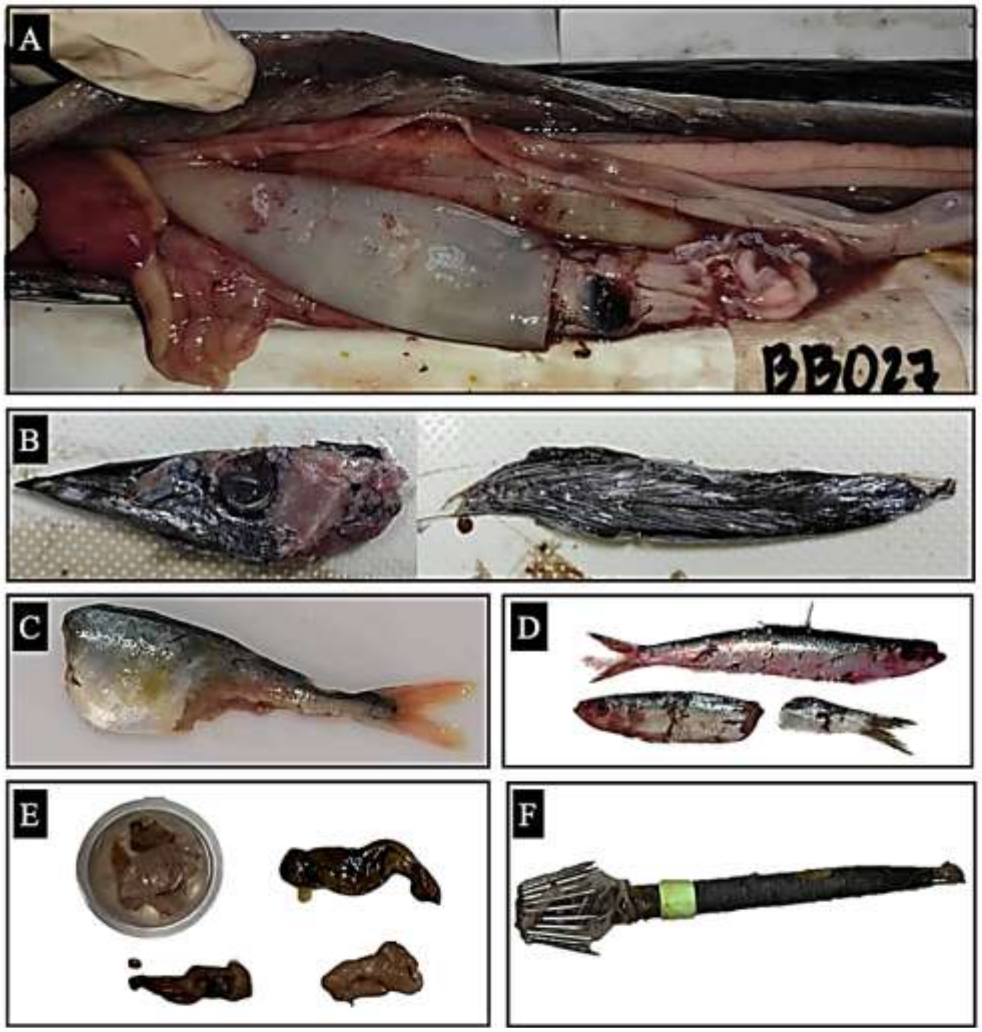

Figure 3. Representative photos of prey and other items found in the gut of *Gempylus serpens*: (A) cephalopod; (B) Snake mackerel, (C) Redtail scad *Decapterus kurroides*, (D) sardines *Sardinella* sp., (E) unidentified food items, and (F) squid lure.

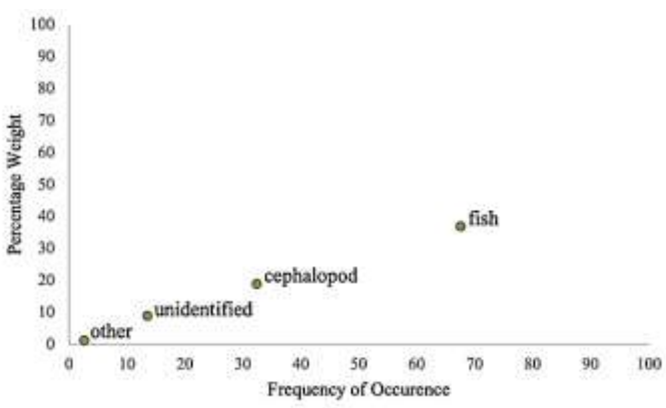

Figure 4. Prey items in the stomach of *Gempylus serpens* using Costello's method.

50%, the other factors had low volume and frequency percentages; thus, *G. serpens* is a generalist (Fig. 4).

Length and weight correlations: Using the Pearson correlation coefficient (r), the r value between the gut length and total length is 0.57 (Fig. 5A). A correlation coefficient greater than 0.5 indicates a relatively strong correlation (Santoso, 2002). Hence, there is a significant positive relationship between gut length and total length in *G. serpens*. A positive correlation between gut length and total length suggests a biological relationship between the two variables. This means that as gut length increases, total length tends to increase as well. As fish increase in size, the volume of their food increases, requiring a longer stomach to maintain effective digestion (Ribble and Smith 1983).

For body weight and gut weight (contents), the correlation was positive, with an r value of 0.54 (Fig. 5B). This means that as stomach weight increases, body weight increases as well. A Pearson correlation coefficient of 0.54 is typically less than 0.05, which means there is less than a 5% chance that the

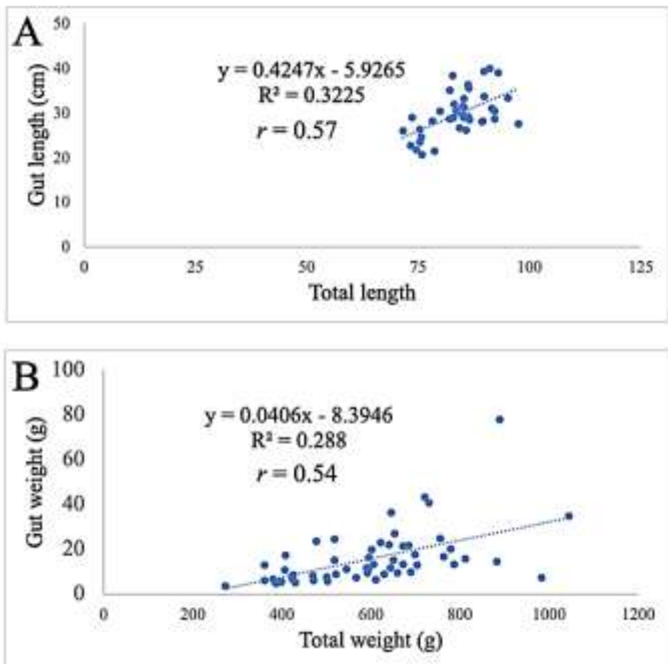

Figure 5. Correlation between the (A) gut length and the total length and (B) gut weight and the total weight of *Gempylus serpens*.

correlation is due to chance. This means the correlation is likely real and not a coincidence.

Discussions

All 58 *G. serpens* individuals collected in this study exceeded the reported size at sexual maturity, i.e., 43 cm standard length (SL) for males and 50 cm SL for females (Bianchi et al., 1999). This confirms that all specimens were mature adults, thereby providing a reliable basis for analyzing dietary composition and interpreting feeding strategies representative of the adult population.

Dietary composition: Gut content analysis is a widely used method for studying fish diets and feeding habits, providing insight into key ecological aspects such as behavior, habitat use, energy intake, and species interactions (Nat et al., 2015). Accurate dietary data is essential for understanding trophic relationships in aquatic food webs (Zanden and Rasmussen, 2001) and for informing Ecosystem-Based Fisheries Management (EBFM). This is particularly important for high-value pelagic species, as diet influences migratory and shoaling behaviors. Fish diets vary based on both extrinsic (e.g., habitat, region) and intrinsic (e.g., species, size, behavior) factors (Hanson et al., 2002).

By analyzing the gut contents of *G. serpens* in this study, we confirmed that it is carnivorous. A study by Osmany et al. (2019) shows that *G. serpens* is carnivorous, feeding primarily on fish and cephalopods. Previous studies have reported that *G. serpens* exhibits diel vertical migration, moving through water depths daily to feed and avoid predators (Watanabe et al., 2009; Blend et al., 2010; Gjøsæter et al., 2017). Its diet is diverse, consisting mainly of squid, shrimp, and krill (Choy et al., 2013). As an ambush predator, it uses its streamlined body and sharp teeth to quickly capture prey, and vertical migration enhances its hunting efficiency (Blend et al., 2010).

Interestingly, a head-and-body fragment of a snake mackerel was found in the stomach contents, suggesting possible cannibalism. While Choy et al. (2013) reported that snake mackerels prey on other gempylid species, they did not document intraspecific predation. Redtail scad, *Decapterus kurroides*, was also found in one of the fish's stomachs, and no reports have been found regarding snake mackerels consuming redtail scads. A sardine species was also identified, further expanding the known diversity of fish prey for snake mackerel. However, other fish prey items could not be identified to species level because almost all of the contents were in advanced stages of digestion, and only fish bones were recognizable. According to Da Costa and Angelini (2020), gut content analysis of carnivorous fishes commonly shows a high rate of digestion and food deterioration, which further implies that snake mackerels are carnivorous.

An IRI of 78.51% for fish and 17.72% for cephalopods suggests that fish are the primary dietary component of *G. serpens*, with cephalopods being the secondary food item. Unidentified food prey and other items make up a much smaller proportion of the diet. This is likely because fish are relatively abundant and easy to catch. Cephalopods are also a common prey item, but they are more difficult to catch than fish. This could also mean that there are more fish in Iligan

Bay than squid, and that fish are a more accessible food than squid and other prey.

The presence of a squid jig in the gut of *G. serpens* suggests accidental ingestion, likely during active predation. As a visual predator that primarily feeds on cephalopods such as squids (Choy et al., 2013), *G. serpens* may have mistaken the jig for a natural prey item. Such incidents are not uncommon among predatory pelagic fishes, especially in areas where squid fishing occurs. Accidental ingestion of fishing gear, including jigs and lures, has been reported in several fish species (Snaft et al., 2018). The finding also suggests spatial overlap between *G. serpens* and squid fisheries, potentially increasing interactions with fishing gear.

Feeding Strategy: Based on Costello's method, snake mackerel are opportunistic feeders that are not picky about their food. They will eat a variety of different prey items depending on availability, but fish are their preferred food. The redtail scad present in its stomach also indicates that the snake mackerel is a generalist, as it was not reported in any other work that redtail scad is part of the snake mackerel's diet. In addition, there have been no studies of snake mackerels as cannibals. However, in this study, snake mackerel body parts were found in the stomachs, further suggesting that snake mackerel is a generalist species.

Length and weight correlations: A positive, moderately strong correlation ($r = 0.57$) was found between total length and gut length in *G. serpens*, indicating that as individuals grow, their digestive tract lengthens proportionally. This is a common allometric adaptation in predatory fish species, in which greater digestive capacity is required with increasing body size (Ribble and Smith, 1983; Kramer and Bryant, 1995). Similarly, a positive correlation ($r = 0.54$) between body weight and gut weight (with contents) was observed, suggesting that heavier fish tend to have recently consumed meals or have greater stomach capacity. Such physiological scaling relationships are consistent with those of other carnivorous fish species and reinforce the conclusion that *G. serpens* is a size-structured predator whose feeding capacity increases with size.

Conclusion

A total of 58 *adult G. serpens* were collected over six months, though this sample does not reflect the species' true abundance or size distribution due to its rarity as longline bycatch. Gut content analysis confirmed a predominantly carnivorous diet, with fish as the primary prey, followed by squid and unidentified digested matter. No crustaceans were found, in contrast to earlier reports. Notably, evidence of cannibalism was observed. The species appears to be a generalist feeder, which may enhance its adaptability to changing environmental conditions. Significant correlations between gut length and body length, as well as body weight and stomach content weight, were observed. Most prey items were in advanced digestion, indicating rapid processing. Further research is recommended to better understand the dietary patterns of *G. serpens*.

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