Repubblica e Cantone Ticino
Dipartimento del territorio

Results from the participation of Switzerland to the International Cooperative Programme on Assessment and Monitoring Effects of Air Pollution on Rivers and Lakes (ICP Waters)

Annual report 2017

Ufficio dell'aria, del clima e delle energie rinnovabili
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Content

Executive Summary

The Convention on Long-Range Transboundary Air Pollution (CLRTAP) of the UN Economic Commission for Europe (UNECE) was concluded in Geneva in 1979 and entered into force in 1983. It comprises eight protocols on the reduction of specific air pollutants. Switzerland has ratified all the protocols, and is actively involved in a variety of CLRTAP bodies. In addition to its Executive Body, the CLRTAP operates in three main working groups and programmes in which Switzerland is actively involved: Working Group on Strategies & Review, European Monitoring & Evaluation Programme (EMEP), Working Group on Effects (WGE). The WGE promotes international cooperation on research into, and the monitoring of, the impacts of air pollutants on human health and the environment. This scientific activities are carried out by six international cooperation programmes (ICPs) plus a working group focusing on health-related impacts of air pollution (Task Force on Health). The effects of cross-border air pollution on aquatic ecosystems are studied by the International Cooperative Programme on Assessment and Monitoring Effects of Air Pollution on Rivers and Lakes (ICP Waters). In Switzerland, because of the abundance of crystalline bedrock many surface waters in northern Canton Ticino are sensitive to acidification. The same region is highly affected by long-range transport of atmospheric pollutants originating from the plain of the River Po, in Italy, one of the most urbanized and industrialized areas of Europe. Therefore, mainly chemical but also biological parameters of mountain lakes and high-altitude stretches of rivers and streams in this area are examined. These investigations are carried out by the Office for Air, Climate and Renewable Energies of the Canton of Ticino on behalf of the Federal Office for the Environment (FOEN) and under the umbrella of ICP Waters. Results of these investigations are reported to the ICP Waters programme center and regularly published in yearly reports.

During 2017 precipitations in southern Switzerland were slightly below the norm values (1981-2010). Particularly low were precipitations in winter (2016/2017) and in October.

Significant time trends were observed for rainwater concentrations of sulphate, nitrate and ammonia as well as for acidifying and eutrophying deposition. As a consequence of reduced SO_2 emissions, sulphate concentrations and depositions decreased significantly at all sites particularly before 2000. Since 1990, annual mean sulphate concentrations decreased from around 75 meq m^{-3} (Locarno Monti and Lugano) to below 20 meq m^{-3} at all sites and sulphate depositions from 110 meq m^{-2} to below 30 meq m^{-2}. After 2000, concentrations and depositions of nitrate also decreased significantly at most sites (7 out of 9 for concentrations and 4 out of 9 for depositions). This can mainly be attributed to the reduction of NO_x emissions. During the last 5 years (2013-2017) annual mean nitrate concentrations ranged from 18 to 36 meq m^{-3} and annual mean nitrate depositions from 22 to 66 meq m^{-2}. Concentrations and depositions of ammonium also slightly decreased at some sites after 2000 (concentrations of 4 out 9 and depositions of 1 out of 9 sites).

Consequently, annual mean concentrations and depositions of acidity decreased significantly at all sites from values around 30-40 meq/m^3 and 60 meq/m^2, respectively to values around -15 meq/m^3 and -25 meq/m^2 on average over the last 30 years. Accordingly, yearly mean pH increased from values around 4.3 in the 1990's to values ranging between 5.3 and 5.7 today.

In agreement with trends of rainwater concentrations and depositions from the 1980's until present, concentrations of sulphate and nitrate decreased in most lakes, leading to an increase of alkalinity and pH. While concentrations of sulphate decreased at almost constant rates since the 1980's, concentration of nitrate decreased at higher rates after 2000. Lake water concentrations of aluminum also decreased, especially after 2005, in the most acidic lakes (pH < 6) Lago Tomé (from 40 μg l^{-1} to 20 μg l^{-1}), Lago del Starlaresc da Sgiof (from 80-100 μg l^{-1} to 30-70 μg l^{-1}) and Laghetto Gardiscio (from 30-60 to 20-30 μg l^{-1}).

The comparison of the autumn water chemistry of 47 lakes sampled in 2017 and during the last large scale assessment in 1995, shows similar result as described above. Concentrations of sulphate decreased in 85% and nitrate in 96% of the lakes. Concentrations of base cations increased in 72%, total alkalinity in 96% and pH in 98% of the lakes. In particular, in 1995 36% and 28% of the lakes had autumn alkalinities below 20 µeq/l and pH's below 6, respectively while in 2017 the percentages decreased to 20% for alkalinity and 9% for pH.

Because of the unusual low precipitation volumes, river water concentrations of sulphate, base cations, silica, alkalinity and pH measured in autumn 2017 were slightly higher and concentrations of nitrate slightly lower compared to the values of the most recent years. Apart from that, concentrations of sulphate, base cations, alkalinity and silica were usually lower during the snowmelt period from March to June and higher during the other months, while the opposite was observed for concentrations of nitrate.

River chemistry also responded to emission reductions of sulphur and nitrogen. The time trend analysis revealed that from 2000 to 2017 concentrations of nitrate decreased significantly in all three rivers, while the decrease of sulphate and the increase of alkalinity was significant in the two less alkaline rivers Vedeggio and Verzasca.

Since the ultimate goal of emission control programmes is biological recovery (e.g. the return of acid sensitive species that have disappeared) and the restoration of biological functions that have been impaired during the course of acidification, macroinvertebrates as bioindicators have been studied in four lakes and a river.

In the four monitored lakes, the macroinvertebrate population changed with lake pH and aluminum concentrations. Numbers of total, EPT (Ephemeroptera, Plecoptera, Trichoptera), acid sensitive and chironomid taxa were lower at sites with higher aluminum concentrations. The same rank order was observed for the relative abundance of acid sensitive taxa. As regards temporal changes, almost no trend can be observed. The only early sign of recovery seems to be the reappearance of *Crenobia alpina* in Lago di Tomè after 2006.

On the scale of Braukmann and Biss (2004) developed for river ecosystems, the composition of macroinvertebrates of the river Verzasca was classified as acidification class 2 on a scale from 5 (not acidified) to 1 (severly acidified). This corresponds to predominantly neutral to episodically weakly acidic waters with pH's normally around 6.5-7.0, reflecting well the measured water chemistry. However, since the beginning of monitoring in 2000, no temporal changes could be observed.

Overall, despite the significant decrease in deposition of acidifying pollutants and the significant increase of alkalinity in most lakes and rivers, the most sensitive surface waters did still not completely recover. A further decrease in emissions, especially for nitrogen oxides and ammonia is needed.

Riassunto

La Convenzione sull'inquinamento atmosferico a lunga distanza (CLRTAP) della Commissione economica per l'Europa delle Nazioni Unite (UNECE) è stata stipulata a Ginevra nel 1979 ed è entrata in vigore nel 1983. Comprende otto protocolli concernenti la riduzione di specifici inquinanti atmosferici. La Svizzera ha ratificato tutti i protocolli e partecipa in modo attivo in diversi gremi della CLRTAP. Oltre all'organo esecutivo la CLRTAP opera in 3 principali gremi: Working Group on Strategies & Review, European Monitoring & Evaluation Programme (EMEP), Working Group on Effects (WGE). Il gruppo di lavoro WGE promuove la collaborazione internazionale nell'ambito della ricerca e della sorveglianza degli effetti degli inquinanti atmosferici sulla salute umana e sull'ambiente. Questi lavori scientifici sono svolti attraverso sei Programmi cooperativi internazionali (ICP) nonché un gruppo di lavoro che indaga sugli effetti degli inquinanti sulla salute (Task Force on Health). Gli effetti dell'inquinamento atmosferico transfrontaliero sugli ecosistemi acquatici sono studiati dal Programma di valutazione e osservazione degli effetti dell' inquinamento atmosferico su fiumi e laghi (ICP Waters). In Svizzera, a causa della geologia prevalentemente cristallina, molte acque superficiali nel nord del Canton Ticino sono sensibili all'acidificazione. Siccome la stessa zona è influenzata fortemente dal trasporto a lunga distanza di inquinanti atmosferici provenienti dalla Pianura Padana, una delle zone maggiormente urbanizzate in Europa, l'Ufficio dell'Aria, del Clima e delle Energie Rinnovabili del Canton Ticino monitora regolarmente la chimica, ma anche parametri biologici di laghi alpini e tratti di fiumi ad alta quota su incarico dell'Ufficio Federale per l'Ambiente (UFAm) nell'ambito dell'ICP Waters. I risultati di questo monitoraggio sono regolarmente pubblicati in rapporti annuali.

Nel 2017 le precipitazioni in Ticino sono state leggermente inferiori ai valori norma (media 1981-2010). Particolarmente asciutti sono stati i mesi invernali (2016/2017) e ottobre.

Trend temporali significativi sono stati osservati per le concentrazioni di ioni nelle precipitazioni e per le deposizioni. Grazie alla riduzione delle emissioni di SO_2, le concentrazioni e le deposizioni di solfato sono diminuite in modo significativo in tutti i punti di prelievo in particolare prima del 2000. Dal 1990, le concentrazioni medie annue sono diminuite da circa 75 meq m^{-3} (Locarno Monti and Lugano) a valori inferiori a 20 meq m^{-3} in tutte le stazioni di campionamento e le deposizioni da 110 meq m^{-2} a valori inferiori a 30 meq m^{-2}. A causa della diminuzione delle emissioni di NO_x, dopo il 2000 le concentrazioni e le deposizioni di nitrato sono diminuite significativamente quasi ovunque (7 stazioni su 9 per le concentrazioni e 4 stazioni su 9 per le deposizioni). Durante gli ultimi 5 anni (2013-2017) le concentrazioni medie annue variavano da un minimo di 18 a un massimo di 36 meq m^{-3} e le deposizioni da un minimo di 22 a un massimo di 66 meq m^{-2}. Le concentrazioni e le deposizioni di ammonio sono anche diminuite leggermente in alcuni punti dopo il 2000 (4 stazioni su 9 per le concentrazioni e 1 stazione su 9 per le deposizioni). Conseguentemente, le concentrazioni e le deposizioni di acidità sono diminuite in modo significativo in tutti i punti di monitoraggio da valori medi annui di 30-40 meq m^{-3} rispettivamente 60 meq m^{-2}, a -15 meq/m^3 e -25 meq/m^2 in media. Analogamente il pH è aumentato da valori medi annui attorno il 4.3 negli anni 1990 a valori che oggi variano tra 5.3 e 5.7.

Similmente ai trend delle concentrazioni nelle precipitazioni e delle deposizioni atmosferiche, dagli anni 1980's ad oggi, le concentrazioni di solfato e nitrato sono diminuite in quasi tutti i laghi, causando un aumento dell'alcalinità e del pH. A differenza delle concentrazioni di solfato, che sono diminuite in pressoché ugual misura durante i 2 periodo temporali analizzati (1980's-2015 and 2000-2016), le concentrazioni di nitrato sono diminuite soprattutto dopo il 2000. Anche le concentrazioni di alluminio disciolto sono diminuite in modo significativo nei laghi maggiormente acidi (pH < 6): dopo il 2005 nel Lago di Tomé da valori medi annui di 40 a 20 $\mu g\ l^{-1}$ e nel Starlaresc da Sgiof da 80-100 $\mu g\ l^{-1}$ a 30-70 $\mu g\ l^{-1}$ e dopo il 2012 nel Laghetto Gardiscio da circa 30-60 a 20-30 $\mu g\ l^{-1}$.

Il confronto della chimica autunnale di 47 laghi campionati nel 2017 e durante l'ultimo campionamento a larga scala nel 1995 mostrano risultati simili a quelli descritti sopra. Le concentrazioni di solfato sono diminuite nell' 85% dei laghi, quelle di nitrato nel 96%, dei cationi basici nel 72%, dell'alcalinità nel 96% e del pH nel 98%. In particolare, nel 1995 il 36% dei laghi aveva un alcalinità inferiore a 20 µeq/l e il 28% un pH inferiore a 6. Queste percentuali nel 2017 sono diminuite a 20% per l'alcalinità e a 9% per il pH.

Per quanto riguarda la chimica dei fiumi Maggia, Vedeggio e Verzasca, a causa delle inusuali scarse precipitazioni in autunno le concentrazioni di solfato, cationi basici alcalinità e pH sono anche state leggermente superiori e le concentrazioni di nitrato leggermente inferiori rispetto agli anni più recenti. Altrimenti le concentrazioni di solfato, cationi basici, alcalinità, silice e il pH sono stati come sempre più bassi e le concentrazioni di nitrato più alte durante il periodo dello scioglimento delle nevi da marzo a giugno.

La riduzione delle emissioni di zolfo e azoto si riflette anche nella chimica dei fiumi. L'analisi delle tendente temporali ha mostrato una diminuzione delle concentrazioni di nitrato in tutti e 3 i fiumi monitorati la diminuzione del solfato e l'aumento dell'alcalinità è stato significativo nei 2 fiumi con minore alcalinità (Vedeggio, Verzasca).

Siccome il fine ultimo delle misure per ridurre le emissioni è la ripresa della biologia, per esempio il ritorno di specie sensibili all'acidificazione precedentemente scomparsi e il ripristino delle funzioni biologiche che sono state alterate durante il processo di acidificazione, si è deciso di studiare anche i macroinvertebrati come bioindicatori in 4 laghi e 1 fiume.

Nei 4 laghi monitorati la popolazione di macroinvertebrati varia con il pH e le concentrazioni di alluminio. I numeri di taxa totale, taxa EPT (Efemerotteri, Plecotteri, Tricotteri) e taxa sensibili all'acidificazione e di chironomidi diminuiscono con l'aumentare delle concentrazioni di alluminio e con il diminuire del pH. L'abbondanza relativa di taxa sensibili all'acidificazione segue la stessa graduatoria. Per quanto riguarda l'evoluzione temporale, non si è osservato praticamente alcuna tendenza. L'unico primo segno di recupero sembra essere il ritorno di *Crenobia alpina* nel Lago di Tomè dopo il 2006.

Il monitoraggio dei macroinvertebrati nel fiume Verzasca ha permesso di assegnare quest'ultimo alla classe 2 secondo il sistema di classificazione di Braukmann and Biss (2004) sviluppato appositamente per i corsi d'acqua. Questa classe caratterizza acque prevalentemente neutre o leggermente acide con pH normalmente attorno i 6.5-7.0, riflettendo in questo modo bene la chimica normalmente misurata nel fiume Verzasca. Dall'inizio del suo monitoraggio nel 2000, non è stato possibile però osservare una tendenza temporale nella popolazione di macroinvertebrati.

Riassumendo, nonostante le concentrazioni di acidità e delle sue deposizioni sono diminuite in modo significativo nella maggior parte dei laghi e dei fiumi, le acque maggiormente sensibili all'acidificazione non si sono ancora riprese completamente. È necessario quindi diminuire ulteriormente le emissioni atmosferiche, in particolare di NO_x e NH_3.

1 Introduction

The International Cooperative Programme on Assessment and Monitoring Effects of Air Pollution on Rivers and Lakes (ICP Waters) was established under the United Nations Economic Commission for Europe's Convention on Long-Range Transboundary Air Pollution (CLRTAP) in 1985, when it was recognized that acidification of freshwater systems provided some of the earliest evidence of the damage caused by sulphur emissions. The monitoring programme is designed to assess, on a regional basis, the degree and geographical extent of the impact of atmospheric pollution, in particular acidification on surface waters. The monitoring data provide a basis for documenting effects of long-range transboundary air pollutants on aquatic chemistry and biota. An additional important programme activity is to contribute to quality control and harmonization of monitoring methods. The Programme is planned and coordinated by a Task Force under the leadership of Norway. Up to now data from about 20 countries in Europe and North America are available in the database of the Programme Centre. Switzerland joined the Programme in 2000 on behalf of the Swiss Federal Office for the Environment with the support of the Canton of Ticino.

1.1 Climatic parameters during 2017

Similarly to 2016, 2017 was characterized by high temperatures. It has been the 6^{th} warmest year in Switzerland since the beginning of measurements in 1864. Annual mean temperature was 0.8°C higher than the norm value (mean 1981-2010). In Southern Switzerland annual mean precipitations were slightly lower than average and in general they varied between 80 and 95% of the norm values. Particularly low were precipitations in winter 2016/2017. As a result the smallest snow cover since the beginning of measurements was observed. At Bosco-Gurin (1500 m a.s.l.) on average only 14 cm of snow were measured during the 3 winter months (snow height is here normally around 70 cm). During the rest of the year precipitations in Southern Switzerland were close to average, except for October which was exceptionally dry, warm and sunny. For further details see MeteoSwiss (2018).

2 Study sites

The study area is located in the southern part of the Alps in the Canton of Ticino in Switzerland. Precipitation in this region is mainly determined by warm, humid air masses originating from the Mediterranean Sea, passing over the Po Plain and colliding with the Alps. The lithology of the north-western part of the Canton of Ticino is dominated by base-poor rocks especially gneiss. As a consequence soils and freshwaters in this region are sensitive to acidification.

In order to assess the impact of long-range transboundary air pollution, monitoring of water chemistry has been conducted in 20 acid sensitive lakes and 3 rivers. In 2017, macroinvertebrates have been sampled in four lakes and a river. In addition, wet deposition has been monitored at 10 sampling sites distributed over all the Canton of Ticino. For contributing to the “ICP Waters regional acidification assessment report” (Austens et al. 2018) with a comprehensive dataset, 34 additional lakes, most of them monitored the last time during the 1990’s, were additionally sampled in autumn 2017. This report contains contributions concerning the current status of surface water acidification from thirteen European and two North American nations.

The lake’s watersheds are constituted mainly by bare rocks with vegetation often confined to small areas of Alpine meadows. The selected Alpine lakes are situated between an altitude of 1690 m and 2590 m and are characterized by intensive irradiation, a short vegetation period, a long period of ice coverage and by low nutrient concentrations. The sampling points of the selected rivers are located at lower altitudes (610-918 m). They are influenced by larger catchment areas and therefore less sensitivity toward acidification than lakes.

The geographic distribution of the sampling sites (wet deposition, rivers and lake sampling) are shown in Fig. 2.1, while their main geographic and morphometric parameters are resumed in Tab. 2.1, 2.2 and 2.3.

Figure 2.1 Sampling sites (Relief map: © Swisstopo)

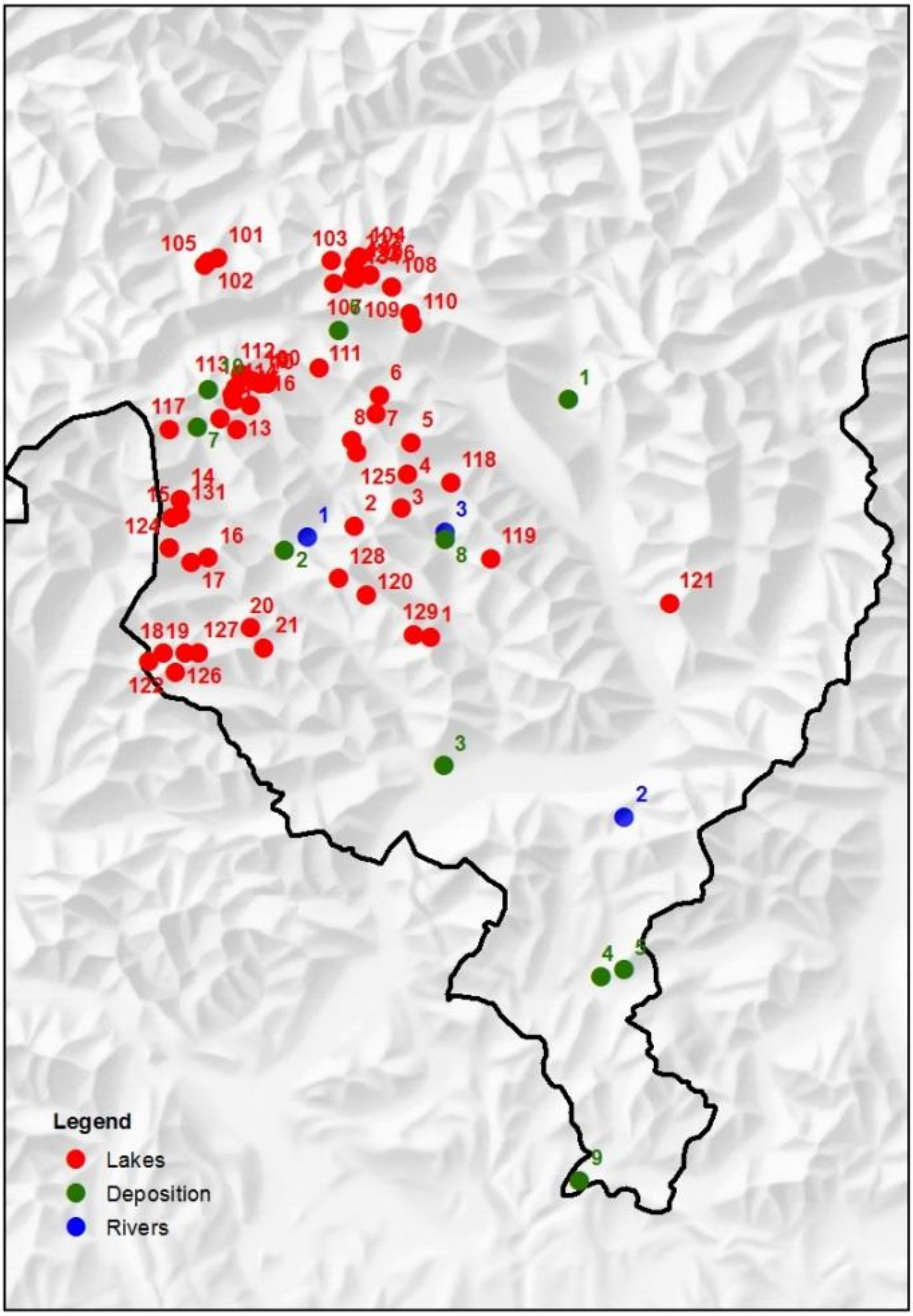


Table 2.1 Geographic and morphometric parameters of the wet deposition sampling sites

Sampling site number	Sampling site	CH1903 LV03 (m)		WGS84		Altitude
		Longitude	Latitude	Longitude	Latitude	m a.s.l.
1	Acquarossa	714998	146440	8°56'12''	46°27'41''	575
2	Bignasco	690205	132257	8°59'17''	46°00'32''	443
3	Locarno Monti	704160	114350	8°47'17''	46°10'27''	366
4	Lugano	717880	95870	8°57'18''	46°00'24''	273
5	Monte Brè	719900	96470	8°59'17''	46°00'32''	925
6	Piotta	694930	152500	8°40'35''	46°31'7''	1007
7	Robiei	682540	143984	8°30'51''	46°26'43''	1890
8	Sonogno	704250	134150	8°47'14''	46°21'05''	918
9	Stabio	716040	77970	8°55'52''	45°51'36''	353
10	Cristallina	683526	147305	8°31'34''	46°28'19''	2575

Table 2.2 Geographic and morphometric parameters of the studied rivers

River number	River name	Sampling site	CH1903 LV03 (m)		WGS84		Altitude	Catchment area
			Longitude	Latitude	Longitude	Latitude	m a.s.l	km^2
1	Maggia	Brontallo	692125	134375	8°38' 8''	46°21'16''	610	ca. 189
2	Vedeggio	Isone	719900	109800	8°59'24''	46°07'45''	740	20
3	Verzasca	Sonogno	704200	134825	8°47'33''	46°21'24'	918	ca. 27

Table 2.3 Geographic and morphometric parameters of the studied lakes

Lake number	Lake name	CH1903 LV03 (m)		WGS84		Altitude	Catchment area	Lake area	Max depth
		Longitude	Latitude	Longitude	Latitude	m a.s.l.	ha	ha	m
1	Lago del Starlaresc da Sgiof	702905	125605	8°46’25’’	46°16’26’’	1875	23	1.1	6
2	Lago di Tomè	696280	135398	8°41’23’’	46°21’47’’	1692	294	5.8	38
3	Lago dei Porchieirsc	700450	136888	8°44’39’’	46°22’33’’	2190	43	1.5	7
4	Lago Barone	700975	139813	8°45’06’’	46°24’07’’	2391	51	6.6	56
5	Laghetto Gardiscio	701275	142675	8°45’22’’	46°45’22’’	2580	12	1.1	10
6	Lago della Capannina Leit	698525	146800	8°43’17’’	46°27’55’’	2260	52	2.7	13
7	Lago di Morghirolo	698200	145175	8°43’00’’	46°27’03’’	2264	166	11.9	28
8	Lago di Mognòla	696075	142875	8°41’19’’	46°25’49’’	2003	197	5.4	11
9	Laghetto Inferiore	688627	147855	8°35’34’’	46°28’34’’	2074	182	5.6	33
10	Laghetto Superiore	688020	147835	8°35’05’’	46°28’34’’	2128	125	8.3	29
11	Lago Nero	684588	144813	8°32’22’’	46°26’58’’	2387	72	12.7	68
13	Lago della Froda	686025	143788	8°33’29’’	46°26’24’’	2363	67	2.0	17
14	Laghetto d'Antabia	681038	137675	8°29’32’’	46°23’08’’	2189	82	6.8	16
15	Lago della Crosa	680375	136050	8°28’60’’	46°22’16’’	2153	194	16.9	70
16	Lago d'Orsalìa	683513	132613	8°31’24’’	46°20’23’’	2143	41	2.6	16
17	Schwarzsee	681963	132188	8°30’11’’	46°20’10’’	2315	24	0.3	7
18	Laghi dei Pozzöi	679613	124200	8°28’17’’	46°15’52’’	1955	33	1.1	4
19	Lago di Sfille	681525	124213	8°29’46’’	46°15’52’’	1909	63	2.8	12
20	Lago di Sascòla	687175	126413	8°34’11’’	46°17’01’’	1740	90	3.2	5
21	Lago d'Alzasca	688363	124488	8°35’05’’	46°15’58’’	1855	110	10.4	40
101	Lago d'Orsino	684387	158877	8°32’22’’	46°34’33’’	2286	96	4.1	
102	Lago d'Orsirora Superiore	683450	158553	8°31’38’’	46°34’23’’	2444	26	3.9	
103	Lago di Froda	694304	158619	8°40’08’’	46°34’20’’	2446	32	0.9	
104	Lago del Piz Curnera	696720	158908	8°42’01’’	46°34’28’’	2587	35	2.3	
105	Lago della Valletta Superiore	683218	158191	8°31’27’’	46°34’11’’	2468	20	0.8	
106	Lago dello Stabbio	697627	157324	8°42’43’’	46°33’36’’	2351	28	8.1	
107	Lago di Stabbiello	694522	156589	8°40’16’’	46°33’14’’	2155	56	0.9	
108	Lago di dentro	699560	156280	8°44’13’’	46°33’01’’	2298	49	6.6	
109	Lago Pécian	701205	154023	8°45’28’’	46°31’47’’	2323	23	1.4	
110	Lago Chièra Superiore	701371	153091	8°45’35’’	46°31’18’’	2361	64	9.5	
111	Lago di Prato	693200	149250	8°39’09’’	46°29’17’’	2055	53	2.7	
112	Lago di Val Sabbia	686313	148699	8°33’46’’	46°29’03’’	2512	49	1.4	
113	Lago del Corbo	685894	147552	8°33’25’’	46°28’26’’	2348	116	2.3	
114	Lago Cristallina	685651	146884	8°33’14’’	46°28’04’’	2398	19	0.7	
115	Lago Laiozz	685767	146299	8°33’19’’	46°27’45’’	2365	110	1.5	
116	Lago della Zòta	687160	145916	8°34’24’’	46°27’32’’	2229	30	1.0	
117	Lago dei Matörgn	680115	143823	8°28’52’’	46°26’27’’	2450	90	2.5	
118	Laghetto di Chironico	704731	139197	8°48’01’’	46°23’45’’	1761	168	16.0	
119	Lago d'Efra	708248	132520	8°50’40’’	46°20’07’’	1836	96	1.8	
120	Lago Coca	697367	129325	8°42’09’’	46°18’30’’	2000	18	0.6	
121	Lago di Canee	723905	128569	9°02’49’’	46°17’50’’	2198	30	2.5	
122	Lago Gelato	678268	123460	8°27’13’’	46°15’29’’	2161	24	0.8	
123	Lago di Taneda Superiore	696127	157153	8°41’32’’	46°33’32’’	2305	13	3.9	
124	Lago di Formazzöö	680094	133423	8°28’45’’	46°20’51’’	2251	68	2.6	
125	Lago del Piatto	696509	141769	8°41’39’’	46°25’13’’	2241	31	0.5	
126	Lago della Cavegna Inferiore	680642	122505	8°29’04’’	46°14’57’’	1958	20	0.5	
127	Lago del Pèzz	682686	124272	8°30’40’’	46°15’53’’	1979	30	1.3	
128	Lago di Spluga	694948	130757	8°40’17’’	46°19’17’’	1964	28	0.4	
129	Laghetto di Pianca	701532	125847	8°45’21’’	46°16’35’’	1915	22	0.7	
130	Lago Scuro	687522	148094	8°34’42’’	46°28’42’’	2306	19	3.1	
131	Lago della Cròsa Inferiore	681050	136350	8°29’31’’	46°22’25’’	2116	200	9.4	
132	Lago di Dentro (Cadlimo)	696350	158359	8°41’44’’	46°34’10’’	2506	14	0.6	
133	Lago Scuro	696555	157612	8°41’53’’	46°33’46’’	2451	35	7.2	
134	Lago di Taneda Inferiore	696382	156996	8°41’44’’	46°33’26’’	2248	8	0.2	

3 Water chemistry analysis

3.1 Introduction

Acid deposition in acid sensitive areas can cause acidification of surface waters and soils. Because of its particular lithology (base-poor rocks especially gneiss) and high altitudes (thin soil layer and low temperatures) the buffer capacity of the north-western part of the Canton of Ticino is low. This area is therefore very sensitive to acidification. Acidification can be defined as a reduction of the acid neutralizing capacity of soils (=alkalinity) or waters. Alkalinity is the result of complex interactions between wet and dry deposition and the soil and rocks of the watershed and biologic processes. A commonly used threshold for surface water acidification for alkalinity (or ANC=acid neutralizing capacity) is 20 µeq/l, originally set based on responses of fish and invertebrate populations to acidification (Lien et al. 1996; CLRTAP 2017). In fact, critical loads of acidity for Swiss Alpine lakes have been calculated based on critical ANC values of 20 µeq/l (Posch et al. 2007). Since concentrations of soluble aluminum start to increase below a pH of ca. 6.3, it is generally assumed that first signs of changes in the biological communities due to of acidification appear, when pH drops below 6 (Wright et al. 1975).

3.2 Sampling methods

In order to monitor and assess acidification of freshwaters in acid sensitive areas of the Canton of Ticino, wet deposition at 10 sites, water chemistry of 20 Alpine lakes (54 in 2017, see Chapter 2) and 3 rivers (Maggia, Vedeggio, Verzasca) have been monitored.

Rainwater is sampled at weekly intervals with wet-only samplers. The first sampler of this type was installed at Locarno Monti in 1988. Other samplers followed in 1989 (Lugano), in 1990 (Acquarossa, Piotta, Stabio), in 1995 (Monte Brè), in 1996 (Robiei) in 2001 (Bignasco, Sonogno). The altitudes of these sites vary between 353 and 1890 m a.s.l. To evaluate the chemical composition of rainwater at higher altitudes, an additional wet deposition sampler has been installed at 2575 m (Capanna Cristallina) in 2017. Samples from this site are collected only during the summer months (May to September) and at monthly intervals.

Between the 1980’s and the 1990’s surface water of totally 62 lakes was sampled irregularly. From 2000 a subgroup of 20 acid sensitive lakes has been sampled every year: between 2000 and 2005 twice a year (once at beginning of summer, once in autumn), from 2006 three times a year (once at the beginning of summer, twice in autumn). During the extended sampling of 54 lakes in autumn of 2017 only one autumn sampling occurred. River water of the three rivers has been sampled monthly since 2000.

3.3 Analytical methods

Measured parameters, conservation methods, analytical methods and quantification limits are summarized in Tab. 3.1. The data quality was assured by participating regularly at national and international intercalibration tests. In addition, data were only considered if the calculation of the ionic balance and the comparison of the measured with the calculated conductivity corresponded to the quality requests indicated by the programme manual of ICP Waters (ICP waters Programme Centre, 2010). Furthermore, the data were checked for outliers. If available, as for metals, dissolved concentrations were compared with total concentrations.

Table 3.1 Measured parameters, conservation methods, analytical methods, accuracy and quantification limits. CA, PC, GF, PP stay for cellulose acetate, polycarbonate, glass fibre and polypropylene, respectively and ICP-OES for inductively coupled plasma atomic-emission spectroscopy.

Parameter	Filtration	Conservation	Method	Accuracy
pH	No	No	potentiometry	0.02
conductivity	No	No	Kolrausch bridge (20°C)	0.5 μS cm^{-1}
alkalinity	No	No	potentiometric Gran titration	0.001 meq l^{-1}
				Quantification limit
Ca^{2+}	CA filter	PP bottle, 4°C	ion cromatography	0.058 mg l^{-1}
Mg^{2+}	CA filter	PP bottle, 4°C	ion cromatography	0.012 mg l^{-1}
Na^{+}	CA filter	PP bottle, 4°C	ion cromatography	0.010 mg l^{-1}
K^{+}	CA filter	PP bottle, 4°C	ion cromatography	0.080 mg l^{-1}
NH_4^{+}	CA filter	PP bottle, 4°C	spectrophotometry	12 μg N l^{-1}
SO_4^{2-}	CA filter	PP bottle, 4°C	ion cromatography	0.050 mg l^{-1}
NO_3^{-}	CA filter	PP bottle, 4°C	ion cromatography	0.020 mg N l^{-1}
NO_2^{-}	CA filter	PP bottle, 4°C	spectrophotometry	6 μg N l^{-1}
Cl^{-}	CA filter	PP bottle, 4°C	ion cromatography	0.037 mg l^{-1}
soluble reactive P	CA filter	PP bottle, 4°C	spectrophotometry	11 μg P l^{-1}
total P	No	glass bottle, immediate mineralisation	persulphate digestion, spectrophotometry	11 μg P l^{-1}
soluble reactive Si	CA filter	PP bottle, 4°C	ICP-OES with ultrasonic nebulizer	0.090 mg SiO_2 l^{-1}
total N	No	glass bottle, immediate mineralisation	persulphate digestion, spectrophotometry	
DOC	PC filter	brown glass bottle, + H_3PO_4	UV-persulfate	0.2 mg C l^{-1}
soluble Al	PC filter	acid washed PP bottle, +HNO_3, 4°C	Adsorptive Stripping Voltammetry (AdSV)	1.0 μg l^{-1}
total Al	No	acid washed PP bottle, +HNO_3, 4°C	Adsorptive Stripping Voltammetry (AdSV)	1.0 μg l^{-1}
soluble Pb	PC filter	acid washed PP bottle, +HNO_3, 4°C	Adsorptive Stripping Voltammetry (AdSV)	0.1 μg l^{-1}
total Pb	No	acid washed PP bottle, +HNO_3, 4°C	Adsorptive Stripping Voltammetry (AdSV)	0.1 μg l^{-1}
soluble Cd	PC filter	acid washed PP bottle, +HNO_3, 4°C	Adsorptive Stripping Voltammetry (AdSV)	0.1 μg l^{-1}
total Cd	No	acid washed PP bottle, +HNO_3, 4°C	Adsorptive Stripping Voltammetry (AdSV)	0.1 μg l^{-1}
soluble Cu	PC filter	acid washed PP bottle, +HNO_3, 4°C	Adsorptive Stripping Voltammetry (AdSV)	0.1 μg l^{-1}
total Cu	No	acid washed PP bottle, +HNO_3, 4°C	Adsorptive Stripping Voltammetry (AdSV)	0.1 μg l^{-1}
soluble Zn	PC filter	acid washed PP bottle, +HNO_3, 4°C	Adsorptive Stripping Voltammetry (AdSV)	0.1 μg l^{-1}
total Zn	No	acid washed PP bottle, +HNO_3, 4°C	Adsorptive Stripping Voltammetry (AdSV)	0.1 μg l^{-1}
soluble Cr	PC filter	acid washed PP bottle, +HNO_3, 4°C	Adsorptive Stripping Voltammetry (AdSV)	0.1 μg l^{-1}
total Cr	No	acid washed PP bottle, +HNO_3, 4°C	Adsorptive Stripping Voltammetry (AdSV)	0.1 μg l^{-1}
soluble Ni	PC filter	acid washed PP bottle, +HNO_3, 4°C	Adsorptive Stripping Voltammetry (AdSV)	0.1 μg l^{-1}
total Ni	No	acid washed PP bottle, +HNO_3, 4°C	Adsorptive Stripping Voltammetry (AdSV)	0.1 μg l^{-1}
soluble Fe	PC filter	acid washed PP bottle, +HNO_3, 4°C	Adsorptive Stripping Voltammetry (AdSV)	1.0 μg l^{-1}
total Fe	No	acid washed PP bottle, +HNO_3, 4°C	Adsorptive Stripping Voltammetry (AdSV)	1.0 μg l^{-1}

3.4 Data handling

Monthly and yearly mean concentrations in precipitation were calculated by weighting weekly concentrations with the sampled precipitation volume, while monthly and yearly wet depositions were calculated by multiplying monthly and yearly mean concentrations with the precipitation volume measured at a meteorological sampling station close to the sampling site. This procedure has been chosen in order to avoid underestimation of monthly and yearly depositions due to occasionally missing weekly samples. In particular, for the sampling sites, data from the pluviometric stations of MeteoSwiss (Acquarossa → Comprovasco, Locarno Monti → Locarno Monti, Lugano → Lugano, Monte Brè → Lugano, Piotta → Piotta, Robiei → Robiei, Stabio → Stabio) and of the Canton of Ticino (Bignasco → Cavergno, Sonogno → Sonogno) have been chosen.

For the data analysis concentrations of calcium, magnesium, sodium and potassium were summed up and are presented as base cations.

3.5 Statistical methods used for trend analysis

Trend analyses were performed with the Mann-Kendall test to detect temporal trends in wet deposition and lake and river water chemistry. For wet depositions a seasonal Mann-Kendall test (Hirsch et al., 1982) was performed on monthly mean concentrations and depositions. For river chemistry the seasonal Mann-Kendall test was performed on monthly measurements. For both wet deposition and river chemistry a correction among block was considered (Hirsch and Slack, 1984). For lake chemistry a simple Mann-Kendall test was performed on autumn concentrations (Mann, 1945). The two sided tests for the null hypothesis that no trend is present were rejected if p-values were below 0.05.

Estimates for temporal variations of wet depositions, river and lake water chemistry were quantified with the seasonal Kendall slope estimator (Gilbert, 1987). All trend analyses were calculated with the CRAN package “rkt 1.4” (Marchetto, 2015).

3.6 Results and discussion

3.6.1 Wet deposition

Spatial variation

Annual average rainwater concentrations of the main chemical parameters and their yearly deposition rates during 2017 are shown in Tab. 3.2.

Table 3.2 Yearly mean rainwater concentrations and deposition rates in 2017

Sampling site	Precipitation (mm)	Analysed precipitation (mm)	Cond 25°C (µS cm^{-1})	pH	Ca^{2+}		Mg^{2+}		Na^{+}		K^{+}		NH_4^{+}		HCO_3^{-}		SO_4^{2-}		NO_3^{-}		Cl^{-}		Acidity	
					Concentration (meq m^{-3})	Deposition (meq m^{-2})	Concentration (meq m^{-3})	Deposition (meq m^{-2})	Concentration (meq m^{-3})	Deposition (meq m^{-2})	Concentration (meq m^{-3})	Deposition (meq m^{-2})	Concentration (meq m^{-3})	Deposition (meq m^{-2})	Concentration (meq m^{-3})	Deposition (meq m^{-2})	Concentration (meq m^{-3})	Deposition (meq m^{-2})	Concentration (meq m^{-3})	Deposition (meq m^{-2})	Concentration (meq m^{-3})	Deposition (meq m^{-2})	Concentration (meq m^{-3})	Deposition (meq m^{-2})
Acquarossa	1094	980	8	5.7	10	11	2	2	4	4	2	2	36	39	17	19	12	13	23	26	4	4	-15	-17
Bignasco	1459	1292	9	5.5	10	14	2	3	6	9	2	3	31	46	11	16	12	18	25	37	6	9	-8	-12
Locarno Monti	1672	1548	10	5.6	11	18	3	4	7	12	1	2	40	67	17	29	15	26	27	46	7	12	-15	-25
Lugano	1506	1213	10	5.6	11	17	3	4	7	10	2	3	45	67	17	25	17	25	30	45	7	10	-14	-22
Monte Brè	1506	1401	11	5.8	13	19	3	4	9	14	4	6	44	66	18	28	16	24	30	45	11	17	-17	-25
Piotta	1287	1110	9	5.5	10	13	2	2	12	16	2	3	33	42	14	19	12	15	22	28	13	16	-11	-15
Robiei	2059	1622	9	5.1	11	23	2	5	3	5	1	3	22	45	2	5	12	24	28	58	3	6	5	10
Sonogno	1772	1639	7	5.8	9	15	2	3	5	9	2	4	30	54	15	27	10	18	21	37	5	10	-14	-24
Stabio	1372	1265	12	5.5	12	16	3	4	8	11	2	3	49	68	22	31	17	23	34	46	8	11	-19	-26

In general, ion concentrations of anthropogenic origin (sulphate, nitrate, ammonia) still decrease with increasing latitude and altitude. The gradients, however, are not as pronounced as they were at the beginning of measurements. In 2017, the highest concentrations of sulphate, nitrate and ammonia were measured at Lugano and Stabio, the lowest at Robiei. The correlation with latitude and altitude reflects the influence of long-range transboundary air pollution moving along a south to north gradient from the Po plain toward the Alps and the distance from pollution sources. Because of the low concentrations of base cations and ammonium highest annual mean rainwater acidity was also measured at Robiei. In fact, concentrations of acidity can be approximated subtracting concentrations of base cations and ammonium from concentrations of acid anions.

Wet deposition of atmospheric pollutants depends on their concentration in and the amount of precipitation. Highest precipitation usually occurs in the north-western part of the Canton of Ticino. The reason for this distribution are air masses rich in humidity that move predominantly from southwest toward the southern Alps and the particular orography of the area that causes a steep raise of the air masses to higher altitudes. During 2017, highest deposition rates of ammonia, nitrate and sulphate occurred at Locarno Monti, Lugano and Monte Brè; the lowest at Acquarossa. Similarly to what observed for concentrations, highest annual mean deposition of acidity was measured at the less polluted site Robiei. At the more polluted sites depositions of base cations partially neutralized depositions of acid anions.

For the first time we can compare rainwater chemistry sampled in summer 2017 (mean May-September) at Robiei (1890 m a s l.) with samples from Cristallina (2575 m a s.l.) (see Tab. 3.3). This comparison is particularly interesting because most monitored lakes are situated between this altitude range. Concentrations of sulphate and ammonium were similar, but nitrate and calcium were significantly lower at higher altitude. Since the decrease of nitrate with altitude was more pronounced than that of calcium, acidity was also lower at Cristallina.

A detailed analysis on the spatial distribution of rainwater quality and deposition rates is foreseen in a separate report later this year.

Table 3.3 Average rainwater concentrations from April to September 2017 at Cristallina and Robiei

	pH	Cond 25°C	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	NH_4^{+}	HCO_3^{-}	SO_4^{2-}	NO_3^{-}	Cl^{-}	Acidity
		(μS cm^{-1})	(meq m^{-3})	(meq m^{-3})	(meq m^{-3})	(meq m^{-3})	(meq m^{-3})	(meq m^{-3})	(meq m^{-3})	(meq m^{-3})	(meq m^{-3})	(meq m^{-3})
Cristallina	5.6	12	9	1	2	1	27	13	11	18	2	-12
Robiei	5.1	10	14	3	3	1	24	3	13	34	3	6

Seasonal variation

Fig. 3.1 shows the amount of monthly precipitation at each sampling site during 2017 and the average values during the previous decade 2007-2016. Seasonal variations of monthly mean rainwater concentrations of the main chemical parameters are presented in Fig. 3.2.

Average monthly precipitation is normally low from December to March and higher from May to November. Highest precipitation volumes usually occur in May and November. Compared to average values, precipitation of 2017 was significantly higher in March in Nothern Ticino (Sopraceneri), in June and in August at Locarno Monti and Sonogno and significantly lower in January, July, October and November at all sites.

During 2007-2016 average sulphate concentrations were higher in summer and lower in winter. This follows the oxidation rate of SO_2 to SO_4^{2-} (highest in summer and lowest in winter) and at high altitudes also the seasonality of thermal convection (occasionally absence of vertical transport in winter).

Monthly mean concentrations of nitrate during 2007-2016 were highest in March and lowest from November to January. The nitrate peak at the end of the winter is most probably the result of the high concentrations of NO_2 in winter, the already increasing oxidation rates of NO_x to NO_3^- in spring (lowest in winter and highest in summer) and at high altitudes the absence of vertical transport of pollutants induced by thermal convection.

The seasonality of monthly mean concentrations of ammonium during 2007-2016 is very similar to that of sulphate. Hedin et al. (1990) explained this similarity with a chemical coupling between ammonia and sulphate, with acidic sulphate aerosols acting as a vehicle for long-range transport of ammonia. Seasonal variations in ammonium concentrations at sites distant from major sources of ammonia emissions thus may be influenced strongly by the supply of sulphate aerosol and by seasonal variations in emissions and oxidation of SO_2.

Average rainwater concentrations of base cations tend to be higher in spring and they are similar at all sites. In winter, variations in concentrations among the different sites are more pronounced. Acid deposition showed an opposite behaviour with the lowest monthly concentrations during spring, indicating that concentrations of base cations heavily influence the seasonality of acidity. Similarly, rainwater pH is usually higher in spring/summer.

In general, compared to the last decade, concentrations of sulphate were slightly lower, while concentrations of nitrate, ammonium and base cations were in the same range of order. Single concentration peaks can often be attributed to an increase due to small precipitation volumes. Concentrations of acidity were in general also similar to the values of the last decade, while pH was slightly higher. In fact, during 2017 only 11% of the analyzed rainwater samples had pH values below 5, while they were 15% between 2007 and 2016. Similarly, during the last year 66% and 36% of the samples had pH values higher than 5.5 and 6.0, respectively. These percentages were only 55% and 30%, respectively during 2007-2016. Only at Robiei between April and October 2017 acidity was slightly higher and pH significantly lower than average. This is not due to higher concentrations of acid anions, base cations and ammonium, but rather due to the slightly lower concentrations of calcium and ammonium and at the same time slightly higher concentrations of nitrate.

Trends of wet depositions behave in general similar to trends of concentrations, with the difference that precipitation amounts gain further importance (Fig. 3.3). Average (2006-2017) monthly depositions of sulphate, nitrate, ammonium and base cations are normally higher during the warm months when both concentrations and precipitations are highest. Average monthly deposition of acidity behaves opposite to this trend. During 2017, depositions of sulphate, nitrate, ammonium, base cations and acidity were in general similar to 2007-2016 average values.

Figure 3.1 Monthly precipitations

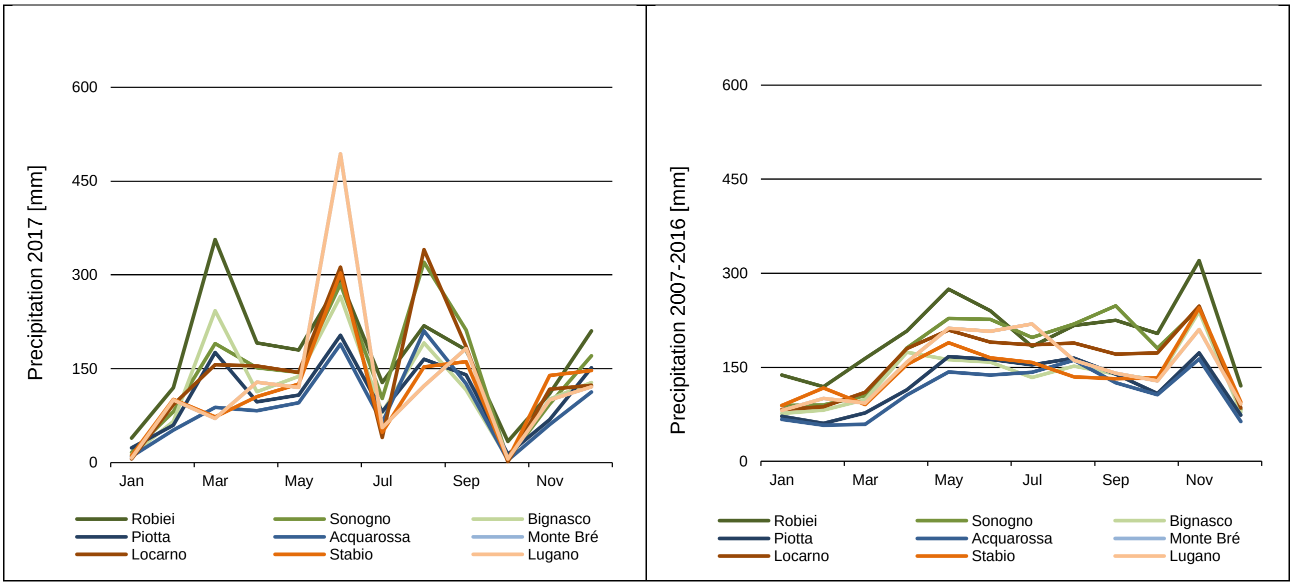
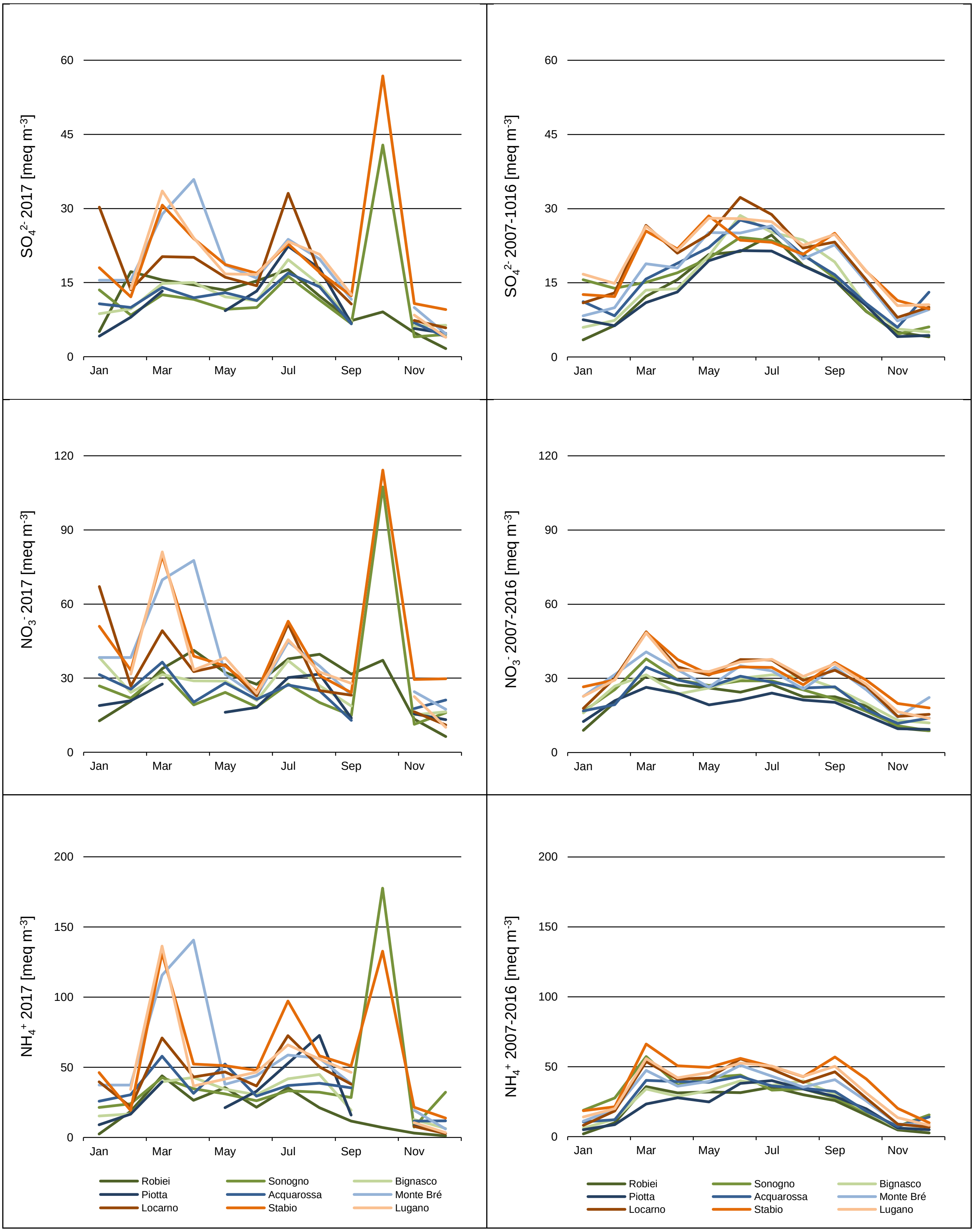
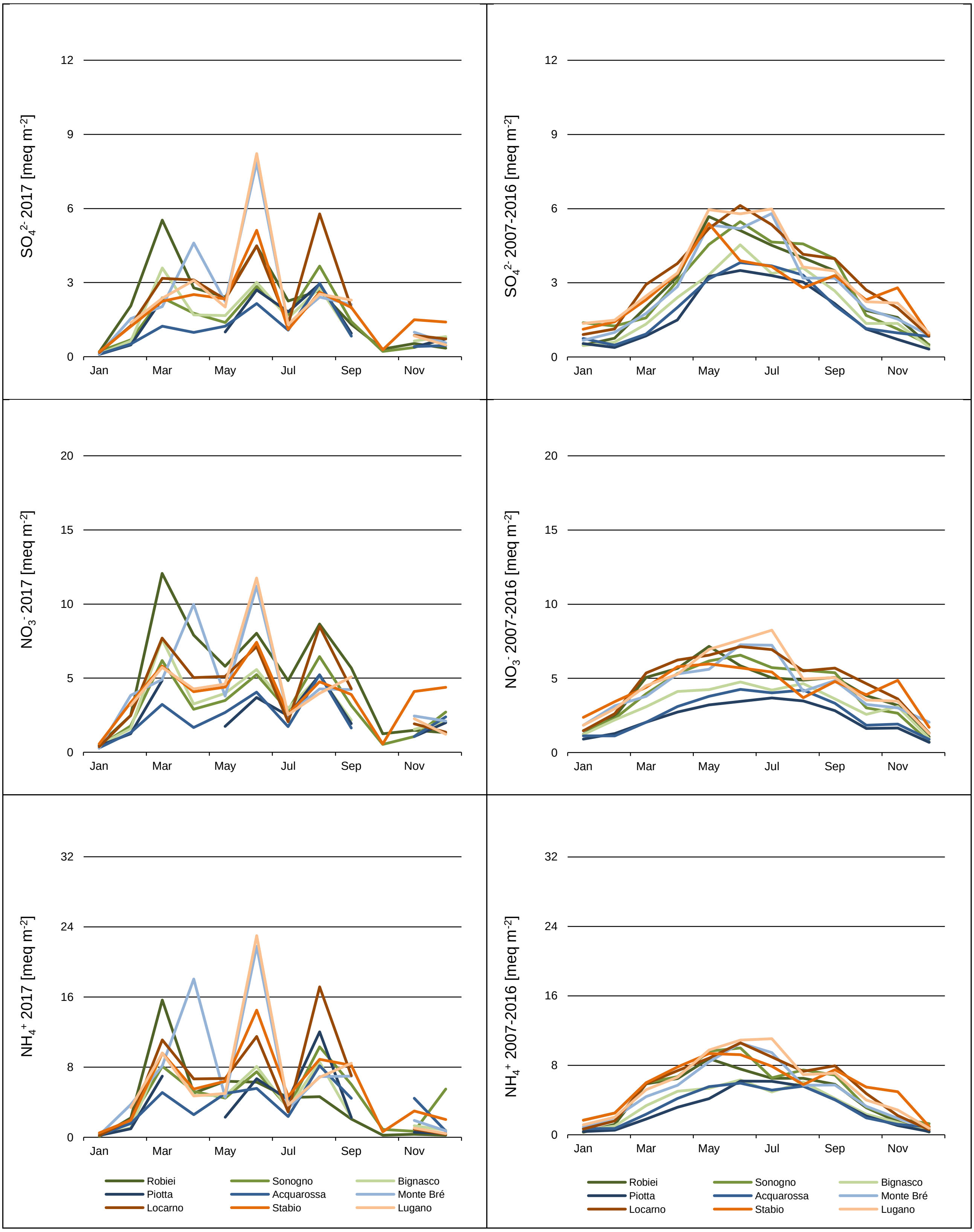


Figure 3.2 Seasonal variations of monthly average rainwater concentrations




Base cations 2017 [meq m-3]
120
90
60
30
0
Jan
Mar
May
Jul
Sep
Nov
Base cations 2007-2016 [meq m-3]
120
90
60
30
0
Jan
Mar
May
Jul
Sep
Nov
Acidity 2017 [meq m-3]
60
0
-60
-120
-180
Jan
Mar
May
Jul
Sep
Nov
Acidity 2007-2016 [meq m-3]
60
0
-60
-120
-180
Jan
Mar
May
Jul
Sep
Nov
pH 2017
7.0
6.5
6.0
5.5
5.0
4.5
Jan
Mar
May
Jul
Sep
Nov
Robiei
Piotta
Locarno
Sonogno
Acquarossa
Stabio
Bignasco
Monte Bré
Lugano
pH 2007-2016
7.0
6.5
6.0
5.5
5.0
4.5
Jan
Mar
May
Jul
Sep
Nov
Robiei
Piotta
Locarno
Sonogno
Acquarossa
Stabio
Bignasco
Monte Bré
Lugano

Figure 3.3 Seasonal variations of monthly wet deposition

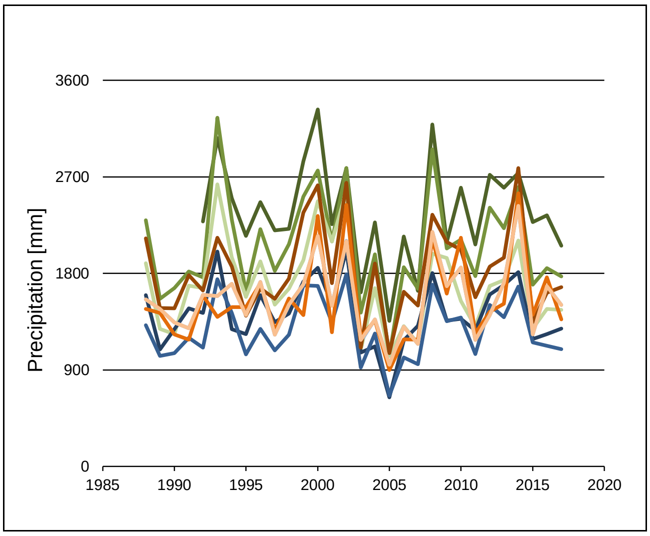



Base cations 2017 [meq m-2]
Base cations 2007-2016 [meq m-2]
Acidity 2017 [meq m-2]
Acidity 2007-2016 [meq m-2]
12
9
6
3
0
-9
-18
-27
Jan
Mar
May
Jul
Sep
Nov
Robiei
Piotta
Locarno
Sonogno
Acquarossa
Stabio
Bignasco
Monte Bré
Lugano

Temporal variations

The amount of yearly precipitations at each sampling site is presented in Fig. 3.4. Precipitations in 2017 amounted to 83-97% of the norm values (1981-2010) reported by MeteoSwiss. Variations of yearly average rainwater concentrations and depositions of the main chemical parameters since 1988 are shown in Fig. 3.5.

Figure 3.4 Yearly precipitations



Temporal trends for some of the measured parameters are immediately visible. The most pronounced trend show concentrations and depositions of sulphate with a steep decrease after 1990 at all sampling sites. This is a direct consequence of reduced SO_2 emissions. A smaller decrease can be seen for concentrations and depositions of nitrate and ammonium. Concentrations and depositions of base cations also decreased and very strong alkaline rain events did not appear anymore in the last decade.

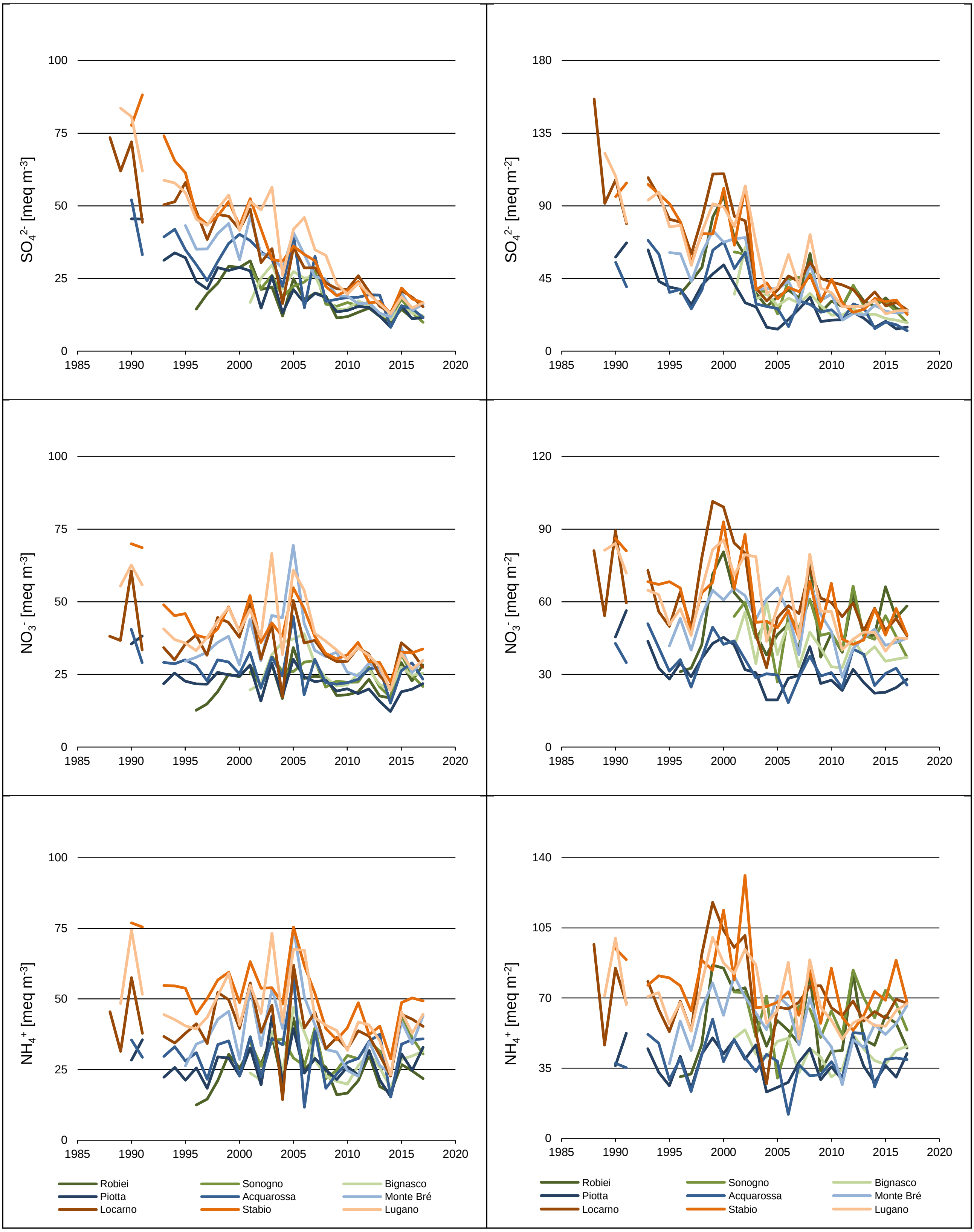
Concentrations and depositions of acidity, which can be calculated as the difference between acid anions and base cations and ammonia, decreased significantly at most sites. In general, concentrations and depositions of acidity decreased from values around 30-40 meq/m^3 and 60 meq/m^2, respectively to values around -15 meq/m^3 and -25 meq/m^2 on average over the last 30 years. Accordingly, average pH increased from values around 4.3 in the 1990's to values ranging between 5.3 and 5.7 today.

Trends of rainwater concentrations were analyzed for two different time periods: from 1988-1991 until 2000 and from 2000 until 2017 (Tab. 3.4). Since trends of depositions are "disturbed" by the precipitation volumes that vary irregularly through time, trends in depositions were calculated only for the entire monitoring period in order to level out as much as possible the influence of rainwater volume.

Sulphate concentrations decreased at all sites and changes in concentrations were higher before 2000, except for Acquarossa. In contrast, nitrate and ammonium started to decrease significantly only after 2000 (7 out of 9 for nitrate and 4 out of 9 for ammonium). Before 2000 a significant decrease could only be observed at Stabio. Because of the decrease in sulphate and nitrate concentrations, concentrations of hydrogen ions and total acidity decreased significantly at all sites, although the changes in concentrations were higher before 2000.

Trends in depositions are similar but less pronounced. The decrease in depositions of sulphate was significant at all sites. Depositions of nitrate decreased significantly at Acquarossa, Locarno Monti, Piotta, Stabio. Trends were smaller for concentrations and depositions of ammonium and significant only at Locarno Monti. Similar to concentrations, depositions of hydrogen ions and total acidity decreased significantly at all sites.

Figure 3.5 Temporal variations of annual mean rainwater concentrations, depositions and rainwater pH



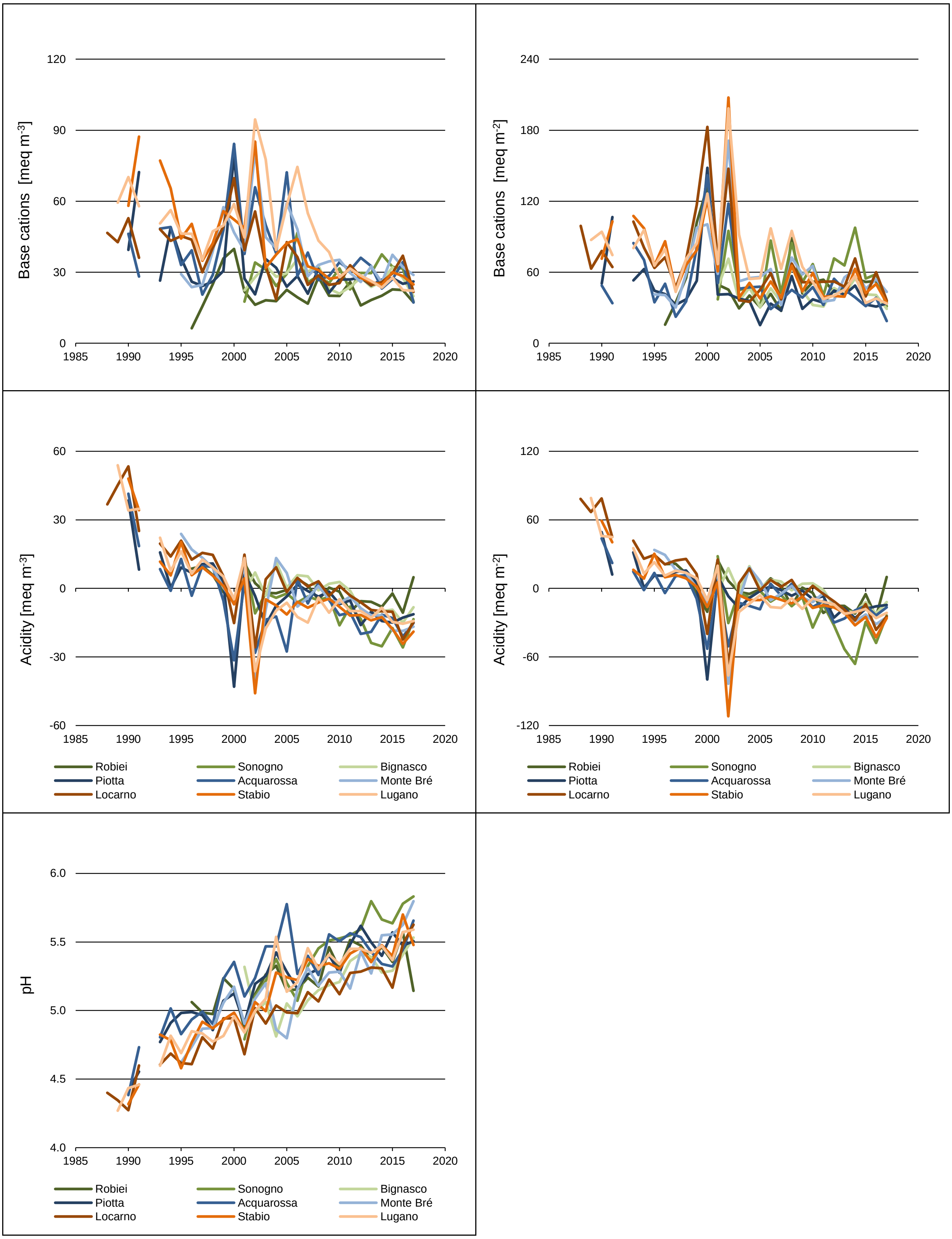

Base cations [meq m-3]
0
30
60
90
120
1985
1990
1995
2000
2005
2010
2015
2020
Base cations [meq m-2]
0
60
120
180
240
Acidity [meq m-3]
-60
-30
0
30
60
Acidity [meq m-2]
-120
-60
0
60
120
pH
4.0
4.5
5.0
5.5
6.0
Robiei
Piotta
Locarno
Sonogno
Acquarossa
Stabio
Bignasco
Monte Bré
Lugano

Table 3.4 Changes in rainwater concentrations and depositions during the indicated time periods. Red rates indicate significant trends.

CONCENTRATIONS	SO_4^{2-}		NO_3^-		NH_4^+		Cl^-		Base cations		H^+		Total acidity	
($meq\ m^{-3}\ yr^{-1}$)	'80/'90-00	'00-17	'90-00	'00-17	'90-00	'00-17	'90-00	'00-17	'90-00	'00-17	'90-00	'00-17	'90-00	'00-17
Acquarossa	-1.41	-1.52	-1.04	-0.41	-1.04	-0.17	-0.83	-0.04	-0.03	-2.03	-2.29	-0.02	-4.53	-0.11
Bignasco		-0.82		-0.58		-0.22		-0.02		-0.45		-0.49		-1.20
Monte Brè		-1.22		-0.64		-0.36		0.04		-0.42		-0.45		-1.68
Locarno Monti	-3.20	-1.45	-0.78	-1.05	-0.54	-0.68	-0.61	-0.05	-0.70	-0.72	-3.48	-0.59	-4.38	-1.40
Lugano	-2.79	-2.35	-1.22	-1.49	-0.10	-1.14	-0.70	-0.24	-0.63	-2.34	-2.85	-0.21	-4.28	-0.92
Piotta	-1.43	-0.67	-0.62	-0.53	-0.11	-0.30	-0.43	-0.05	-1.10	-0.39	-1.63	-0.25	-2.14	-0.59
Robiei		-0.76		-0.14		-0.44		0.00		-0.18		-0.21		-0.40
Sonogno		-0.63		-0.33		-0.04		0.06		-0.15		-0.27		-1.31
Stabio	-3.44	-1.70	-2.08	-0.96	-0.85	-0.75	-0.98	-0.05	-2.93	-0.83	-2.65	-0.23	-3.83	-1.27

DEPOSITIONS	SO_4^{2-}	NO_3^-	NH_4^+	Cl^-	Base cations	H^+	Total acidity
($meq\ m^{-2}\ yr^{-1}$)	beginning-17	beginning-17	beginning-17	beginning-17	beginning-17	beginning-17	beginning-17
Acquarossa	-1.22	-0.53	-0.19	-0.11	-0.65	-0.47	-1.10
Bignasco	-0.72	-0.36	0.07	0.06	-0.06	-0.45	-1.35
Monte Brè	-1.47	-0.58	-0.21	0.11	0.03	-0.79	-2.10
Locarno Monti	-2.44	-0.86	-0.44	-0.27	-0.69	-1.64	-2.71
Lugano	-2.47	-0.60	-0.18	-0.16	-0.93	-1.10	-2.39
Piotta	-0.74	-0.40	-0.11	-0.09	-0.34	-0.53	-1.02
Robiei	-1.20	-0.11	-0.30	-0.01	-0.15	-0.49	-1.01
Sonogno	-0.84	-0.31	0.08	0.12	0.22	-0.44	-2.12
Stabio	-2.53	-0.97	-0.38	-0.17	-1.08	-0.82	-2.26

3.6.2 Alpine lakes

Spatial variations

In 2017, lake sampling occurred on 3rd July, 13th September and 17th October. In July only the regularly monitored lakes (No 1-21 of Tab. 2.3) were sampled, while in autumn sampling of all lakes listed in Tab 2.3 occurred: lakes N° 1 to 131 in September and lakes N° 132 to 134 in October. Autumn concentrations of the main chemical parameters measured in lake surface water are presented in Tab. 3.5. Conductivity at 25°C varied between 5 and 38 µS cm^{-1}, total alkalinity between -3 and 282 meq m^{-3}, pH between 5.4 and 7.6, calcium between 16 and 280 meq m^{-3}, sulphate between 6 and 175 meq m^{-3}, nitrate between 1 and 34 meq m^{-3}, dissolved organic carbon between 0.3 and 2.4 mg C l^{-1}, reactive dissolved silica between 0.3 and 3.8 mg SiO_2 l^{-1} and dissolved aluminum between 3 and 69 µg l^{-1}. 20% of the samples were characterized by total alkalinities below 20 meq m^{-3} and 9% by pH's below 6.

Table 3.5 Lake surface water concentrations in autumn 2017. Values below the quantification limit were preceded with <.

Lake name	Lago del Starlaresc da Sgiof	Lago di Tomè	Lago dei Porchieirsc	Lago Barone	Laghetto Gardiscio	Lago della Capannina Leit	Lago di Morghirolo	Lago di Mognòla	Laghetto Inferiore	Laghetto Superiore	Lago Nero	Lago della Froda	Lago d'Antabia	Lago della Crosa	Lago d'Orsalia	Schwarzsee	Lago dei Pozzöi	Lago di Sfille	Lago di Sascòla	Lago d'Alzasca	Lago d'Orsino
Cond 25°C (µS cm^{-1})	6.6	7.2	20.7	8.6	7.4	28.7	14.3	18.6	9.0	8.7	16.8	14.0	12.9	7.5	10.9	10.2	8.4	8.7	7.8	15.5	7.7
pH	5.4	5.9	6.8	6.3	5.5	6.5	6.7	7.0	6.8	6.8	6.9	6.9	7.3	6.5	6.6	6.6	6.6	6.6	6.1	6.9	6.9
Total Alkalinity (meq m^{-3})	-3	9	70	18	-1	33	45	69	40	40	75	63	81	29	41	42	42	36	20	85	56
Ca^{2+} (meq m^{-3})	16	30	121	44	22	133	65	91	44	43	97	106	78	37	83	56	44	42	30	85	41
Mg^{2+} (meq m^{-3})	5	4	12	5	7	54	15	22	6	6	14	8	5	4	6	7	7	7	8	16	5
Na^{+} (meq m^{-3})	10	11	18	10	7	21	14	25	12	11	16	12	17	11	13	12	14	14	12	20	12
K^{+} (meq m^{-3})	3	3	11	4	6	14	11	12	8	8	13	7	6	4	5	6	4	3	7	11	7
NH_4^{+} (meq m^{-3})	2	1	1	1	2	2	1	1	1	1	1	1	0	1	1	1	0	1	1	2	1
SO_4^{2-} (meq m^{-3})	18	22	81	32	31	175	53	71	22	19	58	37	16	12	21	20	17	20	21	31	9
NO_3^{-} (meq m^{-3})	16	20	20	15	13	12	12	16	13	13	9	19	18	16	34	22	5	10	15	17	1
NO_2^{-}-N (µg l^{-1})	0.5	0.7	1.1	1.9	1.3	1.4	1.4	2.1	1.3	1.3	1.4	1.0	2.3	2.0	3.2	0.7	0.4	1.0	1.1	2.3	0.2
Cl^{-} (meq m^{-3})	4	3	3	3	3	3	3	3	3	3	2	4	3	2	3	3	4	4	3	4	3
SRP (µg P l^{-1})	2.5	2.2	2.0	2.0	1.7	2.0	2.0	2.1	1.7	1.7	2.6	2.6	2.3	1.3	2.0	1.2	1.8	2.2	0.0	0.0	3.6
P_{tot} (µg P l^{-1})	5.7	2.9	3.4	2.5	2.1	2.8	3.1	4.8	3.7	3.5	3.2	3.5	3.9	1.7	2.4	2.2	2.9	2.4	0.1	0.1	6.3
N_{tot} (mg N l^{-1})	0.42	0.47	0.60	0.51	0.40	0.29	0.40	0.55	0.37	0.37	0.32	0.43	0.44	0.33	0.81	0.40	0.25	0.29	0.51	0.47	0.29
DOC (mg C l^{-1})	1.3	0.6	0.5	0.5	0.3	0.5	0.5	0.8	0.8	0.9	0.5	0.6	0.8	0.5	0.6	0.6	1.0	0.8	1.0	0.7	1.2
SiO_2 (mg l^{-1})	1.6	1.7	2.7	1.3	0.9	1.9	1.8	2.8	1.3	1.3	1.7	1.3	2.4	1.5	1.6	1.9	2.1	1.9	1.8	2.5	1.2
$Al_{dissolved}$ (µg l^{-1})	68.7	24.8	3.7	3.4	25.8	7.6	7.4	7.7	7.7	7.9	2.9	6.6	11.1	3.0	6.9	8.2	19.3	15.5	27.0	7.8	14.1
Al_{tot} (µg l^{-1})	75.4	27.3	5.4	6.4	28.3	17.0	32.4	22.8	14.4	15.2	5.8	12.4	13.6	5.1	13.8	11.6	32.0	25.6	34.5	11.1	23.7
$Pb_{dissolved}$ (µg l^{-1})	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Pb_{total} (µg l^{-1})	0.2	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
$Cd_{dissolved}$ (µg l^{-1})	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cd_{total} (µg l^{-1})	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
$Cu_{dissolved}$ (µg l^{-1})	0.3	0.2	0.2	0.1	0.2	0.4	0.4	0.3	0.1	0.1	0.2	0.2	<0.1	<0.1	0.1	0.1	0.1	<0.1	0.2	0.1	0.1
Cu_{tot} (µg l^{-1})	0.4	0.2	0.2	0.1	0.3	0.4	0.4	0.4	0.2	0.2	0.2	0.2	<0.1	<0.1	0.1	0.1	0.1	<0.1	0.2	0.1	0.2
$Zn_{dissolved}$ (µg l^{-1})	2.7	1.2	0.5	0.6	1.7	1.1	0.8	0.7	0.6	0.5	0.8	0.7	0.4	0.7	0.8	0.7	0.9	0.8	1.4	0.6	0.6
Zn_{total} (µg l^{-1})	2.8	1.3	0.5	0.6	3.1	1.2	0.8	0.9	0.9	0.7	0.8	0.7	0.4	0.7	0.8	0.7	0.9	0.9	1.4	0.8	0.7
$Cr_{dissolved}$ (µg l^{-1})	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cr_{total} (µg l^{-1})	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
$Ni_{dissolved}$ (µg l^{-1})	0.2	0.1	<0.1	<0.1	1.3	5.8	0.4	0.6	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1
Ni_{total} (µg l^{-1})	0.2	0.1	<0.1	<0.1	1.3	6.0	0.5	0.6	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1
$Fe_{dissolved}$ (µg l^{-1})	11.9	<1.0	<1.0	-1.0	7.8	6.6	6.4	2.3	<1.0	<1.0	<1.0	1.2	<1.0	<1.0	<1.0	<1.0	1.4	<1.0	6.5	1.5	5.0
Fe_{total} (µg l^{-1})	14.1	1.8	<1.0	1.8	9.6	15.3	30.6	27.2	5.4	6.2	2.5	10.2	2.4	1.2	2.8	2.4	6.3	3.6	11.1	3.1	14.6

Lake name	Lago d'Orsirora Superiore	Lago di Froda	Lago del Piz Curnera	Lago della Valletta Superiore	Lago dello Stabbio	Lago di Stabbiello	Lago di dentro	Lago Pécian	Lago Chièra Superiore	Lago di Prato	Lago di Val Sabbia	Lago del Corbo	Lago Cristallina	Lago Laiozz	Lago della Zòta	Lago dei Matörgn	Laghetto di Chironico	Lago d'Efra	Lago Coca	Lago di Canee	Lago Gelato
Cond 25°C (µS cm^{-1})	5.1	23.1	25.7	7.6	25.3	25.6	38.0	34.5	23.2	23.1	26.1	15.1	7.3	5.5	7.2	15.1	16.2	9.4	9.0	12.3	10.1
pH	6.6	7.2	7.2	6.7	7.2	7.3	7.6	7.2	7.2	7.2	7.3	6.9	6.2	6.4	6.3	7.1	6.8	6.1	6.5	6.7	6.6
Total Alkalinity (meq m^{-3})	37	141	145	61	225	185	282	151	117	97	201	88	19	25	16	79	64	17	36	40	41
Ca^{2+} (meq m^{-3})	25	162	178	41	175	136	280	211	145	107	193	96	36	25	32	112	92	40	35	64	56
Mg^{2+} (meq m^{-3})	3	13	11	4	37	59	23	45	23	31	19	7	5	4	5	14	11	12	8	9	7
Na^{+} (meq m^{-3})	8	12	12	13	10	10	21	17	15	32	11	11	8	8	9	13	18	11	21	14	13
K^{+} (meq m^{-3})	2	9	14	6	15	25	23	18	10	19	11	7	6	4	4	6	9	7	5	7	4
NH_4^{+} (meq m^{-3})	1	1	0	1	1	1	1	1	1	1	0	1	0	1	1	1	2	0	2	2	0
SO_4^{2-} (meq m^{-3})	6	54	74	6	18	40	73	134	78	96	41	36	25	15	21	48	43	35	22	39	27
NO_3^{-} (meq m^{-3})	1	8	10	2	2	1	5	14	10	5	1	9	11	5	17	4	27	16	13	20	12
NO_2^{-}-N (µg l^{-1})	0.3	1.0	1.2	0.1	0.4	0.2	1.0	1.9	1.2	0.9	0.3	0.4	1.0	0.5	1.5	1.0	1.9	0.5	1.6	2.0	0.7
Cl^{-} (meq m^{-3})	2	3	2	3	3	9	2	3	3	3	3	3	2	2	2	3	4	3	4	5	4
SRP (µg P l^{-1})	1.6	2.8	1.3	3.5	0.0	3.7	1.9	0.0	0.0	3.7	0.7	1.9	3.0	1.6	1.7	3.9	0.0	0.6	0.7	0.6	1.6
P_{tot} (µg P l^{-1})	2.5	3.7	1.7	9.3	0.8	43.4	2.4	0.0	0.4	4.9	0.5	2.4	3.9	2.3	2.3	5.8	0.2	1.2	1.7	0.5	1.8
N_{tot} (µg N l^{-1})	0.14	0.27	0.57	0.26	0.24	0.83	0.59	0.36	0.51	0.25	0.09	0.47	0.28	0.29	0.39	0.25	0.49	0.32	0.31	0.39	0.31
DOC (mg C l^{-1})	0.9	0.8	0.5	1.3	1.0	2.4	0.6	0.5	0.6	0.7	0.8	0.5	0.6	0.9	0.8	0.6	0.8	0.7	0.8	0.6	0.8
SiO_2 (mg l^{-1})	0.3	1.2	0.9	1.1	0.9	0.6	0.9	1.4	1.2	3.8	1.3	1.7	1.3	1.0	1.1	1.0	2.3	1.9	3.1	1.6	1.8
$Al_{dissolved}$ (µg l^{-1})	3.9	11.9	7.0	14.8	16.4	12.4	3.6	4.9	3.8	7.1	8.8	8.3	13.8	17.8	11.7	4.9	13.5	19.9	22.7	7.8	14.2
Al_{tot} (µg l^{-1})	7.7	17.0	30.4	58.4	31.2	53.6	5.5	22.8	3.8	13.5	10.8	11.7	21.4	41.7	30.7	8.9	16.2	23.8	27.6	12.6	16.1
$Pb_{dissolved}$ (µg l^{-1})	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Pb_{total} (µg l^{-1})	<0.1	0.1	0.4	0.3	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.2	0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
$Cd_{dissolved}$ (µg l^{-1})	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cd_{total} (µg l^{-1})	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
$Cu_{dissolved}$ (µg l^{-1})	0.2	0.2	0.2	0.2	0.4	0.6	0.2	0.2	0.2	0.3	0.2	0.1	0.3	0.3	0.2	0.1	0.3	0.3	0.1	0.2	<0.1
Cu_{tot} (µg l^{-1})	0.2	0.3	0.3	0.2	0.4	0.6	0.2	0.2	0.2	0.3	0.2	0.1	0.3	0.3	0.2	0.1	0.3	0.3	0.2	0.2	0.1
$Zn_{dissolved}$ (µg l^{-1})	1.4	0.5	0.4	0.6	0.3	0.7	0.5	0.5	1.1	0.5	0.4	0.5	1.2	1.1	1.0	0.7	0.9	1.1	0.9	0.7	0.8
Zn_{total} (µg l^{-1})	1.4	0.6	0.8	1.0	0.4	2.2	0.5	0.6	1.1	0.7	0.4	0.5	1.3	1.4	1.1	0.8	1.0	1.2	1.0	0.9	0.9
$Cr_{dissolved}$ (µg l^{-1})	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cr_{total} (µg l^{-1})	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
$Ni_{dissolved}$ (µg l^{-1})	0.2	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.1	0.1	0.2	<0.1	<0.1	0.3	0.2	<0.1	0.1	0.1	0.4	<0.1	0.2	<0.1
Ni_{total} (µg l^{-1})	0.2	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	0.1	0.1	0.2	<0.1	<0.1	0.3	0.2	<0.1	0.1	0.1	0.4	<0.1	0.2	<0.1
$Fe_{dissolved}$ (µg l^{-1})	2.3	4.7	3.5	7.0	25.3	12.8	<1.0	<1.0	<1.0	1.8	12.2	1.4	<1.0	4.8	1.4	<1.0	3.1	1.6	1.6	3.3	4.3
Fe_{total} (µg l^{-1})	5.7	11.4	26.8	50.4	54.1	13.5	2.0	28.6	<1.0	19.8	19.4	4.4	4.6	30.2	9.1	10.9	5.3	3.6	2.9	6.2	5.9

Lake name	Lago di Taneda Superiore	Lago di Formazzöö	Lago del Piatto	Lago della Cavegna Inferiore	Lago del Pèzz	Lago di Spluga	Laghetto di Pianca	Lago Scuro (Naret)	Lago della Crósa Inferiore	Lago di Dentro (Cadlimo)	Lago Scuro	Lago di Taneda Inferiore
Cond 25°C ($\mu S\ cm^{-1}$)	35.7	16.1	5.6	8.1	6.2	9.1	6.7	34.1	8.5	7.6	16.6	30.1
pH	7.6	7.2	6.0	6.3	5.9	6.2	5.6	7.4	6.6	6.6	7.2	7.4
Total Alkalinity (meq m^{-3})	256	99	14	31	10	17	4	266	43	47	122	264
Ca^{2+} (meq m^{-3})	259	105	17	37	22	38	19	240	42	43	118	196
Mg^{2+} (meq m^{-3})	29	13	8	7	6	7	5	29	5	4	7	44
Na^{+} (meq m^{-3})	16	13	9	12	12	17	14	9	12	10	10	21
K^{+} (meq m^{-3})	17	5	7	4	3	5	3	17	6	5	7	21
NH_4^{+} (meq m^{-3})	1	1	1	1	1	1	1	1	1	1	1	1
SO_4^{2-} (meq m^{-3})	78	28	18	17	15	24	17	49	13	14	24	22
NO_3^{-} (meq m^{-3})	1	18	5	17	17	27	19	9	15	2	7	1
NO_2^{-}-N ($\mu g\ l^{-1}$)	0.3	1.8	0.5	0.7	1.6	0.8	1.0	1.2	1.8	0.2	1.2	0.1
Cl^{-} (meq m^{-3})	3	2	3	4	3	4	5	2	2	5	2	4
SRP (μg P l^{-1})	1.9	2.8	0.6	1.7	2.5	0.4	0.4	1.9	1.8	1.2	1.7	1.9
P_{tot} (μg P l^{-1})	2.3	3.6	0.6	2.0	2.5	0.5	1.2	2.4	2.2	3.9	2.1	2.5
N_{tot} (μg N l^{-1})	0.68	0.52	0.22	0.32	0.74	0.69	0.58	0.74	0.79	0.18	0.16	0.20
DOC (mg C l^{-1})	0.7	0.5	1.2	0.7	0.5	0.6	1.1	0.8	0.3	1.1	0.7	1.3
SiO_2 (mg l^{-1})	0.5	0.9	1.0	2.1	1.9	3.0	2.0	0.8	1.9	0.9	0.6	1.8
$Al_{dissolved}$ ($\mu g\ l^{-1}$)	3.5	12.2	22.7	14.3	14.7	12.4	56.0	30.2	12.2	19.1	3.4	11.4
Al_{tot} ($\mu g\ l^{-1}$)	4.8	30.0	46.9	19.3	19.8	13.6	65.6	36.9	16.8	35.1	6.0	50.7
$Pb_{dissolved}$ ($\mu g\ l^{-1}$)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1
Pb_{total} ($\mu g\ l^{-1}$)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	0.1	<0.1	0.4
$Cd_{dissolved}$ ($\mu g\ l^{-1}$)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cd_{total} ($\mu g\ l^{-1}$)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
$Cu_{dissolved}$ ($\mu g\ l^{-1}$)	0.1	0.1	0.5	<0.1	<0.1	<0.1	0.2	0.3	0.1	0.4	0.2	0.3
Cu_{tot} ($\mu g\ l^{-1}$)	0.1	<0.1	0.7	<0.1	<0.1	<0.1	0.1	0.4	0.2	0.4	0.2	0.3
$Zn_{dissolved}$ ($\mu g\ l^{-1}$)	0.4	0.3	1.4	0.8	0.9	1.0	1.9	0.4	0.3	0.1	0.3	0.5
Zn_{total} ($\mu g\ l^{-1}$)	0.6	0.6	1.4	0.8	1.0	1.1	2.1	0.4	0.3	0.4	0.4	0.9
$Cr_{dissolved}$ ($\mu g\ l^{-1}$)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cr_{total} ($\mu g\ l^{-1}$)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
$Ni_{dissolved}$ ($\mu g\ l^{-1}$)	<0.1	<0.1	0.4	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
Ni_{total} ($\mu g\ l^{-1}$)	<0.1	<0.1	0.4	<0.1	<0.1	<0.1	0.1	0.1	<0.1	0.1	<0.1	<0.1
$Fe_{dissolved}$ ($\mu g\ l^{-1}$)	<1.0	<1.0	4.0	1.2	<1.0	2.6	10.0	1.8	4.9	10.4	<1.0	8.5
Fe_{total} ($\mu g\ l^{-1}$)	<1.0	22.4	26.4	4.1	2.3	3.8	14.4	8.7	7.3	56.4	1.9	45.0

For the regularly monitored lakes (No 1-21 of Tab. 2.3), in order to better compare autumn chemistry of lakes with low alkalinities, values of the main parameters measured during 2017 and their mean values from 2007 to 2016 are shown graphically in Fig. 3.6.

In general, values from 2017 were not much different from average values of the period 2007-2016. Concentrations of sulphate were significantly higher in Lago Leit but in all other lakes concentrations were similar to average values of the previous decade. Highest concentrations of sulphate were measured in lakes which may have sulphur sources in their catchments (Lago della Capannina Leit, Lago dei Porchieirsc, Lago di Mognòla, Lago Nero, Lago di Morghirolo). Because deposition of sulphate does not differ greatly among lakes, concentrations of sulphate in the other lakes were similar to each other.

Concentrations of nitrate were also for most lakes similar to the previous decade. Similar as observed for sulphate, the marginal differences in nitrate concentrations in rainwater did not explain differences in lake nitrate concentrations. These are rather determined by the retention capacity of the lakes catchments.

As observed for sulphate, concentrations of base cations were higher during 2017 than average values of 2007-2016 only in lake Leit, while in the other lakes concentrations were similar. Highest concentrations of base cations normally characterize lakes with highest alkalinities and pH's. Lago Leit again differs from this tendency and has relatively high concentrations of base cations compared to its alkalinity and pH.

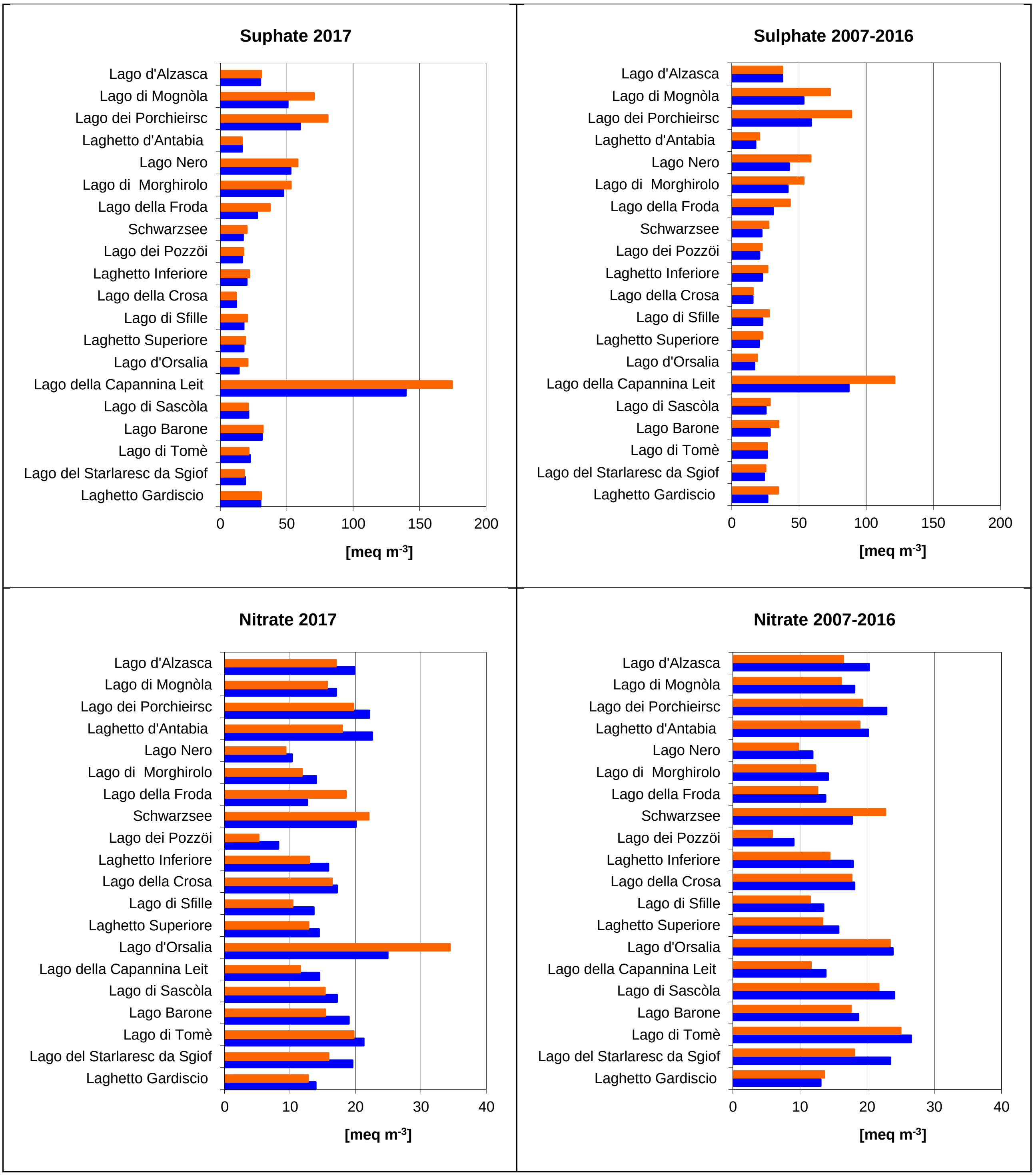
Only Laghetto Gardiscio and Lago del Starlaresc da Sgiof had alkalinities below 0 meq m^{-3}, while alkalinities constantly above 50 meq m^{-3} were measured only in Lago dei Porchieirsc, Laghetto d'Antabia, Lago d'Alzasca and Lago Nero. All other 16 lakes were at least temporary sensitive to acidification (0 < alkalinity < 50 meq m^{-3}).

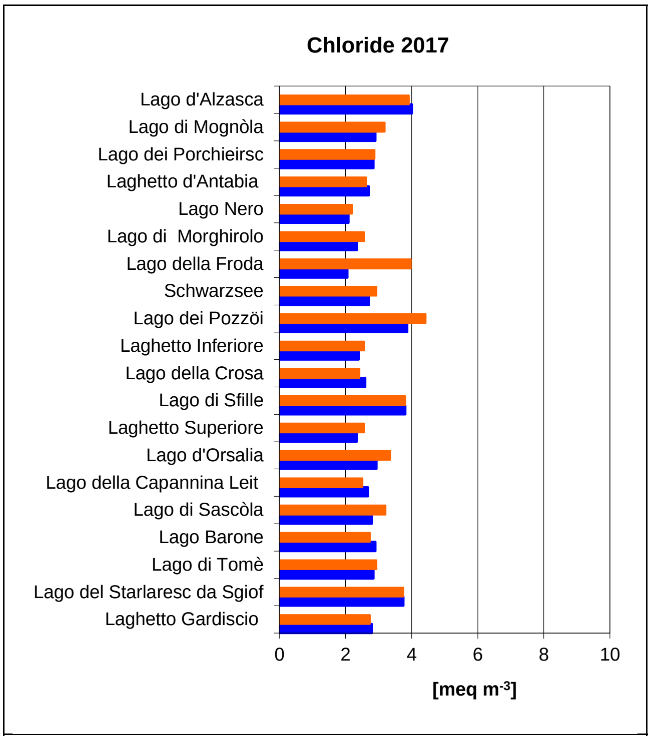
In general, lakes with low pH's are characterized by relatively high concentrations of aluminum (Lago del Starlaresc da Sgiof: 52-54 µg l^{-1}; Laghetto Gardiscio: 40-55 µg l^{-1}, Lago di Tomè: 20-22 µg l^{-1}, Lagi Sascòla: 17 µg l^{-1}). With exception of Laghetto Gardiscio, that was characterized by lower concentrations of aluminum in 2017, compared to the previous decade, in the other lakes concentrations remained almost constant.

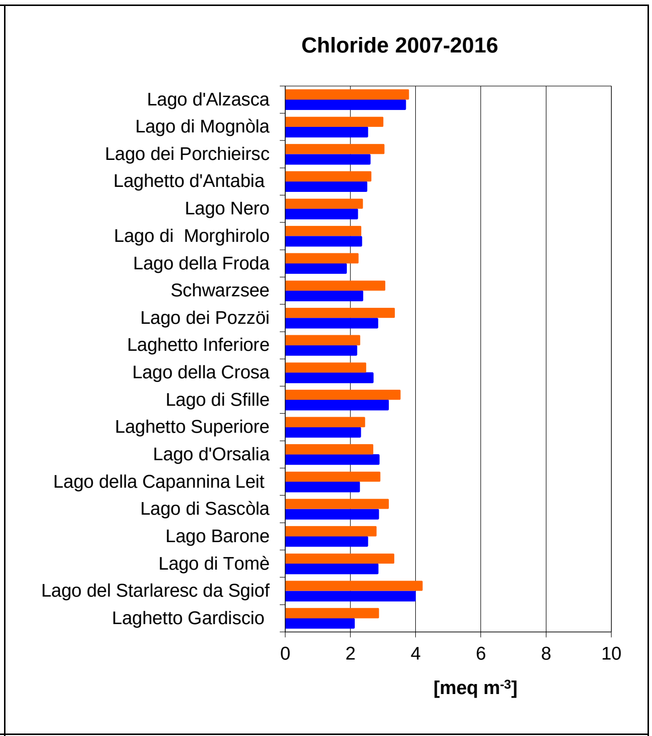
Seasonal variations

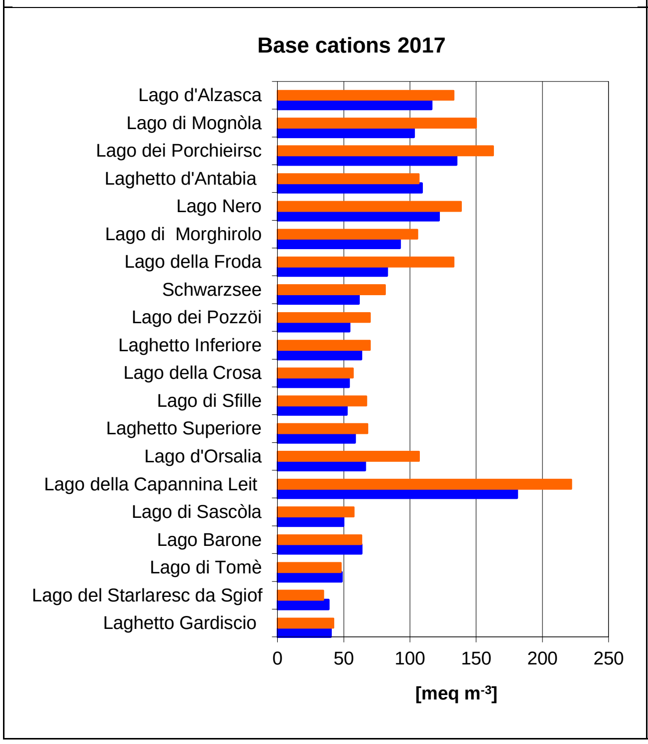
Fig. 3.6 also shows some seasonal differences. In most lakes alkalinity, pH and concentrations of sulphate and base cations tend to be lower in summer than in fall. The reason is the elevated discharge (precipitation and snow melt) in spring that causes a dilution of sulphate, base cations and a combination of dilution and consumption of alkalinity. Differently, concentrations of nitrate are often higher at the beginning of the summer compared to fall and may be caused by a combination of increased nitrate leaching during high discharge in spring and by increased assimilation and, eventually, also denitrification both in the catchment and in the lake itself during the warmer summer months.

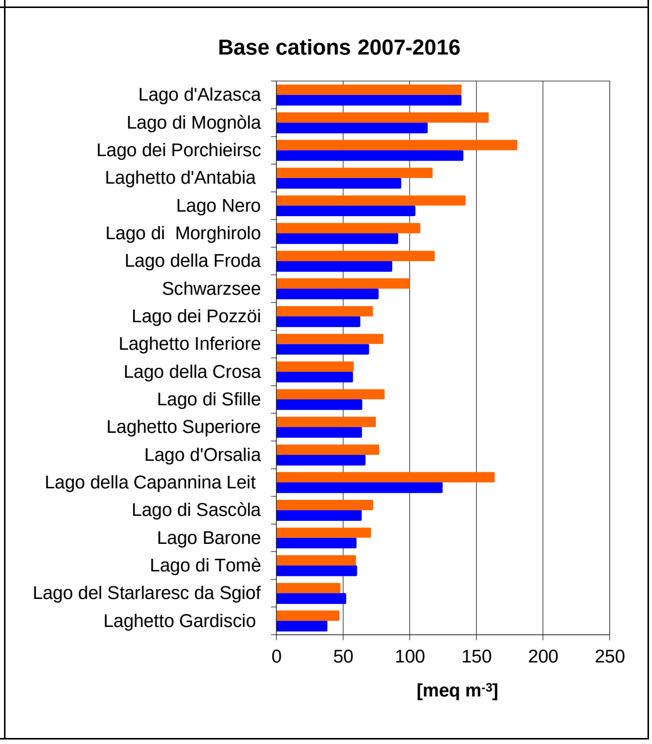
Figure 3.6 Concentrations of the main chemical parameters in 20 Alpine lakes during 2017 and their average values between 2007 and 2016. Blue and orange columns represent summer and autumn values, respectively.

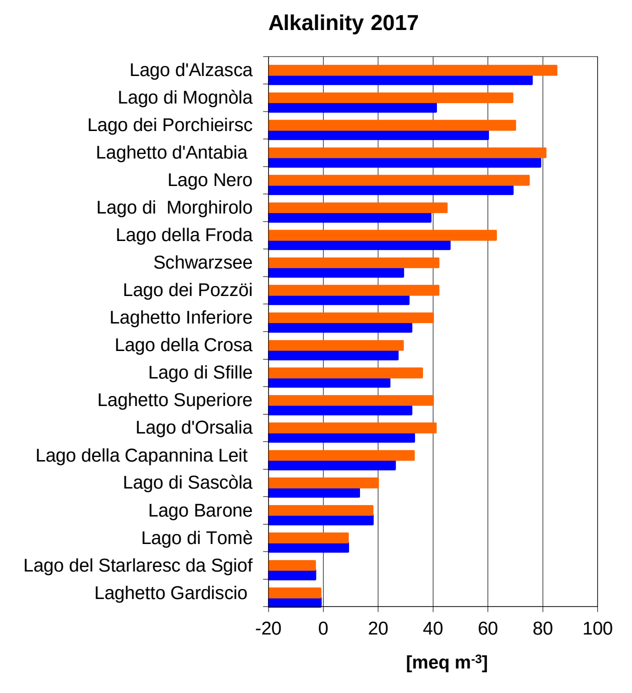


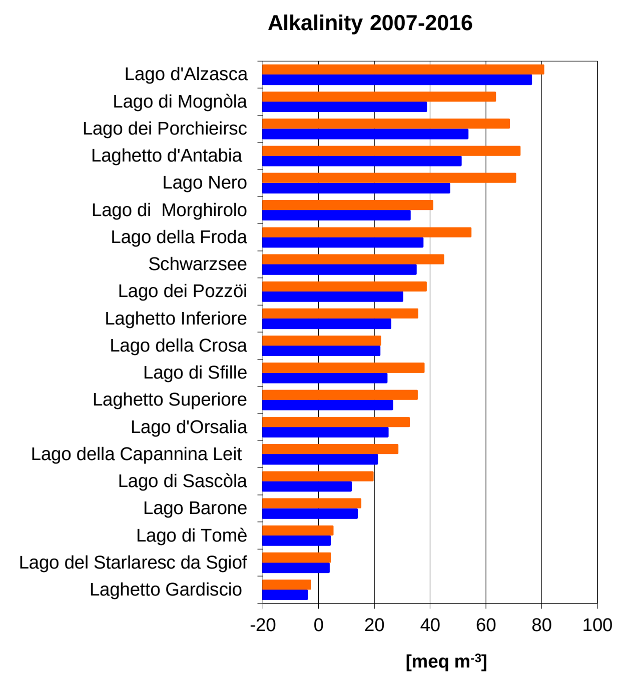

Chloride 2017
Lago d'Alzasca
Lago di Mognòla
Lago dei Porchieirsc
Laghetto d'Antabia
Lago Nero
Lago di Morghirolo
Lago della Froda
Schwarzsee
Lago dei Pozzöi
Laghetto Inferiore
Lago della Crosa
Lago di Sfille
Laghetto Superiore
Lago d'Orsalia
Lago della Capannina Leit
Lago di Sascòla
Lago Barone
Lago di Tomè
Lago del Starlaresc da Sgiof
Laghetto Gardiscio
0 2 4 6 8 10
[meq m-3]

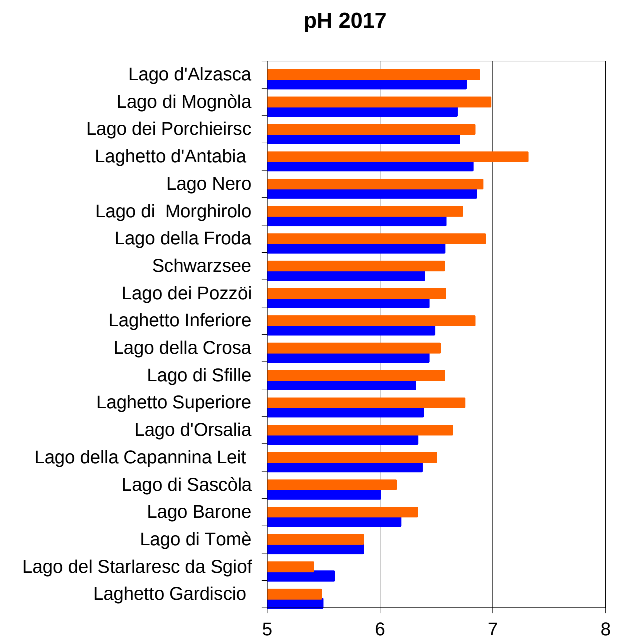

Chloride 2007-2016
Lago d'Alzasca
Lago di Mognòla
Lago dei Porchieirsc
Laghetto d'Antabia
Lago Nero
Lago di Morghirolo
Lago della Froda
Schwarzsee
Lago dei Pozzöi
Laghetto Inferiore
Lago della Crosa
Lago di Sfille
Laghetto Superiore
Lago d'Orsalia
Lago della Capannina Leit
Lago di Sascòla
Lago Barone
Lago di Tomè
Lago del Starlaresc da Sgiof
Laghetto Gardiscio
0 2 4 6 8 10
[meq m-3]

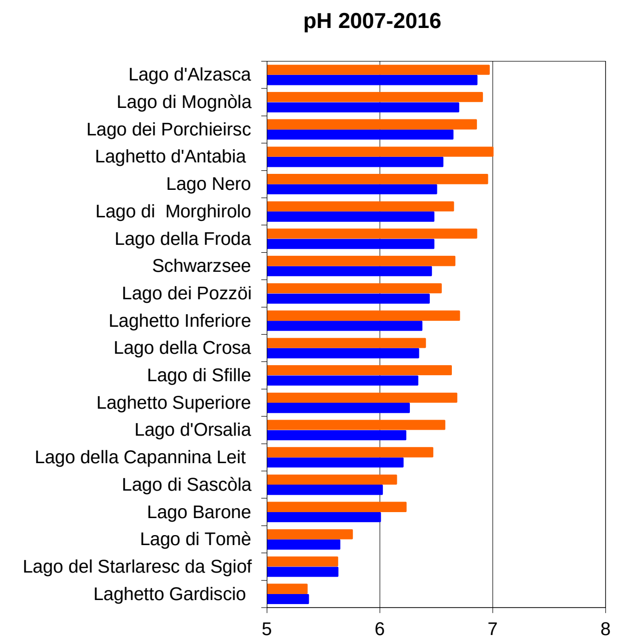

Base cations 2017
Lago d'Alzasca
Lago di Mognòla
Lago dei Porchieirsc
Laghetto d'Antabia
Lago Nero
Lago di Morghirolo
Lago della Froda
Schwarzsee
Lago dei Pozzöi
Laghetto Inferiore
Lago della Crosa
Lago di Sfille
Laghetto Superiore
Lago d'Orsalia
Lago della Capannina Leit
Lago di Sascòla
Lago Barone
Lago di Tomè
Lago del Starlaresc da Sgiof
Laghetto Gardiscio
0 50 100 150 200 250
[meq m-3]

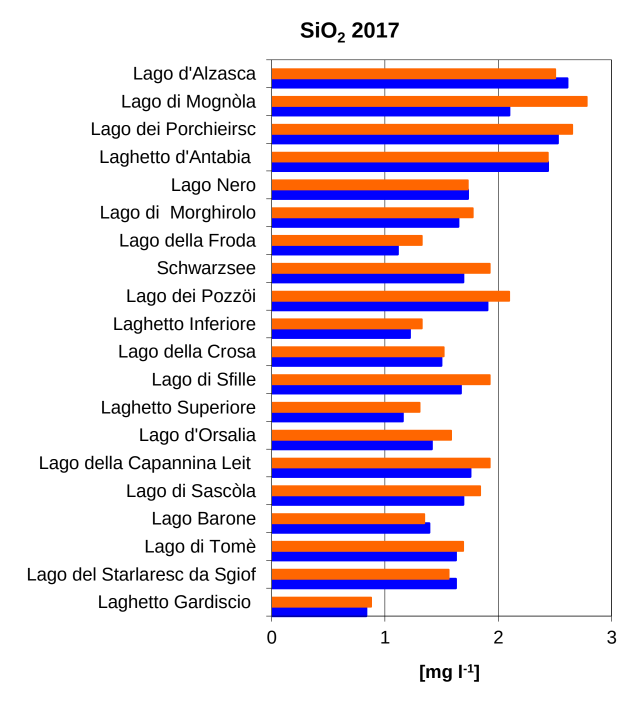

Base cations 2007-2016
Lago d'Alzasca
Lago di Mognòla
Lago dei Porchieirsc
Laghetto d'Antabia
Lago Nero
Lago di Morghirolo
Lago della Froda
Schwarzsee
Lago dei Pozzöi
Laghetto Inferiore
Lago della Crosa
Lago di Sfille
Laghetto Superiore
Lago d'Orsalia
Lago della Capannina Leit
Lago di Sascòla
Lago Barone
Lago di Tomè
Lago del Starlaresc da Sgiof
Laghetto Gardiscio
0 50 100 150 200 250
[meq m-3]

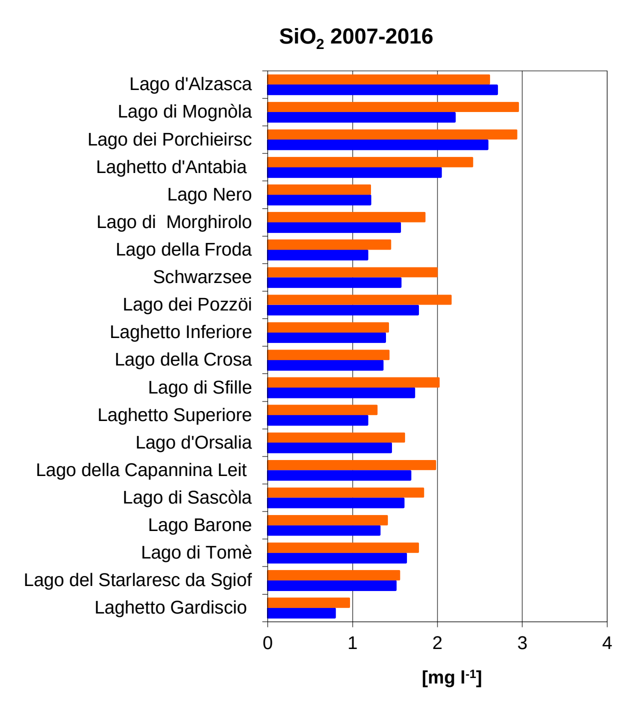

Alkalinity 2017
Lago d'Alzasca
Lago di Mognòla
Lago dei Porchieirsc
Laghetto d'Antabia
Lago Nero
Lago di Morghirolo
Lago della Froda
Schwarzsee
Lago dei Pozzöi
Laghetto Inferiore
Lago della Crosa
Lago di Sfille
Laghetto Superiore
Lago d'Orsalia
Lago della Capannina Leit
Lago di Sascòla
Lago Barone
Lago di Tomè
Lago del Starlaresc da Sgiof
Laghetto Gardiscio
-20
0
20
40
60
80
100
[meq m-3]

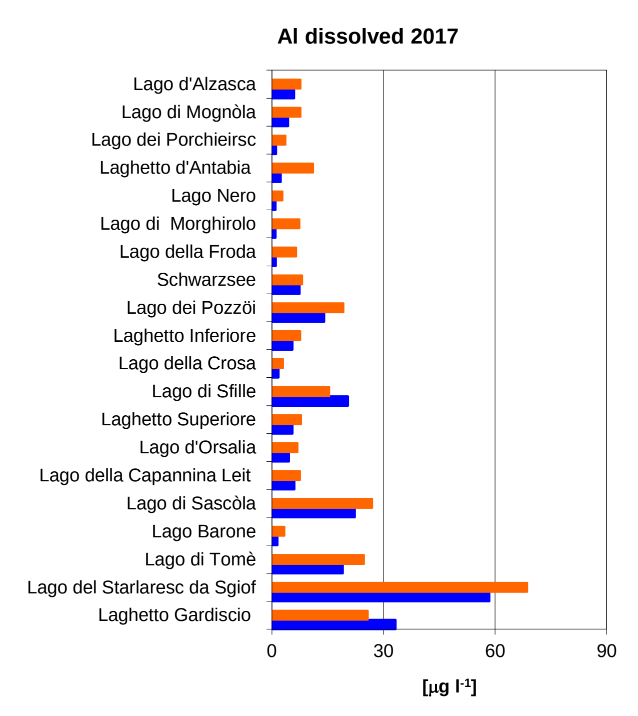

Alkalinity 2007-2016
Lago d'Alzasca
Lago di Mognòla
Lago dei Porchieirsc
Laghetto d'Antabia
Lago Nero
Lago di Morghirolo
Lago della Froda
Schwarzsee
Lago dei Pozzöi
Laghetto Inferiore
Lago della Crosa
Lago di Sfille
Laghetto Superiore
Lago d'Orsalia
Lago della Capannina Leit
Lago di Sascòla
Lago Barone
Lago di Tomè
Lago del Starlaresc da Sgiof
Laghetto Gardiscio
-20
0
20
40
60
80
100
[meq m-3]

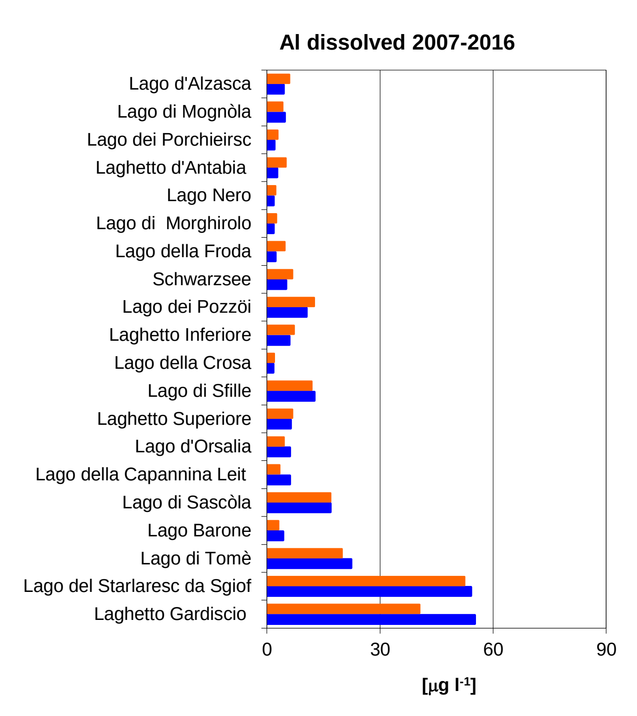

pH 2017
Lago d'Alzasca
Lago di Mognòla
Lago dei Porchieirsc
Laghetto d'Antabia
Lago Nero
Lago di Morghirolo
Lago della Froda
Schwarzsee
Lago dei Pozzöi
Laghetto Inferiore
Lago della Crosa
Lago di Sfille
Laghetto Superiore
Lago d'Orsalia
Lago della Capannina Leit
Lago di Sascòla
Lago Barone
Lago di Tomè
Lago del Starlaresc da Sgiof
Laghetto Gardiscio
5
6
7
8


pH 2007-2016
Lago d'Alzasca
Lago di Mognòla
Lago dei Porchieirsc
Laghetto d'Antabia
Lago Nero
Lago di Morghirolo
Lago della Froda
Schwarzsee
Lago dei Pozzöi
Laghetto Inferiore
Lago della Crosa
Lago di Sfille
Laghetto Superiore
Lago d'Orsalia
Lago della Capannina Leit
Lago di Sascòla
Lago Barone
Lago di Tomè
Lago del Starlaresc da Sgiof
Laghetto Gardiscio
5
6
7
8


SiO2 2017
Lago d'Alzasca
Lago di Mognòla
Lago dei Porchieirsc
Laghetto d'Antabia
Lago Nero
Lago di Morghirolo
Lago della Froda
Schwarzsee
Lago dei Pozzöi
Laghetto Inferiore
Lago della Crosa
Lago di Sfille
Laghetto Superiore
Lago d'Orsalia
Lago della Capannina Leit
Lago di Sascòla
Lago Barone
Lago di Tomè
Lago del Starlaresc da Sgiof
Laghetto Gardiscio
0
1
2
3
[mg l-1]


SiO2 2007-2016
Lago d'Alzasca
Lago di Mognòla
Lago dei Porchieirsc
Laghetto d'Antabia
Lago Nero
Lago di Morghirolo
Lago della Froda
Schwarzsee
Lago dei Pozzöi
Laghetto Inferiore
Lago della Crosa
Lago di Sfille
Laghetto Superiore
Lago d'Orsalia
Lago della Capannina Leit
Lago di Sascòla
Lago Barone
Lago di Tomè
Lago del Starlaresc da Sgiof
Laghetto Gardiscio
0
1
2
3
4
[mg l-1]


Al dissolved 2017
Lago d'Alzasca
Lago di Mognòla
Lago dei Porchieirsc
Laghetto d'Antabia
Lago Nero
Lago di Morghirolo
Lago della Froda
Schwarzsee
Lago dei Pozzöi
Laghetto Inferiore
Lago della Crosa
Lago di Sfille
Laghetto Superiore
Lago d'Orsalia
Lago della Capannina Leit
Lago di Sascòla
Lago Barone
Lago di Tomè
Lago del Starlaresc da Sgiof
Laghetto Gardiscio
0
30
60
90
[µg l-1]


Al dissolved 2007-2016
Lago d'Alzasca
Lago di Mognòla
Lago dei Porchieirsc
Laghetto d'Antabia
Lago Nero
Lago di Morghirolo
Lago della Froda
Schwarzsee
Lago dei Pozzöi
Laghetto Inferiore
Lago della Crosa
Lago di Sfille
Laghetto Superiore
Lago d'Orsalia
Lago della Capannina Leit
Lago di Sascòla
Lago Barone
Lago di Tomè
Lago del Starlaresc da Sgiof
Laghetto Gardiscio
0
30
60
90
[µg l-1]

Temporal variations

In order to show temporal variations of lake water quality, autumn median values of pH, alkalinity and concentrations of base cations, sulphate and nitrate of all lakes and their corresponding boxplots are represented in Fig. 3.7. Only years, where all 20 Alpine lakes have been monitored are shown. After the 1980's, sulphate concentrations decreased in most lakes. This can be attributed to reduced SO_x emissions and the associated decrease in sulphate depositions. Concentrations of nitrate also decreased because of reduced emissions of NO_x. As a consequence of decreasing sulphate and nitrate concentrations, concentrations of base cations decreased as well and alkalinity and pH increased. However, contrary to this general trend, in some lakes concentrations of sulphate and base cations are not decreasing (Porchieirsc, Nero), in some they are even increasing (Leit, Morghirolo, Mognola), that's why 90^{th} percentiles are not decreasing like median values (Fig. 3.7).

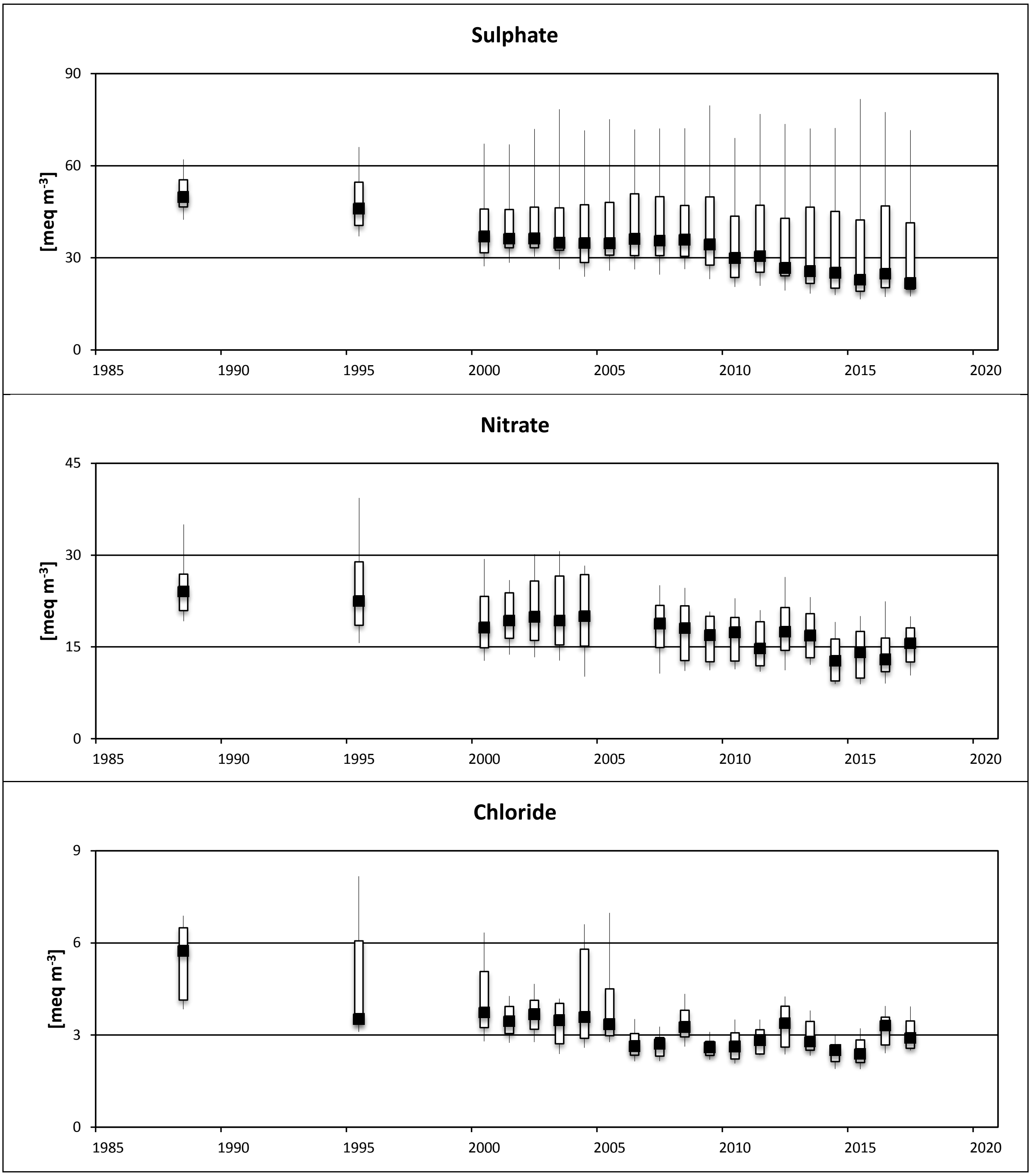
Aluminum concentrations of the three most acidic lakes are presented in Fig. 3.8 (see also trends in Tab. 3.6). The most evident decrease in concentrations occurred in Lago del Starlaresc da Sgiof from 80-100 to 30-70 µg l^{-1}. In Lago di Tomè concentrations decreased from about 40 to 15-25 µg l^{-1} and in Laghetto Gardiscio from 30-60 µg l^{-1} to 23-31 µg l^{-1}.

Results of a detailed trend analysis of the main parameters are presented in Tab. 3.6. Trends were calculated for the entire monitoring period and for the period since 2000, when sampling occurred more regularly and frequently. Since the 1980s, due to decreasing sulphate and nitrate depositions, concentrations of sulphate and nitrate decreased significantly in 15 and 17 lakes, respectively. While the decrease of sulphate was similar for the two analyzed time periods, decrease of nitrate was higher after 2000, indicating a more pronounced decrease more recently. Decreases in anthropogenic sulphate and nitrate also caused decreasing concentrations of hydrogen ions (significant in 16 lakes) and increasing concentrations of total alkalinity (significant in 18 lakes). Concentrations of aluminum decreased significantly in lakes with the highest concentrations (Lago del Starlaresc da Sgiof, in Lago di Tomè, in Lago Gardiscio).

Interestingly, differently to most lakes, concentrations of sulphate increased significantly in three lakes (Lago della Capannina Leit, Lago di Morghirolo and Lago di Mognòla). For Lago Leit and Lago Morghirolo this increase is higher after 2000 and for Lago Leit even more pronounced after 2005 (8.9 meq m^{-3} yr^{-1}, data not shown). A sulphur budget analysis of the catchments revealed that in the two lakes with constant sulphate concentrations (Porchieirsc, Nero), sulphur release from the catchments is significantly increasing (data not shown). Climate change leading to melting of permafrost and rock glaciers (Scapozza and Mari, 2010) might be the reason for the release of sulphur (Thies et al., 2007).

As regards temporal variations, the same conclusions can be derived comparing the large scale assessments in 1995 and 2017 (Fig. 3.9): concentrations of sulphate decreased in 85%, nitrate in 96% and chloride in 66% of the lakes, while concentrations of base cations increased in 72%, total alkalinity in 96% and pH in 98% of the lakes. In particular, in 1995 36% of the lakes had autumn alkalinities < 20 µeq/l and 28% of the lakes had pH's below 6, while in 2017 the percentages decreased to 20% for alkalinity and 9% for pH.

Figure 3.7 Temporal variations of parameters measured in 20 Alpine lakes from 1988 to 2017. Boxplots show the median and the 10th, 25th, 75th, 90th percentiles of autumn mean values.



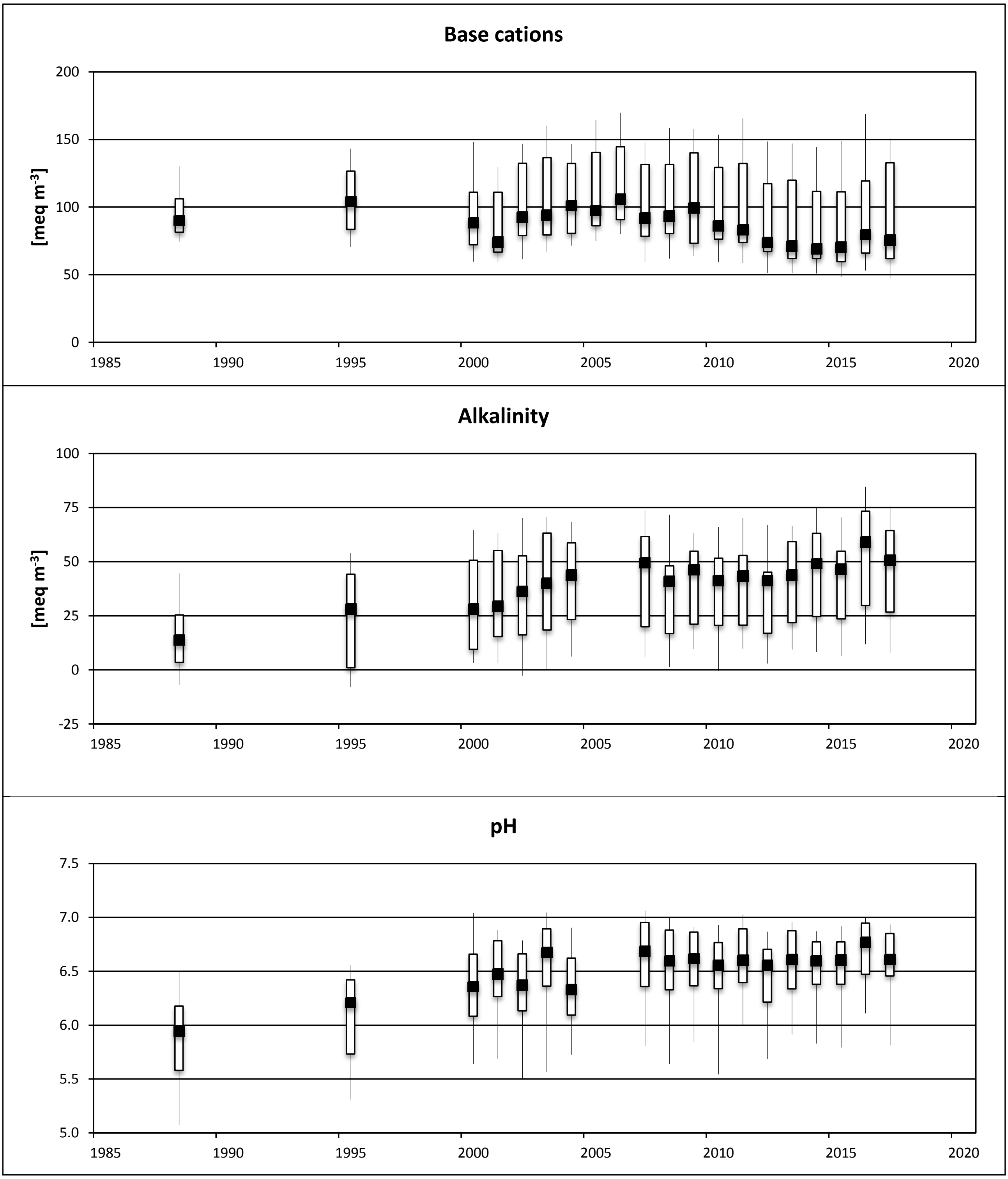

Base cations
[meq m-3]
200
150
100
50
0
1985
1990
1995
2000
2005
2010
2015
2020
Alkalinity
[meq m-3]
100
75
50
25
0
-25
1985
1990
1995
2000
2005
2010
2015
2020
pH
7.5
7.0
6.5
6.0
5.5
5.0
1985
1990
1995
2000
2005
2010
2015
2020

Figure 3.8 Temporal variations of dissolved aluminum from 1988 to 2017 in the three most acidic lakes (mean autumn values).

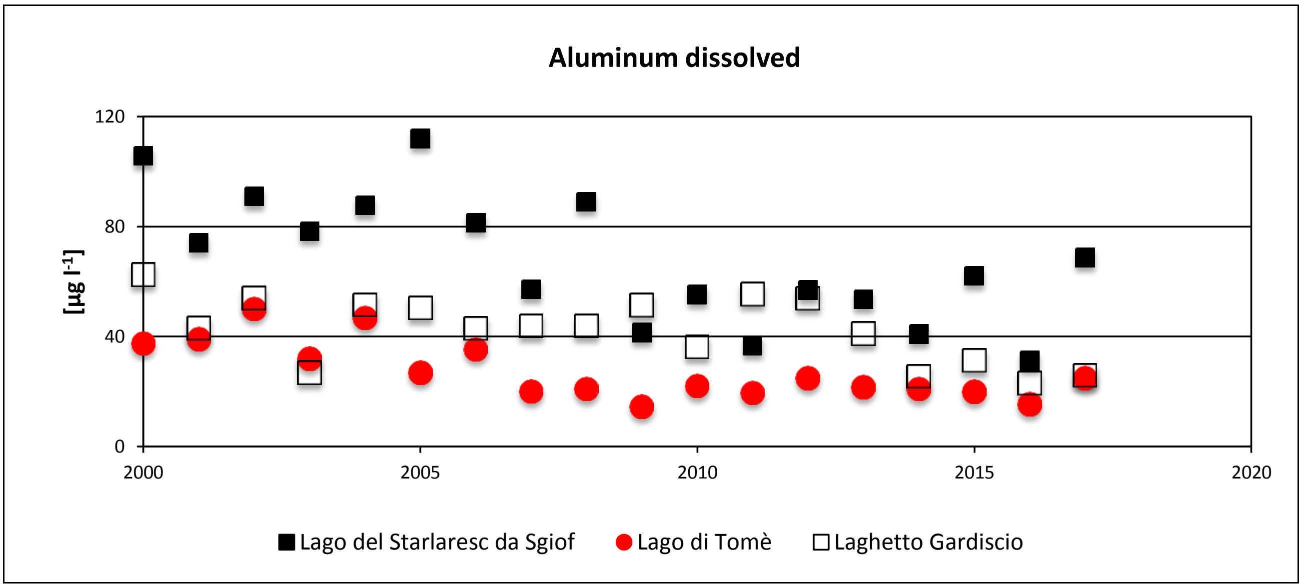
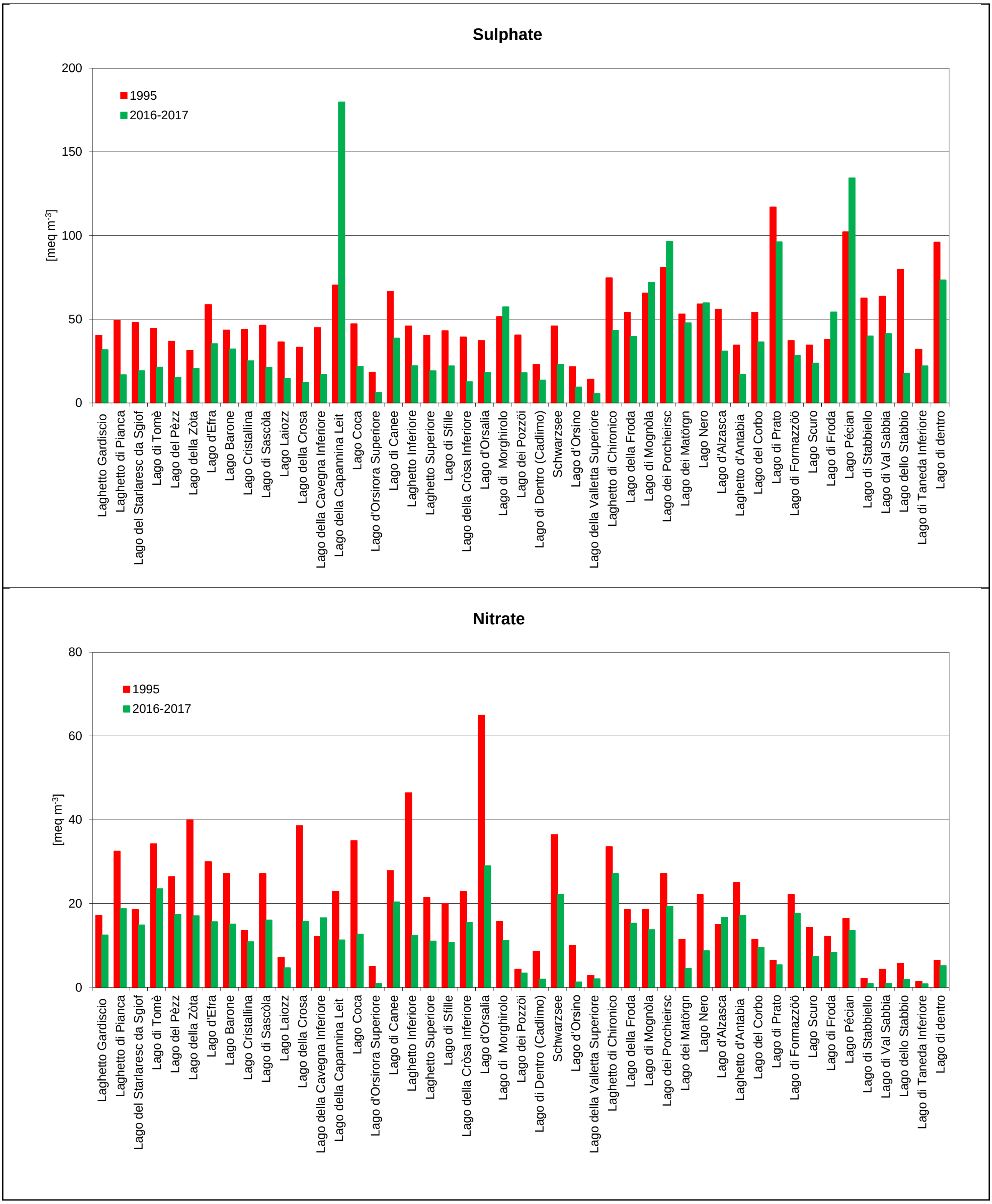
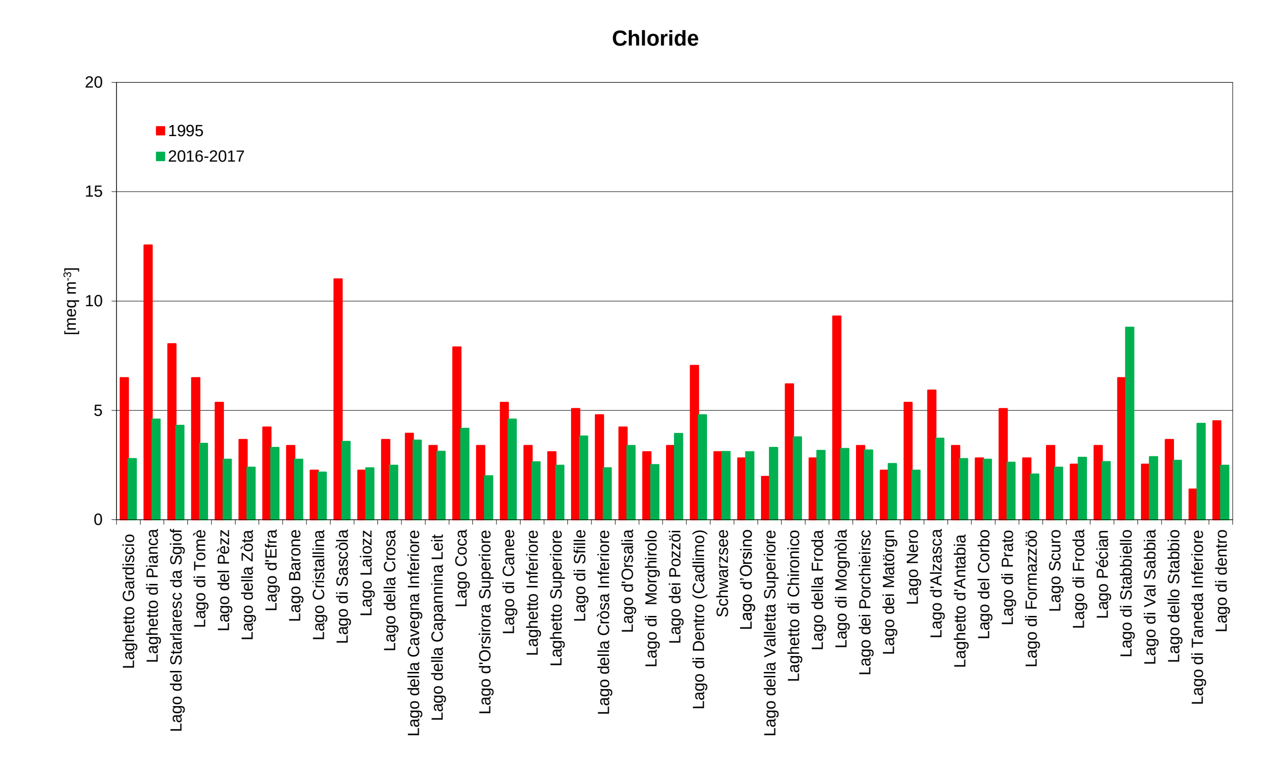


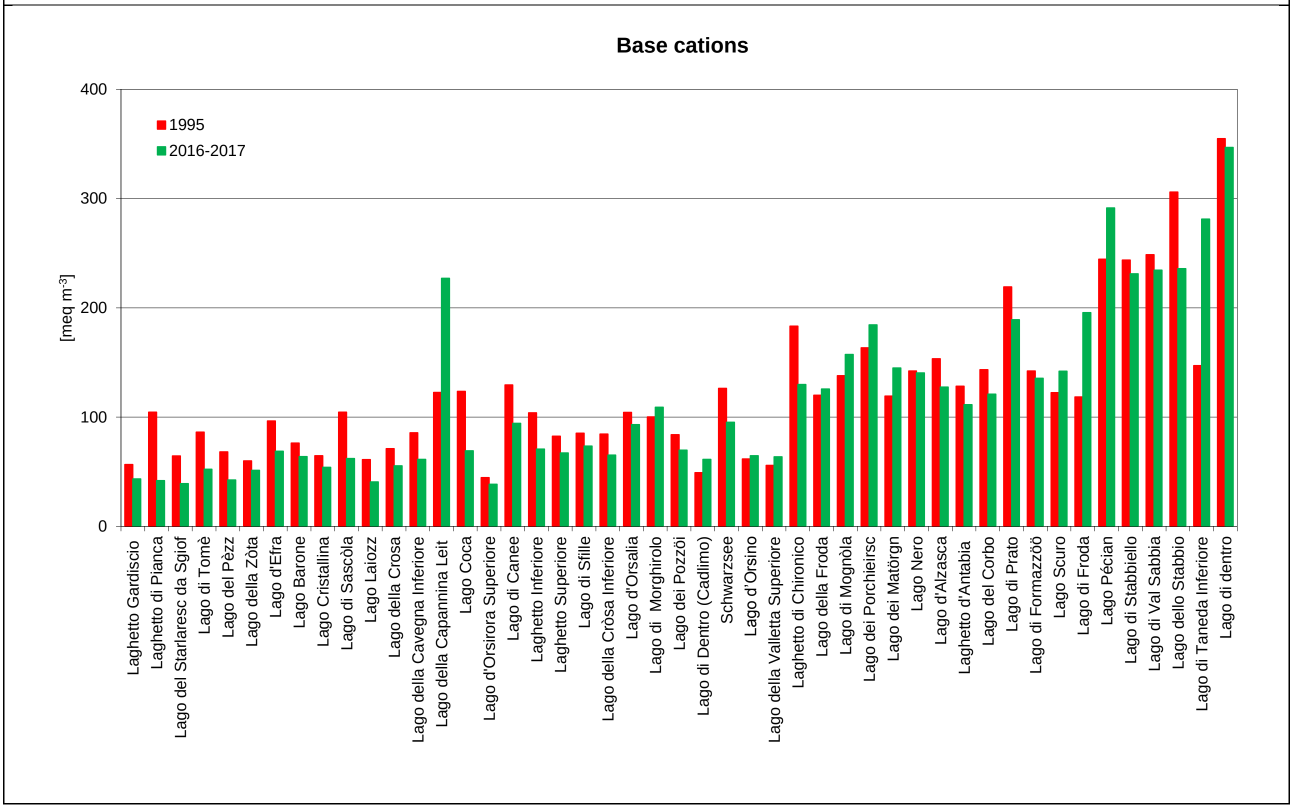
Table 3.6 Changes in lake water concentrations during the indicated time periods. Red values indicate significant trends.

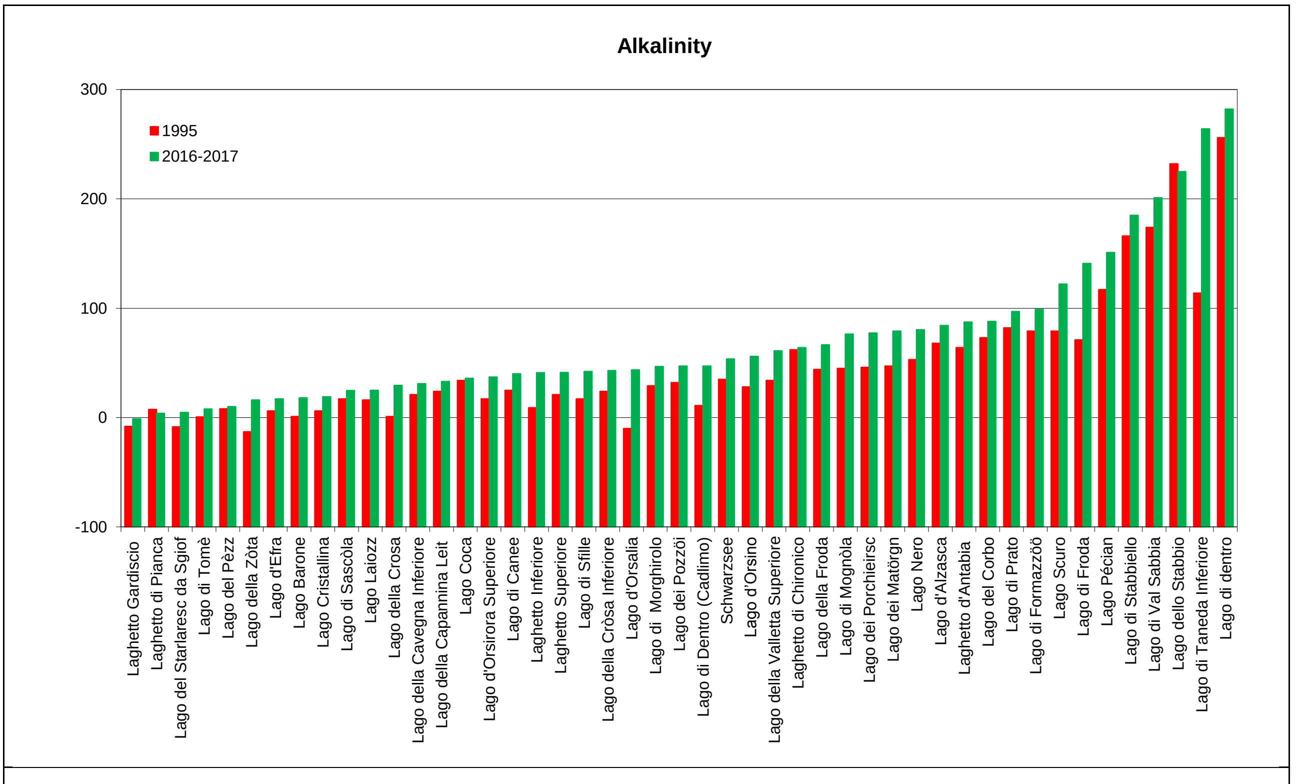
Lake	SO_4^{2-}		NO_3^-		Cl^-		Base cations		H^+		Total alkalinity		Al_{dis}
	'80-17	00-17	'80-16	00-17	'80-17	00-17	'80-17	00-17	'80-17	00-17	'80-17	00-17	00-17
Lago del Starlaresc da Sgiof	-1.29	-1.21	-0.55	-0.83	-0.11	-0.12	-1.15	-1.48	-4.4E-1	-3.2E-1	0.83	1.08	-3.40
Lago di Tomè	-0.91	-0.82	-0.45	-0.89	-0.05	-0.05	-1.28	-1.79	-6.9E-2	-2.9E-2	0.39	0.29	-1.19
Lago dei Porchieirsc	0.45	0.08	-0.36	-0.49	-0.04	-0.06	-0.18	-1.15	-3.6E-3	-4.4E-4	0.69	0.47	
Lago Barone	-0.44	-0.39	-0.29	-0.47	-0.06	-0.07	-0.52	-0.74	-3.6E-2	-1.8E-2	0.57	0.58	
Laghetto Gardiscio	-0.28	-0.26	-0.23	-0.28	-0.06	-0.05	-0.44	-0.48	-1.0E-1	-9.7E-2	0.29	0.23	-1.57
Lago Leit	3.11	5.86	-0.23	-0.27	-0.04	0.00	3.08	5.02	-8.3E-3	6.4E-4	0.50	0.38	
Lago di Morghirolo	0.33	0.69	-0.16	-0.25	-0.05	-0.03	0.59	0.27	-4.8E-3	-2.4E-3	0.77	0.71	
Lago di Mognòla	0.33	0.19	-0.19	-0.35	-0.03	-0.03	0.25	-1.10	-1.2E-3	6.8E-4	0.04	-0.21	
Laghetto Inferiore	-0.94	-0.89	-0.43	-0.58	-0.07	-0.05	-1.09	-1.78	-8.8E-3	-9.0E-3	0.57	0.68	
Laghetto Superiore	-0.84	-0.80	-0.41	-0.70	-0.06	-0.04	-0.49	-1.03	-1.4E-2	-1.2E-2	0.93	1.00	
Lago Nero	0.05	0.21	-0.11	-0.19	-0.03	-0.03	0.25	0.11	-2.4E-3	--1.1E-4	0.71	0.73	
Lago della Froda	-0.35	-0.40	-0.22	-0.25	-0.03	-0.02	0.33	0.31	-5.5E-3	-1.8E-3	0.81	0.56	
Lago d'Antabia	-0.73	-0.76	-0.33	-0.51	-0.08	-0.07	-0.38	-1.54	-4.1E-3	-2.4E-3	0.77	0.65	
Lago della Crosa	-0.82	-0.77	-0.18	-0.29	-0.07	-0.07	-0.58	-0.93	-2.4E-2	-1.0E-2	0.73	0.75	
Lago d'Orsalìa	-0.89	-0.84	-0.19	-0.50	-0.08	-0.07	-0.11	-0.84	-3.6E-2	-1.3E-2	1.07	1.10	
Schwarzsee	-1.09	-1.15	-0.25	-0.26	-0.06	-0.07	-1.36	-2.18	-6.3E-3	-3.3E-3	0.55	0.28	
Laghi dei Pozzöi	-1.06	-0.99	-0.18	-0.26	-0.08	-0.01	-0.83	-1.47	-4.5E-3	-4.1E-3	0.33	0.25	-0.36
Lago di Sfille	-0.94	-0.93	-0.22	-0.26	-0.06	-0.05	-0.88	-1.31	-1.0E-2	-6.4E-3	0.70	0.71	-0.59
Lago di Sascòla	-1.04	-1.03	-0.35	-0.86	-0.10	-0.09	-1.40	-2.24	-1.7E-2	-8.2E-3	0.40	0.33	-0.24
Lago d'Alzasca	-1.00	-1.03	-0.06	-0.09	-0.08	-0.10	-0.50	-1.74	-2.7E-3	-9.6E-5	0.89	0.85	

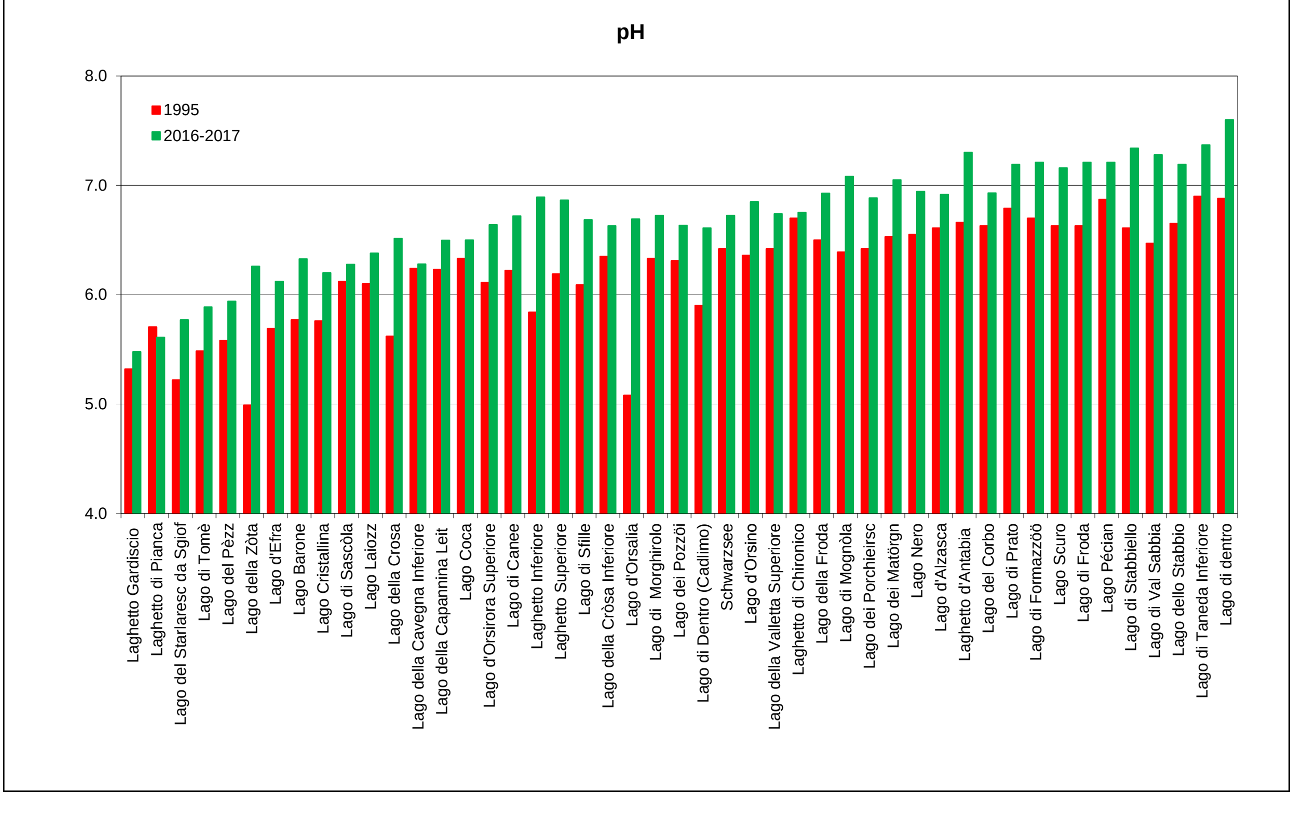
Figure 3.9 Comparison of the main chemical parameters measured in 47 Alpine lakes in 1995 and in 2016-2017.

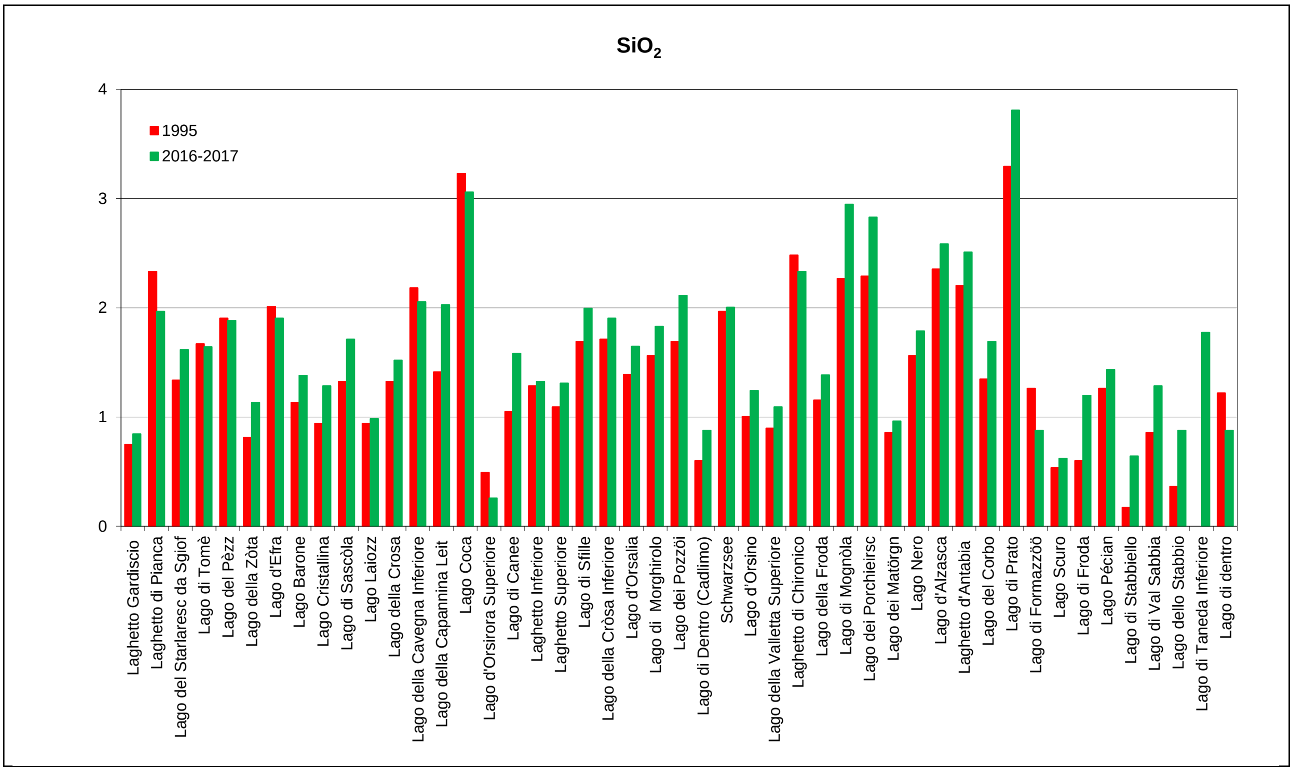



Chloride
[meq m-3]
20
15
10
5
0
1995
2016-2017
Laghetto Gardiscio
Laghetto di Pianca
Lago del Starlaresc da Sgiof
Lago di Tomè
Lago del Pèzz
Lago della Zòta
Lago d'Efra
Lago Barone
Lago Cristallina
Lago di Sascòla
Lago Laiozz
Lago della Crosa
Lago della Cavegna Inferiore
Lago della Capannina Leit
Lago Coca
Lago d'Orsirora Superiore
Lago di Canee
Laghetto Inferiore
Laghetto Superiore
Lago di Sfille
Lago della Cròsa Inferiore
Lago d'Orsalia
Lago di Morghirolo
Lago dei Pozzöi
Lago di Dentro (Cadlimo)
Schwarzsee
Lago d'Orsino
Lago della Valletta Superiore
Laghetto di Chironico
Lago della Froda
Lago di Mognòla
Lago dei Porchieirsc
Lago dei Matörgn
Lago Nero
Lago d'Alzasca
Laghetto d'Antabia
Lago del Corbo
Lago di Prato
Lago di Formazzöö
Lago Scuro
Lago di Froda
Lago Pécian
Lago di Stabbiello
Lago di Val Sabbia
Lago dello Stabbio
Lago di Taneda Inferiore
Lago di dentro


Base cations
[meq m-3]
400
300
200
100
0
1995
2016-2017
Laghetto Gardiscio
Laghetto di Pianca
Lago del Starlaresc da Sgiof
Lago di Tomè
Lago del Pèzz
Lago della Zòta
Lago d'Efra
Lago Barone
Lago Cristallina
Lago di Sascòla
Lago Laiozz
Lago della Crosa
Lago della Cavegna Inferiore
Lago della Capannina Leit
Lago Coca
Lago d'Orsirora Superiore
Lago di Canee
Laghetto Inferiore
Laghetto Superiore
Lago di Sfille
Lago della Cròsa Inferiore
Lago d'Orsalia
Lago di Morghirolo
Lago dei Pozzöi
Lago di Dentro (Cadlimo)
Schwarzsee
Lago d'Orsino
Lago della Valletta Superiore
Laghetto di Chironico
Lago della Froda
Lago di Mognòla
Lago dei Porchieirsc
Lago dei Matörgn
Lago Nero
Lago d'Alzasca
Laghetto d'Antabia
Lago del Corbo
Lago di Prato
Lago di Formazzöö
Lago Scuro
Lago di Froda
Lago Pécian
Lago di Stabbiello
Lago di Val Sabbia
Lago dello Stabbio
Lago di Taneda Inferiore
Lago di dentro


Alkalinity
1995
2016-2017
300
200
100
0
-100
Laghetto Gardiscio
Laghetto di Pianca
Lago del Starlaresc da Sgiòf
Lago di Tomè
Lago del Pèzz
Lago della Zòta
Lago d'Efra
Lago Barone
Lago Cristallina
Lago di Sascòla
Lago Laiozz
Lago della Crosa
Lago della Cavegna Inferiore
Lago della Capannina Leit
Lago Coca
Lago d'Orsirora Superiore
Lago di Canee
Laghetto Inferiore
Laghetto Superiore
Lago di Sfille
Lago della Cròsa Inferiore
Lago d'Orsalia
Lago di Morghirolo
Lago dei Pozzöi
Lago di Dentro (Cadlimo)
Schwarzsee
Lago d'Orsino
Lago della Valletta Superiore
Laghetto di Chironico
Lago della Froda
Lago di Mognòla
Lago dei Porchieirsc
Lago dei Matörgn
Lago Nero
Lago d'Alzasca
Laghetto d'Antabia
Lago del Corbo
Lago di Prato
Lago di Formazzöö
Lago Scuro
Lago di Froda
Lago Pécian
Lago di Stabbiello
Lago di Val Sabbia
Lago dello Stabbio
Lago di Taneda Inferiore
Lago di dentro


pH
1995
2016-2017
8.0
7.0
6.0
5.0
4.0
Laghetto Gardiscio
Laghetto di Pianca
Lago del Starlaresc da Sgiòf
Lago di Tomè
Lago del Pèzz
Lago della Zòta
Lago d'Efra
Lago Barone
Lago Cristallina
Lago di Sascòla
Lago Laiozz
Lago della Crosa
Lago della Cavegna Inferiore
Lago della Capannina Leit
Lago Coca
Lago d'Orsirora Superiore
Lago di Canee
Laghetto Inferiore
Laghetto Superiore
Lago di Sfille
Lago della Cròsa Inferiore
Lago d'Orsalia
Lago di Morghirolo
Lago dei Pozzöi
Lago di Dentro (Cadlimo)
Schwarzsee
Lago d'Orsino
Lago della Valletta Superiore
Laghetto di Chironico
Lago della Froda
Lago di Mognòla
Lago dei Porchieirsc
Lago dei Matörgn
Lago Nero
Lago d'Alzasca
Laghetto d'Antabia
Lago del Corbo
Lago di Prato
Lago di Formazzöö
Lago Scuro
Lago di Froda
Lago Pécian
Lago di Stabbiello
Lago di Val Sabbia
Lago dello Stabbio
Lago di Taneda Inferiore
Lago di dentro


SiO2
4
3
2
1
0
1995
2016-2017
Laghetto Gardiscio
Laghetto di Pianca
Lago del Starlaresc da Sgiof
Lago di Tomè
Lago del Pèzz
Lago della Zòta
Lago d'Efra
Lago Barone
Lago Cristallina
Lago di Sascòla
Lago Laiozz
Lago della Crosa
Lago della Cavegna Inferiore
Lago della Capannina Leit
Lago Coca
Lago d'Orsirora Superiore
Lago di Canee
Laghetto Inferiore
Laghetto Superiore
Lago di Sfille
Lago della Cròsa Inferiore
Lago d'Orsalia
Lago di Morghirolo
Lago dei Pozzöi
Lago di Dentro (Cadlimo)
Schwarzsee
Lago d'Orsino
Lago della Valletta Superiore
Laghetto di Chironico
Lago della Froda
Lago di Mognòla
Lago dei Porchieirsc
Lago dei Matörgn
Lago Nero
Lago d'Alzasca
Laghetto d'Antabia
Lago del Corbo
Lago di Prato
Lago di Formazzöö
Lago Scuro
Lago di Froda
Lago Pécian
Lago di Stabbiello
Lago di Val Sabbia
Lago dello Stabbio
Lago di Taneda Inferiore
Lago di dentro

3.6.3 Alpine rivers

Spatial variations

During 2017 river water was sampled at the following days: 16.1, 13.2, 13.3, 10.4, 15.5, 12.6, 10.7, 7.8, 25.9, 9.10, 13.11, 18.12. Annual mean concentrations of the chemical parameters measured in river Maggia, Vedeggio and Verzasca during 2017 are shown in Tab. 3.7. Conductivity, alkalinity, pH, concentrations of calcium, and sulphate were highest in river Maggia, followed by Vedeggio and Verzasca. As discussed in Steingruber and Colombo (2006), differences in catchment areas and geology are the main cause for differences in concentrations among rivers. In fact, the catchment area of river Maggia is 7 and 10 times larger than the watersheds of river Verzasca and Vedeggio, respectively, implying a longer average water residence time and higher average weathering. Differences in water chemistry of rivers Vedeggio and Verzasca are more related to their different catchment geology. Similarly to the catchment of river Maggia, the watersheds of river Vedeggio and Verzasca are very poor in carbonate containing rocks. But while the catchment of river Verzasca is characterized by the presence of relatively young rocks that were formed during the orogenesis of the Alps (60 millions years ago), the geology of the catchment of river Vedeggio is much older (300 millions to 2.5 milliards years). Therefore much more weathered and fractured, increasing the surface that can interact with water from precipitations. Interestingly, highest concentrations of nitrate were measured in river Vedeggio followed by river Verzasca and Maggia. This may be due to differences in average rainwater nitrogen concentrations and different nitrogen retention capacities of the watersheds. From 2008-2012, average nitrogen rainwater concentrations in the watershed of river Vedeggio, Verzasca and Maggia were 61, 41 and 37 meq m^{-3}, respectively and highest nitrogen retention during the same time period occurred in the larger river Maggia (36%) followed by river Vedeggio (31%) and Verzasca (29%).

During 2017 average alkalinity was 324 meq m^{-3} in river Maggia, 181 meq m^{-3} in river Vedeggio and 81 meq m^{-3} in river Verzasca. Based on these data river Verzasca and river Vedeggio have low alkalinities (50-200 meq m^{-3}), but no river is sensitive to acidification. The same is suggested by their minimum alkalinities that were always > 0 meq m^{-3}. Average pH was 7.5 in river Maggia, 7.1 in river Vedeggio and 6.9 in river Verzasca. Their minimum pH's were not much lower (Maggia: 7.3, Vedeggio: 7.1, Verzasca: 6.8).

Table 3.7 Average concentrations in river water during 2017. Values based on at least one sample below the quantification limit were preceded with <.

River name	pH	Cond 25°C (µS cm^{-1})	Alkalinity (µeq l^{-1})	Ca^{2+} (meq m^{-3})	Mg^{2+} (meq m^{-3})	Na^+ (meq m^{-3})	K^+ (meq m^{-3})	SO_4^{2-} (meq m^{-3})	NO_3^- (meq m^{-3})	Cl^- (meq m^{-3})	SRP (µg P l^{-1})	DOC (mg C l^{-1})	SiO_2 (mg l^{-1})	$Al_{dissolved}$ (µg l^{-1})	Al_{tot} (µg l^{-1})	$Pb_{dissolved}$ (µg l^{-1})	Pb_{tot} (µg l^{-1})	$Cd_{dissolved}$ (µg l^{-1})	Cd_{total} (µg l^{-1})	$Cu_{dissolved}$ (µg l^{-1})	Cu_{tot} (µg l^{-1})	$Zn_{dissolved}$ (µg l^{-1})	Zn_{total} (µg l^{-1})	$Cr_{dissolved}$ (µg l^{-1})	Cr_{total} (µg l^{-1})	$Ni_{dissolved}$ (µg l^{-1})	Ni_{total} (µg l^{-1})
Maggia	7.5	64	324	398	58	77	38	191	34	32	<2	0.7	5.1	7.0	10.9	<0.1	<0.1	<0.1	<0.1	<0.4	0.4	3.6	4.7	<0.1	<0.1	0.2	0.2
Vedeggio	7.1	46	181	233	88	73	14	119	60	28	<2	0.9	7.6	7.1	11.5	<0.1	<0.1	<0.1	<0.1	0.4	0.5	1.2	1.3	<0.1	<0.1	0.9	0.9
Verzasca	6.9	23	81	129	18	32	14	68	33	10	<2	0.6	4.1	6.8	6.7	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	1.0	1.1	<0.1	<0.1	<0.1	0.1

Seasonal variations

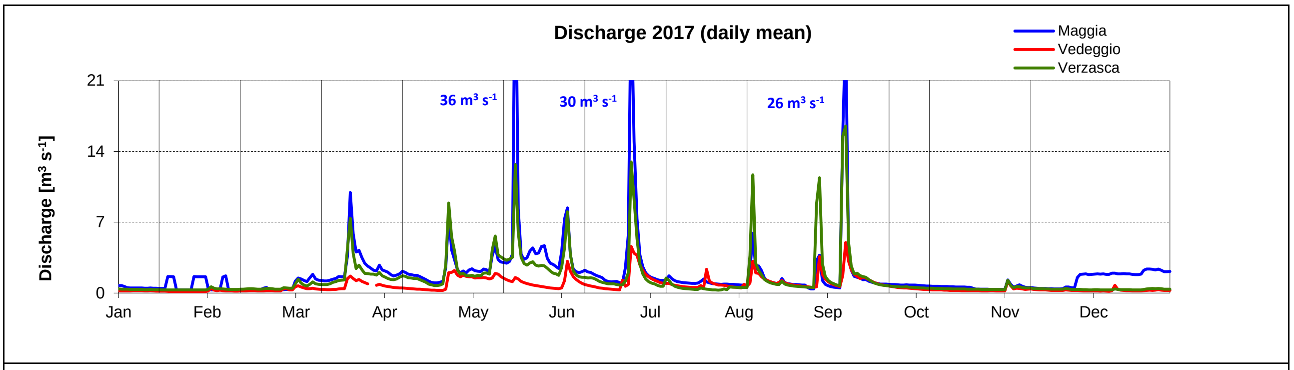
Fig. 3.10 shows the daily mean discharges during 2017 and average values of the previous decade (2007-2016). Discharges are usually low during winter, high in spring because of frequent precipitation and snow melt, average during summer and higher again in autumn. 2017 was characterized by typical low discharges during winter and high values during spring but low values afterwards.

Concentrations of the main chemical parameters in river water during sampling days in 2017 and their average values during 2007-2016 are shown in Fig. 3.11.

During 2007-2016 the seasonality was characterized by concentrations of sulphate, base cations, alkalinity, SiO_2 and pH that are normally lower from spring to autumn when river discharge is higher and more elevated during the rest of the year. Because water quality of surface waters and rain differ greatly, Steingruber and Colombo (2006) suggested that a dilution of sulphate, base cations, chloride and a combination of dilution and consumption of alkalinity occurs during rain events and/or snowmelt. River pH decreases during rain events because of rain acidity. Nitrate concentrations are higher in winter compared to summer and can, in addition, also increase during high flow events. More than one factor are responsible for this variations in concentrations e.g. higher values during winter because of lower discharge (less dilution), lower retention (uptake by vegetation and algae, denitrification) and occasionally higher values during precipitation events or snowmelt because of leakage from soils. Concentrations of aluminum are higher in spring and autumn when discharge is higher, suggesting leakage from soils, probably enhanced by lower pH values during these occasions.

The main chemical parameters during 2017 were in general in the same range as average values measured during 2007-2016. However, in autumn, because of the low precipitation volumes, concentrations of sulphate, base cations, silica, alkalinity and pH were less diluted and therefore slightly higher than usual. Differently, concentrations of nitrate and aluminum that are normally higher during increased discharge, were slightly lower than usual.

Figure 3.10 Daily mean discharge during 2017 and average daily mean discharge during 2005-2015. Discharge of river Vedeggio at Isone was measured by the Canton of Ticino (UCA, 2001-2018), discharge of river Verzasca at Sonogno was estimated by discharge values measured at Lavertezzo by BWG (2001-2004) and BAFU (2005-2018), discharge of river Maggia was measured at Brontallo by Ofima (discharge of days with no data were estimated from measurements at Bignasco by BWG (2001-2004) and BAFU (2005-2018)).



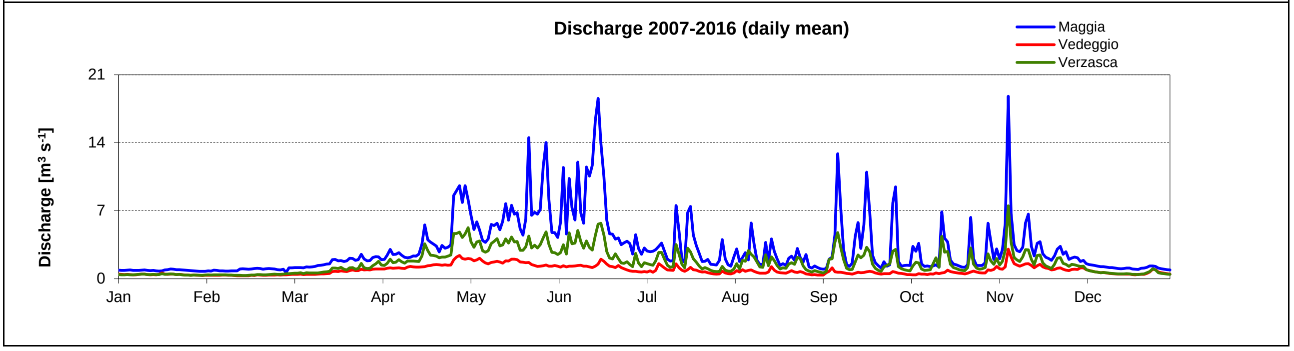
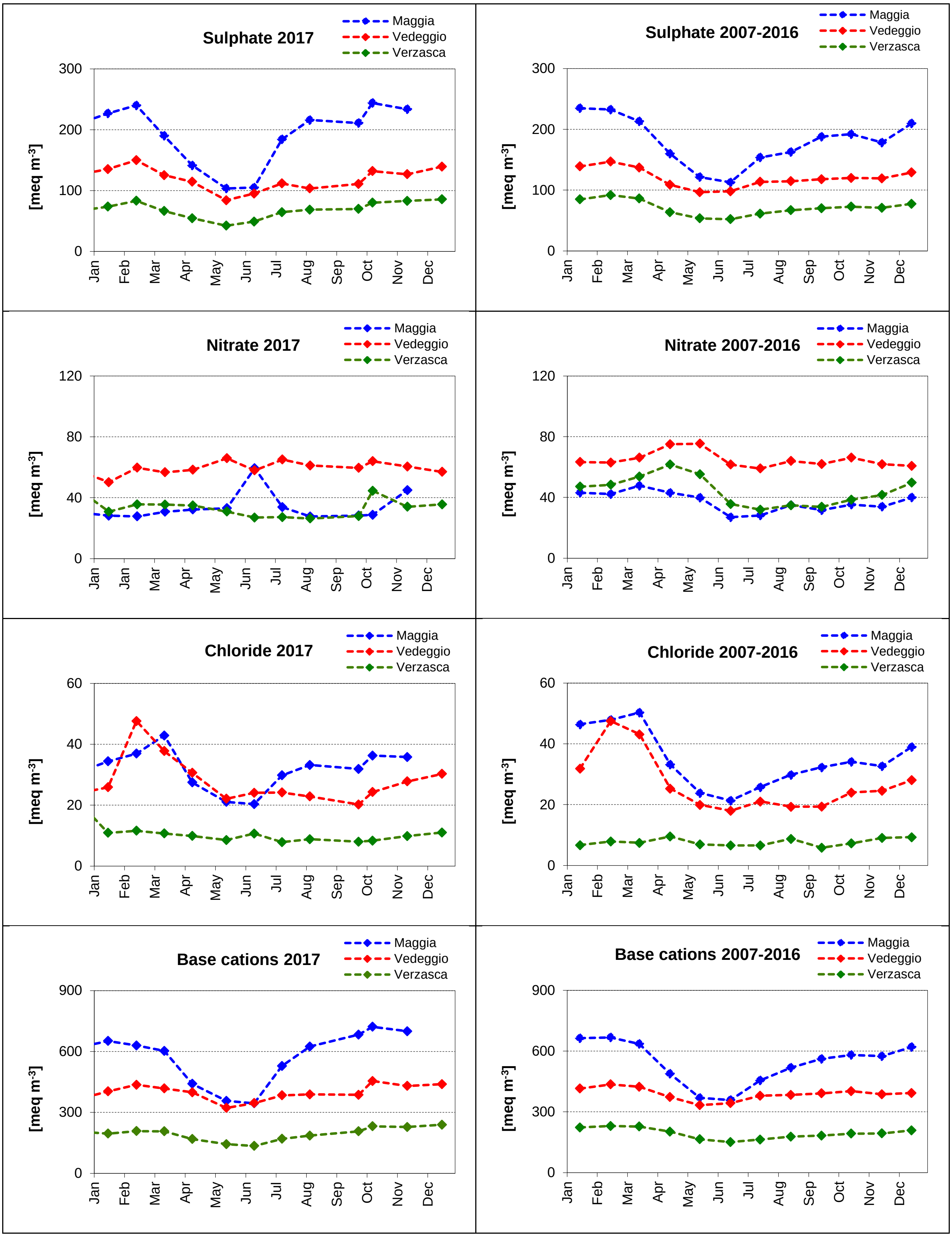
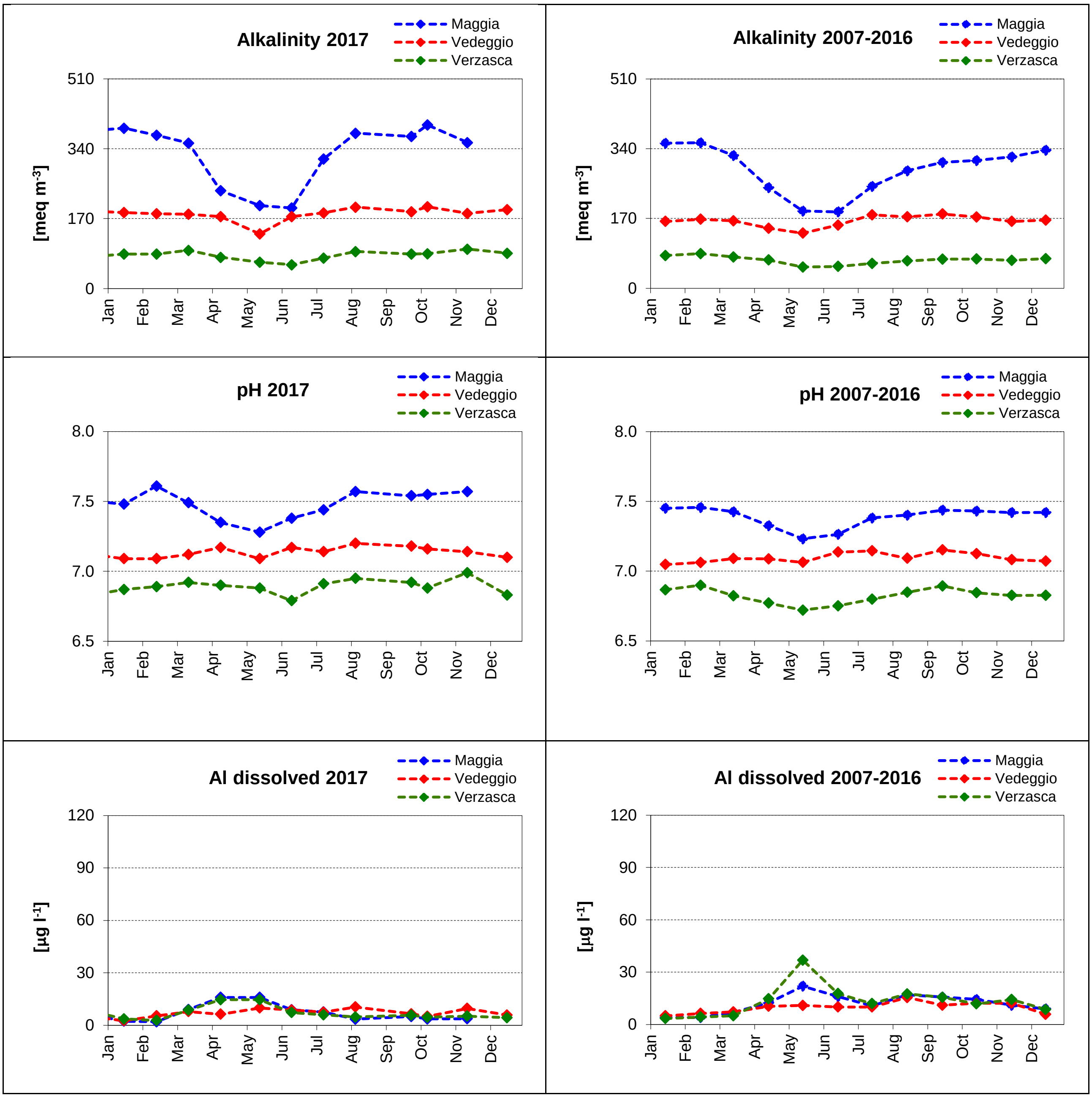
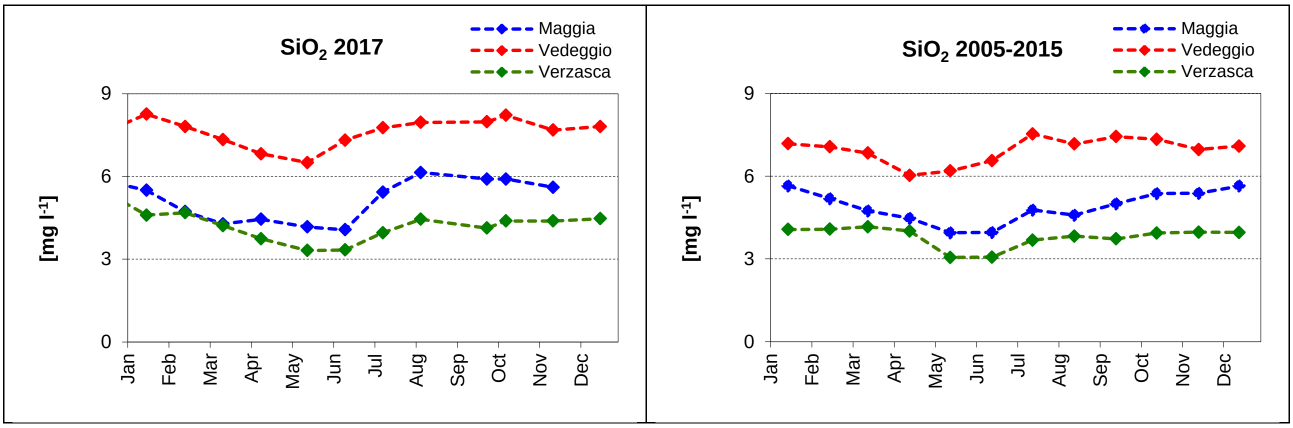


Figure 3.11 Concentrations of the main chemical parameters in river water during sampling days in 2017 and their average values from 2007 to 2016.




Alkalinity 2017
Maggia
Vedeggio
Verzasca
[meq m-3]
510
340
170
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Alkalinity 2007-2016
Maggia
Vedeggio
Verzasca
[meq m-3]
510
340
170
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
pH 2017
Maggia
Vedeggio
Verzasca
8.0
7.5
7.0
6.5
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
pH 2007-2016
Maggia
Vedeggio
Verzasca
8.0
7.5
7.0
6.5
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Al dissolved 2017
Maggia
Vedeggio
Verzasca
[µg l-1]
120
90
60
30
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Al dissolved 2007-2016
Maggia
Vedeggio
Verzasca
[µg l-1]
120
90
60
30
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec



Temporal variations

Variations of monthly average discharges and concentrations of chemical parameters from 2000 to 2017 are presented in Fig. 3.12 and 3.13, respectively.

Similar to the observations for lake chemistry, also in rivers, concentrations of sulphate, and during the last few years also of nitrate, seem to have decreased. However, as described for seasonal variations in river chemistry, concentrations are very much related to the river discharge and a yearly trend in river chemistry is difficult to detect at a glance. We therefore performed a seasonal Mann-Kendall test for the period 2000-2017. Results of the trend analysis are shown in Tab. 3.8. Concentrations of nitrate decreased significantly in all three rivers, while concentrations of sulphate decreased significantly only in rivers Vedeggio and Verzasca. Interestingly, during the same time concentrations of sulphate in river Maggia decreased significantly at Solduno (28.7 km downstream). Interestingly, concentrations of sulphate are also significantly lower at Solduno (mean 2000-2017: 139 meq m^{-3}) compared to Brontallo (189 meq m^{-3}). Sources of geogenic sulphur may be responsible for the missing decrease in sulphate in the upper river stretch (already discussed in the lake chapter). No significant trend can be observed for base cations and pH, while for alkalinity significant increasing trends were detected in river Vedeggio and Verzasca.

Figure 3.12 Monthly mean discharge in river water from 2000 to 2017. Discharge of river Vedeggio at Isone was measured by the Canton of Ticino (UCA, 2001-2018), discharge of river Verzasca at Sonogno was estimated by discharge values measured at Lavertezzo by BWG (2001-2004) and BAFU (2005-2018), discharge of river Maggia at Brontallo was estimated from values measured at Brontallo by Ofima and at Bignasco by BWG (2001-2004) and BAFU (2005-2018).

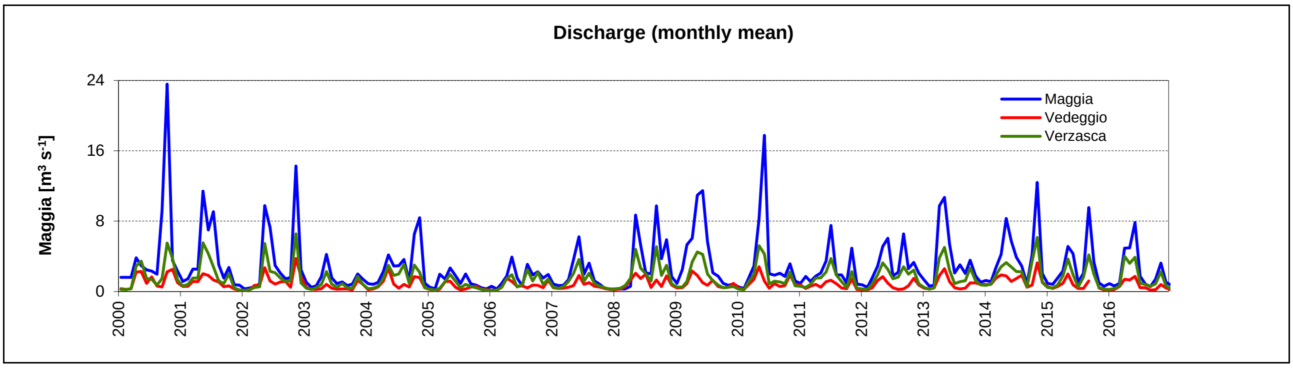
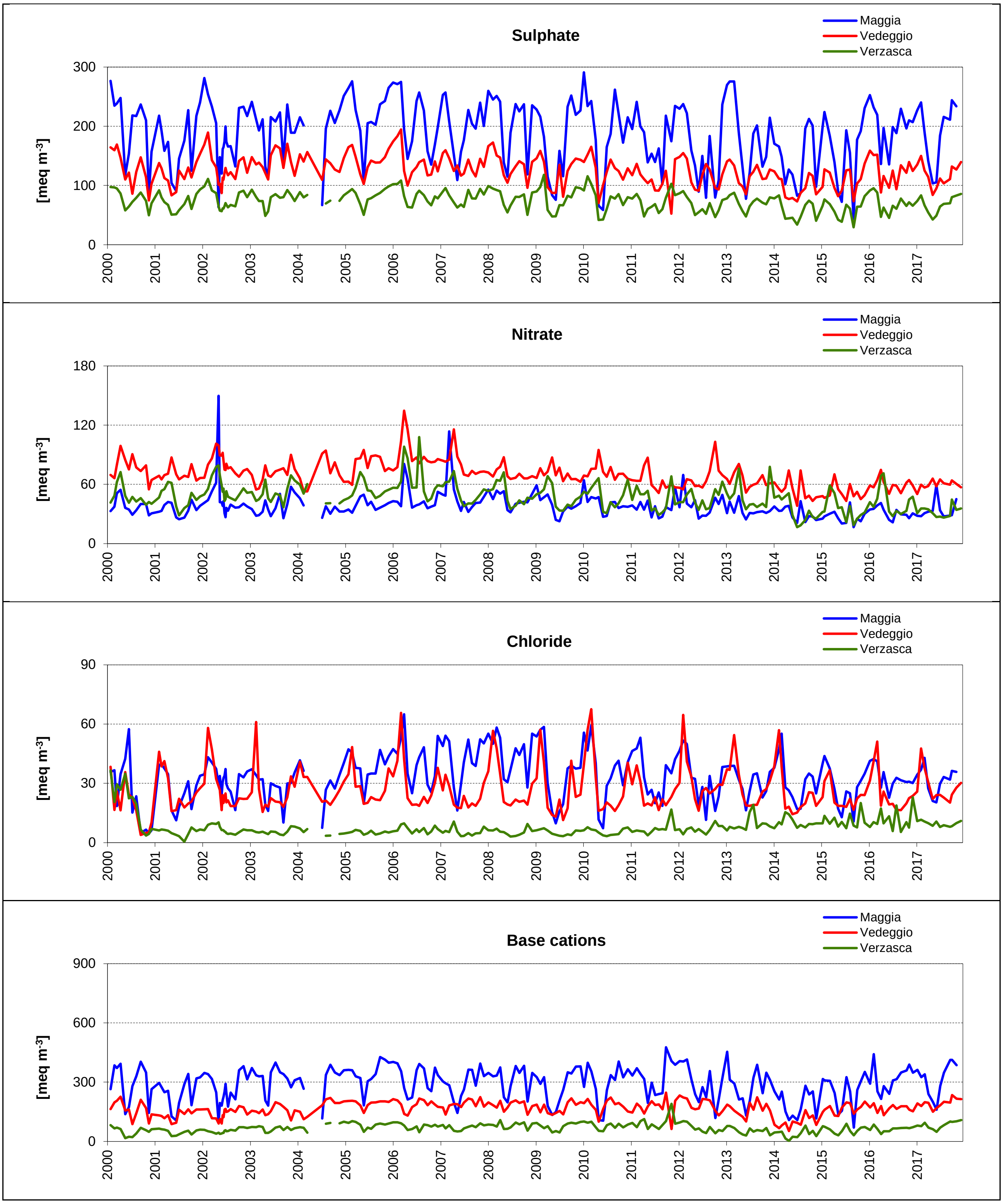
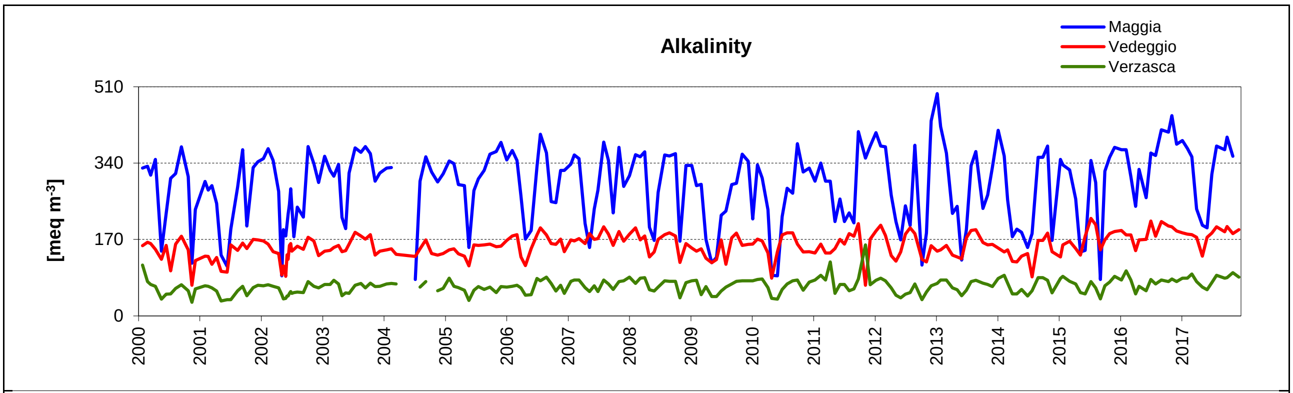
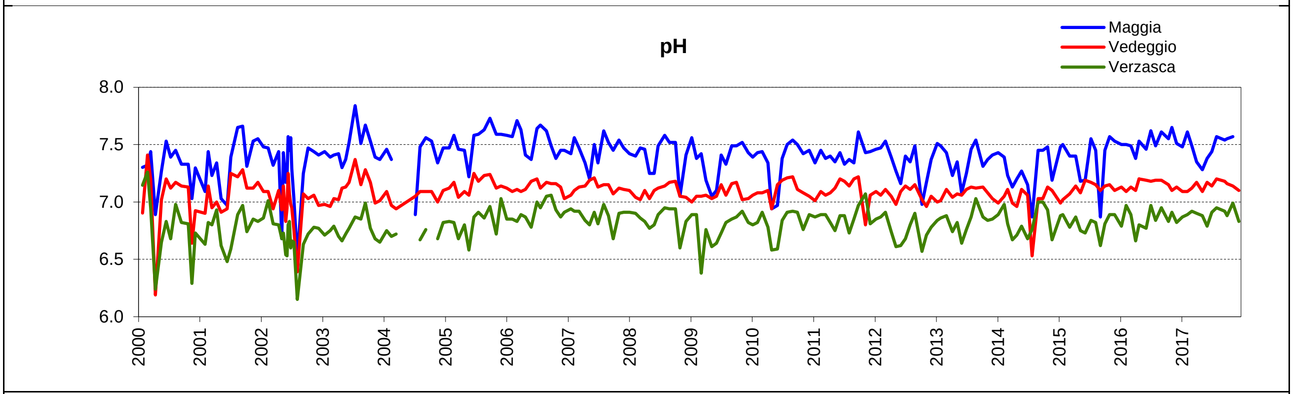
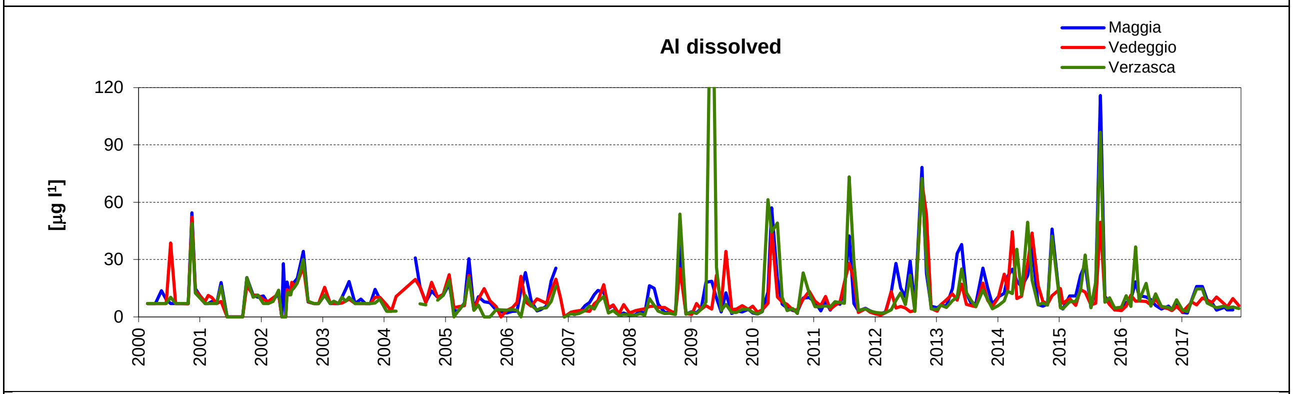


Figure 3.13 Concentrations of the main chemical parameters in river water from 2000 to 2017




Alkalinity
Maggia
Vedeggio
Verzasca
[meq m⁻³]
510
340
170
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017


pH
Maggia
Vedeggio
Verzasca
8.0
7.5
7.0
6.5
6.0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017


Al dissolved
Maggia
Vedeggio
Verzasca
[µg l⁻¹]
120
90
60
30
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

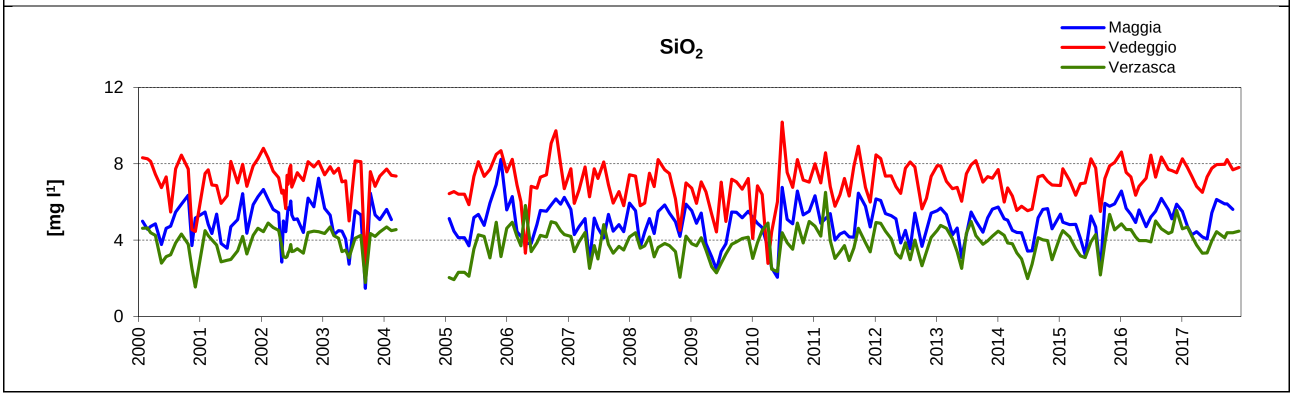

SiO_2
Maggia
Vedeggio
Verzasca
[mg l⁻¹]
12
8
4
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

Table 3.8 The probability level obtained with the seasonal Mann-Kendall test (p) and the changes in river water concentrations during the period 2000-2017 expressed in (meq m^{-3} yr^{-1}) calculated with the Sens's slope. Red values indicate significant trends.

River	SO_4^{2-}		NO_3^-		Cl^-		Base cations		H^+		Alkalinity	
	p	slope	p	slope	p	slope	p	slope	p	slope	p	slope
Maggia	0.138	-1.30	0.024	-0.55	0.662	0.08	0.574	-1.28	0.475	1.7E-4	0.117	1.60
Vedeggio	0.015	-1.30	0.001	-1.32	0.542	0.06	0.311	-1.60	0.249	-3.5E-4	0.004	1.70
Verzasca	0.007	-0.93	0.002	-1.06	0.006	0.23	0.228	-1.11	0.196	-1.3E-3	0.001	1.00

4 Macroinvertebrates as bioindicators

4.1 Introduction

The ultimate goal of emission control programmes is biological recovery (for example the return of acid sensitive species that have disappeared) and the restoration of biological functions that have been impaired during the course of acidification. Since concentrations of soluble aluminum start to increase below a pH of ca. 6.3, it is generally assumed that first signs of changes in the biological communities due to of acidification appear, when pH drops below 6 (Wright et al. 1975). To study biological recovery at sites with acidification problems, macroinvertebrates were included as bioindicators in the monitoring programme. Between 2000 and 2011 macroinvertebrates were regularly monitored in four lakes (Laghetto Inferiore, Laghetto Superiore, Lago di Tomè, Lago del Starlaresc da Sgiof) and three rivers (Maggia, Vedeggio, Verzasca). To facilitate a better interpretation of results from Alpine lakes, the alkaline lake Lago Bianco was added to the monitoring list from 2006 to 2011. After 2012, because of financial restrictions, monitoring of macroinvertebrates was limited to the most acid sensitive sites (Laghetto Inferiore, Laghetto Superiore, Lago di Tomè, Lago del Starlaresc da Sgiof and river Verzasca).

During 2017, spring and autumn lake pH's were 6.5 and 6.8 in Laghetto Inferiore, 6.4 and 6.8 in Laghetto Superiore, 5.6 and 5.4 in Lago del Starlaresc da Sgiof and 5.9 and 5.9 in Lago di Tomè. Concentrations of aluminum were 6 and 8 µg l^{-1} in Laghetto Inferiore and in Laghetto Superiore, 19 and 25 µg l^{-1} in Lago di Tomè and 58 and 69 µg l^{-1} in Lago del Starlaresc da Sgiof. Compared to Alpine lakes, river Verzasca is situated at much lower altitudes, having therefore a larger catchments area, which is responsible for higher average weathering rates. As a consequence river Verzasca is characterized by higher salinity and higher pH. During 2017 values ranged between 6.8 and 7.0 and aluminum between 3 and 15 µg l^{-1}.

From the beginning of the 1980's autumn pH and alkalinity increased significantly in all four lakes. During the macroinvertebrate monitoring period (from 2000 to present) autumn pH and alkalinity increased significantly only in lakes Laghetto Inferiore, Laghetto Superiore and Lago del Starlaresc da Sgiof. In Laghetto Inferiore pH and alkalinity increased from about 6.5 and 28 µeq l^{-1} (average 2000-2003) to 6.8 and 39 µeq l^{-1} (average 2014-2017), in Laghetto Superiore from 6.4 and 24 µeq l^{-1} to 6.8 and 40 µeq l^{-1}, in Lago del Starlaresc da Sgiof from 5.2 and -9 µeq l^{-1} to 5.8 and 5 µeq l^{-1} and in Lago di Tomè from 5.7 and 2 µeq l^{-1} to 5.9 and 7 µeq l^{-1}. Concentrations of dissolved aluminum decreased significantly only in the more acidic Lago del Starlaresc da Sgiof and Lago di Tomè. Values decreased from about 90 to 50 µg l^{-1} in the first and from 40 to 20 µeq l^{-1} in the second. In river Verzasca only alkalinity showed a significant improvement increasing from about 57 to 75 µg l^{-1}.

4.2 Methods

Macroinvertebrate samples were collected by "kicksampling" according to the ICP Waters Manual (ICP Waters Programme Centre, 2010). Until 2013 lake samples (Laghetto Inferiore, Laghetto Superiore, Lago di Tomè, Lago del Starlaresc da Sgiof) were collected from the littoral and the emissary 2-3 times a year. From 2014 because of financial reasons only emissaries have been sampled. Emissaries were preferred to littorals because they are known to be more often inhabited by indicator species for acidity (Steingruber et al. 2013). In fact, many of these species were determined for rivers and are therefore current loving. Sampling in river Verzasca occurred 3-8 times a year, after 2012 separate samples from a pool and a run zone were taken. Usually, for each site samples from fine and coarse substrates were collected separately. Before 2012 for each site a mixed sample from different substrates was sampled. Macroinvertebrates were conserved in 70% ethanol. For lakes, during the first 2 years (2000-2001) mixed littoral and outlet samples were taken. Because the results of these samples are difficult to compare with those after 2002, when littoral and outlet samples were collected separately, they were omitted in the temporal analysis. Instead, we used results from samples taken in the littorals and the outlets of Laghetto Inferiore and Superiore by the Institute for Ecosystem Studies in Pallanza during 1991 and results from samples taken in the littoral and the outlets of Laghetto Inferiore, Laghetto Superiore, Lago di Tomè, Lago del Starlaresc da Sgiof for EMERGE in 2000 (European Mountain lake Ecosystems: Regionalisation, diaGnostic & socio-economic Evaluation).

To show temporal trends, the relative abundances of the main taxonomic groups are shown (average values). In addition, the total number of taxa, the number of taxa belonging to the orders of Ephemeroptera, Plecoptera and Trichoptera (EPT taxa), considered particularly sensitive to pollution, and the number of acid sensitive taxa (AS taxa) according to literature are presented. In order to avoid differences in the taxa number that are caused by different levels of identification used for different surveys, for each taxonomic group a taxonomic identification level was defined and the results were filtered accordingly. The identification levels are the following: Annelida → class, Arachnida → subcohort, Coleoptera → genus, Diptera → family, Ephemeroptera → genus, Heteroptera → genus, Megaloptera → genus, Odonata → genus, Trichoptera → genus, Mollusca → class, Plathelminthes → family. Moreover, since the sample sizes varied greatly from year to year and it is known that the number of taxa/species increases with the number of individuals, the yearly numbers of taxa were standardized. For each sampling site linear regressions were calculated between the logarithm of the yearly number of taxa (total, EPT, AS) and the total number of sampled individuals. If statistically significant, this relations were used to standardize the yearly number of taxa (total, EPT, AS) to a sample size of 1000 individuals for total taxa. For rivers the acidification class described in Braukmann and Biss (2004) was also calculated.

For lakes chironomids are often the most important taxonomic group. In order to gain more information regarding the taxonomic composition of invertebrates, determination of chironomids from past samples down to the species level was started. Since their identification requires supplementary expertizes and therefore additional financial resources, this work is done irregularly when financing is available. Until now chironomids were determined for the years 2003, 2004, 2005, 2007, 2009, 2012, 2014 and 2015.

4.3 Results and discussion

4.3.1 Lakes

Sample size and the relative abundance of identified taxa and taxa groups (EPT, AS) with the most important taxa numbers (total, EPT, AS) in lake outlets during 2017 are shown in Tab. 4.1 and 4.2, respectively. At all sites Diptera was the most abundant taxonomic group, mainly represented by Chironomidae, but also by the current loving Simuliidae in Laghetto Inferiore, Laghetto Superiore, Lago di Tomè and by Ceratopogonidae in Lago del Starlaresc da Sgiof, probably because of the presence of wetland vegetation.

Other quantitatively important taxonomic groups were Oligochaeta (Naididae) and Turbellaria (Planariidae, probably the acid sensitive *Crenobia sp.*) in Laghetto Inferiore and Superiore. Another abundant order was Plecoptera. In Laghetto Inferiore and Superiore prevailed *Nemoura sp.* and *Protonemoura sp.*, in Lago di Tomè *Leuctra sp.* and in Lago del Staraleresc da Sgiof *Nemoura sp.* alone. Trichopterians were present in all lakes but with lower abundance, lowest abundances were found in Lago del Starlaresc da Sgiof. The more acid sensitive Ephemeroptera were found only in Laghetto Inferiore and Laghetto Superiore (*Ecdyonurus sp.*), while Odonata (*Aeshna sp., Libellula sp., Orthetrum sp.*), that are common in wetlands, were observed only in Lago del Starlaresc da Sgiof. In general, relative abundances of invertebrates sampled on fine and coarse substrates did no differ greatly.

As regards total taxa numbers (chironomids not included), highest values were found in Laghetto Inferiore (17) and Laghetto Superiore (16) followed by Lago di Tomè (13) and Lago del Starlaresc da Sgiof (13). The highest number of EPT taxa was identified in Laghetto Inferiore (12), then in Laghetto Superiore (11), Lago di Tomè (7) and at last in Lago del Starlaresc da Sgiof (2), while the highest number of AS taxa was determined in Laghetto Superiore (5), followed by Laghetto Inferiore (3), Lago di Tomè (2) and Lago del Starlaresc da Sgiof (0). The same rank order was observed for the relative abundance of EPT taxa (Laghetto Superiore: 24%, Laghetto Inferiore: 15%, Lago di Tomè: 20%, Lago del Starlaresc da Sgiof: 11%), while the relative abundance of AS taxa decreased as follows: Laghetto Inferiore (31%), Laghetto Superiore (23%), Lago di Tomé (2%), Lago del Starlaresc da Sgiof (0%). These abundances were mainly determined by the presence of Planariidae (probably *Crenobia alpina*). Relative abundances of other AS species were low (Laghetto Inferiore: 1.5% *Ecdyonurus sp.,* 0.2% *Protonemoura nimborum*; Laghetto Superiore: 1.9% *Ecdyonurus sp.,* 0.05% *Protonemoura nimborum,* 0.2% *Isoperla grandis,* 0.2% *Perlodes intricatus;* Lago di Tomè: 0.1% *Atherix ibis*). In Lago del Starlaresc da Sgiof acid sensitive taxa were absent. In general total, EPT, AS taxa and relative abundance of AS taxa decreased in the following lake order Laghetto Inferiore/Laghetto Superiore, Lago di Tomè and Lago del Starlaresc da Sgiof. This is well reflecting the increasing aluminum concentrations of these lakes (see par. 4.1). Also, pH's of both Lago di Tomè and Lago del Starlaresc da Sgiof are still, at least occasionally, below 6.

As mentioned in the method chapter, chironomids were not yet determined for the year 2017. However, during the already analyzed years (Tab. 4.7-4.10) the total number of taxa in the outlets was higher than in the littorals, which is not surprising since in the prior, species typical for both running and standing waters can be found. Among lakes the number of chironomid taxa followed the same rank order than observed for all other macroinvertebrates without the determination to species of chironomids. Highest total taxa numbers were found in Laghetto Superiore (outlet: 51, littoral: 41) and Laghetto Inferiore (outlet: 43, littoral: 35) and lower numbers in Lago di Tomè (outlet: 37, littoral: 25) followed by Lago del Starlaresc da Sgiof (outlet: 28, littoral: 23). This indicates that the number of chironomid taxa may also decrease with increasing acidity. In terms of taxa numbers the richest subfamily was Orthocladiinae followed by similar numbers of Chironominae and Tanypodinae. In terms of relative abundances, as expected from Alpine lakes (Füreder et al. 2012), Orthocladiinae was the dominant subfamily in the outlets of Laghetto Inferiore and Laghetto Superiore. In the littorals, next to Orthocladiinae, Tanypodinae and Tanytarsini (Chironominae) were also abundant. Differently, Tanytarsini dominated in both the outlet and littoral of Lago del Starlaresc da Sgiof. A similar fauna composition was found in warm Alpine lakes by Boggero and Lencioni (2006). Other publications[1] indicate abundance of Tanytarsini together with the presence of abundant algae or other aquatic plants. Indeed, because of its low depth (max. depth: 6 m) and its relatively low altitude (1865 m a.s.l.) Lago del Starlaresc da Sgiof is characterized by high summer surface temperatures (up to 21°C, July 2015) and aquatic vegetation. In the littoral of Lago di Tomè, Tanypodinae were most abundant followed by Orthocladiinae and Tanytarsini. In the outlet the relative abundance of Tanypodinae decreased, Chironomini increased and Orthocladiinae remained relatively unchanged. High abundances of Tanypodinae and Chironomini are reported to occur at warmer temperatures, while Orthocladiinae and Diamesinae seem to be more common in cold waters (Eggermont and Heiri, 2012). High abundance of Tanypodinae were also related to low altitude and high nitrate concentrations (Boggero and Lencioni, 2006). In fact, deep lake Lago di Tomè (max. depth 38 m) is situated at low altitude (1692 m a.s.l.) and has, compared to most other studied lakes, high nitrate concentrations and relatively high summer surface temperatures (up to 18°C, August 2003).

[1](http://www.landcareresearch.co.nz/resources/identification/animals/freshwater-invertebrates/guide/no-jointed-legs2/true-fly-larvae/midges/chironomid-midge13)

Table 4.1 Lake sample sizes during 2017

LAKE OUTLETS	MONTH	Fine substrate	Coarse substrate
INF	July (7.7.2017)	225	324
	October (15.09.2017)	315	319
SUP	July (7.7.2017)	525	333
	October (15.09.2017)	163	210
TOM	July (3.7.2017)	489	284
	October (13.09.2017)	116	88
STA	July (3.7.2017)	149	154
	October (13.09.2017)	177	418

Table 4.2 Relative abundance and number of taxa in lake outlets on different substrates during 2017. ***0.0% indicate values >0.0% but < 0.05%.***

TAXA	INF		SUP		TOM		STA		INF	SUP	TOM	STA
	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse				
OLIGOCHAETA	**10.2%**	**20.9%**	**18.5%**	**23.9%**				**7.7%**	**15.5%**	**21.2%**		**3.9%**
Naididae	10.2%	20.9%	18.5%	23.9%					15.5%	21.2%		
Oligochaeta								7.7%				3.9%
COLEOPTERA				**0.2%**	**0.4%**	**0.6%**		**1.9%**		**0.1%**	**0.5%**	**1.0%**
Agabus sp.				0.2%	0.4%	0.6%		0.3%		0.1%	0.5%	0.2%
Potamophilus sp.								1.6%				0.8%
DIPTERA	**38.6%**	**42.7%**	**37.6%**	**31.5%**	**87.3%**	**69.2%**	**95.9%**	**68.0%**	**40.7%**	**34.5%**	**78.3%**	**82.0%**
Atheriix ibis						0.2%					0.1%	
Ceratopogonidae	0.3%				0.4%		52.7%	13.4%	0.2%		0.2%	33.0%
Chironomidae	26.8%	24.0%	21.8%	27.1%	55.9%	42.8%	42.9%	51.9%	25.4%	24.4%	49.4%	47.4%
Simuliidae	11.5%	18.7%	15.8%	4.4%	31.0%	26.2%	0.3%	2.7%	15.1%	10.1%	28.6%	1.5%
EPHEMEROPTERA	**1.7%**	**1.3%**	**3.7%**	**0.2%**					**1.5%**	**1.9%**		
Ecdyonurus sp.	1.7%	1.3%	3.7%	0.2%					1.5%	1.9%		
ODONATA							**2.6%**	**1.5%**				**2.1%**
Aeshna affinis								0.4%				0.2%
Aeshna sp.							2.0%	1.0%				1.5%
Libellula sp.							0.3%					0.2%
Orthetrum sp.								1.0%				0.1%
Libellulidae							0.3%					0.1%
PLECOPTERA	**9.5%**	**11.7%**	**13.6%**	**22.1%**	**6.5%**	**22.7%**	**1.4%**	**20.7%**	**10.6%**	**17.9%**	**14.6%**	**11.1%**
Leuctra sp.	1.8%		3.1%	2.4%	3.5%	21.0%			0.9%	2.8%	12.2%	
Nemoura avicularis												
Nemoura minima				0.2%						0.1%		
Nemoura mortoni		0.2%			0.9%				0.1%		0.4%	
Nemoura sp.	4.9%	7.5%	8.9%	10.7%	2.1%	1.7%	1.4%	20.7%	6.2%	9.8%	1.9%	11.1%
Protonemoura nimborum.	0.4%		0.1%						0.2%	0.0%		
Protonemoura sp.	2.4%	4.0%	1.5%	8.0%					3.2%	4.7%		
Isoperla grammatica				0.3%						0.2%		
Perlodes intricatus				0.5%						0.2%		
TRICHOPTERA	**3.1%**	**2.0%**	**5.5%**	**2.1%**	**5.8%**	**4.7%**		**0.1%**	**2.6%**	**3.8%**	**5.2%**	**0.1%**
Limnephilus sp.	0.2%					0.7%			0.1%		0.4%	
Plectrocnemia sp.			0.3%	0.2%						0.3%		
Policentropodidae	1.0%								0.5%			
Rhyacophila (Rhyacophila) sp.	1.1%		5.2%	0.2%	2.4%	1.5%			0.6%	2.7%	1.9%	
Rhyacophila praemorsa	0.5%	0.3%		1.7%	0.9%				0.4%	0.8%	0.4%	
Rhyacophila sp.		0.3%			2.6%	2.4%			0.2%		2.5%	
Rhyacophlidae	0.3%	1.4%						0.1%	0.9%			0.1%
TURBELLARIA	**37.0%**	**21.5%**	**21.2%**	**20.1%**		**2.8%**			**29.2%**	**20.6%**	**1.4%**	
Planariidae	37.0%	21.5%	21.2%	20.1%		2.8%			29.2%	20.6%	1.4%	
Rel. abundance EPT taxa	14.3%	15.0%	22.8%	24.3%	12.3%	27.4%	1.4%	20.8%	14.6%	23.5%	19.8%	11.1%
Rel. abundance AS taxa	39.0%	22.7%	24.9%	21.1%		3.0%			30.9%	23.0%	1.5%	0.0%
Number total taxa	15	11	11	15	10	10	7	11	17	16	13	13
Number EPT taxa	10	7	7	10	6	5	1	2	12	11	7	2
Number AS taxa	3	2	3	4	0	2	0	0	3	5	2	0

Temporal changes of the relative abundances of the main taxa and taxa groups (EPT, AS) and most important taxa numbers (total, EPT, AS) are presented in Tab. 4.4-4.6. In Laghetto Inferiore, Laghetto Superiore and Lago del Starlaresc da Sgiof no temporal trends in the invertebrate population can be observed. In the first two lakes, acid sensitive indicators like the relative abundance of AS taxa and the number of AS indicate the presence of acid sensitive species, however their abundance and numbers did not change since the beginning of sampling, in the latter AS species are still absent. The only early sign of recovery seems to be the reappearance of *Crenobia alpina* in Lago di Tomè after 2006. As regards chironomids, results of the already determined years are shown in Tab. 4.7-4.10. Also for this taxa group the relative abundances and numbers of taxa did not change significantly with time.

Table 4.3 Temporal variations of the relative abundances and the number of taxa in the outlet of Laghetto Inferiore. *0% indicates values between 0% and < 0.5%.*

PARAMETER	1991	2000	2002	2003	2004	2005	2006	2007	2008	2009	2011	2012	2013	2014	2015	2016	2017
Sampling times	1	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2
Individuals	64	80	293	1224	2003	8353		7712	10507	5250	958	5170	4587	4587	1222	1669	1183
Rel. abundance OLIGOCHAETA	22%	6%	11%	25%	36%	30%		30%	23%	23%		0%	1%	7%	10%	17%	16%
Rel. abundance HYDRACARINA			1%	0%	0%	0%		0%	0%	0%	1%	0%	0%				
Rel. abundance COLEOPTERA				0%	0%	0%					0%						
Rel. abundance ELMIDAE				*0%*	*0%*												
Rel. abundance HYDROPHILIDAE						*0%*											
Rel. abundance DIPTERA	47%	25%	44%	45%	33%	45%		58%	52%	60%	92%	91%	92%	81%	63%	47%	41%
Rel. abundance ATHERICIDAE		*8%*		*7%*	*5%*	*2%*		*1%*	*1%*	*1%*	*3%*						
Rel. abundance CERATOPOGONIDAE																	*0%*
Rel. abundance CHIRONOMIDAE	*38%*	*13%*	*17%*	*29%*	*23%*	*18%*		*39%*	*46%*	*51%*	*86%*	*50%*	*70%*	*54%*	*55%*	*45%*	*25%*
Rel. abundance EMPIDIDAE						*0%*		*0%*	*0%*								
Rel. abundance LIMONIIDAE			*1%*	*1%*	*0%*				*0%*		*0%*	*0%*	*0%*	*0%*			
Rel. abundance PEDICIIDAE	*9%*																
Rel. abundance SIMULIDAE (%)		*5%*	*26%*	*8%*	*5%*	*25%*		*18%*	*6%*	*8%*	*2%*	*22%*	*22%*	*22%*	*9%*	*2%*	*15%*
Rel. abundance EPHEMEROPTERA				2%	2%	1%		1%	1%	0%	0%	0%	0%	0%	1%	2%	1%
Rel. abundance BAETIDAE						*0%*											
Rel. abundance HEPTAGENIIDAE				*2%*	*2%*	*1%*		*1%*	*1%*	*0%*	*0%*	*0%*	*0%*	*0%*	*1%*	*2%*	*1%*
Rel. abundance HETEROPTERA														0%			
Rel. abundance PLECOPTERA	27%	56%	33%	23%	16%	12%		5%	5%	6%	6%	2%	1%	7%	10%	9%	11%
Rel. abundance LEUCTRIDAE	*2%*		*0%*	*1%*	*0%*	*1%*		*0%*	*0%*	*0%*		*0%*	*1%*	*1%*	*0%*	*0%*	*1%*
Rel. abundance NEMOURIDAE	*25%*	*56%*	*33%*	*22%*	*15%*	*11%*		*5%*	*4%*	*6%*	*6%*	*2%*	*1%*	*7%*	*10%*	*9%*	*10%*
Rel. abundance PERLODIDAE				*0%*	*0%*	*0%*		*0%*	*0%*	*0%*							
Rel. abundance TAENIOPTERIGYDAE						*0%*											
Rel. abundance TRICHOPTERA		8%	1%	3%	3%	3%		0%	1%	1%	1%	0%	0%	1%	2%	2%	3%
Rel. abundance LEPIDOSTOMATIDAE				*0%*							*0%*						
Rel. abundance LIMNEPHILIDAE				*1%*	*0%*	*1%*		*0%*		*0%*				*0%*			*0%*
Rel. abundance PHILOPOTAMIDAE				*0%*	*1%*	*1%*					*0%*						
Rel. abundancePOLYCENTROPODIDAE				*0%*	*0%*	*0%*		*0%*	*0%*	*0%*	*0%*			*0%*	*0%*	*1%*	*0%*
Rel. abundance RHYACOPHILIDAE		*8%*	*1%*	*2%*	*2%*	*0%*		*0%*	*1%*	*1%*		*0%*	*0%*	*1%*	*1%*	*1%*	*2%*
Rel. abundance BIVALVIA											0%						
Rel. abundance TURBELLARIA	5%	5%	11%	2%	10%	8%		5%	18%	9%	1%	6%	4%	4%	14%	23%	29%
Rel. abundance	*5%*	*5%*	*11%*	*2%*	*10%*	*8%*		*5%*	*18%*	*9%*	*1%*	*6%*	*4%*	*4%*	*14%*	*23%*	*29%*
Rel. abundance EPT taxa	27%	64%	34%	28%	21%	16%		7%	6%	8%	6%	2%	2%	9%	13%	13%	15%
Rel. abundance AS taxa	5%	5%	11%	5%	14%	11%		6%	19%	9%	1%	6%	5%	4%	15%	25%	31%
Number of total taxa	8	8	11	21	18	23	15	21	20	17	13	11	11	12	11	11	13
Standardized number of total taxa	9	9	12	21	17	14	16	13	11	13	13	8	9	9	11	11	13
Number of EPT taxa	4	3	5	12	10	15	7	14	12	11	5	5	5	7	7	7	8
Standardized number of EPT taxa	4	3	5	12	9	7	8	7	5	7	5	3	4	5	7	7	8
Number of AS taxa	1	1	1	5	5	7	5	6	4	3	3	2	2	2	2	2	2

Table 4.4 Temporal variations of the relative abundances and the number of taxa in the outlet of Laghetto Superiore. ***0% indicates values between 0% and < 0.5%.***

PARAMETER	1991	2000	2002	2003	2004	2005	2006	2007	2008	2009	2011	2012	2013	2014	2015	2016	2017
Sampling times	1	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2
Individuals	49	34	150	1528	1744	6624	5736	5347	4977	5469	963	6725	1711	1249	1094	1177	1231
Rel. abundance OLIGOCHAETA	6%	3%	6%	21%	20%	38%	50%	64%	43%	29%	1%	24%	7%	26%	17%	18%	21%
Rel. abundance HYDRACARINA					0%	0%	0%	0%	0%	0%							
Rel. abundance COLEOPTERA				0%		0%			0%	0%	0%				0%		0%
Rel. abundance DRYOPIDAE				*0%*													
Rel. abundance DYTISCIDAE									*0%*						*0%*		*0%*
Rel. abundance HELOPHORIDAE											*0%*						
Rel. abundance HYDROPHILIDAE						*0%*											
Rel. abundance DIPTERA	63%	6%	50%	35%	49%	47%	38%	30%	49%	49%	81%	65%	88%	56%	43%	45%	35%
Rel. abundance CHIRONOMIDAE	*59%*	*6%*	*42%*	*30%*	*36%*	*31%*	*27%*	*19%*	*44%*	*43%*	*65%*	*63%*	*83%*	*38%*	*30%*	*41%*	*24%*
Rel. abundance EMPIDIDAE					*0%*	*0%*	*0%*										
Rel. abundance LIMONIIDAE			*3%*	*0%*	*0%*	*0%*	*0%*	*0%*		*0%*							
Rel. abundance PEDICIIDAE									*0%*								
Rel. abundance PSYCHIDIDAE									*0%*								
Rel. abundance PTYCHOPTERIDAE									*0%*								
Rel. abundance SIMULIDAE	*4%*		*5%*	*5%*	*13%*	*16%*	*11%*	*11%*	*5%*	*6%*	*16%*	*3%*	*4%*	*18%*	*12%*	*4%*	*10%*
Rel. abundance EPHEMEROPTERA				9%	7%	1%	0%	0%	0%	0%	1%		1%	0%	0%	2%	2%
Rel. abundance BAETIDAE				*2%*	*0%*	*0%*	*0%*										
Rel. abundance HEPTAGENIIDAE				*6%*	*7%*	*1%*	*0%*	*0%*	*0%*	*0%*	*1%*		*1%*	*0%*	*0%*	*2%*	*2%*
Rel. abundance HETEROPTERA					0%									0%			
Rel. abundance CORIXIDAE					*0%*									*0%*			
Rel. abundance PLECOPTERA	18%	68%	38%	29%	17%	11%	10%	3%	6%	21%	13%	7%	2%	12%	18%	19%	18%
Rel. abundance LEUCTRIDAE	*14%*	*9%*	*6%*	*12%*	*5%*	*5%*	*6%*	*1%*	*1%*	*2%*	*5%*	*2%*	*1%*	*3%*	*3%*	*3%*	*3%*
Rel. abundance NEMOURIDAE	*4%*	*59%*	*32%*	*17%*	*11%*	*6%*	*5%*	*2%*	*4%*	*2%*	*8%*	*5%*	*1%*	*9%*	*15%*	*16%*	*15%*
Rel. abundance PERLODIDAE				*0%*	*1%*	*0%*	*0%*	*0%*	*0%*		*0%*				*0%*	*0%*	*0%*
Rel. abundance TRICHOPTERA		24%	1%	4%	3%	1%	1%	1%	1%	1%	2%	1%	0%	0%	3%	2%	4%
Rel. abundance LIMNEOHILIDAE		*6%*		*0%*		*0%*	*0%*	*0%*				*0%*	*0%*				
Rel. abundance PHILOPOTAMIDAE		*6%*		*0%*	*0%*												
Rel. abundance POLYCENTROPODIDAE		*6%*	*1%*	*2%*	*1%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*1%*	*0%*		*0%*	*0%*	*0%*
Rel. abundance PSYCHO;YIIDAE		*3%*															
Rel. abundance RHYACOPHILIDAE		*3%*		*2%*	*3%*	*1%*	*0%*	*0%*	*0%*	*1%*	*1%*	*0%*	*0%*	*0%*	*3%*	*2%*	*4%*
Rel. abundance TURBELLARIA	12%		5%	1%	4%	1%	1%	2%	1%	1%	3%	2%	1%	5%	19%	15%	21%
Rel. abundance PLANORBIDAE	*12%*		*5%*	*1%*	*4%*	*1%*	*1%*	*2%*	*1%*	*1%*	*3%*	*2%*	*1%*	*5%*	*19%*	*15%*	*21%*
Rel. abundance EPT taxa	18%	91%	39%	43%	27%	13%	11%	4%	7%	21%	15%	8%	3%	13%	21%	22%	24%
Rel. abundance AS taxa	12%	3%	5%	11%	12%	2%	1%	3%	1%	1%	4%	2%	2%	5%	20%	17%	23%
Number of total taxa	6	11	10	19	22	20	18	20	24	17	14	10	11	9	13	11	13
Standardized number of total taxa	6	12	11	18	21	13	12	14	17	12	14	6	10	9	13	11	13
Number of EPT taxa	2	9	5	13	14	11	11	14	12	10	8	6	7	5	8	7	8
Standardized number of EPT taxa	2	10	5	12	13	7	7	10	8	7	8	4	7	5	8	7	8
Number of AS taxa	1	1	1	6	8	5	5	3	3	2	3	1	2	2	4	3	4

Table 4.5 Temporal variations of the relative abundances and the number of taxa in the outlet of Lago di Tomè. *0% indicates values between 0% and < 0.5%.*

PARAMETER	2000	2002	2003	2004	2005	2006	2007	2008	2009	2011	2012	2013	2014	2015	2016	2017
Sampling times	1	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2
Individuals	11	156	331	337	2128	2983	3975	4407	3726	230	866	319	4133	372	981	977
Rel. abundance OLIGOCHAETA		7%	1%	0%	0%	0%	0%	1%	1%	42%	4%	1%	15%			
Rel. abundance HYDRACARINA			1%	1%	0%	2%	1%	0%	0%		1%					
Rel. abundance COLEOPTERA		1%	3%		0%	0%	0%	0%	0%	1%	1%		1%	1%	0%	0%
Rel. abundance DYTISCIDAE		*1%*	*2%*		*0%*	*0%*	*0%*	*0%*	*0%*	*1%*				*1%*	*0%*	*0%*
Rel. abundance ELMIDAE			*1%*													
Rel. abundance DIPTERA	36%	28%	34%	40%	84%	58%	64%	90%	87%	53%	77%	72%	70%	67%	76%	78%
Rel. abundance Athericidae															*0%*	*0%*
Rel. abundance CERATOPOGONIDAE								*0%*						*1%*		*0%*
Rel. abundance CHIRONOMIDAE	*36%*	*14%*	*33%*	*37%*	*75%*	*38%*	*57%*	*61%*	*65%*	*26%*	*40%*	*68%*	*19%*	*50%*	*46%*	*49%*
Rel. abundance EMPIDIDAE					*0%*	*0%*	*0%*	*0%*					*0%*			
Rel. abundance LIMONIIDAE						*0%*										
Rel. abundance PSYCHODIDAE								*0%*		*0%*						
Rel. abundance SIMULIDAE		*14%*	*1%*	*3%*	*9%*	*20%*	*6%*	*29%*	*22%*	*26%*	*36%*	*5%*	*51%*	*16%*	*30%*	*29%*
Rel. abundance HETEROPTERA			0%		0%	0%							1%			
Rel. abundance MESOVELIIDAE													*1%*			
Rel. abundance MEGALOPTERA	18%	2%	1%	1%	0%		0%	0%	0%							
Rel. abundance SIALIDAE	*18%*	*2%*	*1%*	*1%*	*0%*		*0%*	*0%*	*0%*							
Rel. abundance PLECOPTERA	36%	60%	57%	58%	13%	37%	34%	8%	10%	3%	14%	27%	10%	28%	18%	
Rel. abundance LEUCTRIDAE	*36%*	*57%*	*55%*	*58%*	*12%*	*35%*	*34%*	*1%*	*9%*	*3%*	*10%*	*13%*	*4%*	*23%*	*16%*	*12%*
Rel. abundance NEMOURIDAE		*3%*	*2%*		*2%*	*1%*	*0%*	*1%*	*1%*		*4%*	*13%*	*6%*	*4%*	*3%*	*2%*
Rel. abundance PERLODIDAE								*0%*								
Rel. abundance TRICHOPTERA	9%	2%	4%	1%	2%	2%	1%	1%	1%	1%	1%	1%	3%	6%	4%	
Rel. abundance LIMNEPHILIDAE		*1%*	*1%*		*1%*	*1%*		*0%*	*1%*				*3%*	*1%*	*0%*	*0%*
Rel. abundance ODONTOCERIDAE						*0%*	*0%*		*0%*							
Rel. abundance PHILOPOTAMIDAE	*9%*															
Rel. abundance POLYCENTROPODIDAE		*1%*	*3%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*1%*	*1%*	*1%*				
Rel. abundance RHYACOPHILIDAE			*1%*	*1%*	*0%*	*1%*	*1%*	*0%*	*0%*				*0%*	*5%*	*3%*	*5%*
Rel. abundance TURBELLARIA						1%	0%	0%	0%		3%		0%		1%	1%
Rel. abundance PLANARIIDAE						*1%*	*0%*	*0%*	*0%*		*3%*		*0%*		*1%*	*1%*
Rel. abundance EPT taxa	45%	62%	61%	59%	15%	39%	35%	9%	12%	4%	15%	27%	13%	33%	22%	20%
Rel. abundance AS taxa					0%	1%	0%	0%	0%		3%		0%		1%	1%
Number of total taxa	4	10	15	8	17	18	17	22	20	7	10	7	13	8	9	10
Standardized number of total taxa	5	12	17	9	14	12	9	11	12	8	10	8	7	9	9	10
Number of EPT taxa	2	5	6	3	9	9	8	12	11	2	4	4	5	4	4	4
Standardized number of EPT taxa	3	6	7	4	7	5	4	5	5	2	4	5	2	5	4	4
Number of AS taxa	0	0	0	0	1	2	2	3	1	0	1	0	2	0	1	1

Table 4.6 Temporal variations of the relative abundances and the number of taxa in the outlet of Lago del Starlaresc da Sgiof. ***0% indicates values between 0% and < 0.5%.***

PARAMETER	2000	2002	2003	2004	2005	2006	2007	2008	2009	2011	2012	2013	2014	2015	2016	2017
Sampling times	1	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
Individuals	21	706	808	478	2634	6223	3451	3935	2846	604	774	929	1512	1493	976	898
Rel. abundance OLIGOCHAETA			1%	3%	3%	1%	0%	2%	10%		6%	6%		4%	4%	4%
Rel. abundance HYDRACARINA			1%	1%		0%	0%	1%	2%		6%	7%	0%			
Rel. abundance COLEOPTERA	14%	2%	0%	0%	0%	0%	0%	0%	0%	1%	0%		0%	0%		1%
Rel. abundance CHRYSOMELIDAE								*0%*								
Rel. abundance DYTISCIDAE	*14%*	*2%*	*0%*		*0%*	*0%*	*0%*	*0%*	*0%*	*1%*			*0%*	*0%*		*0%*
Rel. abundance ELMIDAE														*0%*		*1%*
Rel. abundance DIPTERA	29%	85%	91%	66%	89%	96%	85%	87%	74%	95%	69%	87%	73%	86%	83%	82%
Rel. abundance ATHERICIDAE					*0%*					*25%*						
Rel. abundance CERATOPOGONIDAE		*16%*	*5%*	*10%*	*14%*	*3%*	*5%*	*14%*	*13%*	*7%*	*20%*	*15%*	*8%*	*12%*	*30%*	*33%*
Rel. abundance CHIRONOMIDAE	*29%*	*69%*	*85%*	*56%*	*75%*	*93%*	*79%*	*71%*	*56%*	*63%*	*35%*	*59%*	*16%*	*73%*	*53%*	*47%*
Rel. abundance LIMONIIDAE							*0%*									
Rel. abundance PSYCHIDIDAE					*0%*					*0%*						
Rel. abundance SIMULIDAE				*0%*	*0%*	*0%*	*1%*	*2%*	*4%*	*0%*	*15%*	*13%*	*49%*	*1%*		*2%*
Rel. abundance TABANIDAE																
Rel. abundance EPHEMEROPTERA								0%								
Rel. abundance BAETIDAE								*0%*								
Rel. abundance HETEROPTERA			1%	11%	0%	0%	0%	0%	0%	0%	0%	0%				
Rel. abundance CORIXIDAE			*0%*	*11%*	*0%*	*0%*	*0%*	*0%*	*0%*							
Rel. abundance GERRIDAE			*0%*							*0%*	*0%*	*0%*				
Rel. abundance MEGALOPTERA									0%							
Rel. abundance SIALIDAE									*0%*							
Rel. abundance ODONATA		6%	0%	13%	5%	1%	3%	2%	2%	2%	3%	0%	1%	1%	1%	2%
Rel. abundance AESHNIDAE		*5%*	*0%*	*12%*	*4%*	*1%*	*3%*	*1%*	*1%*	*1%*	*2%*	*0%*	*0%*	*1%*	*1%*	*2%*
Rel. abundance CORDULIDAE				*1%*	*1%*	*0%*	*0%*	*0%*	*0%*	*1%*						
Rel. abundance LIBELLULIDAE		*1%*									*1%*		*0%*	*0%*	*1%*	*0%*
Rel. abundance PLECOPTERA	24%	2%	2%	5%	1%	1%	9%	8%	12%	1%	16%		26%	8%	12%	11%
Rel. abundance NEMOURIDAE	*24%*	*2%*	*2%*	*5%*	*1%*	*1%*	*9%*	*8%*	*12%*	*1%*	*16%*		*26%*	*8%*	*12%*	*11%*
Rel. abundance TRICHOPTERA	33%	5%	4%		0%	0%	1%	1%	1%				0%	1%		1%
Rel. abundance LIMNEPHLIDAE			*0%*		*0%*	*0%*	*0%*	*0%*								
Rel. abundance PHRYGANEIDAE	*33%*	*5%*	*4%*		*0%*	*0%*	*1%*	*0%*	*0%*				*0%*			
Rel. abundance POLYCENTROPODIDAE						*0%*	*0%*	*0%*	*1%*					*0%*		*0%*
Rel. abundance EPT taxa	57%	7%	6%	5%	2%	1%	10%	9%	13%	1%	16%		26%	9%	12%	11%
Rel. abundance AS taxa								0%								
Number of total taxa	4	8	13	11	16	16	19	23	18	12	10	7	9	12	8	12
Standardized number of total taxa	5	8	13	12	12	6	12	13	13	13	10	7	8	11	8	12
Number of EPT taxa	2	3	3	1	4	6	6	8	6	1	1	0	2	2	1	2
Standardized number of EPT taxa	3	3	3	1	2	1	3	3	3	1	1	0	2	2	1	2
Number of AS taxa	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Table 4.7 Temporal variations of the relative abundances and the number of taxa in Laghetto Inferiore. ***0% indicates values between 0% and < 0.5%.***

SITE	PARAMETER	1991	2002	2003	2004	2005	2006	2007	2008	2009	2011	2012	2013	2014	2015	2016	2017
OUT	Sampling times	1		3	2	3	2	2	2	2		2		2	2	2	2
	Individuals	24		277	204	1256		2584		2410		3718		2344	624		
	Rel. abundance CHIRONOMINAE	21%		5%	0%	9%		2%		3%		0%		3%	2%		
	Rel. abundance Chirnonomini																
	Rel. abundance Tanytarsini	21%		5%	0%	9%		2%		3%		0%		3%	2%		
	el. abundance DIAMESINAE	13%			2%			1%									
	Rel. abundance Diamesini	13%			2%			1%									
	Rel. abundance ORTHOCLADIINAE	67%		94%	96%	91%		96%		95%		100%		97%	96%		
	Rel. abundance PRODIAMESINAE																
	Rel. abundance TANYPODINAE			0%		1%		1%		1%		0%		0%	1%		
	Rel. abundance Macropelopiini							0%									
	R Rel. abundance Pentaneurini			0%		1%		1%		1%		0%		0%	1%		
	R R Rel. abundance Procladiini																
	Rel. abundance NOT DETERMINED			1%	1%					2%							
	Number of total taxa	8		11	10	11		28		13		18		12	11		
	Standardized number of total taxa	9		11	9	6		16		9		13		9	11		
LIT	Sampling times	1		3	3	3	2	2	2	2		2					
	Individuals	147		1103	945	3757		1763		1991							
	Rel. abundance CHIRONOMINAE	17%		18%	34%	36%		19%		20%							
	Rel. abundance Chirnonomini			1%	1%	0%		4%		1%							
	Rel. abundance Tanytarsini	17%		17%	33%	36%		15%		19%							
	el. abundance DIAMESINAE	7%						0%									
	Rel. abundance Diamesini	0%						0%									
	Rel. abundance ORTHOCLADIINAE	61%		50%	28%	43%		47%		39%							
	Rel. abundance PRODIAMESINAE	5%		2%	1%	1%		1%		2%							
	Rel. abundance TANYPODINAE	10%		26%	36%	20%		33%		39%							
	Rel. abundance Macropelopiini			2%	0%	1%		2%		5%							
	R Rel. abundance Pentaneurini	10%		24%	36%	19%		31%		34%							
	R R Rel. abundance Procladiini																
	Rel. abundance NOT DETERMINED			4%	1%					0%							
	Number of total taxa	10		17	13	19		19		11							
	Standardized number of total taxa	11		17	13	13		16		9							

Table 4.8 Temporal variations of the relative abundances and the number of taxa in Laghetto Superiore. *0% indicates values between 0% and < 0.5%.*

SITE	PARAMETER	1991	2002	2003	2004	2005	2006	2007	2008	2009	2011	2012	2013	2014	2015	2016	2017
OUT	Sampling times	1		3	2	2	2	2	2	2		2		1	2	2	2
OUT	Individuals	29		415	423	1316		740		1401		2251		139	309		
OUT	Rel. abundance CHIRONOMINAE	21%		9%	6%	9%		1%		1%		1%			7%		
OUT	Rel. abundance Chirnonomini											0%					
OUT	Rel. abundance Tanytarsini	21%		9%	6%	9%		1%		1%		1%			7%		
OUT	el. abundance DIAMESINAE	17%			1%	0%		7%		0%		0%			1%		
OUT	Rel. abundance Diamesini	17%			1%	0%		7%		0%		0%			1%		
OUT	Rel. abundance ORTHOCLADIINAE	62%		73%	83%	90%		90%		96%		76%		100%	70%		
OUT	Rel. abundance PRODIAMESINAE																
OUT	Rel. abundance TANYPODINAE			16%	5%	2%		1%		2%		23%			21%		
OUT	Rel. abundance Macropelopiini					0%											
OUT	R Rel. abundance Pentaneurini			16%	5%	1%		1%		2%		23%			21%		
OUT	R R Rel. abundance Procladiini																
OUT	Rel. abundance NOT DETERMINED			2%	4%					1%							
OUT	Number of total taxa	7		18	15	15		23		13		18		8	19		
OUT	Standardized number of total taxa	7		17	14	10		17		9		12		8	19		
LIT	Sampling times	1		3	3	3	2	2	2	2		2					
LIT	Individuals	487		1075	1174	5026		1689		3097		2128					
LIT	Rel. abundance CHIRONOMINAE	3%		11%	18%	20%		14%		34%		4%					
LIT	Rel. abundance Chirnonomini			0%	0%			0%				0%					
LIT	Rel. abundance Tanytarsini	3%		11%	18%	20%		13%		34%		3%					
LIT	el. abundance DIAMESINAE	13%															
LIT	Rel. abundance Diamesini	13%															
LIT	Rel. abundance ORTHOCLADIINAE	76%		68%	51%	61%		50%		49%		89%					
LIT	Rel. abundance PRODIAMESINAE	3%		1%	2%	1%		1%		0%		0%					
LIT	Rel. abundance TANYPODINAE	4%		15%	28%	19%		35%		17%		7%					
LIT	Rel. abundance Macropelopiini			2%	2%	1%		3%		2%		1%					
LIT	R Rel. abundance Pentaneurini	3%		13%	25%	18%		32%		15%		6%					
LIT	R R Rel. abundance Procladiini																
LIT	Rel. abundance NOT DETERMINED			4%	1%					0%							
LIT	Number of total taxa	15		17	12	15		21		13		18					

Table 4.9 Temporal variations of the relative abundances and the number of taxa in Lago di Tomè. ***0% indicates values between 0% and < 0.5%.***

LAKE	PARAMETER	2002	2003	2004	2005	2006	2007	2008	2009	2011	2012	2013	2014	2015	2016	2017
OUT	Sampling times		2	1	2	2	2	2	2		2		1	2	2	2
	Individuals		64	115	1035		1845		2606		132		544	193		
	Rel. abundance CHIRONOMINAE		16%	5%	67%		45%		69%		54%		93%	46%		
	Rel. abundance Chirnonomini		14%		63%		42%		65%		54%		93%	42%		
	Rel. abundance Tanytarsini		2%	5%	4%		2%		4%					4%		
	el. abundance DIAMESINAE										1%					
	Rel. abundance Diamesini										1%					
	Rel. abundance ORTHOCLADIINAE		26%	77%	16%		36%		22%		45%		4%	18%		
	Rel. abundance PRODIAMESINAE															
	Rel. abundance TANYPODINAE		58%	18%	15%		16%		4%				2%	36%		
	Rel. abundance Macropelopiini															
	R Rel. abundance Pentaneurini		58%	18%	15%		16%		4%				2%	36%		
	R R Rel. abundance Procladiini															
	Rel. abundance NOT DETERMINED						4%		1%							
	Number of total taxa		6	8	11		23		13		13		8	11		
	Standardized number of total taxa		6	9	10		16		9		13		6	12		
LIT	Sampling times		2	2	2	2	2	2	2		2					
	Individuals		151	119	744		858		2009		362					
	Rel. abundance CHIRONOMINAE		25%	6%	13%		7%		21%		19%					
	Rel. abundance Chirnonomini				1%		0%		0%							
	Rel. abundance Tanytarsini		25%	6%	13%		6%		21%		19%					
	el. abundance DIAMESINAE															
	Rel. abundance Diamesini															
	Rel. abundance ORTHOCLADIINAE		18%	40%	12%		29%		27%		27%					
	Rel. abundance PRODIAMESINAE		1%		1%		1%		1%		1%					
	Rel. abundance TANYPODINAE		56%	51%	73%		60%		44%		53%					
	Rel. abundance Macropelopiini		2%	1%			0%									
	R Rel. abundance Pentaneurini		53%	50%	73%		60%		44%		53%					
	R R Rel. abundance Procladiini															
	Rel. abundance NOT DETERMINED		1%	3%			3%		7%							
	Number total taxa		11	9	11		13		12		13					
	tandardized number of total taxa		12	9	10		12		11		14					

Table 4.10 Temporal variations of the relative abundances and the number of taxa in Lago del Starlaresc da Sgiof. ***0% indicates values between 0% and < 0.5%.***

LAKE	PARAMETER	2002	2003	2004	2005	2006	2007	2008	2009	2011	2012	2013	2014	2015	2016	2017
OUT	Sampling times		2	1	2	2	2	2	2		1		1	2	2	2
	Individuals		625	211	1462		1768		1532		74		270	952		
	Rel. abundance CHIRONOMINAE		81%	32%	58%		46%		60%		50%		90%	72%		
	Rel. abundance Chirnonomini		32%	9%	2%		1%		0%				0%	1%		
	Rel. abundance Tanytarsini		49%	23%	55%		44%		60%		50%		90%	71%		
	el. abundance DIAMESINAE				0%				1%							
	Rel. abundance Diamesini				0%				1%							
	Rel. abundance ORTHOCLADIINAE		10%	48%	37%		43%		36%		14%		9%	28%		
	Rel. abundance PRODIAMESINAE															
	Rel. abundance TANYPODINAE		8%	18%	5%		10%		3%		36%		1%	0%		
	Rel. abundance Macropelopiini		1%		0%		0%									
	R Rel. abundance Pentaneurini		7%	18%	5%		9%		2%		1%		1%	0%		
	R R Rel. abundance Procladiini		0%		0%		0%		0%							
	Rel. abundance NOT DETERMINED		1%	2%			2%		1%							
	Number of total taxa		12	10	16		20		14		12		8	15		
	Standardized number of total taxa		12	11	12		13		10		13		7	14		
LIT	Sampling times		2	1	2	2	2	2	2		2					
	Individuals		216	148	526		1470		784		832					
	Rel. abundance CHIRONOMINAE		84%	64%	57%		60%		79%		44%					
	Rel. abundance Chirnonomini		11%	6%	2%		1%		9%		2%					
	Rel. abundance Tanytarsini		72%	57%	55%		59%		70%		42%					
	el. abundance DIAMESINAE															
	Rel. abundance Diamesini															
	Rel. abundance ORTHOCLADIINAE		7%	26%	26%		25%		9%		6%					
	Rel. abundance PRODIAMESINAE															
	Rel. abundance TANYPODINAE		10%	8%	17%		15%		9%		50%					
	Rel. abundance Macropelopiini		6%	2%	3%		3%		2%							
	R Rel. abundance Pentaneurini		2%	6%	3%		1%		1%		1%					
	R R Rel. abundance Procladiini		2%		11%		11%		6%		18%					
	Rel. abundance NOT DETERMINED			2%			0%		3%							
	Number of total taxa		9	11	14		15		12		13					
	Standardized number of total taxa		10	12	13		11		12		11					

4.3.2 Rivers

The number of identified individuals and the relative abundance of identified taxa and taxa groups (EPT, AS) with the most important taxa numbers (total, EPT, AS) and the Braukmann and Biss (2004) class of river Verzasca during 2017 are shown in Tab. 4.11 and 4.12, respectively. The most abundant taxonomic groups were Ephemeroptera and Plecoptera. From the composition of the invertebrate population a Braukmann and Biss (2004) class of on average 2 can be calculated which stands for predominantly neutral to episodically weakly acidic waters with pH’s normally around 6.5-7.0. This corresponds quite well with the measured water chemistry.

Tab. 4.13 shows the temporal variation of the relative abundances of the main taxa and taxa groups, taxa numbers (total, EPT, AS) and acidification class according to Braukmann and Biss (2004). A significant temporal trend cannot be observed.

Table 4.11 River Verzasca sample sizes during 2017.

RIVER	SITE	SUBSTRATE	March (8.3.17)	July (7.7.17)	November (7.11.17)
VER	Pool	fine	449	451	563
		coarse	964	681	682
	Run	fine	939	717	274
		coarse	911	646	588

Table 4.12 Relative abundance and number of taxa in river Verzasca during 2017. ***0.0% indicate values >0.0% but < 0.05%.***

TAXA	Pool		Run		Yearly average
	Fine	Coarse	Fine	Coarse	
OLIGOCHAETA	**0.2%**	**0.0%**	**0.1%**	**0.1%**	**0.1%**
Naididae	0.1%		0.0%	0.1%	0.1%
Oligochaeta	0.1%	0.0%	0.0%	0.0%	0.0%
HYDRACARINA	**0.1%**	**0.1%**	**0.2%**		**0.1%**
COLEOPTERA	**13.5%**	**13.7%**	**14.1%**	**9.3%**	**12.6%**
Esolus sp.	12.9%	12.3%	11.7%	8.9%	11.4%
Hydraena sp.	0.7%	1.4%	2.3%	0.4%	1.2%
DIPTERA	**27.4%**	**7.6%**	**19.1%**	**20.6%**	**18.7%**
Athericidae	0.1%				0.0%
Atherix ibis	2.5%	1.5%	3.2%	3.8%	2.7%
Blephariceridae		0.2%	0.2%	0.3%	0.2%
Chironomidae	22.5%	4.3%	12.6%	15.2%	13.6%
Hexatoma sp.	0.1%	0.4%	0.2%	0.0%	0.2%
Limoniidae	0.5%	0.1%	0.3%	0.5%	0.3%
Pediciidae	1.3%	0.1%		0.3%	0.4%
Simuliidae	0.4%	1.1%	2.6%	0.4%	1.1%
EPHEMEROPTERA	**37.7%**	**62.9%**	**41.4%**	**37.6%**	**44.9%**
Baetis alpinus				0.1%	
Baetis sp.	25.6%	33.0%	25.3%	24.1%	27.0%
Ecdyonurus helveticus		0.1%	0.0%		0.0%
Ecdyonurus sp.	1.5%	6.3%	5.3%	8.6%	5.4%
Epeorus alpinus	0.2%	0.1%		0.0%	0.1%
Epeorus sp.	0.4%	0.4%	1.7%	0.4%	0.7%
Rhithrogena sp.	10.1%	22.9%	9.1%	4.3%	11.6%
PLECOPTERA	**17.6%**	**12.4%**	**20.5%**	**26.1%**	**19.2%**
Leuctra sp.	3.8%	3.4%	6.8%	6.2%	5.0%
Amphinemoura sulcicollis		0.1%	0.1%	0.1%	0.1%
Amphinemoura standfussi		0.3%			0.1%
Amphinemoura sp.	0.8%	0.7%	0.4%	0.8%	0.7%
Nemoura mortoni	0.3%	0.3%	0.2%	0.1%	0.2%
Nemoura sp.	6.2%	3.6%	3.9%	9.3%	5.7%
Protonemura brevistyla		0.0%			0.0%
Protonemura nimborum			0.0%	7.5%	1.9%
Protonemura sp.	5.2%	3.2%	6.9%	1.2%	4.1%
Perla grandis	0.5%	0.3%	0.2%	0.3%	0.3%
Perla sp.	0.2%	0.4%	2.1%	0.4%	0.8%
Isoperla sp.	0.1%	0.1%		0.1%	0.1%
Rhabdiopteryx neglecta			0.1%	0.0%	0.0%
Rhabdiopteryx sp.	0.5%	0.0%		0.1%	0.1%

TAXA	Pool		Run		Yearly average
	Fine	Coarse	Fine	Coarse	
TRICHOPTERA	**2.0%**	**2.6%**	**4.5%**	**4.5%**	**3.4%**
Hydropsyche modesta		0.1%			0.0%
Hydropsyche sp.			0.1%	0.1%	0.0%
Drusus alpnus	0.1%				0.0%
Drusus annulatus			0.0%		0.0%
Drusus discolor		0.1%		0.1%	0.0%
Drusus muelleri	0.1%		0.1%	0.0%	0.1%
Drusus sp.			0.1%	0.1%	0.1%
Melampophylax mucoreus		0.0%			0.0%
Philopotamus montanus	0.2%	0.9%	0.3%	2.3%	0.9%
Philopotamus sp.		0.1%	1.3%		0.4%
Wormaldia copiosa		0.1%	0.5%	0.1%	0.2%
Wormaldia sp.			1.0%	0.4%	0.3%
Rhyacophila sp.			0.9%	1.0%	0.5%
Rhyacophila torrentium (SG; Hyperrhyacophila)	1.1%	0.3%	0.2%	0.1%	0.4%
Rhyacophila sp. (SG: Hyperrhyacophila)			0.0%		0.0%
Rhyacophila sp. (SG: Hyporhyacophila)	0.1%	0.6%			0.2%
Rhyacophila dorsalis-Gr. (SG: Rhyacophila)	0.1%	0.2%			0.1%
Rhyacophila sp. (SG. Rhyacophila)	0.2%	0.1%		0.5%	0.2%
TURBELLARIA	**1.5%**	**0.6%**	**0.2%**	**1.8%**	**1.0%**
Polycelis tenuis/nigra			0.0%		0.0%
Planariidae	1.5%	0.6%	0.2%	1.8%	1.0%
Rel. abundance EPT taxa	57.3%	77.9%	66.4%	68.2%	67.5%
Rel. abundance AS taxa	43.4%	68.4%	52.5%	54.7%	54.8%
Number total taxa	35	40	39	40	54
Number EPT taxa	22	28	26	28	39
Number AS taxa	12	16	17	17	21
Acidification class (Braukmann & Biss)	2	2	2	2	2

Table 4.13 Temporal variations of the relative abundances and the number of taxa in river Verzasca.
0% indicate values >0% but < 0.5%.

PARAMETER	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2011	2012	2013	2014	2015	2016	2017
Sampling times	8	6	6	6	5	4	4	4	4	4	4	3	3	3	3	3	3
Individuals	1574	2258	2569	3759	4267	12894	15012	21046	20233	11684	4510	8570	8404	5885	6813	7210	7865
Rel. abundance OLIGOCHAETA	0%	1%	0%		0%	1%	0%	3%	1%	5%	0%	1%	0%	0%	3%	0%	0%
Rel. abundance HYDRACARINA	2%	1%	1%	2%	0%	1%	1%	1%	2%	1%	1%	1%	1%	0%	0%	0%	0%
Rel. abundance COLEOPTERA	18%	22%	23%	14%	18%	16%	24%	19%	17%	8%	22%	11%	12%	5%	13%	12%	13%
Rel. abundance CURCUULIONIDAE														*0%*			
Rel. abundance DRYOPIDAE			*0%*														
Rel. abundance DYTISCIDAE		*0%*						*0%*	*0%*								
Rel. abundance ELMIDAE		*17%*	*20%*	*21%*	*14%*	*17%*	*15%*	*24%*	*19%*	*16%*	*8%*	*22%*	*11%*	*5%*	*13%*	*11%*	*11%*
Rel. abundance HALIPLIDAE					*0%*												
Rel. abundance HELODIDAE						*0%*	*0%*		*0%*			*0%*					
Rel. abundance HYDRAENIDAE		*1%*	*2%*	*0%*	*1%*	*1%*	*0%*	*0%*	*0%*	*0%*	*1%*	*0%*		*0%*	*1%*	*1%*	*1%*
Rel. abundance HYDROPHILIDAE									*0%*								
Rel. abundance SCIRTIDAE						*0%*	*0%*		*0%*			*0%*					
Rel. abundance DIPTERA	12%	8%	10%	19%	12%	19%	20%	22%	23%	21%	30%	36%	38%	5%	12%	19%	19%
Rel. abundance ATHERICIDAE	*3%*	*2%*	*2%*	*1%*	*1%*	*1%*	*1%*	*0%*	*1%*	*0%*	*1%*	*0%*	*0%*	*0%*	*2%*	*1%*	*3%*
Rel. abundance BLEPHARICIDAE	*0%*		*0%*	*0%*		*0%*	*0%*	*0%*	*0%*		*1%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Rel. abundance CHIRONOMIDAE	*6%*	*4%*	*4%*	*16%*	*9%*	*17%*	*17%*	*20%*	*21%*	*19%*	*26%*	*32%*	*35%*	*3%*	*7%*	*17%*	*14%*
Rel. abundance EMPIDIDAE	*0%*	*0%*	*0%*		*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*				
Rel. abundance LIMONIIDAE	*3%*	*2%*	*4%*	*2%*	*2%*	*1%*	*1%*	*1%*	*1%*	*1%*	*2%*	*1%*	*1%*	*1%*	*1%*	*1%*	*0%*
Rel. abundance PEDICIIDAE								*0%*							*0%*	*0%*	*0%*
Rel. abundance SIMULIIDAE	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*2%*	*2%*	*1%*	*1%*	*0%*	*1%*
Rel. abundance THAUMALEIDAE								*0%*									
Rel. abundance TIPULIDAE							*0%*										
Rel. abundance EPHEMEROPTERA	46%	45%	36%	41%	55%	45%	36%	41%	38%	34%	35%	37%	33%	59%	45%	41%	45%
Rel. abundance BAETIDAE	*11%*	*25%*	*17%*	*21%*	*46%*	*35%*	*14%*	*30%*	*13%*	*23%*	*21%*	*16%*	*21%*	*19%*	*24%*	*24%*	*27%*
Rel. abundance EPHEMERELLIDAE	*0%*																
Rel. abundance HEPTAGENIIDAE	*35%*	*20%*	*19%*	*20%*	*10%*	*10%*	*22%*	*11%*	*25%*	*10%*	*15%*	*21%*	*11%*	*40%*	*22%*	*17%*	*18%*
Rel. abundance LEPTOPHLEBIIDAE				*0%*					*0%*								
Rel. abundance PLECOPTERA	18%	18%	25%	18%	11%	14%	16%	12%	17%	29%	8%	13%	14%	28%	16%	22%	19%
Rel. abundance CHLOROPERLIDAE	*2%*	*1%*	*2%*	*1%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*							
Rel. abundance LEICTRIDAE	*7%*	*4%*	*7%*	*7%*	*3%*	*5%*	*7%*	*5%*	*1%*	*20%*	*3%*	*7%*	*7%*	*16%*	*4%*	*5%*	*5%*
Rel. abundance NEMOURIDAE	*7%*	*7%*	*9%*	*7%*	*3%*	*5%*	*6%*	*6%*	*7%*	*7%*	*4%*	*5%*	*6%*	*10%*	*10%*	*17%*	*13%*
Rel. abundance PERLIDAE	*2%*	*4%*	*5%*	*2%*	*4%*	*3%*	*2%*	*1%*	*1%*	*1%*	*1%*	*0%*	*0%*	*1%*	*1%*	*1%*	*1%*
Rel. abundance PERLODIDAE	*1%*	*1%*	*1%*	*1%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Rel. abundance TAENIOPTERIGYDAE	*0%*	*0%*	*1%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*				*0%*	*0%*	*0%*	*0%*

PARAMETER	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2011	2012	2013	2014	2015	2016	2017
Rel. abundance TRICHOPTERA	3%	4%	3%	4%	2%	2%	2%	1%	1%	2%	2%	1%	1%	2%	3%	2%	3%
Rel. abundance HYDROPSYCHIDAE				*0%*		*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Rel. abundance HYDROPTILIDAE														*0%*			
Rel. abundance LEPIDOSTOMATIDAE				*0%*													
Rel. abundance LIMNEPHILIDAE	*1%*	*1%*	*0%*	*1%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Rel. abundance ODONTOCERIDAE							*0%*		*0%*					*0%*			
Rel. abundance PHILOPOTAMIDAE	*0%*	*0%*	*1%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*1%*	*2%*	*1%*	*2%*
Rel. abundance POLYCENTROPODIDAE		*0%*															
Rel. abundance RHYACOPHILIDAE	*2%*	*3%*	*2%*	*3%*	*2%*	*2%*	*1%*	*0%*	*1%*	*1%*	*1%*	*0%*	*1%*	*1%*	*1%*	*1%*	*1%*
Rel. abundance SERICOSTOMATIDAE		*0%*	*0%*				*0%*		*0%*					*0%*			
Rel. abundance BIVALVIA												0%					
Rel. abundance GASTROPODA									0%								
Rel. abundance TURBELLARIA	1%	0%	1%	0%	0%	3%	1%	0%	1%	0%	2%	1%	1%	1%	7%	4%	1%
Rel. abundance PLANARIIDAE		*0%*	*0%*	*0%*	*0%*	*3%*	*1%*	*0%*	*1%*	*0%*	*2%*	*1%*	*1%*	*1%*	*7%*	*4%*	*1%*
Rel. abundance EPT taxa	67%	67%	64%	64%	69%	61%	53%	54%	56%	64%	45%	51%	47%	89%	64%	66%	67%
Rel. abundance AS taxa	49%	51%	43%	46%	61%	51%	40%	43%	40%	36%	39%	39%	34%	62%	56%	47%	49%
Number of total taxa	31	29	31	32	27	32	36	38	48	40	29	34	29	32	30	27	28
Standardized number of total taxa	31	28	30	30	25	25	27	25	32	32	27	29	25	29	26	24	24
Number of EPT taxa	19	18	18	21	16	21	24	25	32	27	18	20	17	21	19	16	17
Standardized number of EPT taxa	19	17	17	20	15	16	17	15	20	21	16	17	14	19	16	14	14
Number of AS taxa	10	9	10	12	10	11	13	13	18	13	12	12	12	11	10	10	10
Standardized number of AS taxa	12	11	12	14	11	10	12	10	15	13	13	12	12	12	11	11	10
Acidification class (Braukmann & Biss)	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2

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