

## Distribution of *Zostera* Species in Japan. II *Zostera asiatica* Miki, *Z. caespitosa* Miki and *Z. caulescens* Miki (Zosteraceae)

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**Abstract** The distribution of *Zostera asiatica* Miki, *Z. caespitosa* Miki and *Z. caulescens* Miki, which are endemic to around Japanese archipelago, was assessed based on 396 herbarium specimens collected throughout Japan from 2004 to 2006. A total of 18 sites of *Z. asiatica*, 33 sites of *Z. caespitosa* and 30 sites of *Z. caulescens* were recorded. Some new findings on distribution were shown: *Z. asiatica* occurs in the western Hokkaido; *Z. caespitosa* occurs in Miyagi Prefecture as southernmost population on the Pacific Ocean side; *Z. caulescens* occurs in Miyagi Prefecture and Oki Islands, Shimane Prefecture.

**Key words:** Seagrass, *Zostera asiatica*, *Zostera caespitosa*, *Zostera caulescens*, Zosteraceae.

### Introduction

The Japanese seagrass flora is noteworthy since it contains several endemic species, namely

*Zostera asiatica*, *Z. caespitosa*, *Z. caulescens*, *Z. japonica*, *Phyllospadix iwatensis* and *P. japonicus* (Zosteraceae), despite the fact that most seagrass species are widespread (Short *et al.*, 2001).

However, as described by Tanaka *et al.* (2009), reports on the distribution of seagrass species around Japan are limited. Particularly the information about these endemic species is poor (Miki, 1933, 1934; Omori, 1993, 1996; Environment Agency of Japan, 1994; Kudoh, 1999; Aioi *et al.*, 2000; Shoji and Hasegawa, 2004; Akaike and Goda, 2006; Tanaka *et al.*, 2006; Yatsuya *et al.*, 2007; Fujiwara *et al.*, 2009; Ishikawa, 2009).

Based on a survey of over 6,000 herbarium specimens collected from 2004 to 2006 in the research project being conducted by the Ministry of Agriculture, Forests and Fisheries and held in the herbarium at the National Museum of Nature and Science, Japan (TNS), we have compiled detailed locality data of all *Zostera* species in Japan. In this the second report resulting from this survey, we present distribution data for *Zostera asiatica*, *Z. caespitosa* and *Z. caulescens*.

### Materials and Methods

Surveys of *Zostera* species were conducted by making observations from the seashore, from a ship, and by snorkeling and SCUBA diving excursions. Almost the entire Japanese coastline was surveyed from May 2004 to December 2006. Plants with several shoots connected by rhizomes were collected at each population confirmed in the surveys. Voucher specimens were made for all sites; these have been deposited in the herbarium of the National Museum of Nature and Science, Japan (TNS). Information on habitat parameters, including water depth, water temperature, transparency and bottom sediment, were also collected and recorded on the voucher specimen labels.

### Results and Discussion

A total of 18 sites of *Zostera asiatica* were confirmed only in Hokkaido Prefecture, based on a total of 148 herbarium specimens collected in these surveys (Table 1, Fig. 1). The distribution of *Z. asiatica* has been known as the north of Korean Peninsula, Japan (Hokkaido and Iwate

Prefectures), Sakhalin and the Kurile Islands (den Hartog, 1970, Aioi *et al.* 2000), however, the western Hokkaido had been blank of distribution of the species (Omori, 2000). It became clear for the first time in this survey that *Z. asiatica* inhabits in the western Hokkaido. Although some of the specimens (No. 3, 4, 5, 7, 9, 10, 11, 13, 14, 15 in Table 1 and Fig.1) were collected as drifting shoots (Akaike and Goda, 2006), it is possible that some populations of *Z. asiatica* are present in their neighborhood besides confirmed populations.

A total of 33 sites of *Zostera caespitosa* were confirmed in 9 prefectures, based on a total of 170 specimens (Table 1, Fig. 1). The distribution of *Z. caespitosa* has been reported as Korean Peninsula, northeast China and Japan (Hokkaido and north-central Honshu: Kyoto Prefecture on the Sea of Japan side and Iwate Prefecture on the Pacific Ocean side) (Omori, 2000). In this study, it was revealed that many populations are occurred in Miyagi Prefecture. Particularly noteworthy of them is Samenoura Bay (No. 31 in Table 1 and Fig. 1), which is southernmost population on the Pacific Ocean side. Also on the Sea of Japan side where the density of *Z. marina* populations is reported to be lower (Tanaka *et al.*, 2009), some populations of *Z. caespitosa* are confirmed.

A total of 30 sites of *Zostera caulescens* were confirmed in 5 prefectures, based on a total of 78 specimens (Table 1, Fig. 1). The distribution of *Z. caulescens* has been known to be the south of Korean Peninsula and Japan (north-central Honshu: Iwate, Chiba, Kanagawa, Niigata, Ishikawa and Shimane Prefecture) (Omori, 2000). In this study, it was revealed that many populations are occurred in Miyagi Prefecture. Oki Islands (No. 81 in Table 1 and Fig. 1) is recorded to be southwesternmost population in the Sea of Japan for the first time.

*Z. asiatica*, *Z. caespitosa* and *Z. caulescens* were shown to be primarily occurred in the habitat similar to that of *Z. marina*: sheltered sites not open coastline. The tendency is noticeable on the Sea of Japan where the density of seagrass com-

Table 1. Herbarium specimens of *Zostera* species collected

No.*	Collection Site	Latitude	Longitude	Water depth (m)	Collection Date	TNS accession No.**
<i>Zostera asiatica</i> Miki						
1	Hama-tonbetsu, Hokkaido Pref.	45°07'16"	142°25'01"	10.8	2005. 8.9	9539241–9539296
2	Koetoioki, Wakkanai, Hokkaido Pref.	45°24'20"	141°45'43"	9.5	2006. 7.3	9533317
3	Koetogyokounai, Wakkanai, Hokkaido Pref.	45°24'32"	141°45'21"		2006. 5.30	9533316
4	Esandomari, Wakkanai, Hokkaido Pref.	45°26'43"	141°38'37"		2005.11.9	9536767
5	Keizanpaku, Wakkanai, Hokkaido Pref.	45°26'43"	141°38'37"		2006.11.21	9533330
6	Esanuka, Sarufutsu, Hokkaido Pref.	45°13'31"	141°17'19"	8.1	2005. 8.2	9539171–9539240
7	Oniwakigyokounai, Rishirifuji, Hokkaido Pref.	45°08'04"	141°18'29"		2006. 7.24	9533324
8	Oniwakimumaura, Rishirifuji, Hokkaido Pref.	45°06'50"	141°17'19"	6.4	2006. 7.4	9533318–9533320
9	Oniwaki, Rishiri, Hokkaido Pref.	45°06'40"	141°17'27"		2004. 7.8	9535171
10	Izumi, Kutsugata, Rishiri, Hokkaido Pref.	45°10'58"	141°08'19"		2006.11.21	9533329
11	Tanetomi, Kutsugata, Rishiri, Hokkaido Pref.	45°11'52"	141°08'15"		2006.11.20	9533328
12	Funadomari Harbor, Rebun, Hokkaido Pref.	45°12'21"	141°08'13"	5.4	2005. 6.1	9536756
13	Teshiokounai, Tesio, Hokkaido Pref.	44°52'26"	141°44'18"		2006.11.17	9533326
14	Okitsu, Tomamae, Hokkaido Pref.	44°20'03"	141°40'45"		2006.12.1	9533331
15	Tomamae, Tomamae, Hokkaido Pref.	44°14'73"	141°39'37"		2004.10.29	9541027
16	Cape Entomo, Minami-Usu, Date, Hokkaido Pref.	42°29'18"	140°48'10"	5.2	2005. 8.8	9539407, 9539408
17	Minami-Usu, Date, Hokkaido Pref.	42°29'33"	140°47'27"	4.7	2005. 8.8	9539409–9539412
18	Fukushima, Hokkaido Pref.	41°27'44"	140°14'54"	4.0	2004. 6.24	9539790
<i>Zostera caespitosa</i> Miki						
19	Fujimi, Wakkanai, Hokkaido Pref.	45°25'44"	141°38'16"	0.6	2004. 6.15	9536754, 9541025
20	Fujimi, Wakkanai, Hokkaido Pref.	45°25'18"	141°38'04"	0.3	2004.10.6	9535166, 9541023
21	Mouth of Usu Bay, Usu, Date, Hokkaido Pref.	42°30'31"	140°46'23"	4.2	2005. 8.8	9539404–9539406
22	Tofuga-ura, Noheji Bay, Noheji, Kitakami, Aomori Pref.	40°52'29"	141°08'35"		2006. 8.22	9537267
23	Iwatsuki Dainosawa, Kesennuma, Miyagi Pref.	38°51'39"	141°35'09"	1.0	2004. 7.8	9535048
24	Hajikami Akebo, Kesennuma, Miyagi Pref.	38°49'32"	141°35'36"	0.5	2005. 8.30	9535025
25	Tsuya Nagane, Motoyoshi, Miyagi Pref.	38°47'21"	141°31'23"	1.7	2005. 8.30	9535033
26	Arato Port, Minamisanriku, Motoyoshi, Miyagi Pref.	38°40'37"	141°29'20"	1.9	2006. 5.17	9533620
27	Fusubozaki, Minamisanriku, Motoyoshi, Miyagi Pref.	38°40'34"	141°28'49"	2.0	2006. 5.17	9533616
28	Omori, Minamisanriku, Motoyoshi, Miyagi Pref.	38°40'74"	141°27'34"	1.9	2006. 5.17	9533612
29	Kappazawa, Minamisanriku, Motoyoshi, Miyagi Pref.	38°38'41"	141°28'48"	3.1	2006. 5.16	9533600
30	Fujihama, Minamisanriku, Motoyoshi, Miyagi Pref.	38°38'19"	141°30'15"	2.2	2006. 5.16	9533594
31	Samenoura Bay, Ojika, Ishinomaki, Miyagi Pref.	38°22'12"	141°29'28"	2.7	2006. 8.18	9536569–9536676
32	Katsura Harbor, Tobi Is., Sakata, Yamagata Pref.	39°10'32"	139°33'09"	3.0	2006. 9.16	9536577–9536617

Table 1. —(Continued)—

No.*	Collection Site	Latitude	Longitude	Water depth (m)	Collection Date	TNS accession No.**
33	Uchiura, Awashimaura, Awashima Is. Niigata Pref.	38°27'34"	139°15'18"	10.8	2005. 7.22	9540085
34	Hiramatsu, Sado, Niigata Pref.	38°11'04"	138°29'04"	8.2	2006. 8.3	9535760
35	Shirose, Sado, Niigata Pref.	38°08'23"	138°27'19"	7.8	2005. 8.18	9540087
36	Futami, Sado, Niigata Pref.	37°58'53"	138°15'54"	11.1	2005. 7.13	9540081
37	Toyota, Sado, Niigata Pref.	37°56'32"	138°19'35"	3.6	2006.10.16	9535767, 9537656-9537690
38	Akadomari, Sado, Niigata Pref.	37°51'23"	138°24'35"	7.0	2006. 8.2	9535755
39	Nakanami, Himi, Toyama Pref.	36°57'00"	137°02'24"	8.0	2005. 9.2	9540765
40	Tagarasu, Obama, Fukui Pref.	35°32'33"	135°49'52"	2005. 8.29	2005. 8.29	9540088-9540105
41	Karubihama, Ine, Kyoto Pref.	35°39'30"	135°17'17"	2.0	2006. 8.23	9532149
42	Nagae, Miyazu, Kyoto Pref.	35°39'02"	135°15'13"	5.3	2005. 4.12	9532064-9532066
43	Nagae, Miyazu, Kyoto Pref.	35°38'15"	135°15'04"	6.0	2006. 8.4	9532144
44	Ejiri, Miyazu, Kyoto Pref.	35°35'14"	135°12'23"	4.5	2006. 8.4	9532139
45	Shimakage, Miyazu, Kyoto Pref.	35°35'21"	135°15'02"	2006. 4.17	2006. 4.17	9532076, 9532077
46	Tai, Maizuru, Kyoto Pref.	35°35'10"	135°14'23"	2.5-4.5	2006. 8.4	9532127
47	Shimakage, Maizuru, Kyoto Pref.	35°34'35"	135°15'32"	6.0-7.0	2006. 8.4	9532122
48	Nariu, Maizuru, Kyoto Pref.	35°35'23"	135°27'16"	6.0	2006. 8.21	9532091
49	Nariu, Maizuru, Kyoto Pref.	35°35'15"	135°27'07"	6.0	2006. 8.21	9532088
50	Otsu Is. Maizuru, Kyoto Pref.	35°29'14"	135°20'21"	1.8	2006. 6.14	9532113, 9532114
51	Takugi, Okinoshima, Oki, Shimane Pref.	36°10'10"	133°14'48"	2005.10.8	2005.10.8	9540106-9540130
<i>Zostera caulescens</i> Miki						
52	Iwatsuki Senganda, Kesennuma, Miyagi Pref.	38°52'01"	141°35'15"	5.0	2004. 7.8	9535050, 9535051
53	Iwatsuki Dainosawa, Kesennuma, Miyagi Pref.	38°51'31"	141°35'12"	3.0	2004. 7.8	9535046, 9535047
54	Kodanohama Beach, Nagasaki, Kesennuma, Miyagi Pref.	38°51'13"	141°37'26"	3.0	2005. 1.6	9535053
55	Nagaisomori, Kesennuma, Miyagi Pref.	38°50'50"	141°35'49"	2.0	2004. 7.8	9535043
56	Nagato Shichihanzawa, Kesennuma, Miyagi Pref.	38°50'34"	141°35'31"	4.5	2004. 7.8	9535042
57	Hikado Port, Motoyoshi, Motoyoshi, Miyagi Pref.	38°48'32"	141°33'22"	1.1	2005. 8.30	9535030
58	Tanoura, Minamisanriku, Motoyoshi, Miyagi Pref.	38°44'44"	141°32'53"	3.0	2006. 8.23	9533580
59	Minato Port, Minamisanriku, Motoyoshi, Miyagi Pref.	38°44'35"	141°32'12"	2.4	2006. 8.23	9533583
60	Isatomae, Minamisanriku, Motoyoshi, Miyagi Pref.	38°42'55"	141°31'31"	3.8	2006. 8.23	9533587
61	Tatezaki, Minamisanriku, Motoyoshi, Miyagi Pref.	38°42'30"	141°32'08"	4.9	2006. 8.23	9533586
62	Yoriki, Minamisanriku, Motoyoshi, Miyagi Pref.	38°42'29"	141°31'17"	2.0	2006. 8.23	9533590
63	Hosoura, Minamisanriku, Motoyoshi, Miyagi Pref.	38°41'40"	141°29'57"	1.8	2006. 5.17	9533625
64	Shimizu, Minamisanriku, Motoyoshi, Miyagi Pref.	38°41'22"	141°29'28"	2.4	2006. 5.17	9533622
65	Fusubozaki, Minamisanriku, Motoyoshi, Miyagi Pref.	38°40'34"	141°28'49"	1.6-2.6	2006. 5.17	9533617, 9533618
66	Hiraiso Port, Minamisanriku, Motoyoshi, Miyagi Pref.	38°40'40"	141°28'24"	0.9	2006. 5.17	9533614

Table 1. —(Continued)—

No.*	Collection Site	Latitude	Longitude	Water depth (m)	Collection Date	TNS accession No.**
67	Mouth of Mizushiri River, Minamisanriku, Motoyoshi, Miyagi Pref.	38°40'19"	141°26'41"	1.1	2006. 5.17	9533610
68	Hadenya, Minamisanriku, Motoyoshi, Miyagi Pref.	38°38'52"	141°28'45"	2.3	2006. 5.16	9533601
69	Oriate, Minamisanriku, Motoyoshi, Miyagi Pref.	38°38'42"	141°26'39"	3.2	2006. 5.16	9533607
70	Kappazawa, Minamisanriku, Motoyoshi, Miyagi Pref.	38°38'41"	141°28'48"	3.4	2006. 5.16	9533598
71	Nagashimizu, Minamisanriku, Motoyoshi, Miyagi Pref.	38°38'14"	141°30'38"	2.0	2006. 5.16	9533593
72	Samenoura Bay, Ojika, Ishinomaki, Miyagi Pref.	38°22'16"	141°29'08"	2.9	2006. 8.18	9536539-9536568
73	Oota, Sado, Niigata Pref.	35°54'35"	138°29'26"	13.2	2006. 8.2	9535756, 9535757
74	Shintomi, Futsu, Chiba Pref.	35°20'18"	139°49'64"		2005. 6.27	9541041
75	Futsu, Futsu, Chiba Pref.	35°19'27"	139°47'58"	1.9	2006. 6.26	9534945-9534949
76	Futsu Tidal flat, Futsu, Chiba Pref.	35°19'16"	139°47'35"	1.9	2006. 6.26	9541044
77	Tsuhama, Futsu, Chiba Pref.	35°12'18"	139°50'41"	4.0	2006.10.26	9534950-9534954, 9533566
78	Chojagasaki, Hayama, Miura, Kanagawa Pref.	35°15'15"	139°34'40"	1.8	2004. 7.22	9526486-9526489
79	Sajima, Yokosuka, Kanagawa Pref.	35°13'14"	139°37'31"	1.8	2004. 7.7	9526520-9526523
80	Jogasaki, Miura, Kanagawa Pref.	35°08'15"	139°37'19"	1.5	2004. 7.16	9526562
81	Takagi, Okinoshima, Oki, Shimane Pref.	36°09'25"	133°15'20"	15.0	2005.10.20	9540016

\*Numbers of sites are shown in Fig. 1.

\*\*Accession numbers of National Museum of Nature and Science, Japan (TNS).

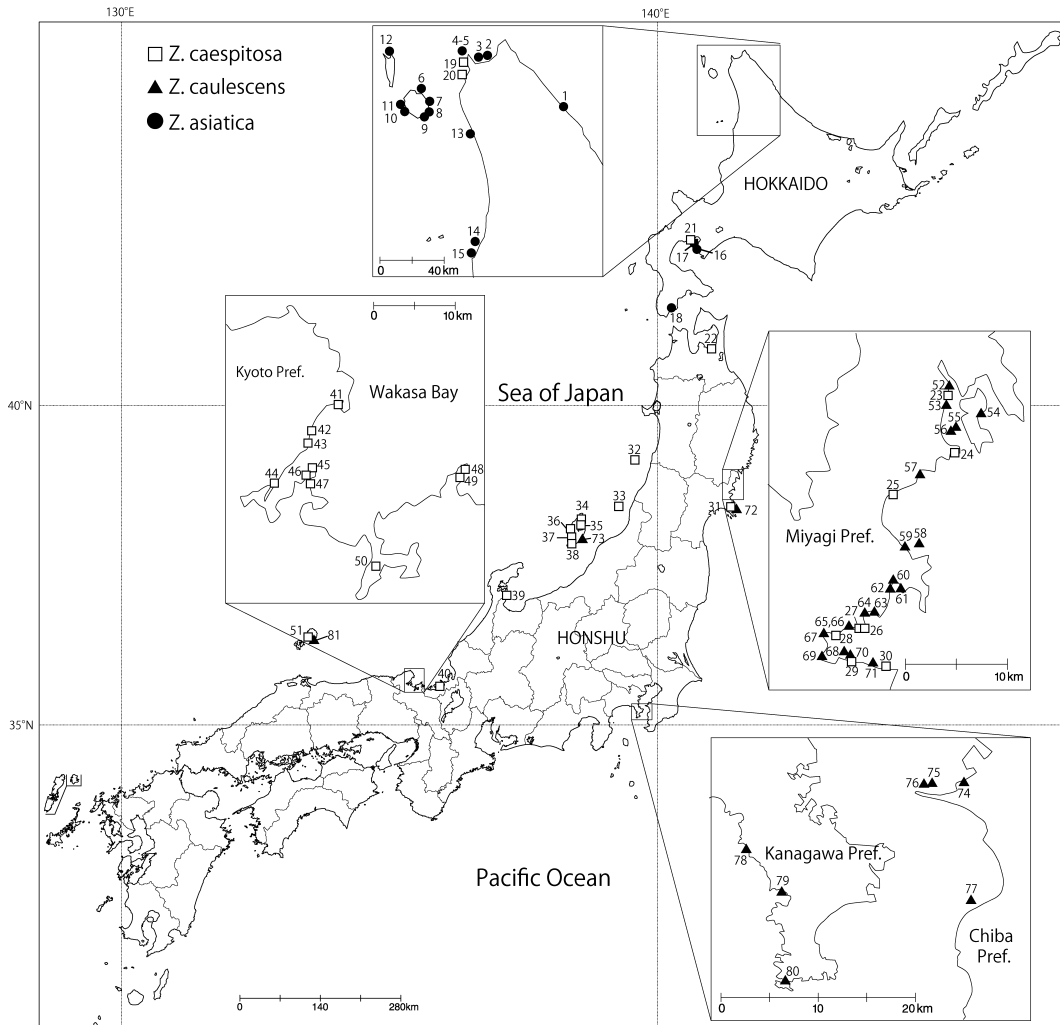


Fig. 1. Distribution of *Zostera asiatica*, *Z. caespitosa* and *Z. caulescens* in Japan. Numbers of the map correlate to collection numbers in Table 1.

munities is lower. The few communities are Tobu Island (No. 32 in Table 1 and Fig. 1), Awashima Island (33), Sado Island (34–38, 73), Toyama Bay (39), Wakasa Bay (40–49) and Oki Islands (51, 81), in which *Z. marina* are also recorded (Tanaka *et al.* 2009).

Water depths of collection sites ranged from 4 m to 10.8 m in *Z. asiatica*, from 0.3 m to 11.1 m in *Z. caespitosa*, and from 0.9 to 15 m in *Z. caulescens* (Table 1). *Z. caulescens* denoted the same tendency of the frequency distribution of *Z. marina*, occurred primarily at depths of up to 3 m

and infrequently over 10 m (Tanaka *et al.*, 2009). In contrast, *Z. asiatica* and *Z. caespitosa* are distributed with uniformity within each range of water depth. *Z. asiatica* was definitely found only at deep depth area. It was reported that *Z. asiatica* produces thinner and larger leaves at deeper bottoms with lower light condition, as in some shade-tolerant species in terrestrial plants (Watanabe *et al.*, 2000). This species may adapt to low light condition. The deep habitat of *Z. asiatica* may have disturbed discovery of their localities.

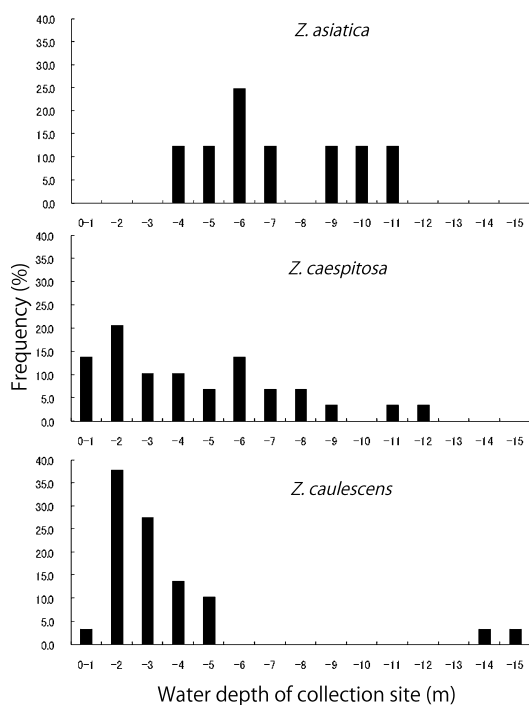


Fig. 2. Frequency distribution of water depths at the *Zostera asiatica*, *Z. caespitosa* and *Z. caulescens* collection sites.

The new findings on distributions of the three species are important information for future investigation about genetic structure, covering whole area of their distribution. It is highly possible that these endemic species and *Z. marina* were differentiated in East Asia including Japanese Archipelago (Tanaka *et al.*, 2003). Conducting studies on genetic structure, the occurrence and diffusion of the species may be discussed in relation with geological history, especially on formation of the Sea of Japan.

### Acknowledgements

The authors thank Yuriko Kawana, Yuki Ando, Sho Nagata for mounting and organizing herbarium specimens, Keiko Aioi, Shogo Arai, Akihiro Dazai, Masaaki Fukuda, Yumiko Kato, Nobuyasu Nakabayashi, Satoshi Ohata, Norihiko Shoji, Ryuta Terada, Yozo Wada for sampling plants, Masahiro Notoya, Yoko Satta, Shinji Kiri-

hara, Hitoshi Iizumi, Masahiro Nakaoka, Toshinobu Terawaki, Hiroshi Sako, Kiyokazu Inoue, Hirofumi Kawakami for conducting the research project.

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