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Feeding dynamics and diet composition of Giant trevally (*Caranx ignobilis*) from the Kerala coast

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Original Article

Abstract

The diet composition and feeding intensity of the Giant trevally, *Caranx ignobilis*, along the Kerala coast, was studied during 2018-2019. The feeding behaviour of *C. ignobilis* revealed that it is a highly carnivorous species having a selective feeding nature, with fish accounting for 82% of the stomach contents, followed by crustaceans (13.7%) and molluscs (2.7%). Crabs emerged as the predominant individual prey item, accounting for an Index of Relative Importance (IRI) of 29%. The Stomach Fullness Index (SFI), the Vacuity Index (VI) and the gastro-somatic index were evaluated to assess its feeding dynamics. The SFI was significantly higher in spawning months (August to December) showing a direct relationship with feeding intensity. The VI showed variation in feeding during different months with the lowest VI in October (15%) and the highest in February (80%). Generally, the VI was higher from January to July and lower from August to December. Gastro somatic index was also found to be in a positive correlation with breeding time for *C. ignobilis.*

Keywords: *Caranx ignobilis, index of relative importance, stomach fullness Index Gastro somatic Index, vacuity index*

Introduction

The understanding of the feeding and diet composition of a fish species is crucial, as it provides important information on its habitat, mainly the feeding ground and feeding nature of the fish. Research on feeding nature and food preferences helps in tracing out the migratory pattern in fishes. A comprehensive study of their diet lends support to aquaculture, conservation, and management of their aquatic environment. It also helps in standardising breeding and farming technology supporting the species in captivity. The ecological role and position of a species in the food web of ecosystems can be assessed by looking at its feeding behaviours (Allan and Castillo, 2007). Studies on feeding intensity can also aid in explaining many physiological changes happening in the body, like the breeding time, spawning season, etc. The feeding nature of the fish is dynamic with size, time, day (dawn and dusk) and season (Azadi *et al*., 2008).

Caranx ignobilis, commonly known as the Giant Trevally, is a species of significant economic importance globally, recognized for its high mariculture potential in countries such as Japan, Australia, and Indonesia. The majority of the studies on *C. ignobilis* have been conducted in Hawaiian waters (United States). In India, comprehensive studies about the species have been conducted by Abdussamad *et al.* (2008) focusing on biology and fishery. In India, the Central Marine Fisheries Research Institute (CMFRI) has successfully bred this species for mariculture. Ecologically, *C. ignobilis* serves as an apex predator in reef habitats, playing a vital role in maintaining the balance of marine ecosystems. Research conducted in the pristine waters of the Hawaiian Islands shows that Giant Trevallies constitute an impressive 71% of apex predator biomass, whereas their populations in heavily fished regions are significantly diminished. Understanding the feeding habits and food preferences of *C. ignobilis* within Indian aquatic ecosystems is essential as unique environmental parameters, including water temperature, salinity, and food availability, directly influence the growth and behaviour of this species. By improving feeding strategies, we can minimize waste and increase profitability for fish farmers. Therefore, a detailed examination of the feeding habits of

C. ignobilis is crucial for advancing aquaculture practices and fostering sustainable management of this economically and ecologically important species.

Material and methods

The study area was in the Arabian Sea, off the southwest coast of India between Lat. 11.84°- 15.552° and long. 73.3870°-75.274°). The samples were collected from local fishing harbours at Cochin. The length, sex, weight, and reproductive maturity of each specimen were also recorded. Samples were categorised in to male and female to determine if there exist any variations in the feeding activity and diet composition among their sexes. Out of the 576 *C. ignobilis* samples collected, 342 were males and 234 were females with length ranging from 45 to 145 cm and weight ranging from 2.5 to 35 kg. the samples were identified (Forsakkal, 1775) and then measured, and weighed to the nearest 0.01g. To study the diet composition, the samples were dissected and the stomach contents were collected. Each of the prey items was identified to the lowest taxonomic level possible by using appropriate taxonomic identification guides. The partially digested fish remains were grouped as semi-digested or unidentified. Each of the prey items inside the dissected stomach was recorded for their weight, number, and frequency of occurrence and are expressed in their corresponding percentage (Hyslop, 1980). The index of relative importance (IRI) (Pinkas *et al.*, 1971) was calculated for each prey item and converted into a corresponding percentage based on three indices: (i) a percentage of the wet weight of each food item to the total wet weight of all food items identified (%W); (ii) a percentage of the number of each food item to the total number of all food items identified (%N); and frequency of occurrence of each food item in the total number of stomachs examined (%F).The index of relative importance (IRI) was calculated as IRI= (%N+%W) ×%F. IRI is a composite index that is used to determine the relative significance of common food groups and to characterise fish diets (Pinkas *et al.*, 1971; Prince, 1975).

Feeding intensity was observed through eye estimation by classifying the stomach as empty, trace, ¼ full, ½ full, ¾ full, and full. The feeding periodicity was observed by assessing the Stomach Fullness Index Gastro/somatic Index and the Vacuity Index respectively. The stomach fullness index was estimated as

$$SFI \; \frac{\text{Weight of the stomach content}}{\text{Body weight-weight of the stomach content}} \; X\,100$$

(Chiou *et al.*, 2006). The vacuity index (VI) of the sampled stomach which corresponds to the percentage of empty stomachs (ES) to the total number of stomach (TS): VI= ES / TS x 100 (Biswas, 1993) classified fish into five categories based on their level of feeding intensity: 0≤VI≤20 denoted fish that were edacious, 20≤VI≤40 somewhat edacious, 40≤VI≤60 moderate feeding, 60≤VI≤80 relatively abstemious, and 80≤VI≤100 abstemious fish (Euzen, 1987). To find the effect of environment and other physiological effects on feeding habits the Gastro somatic Index was also calculated GaSI was calculated using the equation suggested by Desai (1970). GaSI= Weight of the gut (g)/weight of the fish * 100. All these three parameters (SFI, GaSI, VI) and their relationship to the breeding season were tested for any significance by t test in Python software.

Results

Diet composition and IRI

The stomach content of *C. ignobilis* identified 21 taxonomic species from different phyla with 847 individuals weighing a total of 49564 g. Teloest fishes contribute much of the prey items (83%) followed by crustaceans (14%) and molluscs (3%). Among the fishes Anchovies, Puffer fish, Triggerfish*, Decapterus ruesseli* and Sardines make up the high-priority prey item. The second largest is the Crustaceans mainly consisting of *Charybdis smithi* and *Penaeus indicus.* Molluscs were mainly composed of *Uroteuthis duvaucelii* and *Cistopus indicus*. Unidentified semi-digested fish contribute another sizable portion of their diet including various parts of the fishlike fins, scales, bones, and vertebrae. Apart from this, coral stones and sand particles were also found in minor quantities. Among the fishes, *Odonus niger* (IRI -14.53) forms the major prey item and *C. smithi* (IRI 29.29) and *Uroteuthis duvauceli* (IRI-5.4) for crustaceans and molluscs respectively. The percentage composition of each prey item (Table 1) and the contributions of major groups in each month were depicted in Fig. 1. The Observation of food items in each month revealed that the percentage occurrences of fish were highest in February (95%), April (90%), and December (94%). Crustaceans were found to be highest in March (28.7%), September (38%), and

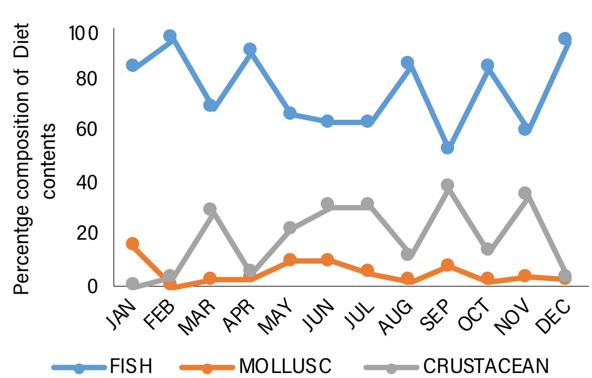

Fig. 1. Major prey groups identified for *C. ignobilis* in different months

Table 1. Diet composition of prey items in the gut of *C. ignobilis*

Species	N%	W%	O%	%IRI
Odonus niger	9.21	16.49	11.11	14.53
Arothron stellatus	7.91	15.08	6.35	7.43
Sardinella longiceps	9.21	6.78	5.56	4.52
Decapterus russelli	5.43	5.65	4.76	2.68
Stolephorus commersoni	12.28	2.32	3.17	2.36
Cynoglossus macrostomus	7.08	2.70	2.78	1.38
Leognathus spp.	4.60	1.29	1.98	0.60
Parupenaeus indicus	1.18	1.13	1.98	0.23
Trichiurus lepturus	0.47	1.58	1.59	0.17
Lutjanus lutjanus	0.71	2.02	1.19	0.17
Lethrinus rubrioperculatus	0.24	0.40	0.40	0.01
Nemipterus japonicus	1.42	0.81	0.79	0.09
Auxis thazard	0.24	1.33	0.79	0.06
Alepis dledaba	0.47	1.01	1.19	0.09
Semi digested fish	13.11	13.69	21.43	29.21
Charybdis smithi	13.58	16.03	19.44	29.29
Penaeus indicus	7.08	1.21	3.97	1.67
Uroteuthis duvaucelii	4.84	7.45	8.33	5.21
Cistopus indicus	0.59	1.92	1.98	0.25
Snail	0.24	0.81	0.79	0.04
Coral stones	0.12	0.29	0.40	0.01

N% -percentage of number, W%- percentage of weight, O% -percentage of occurrence, IRI-Index of relative importance

November (35%) Molluscs comprised of *Uroteuthis duvaucelii* which was highest in January with 13 % (Fig. 1).

Feeding intensity

The proportion of stomach fullness for 576 samples of *C. ignobilis* on visual examination revealed that the proportion of full, 3/4th, half, trace, and empty stomachs were 20%, 2.9%, 15.8%, 5.8%, 6.7% and 47.4% respectively Fig. 3. The feeding intensity of *C. ignobilis was* observed based on Stomach fullness index gastro somatic index and vacuity index. The gastrosomatic index revealed that there is a monthly variation in the feeding intensity with high peaks and falls Fig. 2.

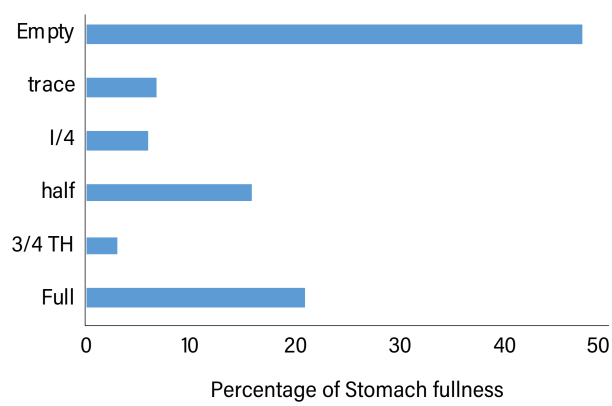

Fig. 3. Percentage stomach fullness of *C. ignobilis* caught on the southwest coast of Kerala

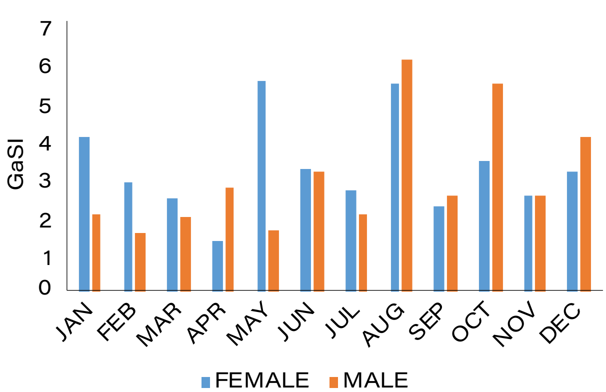

Fig. 2. Gastro somatic index *C. ignobilis* in different months

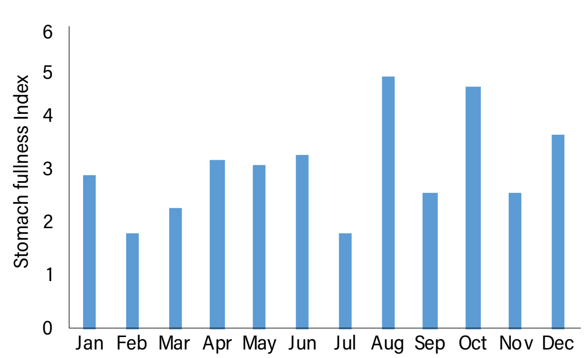

Fig. 4. Stomach fullness index for *C. ignobilis* during different months

The GaSI ranged between 1.3 to 5.4 in females and 1.5 to 6 in males. The GaSI was observed to be highest in August (5.4) for males and May (5.5) for females sexes. GaSI was lowest for females in April (1.3) and for Males in February (1.5). In all the other months GaSI was maintained between 2-5. The gastrosomatic index of *C. ignobilis* during different months is shown in Fig. 2. The gastrosomatic index was found to be non-significant in males and females in t test with a P value (0.068>0.05). Since there was no discernible difference ($p > 0.05$) in the stomach fullness index or VI values between males and females, the data from both sexes were combined and shown for various months. The monthly seasonal change in the feeding intensity in terms of SFI is depicted in Fig. 4. SFI values were highest during August (4.8) and October (4.6) and lowest in February (1.8) and July. The Vacuity index (VI %) of *C. ignobilis* was found to be 47.4 which implies the species is a moderate feeder. The VI as in Fig. 4, varied over different months with the highest in February (80%) and lowest in October (15%).

Discussion

Food composition

Analysis of diet pattern in *C. ignobilis* indicates a preference for a piscivorous diet with a wide diversity of different groups of fishes making it clear that it is a highly carnivorous top predator. The findings of Sudekam *et al.*, 1990 in Hawain waters also was on par with the present finding that they prefer mainly fish in their diet. Studies done by Smith and Parish (2002) also found similar results while comparing the feeding habits of *C. ignobilis* and *C. melampygus*, describing *C. ignobilis* as somewhat more piscivorous than *C. melampygus,* by the measure of the frequency of predation and the number of bulk of prey item observed. At the same time study conducted by Meyer *et al.* (2001) referred *C. ignobilis* as a major benthic crustacean feeder which also supports our findings that even though the fish account for the bulk of the diet, crabs are the major individual prey item identified with highest IRI value of 29.9%. The Presence of fishes from the family Tetraodontidae and Triggerfish indicates the foraging nature of *C. ignobilis* in reef ecosystems. The presence of squids, crab, and other pelagic species like sardines, and *Decapterus* species indicate the exploitation of open water columns as well. Studies by Williams, 1965 also found similar results of diet in *C. ignobilis* exploiting all levels of the water column (both demersal and pelagic). Species like octopuses, and other sea creatures in their diet describe the nocturnal feeding nature of the fish. Okamoto and Kawamoto (1980) concluded *C. ignobilis* is a night feeder in their observations, which also corroborates our result. Observation made from the feeding habit of *C. ignobilis* depicts that the prey items were consumed from different habitats like pelagic, demersal and reef ecosystems which indicates the tropic interaction of *C. ignobilis* in ecological prey-predator relationship. The occurrence of sand and coral stones in the stomach content depicts the bottom-feeding nature of the fish. Study unequivocally shows that *C. ignobilis* maintains a selective feeding behaviour in each ecosystem while eating over a variety of habitats, including reef and pelagic demersal ecosystems. It has a selective preference for feeding mostly *on Sardinella logiceps*, *Decapterus*, and other species, even when important pelagic species such as Mackrels and Tunas are present. It avoids demersal species like rays, and croakers in favour of feeding on crabs, squid, and fish like threadfin bream and sole fish in the demersal environment. Its preference for trigger and puffer fishes over any other reef fishes also shows fish's selective feeding behaviour. This may be because *C. ignobilis* is not indiscriminate in its feeding but selectively hunts prey that are energetically advantageous or abundant in the specific habitat it is occupying at any given time. Studies conducted by Sivakami (1997) in Indian waters on the feeding behaviour of some carangids also pointed to this nature of feeding which corroborates our study observed that Carangids are usually selective feeders and they achieve this pattern of selective feeding by their shoaling behaviour, which assures lower energy expenditure. So despite the availability of food items in their surroundings, they prefer a few food items selectively. Studies conducted in Hawaiian waters by Sudekam *et al.* (1991), also report a similar diet pattern to *Decapterus*, Anchovies and Puffer fishes, which clearly emphasize the selective feeding nature of the species in any geographical area.

Feeding Intensity

The results obtained for gastrsomatic index coincide with the breeding time of *C. ignobilis*. The gastrosomatic Index of males and females shows variation every month. The GaSI was highest for both males and females in August 5.4 and in May. GaSI of female was in a peak of 5.5.which is a peak spawning month for *C. ignobilis*. This is because during the breeding phase they become more voracious as the spawning progress to a peak (Hargreaves and Kearney, 2006). *C. ignobilis* is a frequent spawner (spawn over a prolonged seasonal period) and it usually shows a spawning periodicity in the warmer months (March-April) and in the post-monsoon months from August to December (Williams, 1965). The GaSI is found to be high during the spawning period and shows a positive correlation with the gonado-somatic index. The high value of GaSI in August for both sexes indicates the need for high energy for the initiation of the next spawning after the monsoon. This is on par with the findings of Kestemont and Baras (2004) that the nutritional demands of fish during the spawning season increase the feeding activity, especially as they transit from the spent phase to recovery. Even though the peaks and falls coincide with the breeding time, a consistent GaSI against all the breeding months were not obtained. In months like April and November being the peak spawning period of *C. ignobilis,* the GaSI is as low as 1.3 and 2.5. This observation corroborates the findings of Nair and Sobhana (1980), that variations in the feeding intensity are not solely dependent on the maturation but also on other factors like the non-availability of the preferred food. Differences in values observed for GaSI between males and females might be due to differing energy requirements for females as compared to males for gonad maturation and reproduction. So in our observation, apart from gonadal maturation, GaSI may be affected by other external environmental factors like temperature, rain, availability of food, *etc.* The feeding intensity in terms of the Stomach fullness index also indicates that the feeding intensity of *C. ignobilis* is higher in its breeding months. High peak of SFI in August, October and December Coincides with the breeding months of *C. ignobilis*. A small peak in the feeding intensity Observed in April and May also signifies a positive correlation of SFI with the spawning phase. This is because fish require greater energy intake during spawning to satisfy the requirements of reproduction (Froese and Pauly, 2000). The findings of Farrag (2013) also conclude that the spawning season had the greatest percentage of fullness index. All these statements support our findings that SFI has a direct relation with the spawning cycle of *C. ignobilis*. The High peak of SFI coincides with the lower ESR pattern (VI) during August to December explaining these months as the prominent spawning phase of *C. ignobilis.*

The VI varied in different months and nearly 50% of the stomach was empty during the investigation, indicating *C. ignobilis* is a moderate feeder. Fishes with empty stomach conditions dominated the catch during the present study period. From the observations of Faltas, 1993; Juanes and Conover, 1994, the presence of a high percentage of empty stomachs is characteristic of piscivorous fishes. The diet pattern of *C. ignobilis* also supports these findings as February holds the highest range of VI (80%) with a diet composed of 95% fishes (Fig. 1) and they are easily digestible when compared to crustaceans and mollusc. High gastric enzyme levels in the intestine of this species also contribute to easy meal digestion, which is a plausible explanation for the high number of empty stomachs. A significant decrease in VI was observed in October (VI -15%) may be due to the selective feeding nature of the species since a lot of its preferred food items (*O. niger*) were observed in plenty from its stomach making it edacious during this month. According to Vinson and Angradi (2011), the Vacuity index of a species can be affected by duration of feeding, nature and texture of the food item, prey encounter rate and environmental conditions like temperature. A recent observation by Mahesh *et al.* (2019) reports that there is a heavy landing of *O. Niger* and *Arthrodon stellateous* during the post-monsoon months, especially in October. As these two species are the most preferred diet of *C. ignobilis,* this may be a possible explanation for the decrease in VI during October. The findings regarding the Vacuity Index (VI) of *C. ignobilis* (Fig. 5) reveal a notable contradiction during the peak spawning months of March to May when VI is typically expected to be higher. Instead, our observations indicate a lower VI during these breeding periods. This discrepancy may be attributed to elevated temperatures characteristic of summer, which can lead to accelerated digestion and, consequently, emptier guts. Previous studies, such as those by Wielgosz and Tadajewska (1988), have documented that increased water temperatures can enhance feeding rates and digestion in fish. Similarly, Yalcin-Ozdilek *et al.* (2013) noted that high VI values in fish are often linked to rapid digestion rates driven by warmer conditions. Therefore, it appears that the higher VI observed in *C. ignobilis* during summer months may be influenced by temperature effects, a hypothesis that warrants further investigation. Additionally, statistical analysis using a t-test (0.05<0.12) indicates no significant difference in VI between breeding and non-breeding seasons, suggesting that factors such as prey availability and temperature also play crucial roles in the VI of *C. ignobilis.* Future research should aim to explore these variables more comprehensively. The findings of Sakamoto *et al.*, 1982, also corroborate our findings that VI, also known as the Empty Stomach Ratio Sakamoto *et al.*, 1982, is an inverse indication of feeding intensity that varies based on fish abundance, spawning time, and seasonal fluctuations in water temperature and food source. Thus *C. ignobilis* exhibits moderate feeding overall but becomes highly edacious during specific periods such as breeding months or when preferred prey is abundant. So the diet and feeding behaviour of *C. ignobilis* reveal a strong piscivorous inclination, with a diverse diet that includes various fish species, crabs, squid, and pelagic organisms and

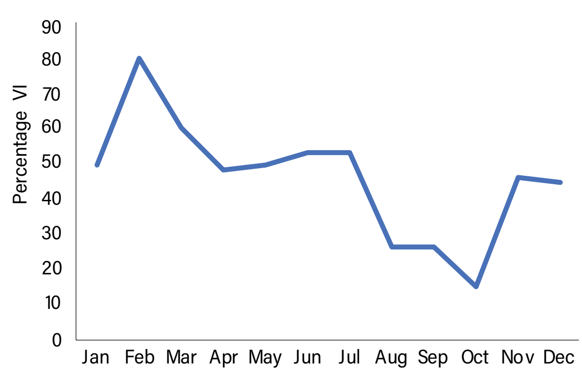

Fig. 5. Vacuity Index of *C. ignobilis* in different months

the adaptability of *C. ignobilis* to effectively exploit different habitats. Feeding intensity, assessed through the Gastric Somatic Index (GaSI) and Stomach Fullness Index (SFI), indicates increased nutritional demands during spawning months that are critical for reproductive success. The VI suggests moderate overall feeding behaviour. Fluctuations in feeding intensity due to factors like food availability and temperature underscore the need to consider environmental conditions when studying predator-prey dynamics. Thus the study enhances our understanding of *C. ignobilis* ecological role and its complex foraging strategies. Knowledge of the feeding behaviour enhances insights into its ecological role within marine food webs, emphasizing its impact on prey populations and overall health. These findings can inform conservation strategies by highlighting the importance of maintaining diverse habitats and food sources to support *C. ignobilis* and related species. These can be valuable for marine biologists, ecologists, and conservationists working to preserve ecosystems and understand predator dynamics, and could explore the long-term effects of environmental changes on feeding behaviours, reproductive success, and population dynamics, which may contribute to a more comprehensive understanding of marine ecosystems.

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Author contributions

Conceptualization: ET, EMA; Methodology: ET; Data Collection: ET; Data Analysis: ET; Writing Original Draft: ET; Writing Review and Editing: TT, AG; Supervision: EMA

Data availability

The data are available and can be requested from the corresponding author

Conflict of interests

The authors declare that they have no conflict of financial or non-financial interests that could have influenced the outcome or interpretation of the results.

Ethical statement

No ethical approval is required as the study does not include activities that require ethical approval or involve protected orms/ human subjects/ collection of samples/ protected environments.

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