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Draft Metagenome Sequences of the *Sphagnum* (Peat Moss) Microbiome from Ambient and Warmed Environments across Europe

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ABSTRACT We present 49 metagenome assemblies of the microbiome associated with *Sphagnum* (peat moss) collected from ambient, artificially warmed, and geothermally warmed conditions across Europe. These data will enable further research regarding the impact of climate change on plant-microbe symbiosis, ecology, and ecosystem functioning of northern peatland ecosystems.

Peat mosses (*Sphagnum* spp.) are keystone species of northern peatlands and have an extraordinary impact on global biogeochemical cycles. These northern latitude ecosystems harbor over one-quarter of terrestrial carbon in the form of peat, or incompletely decomposed biomass, but cover roughly 3% of Earth's land mass (1). Furthermore, peatlands store approximately 9 to 16% of global soil nitrogen (2, 3), which is largely derived from the biological fixation of atmospheric nitrogen by microbes that live in symbiosis with peat mosses (4, 5). Recently, much effort has been dedicated to understanding how *Sphagnum* will respond to projected scenarios of climate change (e.g., see references 6 and 7), but gaps exist in our knowledge about how such changes might affect the community composition and functioning of the *Sphagnum* microbiome. Here, we present microbiome metagenome assemblies for 49 samples of *Sphagnum*, representing 11 species collected from ambient, artificially warmed, and geothermally warmed environmental conditions.

Samples were collected from seven sites across three countries in Europe (Fig. 1), and the dominant species of *Sphagnum* were sampled at each site. Artificial warming experiments have been conducted since 1994 at the Degerö Stormyr peatland in Sweden (8) and since 2008 at the Forbonnet peatland in France (9). The average temperatures of moss samples were 12.2°C under ambient conditions, 14.7°C under artificially warmed conditions, and 27.2°C under geothermally warmed conditions (Table 1). Samples in the *Sphagnum magellanicum* species complex, i.e., *Sphagnum divinum* and *Sphagnum medium*, were identified on the basis of morphological and genetic analyses.

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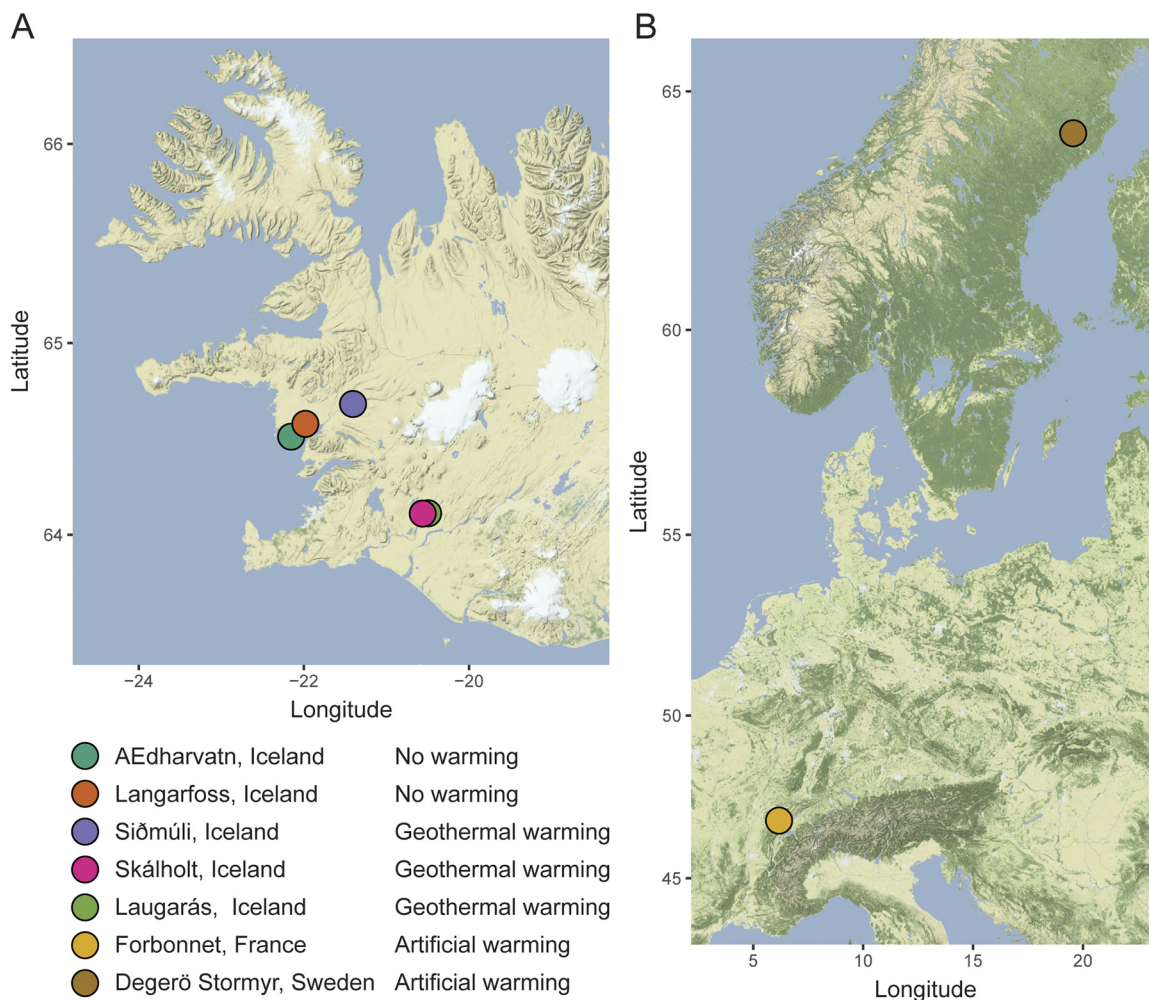


FIG 1 Collection sites for *Sphagnum* metagenome samples. (A) Plants at Icelandic sites were collected from only ambient or both ambient and geothermally warmed conditions. (B) Plants in France and Sweden were collected from both ambient and artificially warmed conditions.

Samples were flash frozen in the field using liquid nitrogen. Genomic DNA extractions were performed using DNeasy Plant Pro DNA extraction kits (Qiagen) according to the manufacturer's instructions. Illumina library construction using KAPA DNA library kits and 2×151 -bp sequencing using the Illumina NovaSeq S4 platform were performed by the U.S. Department of Energy's (DOE) Joint Genome Institute (JGI). All metagenomes were processed by the DOE JGI Metagenome Workflow (10). In brief, reads were quality controlled using the BBTtools package v38.92 (<https://bbtools.jgi.doe.gov>), metagenomes were assembled using metaSPAdes v3.15.2 (11), and the assemblies were annotated using the IMG Annotation Pipeline v5.0.24 (10). MetaBAT v0.32.4 (12) was used to identify genome bins, with a 3-kb minimum contig cutoff value, contig coverage information included, and the $-superspecific$ parameter enforced. Genome bins of at least medium quality were kept according to the minimum information on a metagenome-assembled genome (MIMAG) standards (13). Relevant statistics for these metagenome assemblies and annotations can be found in Table 1. Metadata and annotations can be obtained through the Genome OnLine Database (GOLD study identification number [Gs0154043](https://gold.jgi.doe.gov)) (14) and Integrated Microbial Genomes and Microbiomes (IMG/M) online system (15), respectively.

Data availability. The data have been deposited in the European Nucleotide Archive (ENA) at EMBL-EBI (project number [PRJEB54621](https://www.ebi.ac.uk/ena/record/PRJEB54621)).

TABLE 1 Properties of the *Sphagnum* metagenomes

| <i>Sphagnum</i> species | Sample name | Country of isolation | Region of isolation | Temp treatment | Moss temp (°C) | IMG genome identification no. | ENA sample accession no. | ENA run accession no. |
|-------------------------|-------------|----------------------|---------------------|----------------|----------------|-------------------------------|--------------------------|-----------------------|
| <i>S. angustifolium</i> | NH_ANG_ICE | Iceland | Langarfoss | None | 10.0 | 3300047495 | ERS12393009 | ERR9963747 |
| <i>S. auriculatum</i> | 1_AUR_ICE | Iceland | Laugarás | Geothermal | 34.0 | 3300047328 | ERS12393010 | ERR9963748 |
| <i>S. auriculatum</i> | 3_AUR_ICE | Iceland | Laugarás | Geothermal | 22.0 | 3300047494 | ERS12393011 | ERR9963749 |
| <i>S. auriculatum</i> | 5_AUR_ICE | Iceland | Laugarás | Geothermal | 27.0 | 3300047169 | ERS12393012 | ERR9963750 |
| <i>S. balticum</i> | 16OTC_BA_DE | Sweden | Degerö Stormyr | Artificial | 18.1 | 3300047167 | ERS12393013 | ERR9963751 |
| <i>S. balticum</i> | 11C_BA_DE | Sweden | Degerö Stormyr | None | 14.8 | 3300047166 | ERS12393014 | ERR9963752 |
| <i>S. balticum</i> | 19C_BA_DE | Sweden | Degerö Stormyr | None | 14.8 | 3300047165 | ERS12393015 | ERR9963753 |
| <i>S. divinum</i> | 20TC_MAG_FR | France | Forbonnet | Artificial | 13.4 | 3300047335 | ERS12393016 | ERR9963754 |
| <i>S. divinum</i> | 30TC_MAG_FR | France | Forbonnet | Artificial | 13.4 | 3300047332 | ERS12393017 | ERR9963755 |
| <i>S. divinum</i> | 60TC_MAG_FR | France | Forbonnet | Artificial | 13.4 | 3300047324 | ERS12393018 | ERR9963756 |
| <i>S. divinum</i> | 1C_MAG_FR | France | Forbonnet | None | 11.4 | 3300047326 | ERS12393019 | ERR9963757 |
| <i>S. divinum</i> | 4C_MAG_FR | France | Forbonnet | None | 11.4 | 3300047325 | ERS12393020 | ERR9963758 |
| <i>S. divinum</i> | 5C_MAG_FR | France | Forbonnet | None | 11.4 | 3300047175 | ERS12393021 | ERR9963759 |
| <i>S. fallax</i> | 10OTC_SF_FR | France | Forbonnet | Artificial | 13.4 | 3300047177 | ERS12393022 | ERR9963760 |
| <i>S. fallax</i> | 12OTC_SF_FR | France | Forbonnet | Artificial | 13.4 | 3300047174 | ERS12393023 | ERR9963761 |
| <i>S. fallax</i> | 30TC_SF_FR | France | Forbonnet | Artificial | 13.4 | 3300047176 | ERS12393024 | ERR9963762 |
| <i>S. fallax</i> | 60TC_SF_FR | France | Forbonnet | Artificial | 13.4 | 3300047333 | ERS12393025 | ERR9963763 |
| <i>S. fallax</i> | 80TC_SF_FR | France | Forbonnet | Artificial | 13.4 | 3300047179 | ERS12393026 | ERR9963764 |
| <i>S. fallax</i> | 11C_SF_FR | France | Forbonnet | None | 11.4 | 3300047178 | ERS12393027 | ERR9963765 |
| <i>S. fallax</i> | 1C_SF_FR | France | Forbonnet | None | 11.4 | 3300049214 | ERS12393028 | ERR9963766 |
| <i>S. fallax</i> | 4C_SF_FR | France | Forbonnet | None | 11.4 | 3300047330 | ERS12393029 | ERR9963767 |
| <i>S. fallax</i> | 5C_SF_FR | France | Forbonnet | None | 11.4 | 3300047329 | ERS12393030 | ERR9963768 |
| <i>S. fallax</i> | 7C_SF_FR | France | Forbonnet | None | 11.4 | 3300047334 | ERS12393031 | ERR9963769 |
| <i>S. fallax</i> | 9C_SF_FR | France | Forbonnet | None | 11.4 | 3300047331 | ERS12393032 | ERR9963770 |
| <i>S. girgensohnii</i> | 12_GIR_ICE | Iceland | Skálholt | Geothermal | 20.0 | 3300047171 | ERS12393033 | ERR9963771 |
| <i>S. lindbergii</i> | 16OTC_LL_DE | Sweden | Degerö Stormyr | Artificial | 18.1 | 3300047164 | ERS12393034 | ERR9963772 |
| <i>S. lindbergii</i> | 40TC_LL_DE | Sweden | Degerö Stormyr | Artificial | 18.1 | 3300047173 | ERS12393035 | ERR9963773 |
| <i>S. lindbergii</i> | 11C_LL_DE | Sweden | Degerö Stormyr | None | 14.8 | 3300047473 | ERS12393036 | ERR9963774 |
| <i>S. lindbergii</i> | 19C_LL_DE | Sweden | Degerö Stormyr | None | 14.8 | 3300047327 | ERS12393037 | ERR9963775 |
| <i>S. medium</i> | H_MAG_ICE | Iceland | Siðmúli | Geothermal | 28.0 | 3300047499 | ERS12393038 | ERR9963776 |
| <i>S. medium</i> | H1_MAG_ICE | Iceland | Siðmúli | Geothermal | 28.0 | 3300049255 | ERS12393039 | ERR9963777 |
| <i>S. medium</i> | H2_MAG_ICE | Iceland | Siðmúli | Geothermal | 28.0 | 3300048014 | ERS12393040 | ERR9963778 |
| <i>S. medium</i> | H3_MAG_ICE | Iceland | Siðmúli | Geothermal | 28.0 | 3300048015 | ERS12393041 | ERR9963779 |
| <i>S. medium</i> | C_MAG_ICE | Iceland | Siðmúli | None | 12.0 | 3300047493 | ERS12393042 | ERR9963780 |
| <i>S. medium</i> | C1_MAG_ICE | Iceland | Siðmúli | None | 12.0 | 3300049217 | ERS12393043 | ERR9963781 |
| <i>S. medium</i> | C2_MAG_ICE | Iceland | Siðmúli | None | 12.0 | 3300049218 | ERS12393044 | ERR9963782 |
| <i>S. medium</i> | C3_MAG_ICE | Iceland | Siðmúli | None | 12.0 | 3300049617 | ERS12393045 | ERR9963783 |
| <i>S. subnitens</i> | SUB_ICE | Iceland | Langarfoss | None | 10.0 | 3300047170 | ERS12393046 | ERR9963784 |
| <i>S. teres</i> | NH_TE_ICE | Iceland | AEdharvatn | None | 10.0 | 3300047498 | ERS12393047 | ERR9963785 |
| <i>S. teres</i> | H_TE_ICE | Iceland | Siðmúli | Geothermal | 10.0 | 3300047172 | ERS12393048 | ERR9963786 |
| <i>S. teres</i> | H1_TE_ICE | Iceland | Siðmúli | Geothermal | 28.0 | 3300047462 | ERS12393049 | ERR9963787 |
| <i>S. teres</i> | H2_TE_ICE | Iceland | Siðmúli | Geothermal | 28.0 | 3300049215 | ERS12393050 | ERR9963788 |
| <i>S. teres</i> | C_TE_ICE | Iceland | Siðmúli | None | 12.0 | 3300047168 | ERS12393051 | ERR9963789 |
| <i>S. teres</i> | C1_TE_ICE | Iceland | Siðmúli | None | 12.0 | 3300047994 | ERS12393052 | ERR9963790 |
| <i>S. teres</i> | C2_TE_ICE | Iceland | Siðmúli | None | 12.0 | 3300047678 | ERS12393053 | ERR9963791 |
| <i>S. teres</i> | C3_TE_ICE | Iceland | Siðmúli | None | 12.0 | 3300049216 | ERS12393054 | ERR9963792 |
| <i>S. teres</i> | 7_TE_ICE | Iceland | Skálholt | Geothermal | 34.0 | 3300047497 | ERS12393055 | ERR9963793 |
| <i>S. teres</i> | 9_TE_ICE | Iceland | Skálholt | None | 16.0 | 3300047496 | ERS12393056 | ERR9963794 |
| <i>S. warnstorffii</i> | 11_WAR_ICE | Iceland | Skálholt | Geothermal | 20.0 | 3300047163 | ERS12393057 | ERR9963795 |

TABLE 1 (Continued)

| ENA analysis accession no. | No. of filtered reads | Genome size (bp) | No. of contigs | Contig N_{50} (bp) | Contig L_{50} (bp) | Avg coverage of assembled sequences (x) | No. of genes | No. of genome bins | Estimated no. of genomes |
|----------------------------|-----------------------|------------------|----------------|----------------------|----------------------|---|--------------|--------------------|--------------------------|
| ERZ12298656 | 1.3E+08 | 1.2E+09 | 1.4E+06 | 1.7E+05 | 1,287 | 9.2 | 2.2E+06 | 12 | 172 |
| ERZ12293583 | 1.1E+08 | 1.4E+09 | 1.2E+06 | 1.4E+05 | 2,092 | 9.1 | 2.1E+06 | 31 | 140 |
| ERZ12293588 | 1.3E+08 | 1.5E+09 | 1.6E+06 | 1.7E+05 | 1,266 | 9.8 | 2.3E+06 | 56 | 235 |
| ERZ12293627 | 1.1E+08 | 1.3E+09 | 1.4E+06 | 2.5E+05 | 1,291 | 9.6 | 2.0E+06 | 22 | 105 |
| ERZ12293049 | 1.1E+08 | 1.2E+09 | 1.6E+06 | 2.0E+05 | 1,112 | 8.5 | 2.3E+06 | 6 | 150 |
| ERZ12293046 | 1.0E+08 | 1.3E+09 | 1.7E+06 | 2.7E+05 | 1,053 | 8.0 | 2.4E+06 | 19 | 195 |
| ERZ12298654 | 1.2E+08 | 1.4E+09 | 1.8E+06 | 3.1E+05 | 968 | 8.2 | 2.6E+06 | 16 | 207 |
| ERZ12293584 | 1.4E+08 | 1.5E+09 | 2.1E+06 | 3.9E+05 | 853 | 7.3 | 2.9E+06 | 14 | 238 |
| ERZ12293337 | 1.3E+08 | 1.2E+09 | 1.9E+06 | 4.2E+05 | 633 | 7.0 | 2.4E+06 | 12 | 279 |
| ERZ12293629 | 1.4E+08 | 1.5E+09 | 2.3E+06 | 4.6E+05 | 728 | 7.8 | 2.9E+06 | 17 | 257 |
| ERZ12293615 | 1.3E+08 | 1.5E+09 | 2.0E+06 | 3.3E+05 | 919 | 8.2 | 2.7E+06 | 17 | 237 |
| ERZ12293589 | 1.6E+08 | 1.6E+09 | 2.3E+06 | 4.5E+05 | 767 | 7.9 | 3.1E+06 | 15 | 324 |
| ERZ12293624 | 1.3E+08 | 1.4E+09 | 1.9E+06 | 2.9E+05 | 959 | 9.0 | 2.5E+06 | 21 | 234 |
| ERZ12293045 | 9.4E+07 | 1.0E+09 | 1.5E+06 | 3.2E+05 | 776 | 7.6 | 1.9E+06 | 7 | 170 |
| ERZ12293614 | 1.3E+08 | 1.3E+09 | 1.6E+06 | 2.7E+05 | 1,054 | 9.5 | 2.3E+06 | 16 | 208 |
| ERZ12293587 | 9.6E+07 | 9.0E+08 | 1.0E+06 | 1.5E+05 | 1,310 | 8.3 | 1.5E+06 | 9 | 104 |
| ERZ12297591 | 1.3E+08 | 1.4E+09 | 2.1E+06 | 4.1E+05 | 809 | 7.7 | 2.8E+06 | 9 | 233 |
| ERZ12298564 | 1.3E+08 | 1.3E+09 | 1.7E+06 | 2.3E+05 | 1,075 | 10.8 | 2.4E+06 | 5 | 169 |
| ERZ12293047 | 1.3E+08 | 1.3E+09 | 1.9E+06 | 3.4E+05 | 844 | 9.1 | 2.5E+06 | 21 | 255 |
| ERZ12293582 | 1.2E+08 | 1.4E+09 | 1.8E+06 | 2.8E+05 | 1,004 | 8.7 | 2.6E+06 | 13 | 204 |
| ERZ12293621 | 1.4E+08 | 1.4E+09 | 1.5E+06 | 1.4E+05 | 1,350 | 10.7 | 2.3E+06 | 7 | 171 |
| ERZ12295550 | 1.3E+08 | 1.3E+09 | 2.0E+06 | 4.0E+05 | 819 | 8.1 | 2.4E+06 | 7 | 174 |
| ERZ12298487 | 1.9E+08 | 2.0E+09 | 2.5E+06 | 3.9E+05 | 1,032 | 9.4 | 3.6E+06 | 18 | 341 |
| ERZ12293631 | 1.1E+08 | 1.1E+09 | 1.3E+06 | 1.8E+05 | 1,146 | 9.0 | 1.9E+06 | 4 | 124 |
| ERZ12295332 | 1.1E+08 | 9.9E+08 | 6.4E+05 | 3.1E+04 | 5,777 | 14.1 | 1.4E+06 | 28 | 111 |
| ERZ12298653 | 1.2E+08 | 1.3E+09 | 1.3E+06 | 1.2E+05 | 1,894 | 9.2 | 2.2E+06 | 15 | 183 |
| ERZ12298655 | 1.4E+08 | 1.4E+09 | 1.6E+06 | 2.2E+05 | 1,153 | 9.0 | 2.5E+06 | 26 | 265 |
| ERZ12295331 | 9.4E+07 | 1.2E+09 | 2.0E+06 | 4.5E+05 | 615 | 7.5 | 2.5E+06 | 12 | 212 |
| ERZ12295333 | 1.1E+08 | 1.1E+09 | 8.1E+05 | 3.7E+04 | 4,496 | 10.3 | 1.7E+06 | 19 | 146 |
| ERZ12295052 | 1.5E+08 | 1.6E+09 | 1.3E+06 | 8.6E+04 | 2,974 | 11.4 | 2.4E+06 | 67 | 206 |
| ERZ12298643 | 5.4E+08 | 2.6E+09 | 1.7E+06 | 4.4E+04 | 7,822 | 29.3 | 3.1E+06 | 158 | 335 |
| ERZ12294360 | 3.6E+08 | 2.4E+09 | 2.3E+06 | 1.4E+05 | 2,584 | 19.8 | 3.0E+06 | 96 | 290 |
| ERZ12298651 | 3.4E+08 | 2.3E+09 | 2.7E+06 | 1.8E+05 | 1,940 | 19.6 | 3.0E+06 | 77 | 301 |
| ERZ12293733 | 1.2E+08 | 1.5E+09 | 1.5E+06 | 1.9E+05 | 1,636 | 8.3 | 2.5E+06 | 21 | 222 |
| ERZ12293632 | 4.6E+08 | 2.3E+09 | 3.4E+06 | 2.9E+05 | 1,361 | 24.7 | 3.2E+06 | 61 | 319 |
| ERZ12298641 | 3.7E+08 | 2.3E+09 | 2.4E+06 | 1.4E+05 | 2,432 | 20.9 | 2.9E+06 | 86 | 283 |
| ERZ12293637 | 3.7E+08 | 2.3E+09 | 2.6E+06 | 1.8E+05 | 1,957 | 19.9 | 3.0E+06 | 69 | 304 |
| ERZ12295330 | 1.2E+08 | 1.3E+09 | 1.8E+06 | 3.7E+05 | 796 | 7.8 | 2.4E+06 | 16 | 227 |
| ERZ12295321 | 1.4E+08 | 1.4E+09 | 1.7E+06 | 2.5E+05 | 1,195 | 7.6 | 2.5E+06 | 6 | 166 |
| ERZ12298652 | 1.1E+08 | 1.2E+09 | 1.2E+06 | 1.2E+05 | 1,512 | 9.9 | 1.9E+06 | 54 | 206 |
| ERZ12298644 | 5.1E+08 | 2.9E+09 | 2.8E+06 | 1.5E+05 | 2,554 | 23.6 | 3.7E+06 | 152 | 406 |
| ERZ12294693 | 4.2E+08 | 2.1E+09 | 2.2E+06 | 1.0E+05 | 2,547 | 27.0 | 2.7E+06 | 154 | 387 |
| ERZ12293768 | 3.6E+08 | 1.3E+09 | 1.1E+06 | 3.6E+04 | 3,842 | 10.8 | 2.0E+06 | 38 | 190 |
| ERZ12293633 | 3.6E+08 | 2.4E+09 | 2.8E+06 | 1.7E+05 | 2,009 | 18.8 | 3.1E+06 | 119 | 392 |
| ERZ12298642 | 3.5E+08 | 2.5E+09 | 3.3E+06 | 3.6E+05 | 1,424 | 16.4 | 3.4E+06 | 127 | 475 |
| ERZ12293692 | 4.5E+08 | 2.6E+09 | 2.5E+06 | 1.2E+05 | 2,899 | 23.2 | 3.2E+06 | 129 | 394 |
| ERZ12293630 | 1.3E+08 | 1.3E+09 | 8.2E+05 | 4.4E+04 | 5,424 | 10.9 | 1.9E+06 | 76 | 217 |
| ERZ12298640 | 1.3E+08 | 1.4E+09 | 1.6E+06 | 2.2E+05 | 1,301 | 7.6 | 2.5E+06 | 28 | 274 |
| ERZ12293048 | 1.2E+08 | 1.3E+09 | 1.8E+06 | 3.2E+05 | 868 | 7.7 | 2.5E+06 | 30 | 235 |

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