Bulletin of Pure and Applied Sciences
Vol.40A (Zoology), No.1,
January-June 2021: P.176-191

Print version ISSN 0970 0765
Online version ISSN 2320 3188
DOI 10.5958/2320-3188.2021.00021.8

Content Available online at: https://www.bpasjournals.com/zoology

Review Article

Biodiversity of Parasitic Trematode *Allocreadium* sp. Looss, 1894 (Digenea: Allocreadiidae): A Review

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Article Info:
Received on 16.02.2021
Accepted on 17.05.2021
Published on 15.06.2021

ABSTRACT:
Although there are many heartening studies have been done on the parasitic helminthes of vertebrates but there are serious deficiencies in checklist of trematodes *Allocreadium* Looss (Digenea: Allocreadiidae). The present study based on the literature survey to tabulate biodiversity of *Allocreadium* Looss reported from various hosts in the India and worldwide so far. *Allocreadium* sp. is one of the most important parasitic digenean trematode with wide geographic distribution range across the world. The findings reflected that these trematodes infecting very wide range of hosts from invertebrates to vertebrates. About 104 *Allocreadium* sp. have been summarized in present review recovered from various hosts including 44 Indian species as well. As the aquaculture playing a key role in the food security and economy of country that is deteriorating due to heavy parasitic load in fishes. Therefore, awareness, knowledge of biodiversity and causes of parasites should be in the society at grassroots level. The authors wish to suppose that current review might be helpful in the strategic management of aquaculture for health, economy and sustainable development.

Keywords: Trematode, Helminthes, Parasite, *Allocreadium* sp., Host, Fish, Digenea, Aquaculture, Biodiversity, Disease.

INTRODUCTION

The two third part of the globe is covered by water bodies (Mackenzie, 2011). The India is surrounded by aquatic system surrounded by three directions and comprising prosperous network of fresh water bodies like rivers and their tributaries as well (Upadhyay, 2012; Farzana et al., 2019). The marine and fresh water faunal resources are contributing immensely in food security and economy worldwide (Vörösmarty et al., 2000; Mackenzie, 2011; Jaiswal et al., 2013; Ringler et al., 2016). The fresh water and marine system animals are more common shelter for various species of parasitic helminthes (Malhotra et al.,

How to cite this article: Upadhyay, SK. and Babita (2021). Biodiversity of Parasitic Trematode *Allocreadium* sp. Looss, 1894 (Digenea: Allocreadiidae): A Review. *Bulletin of Pure and Applied Sciences-Zoology,*40A(1), 176-191.

2009; Kumar et al., 2011; Upadhyay et al., 2013a; Kumari and Perveen, 2017). Fishes carry parasitic helminthes infra community as biological tags and serve as the potent source of these parasites for autogenic and others infection either utilizing same habitat or different ecosystem (Shoop, 1988; Upadhyay et al., 2009; Jaiswal et al., 2014a). The digeneans are important group of helminth parasites, usually invade gastro-intestinal tract of fresh water as well as marine Piscean hosts (Upadhyay et al., 2013b; Jaiswal et al., 2014b; Upadhyay et al., 2015a; Upadhyay et al., 2015b; Selbach et al., 2020). Fishes are important due to its high nutritional, medicinal and economic values, therefore known to be the Gold coin of aquatics (Kumar and Upadhyay, 2016; Upadhyay, 2016a; Upadhyay, 2016b; Babita et al., 2019; Nanware et al., 2019; Wake and Geleto 2019). Majority of fresh water fishes carry heavy infection of digenean parasites which cause deterioration in the food value of fish and may even result in their mortality (Upadhyay, 2012; Upadhyay, 2016c; Upadhyay et al., 2016; Rani et al., 2019). Besides these, there are a number of helminth parasites, which are transmitted to human beings only through fishes due to weak association of host and parasites called zoonotic parasites that may affect the general public health (Youn, 2009; Singh et al., 2010; Miranda, 2018; Upadhyay, 2020a; Upadhyay, 2020b; Upadhyay, 2020c; Upadhyay and Nanware, 2020; Majewska et al., 2021; Santan-Lima et al., 2021). These parasites use the fish for their shelter, food and destruct more or less each and every organ resulting deformities in external as well as internal morphological changes (Roberts and Janovy, 2009; Upadhyay, 2017a; Upadhyay, 2017b; Upadhyay, 2018a; Upadhyay, 2019). Parasites also interfere to physiological function of hosts including digestions and nutrition of hosts, metabolism, lesions of the alimentary canal, damage reproductive and nervous system (Upadhyay, 2017c; Upadhyay, 2018b; Upadhyay et al., 2019a; Duan et al., 2021). Parasitic diseases, either alone or in conjunction with other environmental stresses, may influence weight or reproduction of the host, alter population characteristics and/or affect economic importance and production (Shoop, 1988; Upadhyay and Singh, 2018; Upadhyay et al., 2019b; Upadhyay et al., 2019c; Upadhyay et al., 2020). *Allocreadium* sp. (Looss, 1894) is the parasitic trematodes and most commonly found in fresh water cat fishes and cyprinid fish. This is widely distributed in Asia continent (Looss, 1900). *Allocreadium* sp. belongs to the family Allocreadiidae Stossich, 1904 and intestinal parasite microfauna all over the world. It is recorded from Asia (India), Nagano (Central Japan), United States of Russia, Alahama and Florida, Argentina, Poland and China (Hasegawa and Ozaki 1926; Koval, 1950; Thomas, 1957; Rai, 1962; Roytman, 1963; Grabda, 1971; Yamaguti, 1971; Wierzbicka, 1977; Ernest et al., 1993; Shimazu et al., 2000; Shimazu, 2003; Gao et al., 2008; Shimazu et al., 2011; Chandra et al., 2019). The fishes are used as hosts by helminth parasites for food, shelter, affect internal organs and also alter morphological characters (Upadhyay, 2012; Shimazu et al., 2016; Chandra et al., 2019; Upadhyay et al., 2020; Kashinskaya et al., 2021; Montes et al., 2021). The present communication deals with worldwide distribution of *Allocreadium* species so far.

BIODIVERSITY OF *ALLOCREADIUM* LOOSS IN INDIA

Genus *Allocreadium* was discovered by Looss in 19th century for the first time and named as *A. isoporum* Looss (1894; 1900; 1902) that was later recovered redescribed as *A. annandelei* from *Rhynchobatus djiddensis*
by in Southwell and Prasad (1913). Thereafter, Thaper and Dayal reported *Allocreadium* sp. from *Leuciscus indicus* in 1934. However, *A. handidi* from *Ophiocephalus punctatus* and *A. nicolli* from *Gobius giuris* were identified by Pande (1934, 1937, 1938). Dollfus (1949) described an ophthalmoxiphidiocercaria developing from rediae in sphaeriid bivalves as the cercarial stage of the type species *A. isoporum* (Looss, 1894; 1902). Further Kaw (1950) reported *A. nemachilus* from *Nemachilus kashmirensis* after decade of consecutive investigation. During 1950s to 1960s Gupta had explored the genus *Allocreadium* and published *A. thapari* from *Rita rita* and *A. mehri* from *Rhychobdella aculeate* (Gupta,

1950, 1951, 1953, 1956, 1961, 1962). The trematodes *A. raipurensis* from *Clarias batrachus* and *A. spindale* from *Mastacembelus armatus* were extracted and reported by Saxena (1958). Meanwhile during working with *O. punctatus*, Srivastava reported *A. ophiocephali* (1960). At the same duration various scientist across the country contributed a lot to the taxonomic diversity of *Allocreadiun* trematodes and recovered *A. dollfusi, A. singhi* and *A. hirani* from fish *Barbus tor* (Rai, 1962), *A. hetropneustusius* from fish *Hetropneustes fossilis* (Agarwal, 1963, 1964, 1966) and Kakaji (1968, 1969a, 1969b) explored and published *A. catlai* from *Catla catla, A. fasciatusi* from *Trichogaster fasiatus* and *A. gupti* from *R. rita.* On the other hand *A. kasmirensis* from *Schizothorax niger* was investigated by Fotedar and Dhar (1974) from Kashmir. Further, *A. fotedari* from *S. niger* was reported by Dhar and Kharoo (1984). Later on from South India, the parasitic trematodes *A. fascitusi* from *Aplocheilus melastigma* and *A. hamdai* from *Channa punctatus* were described by (1978, 1980). Kalyankar and Deshmukh (1980) extracted *A. indicum* from *Labeo rohita,* however Gupta and Puri (1980) recorded *A. calbasii* from *L. calbasu* and *A. manteri* from *Anabas testudineus.* Meanwhile Khan (1981) reported *A. jainin* from fish *Wallago attu,* and *A. mrigalai* from *Cirrhinus mrigala* in 1981 from Lucknow, Uttar Pradesh. *A. tigarai* was reported by Bhadauria and Dandotia (1986). In early 21st century, *A. tonsi* from *Clupisoma garua* and *A. bimaculatusi* from *Ompok bimaculatum* was reported (Singh, 2009). In the same year *A. bundelkhandensis* and *A. punctatai* recovered from *Channa* sp. of Jhansi, Uttar Pradesh (Sen and Siddiqui, 2010). A new species of trematode *A. tori* from freshwater fish *Tor putitora* was reported by Anjum et al. (2014). The redescription of parasite *A. handiai* was published on the basis of molecular analysis of the conserved gene and *in silico* approaches (Chaudhary et al., 2016). Very recently *A. gomtioensis* was recovered Chandra et al. (2019) from *Mystus tengara.* All the *Allocreadium* species, extracted, recovered, described and published by various scientists and scholars from various hosts inhabiting in India were summarized in Table. 1.

Table 1: Biodiversity checklist of *Allocreadium* species Looss, 1894 from various hosts in India

S.No.	Hosts	Parasites	Authors
1.	*Cyprinus carpio*	*Allocreadium* sp.	Looss, 1894, 1900
2.	*Rhynchobatus djiddensis*	*Allocreadium annandelei*	Southwell and Prasad, 1913
3.	*Leuciscus indicus*	*Allocreadium sp.*	Thaper and Dayal, 1934
4.	*Ophiocephalus punctatus*	*Allocreadium handidi*	Pande, 1934
5.	*Channa punctatus, Mystus tengara*	*Allocreadium handiai*	Pande, 1937; Madhavi, 1980
6.	*Gobius giuris*	*Allocreadium nicolli*	Pande, 1938
7.	*Schizothorax niger*	*Allocreadium crepidostomum*	Kaw, 1944
8.	*Nemachilus kashmirensis*	*Allocreadium nemachilus*	Kaw, 1950
9.	*Rita rita*	*Allocreadium thapari*	Gupta, 1950,1951; Chandra, 2015
10.	*Rhynchobdella aculeate*	*Allocreadium mehri*	Gupta, 1953, 1956, 1961
11.	*Mastacembelus armatus*	*Allocreadium spindale*	Saxena, 1958
12.	*Clarias batrachus*	*Allocreadium raipurensis*	Saxena, 1960
13.	*Ophiocephalus punctatus*	*Allocreadium ophiocephali*	Srivastava, 1960
14.	*Ophiocephalus punctatus*	*Allocreadium makundi*	Gupta, 1961, 1962

15.	*Barbus tor*	*Allocreadium dollfusi*	Rai, 1962
17.	*Barbus tor*	*Allocreadium singhi*	Rai, 1962
18.	*Barbus tor*	*Allocreadium hirani*	Rai, 1962
19.	*Hetropneustes fossilis*	*Allocreadium hetropneustusius*	Agarwal, 1963, 1964, 1966
20.	*Catla catla*	*Allocreadium catlai*	Kakaji, 1968
21.	*Trichogaster fasciatus*	*Allocreadium fasciatusi*	Kakaji, 1969a
22.	*Rita rita*	*Allocreadium guptai*	Kakaji, 1969b
23.	*Schizothorax niger*	*Allocreadium kashmirensis*	Fotedar and Dhar, 1974
24.	*Schizothorax niger*	*Allocreadium fotedari*	Dhar and Kharoo, 1984
25.	*Puntius sarana*	*Allocreadium saranai*	Gupta and Verma, 1976
26.	*Aplocheilus melastigma*	*Allocreadium fascitusi*	Madhavi , 1978, 1979
27.	*Labeo calbasu*	*Allocreadium calbasii*	Gupta and Puri, 1980
28.	*Anabas testudineus*	*Allocreadium manteri*	Gupta and Puri, 1980
29.	*Wallago attu*	*Allocreadium jainin*	Khan, 1981
30.	*Labeo rohita*	*Allocreadium indicum*	Kalyankar and Deshmukh, 1980
31.	*Cirrhinus mirigala*	*Allocreadium mrigalai*	Khan, 1981
32.	*Puntius sophore*	*Allocreadium tigarai*	Bhadauria and Dandotia, 1986
33.	*Mastacembalus armatus*	*Allocreadium dogri*	Agarwal and Sharma, 1989
34.	*Mastacembelus armatus*	*Allocreadium bengalensis*	Banerjee and Chandra, 1992
35.	*Clupisoma garua*	*Allocreadium tonsi*	Singh, 2009, Singh et al., 2010
36.	*Ompok bimaculatum*	*Allocreadium bimaculatusi*	Singh, 2009
37.	*Channa marulius*	*Allocreadium bundelkhandensis*	Sen and Siddiqui, 2010
38.	*Channa punctatus*	*Allocreadium punctatai*	Sen and Siddiqui, 2010
39.	*Brachirus orientalis*	*Allocreadium brachirusi*	Baghepour et al., 2011
40.	*Tor putitora*	*Allocreadium tori*	Anjum et al., 2014
41.	*Mystus tengara*	*Allocreadium handiai*	Chaudhary et al., 2016
42.	*Wallago attu*	*Allocreadium wallagoensis*	Deolalikar, 2017
43.	*Channa punctatus*	*Allocreadium gomtioensis*	Chandra et al., 2019
44.	*Mystus tengara*	*Allocreadium ramai*	Chandra et al., 2019

GLOBAL SCENARIO OF *ALLOCREADIUM* LOOSS

As *Allocreadioides* (Yamaguti, 1971), *Creadium* (Looss, 1900), *Macrolecithus* (Hasegawa and Ozaki, 1926) and *Neollocreadium* (Akhmerov, 1962) were some synonymies of *Allocreadium* (Looss, 1894). It is the most common parasitic trematode species found in the gut of freshwater fishes inhabiting Asia, Europe, Africa, North America, Japan china, etc. (Shimazu, 1992; Shimazu and Hashimoto, 1999; Caira and Bogea, 2005; Shimazu, 2008; Shimazu et al., 2011; Shimazu et al., 2016). The six species of *Allocreadium* from Czechoslovakia including *A. isoporum* (Looss, 1902); *A. transversale* (Szidat, 1938), *A. markewitschi* (Koval, 1949); *A. dogieli* (Koval, 1950), *A. carparum* (Odening, 1959), *A. papiligerum* (Rees, 1968) were studied and reported by Moravec 1984 (2001). Meanwhile *A. lobatum* (Wallin, 1909), *A. ictaluri* (Pearse, 1924), *A. pseudotritoni* (Rankin, 1937) and *A. alloneotenicum* (Wootton, 1957) were extracted and documented from Northern American hosts. It was reported that sphaeriid clams were the first and arthropods found to be second intermediate hosts for all these four North American *Allocreadium* sp. (Schell, 1985). About more than 20 species of *Allocreadium* was reported in China from the southern drainage basin, mainly Yangtze and Minjiang rivers by different parasitologists during past years

investigation (Wang, 1983; Wang, 1984; Zhang and Yang, 1994; Lu and Wu, 1996; Feng and Wang, 1997; Wu et al., 2006; Gao et al., 2008). The *Allocreadium* species documented worldwide (excluding India) so far summarized in Table 2.

Table 2: Global biodiversity checklist of *Allocreadium* species Looss, 1894 from various hosts

S.No.	Hosts	Parasites	Authors	Locality
1.	*Cyprinid fish, Barbatula barbatula*	*Allocreadium isoporum*	Looss, 1894, 1902; Moravec, 1992; Petkeviciute et al., 2018	United States of Russia (USSR)
2.	*Marine Fishes*	*Allocreadium atomon*	Odhner, 1901	United Kingdom (UK)
3.	*Marine host*	*Allocreadium pegorchis*	Stossich, 1901	Lebanon
4.	*Vertebrates hosts*	*Allocreadium alacre*	Stossich, 1905a	USSR and UK
5.	*Vertebrates hosts*	*Allocreadium mormyri*	Stossich, 1905b	USSR and UK
6.	*Vertebrates hosts*	*Allocreadium umbrinae*	Stossich, 1905c	USSR and UK
7.	*Semotilus atromaculates*	*Allocreadium wallini*	Wallin, 1909	Canada, United States (US)
8.	*Aquatic vertebrates*	*Allocreadium pallens*	Wallin, 1909	Canada, US
9.	*Semotilus atromaculates, S. corporalis*	*Allocreadium lobatum*	Wallin, 1909; Willis, 2001, 2002; Curran et al., 2006	Canada, North America, US
10.	*Vertebrate host*	*Allocreadium fowleri*	Leiper and Atkinson, 1914	UK
11.	*Fish hosts*	*Allocreadium chuscoi*	Pearse, 1920	Venezuela
12.	*Vertebrate host*	*Allocreadium priacanthi*	MacCallum, 1921	USSR
13.	*Aquatic hosts*	*Allocreadium ictaluri*	Pearse, 1924	North America
14.	*Opsariichthys uncirostris uncirostris*	*Allocreadium hasu*	Ozaki, 1926; Yamaguti, 1954	Central Japan
15.	*Zacco platypus, Gasterosteus aculeatus leiurus*	*Allocreadium japonicum*	Ozaki, 1926, Yamaguti, 1971	Central Japan
17.	*Misgurnus anguillicaudatus*	*Allocreadium gotoi*	Hasegawa and Ozaki, 1926; Shimazu, 1988, 2017	Central Japan
18.	*Plecoglossus altivelis altivelis*	*Allocreadium incertaesedis*	Kataoka and Momma, 1934	Central Japan
19.	*Carassius arassius, Leuciscus cephalus*	*Allocreadium pseudotritoni*	Rankin, 1937	North America
20.	*Cyprinus carpio, Misgurnus fossilis*	*Allocreadium transversale*	Szidat, 1938; Popiolek et al., 2003	Poland, Czechoslovakia
21.	*Ompok bimaculatus*	*Allocreadium mahaseri*	Pande, 1939	Bangladesh
22.	*Cyprinus carpio*	*Allocreadium markewitschi*	Koval, 1949; 1966, Grabda, 1971	Ukraine, USSR
23.	*Alburnus alburnus*	*Allocreadium album*	Koval, 1950	Ukraine
24.	*Alburnus alburnus*	*Allocreadium dogieli*	Koval, 1950; Wierzbicka, 1977	Ukraine, USSR

25.	*Macrognathus aculeatus*	*Allocreadium mehrai*	Gupta, 1953	Bangladesh
26.	*Carassius carassius*	*Allocreadium dubium*	Koval, 1957; 1966	Ukraine, USSR
27.	*Leuciscus cephalus*	*Allocreadium macrochis*	Bykhovskaya, 1987	USSR
28.	*Alestes macrolepidotus, Fresh water fish*	*Allocreadium sp.*	Thomas, 1957; Shimazu et al., 2016	West Africa, Japan
29.	*Aquatic hosts*	*Allocreadium alloneotenicum*	Wootton, 1957	North America
30.	*Hydroporus rufifrons Pisidium sp., Aquatic hosts*	*Allocreadium neotenicum*	Peters, 1957; Bray et al., 2012; Camp, 1992; Petkeviciute et al., 2018	Great Britain, Bangladesh, Norway
31.	*Cyprinus carpio*	*Allocreadium carparum*	Odening, 1959; Moravec, 1984, 2001	Czechoslovakia
32.	*Cyprinid fish*	*Allocreadium elongatum*	Akhmerov, 1960a	USSR
33.	*Cyprinid fish*	*Allocreadium erythroculteris*	Akhmerov, 1960a	USSR
34.	*Marine fish*	*Allocreadium maculate*	Akhmerov, 1960a	USSR
35.	*Marine fish*	*Allocreadium pseudaspii*	Akhmerov, 1960a	USSR
36.	*Hypophthalmichthys molitrix*	*Allocreadium hypophthalmichthydis*	Akhmerov, 1960b	USSR
37.	*Clarias spp.*	*Allocreadium mazoensis*	Beverley-Burton, 1962	Rhodesia
38.	*Vertebrate hosts*	*Allocreadium hemibarbi*	Roytman, 1963; Vainutis, 2020	USSR
39.	*Cyprinus carpio*	*Allocreadium papiligerum*	Rees, 1968; Moravec, 1984, 2001	Czechoslovakia
40.	*Barbus bynni*	*Allocreadium sudanensis*	Saoud et al., 1974	Sudan
41.	*Tribolodon hakonensis; Salvelinus leucomaenis leucomaenis*	*Allocreadium tosai*	Shimazu, 1988	Central Japan
42.	*Freshwater fish*	*Allocreadium species*	Junyi, 1991	China
43.	*Rhynchocypris percnurus, Gasterosteus aculeatus leiurus*	*Allocreadium brevivitellatum*	Shimazu, 1992	Central Japan
44.	*Percichthys colhuapiensis*	*Allocreadium patagonicum*	Shimazu et al., 2000	Argentina
45.	*Oncorhynchus mykiss, Clinostomus funduloides*	*Allocreadium lucyae*	Williams et al., 1992; Ernest et al., 1993	Alahama, Florida
46.	*Glossogobius giuris*	*Allocreadium glossogobium*	Banerjee and Chandra, 1992	Bangladesh
47.	*Anabas testudineus*	*Allocreadium minutum*	Banerjee and Chandra, 1992	Bangladesh
48.	*Heteropneustes fossilis*	*Allocreadium mymensinghi*	Banerjee and Chandra, 1992	Bangladesh
49.	*Glossogobius giuris*	*Allocreadium ovatum*	Banerjee and Chandra, 1992	Bangladesh

50.	*Molluscs*	*Allocreadium species*	Zhkhov, 1996	USSR
51.	*Gnathopogon elongatus elongatus*	*Allocreadium tribolodontis*	Shimazu and Hashimoto, 1999,	Central Japan
52.	*Phoxinus steindachneri, G. elongatus elongatus*	*Allocreadium shinanoense*	Shimazu, 2003	Central Japan
53.	*Phoxinus steindachneri, G. elongatus elongates*	*Allocreadium aburahaya*	Shimazu, 2003	Central Japan
54.	*Galaxias maculatus*	*Allocreadium pichi*	Flores et al., 2004	Argentina
55.	*Nipponocypris temminckii, Tribolodon hakonensis*	*Allocreadium sp.*	Shimazu, 2005, 2008	Central Japan
56.	*Abbottina rivularis*	*Allocreadium danjiangensis*	Gao et al., 2008	China
57.	*Brachirus orientalis*	*Allocreadium brachirusii*	Bagherpour et al., 2011	Persian Gulf
58.	*Tanakia lanceolata*	*Allocreadium lanceolatum*	Shimazu et al., 2011	Central Japan
59.	*G. elongatus elongatus*	*Allocreadium tamoroko*	Shimazu and Urabe, 2013	Central Japan
60.	*Vertebrate host*	*Allocreadium khankaiensis*	Vainutis, 2020	USSR

CONCLUSIONS

Allocreadium Looss is the parasitic trematodes and most commonly found in aquatic vertebrates of India and all over the world. It is a digenean trematode which causes deterioration in the food value of fish, transmitted to human beings and affect the general public health. These parasites use the fish for the purpose of shelter, food and destruct more or less each and every organ resulting deformities in development, growth, metabolism, digestive, reproductive, nervous system and ultimately result in their mortality. Thus the parasitic helminthes are deteriorating the aquaculture industry in terms production, food security and economy. Although there are many heartening studies have been done on the parasitic helminthes but there are serious deficiencies in checklist to work out the biodiversity *Allocreadium* Looss (Digenea: Allocreadiidae). The present study based on the literature survey and tabulated 44 species of *Allocreadium* from India and 60 species from outside India. The findings showed that these trematodes have immense adaptability hence occupying very wide range of hosts from invertebrates to vertebrates. In India these are most commonly reported from fishes. Therefore, elementary knowledge of these parasites in the society could help in the healthy and disease free aquaculture system. The authors wish to suppose that current review might be helpful in the strategic management of aquaculture for sustainable development. Further research work should be continued to clarify the biodiversity of fish parasites.

Funding Support
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest.

Acknowledgements
Authors are thankful to Head Department of Biotechnology, Maharishi Markandeshwar (Deemed to be University), Mullana-Ambala (HR), India for his kind acquiescence and encouragement to carry out research work.

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