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Diet and trophic ecology of silver pomfret, *Pampus argenteus* (Euphrasen, 1788) exploited from the Southeast Arabian Sea

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Abstract

Stomach content analysis of the silver pomfret, *Pampus argenteus* using the Index of Relative Importance (IRI) revealed that crustaceans (IRI= 48.2%) and semi-digested pulp (IRI= 47.6%) formed the important diet. Copepods formed the largest proportion among crustaceans. Proportion of empty stomachs was higher in large fishes and the diet changed with body size as well as with season. Fishes in smaller length group (<140 mm) had semi-digested pulp as the dominant component, whereas fishes above 140 mm had copepods and fish. The relationship between the mean weight of semi-digested pulp and mean number of copepods with that of predator length suggested probable diet shift from omnivory to carnivorous feeding habits. The mean weight of semi-digested pulp gradually decreased with increasing length of the fish. The highest similarity in diet was observed between the monsoon and post-monsoon seasons, and by length groups, between the fishes of 191-240 and 241-290 mm. Diet breadth is narrow as revealed by Levin's index. The trophic level was estimated as 2.4 ± 0.1. The Amundsen plot showed that *P. argenteus* is a specialized feeder on semidigested pulp and copepods.

Keywords: Trophic ecology, *Pampus argenteus*, ontogeny, diet breadth, trophic level, Arabian Sea

Introduction

Food habit and trophic ecology study of fishes are necessary to understand the role they play in the food web (Gerkin, 1994; Luczkovich *et al.*, 1995). In ecosystem based fishery management studies, these data are integrated in to conceptual models that allow a better understanding of the structure and function of diverse aquatic ecosystems (Pauly and Christensen, 2000). The silver pomfret, *Pampus argenteus* (Euphrasen, 1788) is one of the most valuable food fishes available along the Indian coast. It is an inshore species, usually seen in shoals over the muddy bottoms associated with other demersal fishes. Studies along the east coast indicated the importance of small crustaceans, algae and semi-digested pulp in their diet (Kuthalingam, 1963; Rao, 1964; Pati, 1978). Information on the importance of this species as a constituent of the food web along the west coast of India is limited because there are only a few publications on its feeding habits.

In 2005, an estimated 99 t of silver pomfret was exploited by multi-day trawlers, purse-seiners and gill netters along the Karnataka coast (Srinath *et al.*, 2006). The primary goals of this study are to i) provide a quantitative estimation of the diet of *P. argenteus* along the Karnataka coast, and ii) understand the ontogenetic and seasonal changes in the diet and trophic level of this species.

Materials and methods

Samples of silver pomfret were taken from commercial catches of multi-day trawlers at Mangalore and Malpe, the two major fishing harbours along the Karnataka coast, during the period from September 2001 to May 2002. Total length (TL) of 228 fishes was measured from the tip of the snout to the tip of the lower lobe of caudal fin (mm) and weight was taken to the nearest 0.1 g using an electronic balance. After noting the TL and weight, the fish were dissected and the gut removed and preserved in 5% formalin for diet analysis. In the laboratory, stomach contents were sorted and identified to the lowest possible taxonomic level.

The intensity of feeding was determined from the stomach distension and the amount of food it contained. When the stomachs were full it was considered as actively fed, ¾ and ½ full as moderately fed and ¼ full and traces were considered as poorly fed. The wet weight of the stomach contents was taken by using an electronic balance to the nearest mg. The widely accepted diet index, the Index of Relative Importance (IRI) was used to evaluate the importance of various food items found in the stomach as described by Pinkas *et al.* (1971).

$$IRI_i = (\%N_i + \%V_i) \times \%O_i$$

where, N_i, V_i and O_i represent percentages of number, volume and frequency of occurrence of prey *i* respectively. Since silver pomfret is basically an omnivorous fish, the point (volumetric) method as suggested by Hynes (1950) was adopted. The IRI was expressed to 100% (%IRI) (Cortes, 1997). When calculating IRI for semi-digested pulp, estimation was done without including the %N since it cannot be counted. In order to evaluate variation in food habits as a function of size, specimens from 91 mm to 300 mm were separated in to four 50 mm length groups. To study the seasonality in feeding, seasons were grouped as monsoon (June-September), post-monsoon (October-January) and pre-monsoon (February-May).

Diet breadth was calculated using Levins (1968) index of diet breadth (B) as

$$B = \frac{1}{\Sigma (p_{ij}^2)}$$

where p_{ij} is the proportion of resource state *j* used by length group *i*. The index ranges from 0 (highly specialized) in which only a single resource is used, to n (highly generalized), where n is the total number of prey categories.

Trophic level (TL) of the fish was calculated based on the proportion (by weight) of each prey component in the diet (Odum and Heald, 1975).

$$TL = \Sigma (V_i T_i) + 1$$

where V_i is the percentage by volume contribution of i_{th} prey item and T_i is the trophic level of the i_{th} prey item. Trophic levels of different prey items were taken from Fishbase (Froese and Pauly, 2000).

A graphical technique, Amundsen plot (Amundsen *et al.*, 1996) that plots prey-specific abundance (V_i) against frequency of occurrence was used to interpret predator-feeding strategy. The prey-specific abundance (P_i) is defined as the proportion of a prey item in only predators that contain prey *i* and calculated as,

$$P_i = (\Sigma S_i / \Sigma S_{ti}) \times 100$$

where P_i equals prey-specific abundance (numbers, mass or volume) of prey *i*, S_i equals the abundance of prey in stomachs and S_{ti} equals the total abundance of prey in predators that contain prey *i*. For the present study, proportion by volume of prey items was used to calculate prey-specific abundance.

Statistical differences in diet composition with respect to length group and season were assessed by a chi-square test of frequencies of a given prey. To determine seasonal similarities in feeding, Bray-Curtis similarity indices were computed and hierarchical agglomerative clustering using group-average linking was performed on the resulting similarity matrices. For ontogenetic feeding similarities, the results of hierarchical agglomerative clustering were subjected to a non-parametric multidimensional scaling (NMDS) using the software package PRIMER (Clarke and Warwick, 2001).

Results

General dietary features: Crustaceans (IRI= 48.2%) and semi-digested pulp (IRI= 47.6%) were the major diet components of *P. argenteus*. Fish items, diatoms and worms entangled in the semi-digested pulp were in decreasing order of importance (Table 1). Among the crustaceans, *P. argenteus* fed mostly on copepods (IRI= 41 %) and among diatoms, on *Nitzschia* spp. (IRI= 1.3%). None of the fish prey could be identified; however, presence of scales indicated that *P. argenteus* feeds on fish. Semi-digested pulp occurred most frequently (FO= 67.1%) followed by copepods (FO= 51.5%) and cycloid scales (FO= 11.6%). Among the crustaceans, the most frequently observed items next to copepods were amphipods (FO=9.3%) and nauplii larvae (FO= 7.5%). Semi-digested pulp (V= 46.4%) and amphipods (V= 40.5%) formed generally an important part of the diet by volume. A total of 1,514 prey items were encountered, out of which, copepods formed the largest proportion (N= 48.4%) followed by *Nitzschia* spp. (N= 14.2%) and *Coscinodiscus* spp. (N= 11.8%). Diatoms formed only 2.2 % in the total IRI. Worms were the least important item in the stomach. Amundsen plot shows that *P. argenteus* has a specialized feeding strategy (Fig.1). Most

Table 1. Prey of P. argenteus *in terms of frequency of occurrence (%FO), volume (%V), number (%N), and index of relative importance (IRI)*

Prey	%FO	%V	%N	IRI	%IRI
Fishes					
Fish scales (ctenoid)	1.73	0.01	0.66	1.15	0.02
Fish eggs	6.36	0.53	3.24	23.93	0.37
Fish scales (cycloid)	11.56	0.13	6.01	70.97	1.09
Fish remains	5.20	5.64	0.00	29.32	0.45
Crustaceans					
Mysids	6.36	1.07	2.91	25.30	0.39
Oratosquilla nepa	0.58	0.99	0.07	0.61	0.01
Copepods	51.45	3.75	48.35	2680.21	41.00
Amphipods	9.25	40.49	3.76	409.32	6.26
Nauplii larvae	7.51	0.44	3.24	27.62	0.42
Zoea larvae	2.31	0.32	0.40	1.66	0.03
Crustacean appendages	2.31	0.07	2.77	6.58	0.10
Diatoms					
Coscinodiscus spp.	5.20	0.03	11.82	61.67	0.94
Nitzschia spp.	5.78	0.01	14.20	82.16	1.26
Other diatoms	2.31	0.01	0.00	0.01	0.00
Worms	2.89	0.15	2.58	7.89	0.12
Semi-digested pulp	67.05	46.37	NE*	3108.88	47.56

* Not Estimated

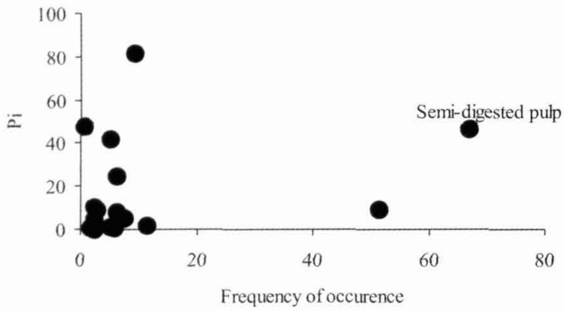

Fig. 1. Amundsen plot for *P. argenteus* showing prey-specific abundance (Pi)

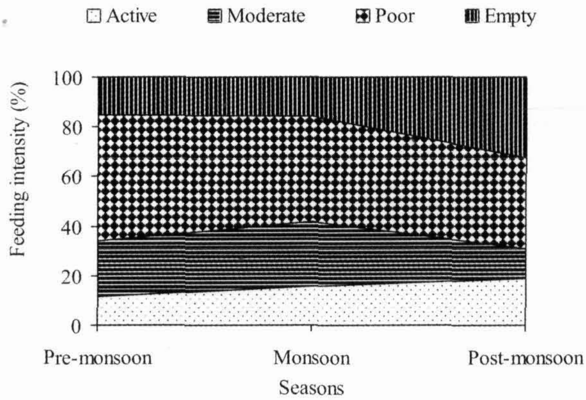

Fig. 2. Feeding intensity (%) of *P. argenteus* in relations to seasons

of the individuals specialized on copepods as its percentage frequency of occurrence and prey-specific abundance were comparatively very high.

Seasons: Fishes with poorly fed stomach condition were dominant in all the seasons. Their proportion was highest in the pre-monsoon followed by the monsoon season (Fig.2). There was no significant difference in the number of fish with different feeding conditions (χ^2 test, df= 6, p>0.001). Semi-digested pulp and copepods ranked first and second respectively in all the seasons (Fig. 3). During the pre-monsoon season, 65% of the diet by IRI was semi-digested pulp followed by copepods. Miscellaneous items such as diatoms and worms were the next important components in the pre-monsoon season. There was a relative increase in the importance of copepods from the pre-monsoon to post-monsoon seasons. Significant differences (χ^2 test, df= 8, p<0.001) were seen in the number of major prey groups consumed in different seasons. Among the prey groups, the variation was mainly due to the diatoms and among seasons, the pre-monsoon and post-monsoon seasons were the main source of variation. Diet breadth was very low (Fig.4) among the seasons

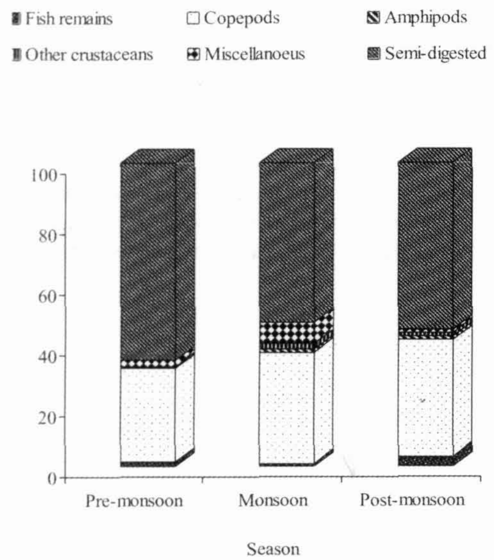

Fig. 3. Seasonal variation in %IRI of prey of *P. argenteus*

(1.9 ± 0.6). The highest value of diet breadth was observed in the monsoon (2.0 ± 0.8) and lowest in the post-monsoon (1.8 ± 0.6) seasons. The trophic level was highest in the pre-monsoon season (2.6 ± 0.5) and lowest (2.3 ± 0.2) in the monsoon season (Fig.4). Bray-Curtis similarity analysis also showed that the highest diet similarity (Fig.5) was between monsoon and post-monsoon seasons (83%). Almost similar proportions of copepods and semi-digested pulp were observed during these two seasons.

Ontogeny: The proportion of fishes with active and moderate feeding reduced with increasing length. The proportion of empty stomachs was higher (44.4%) in the largest length group (241-290 mm) (Fig.6). However, there was no significant difference in the number of fishes with respect to feeding intensity (χ^2 test, df= 18, p>0.001). Copepods formed an important diet in all the length groups. Significant ontogenetic differences were found (χ^2 test, df= 24, p<0.001) in the number of major prey groups consumed. Among prey groups the main source of variation was from other crustaceans and fishes. Among length groups, the main source of variation was from 91-140 mm group. The diet of all fishes showed very high IRI (92.6%) for semi-digested pulp (Fig.7). However in fishes of 140-190 mm, copepods formed the most important diet in all the length groups. Miscellaneous items mainly *Nitzschia* spp. and fish scales formed 3[rd] and 4[th] important food source in 141-190 mm length groups. Due to more quantity and occurrence of semi-digested pulp and copepods, the NMDS segregated fishes of the length group 91-140 mm, to the top of the graph (Fig.8). Other length groups, which fed largely on copepods and diatoms were separated to the bottom of the graph with a very low stress value (0). Semidigested pulp formed higher proportion (%IRI= 88.2) in 191-240 mm length group while in the largest length group (241-290 mm), *Coscinodiscus* spp. was observed to be 3rd important diet

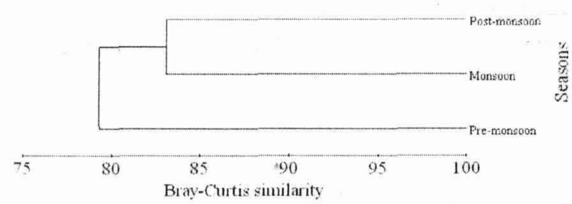

Fig. 5. Dendrogram based on %IRI values of different seasons of *P. argenteus* using group average clustering

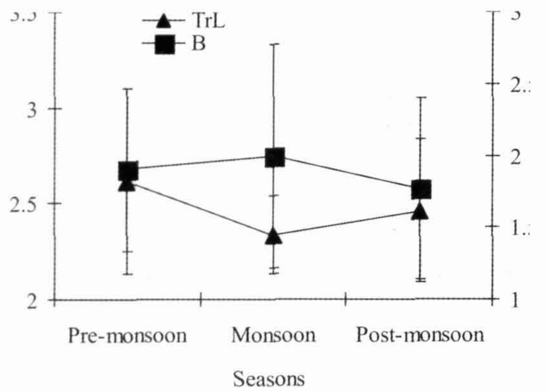

Fig. 4. Seasonal variation in trophic level and diet breadth of *P. argenteus*

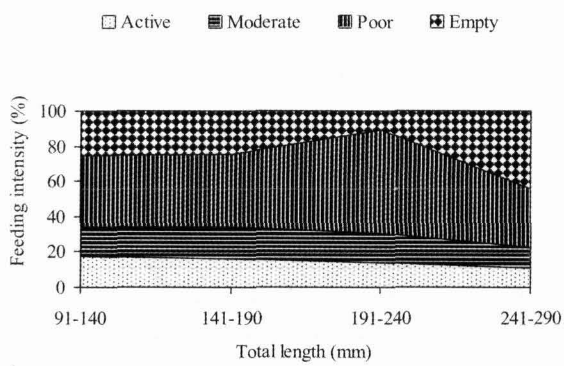

Fig. 6. Feeding intensity (%) of *P. argenteus* in relation to size groups

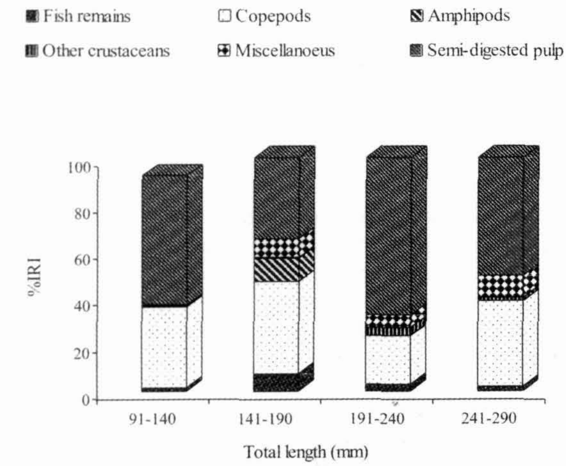

Fig. 7. Ontogenetic variation in %IRI of prey of *P. argenteus*

after semidigested pulp and copepods. The mean weight of semi-digested pulp gradually decreased with increasing length of fish (Fig.9). Similarly, a marginal increase in the mean number of copepods was observed with increasing length of *P. argenteus* (Fig.10).

Diet breadth among the length groups varied with a mean of 1.8 ± 0.3 and the highest value was recorded for 191-240 mm length group (B= 2.1). Trophic level ranged from 2.3 in 91-140 mm to 2.6 in 241-290 mm length group with a mean of 2.4 ± 0.1 (Fig. 11)

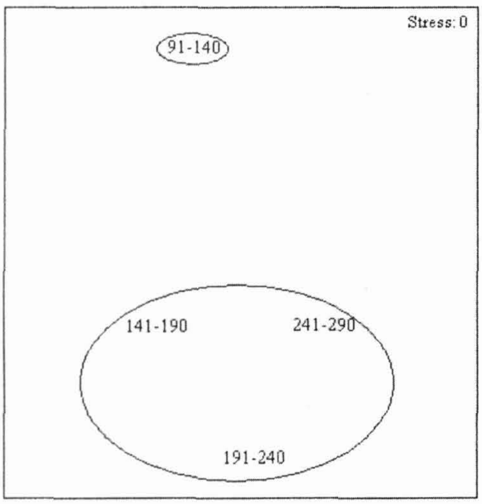

Fig. 8. NMDS based on %IRI values of different length groups of *P. argenteus* showing segregation into two separate groups

Discussion

The present study revealed that *P. argenteus* feed largely on zooplankton. Crustacean zooplankton have been reported to form the largest proportion in the diet of the silver pomfret along the Indian coasts as well as in the Arabian Gulf (Kuthalingam, 1963; Pati, 1978; Dadzie *et al.*, 2000). A high proportion of semi-digested pulp, which contributed the largest proportion by weight to the food item, rendered the identification and sorting of food

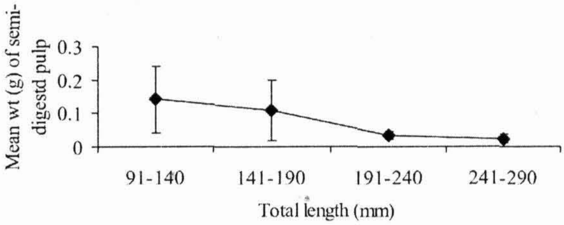

Fig. 9. Relationship between mean weight of semi-digested pulp and the total length of *P. argenteus*

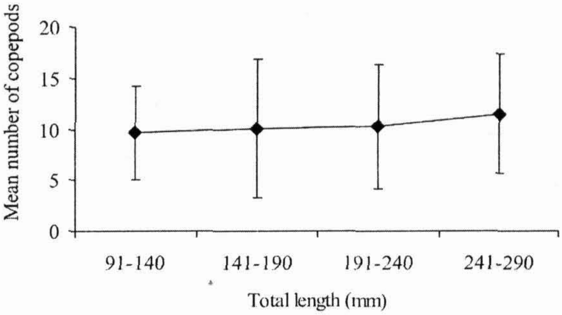

Fig. 10. Relationship between mean number of copepods and total length of *P. argenteus*

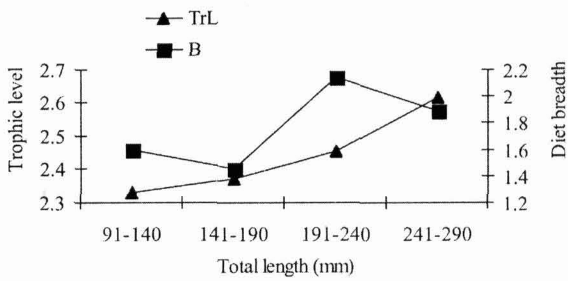

Fig. 11. Ontogenic variation in trophic level and diet breadth of *P. argenteus*

components very difficult. The reason for these difficulties while sorting food components was due to the uniqueness of the gut in pomfrets. Pati (1978) described that pomfrets possess toothed esophageal sac, which acts as grinding mill to make food pulpy and hence making the identification of food components very difficult. None of the fishes could be positively identified but fish scales were frequently encountered which remained undigested in the gut. However, copepods constituted the major proportion of zooplankton in semi-digested pulp. Basheeruddin and Nayar (1961) recorded semi-digested pulp in which scales, bones of fish, copepods and *Acetes* sp. were entangled in the gut of silver pomfret. In a similar species, *Parastromateus niger* also, Sivaprakasam (1967) observed that the food was present in highly macerated and in advanced state of digestion.

Copepods are the most important diet source to silver pomfrets. Their significance in the diet was greatly emphasized in many other studies. Kuthalingam (1963) in his study from north-west part of Bay of Bengal observed copepods and other crustaceans as the main items of food in addition to ostracods, amphipods, larval crustaceans, polychaetes, *Sagitta* sp., fish scales, algal filaments, etc. Similarly, Rao (1964), while studying the feeding habits of *P. argenteus* observed a high percentage of copepods along with amphipods, ostracods, other crustacean zooplankton, gastropod larvae and fish remains. Dadzie *et al.* (2000) from Kuwait waters investigated the feeding habits of silver pomfrets and stated that copepods were the most favorite food of silver pomfrets.

Being a basic copepod feeder, the silver pomfret preferred them in all the seasons. They are a very important part of the diet both in the pre-monsoon and post-monsoon seasons in the Bay of Bengal (Pati, 1978). Occurrence of fish scales, though in less quantities, indicates that small fishes formed diet in all the seasons. Dadzie *et al.* (2000) observed more variety of food items in summer than in winter indicating the seasonal change in feeding according to the availability of prey organisms in the environment. Seasonal variation in major food components especially copepods is highly distinct in the Chinese pomfret (Pati, 1977) and black pomfrets (Sivaprakasam, 1967).

An ontogenetic increase in consumption of copepods is observed to be the reason for decrease in the proportion of semi-digested pulp in large length groups. Also, as length progresses, silver pomfret along Karnataka coast shift to feed on more active moving zooplankton such as copepods, amphipods and even on fishes. Probable diet shift to carnivorous feeding habits with ontogeny was revealed from the relationships between the weight of semi-digested pulp and number of copepods. Pati (1978) observed a striking change in the diet of *P. argenteus* from post-larvae to the adult. He observed that phytoplankton such as *Coscinodiscus centralis, Thallasiothrix frauenfeldii* and *Pleurosigma normanii* are most favorite diet of post-larvae but as the length progressed they shift to feed on copepods, nauplii and other crustaceans. Kuthalingam (1963) observed rare occurrence of large crustaceans such as *Penaeus* spp, *Acetes* spp, *Squilla* spp. and anomurans in addition to copepods in large sized silver pomfrets (>260 mm) as against the juveniles which were mainly feeding on small copepods and diatoms. Hence it is evident that diet change with ontogeny is common in silver pomfret.

The low trophic level values determined for all length groups and seasons examined are directly related to the prey item consumed. Most of prey such as semi-digested pulp (except for fish items in the larger length groups) found in the stomachs themselves occupy lower trophic levels (Vivekanandan *et al.*, 2006). Large proportions of copepods in the stomach indicate their large abundance along the Mangalore coast. Goswami (1996) estimated zooplankton biomass of the Indian EEZ and observed pockets of high zooplankton biomass along the Mangalore coast. Among the zooplankton, copepods are one of most dominant groups in the Arabian Sea (Madhupratap, 1999).

It could be concluded that silver pomfret is a specialised feeder on semidigested pulp and copepods. As observed in the Amundsen plot, preference over copepods and semi-digested pulp supports the theory proposed by MacArthur and Pianka (1996) that feeding will become more selective and specialised when food is abundant. This is again reiterated by the optimal foraging theory which predicts that diets will become more specialised as the abundance of preferred prey increases (Pyke *et al.*, 1977).

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