

Figure S1 The site distribution of studies used in this meta-analysis (79 sites). There are 13 sites for warming, 6 sites for shifting precipitation, 54 sites for nutrient addition, and 6 sites for elevated CO₂.

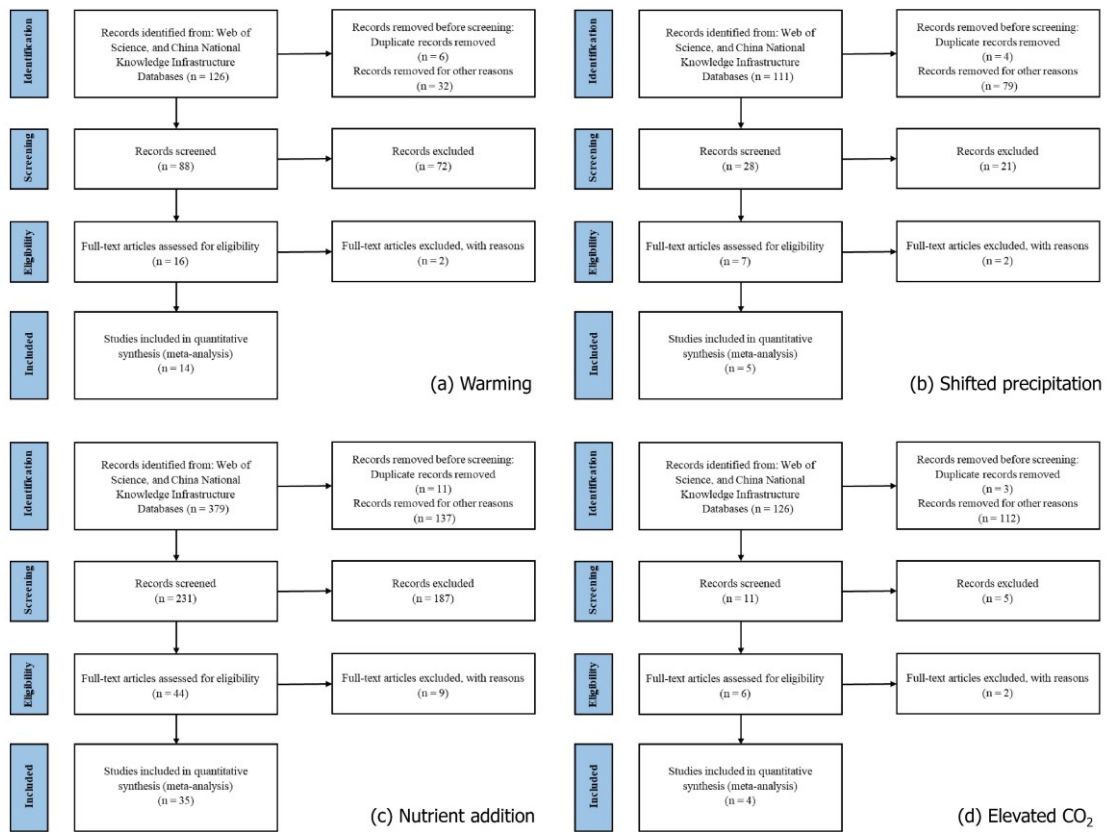


Figure S2 The PRISMA 2020 Flow Diagram of warming (a), shifted precipitation (b), nutrient addition (c), and elevated CO₂ (d). These flow diagrams show how we selected studies for this meta-analysis. The official template is from: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021; 372: n71. doi: 10.1136/bmj.n71.

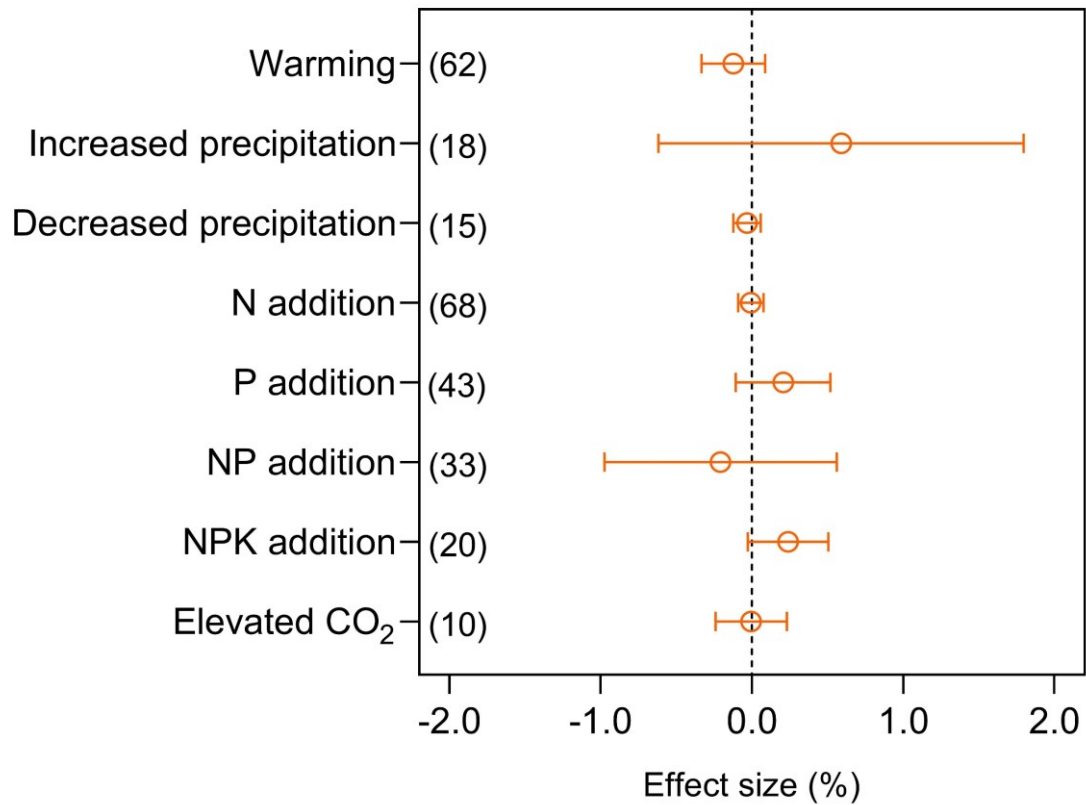


Figure S3 The responses of the ratio of fungal necromass to bacterial necromass ratio to global change factors. The error bars represent 95% confidence interval (CIs). If 95% CIs do not overlap with zero, the response is significant ($p < 0.05$). Solid and hollow dots represent significant and non-significant responses, respectively. The numbers on the left side of each figure represent the sample size. N, nitrogen; P, phosphorus; K, potassium.

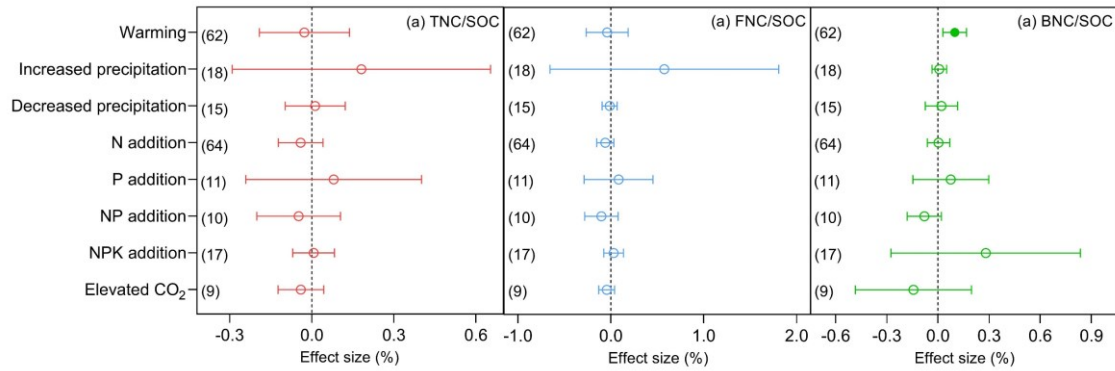


Figure S4 The responses of proportions of total necromass carbon (TNC, a), fungal necromass carbon (FNC, b), and bacterial necromass carbon (BNC, c) in soil organic carbon (SOC) to global change factors. The error bars represent 95% confidence intervals (CIs). If 95% CIs do not overlap with zero, the response is significant ($p < 0.05$). Solid and hollow dots represent significant and non-significant responses, respectively. The numbers on the left side of each figure represent the sample size.

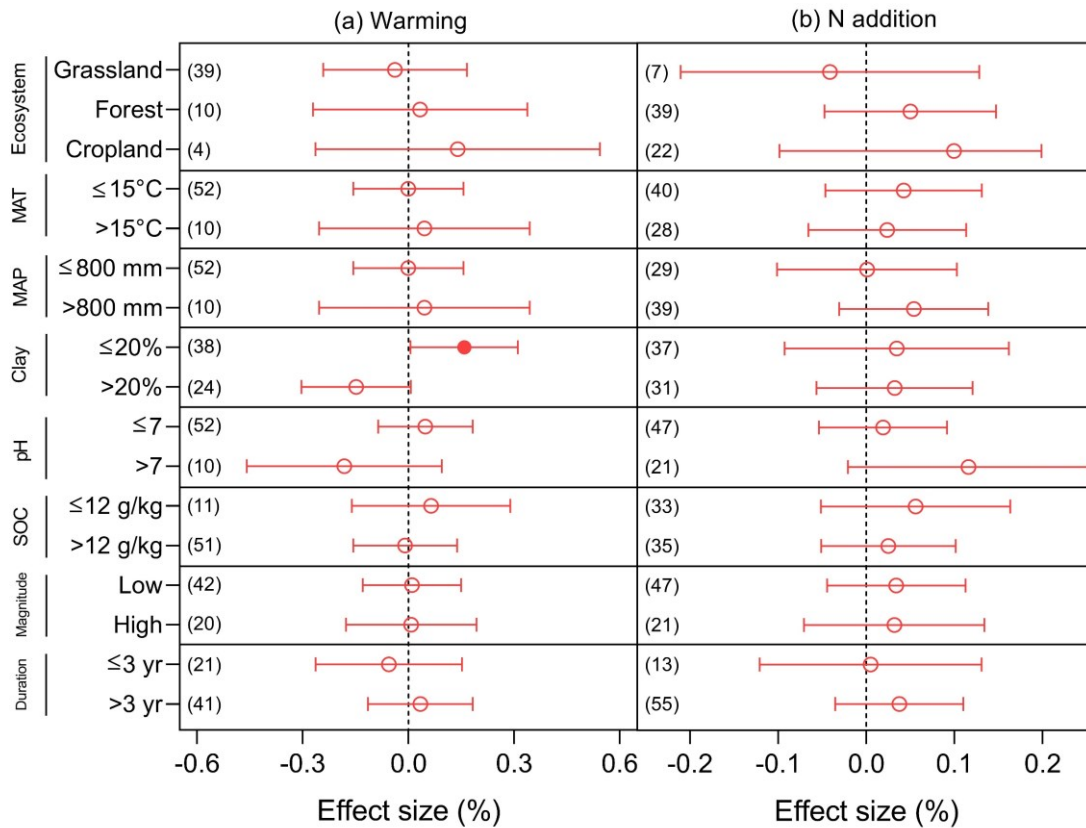


Figure S5 The responses of total necromass carbon to warming (a) and N addition (b) in different climates, soil properties, and experimental conditions. The error bars represent 95% confidence intervals (CIs). If 95% CIs do not overlap with zero, the response is significant ($p < 0.05$). Solid and hollow dots represent significant and non-significant responses, respectively. The numbers on the left side of each figure represent the sample size. MAT, mean annual temperature; MAP, mean annual precipitation; Clay, soil initial clay content; pH, soil initial pH; SOC, soil initial soil organic carbon content; Magnitude, experimental magnitude; Duration, experimental duration.

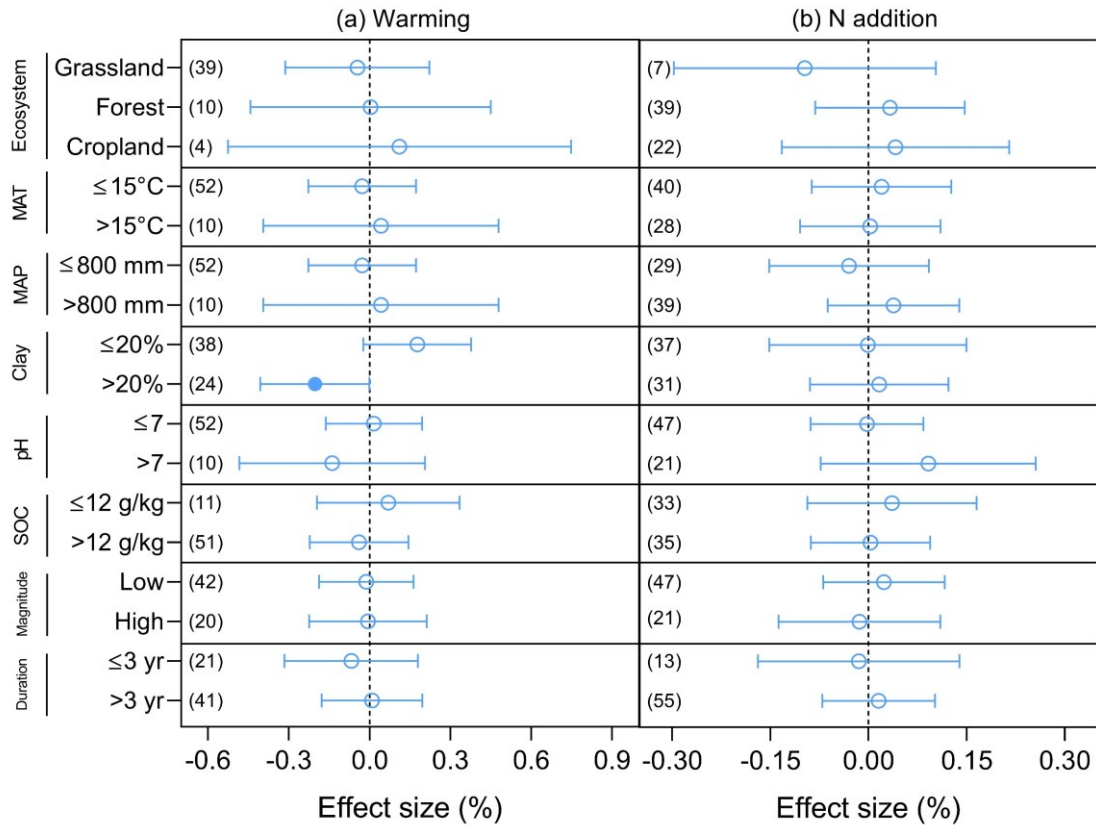


Figure S6 The responses of fungal necromass carbon to warming (a) and N addition (b) in different climates, soil properties, and experimental conditions. The error bars represent 95% confidence intervals (CIs). If 95% CIs do not overlap with zero, the response is significant ($p < 0.05$). Solid and hollow dots represent significant and non-significant responses, respectively. The numbers on the left side of each figure represent the sample size. MAT, mean annual temperature; MAP, mean annual precipitation; Clay, soil initial clay content; pH, soil initial pH; SOC, soil initial soil organic carbon content; Magnitude, experimental magnitude; Duration, experimental duration.

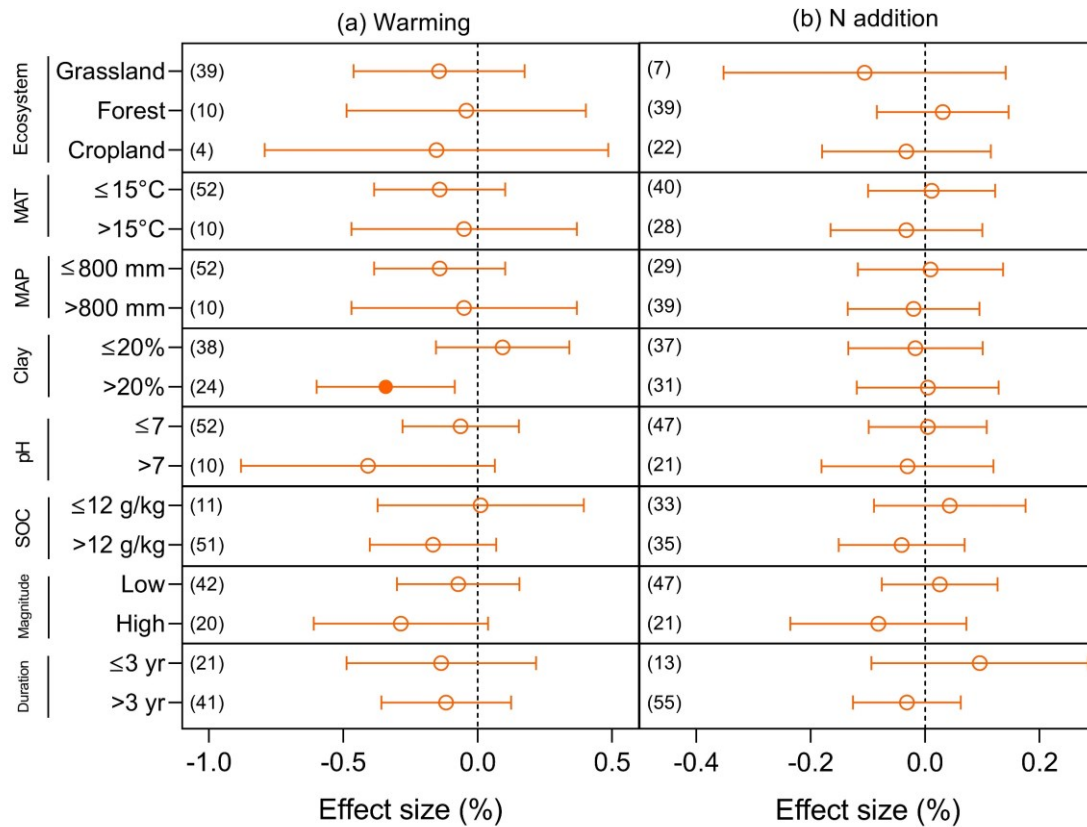


Figure S7 The responses of the ratio of fungal to bacterial necromass carbon to warming (a) and N addition (b) in different climates, soil properties, and experimental conditions. The error bars represent 95% confidence intervals (CIs). If 95% CIs do not overlap with zero, the response is significant ($p < 0.05$). Solid and hollow dots represent significant and non-significant responses, respectively. The numbers on the left side of each figure represent the sample size. MAT, mean annual temperature; MAP, mean annual precipitation; Clay, soil initial clay content; pH, soil initial pH; SOC, soil initial soil organic carbon content; Magnitude, experimental magnitude; Duration, experimental duration.

Table S1 Search terms used for literature retrieval in this study.

Global change factors	Search Terms
Warming	TS = (“microbial necromass” OR “amino sugar” OR “microbial residue*”) AND TS=(“effect of temperature” OR warming OR “increased temperature” OR “elevated temperature” OR “climate change” OR “global change”)
Shifted precipitation	TS = (“microbial necromass” OR “amino sugar” OR “microbial residue*”) AND TS=(“changing precipitation” OR “alterations in precipitation” OR “changing snowfall” OR “increased precipitation” OR “decreased precipitation” OR “increased rainfall” OR “decreased rainfall” OR “changing rainfall” OR “increased snowfall” OR “decreased snowfall” OR “throughfall reduction” OR “climate change” OR “global change”)
Nutrients addition	TS = (“microbial necromass” OR “amino sugar” OR “microbial residue*”) AND TS=(“nitrogen fertilization” OR “nitrogen addition” OR “nitrogen deposition” OR “nitrogen application” OR “urea” OR "N decomposition" OR "N addition" OR “phosphorus fertilization” OR “phosphorus addition” OR “phosphorus application” OR “nutrient addition” OR “climate change” OR “global change”)
Elevated CO ₂	TS=(“microbial necromass” OR “amino sugar” OR “microbial residue*”) AND TS=(“free-air carbon dioxide enrichment” OR “free-air CO ₂ enrichment” OR “elevated CO ₂ ” OR “elevated atmospheric CO ₂ ” OR “eCO ₂ ” OR “climate change” OR “global change”)

Table S2 The studies involved in this meta-analysis and the parameters in these studies for the microbial necromass carbon content. If one parameter is provided in a study, it is indicated by “√”. TNC, total necromass carbon; FNC, fungal necromass carbon; BNC, bacterial necromass carbon; GluN, glucosamine; MurA, muramic acid.

Global change factors	Reference source	TNC	FNC	BNC	GluN	MurA
Warming	Cai et al., 2023	√	√	√		
	Chang et al., 2021	√	√	√		
	Chen et al., 2023				√	√
	Ding et al., 2020	√	√	√		
	Ding et al., 2019	√	√	√		
	Jia et al., 2017				√	√
	Jing et al., 2019				√	√
	Li, 2019				√	√
	Liang et al., 2015				√	√
	Liu et al., 2019				√	√
	Ma et al., 2022	√	√	√	√	√
	Shao et al., 2018				√	√
	Zhang et al., 2022				√	√
	Zhao et al., 2022		√	√	√	√
Shifted precipitation	Jin, 2022				√	√
	Jing et al., 2019				√	√
	Shao et al., 2018				√	√
	Wang et al., 2022				√	√
	Zhou et al., 2022	√	√	√		
Nutrient addition	Anning et al., 2021				√	√
	Chen et al., 2020				√	√
	Ding & Han, 2014				√	√
	Ding, Han & Zhang, 2013				√	√
	Ding et al., 2013				√	√
	Fan et al., 2020				√	√
	Gillespie et al., 2014				√	√
	Jing et al., 2021	√	√	√		
	Jing et al., 2022	√	√	√		
	Li, 2019				√	√
	Li et al., 2015	√	√	√		
	Li et al., 2019				√	√
	Li et al., 2020				√	√
Li et al., 2022				√	√	
Liang et al., 2015				√	√	

	Luo et al., 2020	√	√	√		
	Ma et al. 2018		√	√		
	Ma et al. 2020				√	√
	Ma et al. 2021				√	√
	Ma et al. 2022	√	√	√	√	√
	Ma et al. 2022				√	√
	Ma et al. 2023				√	√
	Schmidt et al., 2017				√	√
	Su et al., 2022				√	√
	van Groenigen et al., 2007				√	√
	Veloso et al., 2020				√	√
	Wang et al., 2022				√	√
	Xu et al., 2022				√	√
	Yang et al., 2020				√	√
	Ye et al., 2019	√	√	√		
	Yuan et al., 2021	√	√	√	√	√
	Zhang et al., 2016				√	√
	Zhang et al., 2018				√	√
	Zhao et al., 2022		√	√	√	√
	Zhao, 2019				√	√
	Zhu et al., 2022	√	√	√		
Elevated CO ₂	Glaser, Millar & Blum, 2006				√	√
	Liang et al., 2015				√	√
	Liu et al., 2021				√	√
	van Groenigen et al., 2007				√	√

Table S3 Results of examinations for publication bias using Egger’s test. If $p < 0.05$, publication bias is considered to exist. There is almost no publication bias in this meta-analysis.

Variables	Egger’s test							
	Warming	Increased precipitation	Decreased precipitation	N addition	P addition	NP addition	NPK addition	Elevated CO ₂
TNC	0.56	0.50	0.88	0.99	0.68	0.49	0.89	0.82
FNC	0.39	0.06	0.91	0.96	0.63	0.62	0.95	0.85
BNC	0.90	0.99	0.90	0.94	0.63	0.01	0.77	0.75
FNC/BNC	0.48	0.06	0.99	0.90	0.99	0.01	0.84	0.99
TNC/SOC	0.65	0.48	0.87	0.99	0.64	0.95	0.86	0.88
FNC/SOC	0.47	0.05	0.90	0.97	0.61	0.96	0.77	0.89
BNC/SOC	0.93	0.98	0.89	0.97	0.68	0.38	0.97	0.87

Table S4 The correlation coefficients between soil microbial necromass carbon and environmental factors under warming and N addition ($*p < 0.05$, $**p < 0.01$, and $***p < 0.001$). TNC, total necromass carbon; FNC, fungal necromass carbon; BNC, bacterial necromass carbon; MBC, microbial biomass carbon; TN, total nitrogen content.

Microbial necromass carbon	Warming			N addition		
	lnRR.pH	lnRR.MBC	lnRR.soil moisture	pH	MBC	TN
TNC	-0.472*	0.179	0.288	0.197	0.828***	0.218
FNC	-0.302	0.214	0.413	0.208	0.800***	0.174
BNC	-0.563**	0.025	0.041	-0.096	0.737***	0.253

Reference list of articles included in this meta-analysis (50 publications).

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