SEVENTH FRAMEWORK PROGRAMME

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Adaptive strategies to Mitigate the Impacts of Climate Change on European Freshwater Ecosystems

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Principal contributors: Francesc Sabater, Eduardo Martin (UB), Eugenia Martí (CSIC)

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PU	Public
PP	Restricted to other programme participants (including the Commission Services)
RE	Restricted to a group specified by the consortium (including the Commission Services)
X CO	**Confidential, only for members of the consortium (including the Commission Services)**

Abstract

This report presents the results from the investigations documenting after-effects of extreme flood events (major deviations in riparian hydrology) carried out in Mediterranean Spain in the EU FP7 project REFRESH. The investigations aimed to document how extreme winter flooding periods affect stream riparian wetlands. Results on wetland biogeochemistry (N and P), biodiversity (plants) and functioning (nutrient cycling) are presented.

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Deliverable nr: 4.8
WP: 4

Contributed paper

Title: Contrast in temporal and spatial patterns of N2O and CO2 emissions between a wet and dry year in a Mediterranean riparian zone.

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Estimated person months: 6

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Abstract

The aim of this study was to examine temporal and spatial patterns of nitrous oxide (N2O) and carbon dioxide (CO2) fluxes across a Mediterranean riparian gradient under contrasting climatic conditions (flood and drought), and identify the environmental factors that controls this variability. Gas emissions were fortnightly measured from May 2011 to October 2012. Two years that differed in hydrological conditions: During spring of 2011 the riparian zone was entirely inundated after a 50-year recurrence flood; in contrast of 2012 that was relatively dry. The gas emissions were measured in situ using close chambers distributed at 18 sampling plots (40x40 cm) across the stream-riparian gradient based on differences in soil texture and dominant vegetation types. At each plot, we also measured soil moisture, temperature, REDOX, pH, soil nitrate, total C and N, organic matter debris, and % of grass coverage. The rate of N2O fluxes ranged from 0.5 to 8 µg N m-2 h-1. The highest rates were measured in semi-inundated plots near the stream edge, whereas the lowest rates were measured uphill of the riparian zone. A contrasting pattern was observed for rates of CO2 fluxes, which ranged from 0.2 to 20 g CO2 m-2 h-1. The lowest rates were measured at the stream edge, and the highest rates were measured uphill. However, both gas emissions showed a remarkable seasonal pattern with higher rates during the vegetative period, although we found high variability of fluxes between the two years, and with a contrast annual emission between the magnitude of CO2 and N2O fluxes. During the wet year, spatial variability of gas emissions was mostly driven by soil moisture and REDOX, but during the dry year, there was a threshold at 20% of soil moisture for N2O emissions, while other factors (Organic matter, temperature, soil texture) additionally control the emission rates of the two gases.

Deliverable nr: 4.8
WP: 4

Contributed paper

Title: The effects of extreme hydrological events on biogeochemistry in a Meditteranean riparian zone

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Abstract

Hydrologic regime of Mediterranean streams is characterized by episodic floods and summer droughts. This high hydrological variability, especially associated with floods, modifies the physical, chemical and morphological characteristics of the stream, and affects the lateral hydrologic exchange between the stream and the riparian zone. This study aims to examine the hydrological and biogeochemical linkages between surface stream and the riparian groundwater under variable stream flow conditions. The study was done in Riera d´Arbúcies (NE Spain) from April 2001 to November 2012. In March a major flood occurred (14 m 3 /s). From September to October we induced an experimental drought to force expanding the range of hydrologic conditions, since this stream usually has permanent flow year round. We selected a 130-m reach in which we installed 24 piezometers which were distributed in 6 transects across the riparian zone. The discharge and morphology of the stream channel was measured weekly at 14 transects. We also collected water from the stream and from the wells, and measured water temperature, dissolved oxygen (DO), nutrient concentrations, and the water level elevation in the wells. The temporal variation in water table elevation showed a fast response to changes in stream discharge suggesting a strong hydrological linkage between the stream and the riparian zone that extended even at the furthest wells from the stream channel (c.a. 15 m into the riparian zone). Groundwater chemistry also showed considerable temporal variation following stream hydrologic conditions and changes were mostly related to REDOX conditions. Groundwater had higher DO and nitrate and lower ammonium concentrations at the beginning of the study than during the drought conditions.

The effects of extreme hydrological events on biogeochemistry in a Meditteranean riparian zone.

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Abstract

Hydrologic regime of Mediterranean streams is characterized by episodic floods and summer droughts. This high hydrological variability, especially associated with floods, modifies the physical, chemical and morphological characteristics of the stream, and affects the lateral hydrologic exchange between the stream and the riparian zone. This study aims to examine the hydrological and biogeochemical linkages between surface stream and the riparian groundwater under variable stream flow conditions. The study was done in Riera d´Arbúcies (NE Spain) from April 2011 to November 2012. In March of 2011 a major flood occurred (14 m^3/s). From September to October we induced an experimental drought to force expanding the range of hydrologic conditions, since this stream usually has permanent flow year round. We selected a 130-m reach in which we installed 24 piezometers which were distributed in 6 transects across the riparian zone. The discharge and morphology of the stream channel was

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Introduction

The stream–riparian interface is the zone connecting the stream and the catchment and it has been defined as a spatially fluctuating ecotone between the surface stream and the deep groundwater (Boulton and others 1998). Consequently, several field studies have investigated the stream– riparian interface in regulating stream hydrology (McGlynn and McDonnell 2003; Butturini and others 2002) or biogeochemistry (Schindler and Krabbenhoft 1998; Vidon and Hill 2004; Wigington and others 2003). In Mediterranean regions, the Hydrologic regime of Mediterranean streams is characterized by episodic floods and summer droughts. This high hydrological variability modifies the physical, chemical and morphological characteristics of the stream, and affects the lateral hydrologic exchange between the stream and the riparian zone (Gasith and Resh 1999). During drought conditions there is a disruption in hydrological connectivity that ranges from flow reduction to loss of hydrologic connectivity between surface water, groundwater and the riparian zone (Lake 2003). Recent studies in the Mediterranean adduce evidence of a severe alteration of precipitation and hydrological regimes and hypothesize an increase in the frequency of extreme events particularly in summer (Christensen and Christensen 2003; Schröter and others 2005). In this context, it is essential to assess how the stream riparian interface controls the transport and fate of nutrients that flow in Mediterranean freshwater ecosystems under the extreme effects of dry–wet hydrological shifts. During this transitional period between dry and wet conditions the hydrology of the stream–riparian interface is highly dynamic due to: (1) abrupt changes in groundwater levels; (2) occurrence of reverse fluxes in the subsurface stream–catchment interface; (3) rapid expansion and shrinkage of the boundary of the stream–catchment interface; (4) longer riparian groundwater flow-paths (Butturini and others 2003). Nevertheless, there is little information about the effect of the abrupt hydrological processes that take place in the stream riparian interface on reactivity and transport of nutrients from the riparian areas to the streams. Whilst some initial studies have been undertaken in Mediterranean streams covering the effect of the antecedent hydrological conditions on temporal dynamics and the fate of total DOC (Dissolved Organic Carbon) and discrete dissolved organic molecular fractions transported across the stream–riparian interface to improve our knowledge of the possible effect of altering the discharge pattern on stream DOC transport after abrupt hydrological shifts (Vazquez and others 2007).

Within this framework, our main objective is to explore the hydrological and biogeochemical linkages between surface stream and the riparian groundwater under the effects of extreme hydrological conditions (flood and drought). For this purpose, groundwater samples were collected from a wide Mediterranean riparian gradient during two years characterized by contrasting antecedent hydrological conditions. During spring of 2011 the riparian zone was entirely inundated after a 50-year recurrence flood; in contrast, 2012 was characterized by severe dry conditions. At some point the stream channel became completely dry in summer although this stream has usually permanent flow throughout the year. Therefore, we hypothesize that a change in discharge regime in Mediterranean regions, as a consequence of a warmer climate, might intensify more severe and dynamic hydrological processes at the stream–riparian interface, which might affect biogeochemical process occurring at the riparian zone and to have consequences on inputs of leaching of nutrients, especially nitrate, during flood episodes.

Material and methods

Study site

The location of this study was situated in the low part of Riera de Arbucies, in La Tordera catchment (Catalonia, NE, Spain). This is a 4th order stream, tributary of the main river in the catchment, La Tordera. Climate of the Arbucies catchment can be classified as humid Mediterranean. Mean annual rainfall is more than 950 mm. Riera de Arbucies drains an area of 114km^2. More than 50 % of catchment area is occupied by forested zones and over 25 % is occupied by agricultural and urban zones. Cachtment is dominated by siliceous geology and its river bed is mainly composed by grains of quartz sand and fine gravels. The study site comprises a 120 m long and 20 m wide riparian zone. The vegetation of the site was basically grasses, hydrophytes and a few riparian trees and shrubs (*Salix sp* and *Populus sp*).

Water table level and precipitation

Stretch was divided in two different zones: one upstream water (Up Zone) and one downstream water (Down Zone) (Figure 1). The selected reaches were homogeneous in altitude, topography variations and vegetation. A grid of dipwells was installed in each section across right shore riparian zone. Grids were composed by 4 rows of 3 piezometers each one. The distances from the stream were 1, 3, 7 and 15 m. These rows were named line 1, 2, 3 and 4 respectively. Each piezometer consists in 32-mm diameter PVC. Wells were screened (4-5mm holes at 50 mm intervals) the last 40, 60 and 100 cm respectively. They were varied in length according to the location in the stream-riparian gradient (1 to 4m). The top of the wells were covered by a cap.
Water table elevation was measured from July 2011 to October 2012 each 15 days using a portable probe in each line. Complementary, in line 4 at each stretch, a continuous water level data logger (HOBO U-20, Onset) was installed at 20 min intervals to establish the elevation of the groundwater.
Precipitation data were provided by a meteorological station located 5 km from the study site.

Field sampling

From July 2011 to October 2012, stream water and groundwater were sampled 21 times, at least once a month. In order to do that, a peristaltic pump was used. Electrical Conductivity (EC), dissolve oxygen (D.O) and temperature were measured directly in the field. Prior to sampling and readings, wells were purged. All water samples were filtered in situ through glass microfiber filters and stored at -20ºC until their analysis in the laboratory. SPR, NO_3^- , NO_2^- and NH_4^+ were determined by standard colorimetric methods (APHA 1995) using an autoanalyser (Integral Futura, Alliance Instruments, Frépillon, France). In addition, stream discharge was measured every 15 days by performing a slug injection of sodium chloride used as a hydrological tracer (Gordon *et al*, 1992).

Results

Hydrological setting

Discharge and groundwater level showed a clear response to the rainfall (Fig 2 a-c). Just before the study started, a major flood, one in fifty years, happened. This flood raised 13, 7 $m^{3.}$ During the study, two big flood (December 2011 and October 2012) and an exceptional drought (August 2012) occurred. Maximum and minimum discharge were 4, 5 m^3 (25th December 2011) and 0,00 m^3 (whole August 2012) respectively.

In Fig 2 c, water table level is showed from line 4. It showed a clear relationship with rain, even 15 m far from the water channel. Groundwater increased its level when rains occurred and suffered a huge decrease during drought periods. Groundwater level in Line 4 varied from 0,5 m (during flood events) to more than 2,5 m (during drought event) depth from soil. Levels are corrected by topography. Up and down zone groundwater levels presented differences. This difference was about 40 cm, according to the slope of the stretch (0, 3 cm/km). To have knowledge about the evolution of this disparity between both water levels, a temporal difference was performed (Up – Dw) and these new data was standardized by mean and standard deviation (x-μ/σ). Results are shown in Fig 2-d. Negative values indicated periods when the difference between sections decreased (wet periods) and positive values indicated difference increase (dry periods). This variance shows an annual pattern: drought winter and summers and wet spring and autumn.

In order to determine different hydrological phases, four periods were determined using this hydrological variance. First period is called Sumer 2011 and included summer and early autumn since they were the driest months during this year. Despite that fact, this summer was particularly wet and rains raised more than 200 mm. In particular this period included from 1st July 2011 to 31st October 2011. Next period was defined as winter and it covered from 1st November 2011 to 31st March 2012. This period included both wet and dry periods and had 275 mm rain. Spring period lasted from 1st May 2012 to 15th July 2012. It was a wet period (155 mm) since rains in Mediterranean climate are concentrated in this season. Summer 2012 was defined from 16th July to 30th September. It was a very dry summer, with less than 20 mm in more than 2 months.

Water level profiles

Water level across Stream Riparian Gradient showed differences between zones and periods (Fig 3). Summer 2011 was a wet summer in comparison with summer 2012. Consequently in both zones, water level is higher in 2011 than in 2012. In the two years, up and down zone had differences, since down profile had in both cases a stepper slope. That suggests that down zone is a losing stretch, discharging water into the aquifer during summer.

In both zones, winter period had the highest water level, due to winter rains and lack of vegetation evapotranspiration in the catchment. Spring period had very similar discharge, but the start of evapotranspiration created a decrease of groundwater level during this period.

Groundwater Chemistry Variation along SRG

Annual data are shown in Figure 4. Each analyzed parameter showed a clear pattern along stream riparian gradient SRP (given as PO_4) in the stream was similar to line 4. Meanwhile in lines 1, 2 and 3, SRP is higher. This pattern was showed in both sections. A similar pattern was found in N-NH_4 concentration. In that case, concentration was higher in up zone than in down zone but always following the same pattern, with higher concentrations in riparian zone than in stream or riparian edge. In the other side, dissolve oxygen and NH_3 showed and opposite pattern with lower concentration in the lines 1, 2 and 3 than in stream or line 4 water. Those patters are showed in both zones. NH4 and NO3 showed the same tendency in every period.

Discussion

Our results show that the temporal variation in water table elevation confirms a fast response to changes in stream discharge suggesting a strong hydrological linkage between the stream and the riparian zone. Likewise, groundwater chemistry proves considerable temporal variation following stream hydrologic conditions and changes related to REDOX conditions of the groundwater. Observed water level variations along the stream riparian gradient were mainly controlled by the adjacent stream discharge events and by the riparian water table fluctuations. Nevertheless, under natural conditions the hydrological regime of riparian areas often leads to large seasonal fluctuations in water table elevation. (Burt et al. 2002),

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Fig 1: Vertical View of the riparian study site

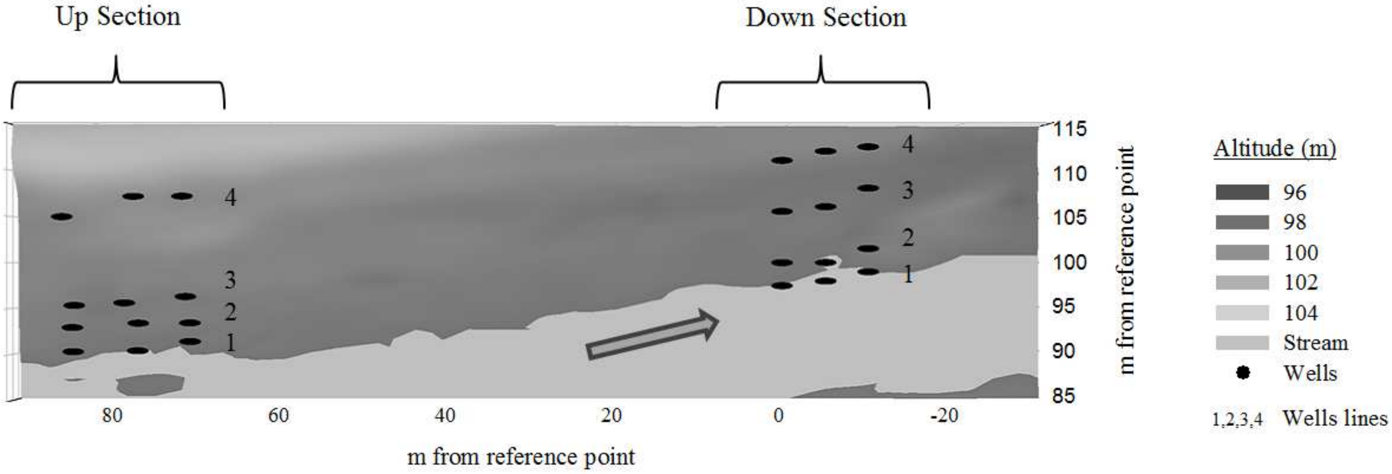


Fig 2: **Time series** of rainfall (a), stream discharge (b), Water table level (c) and Standard Difference (Up-Dw) (d)

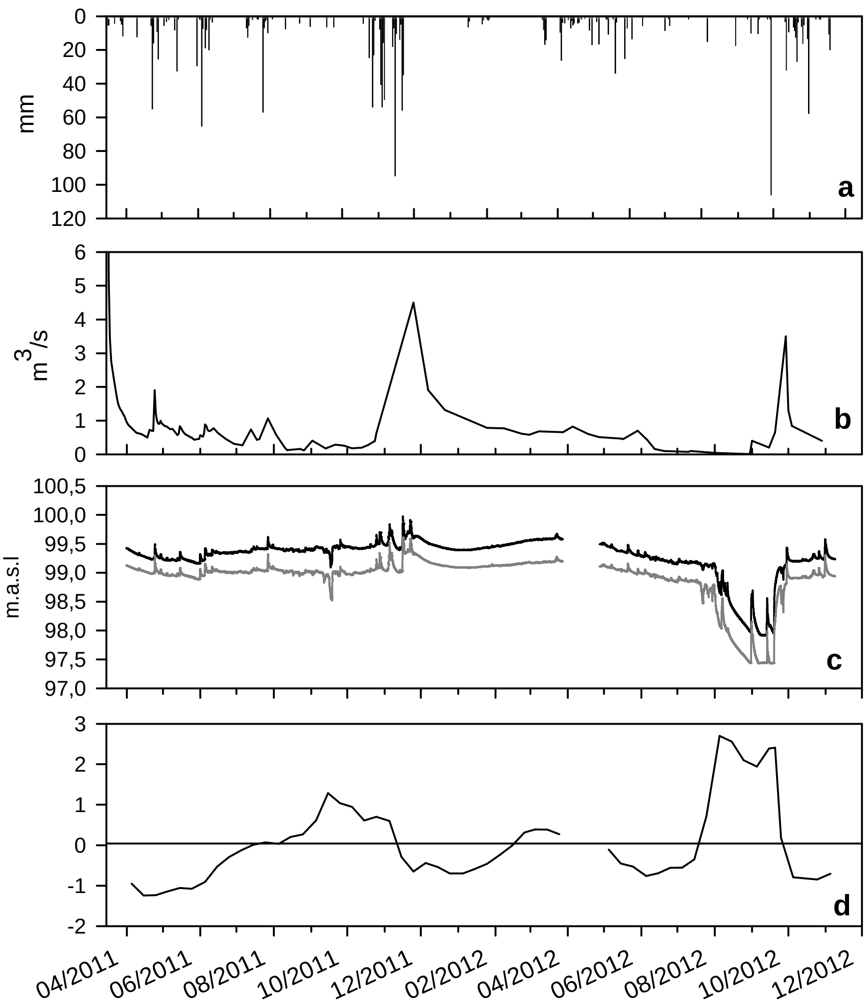


Figure 3: Seasonal water table profiles by stream distance

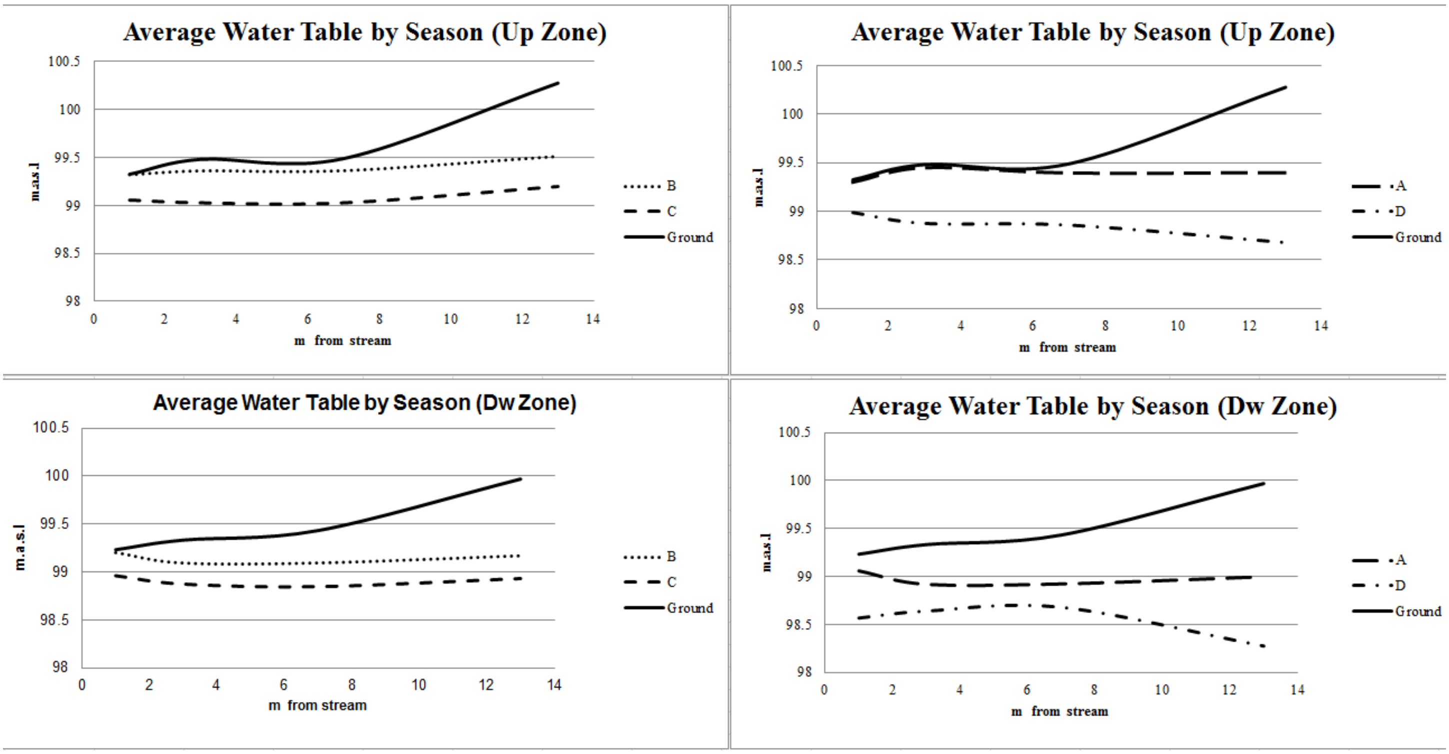
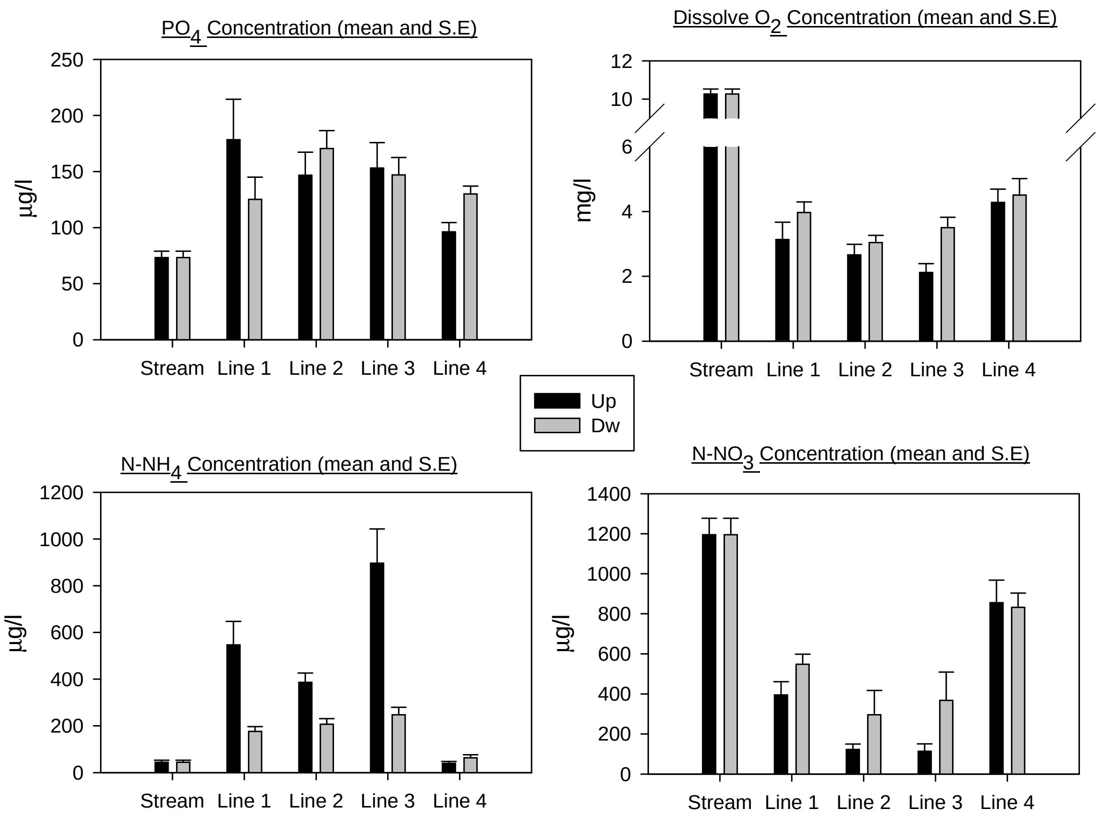


Figure 4: PO_4, Dissolve O_2, NH_4 and NO_3 concentration along Stream Riparian Gradient wells in Up and Dw zone (Annual mean and S.E)


PO4 Concentration (mean and S.E)
µg/l
Stream
Line 1
Line 2
Line 3
Line 4
Dissolve O2 Concentration (mean and S.E)
mg/l
Up
Dw
N-NH4 Concentration (mean and S.E)
N-NO3 Concentration (mean and S.E)