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IS THE REPUBLIC OF CROATIA FOLLOWING THE TREND IN SALMONELLOSIS IN RELATION TO THE EUROPEAN UNION?

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Salmonellosis remains a persistent public health threat globally and within the European Union, as shown by statistical data from 2014 to 2023. This review compares the incidence of non-typhoidal salmonellosis in the Republic of Croatia with trends in European Union member states, drawing on both European and national infectious disease surveillance data. Across the EU, 810,082 cases of salmonellosis were reported during this ten-year period, with an average morbidity rate of 18.2 per 100,000 inhabitants; the highest count occurred in 2015 and the lowest in 2020 - a decline likely associated with the COVID-19 pandemic. In Croatia, 11,896 cases were registered during the same period, with the highest number in 2015 and the lowest in 2021, and an average morbidity rate of 29.2 per 100,000 inhabitants. With respect to age groups, the greatest variation among EU member states was observed in children aged 0-4 years (23.5%) and adults aged ≥65 years (17.8%). Croatia follows the EU trend in the youngest group (28.9%) but stands out due to a significantly lower proportion of cases (10.5%) in the oldest population. The predominant serotype in the EU is Salmonella Enteritidis (59.8%), with particularly high proportions in Poland (89.7%) and Hungary (75.3%), whereas Croatia mirrors the EU average at 60.0%. Salmonella Typhimurium is the second most common serotype, with higher prevalence in Germany, Cyprus, and Croatia. Salmonellosis unfortunately results in fatalities: during the observed decade, 1,049 deaths were reported in the EU (primarily in the United Kingdom, Germany, and the Czech Republic), and 9 deaths (0.9% of the total) were recorded in Croatia. Although salmonellosis cases declined in 2020, an upward trend has been observed across the EU in subsequent years.

Keywords: CROATIA, EUROPEAN UNION, MORBIDITY, SALMONELLOSIS

INTRODUCTION

Salmonellosis remains the second leading zoonotic disease worldwide after campylobacteriosis, representing a serious public health threat characterized by high global morbidity and mortality. According to statistical data, non-typhoidal *Salmonella* affects approximately 150 million people annually across the globe, resulting in more than 60,000 deaths (1, 2). In Europe, diseases caused by bacteria of the genus *Salmonella* have been documented since the Peloponnesian Wars (3). During World War I, they caused nearly 3 million deaths (4). Significant scientific advances; from Dr. Eberth's first visualization of the pathogen in 1880, to Dr. Salmon's isolation of the organism from the intestines of a dead pig, and modern classification into two species (*S. enterica* and *S. bongori*), have not diminished the ubiquity of these bacteria (5-7). *S. enterica* comprises 2,659 serotypes (99%), more than 100 of which are pathogenic to humans, while 22 serotypes (0.8%) belong to *S. bongori* (8). Detailed classification is based on the identification of three surface antigens: somatic (O), flagellar (H), and capsular (Vi) (7). Despite the development of advanced diagnostic techniques such as polymerase chain reaction (PCR), enzyme-linked immunosorbent assay (ELISA), and other methods, culture media remain essential, relying on classical biochemical reactions, including detection of proteolytic activity, hydrogen sulphide (H_2S) production, and carbohydrate fermentation using pH indicators (9-11). *Salmonella* most commonly enters the human host through ingestion, passes the gastric barrier, infiltrates the intestinal epithelium, attaches to cells in the intestinal lumen, and invades to produce virulence factors (disease development requires 10^3-10^9 bacteria). The incubation period typically ranges from 6-72 hours, followed by symptoms such as fever, diarrhoea, vomiting, and digestive disturbances. Transmission can be primary, secondary, or vertical; key reservoirs include animals and their products, infected humans, and contaminated fruits and vegetables. Diagnosis is based on clinical presentation and laboratory tests, with treatment usually being symptomatic, including electrolyte replacement, rehydration, and antipyretics as necessary (12, 13).

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The term "salmonellosis" broadly refers to all diseases caused by *Salmonella* species. However, because of the distinct biological properties and clinical presentation of *Salmonella Typhi*, in medical practice the term generally refers to non-typhoidal salmonellae, excluding typhoid and paratyphoid fever (14). This definition will be used throughout the text. The Republic of Croatia (Croatia), a full member of the European Union (EU) since 2013, is geographically positioned at the crossroads of Central and Southeastern Europe. In light of Croatia's EU membership and the public health significance of salmonellosis, this paper aims to present salmonellosis incidence trends in Croatia and compare them with morbidity in other EU member states between 2014 and 2023.

METHODS

This study was conducted by analysing publicly available statistical data from the Croatian Institute of Public Health (CIPH) and from the European Surveillance System (TESSy), the main disease surveillance tool of the European Centre for Disease Prevention and Control (ECDC). Demographic data on EU member states were obtained from the publicly accessible Eurostat platform (15). Only laboratory-confirmed cases were included in the statistical analysis. Data processing was performed using descriptive statistics in Microsoft Excel, with results presented in tables and figures. In Croatia, reports of infectious diseases are consolidated in the Infectious Disease Reporting Registry, under the authority of the CIPH, which continuously reports to the ECDC. As clinical practice primarily considers only non-typhoidal cases, and according to the International Classification of Diseases (ICD), typhoid and paratyphoid fevers are coded as A01-A01.4, while non-typhoidal salmonellosis is coded as A02-A02.9. EU results are presented according to member-state status; thus, up to 2020, the United Kingdom (UK) was included in the statistics, but excluded thereafter due to Brexit. Furthermore, because incidence rates are not age-standardised and population age structure and surveillance methods differ between countries, interpretation of comparative results should be made with caution.

RESULTS

A total of 810,082 cases of salmonellosis were reported within the EU during the ten-year period from 2014 to 2023, with the highest number in 2015 and the lowest in 2020 (Table 1). During this period, annual incidence ranged from 94,477 cases (2015) to 52,690 cases (2020), representing a 44.23% decrease. The average annual number of salmonellosis cases was 81,008, and after 2020 a gradual upward trend was observed. In Croatia, 11,896 cases were recorded, peaking in 2015 and reaching a minimum in 2021. Germany (14.8%) and the Czech Republic (13.3%) accounted for the largest proportions of cases, while Cyprus recorded the lowest rate (0.08%). The sharpest annual reductions in 2020 (compared to 2019) occurred in Spain (59.61%) and Ireland (38.33%). The UK was excluded from statistics after 2019 due to Brexit, which explains the apparent 100% reduction rather than any true disease elimination. In total, 1,049 fatalities were recorded in the EU, with an annual average of 105 deaths, the highest number in 2017 and the lowest in 2020. Most fatalities occurred in the United Kingdom (26.5%), Germany (16%), the Czech Republic (15.7%), Spain (13.2%), and Hungary (11.4%). Eleven member states reported no deaths. Although ECDC reports do not detail fatalities for Croatia, mortality analysis including CIPH data indicated 9 deaths during the study period.

Morbidity data for the study period are presented in Table 2. The mean salmonellosis morbidity rate was 29.2 per 100,000 inhabitants in Croatia and 18.2 per 100,000 in the EU, indicating a 1.6-fold higher rate in Croatia. Croatian rates were calculated while accounting for a population decline from 4.20 million to 3.86 million (16). For comparative purposes, average morbidity rates for selected EU member states were: Germany 14.5/100,000; Ireland 6.2/100,000; and Lithuania 24.7/100,000. Croatia's average rate was nearly fivefold higher than that of Ireland and 18% higher than that of Lithuania. Temporal morbidity patterns differed substantially between countries. Croatia recorded its peak morbidity rate in 2015 (37.8/100,000) and its lowest rate in 2021 (15.3/100,000). Comparative trends also varied: Germany's rates ranged from 19.8/100,000 (2014) to 9.8/100,000 (2020); Ireland recorded its highest rate in 2017 (7.9/100,000) and lowest in 2021 (3.4/100,000); and Lithuania had the group's highest rate in 2014 (38.8/100,000) and its lowest in 2022 (8.3/100,000).

The analysis of case distribution by age group across the EU shows a parabolic morbidity pattern (Figure 1). The highest proportion of cases occurs in children aged 0-4 years (23.5%), decreasing to the lowest proportion in the 15-24 years group (10.3%), and rising again in those aged ≥65 years (17.8%). Marked deviations from the EU pattern were observed among member states. Cyprus (41.9%) and Poland (39.1%) had the highest shares in the 0-4 years group, well above the EU average, whereas Austria had a notably lower share in this group (15.8%) and a higher share in those aged 25-44 years (19.9% vs. 14.1% in the EU). In the 45-64 years group, Finland recorded the highest share (33.5%), followed by Sweden (24.9%), while Malta recorded the highest share among those aged ≥65 years (31.7%). In Croatia, the distribution broadly followed the EU trend but with more pronounced differences in specific groups. The proportion in the 0-4 years group (28.9%) was 23.5% higher than the EU average, and Croatia exceeded the EU average by 13.5% in the 25-44 years group. Conversely, a lower proportion was observed among those aged ≥65 years (10.5% vs. 17.8% in the EU).

The distribution of reported *Salmonella* serotypes in the EU and selected member states showed that the predominant serotype was *Salmonella Enteritidis* (59.8%), followed by *Salmonella Typhimurium* (11.9%), monophasic *S. Typhimurium* (MVST) (5.7%), and *Salmonella Infantis* (2.0%) (Table 3). The remaining serotypes, grouped as "Other," accounted for 20.6% of cases. *S. Enteritidis* showed particularly high proportions in Poland (89.7%) and Hungary (75.3%), while Croatia closely matched

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Table 1.
Occurrence and Mortality of Salmonellosis in European Union Member States during the period 2014-2023

Member state	Year													
	2014.		2015.		2016.		2017.		2018.		2019.		2020.	
	RC	†	RC	†	RC	†	RC	†	RC	†	RC	†	RC	†
Austria	1654	6	1544	3	1415	8	1667	11	1538	5	1866	5	817	1
Belgium	2698	0	3050	0	2699	0	2298	0	2958	0	2527	0	1595	0
Bulgaria	730	0	1076	0	718	0	796	0	586	0	594	0	187	0
Croatia	1494	1	1593	0	1240	4	1242	0	1323	1	1308	2	786	0
Cyprus	88	0	65	0	77	0	59	0	44	0	62	0	70	0
Czechia	13255	21	12408	15	11610	20	11473	21	10901	13	13009	23	10516	21
Denmark	1124	0	925	0	1081	0	1067	0	1168	0	1119	0	614	0
Estonia	92	1	112	0	351	0	265	0	314	0	150	1	91	1
Finland	1622	0	1650	0	1512	0	1535	0	1431	0	1175	0	516	0
France	8880	0	10305	0	8876	0	7993	0	8936	0	8935	0	7071	0
Germany	16000	17	13667	16	12858	18	14051	20	13293	14	13494	18	8664	13
Greece	349	2	466	1	735	3	672	4	640	4	643	2	381	0
Hungary	5249	9	4894	12	4722	12	3922	12	4161	9	4452	12	2964	9
Ireland	259	0	270	0	299	1	379	0	352	0	347	2	214	0
Italy	4467	0	3825	0	4134	0	3347	0	3635	0	3256	0	2713	0
Latvia	278	0	380	0	454	0	225	0	409	1	438	0	296	0
Lithuania	1145	0	1082	1	1076	0	1005	1	779	0	736	0	419	0
Luxembourg	110	0	106	0	108	0	118	0	135	0	131	0	93	0
Malta	132	0	126	0	162	0	107	0	116	0	131	1	176	0
Netherlands	970	0	974	0	1150	0	954	0	1061	0	1197	0	695	0
Poland	8042	0	8245	0	9718	0	8921	20	9064	2	8373	2	5192	4
Portugal	244	2	325	3	376	4	462	3	302	4	432	4	262	3
Romania	1512	1	1330	0	1479	1	1154	0	1410	0	1383	0	408	0
Slovakia	4078	1	4841	2	5299	0	5789	1	6791	0	4992	0	3385	1
Slovenia	597	0	401	0	311	0	275	0	274	0	362	0	214	0
Spain	6633	1	9015	8	9818	13	9426	6	8730	10	5087	23	3526	8
Sweden	2211	0	2312	0	2247	0	2280	0	2041	0	1990	0	825	0
United Kingdom	8099	4	9490	65	9900	51	10105	55	9466	57	9718	46	0	0
Total	92012	66	94477	126	94425	135	91587	154	91858	120	87907	141	52690	61

RC - reported cases; † - number of death

Table 1. (continued)
Occurrence and Mortality of Salmonellosis in European Union Member States during the period 2014-2023

Member state	Year						Total RC	Total †
	2021.		2022.		2023.			
	RC	†	RC	†	RC	†		
Austria	993	2	1192	2	1279	4	13965	47
Belgium	2084	0	2375	0	2040	0	24324	0
Bulgaria	241	0	310	0	516	0	5754	0
Croatia	593	0	1047	0	1270	1	11896	9
Cyprus	41	0	66	0	64	0	636	0
Czechia	9894	18	7563	11	7482	2	108111	165
Denmark	692	0	898	0	1206	0	9894	0
Estonia	112	1	134	0	168	0	1789	4
Finland	474	0	666	0	803	0	11384	0
France	9315	0	11162	0	11848	0	93321	0
Germany	8144	18	9064	13	10599	21	119834	168
Greece	284	1	640	4	936	10	5746	31
Hungary	3298	14	3249	15	4416	16	41327	120
Ireland	173	0	340	0	402	0	3035	3
Italy	3768	0	3572	0	3333	0	36050	0
Latvia	218	0	90	0	101	0	2889	1
Lithuania	281	0	234	0	344	1	7101	3
Luxembourg	133	0	161	0	167	0	1262	0
Malta	249	0	199	0	169	1	1567	2
Netherlands	862	0	1027	0	1456	0	10346	0
Poland	7708	2	6054	2	9196	0	80513	32
Portugal	361	3	412	6	535	4	3711	36
Romania	518	0	1010	0	1388	0	11592	2
Slovakia	4439	1	3669	1	3999	3	47282	10
Slovenia	185	0	384	0	297	0	3300	0
Spain	6168	16	8832	27	12161	26	79396	138
Sweden	933	0	1128	0	1312	0	17279	0
United Kingdom	0	0	0	0	0	0	56778	278
Total	62161	76	65478	81	77487	89	810082	1049

RC - reported cases; † - number of death

Table 2.
Trends in Morbidity during the period 2014-2023 in the EU and selected EU Member States

Year	EU population	Morbidity* EU	Population Croatia	Morbidity* Croatia	Morbidity* Germany	Morbidity* Ireland	Morbidity* Lithuania
2014.	442,268,078	20.80	4,238,389	35.2	19.8	5.6	38.8
2015.	442,924,865	21.33	4,210,700	37.8	16.8	5.8	37.0
2016.	444,003,268	21.27	4.174.349	29.7	15.6	6.3	37.2
2017.	444,670,605	20.60	4.124.531	30.1	17.0	7.9	35.2
2018.	445,301,376	20.63	4,087,843	32.4	16.1	7.2	27.6
2019.	446,149,924	19.70	4,065,253	32.2	16.3	7.0	26.2
2020.	447,030,024	11.79	4,047,680	19.4	10.4	4.3	14.9
2021.	445,891,011	13.94	3,871,833	15.3	9.8	3.4	10.0
2022.	445,998,928	14.68	3,855,641	27.2	10.9	6.6	8.3
2023.	447,704,445	17.31	3,859,686	32.9	12.8	7.6	12.0
Total		18.20		29.22	14.55	6.18	24.71

*Morbity is per 100,000 population

the EU average (60.0%). *S. Typhimurium*, the second most frequent serotype, was especially common in Central and Western Europe-particularly Germany (27.7%), Cyprus (27.3%), and Slovenia (22.6%) - with Croatia also exceeding the EU mean at 19.3%. MVST was most prevalent in Belgium (17.3%) and France (15.0%). *S. Infantis* was unusually common in Cyprus (15.2%), approximately seven times the EU average. The "Other" serotypes collectively accounted for a substantial share of EU cases, underscoring notable diversity beyond the most common types.

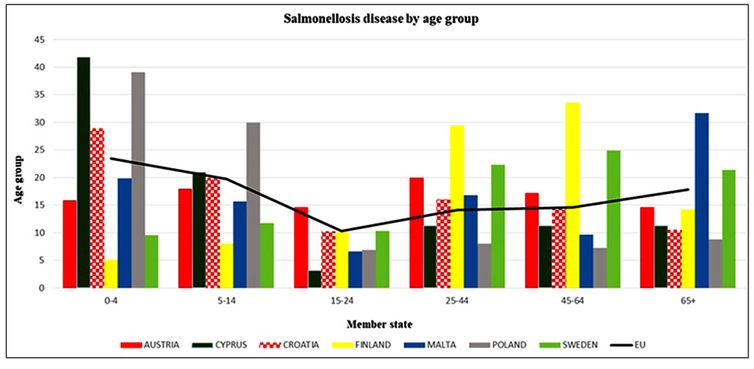

Figure 1.
Salmonellosis disease by age group

DISCUSSION

Salmonellosis remains a significant public health problem in the EU, as confirmed by data from the study period (Table 1). The sharp temporary decline in 2020 is most likely attributable to the COVID-19 pandemic, as also reported in the EU One Health Zoonoses Report 2020 (17). Geographic differences in case numbers-such as the large shares in Germany and the Czech Republic-suggest variation in exposure, surveillance, and reporting practices. In the Czech Republic, for instance, a GAM analysis for 1998-2017 showed that higher air temperatures and seasonal patterns significantly influenced non-typhoidal *Salmonella* incidence and that poultry-focused veterinary measures reduced the average annual case number to about one-third of previous levels (18). Croatia occupies an intermediate position among EU member states in terms of overall burden.

Morbidity data show that the average salmonellosis rate in Croatia was 1.6 times higher than the EU average (Table 2). For comparison, Germany (the most populous country with the highest absolute case count), Ireland (a contrasting low-morbidity example), and Lithuania (a country of similar size with a high morbidity rate) were examined. Croatia recorded a rate nearly five times higher than Ireland and 18% higher than Lithuania. Lower rates in Germany and Ireland compared to Croatia and Lithuania indicate substantial differences in registered disease burden between countries. The 2021 Annual Epidemiological Report noted that although EU case numbers were stable from 2017 to 2019, there was a sharp decline from March 2020 onward in nearly all countries (except Cyprus and Malta), with only partial recovery in 2021 (19). Croatia, however, had its peak morbidity in 2015 and its lowest in 2021, while most other countries showed a marked decline around 2020. To enable valid comparisons, the Croatian morbi-

Table 3.
Overview of the most common Salmonella serotypes in the EU and selected EU Member States during the period 2014-2023

Member state	Serotype				
	S. Enteritidis	*S. Typhimurium*	MVST	*S. Infantis*	Other
EU	59.8	11.9	5.7	2	20.6
Belgium	33.5	13.7	17.3	2.7	32.9
Croatia	60	19.3			20.7
Cyprus	39.4	27.3		15.2	18.2
France	38.8	10.6	15	2.3	33.3
Germany	41.9	27.7	1.5	2.1	26.7
Hungary	75.3	6	6.5	3.5	8.6
Poland	89.7	2.6		1.1	6.6
Slovenia	35	22.6	7.1	4.4	31
Average	52.6	15.7	8.85	4.16	22.07

dity rate was adjusted for demographic decline. As Gibbons et al. note, underreporting poses a major limitation to accurately assessing global morbidity (20).

Age-specific distribution shows the typical U-shaped risk profile: greatest burden in early childhood and older age, and the lowest in adolescents and young adults. Very high shares in the 0-4 years group in Cyprus and Poland may reflect increased household exposure to contaminated food or age-specific differences in diagnosis and reporting. The risk profile for this age group also likely differs substantially from that of adults; as Williams et al. reported, salmonellosis in children under 5 years is linked to modifiable non-food risk factors (21). In contrast, Austria shows a lower proportion in the youngest age category and a shift of cases toward adults aged 25-44 years. Higher proportions in middle age in Finland and Sweden, and in the oldest age group in Malta, further demonstrate considerable heterogeneity across member states. Croatia generally resembles the EU pattern in young children but shows a more pronounced burden among adults aged 25-44 years.

The findings in Table 3 confirm the dominance of *Salmonella Enteritidis* as the primary human serotype in the EU, with exceptionally high isolation rates in Poland and Hungary, while Croatia closely mirrors the EU pattern. This aligns with baseline studies of laying hens showing that *S. enterica*, particularly *S. Enteritidis*, is widespread in large-scale commercial flocks across the EU, strongly indicating that table eggs remain a major source of human salmonellosis (22). *S. Typhimurium* is the second most common serotype and shows elevated prevalence in Germany, Cyprus, and Slovenia, with Croatia also exceeding the EU average. MVST is especially prominent in Belgium and France. *S. Infantis* reaches notably high levels in Cyprus, far above the EU average. The "Other" serotypes collectively account for a significant share of reported isolates, underscoring that less common serotypes still contribute meaningfully to the overall burden.

CONCLUSION

The results of this study show that Croatia, as a country with a smaller population than most EU Member States, not only follows the general trend of the European Union but also carries a consistently higher and differently structured burden of salmonellosis. This burden is particularly pronounced among working adults and young children, which may indicate that exposure pathways, dietary habits, and health behaviours in Croatia differ from those in many other Member States. It is therefore important to prioritise prevention and control measures for the most affected age groups and to improve the quality of surveillance in order to reduce disease incidence and prevent outbreaks. Achieving this requires intensive monitoring, rapid anti-epidemic measures, and continuous public education.

Abbreviations:

RC - Reported cases
† - Number of death
MVST - Monophasic *S. Typhimurium* (antigenic formula 1,4,[5],12:i:-)

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Sažetak

PRATI LI REPUBLIKA HRVATSKA TREND OBOLJENJA OD SALMONELOZE U ODNOSU NA EUROPSKU UNIJU?

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Salmoneloze su kontinuirana javnozdravstvena prijetnja kako diljem svijeta, tako i u državama članicama Europske unije, a potvrđuje to i analiza statističkih podataka iz razdoblja 2014.-2023. godine. U ovom preglednom radu uspoređena je pojavnost netifusnih salmoneloza u Republici Hrvatskoj s trendovima u državama članicama Europske unije, koristeći europske i nacionalne podatke prikupljene u sklopu praćenja zaraznih bolesti. Na nivou cijele Europske unije, u promatranom desetogodišnjem razdoblju prijavljeno je 810.082 slučajeva salmoneloza, s prosječnom stopom morbiditeta od 18,2/100.000 stanovnika, te najvećim brojem oboljelih 2015., a najmanjim 2020. godine, što se vjerojatno povezuje s pandemijom COVID-19. U Republici Hrvatskoj u istom razdoblju zabilježeno je 11.896 slučajeva, s najvećim brojem oboljelih 2015., a najmanjim 2021. godine, te s prosječnom stopom morbiditeta od 29,2/100.000 stanovnika. Kod distribucije oboljenja prema dobnim skupinama, u Europskoj uniji bilježe se veća prosječna odstupanja unutar država članica u skupini 0 - 4 godine (23,5%) i u skupini osoba starijih od 65 godina (17,8%). Hrvatska prati trend Europske unije u najmlađoj skupini (28,9%), ali se izdvaja sa značajno nižim prosječnim pobolom (10,5%) u najstarijoj populaciji. Dominantan serotip u Europskoj uniji je Salmonella enteritidis (59,8%), uz ekstremnu dominaciju u Poljskoj (89,7%) i Mađarskoj (75,3%), dok Hrvatska prati europski prosjek sa 60,0%. Slijedi ga Salmonella Typhimurium, s izraženijim udjelom u Njemačkoj, na Cipru i u Hrvatskoj. Salmoneloze nažalost bilježe i smrtne ishode, pa je tako u promatranom desetogodišnjem razdoblju u Europskoj uniji umrlo 1.049 osoba (najviše u Ujedinjenom Kraljevstvu, Njemačkoj i Češkoj), dok je Republika Hrvatska zabilježila 9 smrtnih ishoda (0,9% ukupnog broja). Iako je 2020. godine zabilježen pad oboljenja od salmoneloza, nakon te godine uočena je uzlazna krivulja rasta oboljelih u cijeloj Europskoj uniji.

Ključne riječi: HRVATSKA, EUROPSKA UNIJA, MORBIDITET, SALMONELOZA

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