Supplementary information

The Community, Distribution and Ecological Functions of Archaea in Estuaries

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Supplementary methods

The summary of metabolic potentials of different archaeal groups in the Figure 1 were mainly based on previous studies, including Baker et al. (2020) (for *Thaumarchaeota*, *Lokiarchaeota*, and *Thorarchaeota*), Zhou et al. (2018) (for *Bathyarchaeota*), Liu et al. (2018a) (for *Woesearchaeota*), and Zhou et al. (2019) and Zhou et al. (2020) (for MBG-D, MGII and methanogens).

The archaeal community composition for all sites in the Figure 2 were direct retrieved from its original paper without any analysis. Detailed information for sequencing information for total archaea and *Bathyarchaeota* in water and sediment samples (Figure 2 and Figure 4), and archaeal *amoA* genes (Figure 3) can be found in Table S1 and Table S2, respectively.

For the identification of archaeal *amoA* genotypes in each site, all cloned sequences were blast against the database constructed by Alves et al. (2018) using BLASTN, with e-value as 1e-5. For the classification of bathyarchaeotal subgroups for those sites using clone libraries, cloned sequences were blast against the database constructed by Zhou et al. (2018) using BLASTN, with e-value as 1e-5, while the composition for *Bathyarchaeota* in other sites (using high-throughput sequencing) was direct retrieved from the original paper.

The detailed community composition for total archaea (Figure 2), *amoA* genes (Figure 3) and subgroups of *Bathyarchaeota* (Figure 4) were listed in Table S3-35, respectively.

Supplementary tables

Table S1 Detailed sequencing information in the Figure 1 and Figure 3.

Location	Method	Primer pair	Sequences*	OTUs*	Reference
Water samples					
Liaohe River estuary	High-throughput sequencing	344F/915R	38179	528	Li et al., 2020
Yellow River estuary	High-throughput sequencing	344F/915R	23216	497	Wei et al., 2016
Changjiang River estuary	High-throughput sequencing	515F/806R	-	-	Sun et al., unpublished
Jiulong River estuary	High-throughput sequencing	958F/1048R	30000	447	Hu et al., 2015
Pearl River estuary	High-throughput sequencing	341F/806R	19861	576	Xie et al., 2018
Tomoe estuary	Clone library	515F/806R	-	22	Liu et al., 2018b
Ashtum El Gamil estuary	Clone library	515F/806R	-	17	Liu et al., 2018b
Mackenzie River estuary	Clone library	109F/934R	144	57	Galand et al., 2008
Mississippi River estuary	Clone library	515F/806R	-	41	Liu et al., 2018b
Urucu estuary	Clone library	21F/958R	143	-	Toyama et al., 2017
Solimões River estuary	Clone library	21F/959R	163	-	Toyama et al., 2017
Cunha estuary	Clone library	515F/806R	-	86	Liu et al., 2018b
Sediment samples (including Bathyarchaeota)					
Liaohe River estuary	High-throughput sequencing	344F/915R	12630	891	Liu et al., 2020
Yellow River estuary	High-throughput sequencing	344F/915R	23216	887	Wei et al., 2016
Changjiang River estuary	High-throughput sequencing	344F/915R	12630	520	Liu et al., 2020

Jiulong River estuary	High-throughput sequencing	958F/1048R	30000	507	Hu et al., 2015
Pearl River estuary	High-throughput sequencing	Arch524F/Arch958R	51311	789	Zou et al., 2020a
Orikasa River estuary	Clone library	AN341If/A1391r	-	78	Kaku et al., 2005
Mandovi estuary	High-throughput sequencing	A-967F/B-1046R	14,271	-	Khandeparker et al., 2017
Zuari estuary	Clone library	21F/958R	254	48	Singh et al., 2010
Colne estuary	High-throughput sequencing	109F/958R	11288	224	Webster et al., 2015
Severn estuary	Clone library	SAfGC-PARCH519R	252	45	Webster et al., 2010
Beaulieu estuary	Clone library	109F/915R	-	18	Liu et al., 2018b
Rhone River estuary	Clone library	22F/1391R	-	48	Liu et al., 2018b
White Oak River estuary	Clone library	A24F/Arch915R	964	-	Lazar et al., 2015
Santos-Sao Vicente estuary	Clone library	515F/806R	-	243	Liu et al., 2018b

*The sequence and OTU number for the high-throughput sequencing stand for the normalized number for all samples in the original paper; for the clone library, it stands for the total number for all samples in the original.

-: Data not mentioned in the original paper.

Table S2 Detailed sequencing information in the Figure 2 and general abundance for archaeal *amoA* genes

Location	Primer pair	Clones	OTUs	Abundance	Reference
Water samples (copies/L)					
Pearl River estuary	Arch-amoAF/Arch-amoAR	409	104	6.06e6-2.41e7	Li et al., 2013

Yellow River estuary	Arch-amoAF/Arch-amoAR	171	53	6.53e4-1.06e6	Li et al., 2018b
Changjiang River estuary	Arch-amoAF/Arch-amoAR	386	38	6.66e6-1.72e8	Zhang et al., 2014
Jiulong River estuary	CrenamoA23f/CrenamoA616r	-	-	4.69e5-1.81e8	Zou et al., 2020b
Yong River estuary	Arch-amoAF/Arch-amoAR	20	-	2.31e6-6.57e7	Zhang et al., 2015
Puget Sound estuary	Arch-amoAF/Arch-amoAR	143	16	1.00e3-2.10e6	Urakawa et al., 2014
Sediment samples (copies/g)					
Pearl River estuary	Arch-amoAF/Arch-amoAR	145	36	9.60e6-5.10e7	Jin et al., 2011
Yellow River estuary	Arch-amoAF/Arch-amoAR	286	34	6.53e4-1.06e6	Li et al., 2018b
Changjiang River estuary	Arch-amoAF/Arch-amoAR	760	60	2.42e5-6.09e6	He et al., 2014
Jiulong River estuary	CrenamoA23f/CrenamoA616r	-	-	4.69e5-1.81e8	Zou et al., 2020b
San Francisco Bay estuary	Arch-amoAF/Arch-amoAR	392	67	1.40e4-3.90e7	Mosier et al., 2008
Plum Island Sound estuary	Arch-amoAF/Arch-amoAR	451	-	3.80e4-2.40e8	Bernhard et al., 2010
Bahia del Tobari estuary	Arch-amoAF/Arch-amoAR	282	42	9.17e5-5.97e6	Beman et al., 2006
Huntington Beach estuary	Arch-amoAF/Arch-amoAR	338	52	1.10e4-6.60e5	Santoro et al., 2008
Douro River estuary	Arch-amoAF/Arch-amoAR	50	23	9.00e4-8.50e5	Magalhães et al., 2009
Elkhorn Slough estuary	Arch-amoAF/Arch-amoAR	250	52	4.90e3-1.20e5	Wankel et al., 2011
Fitzroy river estuary	Arch-amoAF/Arch-amoAR	132	27	9.50e6-3.50e7	Abell et al., 2010

-: Data not mentioned in the original paper.

Table S3 Detailed community composition fractions for total archaea

Location	Thaumarchaeota	Euryarchaeota	Bathyarchaeota	Woesearchaeota	Lokiarchaeota	Thorarchaeota	Others
Water samples							
Liaohe River estuary	0.18	0.31	0.05	0.39	-	-	0.07
Yellow River estuary	0.40	0.48	0.02	-	-	-	0.10
Changjiang River estuary	0.48	0.46	0.03	-	-	-	0.03
Jiulong River estuary	0.28	0.39	0.29	-	-	-	0.04
Pearl River estuary	0.43	0.12	0.26	0.12	-	-	0.07
Tomoe estuary	0.35	0.26	0.39			-	-
Ashtum El Gamil estuary	0.35	0.24	0.29	-	-	-	-
Mackenzie River estuary	0.45	0.02	-	0.51	-	-	0.02
- Mississippi River estuary	0.49	0.17	0.34	-	-	-	-
Urucu estuary	0.74	0.08	0.16	-	-	-	0.02
Solimões River estuary	0.95	0.02	0.02	-	-	-	0.01
Cunha estuary	0.09	0.90	-	-	-	-	0.01
Sediment samples							
Liaohe River estuary	0.62	0.05	0.04	0.11	-	-	0.18
Yellow River estuary	0.28	0.42	0.04	-	-	0.15	0.11
Changjiang River estuary	0.22	0.14	0.43	0.05	-	0.07	0.09

Jiulong River estuary	0.01	0.31	0.53	-	-	-	0.15
Pearl River estuary	0.25	0.12	0.53	-	0.06	-	0.04
Orikasa River estuary	-	0.25	-	0.68	-	-	0.07
Mandovi estuary	0.02	0.58	0.04	-	-	-	0.36
Zuari estuary	0.60	0.12	0.28	-	-	-	0
Colne estuary	0.25	0.19	0.46	-	-	0.06	0.04
Severn estuary	0.14	0.04	0.55	-	-	-	0.27
Beaulieu estuary	-	0.56	0.22	0.17	-	-	0.05
Rhone River estuary	-	0.81	0.05	-	0.11	-	0.03
White Oak River estuary	-	0.13	0.70	-	-	0.09	0.08
Santos-Sao Vicente estuary	0.05	0.35	0.28	0.29	-	-	0.03

-: Data not mentioned in the original paper.

Table S4 Detailed community composition for archaeal *amoA* genes

Location	NP-α	NP-β	NP-γ	NP-δ	NP-ε	NP-η	NP-θ	NS-θ	NS-θ	NS-γ	NS-δ	NS-ε	NT-α	NT-γ	Other
Water samples															
Pearl River estuary	0.000	0.000	0.618	0.000	0.000	0.000	0.000	0.147	0.000	0.000	0.059	0.000	0.059	0.000	0.118
Yellow River estuary	0.000	0.000	0.643	0.000	0.000	0.094	0.000	0.053	0.000	0.000	0.164	0.000	0.000	0.023	0.023

Changjiang River estuary	0.000	0.000	0.134	0.000	0.576	0.271	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018
Jiulong River estuary	0.000	0.000	0.970	0.000	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010
Yong River estuary	0.000	0.000	0.238	0.095	0.048	0.381	0.000	0.000	0.000	0.000	0.238	0.000	0.000	0.000	0.000
Puget Sound estuary	0.000	0.000	0.043	0.000	0.904	0.000	0.000	0.000	0.000	0.032	0.000	0.000	0.000	0.000	0.021

Sediment samples

Pearl River estuary	0.031	0.000	0.806	0.000	0.000	0.000	0.082	0.000	0.000	0.000	0.031	0.000	0.000	0.000	0.051
Yellow River estuary	0.000	0.000	0.143	0.000	0.000	0.178	0.000	0.122	0.000	0.056	0.458	0.000	0.000	0.021	0.021
Changjiang River estuary	0.355	0.019	0.102	0.373	0.064	0.053	0.000	0.000	0.000	0.000	0.026	0.000	0.000	0.000	0.008
Jiulong River estuary	0.000	0.000	0.00	0.000	0.900	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.100
San Francisco Bay estuary	0.000	0.000	0.848	0.000	0.000	0.000	0.018	0.000	0.018	0.057	0.000	0.039	0.000	0.000	0.022
Plum Island Sound estuary	0.000	0.000	0.782	0.136	0.000	0.000	0.000	0.000	0.026	0.000	0.022	0.000	0.000	0.000	0.033
Bahia del Tobari estuary	0.459	0.000	0.055	0.083	0.000	0.000	0.000	0.216	0.000	0.133	0.037	0.000	0.000	0.000	0.018
Huntington Beach estuary	0.000	0.184	0.171	0.267	0.102	0.000	0.244	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Douro River estuary	0.000	0.000	0.375	0.225	0.000	0.000	0.000	0.000	0.000	0.175	0.125	0.000	0.000	0.000	0.100
Elkhorn Slough estuary	0.000	0.000	0.192	0.088	0.000	0.000	0.000	0.000	0.064	0.180	0.172	0.136	0.116	0.000	0.052
Fitzroy river estuary	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.135	0.068	0.150	0.594	0.000	0.000	0.000	0.045

Table S5 Detailed subgroups composition for *Bathyarchaeota*

Location	Bathy-17	Bathy-15	Bathy-8	Bathy-6	Bathy-14	Bathy-13	Bathy-12	Bathy-4	Bathy-3	Bathy-1	Other
Liaohe River estuary	0.101	0.492	0.193	0.181	0.000	0.000	0.000	0.000	0.000	0.000	0.034
Yellow River estuary	0.079	0.897	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.014
Changjiang River estuary	0.175	0.239	0.106	0.094	0.038	0.063	0.033	0.000	0.000	0.119	0.135
Jiulong River estuary	0.101	0.101	0.145	0.348	0.014	0.029	0.058	0.014	0.014	0.000	0.174
Pearl River estuary	0.105	0.187	0.241	0.137	0.024	0.041	0.064	0.021	0.042	0.033	0.106
Mandovi estuary	0.508	0.066	0.180	0.066	0.016	0.033	0.016	0.033	0.033	0.016	0.033
Zuari estuary	0.074	0.000	0.463	0.222	0.000	0.037	0.037	0.019	0.019	0.019	0.111
Colne estuary	0.000	0.314	0.257	0.286	0.000	0.000	0.086	0.000	0.000	0.000	0.057
Severn estuary	0.286	0.286	0.071	0.143	0.000	0.143	0.000	0.000	0.000	0.000	0.071
Beaulieu estuary	0.071	0.143	0.286	0.357	0.000	0.000	0.000	0.000	0.000	0.000	0.143
Rhone River estuary	0.063	0.031	0.250	0.094	0.000	0.000	0.000	0.000	0.000	0.500	0.063
White Oak River estuary	0.077	0.000	0.247	0.111	0.000	0.052	0.029	0.133	0.027	0.092	0.232
Santos-Sao Vicente estuary	0.053	0.307	0.040	0.200	0.000	0.013	0.013	0.000	0.000	0.347	0.027

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