Ecosphere

Calcium and strontium stable isotopes reveal similar behaviors of essential Ca and nonessential Sr in stream food webs

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Appendix S1

Table S1. $\delta^{88/86}Sr \pm 2\sigma$ and $^{87}Sr/^{86}Sr$ values of rock cobbles.

Stream	Location	Rock type	$\delta^{88/86}Sr \pm 2\sigma$	$^{87}Sr/^{86}Sr$
			(‰)	
Ado	Upper	Mudrock	0.21 ± 0.02	0.738499
		Mudrock	0.24 ± 0.02	0.735063
	Lower	Mudrock	0.51 ± 0.02	0.731784
		Mudrock	0.36 ± 0.02	0.732264
Yasu	Upper	Mudrock	0.29 ± 0.02	0.733549
		Granite	0.01 ± 0.02	0.724949
		Granite	-0.04 ± 0.02	0.729560
	Lower	Mudrock	0.43 ± 0.02	0.732865
		Sandstone	0.25 ± 0.01	0.723123

Table S2. Water temperature (T) during the sampling, $\delta^{44/40}Ca \pm 2\sigma$ and $\delta^{88/86}Sr \pm 2\sigma$ values, $^{87}Sr/^{86}Sr$ ratios, Ca and Sr concentrations, and the log(Sr/Ca) ratios of stream water.

Stream	Location	Month	T	$\delta^{44/40}Ca_{NIST915b} \pm 2\sigma$	$\delta^{88/86}Sr \pm 2\sigma$	$^{87}Sr/^{86}Sr$	Ca	Sr	Log(Sr/Ca)
			(°C)	(‰)	(‰)		(mg/L)	(mg/L)	
Ado	Upper	May	12.1	0.14 ± 0.12	0.27 ± 0.02	0.713652	3.88	0.044	-1.94
		November	12.0	0.15 ± 0.12	0.23 ± 0.02	0.713478	3.95	0.043	-1.96
	Lower	May	15.1	0.20± 0.12	0.30 ± 0.02	0.715916	4.59	0.040	-2.06
		November	16.6	0.19 ± 0.12	0.28 ± 0.02	0.715987	5.47	0.045	-2.08
Yasu	Upper	May	10.2	0.12 ± 0.11	0.39 ± 0.03	0.714461	5.08	0.025	-2.32
		November	11.4	0.13 ± 0.10	0.37 ± 0.03	0.714544	6.69	0.030	-2.34
	Lower	May	18.5	0.19 ± 0.10	0.33 ± 0.02	0.711601	8.78	0.048	-2.27
		November	17.3	0.23 ± 0.09	0.37 ± 0.03	0.711490	10.26	0.055	-2.27

Table S3. $\delta^{44/40}Ca \pm 2\sigma$, $\delta^{88/86}Sr \pm 2\sigma$ values, $^{87}Sr/^{86}Sr$ ratio, Ca and Sr concentrations, and the log(Sr/Ca) ratios of plant litter samples.

Stream	Location	Month	Family	Scientific name	$\delta^{44/40}Ca_{NIST915b} \pm 2\sigma$	Ca	$\delta^{88/86}Sr \pm 2\sigma$	$^{87}Sr/^{86}Sr$	Sr	Log(Sr/Ca)
					(‰)	(mg/g)	(‰)		(mg/g)	
Ado	Upper	May	Fagaceae	*Quercus salicina*	0.35 ± 0.13	8.08	0.18 ± 0.02	0.714225	0.021	-2.59
			Fagaceae	*Fagus crenata*	-0.07 ± 0.13	10.08	0.23 ± 0.02	0.713812	0.111	-1.96
			Sapindaceae	*Acer mono var ambiguum*	-0.15 ± 0.12	10.50	0.21 ± 0.02	0.713673	0.131	-1.91
		November	Rosaceae	*Sorbus alnifolia*	0.05 ± 0.12	8.37	0.11 ± 0.02	0.714293	0.051	-2.22
			Sapindaceae	*Acer diabolicum*	0.23 ± 0.15	8.45	0.14 ± 0.02	0.714291	0.051	-2.22
			Lauraceae	*Lindera umbellata*	-0.12 ± 0.14	8.76	0.14 ± 0.02	0.713849	0.087	-2.01
	Lower	May	Fagaceae	*Quercus myrsinaefolia*	0.12 ± 0.12	9.03	0.14 ± 0.02	0.715942	0.047	-2.28
		November	Salicaceae	*Salix integra*	0.00 ± 0.12	14.30	0.22 ± 0.02	0.715573	0.063	-2.36
			Rosaceae	*Sorbus alnifolia*	-0.05 ± 0.12	15.23	0.22 ± 0.02	0.715943	0.124	-2.09
			Lauraceae	*Lindera umbellata*	0.12 ± 0.14	20.33	0.21 ± 0.02	0.715787	0.097	-2.32
Yasu	Upper	May	Fagaceae	*Quercus salicina*	-0.27 ± 0.09	8.11	0.14 ± 0.02	0.715203	0.025	-2.52
			Fagaceae	*Fagus crenata*	-0.10 ± 0.09	13.25	0.27 ± 0.02	0.714762	0.061	-2.34
			Ulmaceae	*Ulmus davidiana var. Japonica*	-0.15 ± 0.09	15.55	0.30 ± 0.02	0.714644	0.077	-2.30
		November	Eupteleaceae	*Euptelea polyandra*	-0.39 ± 0.09	17.07	0.19 ± 0.03	0.715037	0.074	-2.36
			Cercidiphyllaceae	*Cercidiphyllum japonicum*	-0.31 ± 0.10	25.71	0.18 ± 0.03	0.715256	0.101	-2.41
			Fagaceae	*Fagus japonica*	-0.14 ± 0.10	10.00	0.16 ± 0.03	0.716395	0.055	-2.26
	Lower	May	Fagaceae	*Quercus myrsinaefolia*	0.19 ± 0.10	14.15	0.26 ± 0.02	0.711507	0.043	-2.51
		November	Salicaceae	*Salix integra*	-0.24 ± 0.10	22.16	0.24 ± 0.02	0.711637	0.128	-2.24
			Oleaceae	*Ligustrum japonicum*	-0.22 ± 0.09	24.15	0.25 ± 0.02	0.711675	0.130	-2.27
			Lauraceae	*Lindera umbellata*	-0.15 ± 0.09	19.32	0.29 ± 0.02	0.710740	0.101	-2.28

Table S4 $\delta^{44/40}Ca \pm 2\sigma$, $\delta^{88/86}Sr \pm 2\sigma$ values, $^{87}Sr/^{86}Sr$ ratio, Ca and Sr concentrations, and the log(Sr/Ca) ratios of periphyton.

Stream	Location	Month	$\delta^{44/40}Ca_{NIST915b} \pm 2\sigma$	Ca	$\delta^{88/86}Sr \pm 2\sigma$	$^{87}Sr/^{86}Sr$	Sr	Log(Sr/Ca)
			(‰)	(mg/g)	(‰)		(mg/g)	
Ado	Upper	May	-0.18 ± 0.12	0.77	0.19 ± 0.02	0.713653	0.014	-1.75
		November	0.02 ± 0.12	0.52	0.17 ± 0.02	0.713550	0.013	-1.59
	Lower	May	-0.27 ± 0.12	1.08	0.17 ± 0.02	0.715946	0.010	-2.03
		November	-0.27 ± 0.10	0.71	0.15 ± 0.02	0.716079	0.007	-2.02
Yasu	Upper	May	0.03 ± 0.10	0.97	0.27 ± 0.02	0.714860	0.008	-2.10
		November	0.11 ± 0.10	0.87	0.28 ± 0.03	0.715442	0.009	-2.01
	Lower	May	-0.03 ± 0.09	0.82	0.22 ± 0.02	0.711616	0.009	-1.94
		November	-0.05 ± 0.09	0.80	0.26 ± 0.02	0.711694	0.009	-1.95

Table S5. $\delta^{44/40}Ca \pm 2\sigma$, $\delta^{88/86}Sr \pm 2\sigma$ values, $^{87}Sr/^{86}Sr$ ratio, Ca and Sr concentrations, and the log(Sr/Ca) ratios of aquatic macroinvertebrates.

Stream	Location	Month	Order	Scientific name	Feeding habits	$\delta^{44/40}Ca_{NIST915b} \pm 2\sigma$	Ca	$\delta^{88/86}Sr \pm 2\sigma$	$^{87}Sr/^{86}Sr$	Sr	Log(Sr/Ca)
						(‰)	(mg/g)	(‰)		(mg/g)	
Ado	Upper	May	Japanese Freshwater Crab*	*Geothelphusa dehaani*	Collector-gatherer	-0.51±0.12	269.06	0.09±0.02	0.713674	2.399	-2.05
Ado	Upper	May	Caddisfly	Hydropsychidae spp.	Filter-feeder	0.11±0.13	0.51	ND$^{\$}$	ND	0.006	-1.90
Ado	Upper	May	Crane fly	Tipulidae	Shredder	-0.55±0.12	0.80	0.31±0.02	0.715166	0.008	-1.99
Ado	Upper	May	Mayfly	*Baetis* spp.	Grazer	-0.40±0.13	1.08	0.07±0.02	0.715035	0.007	-2.18
Ado	Upper	May	Mayfly	Heptageniidae spp.	Grazer	-0.06±0.11	1.77	0.17±0.03	0.715834	0.014	-2.12
Ado	Upper	May	Caddisfly	Rhyacophilidae spp.	Predator	0.34±0.12	0.74	0.16±0.03	0.713729	0.013	-1.74
Ado	Upper	May	Stonefly	*Kamimuria* spp.	Predator	-0.59±0.13	11.13	0.06±0.02	0.713914	0.048	-2.36
Ado	Upper	May	Stonefly	*Oyamia* spp.	Predator	-0.78±0.13	16.73	0.06±0.02	0.713842	0.079	-2.33
Ado	Upper	May	Dobsonfly	*Protohermes grandis*	Predator	-0.13±0.12	0.93	0.17±0.02	0.714851	0.006	-2.17
Ado	Upper	November	Japanese Freshwater Crab*	*Geothelphusa dehaani*	Collector-gatherer	-0.35±0.11	271.28	0.09±0.02	0.713477	2.344	-2.06
Ado	Upper	November	Caddisfly	Hydropsychidae spp.	Filter-feeder	0.29±0.12	0.53	0.24±0.02	0.714622	0.009	-1.80
Ado	Upper	November	Crane fly	Tipulidae	Shredder	-0.20±0.12	2.77	0.32±0.02	0.713829	0.019	-2.17
Ado	Upper	November	Mayfly	*Baetis* spp.	Grazer	-0.30±0.12	1.26	0.16±0.02	0.714938	0.007	-2.29
Ado	Upper	November	Mayfly	Heptageniidae spp.	Grazer	-0.26±0.12	1.70	0.16±0.02	0.715319	0.009	-2.28
Ado	Upper	November	Stonefly	*Kamimuria* spp.	Predator	-0.62±0.12	3.67	0.01±0.02	0.713884	0.048	-2.36
Ado	Upper	November	Stonefly	*Oyamia* spp.	Predator	-0.84±0.12	11.84	0.05±0.02	0.713780	0.079	-2.33

Ado	Upper	November	Dragonfly	Gomphidae spp.	Predator	-0.69±0.12	0.94	0.09±0.02	0.714058	0.013	-1.86
Ado	Upper	November	Dobsonfly	*Protohermes grandis*	Predator	0.03±0.12	1.16	0.22±0.02	0.715500	0.006	-2.31
Ado	Lower	May	Caddisfly	Hydropsychidae spp.	Filter-feeder	-0.13±0.13	3.04	ND	ND	0.030	-2.00
Ado	Lower	May	Mayfly	*Baetis* spp.	Grazer	-0.61±0.12	1.32	0.21±0.03	0.716955	0.002	-2.79
Ado	Lower	May	Mayfly	Heptageniidae spp.	Grazer	-0.18±0.12	1.90	0.15±0.02	0.717442	0.009	-2.31
Ado	Lower	May	Stonefly	*Kamimuria* spp.	Predator	-0.54±0.13	16.37	0.10±0.02	0.715978	0.058	-2.45
Ado	Lower	May	Stonefly	*Oyamia* spp.	Predator	-0.85±0.13	18.48	0.05±0.02	0.715914	0.075	-2.39
Ado	Lower	May	Dragonfly	Gomphidae spp.	Predator	-0.45±0.11	0.39	0.04±0.02	0.717413	0.008	-1.70
Ado	Lower	May	Dobsonfly	*Protohermes grandis*	Predator	-0.13±0.12	0.45	0.24±0.03	0.720017	0.001	-2.51
Ado	Lower	November	Caddisfly	Hydropsychidae spp.	Filter-feeder	0.30±0.13	0.55	ND	ND	0.004	-2.13
Ado	Lower	November	Caddisfly	*Stenopsyche marmorata*	Filter-feeder	1.58±0.12	0.39	0.56±0.03	0.715974	0.003	-2.16
Ado	Lower	November	Mayfly	*Baetis* spp.	Grazer	-0.25±0.13	1.39	0.18±0.03	0.718874	0.007	-2.32
Ado	Lower	November	Mayfly	Heptageniidae spp.	Grazer	-0.13±0.11	2.10	0.21±0.02	0.718372	0.010	-2.34
Ado	Lower	November	Stonefly	*Kamimuria* spp.	Predator	-0.59±0.13	1.48	0.01±0.02	0.716418	0.009	-2.22
Ado	Lower	November	Stonefly	*Oyamia* spp.	Predator	-0.84±0.12	12.39	0.04±0.02	0.716019	0.052	-2.38
Ado	Lower	November	Dragonfly	Gomphidae spp.	Predator	-0.30±0.12	0.87	0.06±0.02	0.717815	0.011	-1.89
Ado	Lower	November	Dobsonfly	*Protohermes grandis*	Predator	-0.19±0.12	0.45	ND	ND	0.001	-2.52
Ado	Lower	November	Shrimp*	Atyidae spp.	Omnivore	-0.89±0.12	87.34	0.04±0.02	0.71596	0.604	-2.16
Yasu	Upper	May	Japanese Freshwater Crab*	*Geothelphusa dehaani*	Collector-gatherer	-0.55±0.09	257.81	0.16±0.02	0.714571	0.964	-2.43
Yasu	Upper	May	Caddisfly	Hydropsychidae spp.	Filter-feeder	-0.15±0.11	3.48	0.16±0.03	0.714910	0.029	-2.08

Yasu	Upper	May	Crane fly	Tipulidae	Shredder	-0.41±0.10	0.96	0.38±0.02	0.716418	0.004	-2.33
Yasu	Upper	May	Mayfly	*Baetis* spp.	Grazer	-0.07±0.13	1.09	0.10±0.02	0.714629	0.007	-2.19
Yasu	Upper	May	Mayfly	Heptageniidae spp.	Grazer	-0.10±0.10	1.37	ND	ND	0.004	-2.49
Yasu	Upper	May	Caddisfly	Rhyacophilidae spp.	Predator	0.26±0.10	0.52	ND	ND	0.006	-1.97
Yasu	Upper	May	Stonefly	*Kamimuria* spp.	Predator	-0.62±0.10	6.92	0.15±0.03	0.714602	0.014	-2.68
Yasu	Upper	May	Stonefly	*Oyamia* spp.	Predator	-1.09±0.09	18.13	0.03±0.03	0.714813	0.042	-2.63
Yasu	Upper	May	Dragonfly	Gomphidae spp.	Predator	-0.38±0.10	0.45	0.23±0.02	0.716463	0.004	-2.43
Yasu	Upper	May	Dobsonfly	*Protohermes grandis*	Predator	-0.51±0.09	1.11	0.19±0.01	0.715391	0.001	-2.53
Yasu	Upper	November	Mayfly	*Baetis* spp.	Grazer	-0.16±0.10	1.32	0.16±0.02	0.715167	0.006	-2.34
Yasu	Upper	November	Mayfly	Heptageniidae spp.	Grazer	-0.15±0.13	1.77	0.22±0.03	0.715912	0.007	-2.47
Yasu	Upper	November	Stonefly	*Kamimuria* spp.	Predator	-0.65±0.09	5.19	0.11±0.02	0.714645	0.011	-2.69
Yasu	Lower	May	Caddisfly	Hydropsychidae spp.	Filter-feeder	-0.17±0.10	2.58	0.21±0.02	0.711677	0.017	-2.19
Yasu	Lower	May	Caddisfly	*Stenopsyche marmorata*	Filter-feeder	1.39±0.09	0.42	0.43±0.02	0.714162	0.002	-2.26
Yasu	Lower	May	Mayfly	*Baetis* spp.	Grazer	0.12±0.10	1.27	0.17±0.03	0.712740	0.006	-2.33
Yasu	Lower	May	Mayfly	Heptageniidae spp.	Grazer	-0.11±0.09	2.10	0.23±0.02	0.713296	0.007	-2.49
Yasu	Lower	May	Caddisfly	Rhyacophilidae spp.	Predator	0.20±0.09	1.14	0.24±0.02	0.711801	0.009	-2.08
Yasu	Lower	May	Stonefly	*Kamimuria* spp.	Predator	-0.41±0.09	1.12	ND	ND	0.005	-2.38
Yasu	Lower	May	Dragonfly	Gomphidae spp.	Predator	-0.20±0.11	0.83	0.19±0.02	0.712154	0.002	-2.26
Yasu	Lower	May	Dobsonfly	*Protohermes grandis*	Predator	0.06±0.09	0.64	0.25±0.02	0.713156	0.002	-2.49
Yasu	Lower	May	Shrimp*	Atyidae spp.	Omnivore	-0.73±0.10	142.35	0.10±0.02	0.712021	0.624	-2.36

Yasu	Lower	November	Caddisfly	Hydropsychidae spp.	Filter-feeder	0.36±0.09	0.63	0.28±0.03	0.713300	0.004	-2.20
Yasu	Lower	November	Caddisfly	*Stenopsyche marmorata*	Filter-feeder	1.01±0.09	0.90	0.34±0.03	0.714594	0.006	-2.20
Yasu	Lower	November	Mayfly	*Baetis* spp.	Grazer	0.13±0.10	1.11	0.20±0.02	0.712434	0.005	-2.36
Yasu	Lower	November	Mayfly	Heptageniidae spp.	Grazer	0.07±0.10	1.39	0.26±0.02	0.712198	0.007	-2.48
Yasu	Lower	November	Stonefly	*Kamimuria* spp.	Predator	-0.33±0.09	1.08	ND	ND	0.003	-2.52
Yasu	Lower	November	Dragonfly	Gomphidae spp.	Predator	-0.57±0.09	0.48	0.14±0.03	0.714622	0.004	-2.04
Yasu	Lower	November	Dobsonfly	*Protohermes grandis*	Predator	0.13±0.10	0.78	0.26±0.02	0.713411	0.003	-2.43
Yasu	Lower	November	Shrimp*	Atyidae spp.	Omnivore	-0.55±0.09	155.15	0.15±0.02	0.711502	0.683	-2.36

*shells
ND: not determined

Table S6. $\delta^{44/40}Ca \pm 2\sigma$, $\delta^{88/86}Sr \pm 2\sigma$ values, $^{87}Sr/^{86}Sr$ ratio, Ca and Sr concentrations, and the log(Sr/Ca) ratios of fish bones and muscles.

Stream	Location	Month	Order	Scientific name	Sample type	$\delta^{44/40}Ca_{NIST915b} \pm 2\sigma$	Ca	$\delta^{88/86}Sr \pm 2\sigma$	$^{87}Sr/^{86}Sr$	Sr	Log(Sr/Ca)
						(‰)	(mg/g)	(‰)	(‰)	(mg/g)	
Ado	Upper	May	Chub	*Rhynchocypris oxycephalus jouyi*	bone	-1.63±0.12	246.69	-0.04±0.02	0.713844	0.979	-2.40
					muscle	-1.54±0.11	1.70	ND[$]	ND	0.005	-2.52
Ado	Upper	November	-	-	-	-	-	-	-	-	-
					-	-	-	-	-	-	-
Ado	Lower	May	Goby	*Rhinogobius kurodai*	bone	-1.41±0.13	225.35	-0.01±0.02	0.715886	0.565	-2.60
					muscle	-0.94±0.12	1.14	ND	ND	0.002	-2.68
Ado	Lower	November	Goby	*Rhinogobius kurodai*	bone	-1.17±0.12	238.42	0.09±0.02	0.715842	0.607	-2.59
					muscle	-0.76±0.12	1.02	ND	ND	0.002	-2.81
Yasu	Upper	May	Goby	*Cottus pollux*	bone	-1.36±0.10	252.14	0.21±0.02	0.714448	0.315	-2.90
					muscle	-0.91±0.11	0.81	ND	ND	0.001	-3.11
Yasu	Upper	November	Goby	*Cottus pollux*	bone	-1.26±0.10	260.15	0.18±0.02	0.714501	0.298	-2.94
					muscle	-0.99±0.10-	0.96	ND	ND	0.001	-3.14
Yasu	Lower	May	Goby	*Rhinogobius kurodai*	bone	-1.36±0.09	262.41	0.08±0.02	0.711844	0.311	-2.93
					muscle	-1.13±0.10	3.33	ND	ND	0.004	-2.88
Yasu	Lower	November	Goby	*Rhinogobius kurodai*	bone	-1.56±0.09	227.39	0.07±0.02	0.711809	0.339	-2.83
					muscle	-1.69±0.10	17.91	ND	ND	0.028	-2.80

[$]ND: Not determined