



The Effect of the Ctenophore *Mnemiopsis leidyi* (Ctenophora: Lobata) on the Population Density and Species Composition of Mesoplankton in Inshore Waters of the Caspian Sea

Aboulghasem Roohi^{1,*}, Mozhgan Rowshantabari¹, Mehdi Naderi Jolodar¹,
Seyedeh Ameneh Sajjadi²

¹Iranian Fisheries Research Organization (IFRO), Caspian Sea Ecology Research Center, Education and Research Organization of Agriculture Ministry, Khazarabad Boolvar, Ecology Dept., Sari, Iran

²Department of Agronomy, Rasht Branch, Islamic Azad University, Rasht, Guilan, Iran

Email address:

Roohi_ark@yahoo.com (A. Roohi)

*Corresponding author

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Abstract: This paper examined the qualitative and quantitative of food composition of the ctenophore *Mnemiopsis leidyi*, as well as its feeding intensity and predatory impact on selected mesoplankton species in the inshore waters of the southern Caspian Sea. The ctenophore *Mnemiopsis leidyi* initially increased during 2001-2002 with the abundance and biomass of 381-480 ind.m⁻³ and 15.1-27.7 g.m⁻³, respectively, and during recent years (2012-2013) its population and biomass reached at a low level with an average of 5-46 ind.m⁻³ and 0.6-4.0 g.m⁻³. The highest summer-autumn average of *M. leidyi* abundance was observed in 2002 with 1338 ± 334 ind.m⁻³ and the maximum biomass in 2001 with 77.5±19.4 g.m⁻³. Over the years, 2003-2012, *M. leidyi* population did not reach to its initial value and the mean range of abundance and biomass 5-25 ind.m⁻³ and 0.6-19.2 g.m⁻³. Interannual and interspecies differences in the intensity of predatory impact on zooplankton were found. Copepod nauplii of *Acartia (Acanthacartia) tonsa*, the cladocerans *Podon (Pleopsis) polyphemoides*, experienced the highest pressure from ctenophore predation. Zooplankton species composition showed there were 36 species before the *M. leidyi* introduction, while now days it is 12 species. Food spectra of *M. leidyi* consisted of zooplankton in which the copepods were the main in the southern Caspian Sea. The mass development of *M. leidyi* defines the qualitative and quantitative composition of zooplankton community through the control of abundance of copepod and cladoceran nauplii, which, in turn, results in changes in the trophic structure of the whole food chain.

Keywords: Caspian Sea, *Mnemiopsis leidyi*, Mesoplankton, Food Composition, Predatory Impact

1. Introduction

As opposed to the Black Sea and its adjacent ocean, the Caspian Sea is not crowded for shipping purposes and maritime traffic, so due to its closed ecosystem, it has a high potential and high risk in, non-native aquatic species introduction. Many aquatic species from the Black Sea have been introduced into the Caspian in recent years that have had great success in implementing the Caspian Sea [10]. International Maritime Organization (IMO) has been

estimated that 7,000 species are carried around the world in ballast water every day and 10 billion tonnes of ballast water are transferred globally each year. This means that we are now capable of moving more organisms around the world in the ballast water of ships in one month, than we used to in one century [8]. One of the invasive species is the comb jelly *Mnemiopsis leidyi*. The invasion of the Black and Caspian Seas by a voracious comb jellyfish from North America (*Mnemiopsis leidyi*) is one of the best-documented examples of a marine alien invasive species introduced through ballast

water [5], [23]. It eats both zooplankton, the food of commercially important fish in the Caspian Sea, and the eggs and larvae of the same fish species [18], [19]. However, in 1999, it was first observed on the Caspian Sea that has already created a lot of problems in the Black Sea [12]. This animal lives floating and suspended in the sea water, and has jelly-like body and transparent which can feed insatiable on mesoplankton. The newcomer *Mnemiopsis leidyi* can reproduce very quickly and will mature in 14 days [20]. This animal was found that bisexual [15], therefore, any jelly can be used alone reproduction and in a short time become 2000-16000 newly once [11], [14].

Zooplankton data showed that the species diversity, density and biomass of zooplankton sharply decreased after the jelly invasion [6], [9]. The aim of this study was to assess changes in the density and biomass of *Mnemiopsis*, as well as changes of mesoplankton as food spectra of jelly in the southern Caspian Sea.

2. Methods

Biological and environmental data used in this study were collected by the R/V Guilan cruises conducted in 1996 [9] and 2001–2006. Samples were collected based on geographical location by GPS¹ at 53° 22' latitude and 36° 22' longitude monthly along six transects (Lisar, Anzali, Sepidroud, Tonekaboon, Nowshar, Babolsar and Amirabad) off the Iranian coast of the southern Caspian Sea. Each transect had four stations located at the points off the shore where the bottom depth was 5, 10, 20 and 50 m, respectively, and two transects (Anzali and Babolsar) had an additional station further offshore at the point at which the bottom depth was 100 m (Fig. 1).

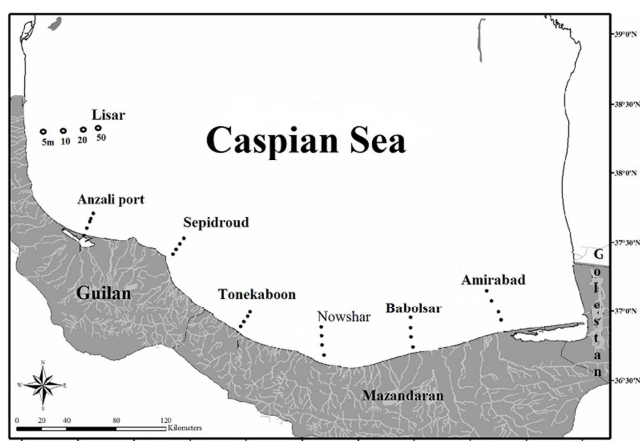


Fig. 1. Distribution of sampling stations in the southern Caspian Sea.

Mnemiopsis leidyi was collected with a METU net having a mouth opening of 0.2 m² and mesh size of 500 μ m, from the same depth intervals as the Juday net [13], [23]. The body length of each individual with lobes was measured onboard and the density of *M. leidyi* (per m³) was calculated from the

net diameter and the tow depth. The ctenophores were sorted in length groups at 5 mm intervals up to 70 mm, to determine the abundance of different size groups. In order to define reproductive individuals, lengths were categorized into two groups, 15 mm and 16–70 mm [4]. Length measurements were converted to weight/biomass (wet weight per m³) using the following equation [13]:

$W = 0.0011 \times L^{2.34}$, where W is wet weight of *M. leidyi* in mg and L is the length in mm.

Non-gelatinous zooplankton samples were taken by vertical hauls using a Juday net, having a mesh size of 100 μ m and a mouth opening of 0.1 m², from different layers. At the three shallowest stations, hauls were taken from the bottom to the surface at each (i.e. from 5–0 m, 10–0 m and 20–0 m). At the fourth station offshore hauls were taken from the bottom at 50–20 m, and from 20 m to the surface. At the most offshore station (two transects only) the hauls were from 100–50 m, 50–20 m and 20–0 m. Samples were preserved with neutral formaldehyde at a 4–5% final concentration for analyses in the laboratory. They were subsampled using a 1-ml Hensen–Stempel pipette and transferred to a Bogorov tray for counting. An inverted microscope was used for identification of non-gelatinous zooplankton. At least 100–150 individuals were counted per sample [17].

3. Results

The highest abundance of *M. leidyi* was observed in 2002 with 480±68 ind.m³, but the biomass was 15.1±0.1 gm³ which was less than in 2001 with 27.7±1.8 gm³ (Fig. 2). During 2003 to 2013, the population of *Mnemiopsis* never reached to the point of the primary level (mean density and biomass of 381-480 ind.m³ and 15.1-27.7 gm³), and even the density and biomass severely decreased and were recorded to 5-46 ind.m³ and 0.4-0.6 gm³, respectively (Table 1).

Table 1. Mean density and biomass of the comb jelly *Mnemiopsis leidyi* during 2001-2013.

| Year | Abundance (ind.m ³) ±SE | Biomass (gm ³) ±SE |
|------|-------------------------------------|--------------------------------|
| 2001 | 381±25 | 27.7±1.8 |
| 2002 | 480±68 | 15.1±1.0 |
| 2003 | 250±17 | 12.3±0.8 |
| 2004 | 106±7 | 7.3±0.5 |
| 2005 | 119±8 | 13.3±0.9 |
| 2006 | 54±4 | 5.6±0.4 |
| 2007 | 68±4 | 5.9±1.3 |
| 2008 | 62±2 | 19.2±2.6 |
| 2009 | 65±7 | 6.2±0.4 |
| 2010 | 23±0.3 | 1.8±0.3 |
| 2011 | 152±12 | 7.7±0.5 |
| 2012 | 5±0.3 | 0.6±0.01 |
| 2013 | 46±3 | 4.0±0.3 |

¹ Global Positioning System

Mnemiopsis seasonal dynamics density and biomass represent its increased during the summer and autumn and significant reductions in spring and winter. Total mean of *Mnemiopsis leidyi* abundance and biomass were 105 ± 7 ind.m³ and 7.9 ± 1.1 gm³ in the southern Caspian Sea. The

highest average density was recorded in autumn with 210 ± 15 ind.m³ and the highest average biomass of *Mnemiopsis* was in summer with 14.5 ± 1.8 gm³. The lowest average density and biomass of comb jelly were observed in winter with 12 ± 3 ind.m³ and 2.01 ± 0.7 gm³, respectively ($p < 0.05$, Fig. 2).

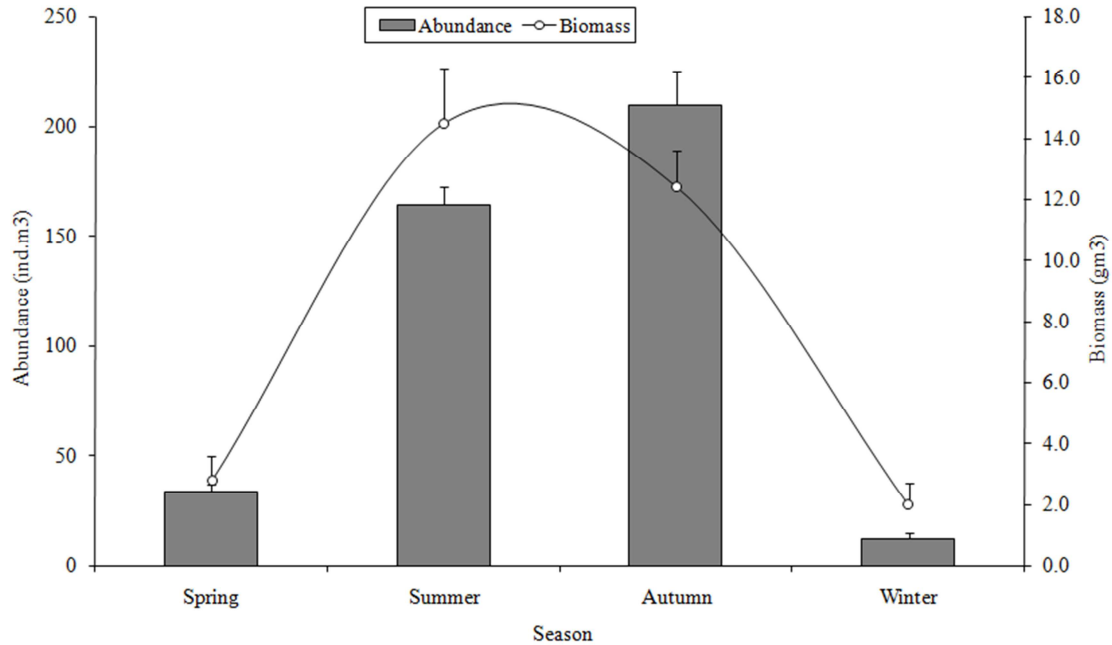


Fig. 2. Seasonal variations in the abundance and biomass of *Mnemiopsis leidyi* in the southern Caspian Sea during 2001–2013 (values are depth and station averages).

Mnemiopsis length distribution of the Caspian Sea showed that 90.8% of the population belonged to the larval group (0–5 mm, larvae and Cydippid), 7.8% of the transition group (6–15 mm, transitional) and the adults group consisted only

1.4% (>16 mm, adults), respectively. So, the group of larvae and transitional of comb jelly made of 98.6% of the total population (Fig. 3).

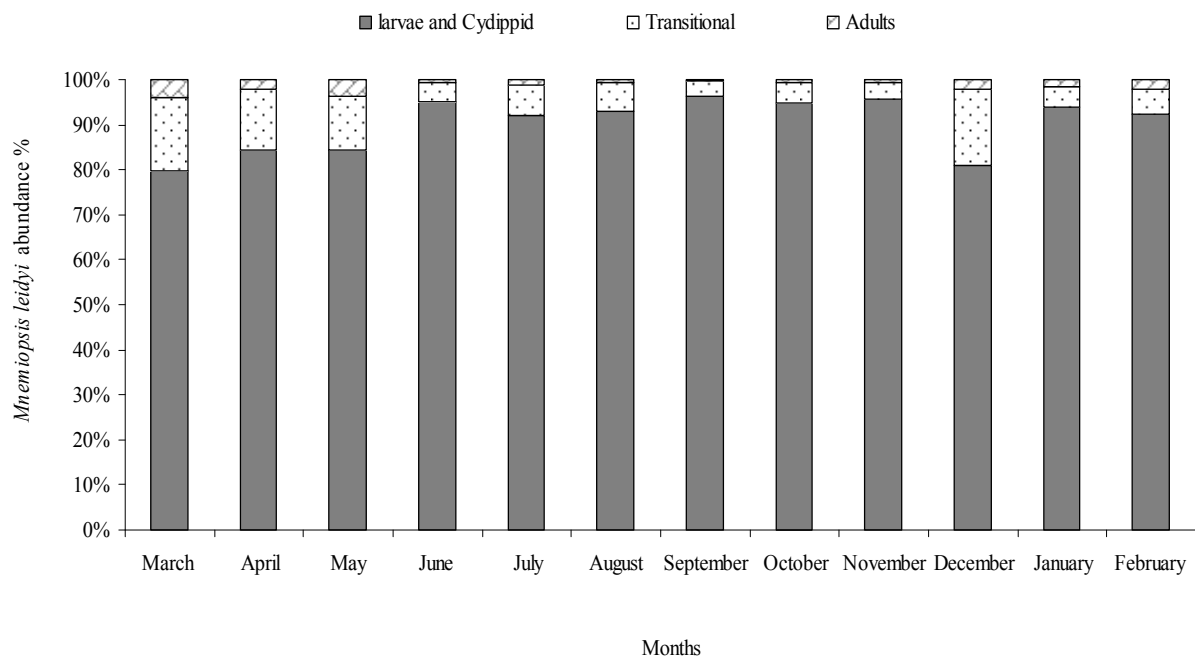


Fig. 3. Monthly variations in abundance of three different size classes frequency of *Mnemiopsis leidyi* in the southern Caspian Sea during 2001–2013.

Caspian Sea zooplankton species composition indicated that before the comb jelly invasion, there were 36 species of 31 holoplankton and five meroplankton species in the sea [9], [19]. While, now a days, a total of 12 zooplankton species including 5 holoplankton remains after the introduction of *Mnemiopsis* to the Caspian Sea (Table 2).

Copepoda and Cladocera groups constitute a major representative jelly comb food with 3 and 2 species, respectively. Cladocereans in which consisted the greatest pelagic organisms food spectrum such as Clupeidae (Kilka fishes) before the comb jelly invasion, It is now one of the resistant and rapid reproducing rate species as *Podon*

(*Pleopsis*) *polyphemoides* formed web chain have sustained life on the Caspian Sea. Another mesoplankton species that plays a fundamental role in the Caspian Sea pelagic food chain and the web of life, and now also appears with the appropriate propagation resistance and managed to control the interaction food web of the Caspian Sea, is *Acartia* (*Acanthacartia*) *tonsa* (Copepoda, Calanoida). Although, a valuable species of the same group (Copepods, *Eurytemora* *grimmeri*) that had been made up the main food mesoplankton source of anchovy Kilka were disappeared after the introduction of the ctenophore.

Table 2. Checklist of zooplankton taxa in the southern Caspian Sea waters in 1996 till 2013.

| Zooplankton | Before <i>Mnemiopsis</i> invasion [9] | After <i>Mnemiopsis</i> invasion |
|---|---------------------------------------|----------------------------------|
| <i>Acartia</i> (<i>Acanthacartia</i>) <i>tonsa</i> | + | + |
| <i>Limnocalanus</i> <i>grimaldii</i> | + | |
| <i>Calanipeda</i> <i>aquae-dulcis</i> | + | |
| <i>Eurytemora</i> <i>grimmeri</i> | + | |
| <i>Eurytemora</i> <i>minor</i> | + | |
| <i>Halicyclops</i> <i>sarssi</i> (Cyclopoida) | + | + |
| <i>Ectinosoma</i> <i>consimum</i> (Harpacticoida) | + | + |
| Copepoda | 7 | 3 |
| <i>Podon</i> (<i>Pleopsis</i>) <i>polyphemoides</i> | + | + |
| <i>Polyphemus</i> <i>exicus</i> | + | + |
| <i>Podocadva</i> <i>camptonyx typica</i> | + | |
| <i>P. camptonyx</i> <i>orthonyx</i> | + | |
| <i>P. camptonyx</i> <i>podonoides</i> | + | |
| <i>P. camptonyx</i> <i>kajdakensis</i> | + | |
| <i>P. camptonyx</i> <i>macronyx</i> | + | |
| <i>P. camptonyx</i> <i>humulos</i> | + | |
| <i>P. Angusta</i> | + | |
| <i>Podocadva</i> <i>trigona</i> | + | |
| <i>P. trigona</i> <i>typical</i> | + | |
| <i>P. trigona</i> <i>intermedia</i> | + | |
| <i>Cercopagis</i> <i>pengoi</i> | + | |
| <i>C. socialis</i> | + | |
| <i>C. cylindrata</i> | + | |
| <i>C. longicaudata</i> | + | |
| <i>C. ossiani</i> | + | |
| <i>C. anonyx</i> | + | |
| <i>C. robusta</i> | + | |
| <i>Apagis</i> <i>longicaudata</i> | + | |
| <i>A. ossiani</i> | + | |
| <i>A. cylindrata</i> | + | |
| <i>Evadne</i> <i>anonyx producta</i> | + | |
| <i>E. anonyx</i> <i>deflexa</i> | + | |
| Cladocera | 24 | 2 |
| Lamellibranchiate larvae spp. | + | + |
| Cirripedia larvae (<i>Balanus</i> sp.) | + | + |
| Arachnida larvae | | + |
| Nematidae | + | + |
| Nereidae larvae | + | + |
| Chironomidae larvae | + | + |
| Oligochaeta larvae | | + |
| Meroplankton | 5 | 7 |
| Total Zooplankton | 36 | 12 |

Comparing the long-term fluctuations of zooplankton in the southern Caspian Sea showed that the average abundance was observed $41945 \pm 11797 \text{ ind.m}^3$ (values are depth and station averages) and the biomass was $323.6 \pm 128.2 \text{ mg.m}^3$ in 1996 (before *Mnemiopsis* invasion) (Fig. 3).

Zooplankton density decreased a 10-fold after the invasion of comb jelly (average density and biomass: $4568 \pm 482 \text{ ind.m}^3$, $34.8 \pm 3.6 \text{ mg.m}^3$, respectively, which did not rise to its initial density after the invasion of *Mnemiopsis* in the southern Caspian Sea.

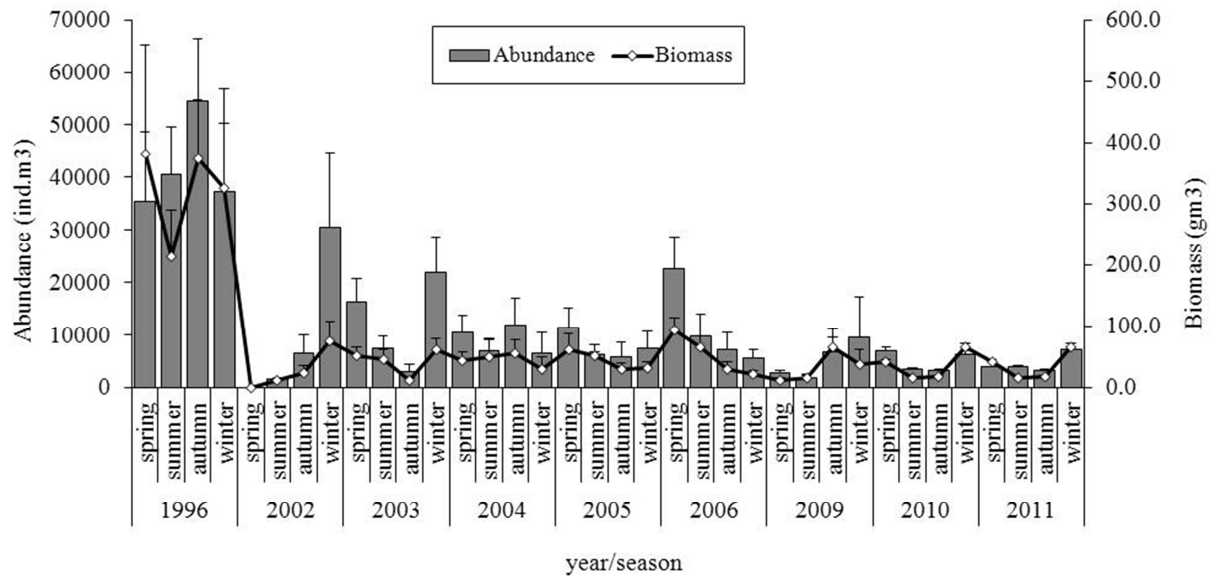


Fig. 4. Fluctuation of mesoplankton density and biomass in the southern Caspian Sea in 2002-2011.

4. Discussion and Conclusions

Mnemiopsis leidyi has a broad food spectrum, which includes fish eggs and larvae, different kinds of smaller mesoplanktonic animals, pelagic larvae and even protozoan plankton in which the copepods (Calanoids) constitute a major almost more than 75% in the southern Caspian Sea [2], [3]. With the invasion of the comb jelly there has been changed in some zooplankton species composition and abundance such as in Cladocera and copepods. However, the results in Iranian waters of the Caspian Sea showed a sharply dropped of mesoplankton after jelly invasion, and in the later years due to changes in species composition, orally available zooplankton such as copepods and Cladocera have not managed to increase their frequency. According to [21], in recent years 83% of the comb jelly bellies with diving and fresh collections from the sea were devoid of any foods. But in 20% of fed ctenophore, the copepodites (IV) and adults stages of *Acartia* (*Acanthacartia*) *tonsa* (copepoda) were the main course of comb jelly stomach [21]. Laboratory studies of the ctenophore reproduction in the southern Caspian Sea by Shiganova *et al.* [22] showed that when the comb jellies were in size of 16 mm were capable of spawning and the average number of eggs/day was 1174 and the highest number of 2824 eggs/day with ctenophore of 30-39 mm and weighs about 2.0-2.7 g. While, recent studies by [2] indicated that the comb jelly has an average spawning of 12 eggs/day that the most spawning with 115 eggs/day, in which by increasing the size of ctenophore, the spawning increased.

With the regards of the sharp decline in mesoplankton species composition and abundance of the Caspian Sea after the introduction of the comb, *Mnemiopsis* reduced fecundity due to lack of proper nutrition and food shortages is obvious and thus caused to the drastically reduction of the ctenophore in recent years (2013) compared to the early years (2001). On the other hand, laboratory studies showed that although the comb jelly *Mnemiopsis leidyi* feeds on a range of mesoplankton but has selective in the type of feeding [1], [19], [20]. *Mnemiopsis* is also a great carnivorous animal that actively hunts and feeds up to 10 times to its own weight per day [13]. So in the southern Caspian Sea, reduction of zooplankton and adverse conditions are the major reasons for *Mnemiopsis* reduced fertility. The results of this studies and finding of Finenko *et al.* [7] showed that excessive pressure by *Mnemiopsis* on zooplankton organisms and in particular to copepods will not let them to rise again, and resulting in a return to optimal nutrition can not be predicted in the southern Caspian Sea unless as long as the comb jelly *Mnemiopsis leidyi* to be removed or control from the sea. However, life cycle changes (phytoplankton → mesoplankton → Planktivorous fish) occurred in the Caspian Sea and, as with the similar example of invasion of *Mnemiopsis leidyi* in the Black Sea with its increased during the years of 1970 to 1980 has resulted in the disruption of the food chain in the sea, now a days with the introduction of *Mnemiopsis* into the Caspian Sea since 1999 we are facing with a new experience in which instead of fish, comb jelly plays as secondary consumers.

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