Ecography

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Supplementary material

Appendix 1: Characteristics of the study areas and field sampling campaigns

This section details the study area characteristics, benthic and subsurface invertebrate field sampling campaigns and laboratory procedures for each of the five rivers. The taxonomic resolution to which invertebrates were identified is stated in Table A1. Information on the Albarine, Asse and Selwyn is taken from the Supplementary material of Datry et al. (2014) and is reproduced modified with the authors' permission.

Albarine River, France

Study area

The Albarine River is located in temperate eastern France and drains a 313 km^2 catchment. The river flows for 45 km through the Jura Mountains, then 15 km across an alluvial plain to its confluence with the Ain River. On the alluvial plain, the river is perched 1-14 m above the water table, and surface water is lost to the underlying sediments and aquifer at an average rate of 0.4 m^3 s^{-1} km^{-1}. Due to this rapid seepage loss, the river is temporary as it crosses the alluvial plain. Further description of the climate, geology and geomorphology of the Albarine River catchment is provided by Datry (2012).

Flow cessation begins in the spring of most years at the confluence with the Ain River, and the drying front moves upstream during the summer. Flow generally resumes along the entire temporary reach in late autumn/early winter. With distance downstream, water permanence declines and the average annual % time dry and drying frequency both increase. At the downstream end of the temporary reach, annual water permanence ranges from 10% to 50%.

Invertebrate sampling

Invertebrates were collected from riffles at 18 (seven perennial, 11 temporary) sites prior to water loss in spring (30 March 2009 and 27 May 2010) and at least 3 weeks after flow resumed in autumn/early winter (15 October 2008, 1 December 2009 and 12 October 2010). In October 2008, the five sites furthest downstream were not sampled because they dried two weeks after flow resumed. At each site, on each sampling date, and for both benthic and subsurface communities, two samples were collected from each of two riffles and pooled. Benthic communities were collected with a Hess sampler (0.125-m^2 area, 200-µm mesh), and subsurface communities were sampled using a Bou-Rouch pump. A steel pipe was driven into the bed to a depth of 30 cm using a sledgehammer, a piston-pump attached, then 6 L of water, sediments and associated organisms were extracted and filtered through a 63-µm mesh (Datry 2012). All invertebrate samples were preserved with 96% ethanol. Datry (2012) provide further details of invertebrate sampling and processing.

Asse River, France

Study area

The Asse River is located in the Provence region of south-eastern France and drains a 657 km^2 catchment in the south-western French Alps. The main tributaries of the Asse River rise in the Préalpes de Digne, then converge 45 km downstream to form the Asse River mainstem, which flows for 30 km across an alluvial plain to its confluence with the Durance River. On the alluvial plain, the upper 15-km-long reach is perennial and the lower 15-km-long reach is temporary. Water loss is caused by the combined effects of seepage into the underlying aquifer, high groundwater abstraction in the floodplain for agriculture, and bed aggradation. Along the temporary section, drying events occurred in two 4-km-long reaches spaced 7 km apart. Descriptions of the climate, geology and geomorphology of the Asse River catchment are given in Mano et al. (2009).

Flow cessation begins in spring of most years 2-3 km from the confluence with the Durance River, and the drying front moves upstream and downstream during the summer. Flow generally resumes throughout the temporary reaches in autumn. In the middle of the temporary reach, annual water permanence is lowest and ranges from 80% to 90%.

Invertebrate sampling
Invertebrates were collected from riffles at 13 sites (five perennial, eight temporary). Samples were collected in spring, just before the beginning of summer dry events (15 April 2009 and 8 June 2010), and in autumn, at least 3 weeks after flow resumed (2 October 2008 and 10 November 2009). On each sampling date, two invertebrate samples were collected from each of two riffles per site and pooled. Invertebrates were collected and preserved using comparable methods to those summarized above and described by Datry (2012) for the Albarine.

The River Glen

Study area
The River Glen rises from a limestone outcrop in Lincolnshire, central England, UK. The upper reaches comprise two third-to-fourth-order tributaries, the East Glen and West Glen, which respectively flow for 37 km and 39 km across a 342-km^2 catchment dominated by arable land use, before joining to form the River Glen. Fissures and other features of the limestone bedrock enable rapid recharge of the underlying aquifer, resulting in surface water loss from losing reaches. The area is also subject to anthropogenic water resource use, exacerbating natural surface water loss and contributing to partial or complete streambed drying. In years with average precipitation, site 1 is perennial, and sites 2, 3 and 4 (based on expert interpretation of nearby gauging station data, J. Murphy, pers. comm.) dry in summer for approx. 3, 6 and 9 weeks, respectively, although sporadic sinkhole development near site 2 hinders definition of a ‘typical’ year. Further details of the catchment, including its geology, hydrology, climate and land use are provided by Stubbington (2011, and references therein) and Stubbington et al. (2011b).

Invertebrate sampling
Samples were collected at approximately monthly intervals for five months between May and September 2009. On each date, four replicate benthic invertebrate samples were collected from each of two sites on the West Glen (site 1, 0% time dry; site 2, 5% time dry) and two sites on East Glen (site 3, 10% time dry; site 4, 20% time dry) using a Surber sampler. The 0.09-m^2 Surber frame was placed on the bed and sediments manually disturbed to a depth of approx. 5 cm for 30 s, with dislodged invertebrates captured in a 500-µm net. At each benthic invertebrate sampling point, a 6-L sample of water, sediments and associated organisms was pumped from a semi-permanent 30-cm-depth sampling well (comprising a PVC tube, 19-mm internal diameter) using a vacuum pump, following the method of Boulton and Stanley (1995) and Hunt and Stanley (2000). Further details and critical evaluation are provided by Stubbington (2011) and Wood et al. (2010). All invertebrate samples were preserved using 70% industrial methylated spirits.

The River Lathkill

Study area

The River Lathkill is a second order stream that originates from groundwater springs within a limestone outcrop in Derbyshire, central England, UK and flows for <9 km to drain a <52 km^2 catchment before joining the River Wye. The Lathkill is within an area designated by national and European legislation to protect features of biological and geological interest, and catchment land uses comprise deciduous woodland and low-intensity sheep grazing. Surface water is lost to natural fissures and voids within the underlying karst limestone bedrock and also to historic lead mining drainage levels, a legacy of local industrial activity in the 1800s. Groundwater inputs from the aquifer dominate streamflow and surface flow therefore experiences fairly predictable, seasonal changes, although sudden floods can occur when heavy rainfall saturates the soil and groundwater stores. In typical years, continuous flow is maintained at sites 1 and 2, although riffle crests are exposed. Drying durations increase with progression downstream within a <2 km stretch, with surface flows typically receding to leave the benthic and shallow subsurface sediments dry at sites 3-5 for 2-3 months from July-August onwards. Further details of the catchment, including its geology, hydrology, climate and land use are provided by Stubbington (2011, and references therein) and Stubbington et al. (2011a,b).

Invertebrate sampling

Samples were collected from the two perennial and three temporary sites using a comparable sampling strategy to that described for the Glen, although sample collection did not begin until June at site 5, and four not five sets of samples were thus collected here.

Selwyn River, New Zealand

Study area

The Selwyn River drains a 975-km^2 catchment located 90 km north of the Orari River on New Zealand's South Island. The Selwyn rises in the foothills of the eastern Southern Alps and flows across the Canterbury Plains. The river mainstem flows for 35 km through the foothills, then 54 km across inland and coastal plains to coastal Lake Ellesmere. The Selwyn River is perched over a deep vadose zone beneath the inland plains, and loses water with distance downstream. The first 3 km of the losing reach are perennial, and the next 43 km are temporary. In the coastal plains, upwelling groundwater causes progressive flow gains, and the river becomes perennial approximately 8 km from its terminus. At its most temporary point, the river's annual average water permanence is approximately 30%. During extended droughts, the river dries for most of its length on the Canterbury Plains, and portions of the central reach may remain dry for >1 year. Larned et al. (2008) describe the climate, geology and geomorphology of the Selwyn River catchment.

Invertebrate sampling

Invertebrates were collected on 11 dates between November 2003 and October 2004. On each date, 1-4 replicate samples were collected from 10-16 of 16 (three perennial, 13 temporary) sites, with each site sampled only on dates when water depth flowing over riffle tails exceeded 30 cm (Datry et al. 2007). At least one site was dry on each sampling date, and the total number of sampling dates therefore varied from 1-11 per site, with each 'date' comprising a 1-4-day period. On each date, four replicate benthic invertebrate samples were collected with a Surber sampler (0-09 m^2 area, 250-μm mesh), then two samples combined in each of two composite samples. To sample subsurface invertebrates, 4-L samples were collected using the vacuum-pump method described above for the Glen, with samples filtered through a 63-µm mesh sieve. All invertebrate samples were preserved in 70% isopropyl alcohol (Datry et al. 2007).

Preparation of invertebrate data for analysis

Further to the *Invertebrate data* described in the main text, 53 (of 105) benthic and 65 (of 93) subsurface samples collected within 2 d of each other at 10 (of 16) sites were used to create the 43 subsurface–benthic sample 'pairs'.

References

Almeida-Neto, M. et al. 2008. A consistent metric for nestedness analysis in ecological systems: reconciling concept and measurement. – Oikos 117: 1227–1239.

Datry, T. 2012. Benthic and hyporheic invertebrate assemblages along a flow intermittence gradient: effects of duration of dry events. – Freshwat. Biol. 57: 563–574.

Datry, T. et al. 2007. Responses of hyporheic invertebrate assemblages to large-scale variation in flow permanence and surface–subsurface exchange. – Freshwat. Biol. 52: 1452–1462.

Datry, T. et al. 2014. Broad-scale patterns of invertebrate richness and community composition in temporary rivers: effects of flow intermittence. – Ecography 37: 94–104.

Boulton, A. J. and Stanley, E. H. 1995. Hyporheic processes during flooding and drying in a Sonoran Desert stream. 2. Faunal dynamics. – Arch. Hydrobiol. 134: 27–52.

Hunt, G. W. and Stanley, E. H. 2000. An evaluation of alternative procedures using the Bou-Rouch method for sampling hyporheic invertebrates. – Can. J. Fish. Aquat. Sci. 57: 1545–1550.

Larned, S. T. et al. 2008. The Selwyn River of New Zealand: a benchmark system for alluvial plain rivers. – River Res. Appl. 24: 1–21.

Mano, V. et al. 2009. Assessment of suspended sediment transport in four alpine watersheds (France): influence of the climatic regime. – Hydrol. Proc. 23: 777–792.

Stubbington, R. 2011. The hyporheic zone as a refugium for benthic invertebrates in groundwater-dominated streams [PhD thesis]. – Loughborough University, UK, 354 pp.

Stubbington, R. et al. 2011a. Spatial variability in the hyporheic zone refugium of temporary streams. – Aquat. Sci. 73: 499–511.

Stubbington, R. et al. 2011b. Benthic and hyporheic invertebrate community responses to seasonal flow recession in a groundwater-dominated stream. – Ecohydrology 4: 500–511.

Stubbington, R. et al. 2016. Characterization of macroinvertebrate communities in the hyporheic zone of river ecosystems reflects the pump-sampling technique used. – PLoS One 11: p.e0164372.

Wood, P. J. et al. 2010. Is the hyporheic zone a refugium for aquatic macroinvertebrates during severe low flow conditions? – Fundam. App. Limnol. 176: 377–390.

Appendix 2: Supplemental tables and figures

Table A1. Taxonomic resolution to which invertebrates were identified in each study, listed alphabetically by taxon within major taxa (i.e. phylum, sub-phylum, class, sub-class or unranked taxon). F, family; G, genus; GG, genus group; Group, taxon stated; NA, not applicable (i.e. taxon not recorded); S, species; SF, sub-family; SG, species group.

Major taxon	Taxon	Albarine	Asse	Glen	Lathkill	Selwyn
Acari	Hydrachnidia	Group	Group	Group	Group	Group
Bivalvia		S	NA	F	F	NA
Cnidaria		NA	NA	NA	NA	G
Crustacea	Amphipoda	G, F	G, F	S	S	Order
	Cladocera	Group	NA	Group	Group	F
	Cyclopoida	Group	Group	Group	Group	Group
	Harpacticoida	Group	Group	Group	Group	Group
	Isopoda	F	NA	S	S	F
	Ostracoda	Group	Group	Group	Group	Group
	Syncarida	NA	NA	NA	NA	Group
Gastropoda		S, G	F	S	S	G
Hirudinea		F	F	S	S	NA
Insecta	Coleoptera	G	G	S, G, F	S, G, F	S, G, F
	Diptera	F	F	G, F	G, F	G, SF, F
	Ephemeroptera	G	G	S, G	S, G	S, G
	Hemiptera	NA	F	S	S	NA
	Lepidoptera	NA	F	NA	NA	NA
	Megaloptera	F	F	S	NA	S
	Odonata	NA	G	S	NA	NA
	Plecoptera	G	G	NA	S, G	S, G
	Trichoptera	G	G	S, G	S, GG	S, G
Nematoda		Group	Group	Group	Group	Group
Oligochaeta		Group	Group	Group	Group	G, F
Tardigrada		NA	NA	NA	NA	Group
Turbellaria		F	F	S, SG	S, SG, F	Group

Table A2. Differences in subsurface-benthic community composition between subsurface (S) and benthic (B) habitats at perennial (P) and temporary (T) sites in five rivers, as calculated using Sørensen distance matrices and tested using permutational multivariate ANOVA. Significant p values are in bold.

		Albarine	Asse	Glen	Lathkill	Selwyn
S-B	**df**	1,146	1,94	1,154	1,186	1,110
	F	77.1	35.8	75.5	77.6	130.7
	p	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**
P-T	**df**	1,146	1,94	1,154	1,186	1,110
	F	28.7	0.67	12.7	12.4	13.3
	p	**0.001**	0.642	**0.001**	**0.001**	**0.001**
S-B:P-T	**df**	1,146	1,94	1,154	1,186	1,110
	F	0.12	0.82	2.9	2.1	11.1
	p	0.977	0.527	**0.017**	**0.043**	**0.008**

Subsurface and benthic invertebrate community composition

Summaries of subsurface and benthic communities in each river are presented in Tables A3-5; caution is advised in comparing studies, due to differences in estimates produced by different sampling methods (e.g. Stubbington et al. 2016; see page 4 for details), in sampling effort among studies, and in the taxonomic resolution achieved (Table A1).

Table A3. Subsurface and benthic invertebrate communities in five rivers, indicating the total number of taxa, the total number of individuals and the % of each common taxon (>1% of all individuals), calculated based on combined subsurface-benthic data sets. Taxa are listed alphabetically by major taxon then by the lowest taxonomic resolution.

	River	**Albarine**	**Asse**	**Glen**	**Lathkill**	**Selwyn**
	Total no. taxa	70	49	86	68	74
	Total no. individuals	107,660	6,332	56,409	37,779	189,967
Acari	Hydrachnidia	4.4	2.6	1.9		
Coleoptera	*Elmis / E. aenea*	1.4			4.3	
	Esolus	2.0				
	Limnius	1.0				
	Oulimnius			4.9		
	Riolus subviolaceus				2.4	
Crustacea	Cyclopoida	2.3	2.7			
	Gammarus / G. pulex	4.4		2.0	37	
	Harpacticoida	4.5				3.5
	Ostracoda	13			1.6	
Diptera	Ceratopogonidae	1.0	1.4			
	Chironomidae	25	37	37	19	
	Cricotopus					4.1
	Eukiefferiella					4.5
	Psychodidae				1.2	
	Simuliidae	3.0		4.2		
Ephemeroptera	*Baetis*	5.1	2.6	8.0	4.0	
	Caenis / C. luctuosa	1.5	4.4	1.7		
	Deleatidium					10.1
	Ecdyonurus	1.0	10			
	Ephemerella / E. ignita	4.8		1.4	4.0	
	Habroleptoïdes	2.6				
	Rhithrogena	1.9				
Hirudinea	*Erpobdella octoculata*			1.8		
Mollusca	*Potamopyrgus / P. antipodarum*			6.9		3.3
	Sphaeriidae			5.5		
Nematoda	Nematoda	1.2				
Oligochaeta	Oligochaeta	6.8	3.2	16	5.1	
Plecoptera	*Leuctra*	3.9	4.2		4.6	
Trichoptera	*Agapetus fuscipes*				2.1	
	Drusus annulatus				2.2	
	Hydropsyche	3.3	26			
	Hydroptila			1.8		
	Olinga / O. feredayi					9.9
	Pycnocentria					3.2
	Pycnocentrodes					50.2
Turbellaria	*Polycelis felina*				6.5	

Table A4. Subsurface invertebrate communities in five rivers, indicating the total number of taxa and individuals, the mean richness (taxa per 4-L to 6-L sample) and the % of each do common minant taxon (>1% of all individuals), calculated based on the subsurface data set. Taxa are listed alphabetically by major taxon then by the lowest taxonomic resolution.

	River	**Albarine**	**Asse**	**Glen**	**Lathkill**	**Selwyn**
	Total no. taxa	49	26	43	23	53
	Mean ± SE taxa	11 ± 0.47	6.0 ± 0.24	4.4 ± 0.24	5.7 ± 0.26	11 ± 0.55
	Total no. individuals	18,914	1,600	1,892	2,794	17,469
	Mean ± SE individuals	249 ± 30	33 ± 4.0	24 ± 3.0	29 ± 2.7	188 ± 33
Acari	Hydrachnidia	2.6		2.5	1.0	10
Coleoptera	*Elmis aenea*				1.6	
Crustacea	Amphipoda					5.1
	Chydoridae					1.8
	Cyclopoida	9.6	9.8	2.1	6.0	11
	Gammarus pulex				15	
	Harpacticoida	22				40
	Janiridae					4.9
	Niphargus	2.1				
	Ostracoda	5.8			21	
Diptera	Ceratopogonidae		2.8			
	Chironomidae	27	69	49	28	
	Simuliidae			12		
Ephemeroptera	*Baetis*			6.6	2.3	
	Caenis / C. luctuosa		1.0	1.6		
	Deleatidium					1.6
	Ephemerella / E. ignita	1.4			1.4	
Mollusca	*Potamopyrgus*					5.1
	Sphaeriidae			8.4		
Nematoda	Nematoda	5.1	2.2	1.4	1.4	8.7
Oligochaeta	Enchytraeidae					1.0
	Naididae[1]					4.6
	Oligochaeta	16	8.3	9.6	7.1	
	Tubificidae[1]					1.0
Plecoptera	*Leuctra*	1.6	1.3			
	Leuctra geniculata				2.1	
	Nemoura				4.3	
	Hydropsyche		2.7			
Turbellaria	*Polycelis felina*				4.8	

[1]Differentiated in the Selwyn study (Datry et al. 2007; see page 4 for details).

Table A5. Benthic invertebrate communities in five rivers, indicating the total number of taxa and individuals, the mean richness (taxa per approx. 0.1 m^2 sample) and the % of each common taxon (>1% of all individuals), calculated based on the benthic data set. Taxa are listed alphabetically by major taxon then by the lowest taxonomic resolution.

	River	Albarine	Asse	Glen	Lathkill	Selwyn
	Total no. taxa	69	47	84	65	89
	Mean ± SE taxa richness	25 ± 0.84	13 ± 0.56	22 ± 0.70	15 ± 0.36	22 ± 1.0
	Total no. individuals	88,746	4,786	54,471	34,988	206,924
	Mean ± SE individuals	1168 ± 94	98 ± 9.4	681 ± 53	364 ± 32	1934 ± 345
Acari	Hydrachnidia	4.8	3.3	1.8		
Coleoptera	Elmidae					1.0
	Elmis / E. aenea	1.7		1.0	4.5	
	Esolus	2.3				
	Limnius	1.1				
	Oulimnius			3.0		
	Riolus subviolaceus				2.6	
Crustacea	*Gammarus / G. pulex*	5.2		2.0	39	
	Ostracoda	15				
Diptera	Ceratopogonidae	1.1				
	Chironomidae	25	26	37	18	
	Cricotopus					4.1
	Eukiefferiella					6.9
	Naonella					1.2
	Psychodidae				1.3	
	Simuliidae	3.7		4.0		
Ephemeroptera	*Baetis*	6.0	3.4	8.0	4.2	
	Caenis / C. luctuosa	1.7	5.5	1.7		
	Deleatidium					14
	Ecdyonurus	1.2	12			
	Ephemerella / E. ignita	5.6		1.4	4.2	
	Habroleptoïdes	3.0				
	Oligoneuriella		1.0			
	Rhithrogena	2.3	2.0			
Hirudinea	*Erpobdella octoculata*			1.8		
Mollusca	*Potamopyrgus / P. antipodarum*			7.1		2.9
	Sphaeriidae			5.4		
Oligochaeta	Naididae					1.8
	Oligochaeta	4.8	1.5	16	4.9	
Plecoptera	*Leuctra*	4.4	5.1		4.8	
Trichoptera	*Agapetus fuscipes*				2.2	
	Drusus annulatus				2.4	
	Hydropsyche	3.9	33			
	Hydroptila			1.8		
	Olinga feredayi					9.6
	Pycnocentria					3.0
	Pycnocentrodes					47
Turbellaria	*Polycelis felina*				6.7	

Table A6. Beta-diversity measures for benthic (B) and subsurface (S) invertebrate communities in five rivers. Incidence-based total Sørensen dissimilarity (β_{SOR}) and its nestedness-resultant (β_{SNE}) and turnover (β_{SIM}) components. Communities compared using PERMDISP; significant differences ($p < 0.05$) and higher values are indicated in bold.

River	**Habitat**	**β-diversity measure**					
		β_{SOR}		**β_{SNE}**		**β_{SIM}**	
Albarine	**B**	0.39	$F_{1,150} = 2.5$	0.13	$F_{1,150} = 3.1$	0.26	$F_{1,150} = 1.3$
	S	0.42	$p = 0.119$	0.16	$p = 0.078$	0.27	$p = 0.265$
Asse	**B**	0.39	$F_{1,96} = 1.2$	0.13	$F_{1,96} = 0.4$	0.25	$F_{1,96} = 5.5$
	S	0.45	$p = 0.278$	0.12	$p = 0.548$	**0.32**	**$p = 0.022$**
Glen	**B**	0.44	$F_{1,158} = 8.2$	**0.12**	$F_{1,158} = 70.5$	0.33	$F_{1,158} = 42.5$
	S	**0.62**	**$p < 0.001$**	0.15	**$p < 0.001$**	**0.47**	**$p < 0.001$**
Lathkill	**B**	0.43	$F_{1,190} = 72.0$	0.09	$F_{1,190} = 35.4$	**0.33**	$F_{1,190} = 34.5$
	S	**0.59**	**$p < 0.001$**	**0.15**	**$p < 0.001$**	0.45	**$p < 0.001$**
Selwyn	**B**	**0.60**	$F_{1,116} = 5.8$	0.14	$F_{1,116} = 4.7$	**0.46**	$F_{1,116} = 10.4$
	S	0.46	**$p = 0.018$**	**0.17**	**$p = 0.031$**	0.29	**$p < 0.001$**
Mean	**B**	0.45 ± 0.04		0.12 ± 0.01		0.33 ± 0.04	
	S	0.51 ± 0.04		0.15 ± 0.01		0.36 ± 0.04	

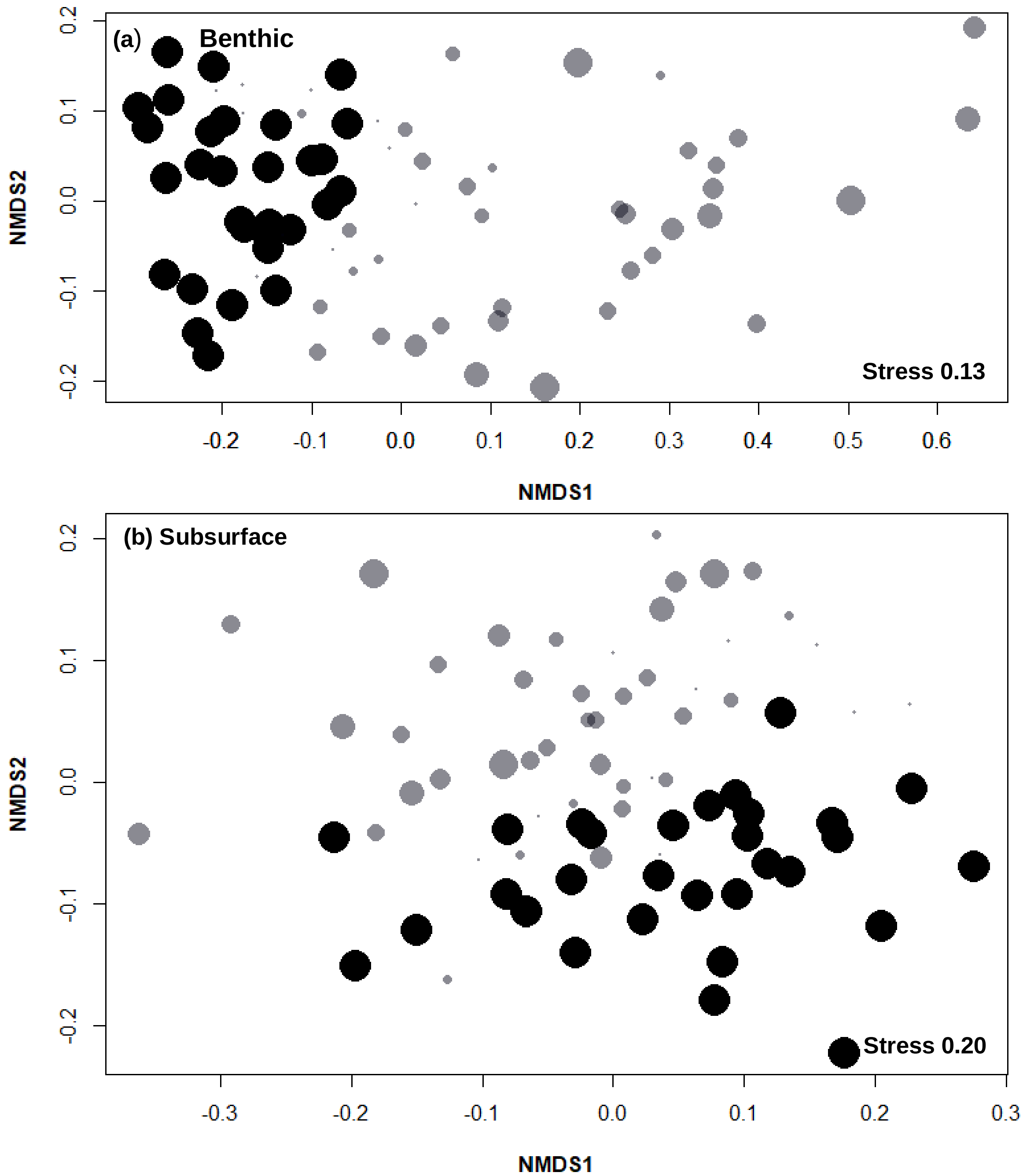

Figure A1. Non-metric multidimensional scaling of (a) benthic and (b) subsurface invertebrate communities in the Albarine River, in relation to surface water permanence. Black and grey symbols indicate perennial and temporary sites, with symbol size proportional to the % of time temporary sites dried; note that symbol sizes are not comparable among Fig. A1 panes, and scales vary between panes. Outlier values were normalized to facilitate presentation. Fig. A1 spans pages 10-13.

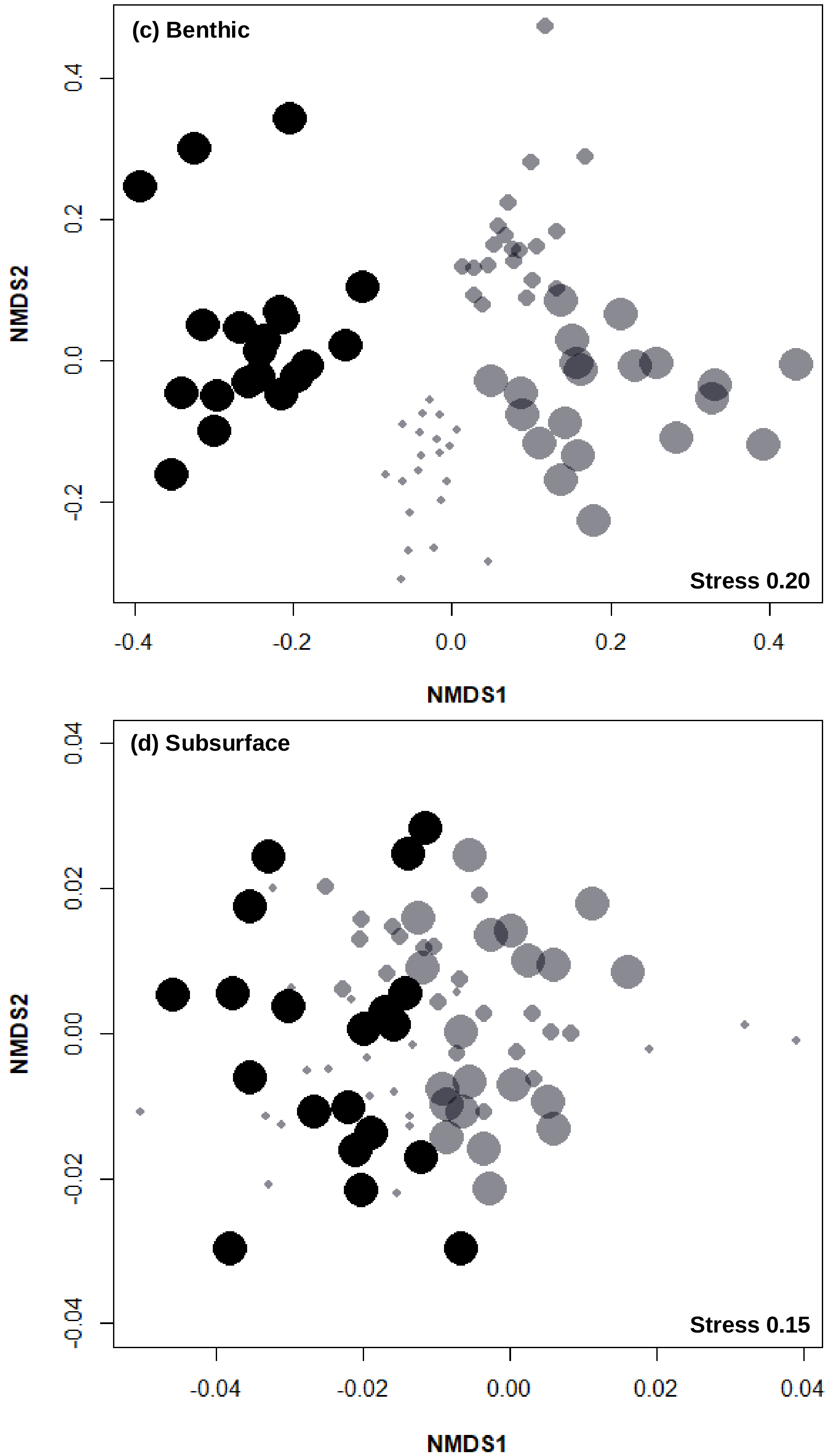

Figure A1 continued**.** Non-metric multidimensional scaling of (c) benthic and (d) subsurface invertebrate communities in the River Glen, in relation to surface water permanence. Black and grey symbols indicate perennial and temporary sites, with symbol size proportional to the % of time temporary sites dried; note that symbol sizes are not comparable among Fig. A1 panes, and scales vary between panes. Outliers were normalized to facilitate presentation. Fig. A1 spans pages 10-13.

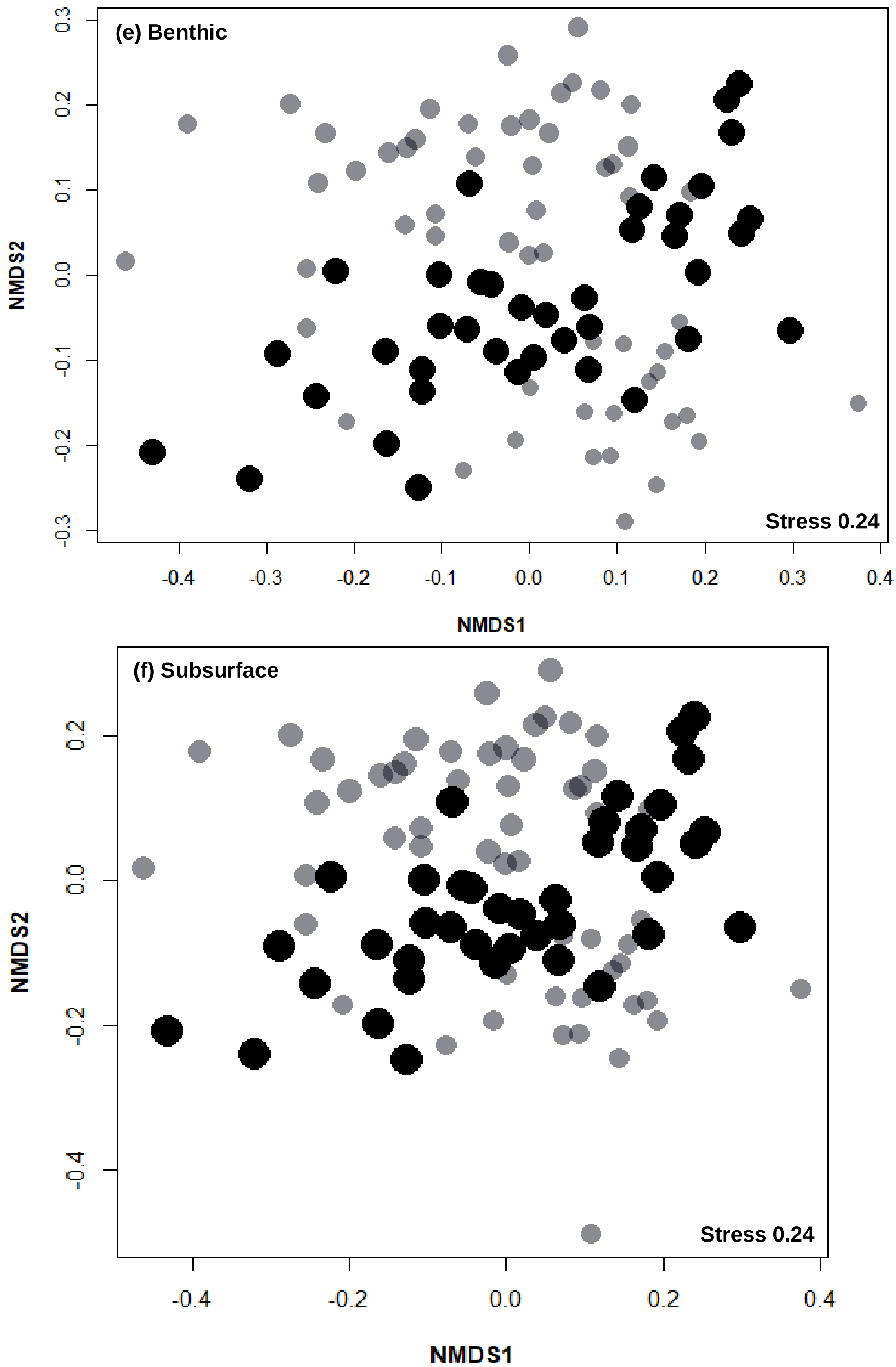

Figure A1 continued. Non-metric multidimensional scaling of (e) benthic and (f) subsurface invertebrate communities in the River Lathkill, in relation to surface water permanence. Black and grey symbols indicate perennial and temporary sites, with symbol size proportional to the % of time temporary sites dried; note that symbol sizes are not comparable among Fig. A1 panes, and scales vary between panes. Outliers were normalized to facilitate presentation. Fig. A1 spans pages 10-13.

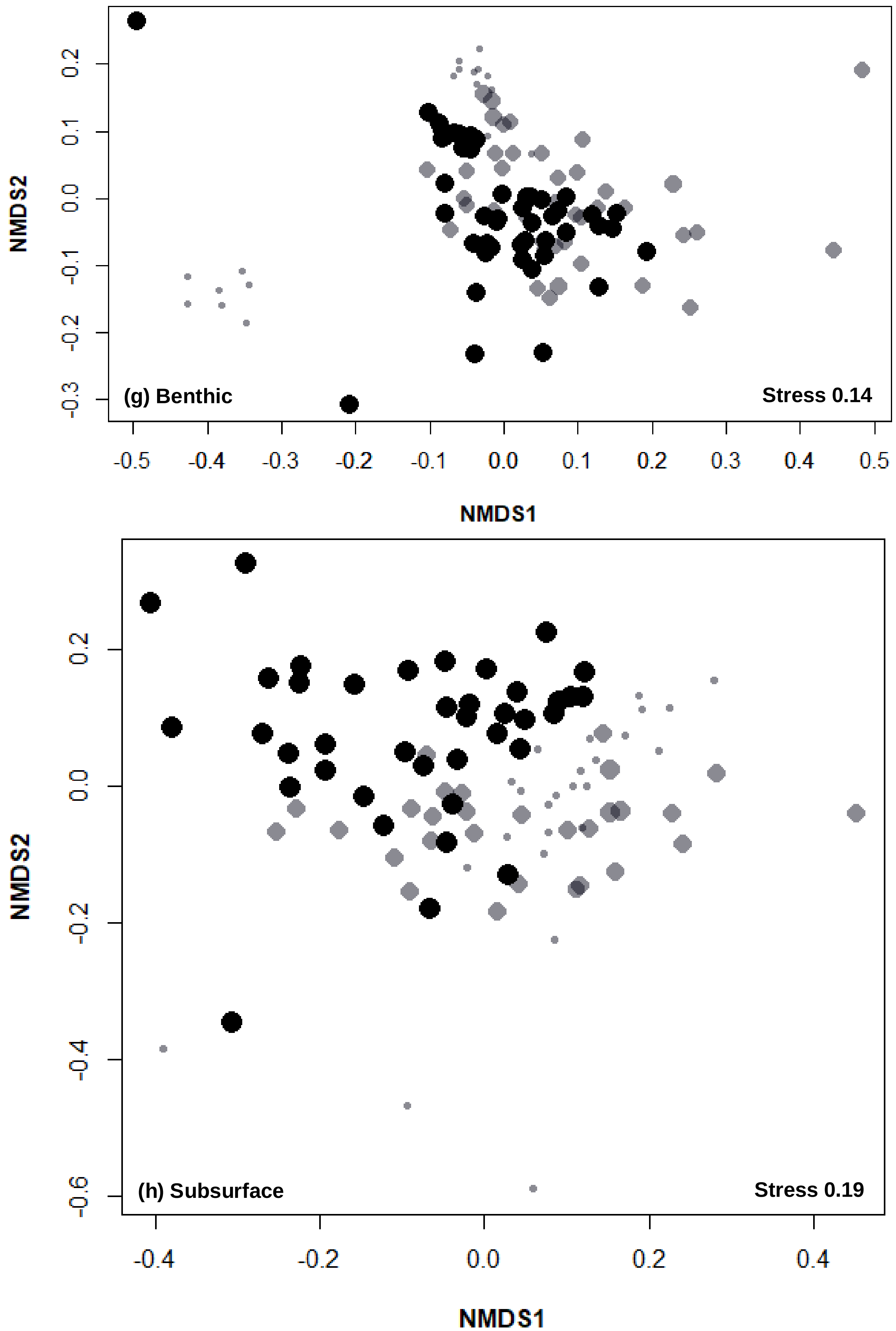

Figure A1 continued. Non-metric multidimensional scaling of (g) benthic and (h) subsurface invertebrate communities in the Selwyn River, in relation to surface water permanence. Black and grey symbols indicate perennial and temporary sites, with symbol size proportional to the % of time temporary sites dried; note that symbol sizes are not comparable among Fig. A1 panes, and scales vary between panes. Outliers were normalized to facilitate presentation. Fig. A1 spans pages 10-13.

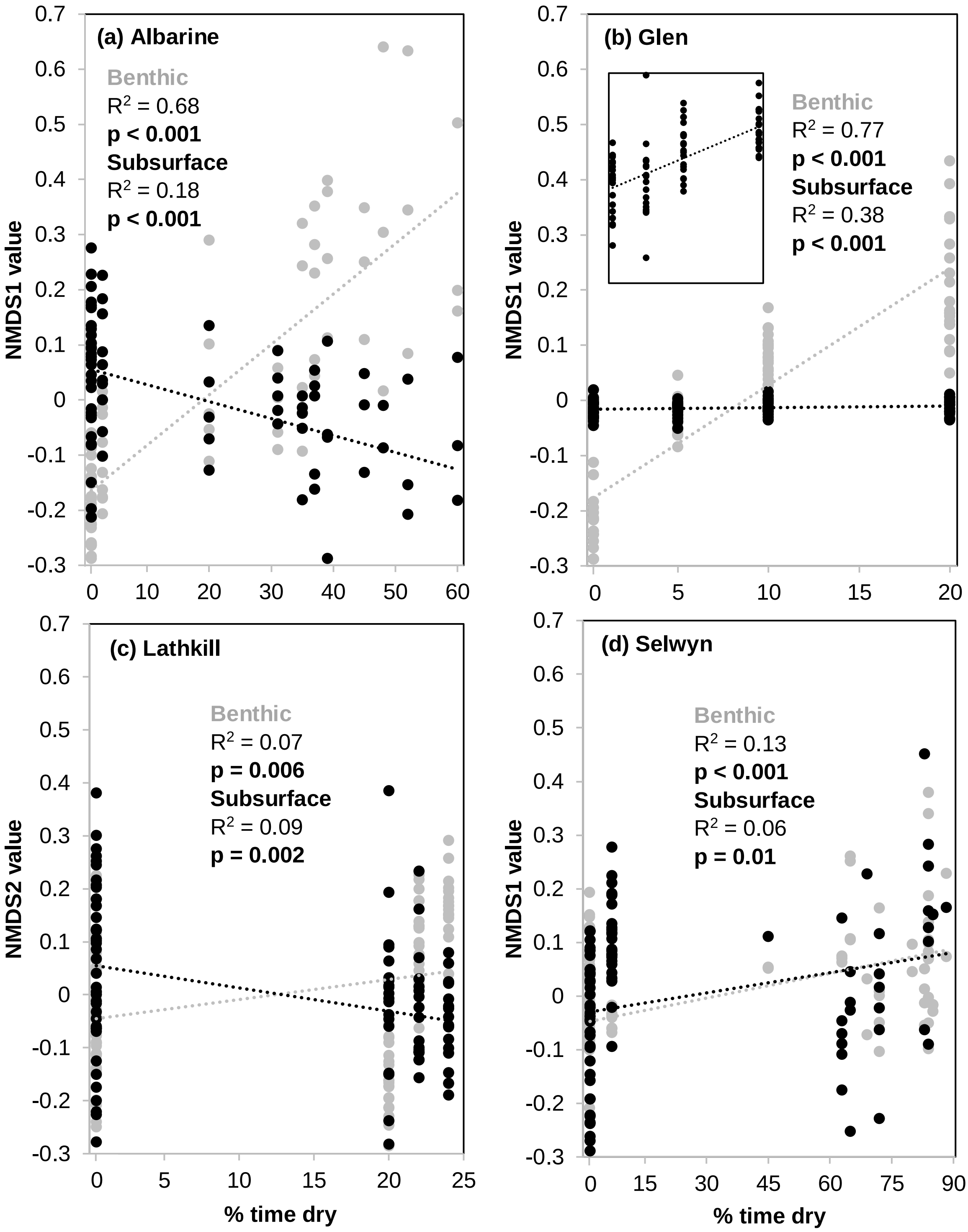

Figure A2. Non-metric multidimensional scaling dimension 1 or 2 values for subsurface (black) and benthic (grey) invertebrate communities in relation to the % of time without surface water in four rivers: the (a) Albarine; (b) Glen, with inset showing the subsurface slope between NMDS2 values of -0.05 to 0.02; (c) Lathkill; (d) Selwyn. Strength and significance of relationships are described by adjusted R^2 and p values, respectively. Slope direction should not be considered.

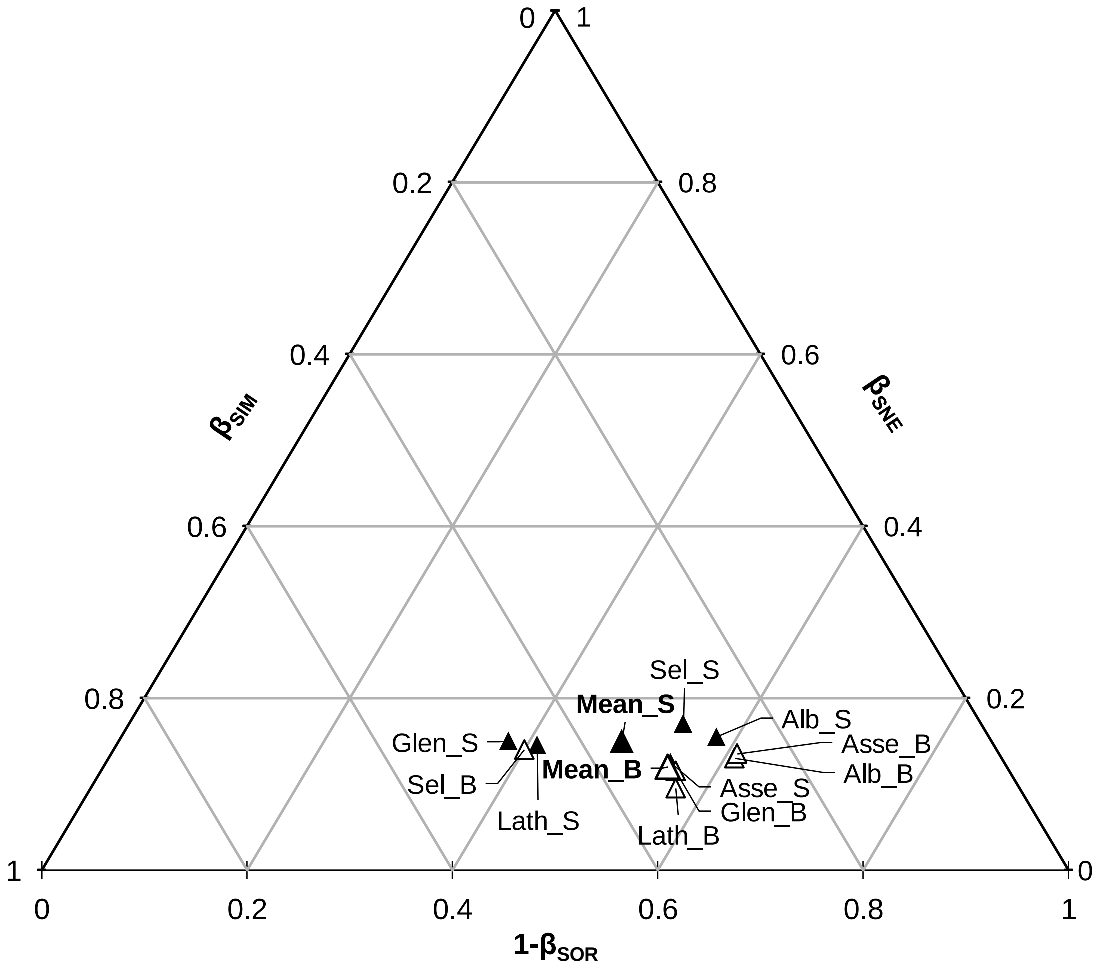

Figure A3. Benthic (B, white-filled symbols) and subsurface (S, black symbols) invertebrate community β-diversity in the rivers Albarine, Asse, Glen, Lathkill and Selwyn, and mean values, calculated using incidence-based 1-the Sørensen index ($1\text{-}\beta_{SOR}$) and its turnover (β_{SIM}) and nestedness (β_{SNE}) components. See Table A6 for significance values.

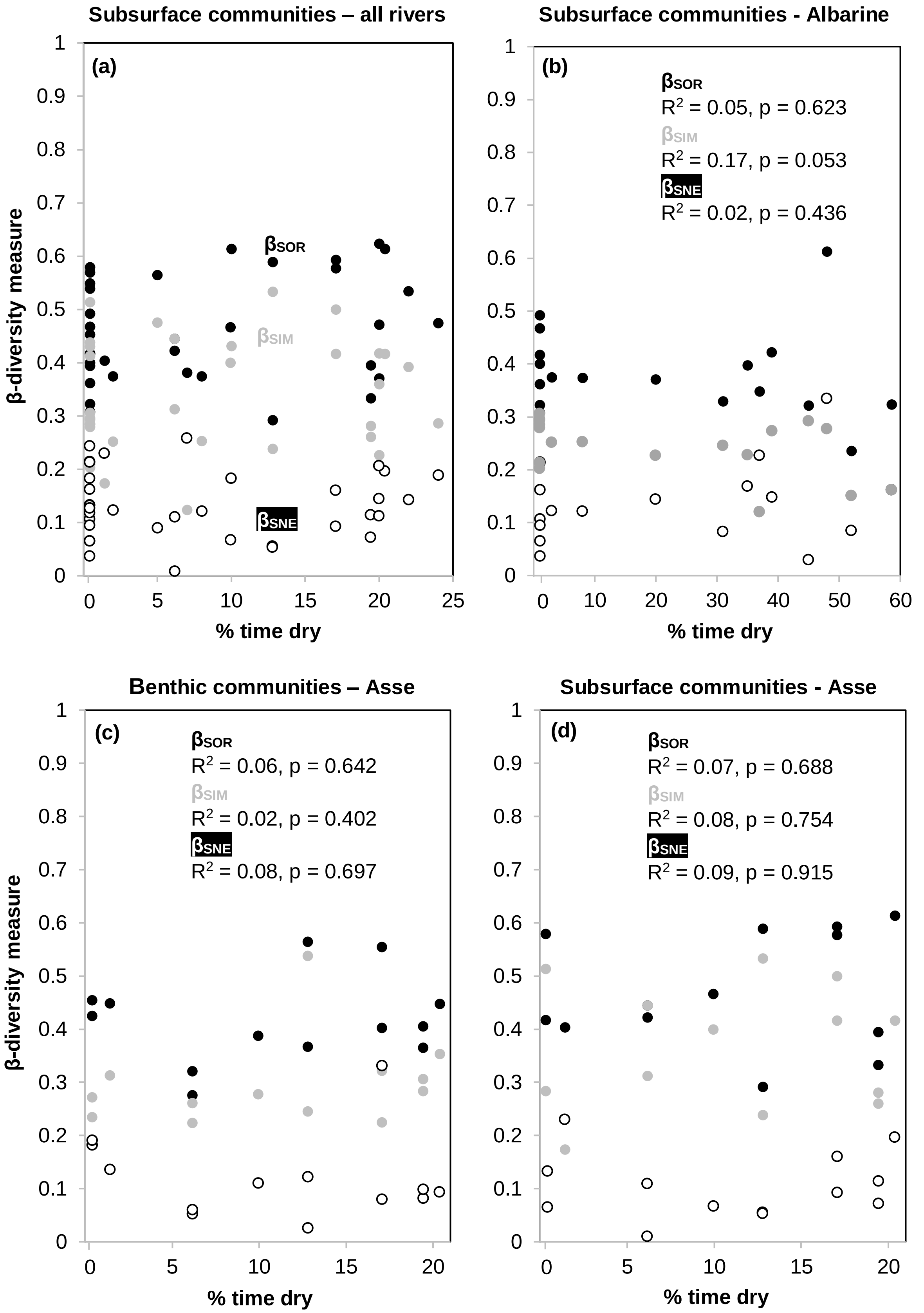

Figure A4. Beta diversity in relation to the % of time without surface water, for invertebrate communities on five rivers, based on the Sørensen index (β_{SOR}, black) and its turnover (β_{SIM}, grey) and nestedness (β_{SNE}, white-filled) components: subsurface communities (a) at sites with 0-25% drying durations across all rivers, (b) in the Albarine and (c) in the Asse; and benthic communities (d) in the Asse. Significant relationships for benthic communities on all rivers and the Albarine are shown in Fig. 3. Fig. A4 spans pages 16-17.

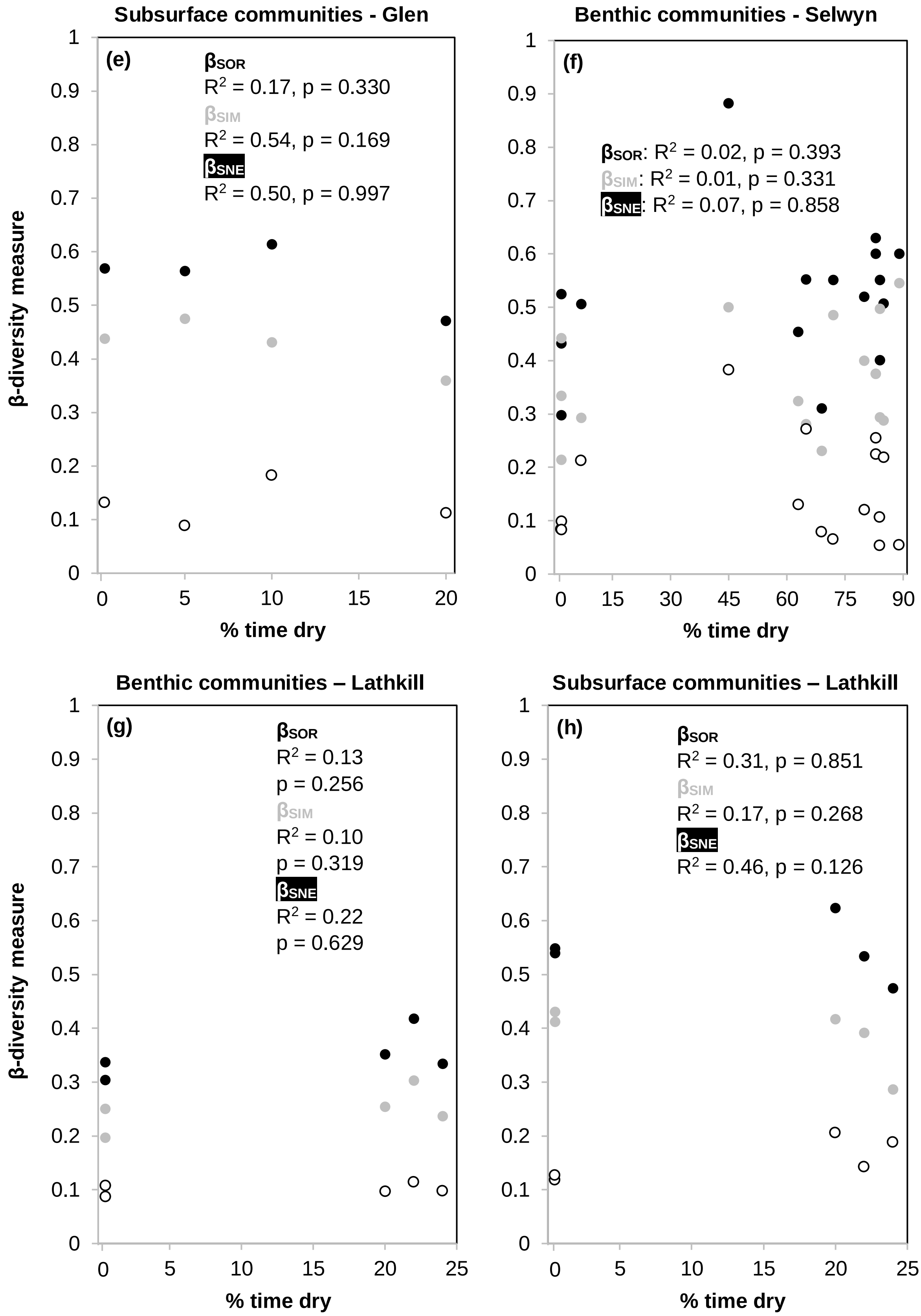

Figure A4 continued. Beta-diversity in relation to the % of time without surface water, for invertebrate communities on five rivers, based on the Sørensen index (β_{SOR}, black) and its turnover (β_{SIM}, grey) and nestedness (β_{SNE}, white-filled) components: subsurface communities in the Glen (e); benthic communities in the Selwyn (f); and benthic (g) and subsurface (h) communities in the Lathkill. Significant relationships for benthic communities in the Glen and subsurface communities in the Selwyn are shown in Fig. 3. Fig. A4 spans pages 16-17.

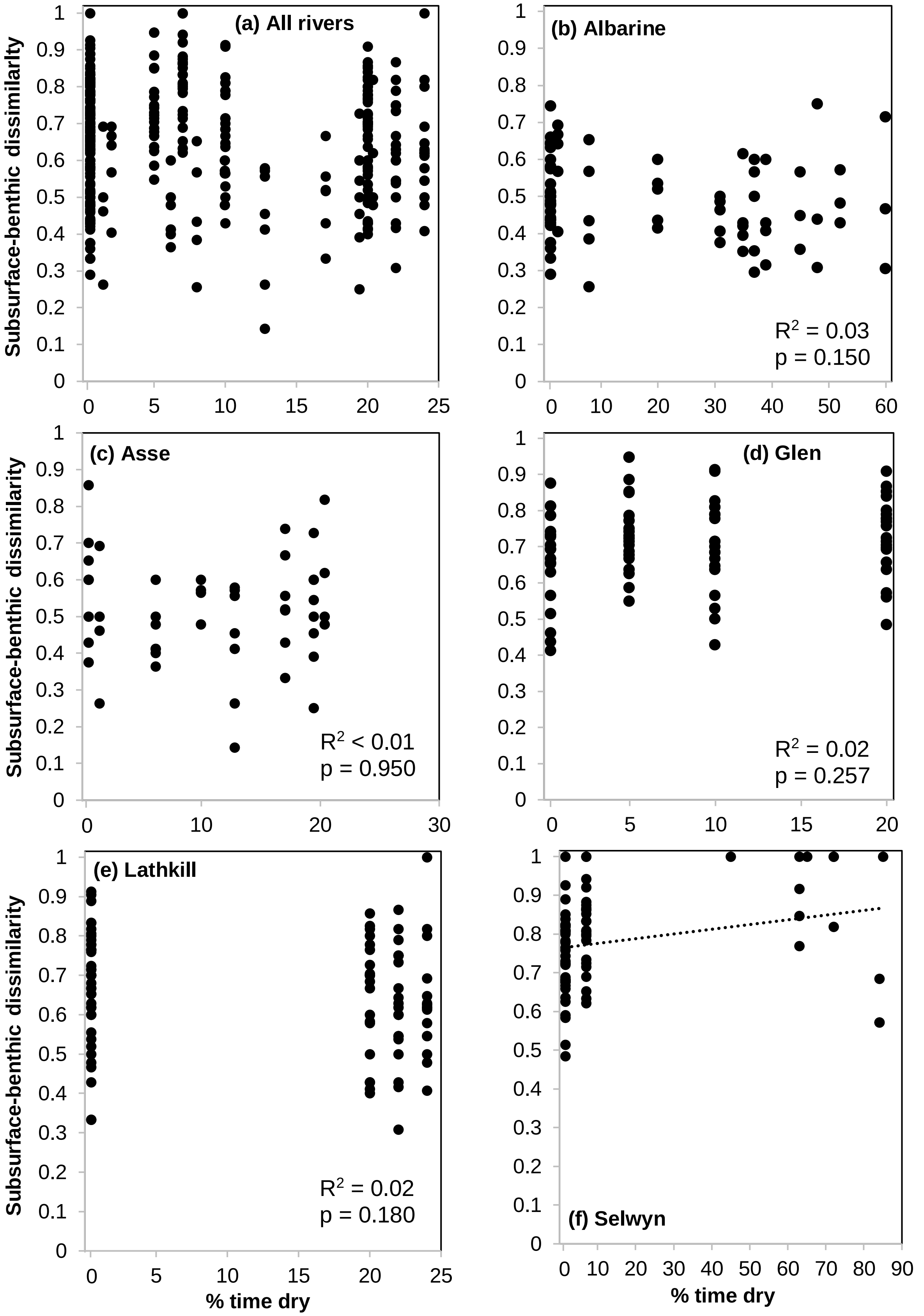

Figure A5. Dissimilarity (as Sørensen distances) between subsurface and benthic invertebrate communities in relation to the % of time without surface water: (a) at sites with 0-25% drying durations across all rivers; and in the (b) Albarine; (c) Asse; (d) Glen; (e) Lathkill; (f) Selwyn. Strength and significance of relationships are described by adjusted R^2 and p values, respectively, for panes (b) to (e). Relationships identified using linear mixed-effects models are described in the text for (a) and (f).

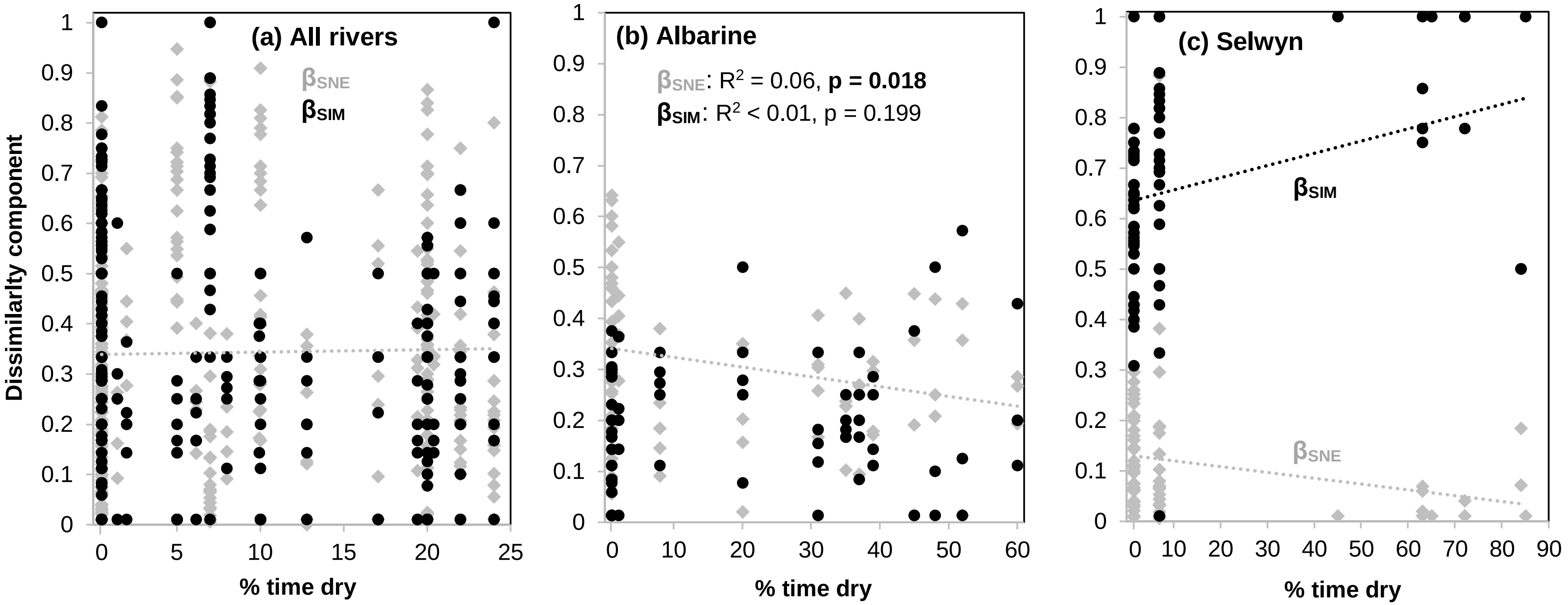

Figure A6. The contribution of the nestedness-resultant (β_{SNE}, grey diamonds) and turnover (β_{SIM}, black circles) components to total Sørensen dissimilarity between subsurface and benthic invertebrate communities, in relation to the % of time without surface water: (a) at sites with 0-25% drying durations across all rivers, and in the (b) Albarine and (c) Selwyn. Adjusted R^2 and p values indicate relationship strength and significance, respectively, for (b). Relationships identified using linear mixed-effects models are described in the text for (a) and (c). Total subsurface-benthic dissimilarity is presented in Fig. A5.

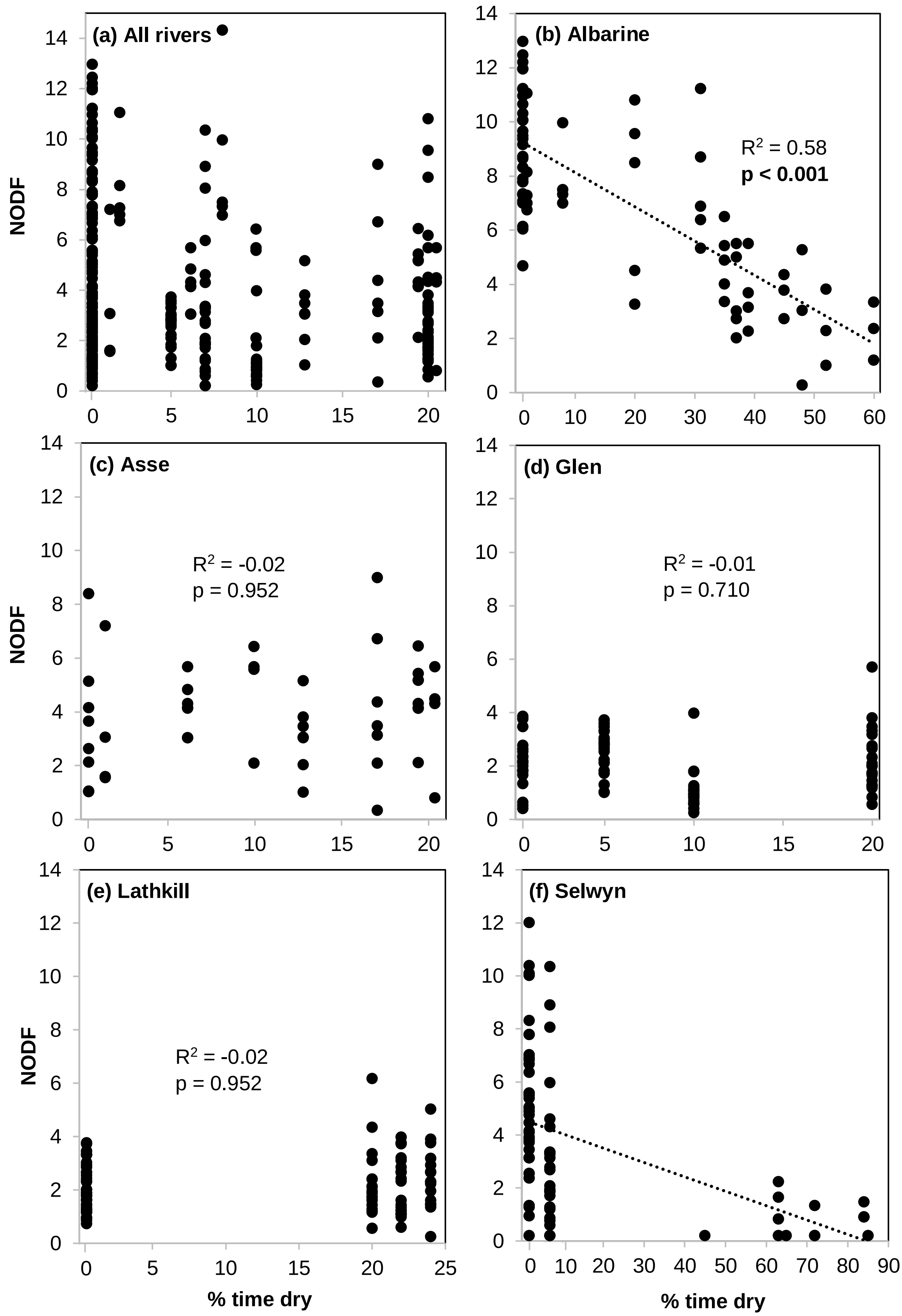

Figure A7. True nestedness (as NODF; Nestedness metric based on Overlap and Decreasing Fill; Almeida-Neto et al. 2008; see page 4) between subsurface and benthic communities in relation to the % time without surface water: (a) at sites with 0-25% time dry across all rivers; and in the (b) Albarine; (c) Asse; (d) Glen; (e) Lathkill; (f) Selwyn. Adjusted R^2 and p values show relationship strength and significance, respectively, for (b) to (e). Relationships identified using linear mixed-effects models are described in the text for (a) and (f).

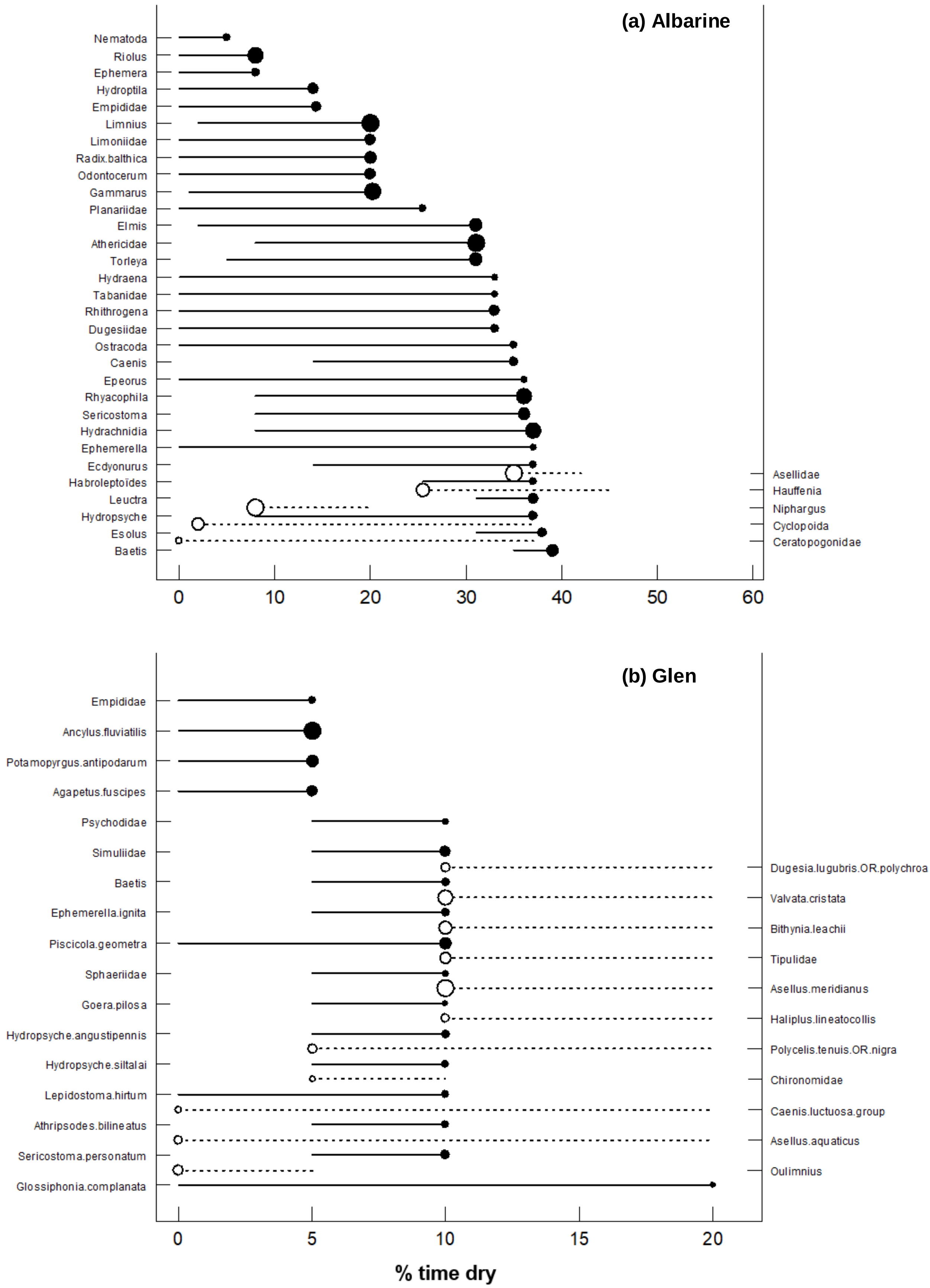

Figure A8. Title and legend provided over the page.

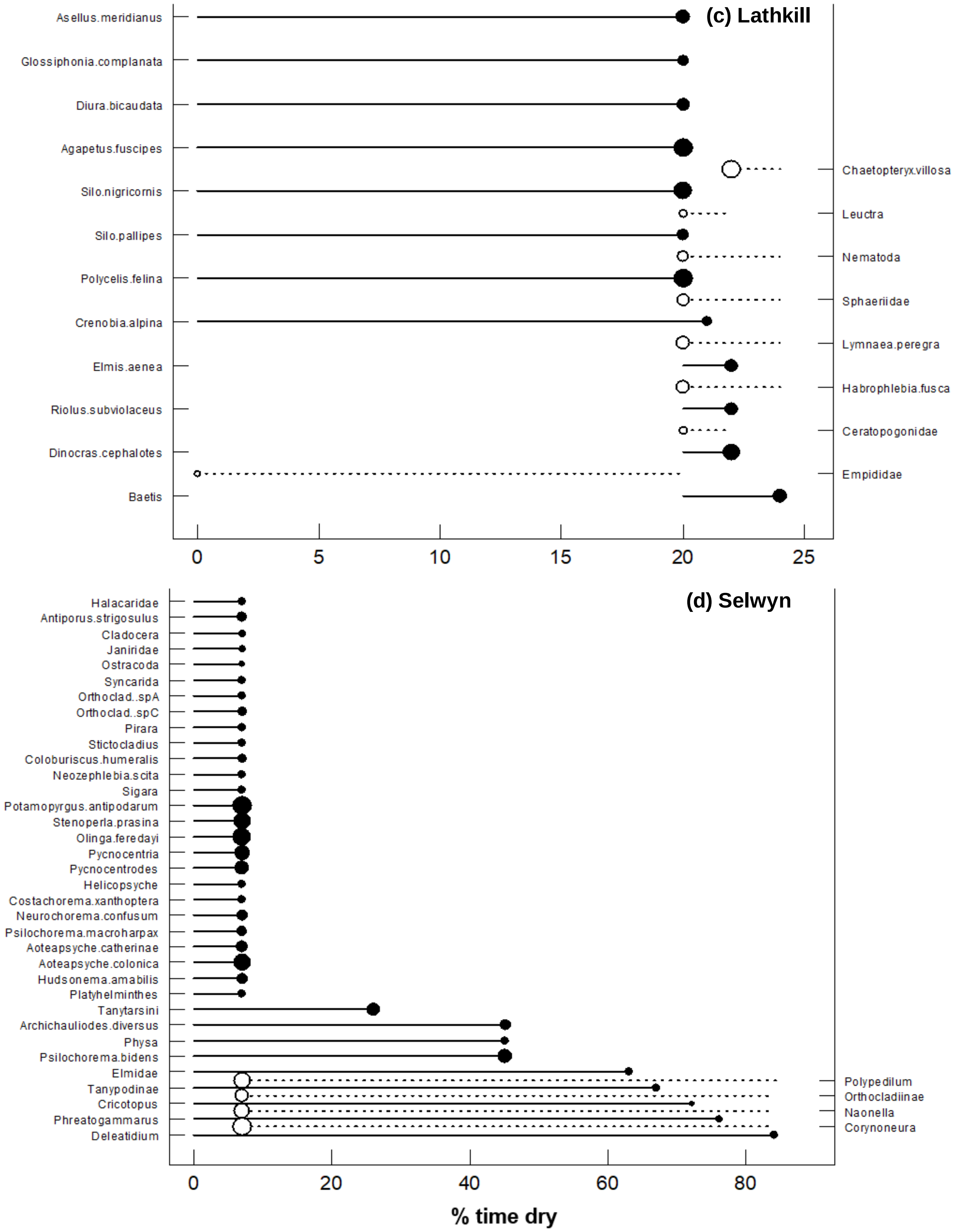

Figure A8. Threshold Indicator Taxa ANalysis (TITAN) plot of taxa whose benthic occurrence decreased (black circles, y axis 1) or increased (white-filled circles, y axis 2) in response to the % of time without surface water in four rivers: (a) the Albarine; (b) the Glen; (c) the Lathkill; (d) the Selwyn (note that no benthic taxa responded significantly to % time dry in the Asse). Circle size indicates IndVal scores rescaled as *z* scores i.e. the relative magnitude of change in a taxon's frequency of occurrence. See Table 1 for river-specific % time dry details, e.g. a threshold of 0% indicates responses at sites with 2%, 5%, 7% and 20% time dry on the Albarine, Glen, Selwyn and Lathkill, respectively.