Data analysis and study design review:

Haller's Apple Moss (*Bartramia halleriana* Hedw.), Jasper National Park, Alberta

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Cover photo: Haller's Apple Moss (*Bartramia halleriana*) at the Jasper West Gate population, Jasper National Park, Alberta (photo taken in August 2007, courtesy of Richard Caners).

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Executive summary

Haller's Apple Moss (*Bartramia halleriana* Hedw.) is presently known from 11 locations in North America and is listed as Threatened in Canada under the Species at Risk Act. During the winter of 2007-2008, one population ("Fitzwilliam Spur", FW) in Mount Robson Provincial Park, British Columbia, was affected by tree removal during the construction of a pipeline. This report includes an analysis of 2008-2009 microclimate data obtained from Fitzwilliam Spur and two unaffected populations located nearby ("Jasper West Gate", JW, and "Jasper Meadow Creek", MC). The objective of the data analysis was to assess the effectiveness of attempts to mitigate microclimatic change at Fitzwilliam Spur to ensure the continued viability of the population. This report also provides a review of reclamation procedures and monitoring protocols currently proposed for the Fitzwilliam Spur population.

Results of the data analysis indicate that although measures were taken to minimize the effects of forest canopy removal on microclimatic change at Fitzwilliam Spur, only minor improvements were detected. Temperature was slightly lower and relative humidity was slightly higher inside the protective jute screen (established to reduce incident solar radiation) as compared to sensor readings taken immediately outside the screen. However, when tested statistically, there were few differences between microclimate readings taken inside and outside the screen for either 2008 or 2009. At the undisturbed sites (MC and JW) there were also no differences in microclimate readings between population and control sensors in 2008. However, in 2009, significant differences were detected at MC (data for JW could not be tested for that year), suggesting the population may be sheltered from surrounding climate conditions in some years. Furthermore, comparisons of population sensor readings among the undisturbed and disturbed sites revealed that microclimate did not differ between the undisturbed populations (JW and MC) but differed significantly between the undisturbed populations and Fitzwilliam Spur. Although preliminary, these findings reveal that microclimate at Fitzwilliam Spur may not have been mitigated sufficiently in relation to the undisturbed populations to provide the growing conditions necessary for population persistence.

Reclamation procedures and monitoring protocols have been proposed for the Fitzwilliam Spur population. However, changes to these methods may be required to better mitigate the effects of pipeline construction on microclimate and to more closely monitor population viability. Additional measures to decrease temperature and increase humidity at FW should be implemented as soon as feasible. The collection of microclimate data at FW and the undisturbed locations should continue, with attempts to minimize the presence of missing values. The collection of light intensity and air movement data should also be considered to monitor additional sources of microclimatic variation and to provide insight about factors driving temperature and moisture fluctuations. These measurements need to be combined with the regular and detailed monitoring of population biology at each location, including colony size, health, and fecundity.

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Abbreviations used in this report: FW - Fitzwilliam Spur; JW - Jasper West Gate; MC - Jasper Meadow Creek; VPD - vapour pressure deficit; RH - relative humidity.

Figures and tables

Background

Haller's Apple Moss (*Bartramia halleriana* Hedw.) is presently known from 11 locations in North America and is listed as Threatened under the Species at Risk Act in Canada[1]. In North America, the species occurs exclusively in Canada, and is restricted in phytogeographic distribution to the Interior Cedar Hemlock biogeoclimatic zone of east-central British Columbia (7 populations), and the adjacent Sub-Boreal Spruce zone in eastern British Columbia and similar habitats in western Alberta (4 populations) (Haller's Apple Moss Recovery Team 2010). Habitats are typically north-facing, mesic, non-calcareous cliffs, bedrock, outcrops, or talus, under a dense forest canopy cover. Microclimate is generally moist and cool, and is influence by seepage, nearby streams or water pools, and cold air movement through talus. The species is described as having a narrow ecological tolerance, and is thought to be limited in distribution because of a combination of specialized habitat requirements, interspecific competition, and dispersal limitation (Haller's Apple Moss Recovery Team 2010).

During the winter of 2007-2008, the "Fitzwilliam Spur" population of Haller's Apple Moss (**inset**) at Mount Robson Provincial Park, British Columbia, was disturbed by forest canopy removal during the installation of a buried pipeline. A jute screen was erected over the population as a preliminary measure to reduce the effects of canopy removal and associated changes in microclimate. Electronic sensors were established to measure temperature and moisture at Fitzwilliam Spur (abbreviated FW) and the two closest populations unaffected by pipeline construction ("Jasper West Gate", JW, and "Jasper Meadow Creek", MC; **Fig. 1**), situated in Jasper National Park, Alberta.

Haller's Apple Moss population at Fitzwilliam Spur, Mount Robson Provincial Park, British Columbia. Photo taken in August 2007, before pipeline construction (courtesy of Richard Caners).

Microclimate data collected from the disturbed (FW) and undisturbed (JW and MC) locations during 2008-2009 were examined in this report to assess the effectiveness of measures taken to moderate changes in microclimate at Fitzwilliam Spur, and implications for maintaining population integrity. Furthermore, this report provides an assessment of reclamation and monitoring strategies currently proposed by the Haller's Apple Moss Recovery Team.

[1] For further details on the status of the species refer to the SARA Registry: http://www.sararegistry.gc.ca/sarredirect/

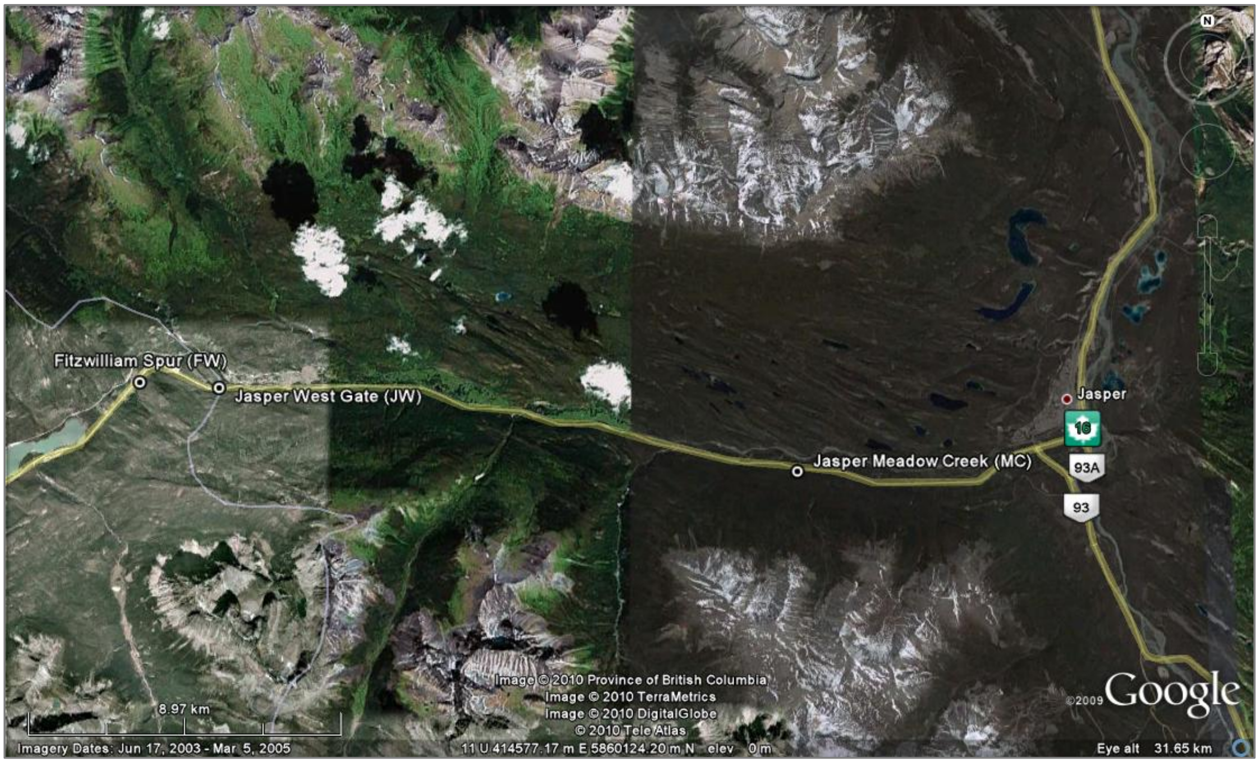

Fig. 1. Location of the three Haller's Apple Moss populations examined in this report. The effects of pipeline construction during the winter of 2007-2008 on microclimate conditions at Fitzwilliam Spur (FW) are examined. The thin line that runs north and south of the Jasper West Gate (JW) location is the provincial border between Alberta and British Columbia. Imagery was obtained from Google Earth (version 5.1.3533.1731).

Analytical methods

Data organization

Microclimate sensor data were obtained for the three Haller's Apple Moss locations (FW, JW, and MC) for 2008 and 2009. The data consisted of both average hourly and average daily values of the following variables:

Growing degree days
Minimum growing degree days
Average temperature (ºC)
Maximum temperature (ºC)
Minimum temperature (ºC)
Average relative humidity (%)
Maximum relative humidity (%)
Minimum relative humidity (%)
Count of temperature

Average daily values were selected instead of average hourly values for both expediency of data analysis and ease of results interpretation. From the above variables, temperature (daily average, maximum, and minimum) and relative humidity (RH; daily average, maximum, and minimum) were selected as they can be important descriptors of bryophyte species productivity and mortality (Rincon and Grime 1989). However, because values of RH correspond closely with temperature, the recommended vapour pressure deficit (VPD) was also calculated. VPD is the difference between the measured amount of moisture in the air and maximum amount of moisture the air can hold when saturated. VPD was calculated from average daily air temperature and average daily relative humidity readings using the following equation (Allen et al. 1998; Chapter 3, Meteorological data):

$$\text{VPD} = e_s - e_a$$

where e_s is the saturation vapour pressure in kilopascals (Kpa) at air temperature T in degrees Celsius (ºC); and e_a is the actual vapour pressure, which is equivalent to e_s(RH/100) with RH expressed in percent (%). VPD can be calculated using different measures of temperature and RH (e.g., average, maximum, minimum) but for this study was calculated using average values to reflect the general long-term trends at a location. Calculations of VPD using both maximum daily temperature and minimum daily RH may have provided a measure of extreme daily VPD but were not examined in this report.

The range of dates for which data were available differed between 2008 and 2009. In addition, data for a given year were not always perfectly matched for all locations since data were sometimes missing. There were also some strongly outlying values (often at the beginning of a series of data) and these were removed prior to analysis.

Statistical analyses

Temperature and moisture data were compared between the "control" and "population" sensors at each location and also among locations. Population sensors were located within the Haller's Apple Moss colonies at a location, while control sensors were located adjacent to the population[2]. At the Fitzwilliam Spur location only, control sensors were situated both inside and outside the jute screen, erected to provide protection for the population.

There were two types of control and population sensors at each location, designated as "left" and "right" depending on whether they were situated to the left or right when facing a population. Since the location of the left and right sensors are not directly comparable among locations, and likely do not correspond to biologically meaningful positions in reference to a population, the average value of the sensors was obtained for each microclimate variable prior to analysis. For example, values of maximum daily temperature obtained separately from left and right control sensors at a location were averaged for each day. This simplified the presentation of data and reduced the number of missing values for data analysis. The data collected from the vertical microclimatic sensors at FW were not analyzed in this report because there were no comparable reference data from the undisturbed (JW and MC) locations. Such an analysis may be warranted in the future if data are obtained for comparison (see section entitled, "Review of proposed reclamation and monitoring procedures").

Each microclimatic variable was first summarized using descriptive statistics in tabular format. At each location, variables were examined separately for each type of sensor (i.e., control, population). The average, standard deviation, minimum, and maximum values of each variable were calculated for every month and all months combined, separately for both 2008 and 2009. Each variable was then summarized graphically to illustrate changes over time (separately for 2008 and 2009), and to compare variables at each location and among locations.

Because all of the microclimatic variables have values that are correlated over time, standard parametric (e.g., analysis of variance) and non-parametric (e.g., Kruskal Wallis, Wilcoxon signed rank, Mann-Whitney U) statistical tests are generally not appropriate for testing differences between data series. These tests assume independence among all observations, which is violated when data points are repeated in time. Furthermore, there is also only one disturbed location (the experimental unit to which the "treatment" was applied) instead of multiple replicates usually required to assess variation around a mean response (the different sensors at a location are only subsamples of the experimental unit). Therefore, when possible, a more complicated form of data analysis had to be used to test for differences in microclimate between sensors at a site and among sites.

[2] Information about data collection methods may be obtained from Parks Canada Agency, Jasper National Park, Alberta.

To compare the means of two time series, each series was first tested to ensure it fit an autoregressive model of lag 1, using the Forecasting module in PASW 17.0 (SPSS, Chicago, IL). When this was confirmed, the first serial correlation coefficient was calculated on the residuals of each series. Data were transformed when necessary to maximize normality prior to analysis. The adjusted standard error for the difference in averages of the two time series was calculated using the pooled estimate of the first serial correlation. This adjusted standard error was then used to test for a significant difference between the two time series. The significance of the derived z-value was tested using a standard normal table. These methods are explained in detail in Ramsey and Shafer (1997; Chapter 15, Adjustment for serial correlation).

Each microclimate variable was compared statistically 1) at each site between control and population sensors and 2) among sites for population sensors only using pair-wise tests. In addition, each microclimate variable at FW was compared statistically between control sensors located inside and outside the screen. The significance of P-values were adjusted to account for the multiple tests for each variable. Differences in variables between years (2008 and 2009) could not be tested since the range of dates available for each year differed substantially. Furthermore, data for Jasper West Gate (JW) from 2009 could not be used in pair-wise tests because data were often missing. This meant the autoregressive model of lag 1 could not be verified and the first order serial correlation coefficient could not be calculated (both require continuous sampling intervals).

Microclimate conditions for control sensors were expected to be more extreme than population sensors at a site; therefore, pair-wise tests were considered to be one-tailed under the hypothesis that control sensors had greater temperatures, VPD, and RH range (difference between daily maximum and minimum values); and lower average RH and minimum RH than population sensors. Furthermore, microclimate conditions at the disturbed location (FW) were expected to be more extreme than undisturbed locations (JW and MC); therefore, pair-wise tests were also considered to be one-tailed under the hypothesis that the disturbed site had greater temperatures, VPD, and RH range; and lower average RH and minimum RH than undisturbed sites. Since the two undisturbed locations (JW and MC) were not expected to differ in microclimate, pair-wise tests for all variables were considered to be two-tailed.

All statistical tests are considered to be significant at alpha = 0.05.

Analytical results summary

Comparison of control and population sensor data at each location

For both the disturbed (Fitzwilliam Spur, FW) and undisturbed (Jasper West Gate, JW, and Jasper Meadow Creek, MC) locations, microclimate conditions recorded by control sensors were typically more extreme than conditions recorded by population sensors, for both 2008 and 2009.

In particular, the daily average, maximum, and range (difference between daily maximum and minimum values) of temperatures were usually higher for control sensors than population sensors for each location (**Tables 1a** and **2a**). In addition, control sensors at FW situated outside the protective screen often had values that were more extreme than those obtained from control sensors situated inside the screen. For moisture measures, daily VPD and RH range were generally higher for control sensors, whereas average RH and minimum RH were generally lower for control sensors (**Tables 1b** and **2b**). The differences between control and population sensors at each location are clearly visible over time for 2008 (**Figs. 2a**, **3a**, and **4a**) and 2009 (**Figs. 2b**, **3b**, and **4b**) (note differences in y-axis scales among figures). At each location, values of maximum temperature and minimum RH (i.e., extreme daily values), and the ranges of temperature and RH (i.e., daily site variability), were most pronounced and may be the greatest stressors for plants.

Although differences in microclimate variables often appeared pronounced in the tables and graphs, there were few significant differences when tested statistically (**Table 3a**). In 2009, RH range at FW was significantly greater for control sensors outside the screen as compared to population sensors, indicating that RH values were more variable outside the screen. This difference is not necessarily attributable to the screen itself, as variation in microclimate may be naturally reduced where the population is located. The same trend was observed in 2008 at FW but was not significant after P-values were adjusted for multiple tests. In 2009, the control sensors at MC recorded a significantly greater temperature range and lower minimum RH as compared to population sensors. Although preliminary, these findings indicate that 1) measures taken to protect the disturbed population at FW may have had some benefits, but they are probably minor, and 2) differences in microclimate between control and population sensors at MC were relatively few, suggesting that the capacity of this undisturbed site to support Haller's Apple Moss may be determined by the provision of shelter at broader geographic scales (e.g., site topographic location) or during episodes of extreme climate conditions.

Comparison of population sensor data among locations

Comparisons of population sensor data among the disturbed (FW) and undisturbed (JW and MC) locations revealed further insights into the effects of pipeline construction on microclimate at FW. Trends for all microclimate variables are depicted in **Fig. 5a** (2008 data) and **Fig. 5b** (2009 data) (note differences in y-axis scales between figures). Whereas average temperature and average RH did not show pronounced differences among the disturbed and undisturbed sites, trends for other variables were more pronounced. In particular, trends for maximum temperature, temperature range, minimum RH, RH range, and VPD were often more extreme at FW than either JW or MC. Interestingly, values of most microclimate variables at JW were often intermediate between those of FW and MC, but tended to be closer in value to MC.

Additional insights were revealed by the pair-wise statistical tests of population sensor data among the locations, after taking into account the correlated structure of the data (**Table 3b**). No significant differences in microclimate were detected between population sensors for the undisturbed (JW and MC) sites (tests could only be performed for 2008). However, significant differences in temperature and RH were detected between population sensors at FW and population sensors at the undisturbed locations in 2008 and 2009. In 2008, FW had a significantly lower minimum RH and greater RH range as compared to both JW and MC, and a significantly greater temperature range as compared to MC (a weak trend was present for JW). In 2009, FW had a significantly lower minimum RH and greater RH range, and a significantly greater maximum temperature and temperature range as compared to MC (JW could not be tested in 2009 because of discontinuous data).

Conclusions

The results illustrate that population sensors at the disturbed FW location detected more extreme microclimate conditions in terms of temperature and relative humidity (RH) in 2008 and 2009 than population sensors at the undisturbed JW and MC locations. Some of these differences may be the result of natural variation in habitat features among the sites (e.g., slope, aspect, forest canopy composition and cover, exposure to wind and incident solar radiation, moisture conditions); however, given the reportedly narrow ecological requirements of the species (Haller's Apple Moss Recovery Team 2010), these differences could very well be attributable to pipeline construction and associated habitat alteration.

There were no significant differences in population sensor readings of average temperature and average RH between the disturbed and undisturbed locations for either 2008 or 2009, but significant differences were detected for the more extreme measures of microclimate, including temperature range (difference between daily maximum and minimum values), maximum temperature, RH range, and minimum RH. This suggests that microclimatic extremes are better discriminators of growing conditions among the different locations than generalized measures of microclimate, and may signal important sources of stress for the Haller's Apple Moss population at FW. Interestingly, measures of vapour pressure deficit (VPD) calculated from population sensors did not differ significantly among the disturbed and undisturbed locations. This was likely a consequence of VPD being calculated from average temperature and average RH. Measures of VPD calculated from maximum temperature and minimum RH would have been more extreme, amplifying differences between the disturbed and undisturbed sites.

There were few significant differences in microclimate between the control and population sensors at FW, and multiple significant differences between population sensors at FW and the undisturbed sites. These findings suggest that additional steps should be taken 1) to mitigate the effects of pipeline development on microclimatic change at FW, and 2) to monitor the potentially detrimental effects of microclimatic change on the FW population for a minimum of five years to demonstrate progress towards species recovery (Haller's Apple Moss Recovery Team 2010). The next section of this report provides feedback on the reclamation strategies and monitoring procedures that have been proposed[3] for the Haller's Apple Moss population at FW, with suggestions for consideration.

Review of proposed reclamation and monitoring procedures

Proposed *reclamation* objectives for the Fitzwilliam Spur population are to maintain or increase the size of the population, in accordance with the Recovery Strategy of the species (Haller's Apple Moss Recovery Team 2010). Proposed *monitoring* objectives are 1) to determine the success of reclamation towards achieving a forest canopy structure that approximates pre-disturbance conditions, 2) to determine if restoration efforts can create the microclimate conditions necessary to maintain the Haller's Apple Moss population, and 3) to detect changes in population size and condition over time.

Reclamation − The short- and long-term reclamation strategies outlined in the proposal focus on establishing densities of trees and shrubs that approximate pre-disturbance conditions. In addition, plans call for the installation of vertical screening to reduce light intensity and air movement from the west along the cliff face. Results of the data analysis demonstrated that at FW temperature and moisture did not differ substantially between the population sensors and control sensors located outside of the protective screen. Furthermore, temperature and moisture readings from the population sensors at FW differed significantly from the undisturbed locations. Assuming these differences in microclimate are attributable to canopy removal at FW, short-term reclamation goals should focus on the establishment of additional screening and barriers to protect the FW population. Since the screen currently in place at FW does not appear to be providing substantial protection (e.g., **Tables 1a-b** and **2a-b**; **Figs. 5a-b**), and the species has high moisture requirements (Haller's Apple Moss Recovery Team 2010), steps are required to reduce temperature and increase humidity at the site. Without detailed biological information for the population it is difficult to assess the effects of current microclimate conditions on population health. Greater forest canopy cover and the establishment of understory vegetation will have an important influence on near ground growing conditions by reducing light intensity, temperature, wind speed, and evapotranspiration (e.g., Chen et al. 1999, Heithecker and Halpern 2006). The establishment of pre-disturbance vegetation conditions will take an indeterminate amount of time, suggesting a stronger focus on reclamation actions with noticeable short-term benefits. Reclamation actions should be performed in conjunction with population monitoring in order to remain adaptive to changes in population health.

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[3] The proposed reclamation and monitoring procedures were provided in a document entitled, "Reclamation advice and monitoring proposal: Haller's Apple Moss in Mount Robson Provincial Park (the Fitzwilliam Spur site)", Parks Canada.

Monitoring − Monitoring will be essential for assessing the effectiveness of reclamation activities over time. Monitoring will also facilitate a comparison of local abiotic (e.g., microclimate) and biotic (e.g., forest vegetation) factors on population health. Collection of microclimatic data should continue at both the disturbed (FW) and undisturbed (JW and MC) locations but the addition of light intensity and air movement measurements should be considered to supplement the temperature and moisture readings. Forest canopy removal can inhibit the growth of some mosses through photoinhibition (Murray et al. 1993) and moisture loss (Stewart and Mallik 2006). Measures of light intensity and air movement may help explain changes in temperature and moisture at the different locations. Data collection efforts should try to minimize missing data values from sensors, as missing data can affect the quality and interpretation of data analysis. Microclimate data from JW in 2009 could not be compared with different sites (**Tables 3a** and **3b**) because discontinuous data prevented the calculation of first serial correlation coefficients.

Vertical measures of microclimate at FW may help detect a gradient from the base of the population to the upper colonies. However, the data will be difficult to interpret without comparable measurements from reference (undisturbed) locations. Vertical data sensors should be installed at the undisturbed locations to make these comparisons. Furthermore, population data, including measures of colony elevation and indicators of population health (see next paragraph), should be obtained to make the best use of vertical microclimate data. These measurements would allow one to make meaningful inferences about the effects of disturbance at FW on vertical microclimate gradients, and how population density and health are distributed vertically at disturbed and undisturbed locations.

One of the most important reasons to collect detailed microclimate data is to relate this information to population health. Biological data may require substantial effort to collect but can provide valuable information about the effects of habitat change on species. Specific measurements need to be decided upon and obtained repeatedly (e.g., annually) in order to detect changes in health and to implement appropriate mitigation procedures when necessary. The Haller's Apple Moss Recovery Team (2010) recommends that monitoring be conducted for at least five years in order to demonstrate that progress towards recovery is being made. Population measures at a location should include at least the following: colony number; size (area/dimensions); sporophyte density and age; colony colouration (indication of vigour); and distance to nearest neighbouring

Haller's Apple Moss (darker colony in foreground) associated with *B. pomiformis* (lighter colony in background). Photo taken at Jasper West Gate in August 2007 (courtesy of Richard Caners).

colony of the same or different species that may act as a competitor for resources (e.g., space, moisture). *Bartramia pomiformis* has been cited as commonly occurring at Haller's Apple Moss locations (Haller's Apple Moss Recovery Team 2010) and is often in direct physical contact with Haller's Apple Moss (**inset**) to suggest it may be a competitor for available resources. The measures of population health may also be recorded for these neighbouring colonies to assess the potential effects of competition on Haller's Apple Moss.

Acknowledgements

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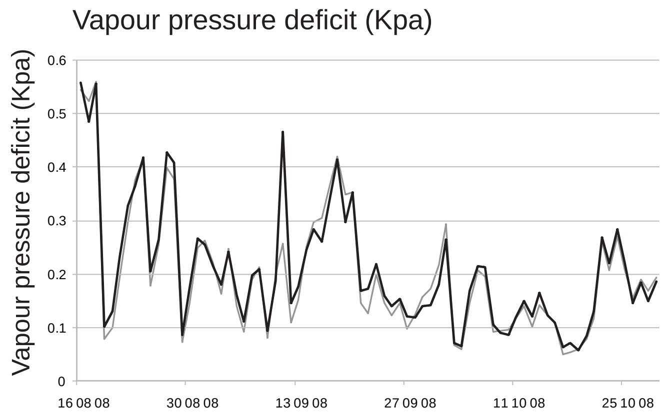
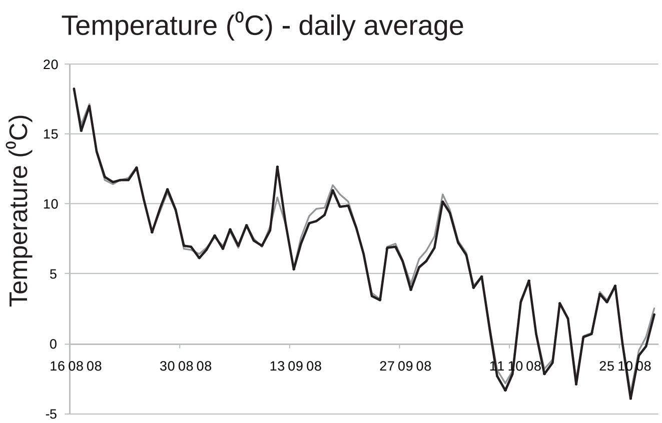
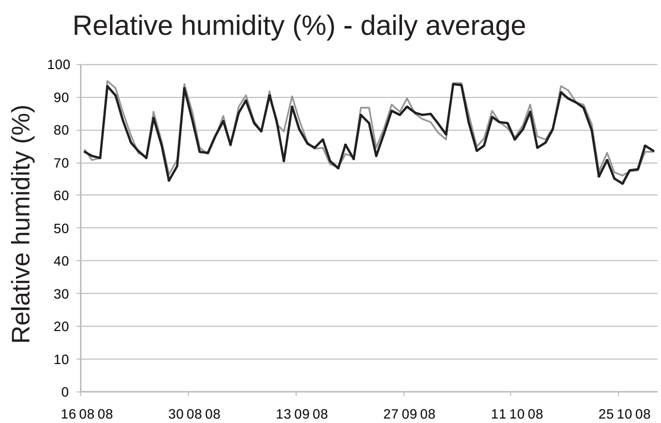
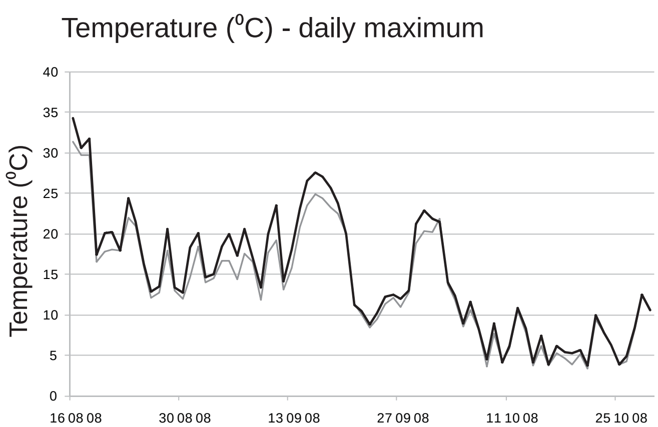
Fig. 2a. Comparison of daily temperature and humidity data over the 2008 growing season for control sensors at the Fitzwilliam Spur (FW) population. Note: “Control-In” and “Control-Out” refer to the averages of the left and right sensors situated inside and outside the protective screen, respectively.

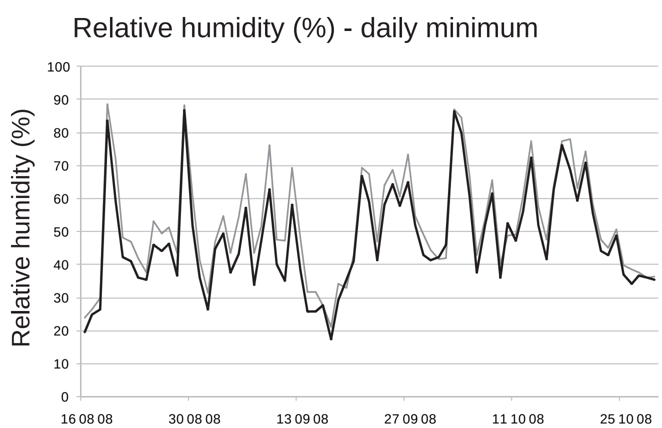
FW Control-In
FW Control-Out

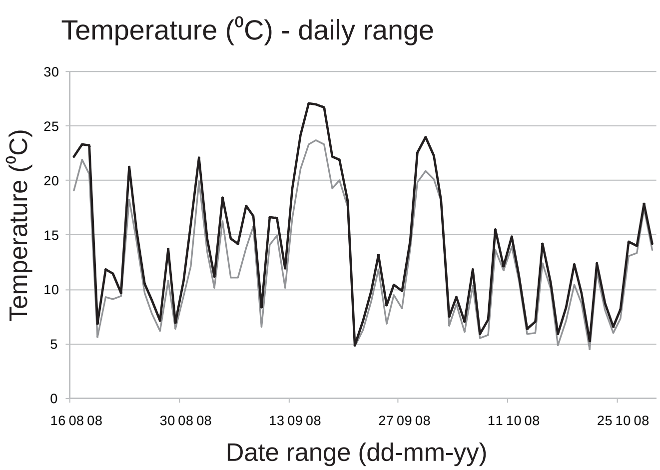












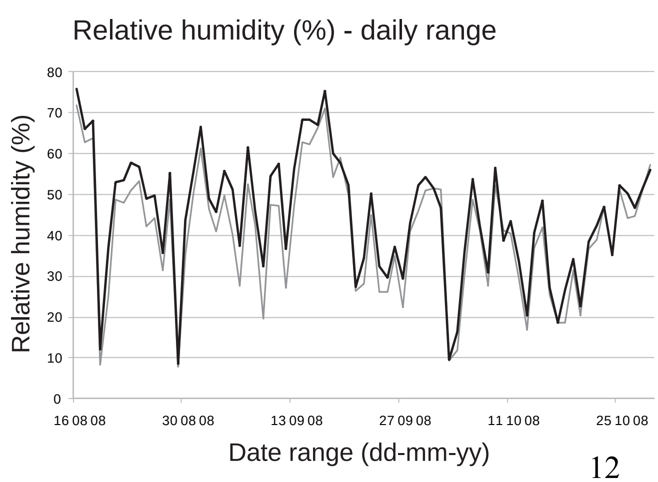
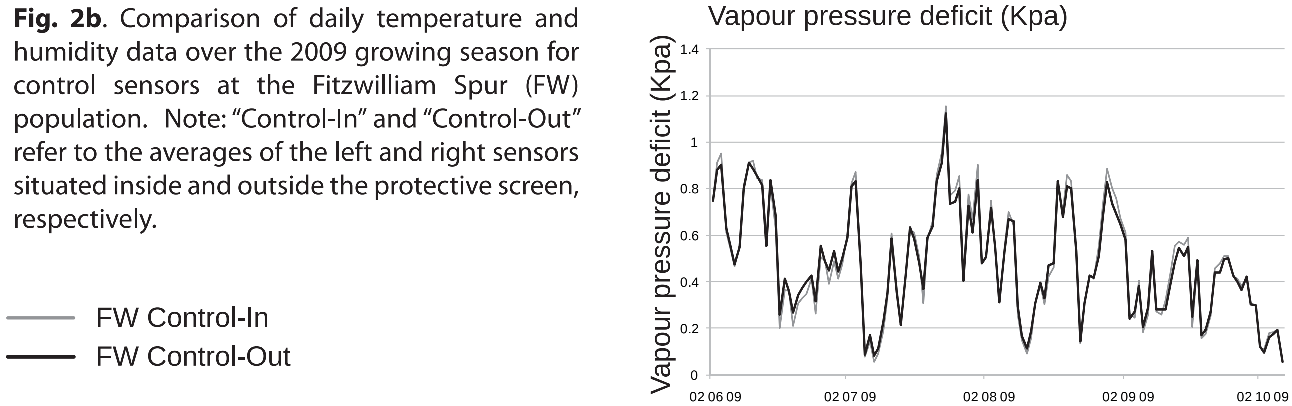


Fig. 2b. Comparison of daily temperature and humidity data over the 2009 growing season for control sensors at the Fitzwilliam Spur (FW) population. Note: "Control-In" and "Control-Out" refer to the averages of the left and right sensors situated inside and outside the protective screen, respectively.



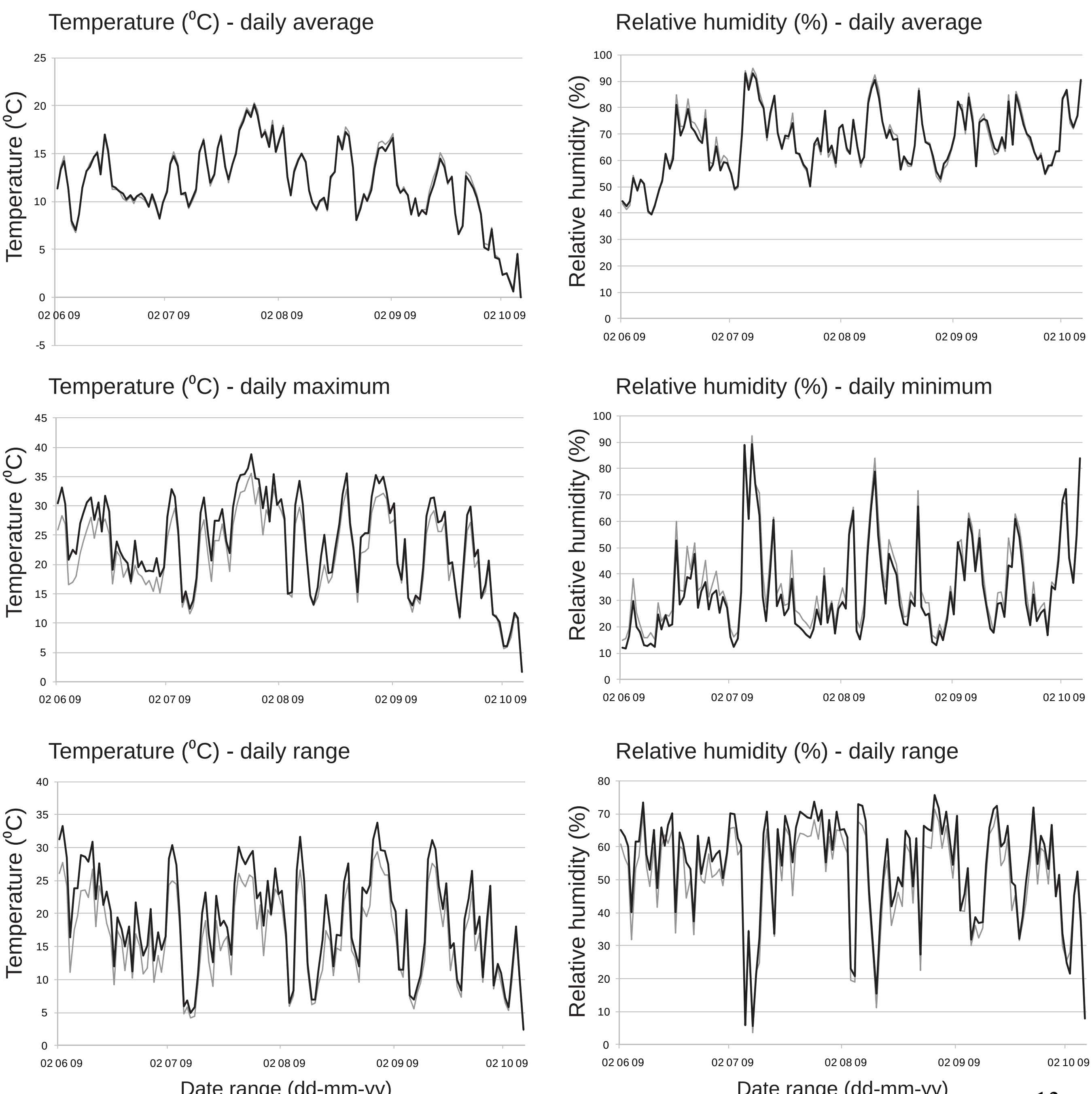
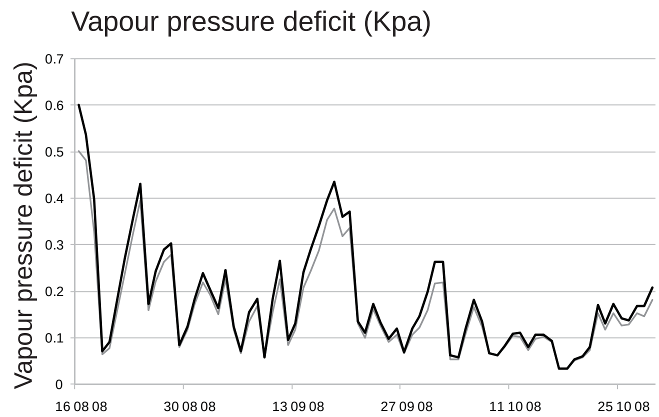


Fig. 3a. Comparison of daily temperature and humidity data over the 2008 growing season for control and population sensors at the Jasper West Gate (JW) population. Note: “Control” and “Population” refer to the averages of the left and right control and population sensors, respectively.



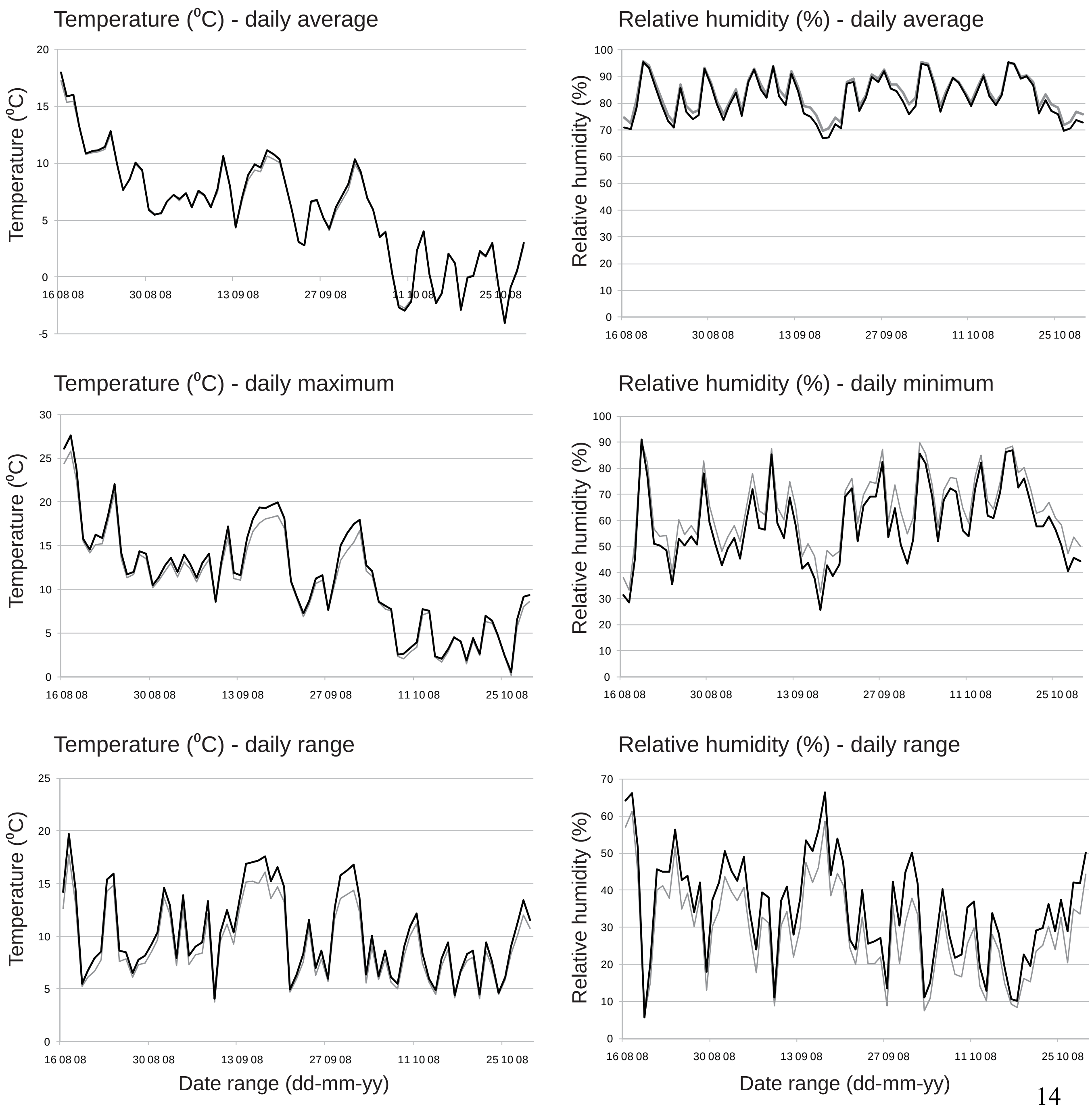
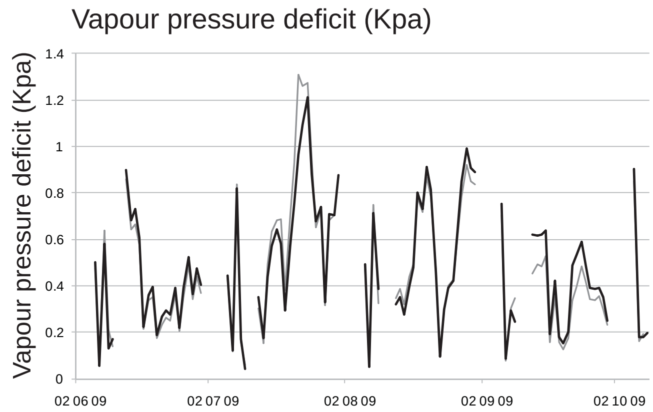


Fig. 3b. Comparison of daily temperature and humidity data over the 2009 growing season for control and population sensors at the Jasper West Gate (JW) population. Note: "Control" and "Population" refer to the averages of the left and right control and population sensors, respectively. Some data are incomplete and have missing sections.

— JW Control
— JW Population



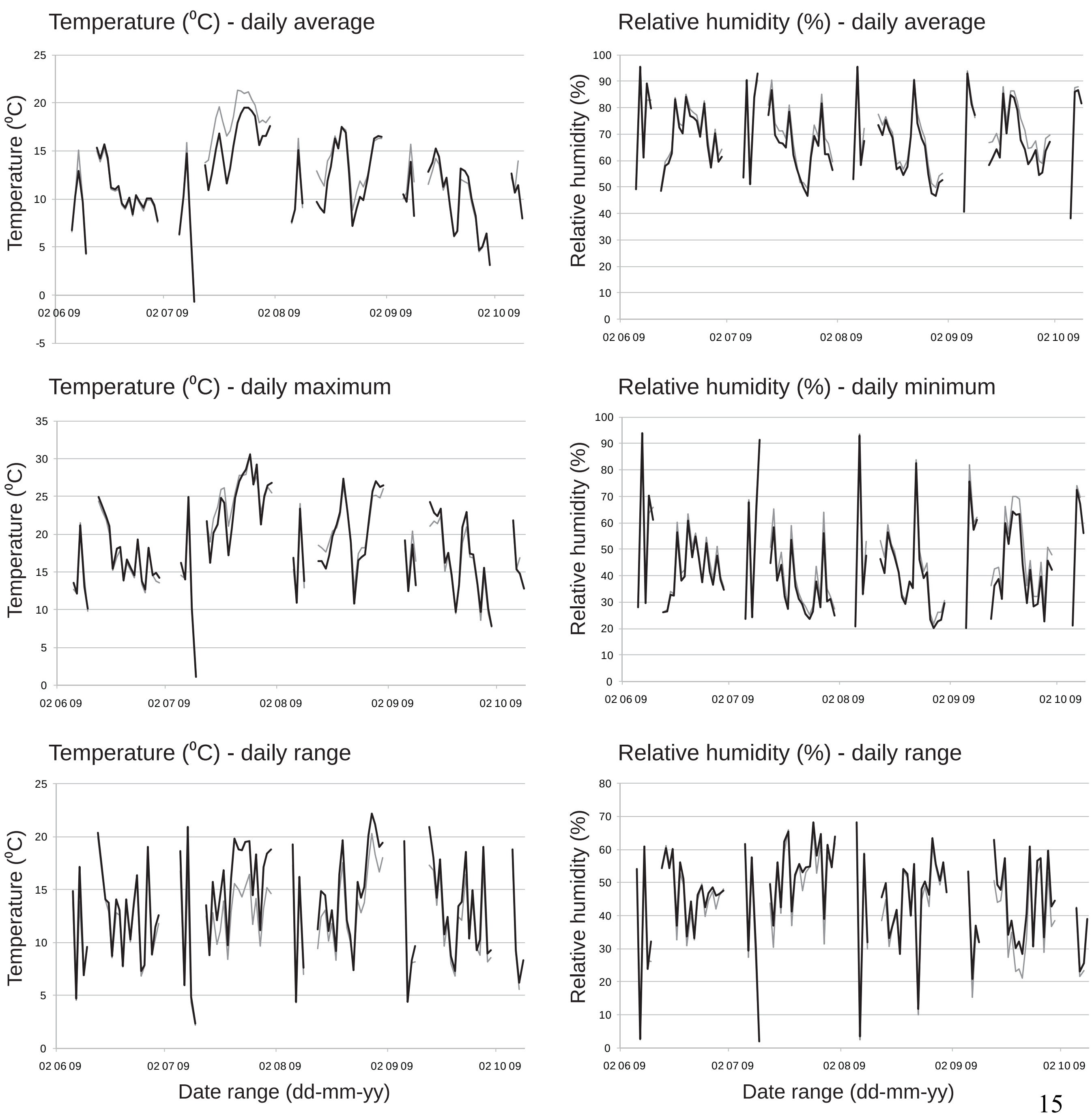
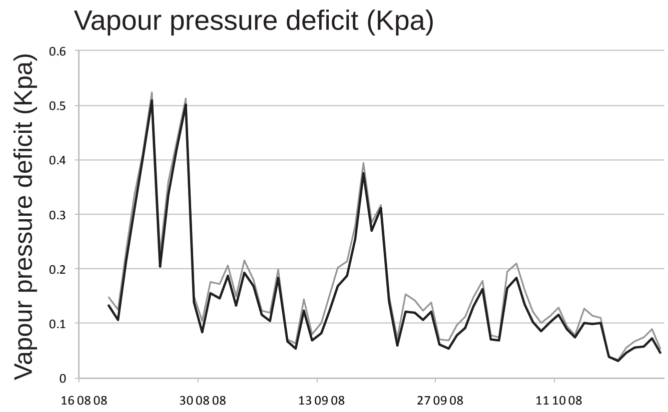


Fig. 4a. Comparison of daily temperature and humidity data over the 2008 growing season for control and population sensors at the Jasper Meadow Creek (MC) population. Note: "Control" and "Population" refer to the averages of the left and right control and population sensors, respectively.



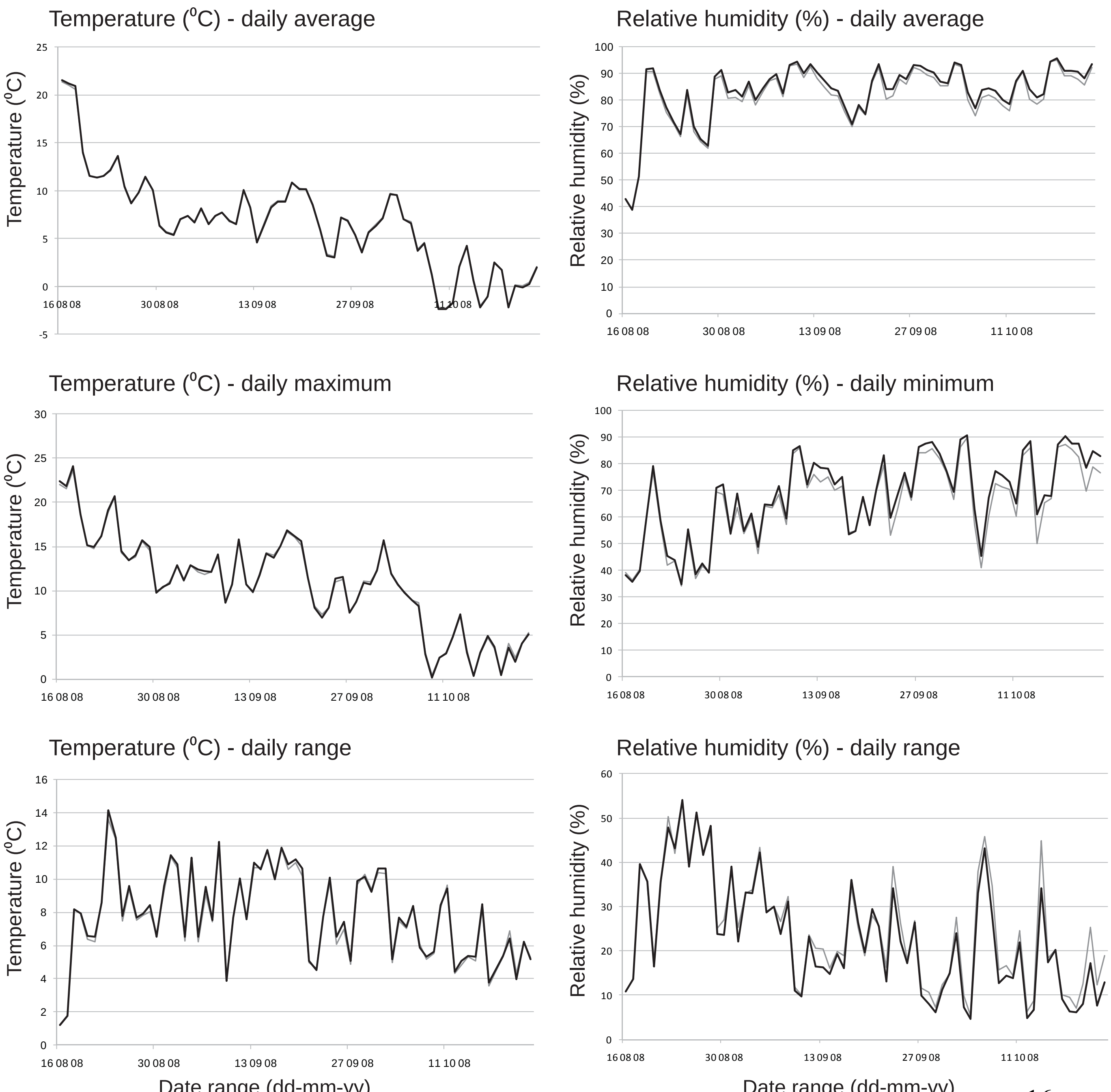
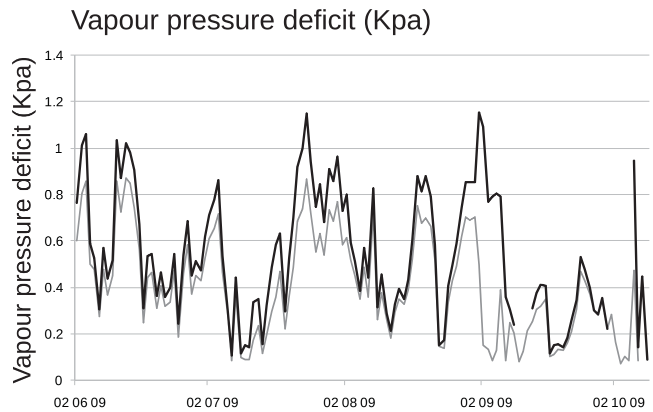
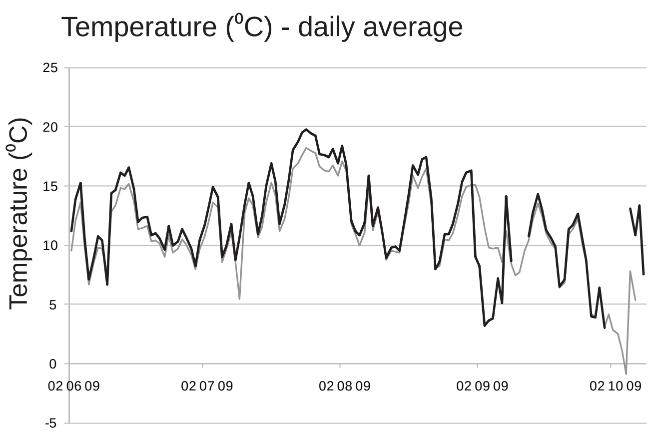
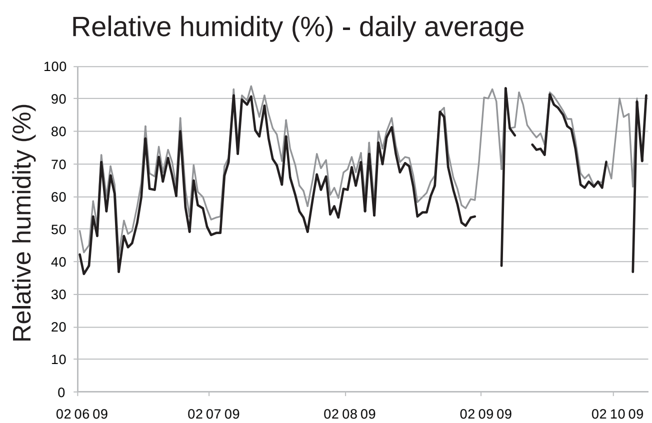


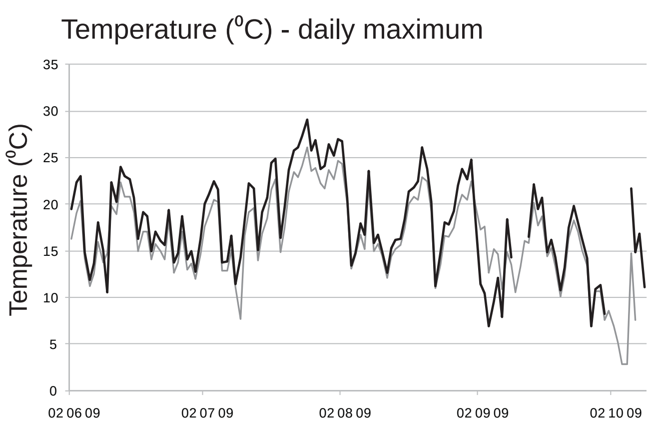
Fig. 4b. Comparison of daily temperature and humidity data over the 2009 growing season for control and population sensors at the Jasper Meadow Creek (MC) population. Note: "Control" and "Population" refer to the averages of the left and right control and population sensors, respectively. Some data are incomplete and have missing sections.

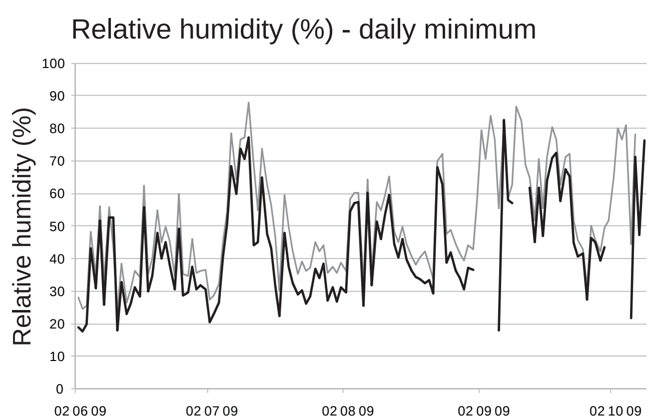
MC Control
MC Population

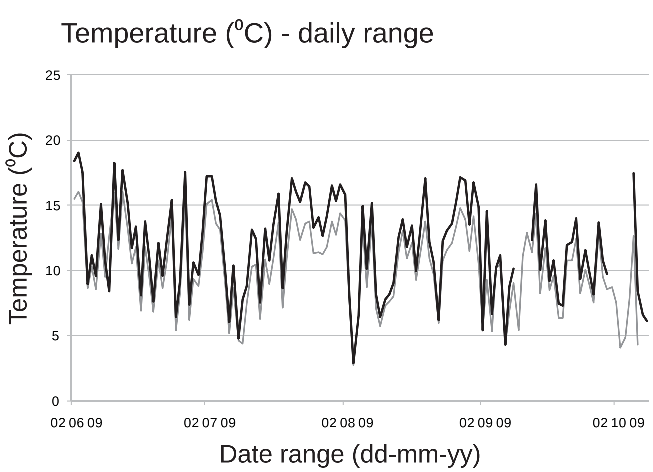












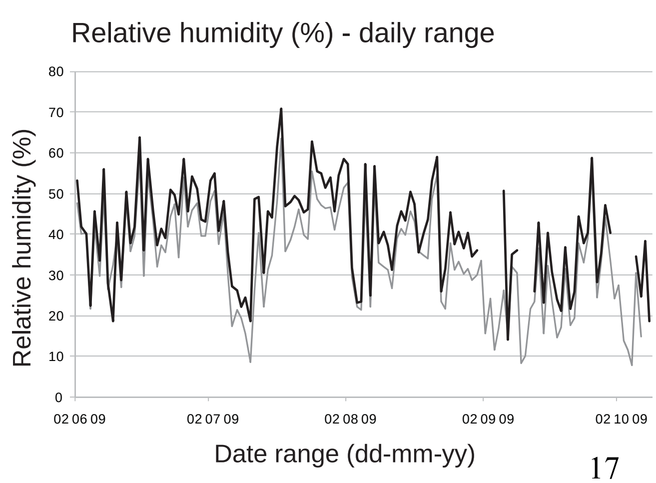
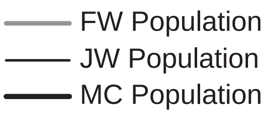
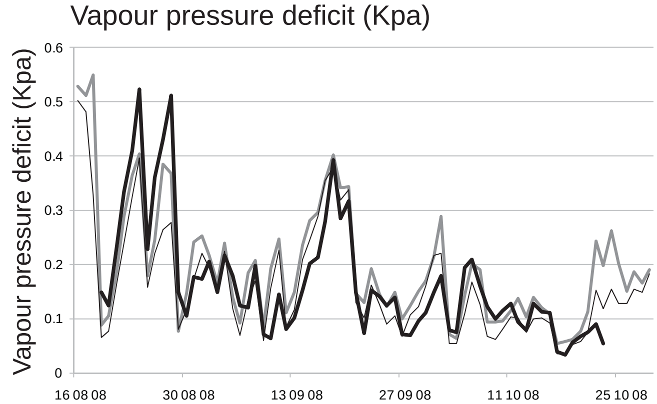


Fig. 5a. Comparison of daily temperature and humidity data over the 2008 growing season for population sensors at the Fitzwilliam Spur (FW), Jasper West Gate (JW), and Jasper Meadow Creek (MC) populations. Note: "Population" refers to the average of the left and right population sensors at each site.





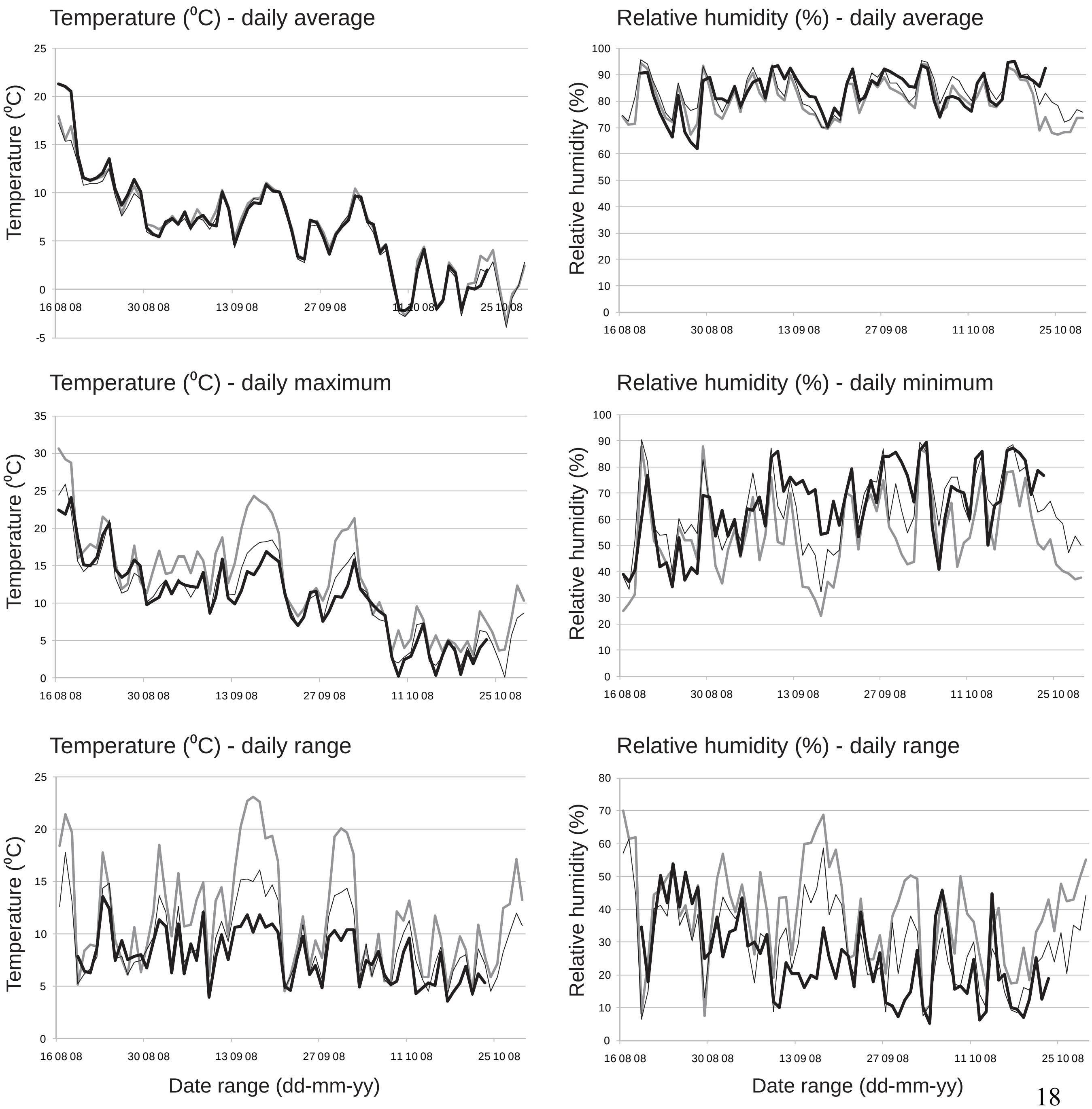
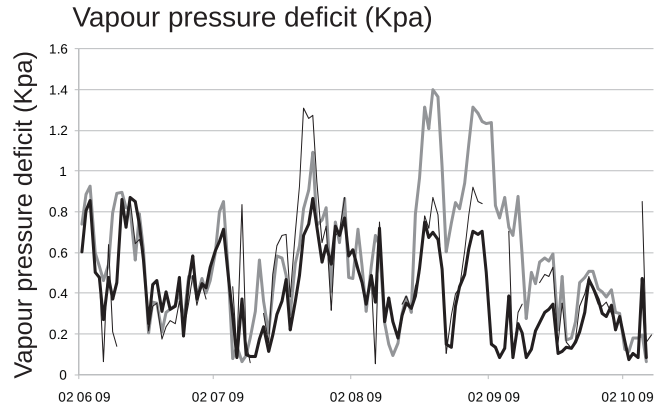
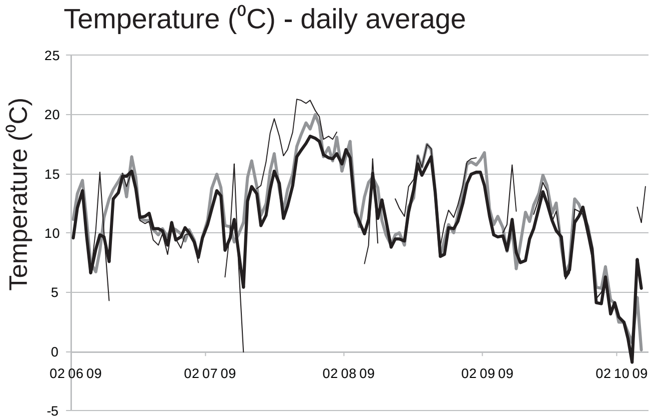
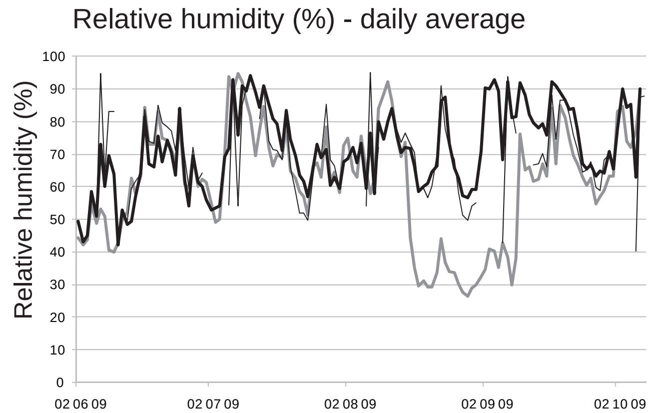


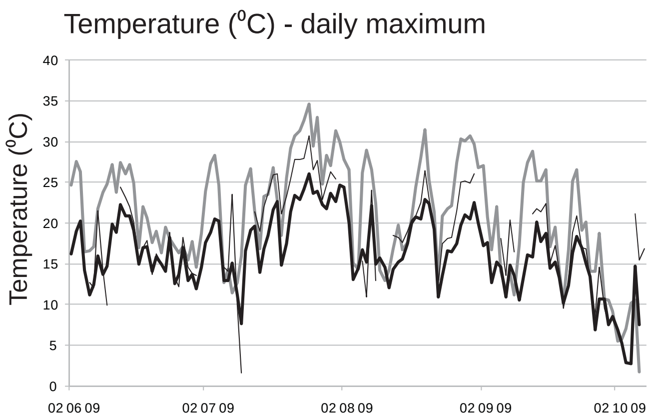
Fig. 5b. Comparison of daily temperature and humidity data over the 2009 growing season for population sensors at the Fitzwilliam Spur (FW), Jasper West Gate (JW), and Jasper Meadow Creek (MC) populations. Note: "Population" refers to the average of the left and right population sensors at each site. Some data are incomplete and have missing sections.

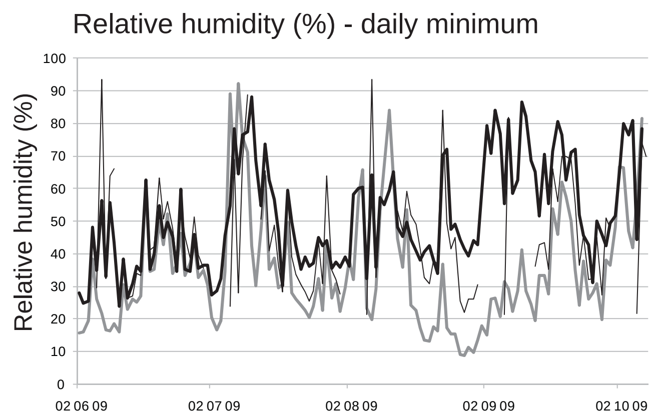
FW Population
JW Population
MC Population

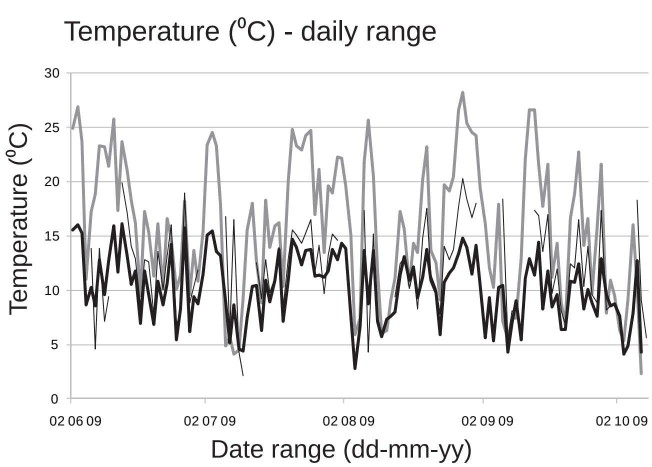












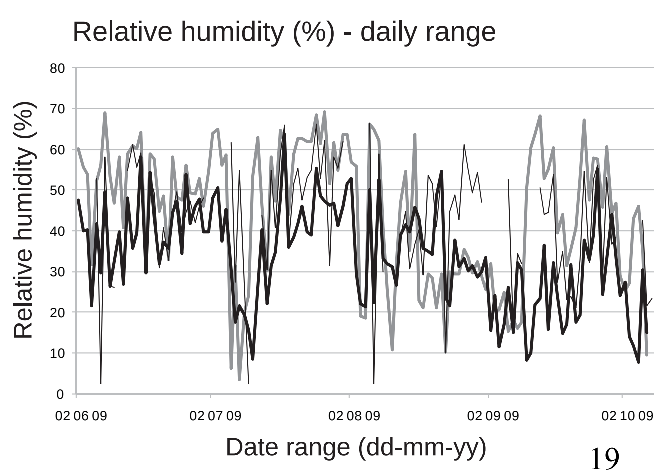


Table 1a. Mean and range of temperature data for the 2008 growing season, for the Fitzwilliam Spur (FW), Jasper West Gate (JW), and Jasper Meadow Creek (MC) control and population sensors.

		Fitzwilliam Spur (FW)			**Jasper West Gate** (JW)		**Jasper Meadow Creek** (MC)	
		Control-In[a]	Control-Out	Population	Control	Population	Control	Population
Temperature (ºC) - daily average								
Aug 16 - 31	Mean (SD)	11.6 (3.34)	11.64 (3.25)	11.47 (3.3)	11.09 (3.5)	10.92 (3.29)	12.51 (4.86)	12.48 (4.75)
	Min - max	6.69 - 18.19	6.95 - 18.23	6.56 - 17.94	5.48 - 18	5.52 - 17.26	5.59 - 21.54	5.69 - 21.33
Sep 1 - 30	Mean (SD)	7.51 (1.99)	7.37 (2.09)	7.39 (1.94)	7.18 (2.16)	7.02 (2.02)	7.04 (2)	7.11 (1.97)
	Min Max	3.16 - 11.31	3.14 - 12.65	3.15 - 11.08	2.75 - 11.14	2.82 - 10.66	3.03 - 10.86	3.15 - 10.86
Oct 1 - 29[b]	Mean (SD)	2.21 (3.72)	1.98 (3.75)	2.17 (3.67)	1.7 (3.76)	1.68 (3.63)	2.19 (3.76)	2.29 (3.74)
	Min Max	-3.46 - 10.65	-3.95 - 10.13	-3.44 - 10.5	-4.08 - 10.35	-3.94 - 9.89	-2.36 - 9.65	-2.24 - 9.7
Total[b]	Mean (SD)	6.34 (4.72)	6.19 (4.81)	6.24 (4.66)	5.89 (4.8)	5.79 (4.66)	6.69 (5.14)	6.75 (5.07)
	Min Max	-3.46 - 18.19	-3.95 - 18.23	-3.44 - 17.94	-4.08 - 18	-3.94 - 17.26	-2.36 - 21.54	-2.24 - 21.33
Temperature (ºC) - daily maximum								
Aug 16 - 31	Mean (SD)	18.88 (6.35)	20.35 (6.8)	18.44 (6.2)	16.77 (5.35)	16.05 (4.89)	16.62 (4.16)	16.48 (4.05)
	Min Max	11.95 - 31.32	12.7 - 34.27	11.39 - 30.64	10.5 - 27.63	10.16 - 25.84	9.74 - 24.1	9.93 - 23.67
Sep 1 - 30	Mean (SD)	16.37 (4.74)	18 (5.52)	15.87 (4.61)	13.53 (3.68)	12.73 (3.24)	11.78 (2.64)	11.76 (2.56)
	Min Max	8.41 - 24.93	8.82 - 27.59	8.18 - 24.36	7.23 - 19.93	6.86 - 18.47	6.98 - 16.86	7.34 - 16.68
Oct 1 - 29[b]	Mean (SD)	8.05 (4.66)	8.53 (4.65)	7.74 (4.61)	6.34 (4.43)	5.87 (4.12)	5.58 (4.26)	5.64 (4.19)
	Min Max	3.35 - 21.88	3.74 - 21.83	3.1 - 21.27	0.58 - 18	0.15 - 16.75	0.22 - 15.72	0.34 - 15.58
Total[b]	Mean (SD)	13.69 (6.81)	14.84 (7.46)	13.27 (6.69)	11.44 (6.05)	10.78 (5.69)	10.84 (5.5)	10.82 (5.39)
	Min Max	3.35 - 31.32	3.74 - 34.27	3.1 - 30.64	0.58 - 27.63	0.15 - 25.84	0.22 - 24.1	0.34 - 23.67
Temperature (ºC) - daily range								
Aug 16 - 31	Mean (SD)	11.89 (5.34)	13.71 (5.9)	11.5 (5.21)	10.48 (4.12)	9.57 (3.74)	7.81 (3.21)	7.56 (3.19)
	Min Max	5.6 - 21.87	6.85 - 23.35	5.18 - 21.42	5.51 - 19.68	5.26 - 17.76	1.22 - 14.13	0.95 - 13.6
Sep 1 - 30	Mean (SD)	14.45 (5.59)	16.49 (6.27)	13.93 (5.42)	11.76 (4.04)	10.66 (3.54)	8.96 (2.42)	8.82 (2.41)
	Min Max	4.75 - 23.72	4.85 - 27.08	4.56 - 23.09	4.06 - 17.63	3.81 - 16.09	3.85 - 12.25	3.98 - 12.09
Oct 1 - 29[b]	Mean (SD)	10.06 (4.17)	11.02 (4.3)	9.68 (4.01)	8.54 (3.07)	7.81 (2.64)	6.45 (2.02)	6.4 (1.99)
	Min Max	4.52 - 20.11	5.29 - 22.3	4.24 - 19.71	4.41 - 16.84	4.1 - 14.34	3.8 - 10.65	3.56 - 10.39
Total[b]	Mean (SD)	12.21 (5.33)	13.78 (5.95)	11.77 (5.17)	10.25 (3.94)	9.33 (3.47)	7.86 (2.7)	7.72 (2.67)
	Min Max	4.52 - 23.72	4.85 - 27.08	4.24 - 23.09	4.06 - 19.68	3.81 - 17.76	1.22 - 14.13	0.95 - 13.6

[a] "Control-In" refers to the average of the left and right control sensors, situated inside the protective screen
"Control-Out" refers to the average of the left and right control sensors, situated outside the protective screen
"Control" refers to the average of the left and right control sensors
"Population" refers to the average of the left and right population sensors

[b] For Jasper Meadow Creek (MC) data were only available to Oct 23, 2008

Table 1b. Mean and range of humidity data for the 2008 growing season, for the Fitzwilliam Spur (FW), Jasper West Gate (JW), and Jasper Meadow Creek (MC) control and population sensors.

		Fitzwilliam Spur (FW)			**Jasper West Gate** (JW)		**Jasper Meadow Creek** (MC)	
		Control-In[a]	Control-Out	Population	Control	Population	Control	Population
Vapour pressure deficit (Kpa)								
Aug 16 - 31	Mean (SD)	0.3 (0.16)	0.31 (0.15)	0.29 (0.16)	0.27 (0.16)	0.24 (0.14)	0.27 (0.15)	0.29 (0.15)
	Min Max	0.07 - 0.56	0.09 - 0.56	0.08 - 0.55	0.07 - 0.6	0.07 - 0.5	0.08 - 0.51	0.11 - 0.52
Sep 1 - 30	Mean (SD)	0.15 (0.07)	0.15 (0.07)	0.14 (0.06)	0.12 (0.06)	0.11 (0.05)	0.09 (0.04)	0.11 (0.05)
	Min Max	0.05 - 0.29	0.06 - 0.28	0.05 - 0.29	0.03 - 0.26	0.04 - 0.22	0.03 - 0.18	0.03 - 0.21
Oct 1 - 29[b]	Mean (SD)	0.2 (0.09)	0.21 (0.09)	0.2 (0.08)	0.2 (0.1)	0.17 (0.09)	0.14 (0.08)	0.16 (0.08)
	Min Max	0.08 - 0.42	0.09 - 0.47	0.08 - 0.4	0.06 - 0.44	0.06 - 0.38	0.05 - 0.38	0.06 - 0.39
Total[b]	Mean (SD)	0.2 (0.12)	0.21 (0.12)	0.2 (0.11)	0.18 (0.12)	0.16 (0.1)	0.15 (0.11)	0.17 (0.11)
	Min Max	0.05 - 0.56	0.06 - 0.56	0.05 - 0.55	0.03 - 0.6	0.04 - 0.5	0.03 - 0.51	0.03 - 0.52
Relative humidity (%) - daily average								
Aug 16 - 31	Mean (SD)	79.09 (9.26)	77.88 (8.78)	79.32 (8.88)	80.49 (8.35)	82.29 (7.64)	72.65 (17.1)	71.62 (16.48)
	Min Max	66.48 - 94.98	64.57 - 93.51	67.38 - 94.38	70.19 - 95.33	72.42 - 95.71	39.02 - 92.13	38.89 - 90.85
Sep 1 - 30	Mean (SD)	80.88 (6.66)	79.97 (6.14)	81.17 (6.32)	81.51 (7.59)	83.27 (6.82)	86.36 (5.95)	84.73 (6.04)
	Min Max	68.63 - 91.9	68.41 - 90.56	69.56 - 91.58	67.01 - 93.78	69.75 - 93.77	71.13 - 94.54	70.06 - 93.54
Oct 1 - 29[b]	Mean (SD)	79.72 (8.5)	78.88 (8.44)	80.06 (8.04)	82.84 (7.5)	84.3 (6.62)	87.02 (5.47)	85.21 (6.24)
	Min Max	66.22 - 94.38	63.67 - 93.97	67.33 - 94.09	69.7 - 95.2	71.95 - 95.35	76.84 - 95.59	74.05 - 95.17
Total[b]	Mean (SD)	80.05 (7.91)	79.1 (7.62)	80.35 (7.52)	81.81 (7.67)	83.46 (6.87)	83.4 (11.17)	81.85 (10.96)
	Min Max	66.22 - 94.98	63.67 - 93.97	67.33 - 94.38	67.01 - 95.33	69.75 - 95.71	39.02 - 95.59	38.89 - 95.17
Relative humidity (%) - daily minimum								
Aug 16 - 31	Mean (SD)	50.24 (19.22)	44.83 (18.66)	51.67 (18.76)	53.45 (16.63)	58.34 (15.79)	50.47 (14.22)	49.48 (13.48)
	Min Max	24.06 - 88.45	19.72 - 86.73	25.19 - 88	28.58 - 90.89	33.33 - 90.48	34.71 - 78.97	34.12 - 76.94
Sep 1 - 30	Mean (SD)	50.13 (14.86)	44.23 (13.58)	52.01 (14.44)	56.1 (13.97)	62.03 (13.18)	70.82 (11.44)	68.63 (11.1)
	Min Max	21.06 - 76.28	17.51 - 66.95	23.12 - 76.28	25.62 - 85.36	32.33 - 87.38	48.76 - 88.17	46.28 - 85.91
Oct 1 - 29[b]	Mean (SD)	55.63 (15.55)	52.88 (14.76)	57.42 (15.11)	64.01 (13.52)	69.22 (11.94)	76.58 (11.76)	72.59 (12.92)
	Min Max	36 - 87.1	34.1 - 86.29	37.11 - 86.94	40.57 - 86.78	47.21 - 89.62	45.47 - 90.58	40.95 - 89.55
Total[b]	Mean (SD)	52.28 (16.12)	47.7 (15.57)	54.03 (15.71)	58.6 (14.88)	64.02 (13.85)	68.02 (15.68)	65.51 (15.11)
	Min Max	21.06 - 88.45	17.51 - 86.73	23.12 - 88	25.62 - 90.89	32.33 - 90.48	34.71 - 90.58	34.12 - 89.55
Relative humidity (%) - daily range								
Aug 16 - 31	Mean (SD)	43.32 (18.13)	48.63 (18.21)	41.52 (17.69)	41.24 (15.99)	35.99 (15.01)	35.18 (13.59)	35.18 (13.62)
	Min Max	7.75 - 71.85	8.55 - 75.75	7.54 - 70.08	5.78 - 66.14	6.41 - 61.37	10.77 - 53.99	9.7 - 53.75
Sep 1 - 30	Mean (SD)	44.1 (14)	49.64 (13.28)	41.81 (13.73)	38.37 (12.84)	31.7 (11.7)	21.88 (9.38)	23.15 (9.05)
	Min Max	19.7 - 71	27.53 - 75.29	19.05 - 68.7	10.97 - 66.49	8.77 - 58.72	6.05 - 42.12	7.21 - 43.32
Oct 1 - 29[b]	Mean (SD)	36.29 (13.36)	38.58 (12.78)	34.01 (12.97)	28.69 (11.42)	23.09 (9.79)	16.05 (10.52)	19.2 (11.91)
	Min Max	9.26 - 57.17	9.62 - 56.58	9.09 - 55	10.27 - 50.21	7.4 - 44.28	4.64 - 43.22	5.32 - 45.8
Total[b]	Mean (SD)	40.91 (14.99)	45.15 (15.03)	38.73 (14.67)	35.24 (13.94)	29.29 (12.76)	23.02 (12.88)	24.62 (12.6)
	Min Max	7.75 - 71.85	8.55 - 75.75	7.54 - 70.08	5.78 - 66.49	6.41 - 61.37	4.64 - 53.99	5.32 - 53.75

[a] "Control-In" refers to the average of the left and right control sensors, situated inside the protective screen
"Control-Out" refers to the average of the left and right control sensors, situated outside the protective screen
"Control" refers to the average of the left and right control sensors
"Population" refers to the average of the left and right population sensors

[b] For Jasper Meadow Creek (MC) data were only available to Oct 23, 2008

Table 2a. Mean and range of temperature data for the 2009 growing season, for the Fitzwilliam Spur (FW), Jasper West Gate (JW), and Jasper Meadow Creek (MC) control and population sensors.

		Fitzwilliam Spur (FW)			**Jasper West Gate** (JW)		**Jasper Meadow Creek** (MC)	
		Control-In[a]	Control-Out	Population	Control	Population	Control	Population
Temperature (ºC) - daily average								
Jun 2 - 30	Mean (SD)	11.4 (2.44)	11.49 (2.34)	11.23 (2.38)	10.46 (2.68)	10.38 (2.76)	11.65 (2.62)	10.83 (2.21)
	Min - max	6.79 - 16.74	6.99 - 16.98	6.7 - 16.44	4.37 - 15.66	4.28 - 15.23	6.71 - 16.6	6.66 - 15.19
Jul 1 - 31	Mean (SD)	14.76 (3.27)	14.66 (3.09)	14.51 (3.17)	14.27 (4.81)	16.24 (5.32)	14.65 (3.36)	13.42 (3.24)
	Min - max	9.27 - 20.25	9.45 - 20.13	9.23 - 19.97	-0.67 - 19.51	-0.06 - 21.32	8.75 - 19.78	5.44 - 18.18
Aug 1 - 31	Mean (SD)	13.19 (2.97)	13.03 (2.82)	13.01 (2.89)	12.36 (3.41)	13.26 (2.96)	13.15 (3.04)	12.49 (2.71)
	Min - max	8.1 - 17.98	8.1 - 17.71	8.04 - 17.71	7.21 - 17.49	7.44 - 17.51	8.01 - 18.41	8.04 - 17.06
Sep 1 - 30	Mean (SD)	10.6 (3.14)	10.31 (3.06)	10.52 (3.15)	10.01 (3.53)	9.87 (3.39)	8.58 (3.57)	9.54 (2.89)
	Min - max	4.44 - 17.05	4.14 - 16.68	4.35 - 16.77	3.08 - 15.26	3.18 - 15.72	3.06 - 14.3	3.16 - 15.1
Oct 1 - 7	Mean (SD)	2.35 (1.61)	2.21 (1.67)	2.29 (1.62)	11.65 (1.4)	11.54 (0.92)	11.95 (1.59)	3.28 (2.83)
	Min - max	0.13 - 4.59	-0.04 - 4.5	0.1 - 4.53	10.66 - 12.65	10.89 - 12.19	10.83 - 13.08	-0.88 - 7.78
Total	Mean (SD)	11.97 (4.02)	11.85 (3.95)	11.8 (3.95)	11.82 (3.98)	12.48 (4.47)	12.13 (3.8)	11.14 (3.65)
	Min - max	0.13 - 20.25	-0.04 - 20.13	0.1 - 19.97	-0.67 - 19.51	-0.06 - 21.32	3.06 - 19.78	-0.88 - 18.18
Temperature (ºC) - daily maximum								
Jun 2 - 30	Mean (SD)	21.29 (4.53)	24.31 (5.01)	20.83 (4.33)	16.64 (3.96)	16.26 (3.89)	17.53 (3.74)	16.15 (3.04)
	Min - max	15.1 - 28.26	17.17 - 33.09	14.59 - 27.51	10.17 - 24.92	9.88 - 24.38	10.59 - 24.04	11.18 - 22.32
Jul 1 - 31	Mean (SD)	24.94 (6.77)	27.47 (7.43)	24.3 (6.43)	21.97 (6.81)	22.47 (6.61)	21.23 (4.71)	18.99 (4.46)
	Min - max	11.6 - 35.54	12.39 - 38.87	11.48 - 34.68	1.1 - 30.57	1.59 - 30.66	11.39 - 29.09	7.66 - 26.07
Aug 1 - 31	Mean (SD)	23.54 (6.49)	25.48 (7.02)	22.82 (6.04)	19.69 (4.99)	19.92 (4.36)	19.27 (4.33)	17.92 (3.72)
	Min - max	13.04 - 32.82	13.16 - 35.53	12.97 - 31.42	10.82 - 27.32	10.99 - 26.38	11.19 - 26.97	10.99 - 24.63
Sep 1 - 30	Mean (SD)	19.76 (5.95)	21.08 (6.76)	19.23 (5.99)	16.51 (4.97)	15.98 (4.5)	14.12 (4.39)	14.36 (3.38)
	Min - max	10.7 - 29.19	11 - 31.42	10.27 - 28.82	7.83 - 24.32	7.77 - 22.44	6.91 - 22.11	6.97 - 20.16
Oct 1 - 7	Mean (SD)	7.43 (3.29)	7.92 (3.52)	7.15 (3.1)	18.61 (4.64)	18.29 (3.98)	18.27 (4.78)	6.95 (4.11)
	Min - max	1.82 - 11.13	1.72 - 11.77	1.79 - 10.58	15.33 - 21.89	15.47 - 21.1	14.89 - 21.65	2.8 - 14.76
Total	Mean (SD)	21.61 (7.03)	23.7 (7.8)	21.03 (6.78)	18.76 (5.66)	18.72 (5.56)	18.18 (4.96)	16.34 (4.64)
	Min - max	1.82 - 35.54	1.72 - 38.87	1.79 - 34.68	1.1 - 30.57	1.59 - 30.66	6.91 - 29.09	2.8 - 26.07
Temperature (ºC) - daily range								
Jun 2 - 30	Mean (SD)	17.58 (5.62)	21.17 (6.36)	17.14 (5.38)	12.35 (4.2)	11.82 (3.97)	12.36 (3.76)	11.09 (3.19)
	Min - max	9.17 - 27.73	11.27 - 33.29	9.53 - 26.85	4.69 - 20.37	4.55 - 19.88	6.42 - 19.07	5.4 - 16.08
Jul 1 - 31	Mean (SD)	17.23 (6.88)	20.17 (7.68)	16.61 (6.49)	14.79 (5.21)	12.15 (3.91)	12.92 (3.46)	10.9 (3.1)
	Min - max	4.17 - 26.13	4.97 - 30.34	4.06 - 24.83	2.34 - 20.89	2.15 - 16.77	4.79 - 17.23	4.38 - 15.41
Aug 1 - 31	Mean (SD)	17.54 (7.15)	19.98 (8.03)	16.78 (6.7)	14.56 (4.82)	13.13 (4.19)	11.91 (3.81)	10.56 (3.11)
	Min - max	5.98 - 29.4	6.39 - 33.8	5.89 - 28.21	4.4 - 22.15	4.28 - 20.29	2.86 - 17.18	2.77 - 14.76
Sep 1 - 30	Mean (SD)	15.54 (6.33)	17.41 (7.1)	14.94 (6.12)	12.73 (4.62)	11.77 (4)	10.55 (2.95)	9.24 (2.5)
	Min - max	5.61 - 27.62	6.98 - 31.1	5.5 - 26.61	4.39 - 20.9	5.47 - 18.41	4.35 - 16.59	4.33 - 14.41
Oct 1 - 7	Mean (SD)	8.69 (4.68)	9.48 (4.98)	8.41 (4.34)	14.03 (6.75)	13.68 (6.51)	12.92 (6.42)	7.17 (3.06)
	Min - max	2.35 - 17.11	2.4 - 18.02	2.34 - 15.99	9.25 - 18.81	9.08 - 18.28	8.38 - 17.46	4.08 - 12.68
Total	Mean (SD)	16.52 (6.68)	19.12 (7.62)	15.93 (6.35)	13.64 (4.78)	12.25 (4.01)	11.99 (3.61)	10.27 (3.12)
	Min - max	2.35 - 29.4	2.4 - 33.8	2.34 - 28.21	2.34 - 22.15	2.15 - 20.29	2.86 - 19.07	2.77 - 16.08

[a] "Control-In" refers to the average of the left and right control sensors, situated inside the protective screen
"Control-Out" refers to the average of the left and right control sensors, situated outside the protective screen
"Control" refers to the average of the left and right control sensors
"Population" refers to the average of the left and right population sensors

Table 2b. Mean and range of humidity data for the 2009 growing season, for the Fitzwilliam Spur (FW), Jasper West Gate (JW), and Jasper Meadow Creek (MC) control and population sensors.

		Fitzwilliam Spur (FW)			**Jasper West Gate** (JW)		**Jasper Meadow Creek** (MC)	
		Control-In[a]	Control-Out	Population	Control	Population	Control	Population
Vapour pressure deficit (Kpa)								
Jun 2 - 30	Mean (SD)	0.56 (0.23)	0.58 (0.21)	0.55 (0.23)	0.4 (0.21)	0.38 (0.2)	0.61 (0.24)	0.51 (0.2)
	Min - max	0.2 - 0.95	0.26 - 0.91	0.21 - 0.93	0.05 - 0.9	0.06 - 0.86	0.24 - 1.06	0.19 - 0.87
Jul 1 - 31	Mean (SD)	0.56 (0.29)	0.54 (0.26)	0.53 (0.27)	0.59 (0.31)	0.64 (0.36)	0.59 (0.3)	0.45 (0.24)
	Min - max	0.06 - 1.15	0.08 - 1.13	0.06 - 1.09	0.04 - 1.21	0.06 - 1.31	0.11 - 1.15	0.08 - 0.87
Aug 1 - 31	Mean (SD)	0.51 (0.23)	0.5 (0.21)	0.74 (0.4)	0.55 (0.27)	0.54 (0.25)	0.56 (0.23)	0.47 (0.18)
	Min - max	0.09 - 0.89	0.12 - 0.83	0.1 - 1.4	0.05 - 0.99	0.06 - 0.92	0.15 - 0.88	0.14 - 0.75
Sep 1 - 30	Mean (SD)	0.4 (0.15)	0.39 (0.13)	0.55 (0.27)	0.4 (0.19)	0.34 (0.15)	0.43 (0.28)	0.24 (0.12)
	Min - max	0.16 - 0.67	0.17 - 0.65	0.17 - 1.24	0.09 - 0.75	0.08 - 0.71	0.11 - 1.15	0.08 - 0.5
Oct 1 - 7	Mean (SD)	0.16 (0.08)	0.16 (0.08)	0.17 (0.08)	0.54 (0.51)	0.51 (0.49)	0.54 (0.57)	0.18 (0.15)
	Min - max	0.06 - 0.3	0.06 - 0.3	0.07 - 0.3	0.18 - 0.9	0.16 - 0.85	0.14 - 0.95	0.07 - 0.47
Total	Mean (SD)	0.49 (0.24)	0.48 (0.23)	0.57 (0.32)	0.49 (0.26)	0.48 (0.28)	0.55 (0.27)	0.4 (0.22)
	Min - max	0.06 - 1.15	0.06 - 1.13	0.06 - 1.4	0.04 - 1.21	0.06 - 1.31	0.11 - 1.15	0.07 - 0.87
Relative humidity (%) - daily average								
Jun 2 - 30	Mean (SD)	59.58 (13.45)	58.41 (12.03)	60.02 (13.32)	69.86 (12.39)	71.34 (11.6)	57.29 (11.83)	61.51 (11.09)
	Min - max	39.42 - 84.76	39.64 - 81.05	39.91 - 84.48	48.64 - 95.61	49.63 - 94.85	36.16 - 80	42.05 - 84.01
Jul 1 - 31	Mean (SD)	69.09 (13.19)	69.17 (12.45)	69.78 (12.94)	67.07 (13.16)	69.77 (12.98)	67.07 (13.71)	72.68 (12.89)
	Min - max	48.6 - 95.06	49.2 - 93.19	49.17 - 94.65	46.53 - 92.83	49.55 - 90.53	48.21 - 91.18	52.82 - 94
Aug 1 - 31	Mean (SD)	68.28 (10.86)	68.11 (9.94)	52.54 (22.26)	64.35 (12.61)	66.71 (12.14)	65.07 (9.87)	68.89 (8.83)
	Min - max	51.68 - 92.58	52.97 - 90.56	26.43 - 92.16	46.68 - 95.53	49.76 - 95.19	50.95 - 86.03	56.49 - 87.41
Sep 1 - 30	Mean (SD)	69.59 (9.08)	69.47 (8.43)	58.07 (15.9)	67.99 (12.6)	72.05 (11.62)	74.13 (12.43)	79.93 (9.98)
	Min - max	54.53 - 86.01	55 - 84.84	29.89 - 85.08	40.7 - 92.82	42.67 - 93.94	38.92 - 93.12	63.33 - 93
Oct 1 - 7	Mean (SD)	78.07 (9.08)	78.49 (9.15)	77.6 (8.81)	62.16 (33.81)	63.87 (33.58)	63.04 (36.77)	79.48 (11.22)
	Min - max	63.68 - 90.09	63.4 - 90.43	63.19 - 89.16	38.25 - 86.07	40.12 - 87.62	37.04 - 89.04	63.06 - 90.16
Total	Mean (SD)	67.35 (12.4)	67.06 (11.79)	61.08 (17.63)	67.2 (13.01)	69.82 (12.49)	65.35 (13.49)	71.3 (12.59)
	Min - max	39.42 - 95.06	39.64 - 93.19	26.43 - 94.65	38.25 - 95.61	40.12 - 95.19	36.16 - 93.12	42.05 - 94
Relative humidity (%) - daily minimum								
Jun 2 - 30	Mean (SD)	30.52 (12)	25.99 (10.74)	31.41 (12.17)	44.94 (16.14)	46.5 (15.82)	34.58 (11.17)	39.82 (10.81)
	Min - max	15.08 - 59.98	11.9 - 52.77	15.61 - 62.62	26.07 - 93.92	26.27 - 93.37	17.73 - 55.9	23.78 - 62.51
Jul 1 - 31	Mean (SD)	37.6 (20.87)	33.93 (21.32)	38.85 (20.77)	39.62 (17.47)	42.72 (17.59)	40.89 (16.28)	49.76 (16.83)
	Min - max	16.17 - 92.42	12.28 - 89.17	16.68 - 92.13	23.62 - 91.52	24.01 - 88.82	20.59 - 77.29	27.32 - 87.98
Aug 1 - 31	Mean (SD)	37.84 (17.93)	34.08 (17.5)	30.91 (20.54)	40.89 (18.07)	43.09 (18.13)	42.41 (11.62)	48.22 (11.02)
	Min - max	15.56 - 84.08	13.05 - 78.93	8.77 - 84.06	20.32 - 93.03	21.49 - 93.56	25.66 - 68.02	32.23 - 72.07
Sep 1 - 30	Mean (SD)	38.96 (13.41)	35.74 (13.04)	32.35 (11.79)	44.14 (15.91)	49.35 (16.1)	52.66 (15.37)	63.36 (14.61)
	Min - max	18.09 - 63.28	16.77 - 60.94	15.04 - 61.92	20.18 - 75.68	21.34 - 81.88	17.95 - 82.48	31.25 - 86.62
Oct 1 - 7	Mean (SD)	57.89 (15.36)	58.08 (17.14)	58.23 (14.07)	46.78 (36.19)	47.86 (36.91)	46.38 (34.97)	68.1 (14.85)
	Min - max	38.74 - 82.99	36.6 - 84.06	41.7 - 81.54	21.19 - 72.37	21.76 - 73.96	21.65 - 71.1	44.46 - 81.01
Total	Mean (SD)	37.48 (17.24)	33.91 (17.47)	34.78 (17.81)	42.44 (17.05)	45.4 (17.15)	42.05 (15.06)	51.33 (16.23)
	Min - max	15.08 - 92.42	11.9 - 89.17	8.77 - 92.13	20.18 - 93.92	21.34 - 93.56	17.73 - 82.48	23.78 - 87.98
Relative humidity (%) - daily range								
Jun 2 - 30	Mean (SD)	53.05 (9.32)	57.95 (8.68)	51.82 (9.31)	44.88 (13.36)	43.4 (13.52)	43.53 (10.72)	40.19 (8.93)
	Min - max	31.8 - 70.05	37.36 - 73.35	30.77 - 68.98	2.62 - 60.99	2.52 - 61.07	18.65 - 63.67	21.69 - 58.07
Jul 1 - 31	Mean (SD)	52.74 (17.76)	56.74 (18.94)	51.34 (17.69)	50.63 (15.02)	48.12 (15.52)	45.43 (12.31)	37.86 (12.64)
	Min - max	3.57 - 70.07	5.74 - 73.62	3.59 - 69.3	2.06 - 68.2	2.48 - 66.3	18.75 - 70.92	8.59 - 63.65
Aug 1 - 31	Mean (SD)	50.17 (16.71)	54.54 (16.93)	36.42 (16.61)	44.77 (15.34)	43.09 (15.25)	40.94 (10.45)	35.81 (10.01)
	Min - max	11.11 - 71.44	15.44 - 75.61	10.31 - 66.2	3.5 - 68.31	2.56 - 66.35	23.29 - 59.07	21.47 - 54.6
Sep 1 - 30	Mean (SD)	50.05 (11.75)	53.49 (12.22)	42.48 (16.78)	43.21 (12.45)	38.33 (12.48)	34.61 (10.89)	25.94 (10.97)
	Min - max	30.07 - 70.74	31.94 - 72.55	15.38 - 68.21	20.96 - 62.88	15.29 - 56.02	14.16 - 58.82	8.26 - 55.24
Oct 1 - 7	Mean (SD)	32.01 (13.54)	31.9 (15.14)	30.73 (12.24)	32.69 (13.4)	32.14 (14.81)	29.58 (7.02)	18.65 (8.64)
	Min - max	9.1 - 49.93	7.91 - 52.62	9.52 - 46.05	23.22 - 42.16	21.67 - 42.61	24.61 - 34.54	7.83 - 30.5
Total	Mean (SD)	50.42 (14.88)	54.36 (15.7)	44.63 (16.75)	45.67 (14.23)	43.11 (14.49)	41.39 (11.67)	34.05 (12.31)
	Min - max	3.57 - 71.44	5.74 - 75.61	3.59 - 69.3	2.06 - 68.31	2.48 - 66.35	14.16 - 70.92	7.83 - 63.65

[a] "Control-In" refers to the average of the left and right control sensors, situated inside the protective screen
"Control-Out" refers to the average of the left and right control sensors, situated outside the protective screen
"Control" refers to the average of the left and right control sensors
"Population" refers to the average of the left and right population sensors

Table 3a. Comparisons of temperature and humidity data between control and population sensors at the Fitzwilliam Spur (FW), Jasper West Gate (JW), and Jasper Meadow Creek (MC) populations for the 2008 and 2009 growing seasons (see Methods for calculations).

2008

	FW Control-Out *versus* FW Control-In[a,b]		FW Control-Out *versus* FW Population		JW Control *versus* JW Population		MC Control *versus* MC Population	
	z-value	P-value[c]	z-value	P-value	z-value	P-value	z-value	P-value
Temperature (ºC) - daily average	-0.052	0.479	-0.017	0.493	0.036	0.485	0.019	0.492
Temperature (ºC) - daily maximum	0.319	0.375	0.435	0.332	0.201	0.421	0.007	0.497
Temperature (ºC) - daily range	0.926	0.177	1.194	0.116	-0.765	0.222	0.42	0.337
Vapour pressure deficit (Kpa)	0.284	0.388	0.392	0.348	0.443	0.329	0.462	0.322
Relative humidity (%) - daily average	0.437	0.331	0.573	0.283	0.765	0.222	0.42	0.337
Relative humidity (%) - daily minimum	1.114	0.133	1.540	0.062	1.311	0.095	0.503	0.307
Relative humidity (%) - daily range	1.136	0.128	1.721	0.043	1.635	0.051	0.497	0.31

2009

	FW Control-Out *versus* FW Control-In[a,b]		FW Control-Out *versus* FW Population		JW Control *versus* JW Population		MC Control *versus* MC Population	
	z-value	P-value[c]	z-value	P-value	z-value	P-value	z-value	P-value
Temperature (ºC) - daily average	-0.055	0.478	0.022	0.491	-[d]	-	0.763	0.322
Temperature (ºC) - daily maximum	0.581	0.28	0.742	0.229	-	-	1.208	0.113
Temperature (ºC) - daily range	1.075	0.141	1.317	0.094	-	-	2.114	**0.017**
Vapour pressure deficit (Kpa)	0.012	0.495	-0.695	0.243	-	-	1.321	0.093
Relative humidity (%) - daily average	0.072	0.471	1.480	0.069	-	-	1.188	0.118
Relative humidity (%) - daily minimum	0.78	0.218	0.138	0.445	-	-	2.29	**0.011**
Relative humidity (%) - daily range	1.011	0.156	2.500	**0.006**	-	-	2.481	0.039

[a] Site codes:

FW Control-In - Fitzwilliam Spur (FW) control sensors, situated inside protective screen
FW Control-Out - Fitzwilliam Spur (FW) control sensors, situated outside protective screen
FW Population - Fitzwilliam Spur (FW) population sensors
JW Control - Jasper West Gate (JW) control sensors
JW Population - Jasper West Gate (JW) population sensors
MC Control - Jasper Meadow Creek (MC) control sensors
MC Population - Jasper Meadow Creek (MC) population sensors

"Control-In" refers to the average of the left and right control sensors, situated inside the protective screen (FW only)
"Control-Out" refers to the average of the left and right control sensors, situated outside the protective screen (FW only)
"Control" refers to the average of the left and right control sensors
"Population" refers to the average of the left and right population sensors

[b] Date ranges used for analyses:

2008

FW Control-In *versus* FW Control-Out	Aug 16 - Oct 29
JW Control *versus* JW Population	Aug 16 - Oct 29
MC Control *versus* MC Population	Aug 16 - Oct 23

2009

FW Control-In *versus* FW Control-Out	Jun 2 - Oct 7
JW Control *versus* JW Population	Not performed
MC Control *versus* MC Population	Jun 2 - Aug 31

[c] P-values in bold are significant after correcting for multiple pair-wise tests

[d] Dash ("-") indicates test could not be performed

Table 3b. Comparisons of temperature and humidity data among the Fitzwilliam Spur (FW), Jasper West Gate (JW), and Jasper Meadow Creek (MC) population sensors for the 2008 and 2009 growing seasons (see Methods for calculations).

2008

	FW Population *versus* JW Population[a,b]		FW Population *versus* MC Population		JW Population *versus* MC Population	
	z-value	P-value[c]	z-value	P-value	z-value	P-value
Temperature (ºC) - daily average	0.163	0.435	-0.176	0.43	0.329	0.742
Temperature (ºC) - daily maximum	0.737	0.231	0.725	0.234	0.01	0.685
Temperature (ºC) - daily range	1.802	0.036	3.288	**0.001**	1.835	0.066
Vapour pressure deficit (Kpa)	1.063	0.144	0.068	0.473	0.604	0.546
Relative humidity (%) - daily average	1.49	0.068	0.506	0.307	0.545	0.585
Relative humidity (%) - daily minimum	2.434	**0.007**	2.534	**0.006**	0.334	0.739
Relative humidity (%) - daily range	2.586	**0.005**	3.774	**<0.001**	1.292	0.196

2009

	FW Population *versus* JW Population[a,b]		FW Population *versus* MC Population		JW Population *versus* MC Population	
	z-value	P-value[c]	z-value	P-value	z-value	P-value
Temperature (ºC) - daily average	-[d]	-	0.319	0.375	-	-
Temperature (ºC) - daily maximum	-	-	1.76	**0.039**	-	-
Temperature (ºC) - daily range	-	-	4.002	**<0.001**	-	-
Vapour pressure deficit (Kpa)	-	-	0.945	0.172	-	-
Relative humidity (%) - daily average	-	-	1.043	0.149	-	-
Relative humidity (%) - daily minimum	-	-	2.147	**0.016**	-	-
Relative humidity (%) - daily range	-	-	2.426	**0.008**	-	-

[a] Site codes:
FW Population - Fitzwilliam Spur (FW) population sensors
JW Population - Jasper West Gate (JW) population sensors
MC Population - Jasper Meadow Creek (MC) population sensors
"Population" refers to the average of the left and right population sensors

[b] Date ranges used for analyses:

2008
FW Population *versus* JW Population — Aug 16 - Oct 29
FW Population *versus* MC Population — Aug 16 - Oct 23
JW Population *versus* MC Population — Aug 16 - Oct 23

2009
FW Population *versus* JW Population — Not performed
FW Population *versus* MC Population — Jun 2 - Oct 7
JW Population *versus* MC Population — Not performed

[c] P-values in bold are significant after correcting for multiple pair-wise tests

[d] Dash ("-") indicates test could not be performed