Habitat Monitoring: An Ecological Qualification Based on Water and Soil Sampling and Panoramic Photographs in Costa Rica

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INTRODUCTION

Costa Rica is a very environmentally conscious nation, especially with regards to habitat protection and conservation. Due to high levels of public awareness regarding environmental problems, there is a growing emphasis being made on reforestation efforts (Blum, 2007). For this reason Costa Rica has earned its name as the "green republic". The site that is the focus of this study, Leaves and Lizards Volcano Cabin Retreat (Figure 1), is one of many privately-owned properties being transformed into reforestation areas that aim at doing their part for the environment as a whole. When the students from the Field Ecology course in 2008 visited the Leaves and Lizards property, they produced the groundwork for this year's projects. By mapping the property, analyzing water sources and enumerating plant life they created the outline from which we simply had to continue their research.

The main objective of this project was to monitor the habitat to further understand how to make reforestation successful. As stated in the 2008 Field Ecology GPS Mapping and Water Source Analysis, electronic ecological cartography via clickable icons and panoramic photographs is a most helpful medium for enhancing reforestation progress as it connects you to the mapped area. Leaves and Lizards lies on soils developed from volcanic ash deposit, which implies that the site has great potential for fertility (Vásquez Morera, 1983). Furthermore, the Holdridge Life Zones say that tropical rain forests, like the one in which the site is located, are usually very dense and lush. With this in mind, we sought to continue monitoring the Leaves and Lizards habitat for the benefit of successful reforestation.

The objectives of this year's study were to continue water data collection and vegetation growth observations from 2008. Also, we re-photographed the site by taking panoramic photos at points from the previous year in order to actually see reforestation progress at the site. In addition, we added a new objective for soil sampling. We hoped that soil sampling would allow the property owners to know of the relationship between plants that are best suited for the property based on the different types of soil found. We expected that the objectives of habitat monitoring would aid the reforestation efforts and environmental protection by providing scientific information and clues as to how to continue to make this habitat more natural.

MATERIALS AND METHODS

I – Water Sampling

The purpose of water sampling during the May 2009 Field ecology course was to continue the data retrieved in 2008 at the Leaves and Lizards site. We gathered and compared water and air temperature using a HOBO thermometer device over twenty-four hour periods in various stream sample points. We also calculated the flow rate at stream sample points. Compared to last year, we found that the vast growth in the surrounding vegetation narrowed our research from four water-sampling points down to two. Regardless, we were able to gather sufficient data for assessing water.

The first step was to pinpoint the locations where water sampling would take place. The first water source we sampled we labeled Spring Stream 2 as it was named that by the students in 2008. This particular stream was thought to be a potential hot spring, but as the results from last year pointed out it was just lukewarm. The second sample point we labeled Spring Stream 1 following last year's naming.

After locating the sample points, we set up the HOBO thermometer devices and readied them for deployment. For both Stream locations, the thermometers were programmed to record the temperature at 15minute intervals. For the Stream 2 location, we had to unearth the water source by digging a whole to create a deep enough puddle in which to bury the HOBO device. In order to make sure the device stayed submerged, we tied it with a zip tie to a stick and pushed it down with a strategically trimmed tree limb in the shape of a fork. We then hung the second HOBO device from a branch with another zip tie directly above the first one so that the devices would measure the water and air temperature of Stream 2 simultaneously. We covered the one reading the water temperature with grass and the one taking air temperature with a cloth sack in order to minimize the impact of solar warming in the area. The devices were left for two twenty-four hour periods at the first location from May 26-27 and then from May 27-28. After each period we retrieved and reset the HOBO devices. At the second location, Stream 1, we simply placed the first HOBO device in the stream, making sure to submerge it like at the first point using the forked tree limb. We then hung the second HOBO device from a tree branch again with a zip tie hanging directly over the submerged HOBO. The first time we left these two devices for a twenty-four hour period from May 28-29, retrieved them, and then reset them. However, the second time they were placed in the Stream 1 location we left them for forty-eight hours—from May 29-31—to see how the data would vary if the devices were left for longer periods of time. The last step was to compare the different water and air temperature readings from either Stream location.

We also attempted to take the flow rate of Spring Stream 1 by determining a specific distance then tossing a "fishing floater" in the stream and timing it. Three trials were conducted on one day. We used a tape measure to mark off two meters in the stream for the length, then to determine the width (w) at the widest point and depth (d) at the deepest point of that area. To calculate the flow rate (m^3/s) we first obtained the cross-sectional area (c) and the velocity (v) using the following equations:

$$c = (1/2)(w)(d)$$

$$v = \text{distance/time}$$

To calculate the flow rate (F) we used the following equation:

$$F = (c)(v)$$

After arriving at the flow rate for each of the three tries, we calculated the average flow rate for that day.

II – Soil Sampling

This study was conducted in order to find which types of soils occurred on the Leaves and Lizards property in comparison to soils found in exterior locations closer to Arenal Volcano and in areas of primary forest. The goal was to characterize the soils found and deduce what were the best possible kinds of plants that would grow well at the reforestation site. Like in the water-sampling project, the first step was to flag the soil sampling locations around the property. We chose to sample the fourteen different bird points across the site and also the spring stream points.

After flagging our sample points, we used a metal "T" tube to collect the soil, which we placed in individually labeled zip-logged bags for easy identification. At every point we also measured the pH and moisture levels of the soil using a pH/moisture calculator. The next step was to determine the chroma, value, and hue of the various samples using the Munsell soil chart. Then we scooped about 15 mL of soil out of each bag into tubes using disposable spoons, filled the tubes with equal parts water and shook them up to mix them. This flocculation method, when allowed to sit for 24 hours, enabled us to distinguish between the sand, silt, and clay layers and to characterize the soil texture.

The same process was followed at the exterior sites. There were 5 total exterior sampling points: 2 at the Arenal Volcano site and 3 at Orlando's Jungle Forest.

Once we were able to determine the soil type of each location we could pass this information along to the property owners so that they can proceed with the most efficient reforestation efforts.

III – Vegetation Qualification

For this study, we relied heavily on the data collected by the students in 2008, especially the panoramic photographs of the Leaves and Lizards property and the maps they created of the area. This was more of a subjective study aimed at seeing and confirming the progress made in the area towards reforestation.

Using the maps the students created in 2008, we went to each of the 15 vegetational parameters documented and carefully recorded all the significant changes. The main changes we looked for dealt with vegetation increase or decrease. Such changes included average height of trees and percent grass coverage, among others. While this was more of a cursory observation, the use of panoramic photographs both furthered and affirmed our findings. We took panoramic photographs of the 14 bird points on the Leaves and Lizards property, which allowed us to compare them to those taken in 2008 and let us actually see the physical changes in the environment. Using a compass, flagging, and a magnetic leveler, we located almost the exact spots the pictures were taken last year and recreated them using a Canon camera. These photographs were then uploaded onto the EcoMapCostaRica.com website for comparison with the previous year's photographs.

RESULTS

I – Water Sampling

Each of the figures derived from the temperature readings of the HOBO devices show either the water or air temperature of the location in both degrees Fahrenheit and Celsius.

Figures 2 and 3 represent the first day of data collection from Stream 2. Air temperature readings starting on May 26 and ending May 27 indicate that early to mid-afternoon is the peak hour of heat, despite having covered the HOBO device in attempts to eliminate solar warming. At about 3pm the air temperature reached highs over 95°F/35°C, then drastically dropped into the lower 70's°F/20's°C. Figure 3, which shows the water temperature for that same period, indicates that water temperature peaked earlier in the day—reaching a little over 85°F/30°C—than air temperature did. But then it also drastically dropped into a steady 77°F/25°C throughout the day before falling again over night to a low 73°F/23°C.

The second air and water temperature readings taken from May 27 to 28 at Stream 2 indicate similar trends (Figures 4 and 5). During the day, the air temperature rose in the early afternoon to a high over 85°F/30°C before dropping to a semi-constant 70°F/20°C. The water temperature reached its peak of 79°F/26°C in the early morning at around 8:30am. It then dropped to a very steady 76°F/24°C until we retrieved it the next morning.

Figures 6 and 7 represent the first day of data collection from Stream 1. This was also a 24hour period, like the first two collections, that started on May 28 and ended on May 29. The data collected at Stream 1 shows that air temperature rose steadily and reaching its high in the early afternoon then barely decreased throughout the night, but rapidly rose again in the early morning. It peaked at about 80°F/26°C and reached a low of 69°F/21°C. In the early morning just after dawn it rose to nearly the same highs as the day before. As for the submerged HOBO device, its temperature immediately fell to a semi-constant 75°F/24°C as soon as it was placed in water.

The most unsteady temperature readings for both air and water temperatures are seen in Figures 8 and 9, which represent the second trial at Stream 1 over a 48hour period from May 29-31. The air temperature rose quickly once the device was secured and fell steadily throughout the first day repeating this trend the following day, in a slightly more pronounced way. Both days it peaked at about 85°F/30°C and fell to about 70°F/23°C. The water temperature is somewhat steady as the margin between highs and lows is quite narrow. Water temperatures peak around 12pm both days at 77°F/24°C and drop during the night to 74°F/23°C.

The first day that we attempted to measure the flow rate there was a steady current in Stream 1 and we successfully performed three trials. We found that the current was fairly consistent. The average flow rate we obtained from the three tries was $4.38m^3/s$ (Table 1). We were however not able to perform any other trials on the other days due to weather disturbances.

II – Soil Sampling

The results of soil sampling show the pH, moisture, chroma, value, hue, and texture of the soils tested. Table 2 indicates the results for soils taken on the Leaves and Lizards site from the 14 bird points and 4 water points. Table 3 shows the results for the 5 soils samples taken from exterior locations.

The pH throughout the Leaves and Lizards property indicates an overall neutral trend averaging at 7. As for moisture, with the exception of samples taken from the water points, the rest of the property is pretty dry. The chroma shows that most of the soils on Leaves and Lizards are of a yellow-red tint, only getting more yellow in the water areas. From the value and hue we can see that most of the soil is a dark brown in color. The drier areas are more so red and the wetter areas are more olive or grey. As for soil type, the Leaves and Lizards site is predominantly silt loam with moderate levels of sand (~40%) and barely any clay (~5%) in the mixture.

The samples taken from outside places confirms that most Costa Rican soil in this area is mainly silt with a little bit of sand and hardly any clay. Both of the samples taken from the Arenal Volcano site are dark grey and black in color. The soil sample from the interior forest of Orlando's jungle and the sample taken from the top layer (A) of the exterior part of Orlando's jungle are similar in color—dark brown. However, the lower layer (B) from the exterior part of Orlando's jungle shows that vibrant red soils are located deeper in the earth.

III – Vegetation Qualification

Characterization of the fifteen vegetation areas at Leaves and Lizards can be seen in Table 4. This table shows the plot type, any disturbance that can encounter any plot, the percent grass of each plot in both 2008 and 2009, the dominant tree type in each plot, the average tree height of each plot both in 2008 and 2009, and the distance between trees in the various plots in both 2008 and 2009. It is a qualitative account of the significant differences noted in the plots on the property from last year to the present date. As reforesting progress is made, percent grass coverage has declined because other plants have overtaken the areas. Another significant change was the average tree height, which in most plots has nearly doubled from the previous year. In some plots the distance between trees also varied. The other categories mostly stayed the same including plot type, disturbance, and dominant tree species.

The panoramic photographs[1] of the 14 bird points visibly show the differences recorded in the vegetation characterization above. To begin, From May 2008, photopoint A has been groomed and maintained more than in the previous year. While the surrounding vegetation, mainly trees, has indeed grown, they no longer look disheveled. Also, the hedges have grown, but have been trimmed and well kept. The grassy area in 2009 is a well-cut and maintained green plot, whereas in 2008 it was sporadic patches of tall grass intermixed with patches of both dead and no grass.

The main theme of photopoint B is growth. The path in 2009 still has healthy hedges on either side, however they have grown thicker. On the north side, not only have the hedges grown, but also the shrubbery has developed into tall trees that drape over the path like umbrellas.

Where once you could see the cabins, photopoint C no longer offers that view. Tall shrubs and trees have blocked the cabins. On the opposite side, the trees have grown much taller leaving this portion of the path well shaded.

The spot in which photopoint D was taken looks healthier from 2008. All the plants have grown, but they have also become more verdant. The grass is greener and better kept. The path in the photopoint from 2009 is more defined than in the previous year because of the better maintenance and all-around health of the vegetation.

There was hardly any visible change between the photopoints of point E from 2008 and 2009. The tall grass on either side of the fence still stands, and the trees that act as posts on the fence look about the same height.

The main difference that occurred during the year seen in photopoint F was the growth of the teak trees. In 2008, the trees stood barely two meters high, but now they stand at an average eight meters high. It follows that the area below the bird point looks more lush and dense. Also, the construction of a new cabin is currently underway, which can be seen in the photopoint from 2009.

In photopoint G, the main difference is the blossoming of flowers. In 2008, the area was dominated by trees and other green plants. Now, the bird point has flowers lightly interspersed here and there. The cabins are still visible, and construction of the new cabin is also featured.

The significant difference between the 2008 photo for point H and the one in 2009 is that the cabins are far less visible. While this photopoint takes place in

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[1] http://www.ecomapcostarica.com/panoramas/index.shtml

a higher up area, the growth in height of the trees has blocked nearly all visibility of the cabins.

Photopoint I is in the garden of the Leaves and Lizards main house. Since 2008, an outdoor bar was constructed and the small plants around the house have grown. In the photopoint for 2009, the house and bar are both blocked by the growth of plants and flowers. The view away from the house looks much more full and green again because of plant growth throughout the property.

The photo for point J is one of life and death. While the trees on the north side of the path and down the hill have grown significant amounts, the grass on the opposite side has died. Other than the dead grass and the sky, this photopoint is nearly all green. On a curious note, there is an animal—a different animal—in the exact same spot on both photopoints.

The K photopoint also retains the elements of life and death that the previous one did. The area facing north is much more dense and green in 2009 than it was in 2008. However the side opposite is not necessarily less verdant than before, rather it is just the same. The only area that suffered was the grass on the northwest hill in the photopoint.

Photopoint L in 2008 was about ten meters higher up the hill than in 2009 as it was relocated due to the barbed wire fence that was put up. Either way, the grass area on the north end of photopoint L is partially dying and only in small sections still green. On the opposite side, however, the forest area grew much thicker, taller, and greener.

The M photopoint lies just around the corner from photopoint L and it resembles it greatly. While it did not have to be shifted, the new barbed wire fence does cut through it. From 2008, the grass area on the other side of the fence from the path is dying, while the grass on the path is still green. The forest in the photopoint from 2009, like the one in photopoint L, shows the dense growth of the forest.

Photopoint N is about life. Facing slightly northwest, the cabins are visible in both photopoints for 2008 and 2009. The difference is the hill below the cabins is no longer bare grass with a few trees scattered here and there, but is now a dense and verdant area covered in taller trees and much vegetation. The opposite side of the photopoint looks down towards the forest area, which is also much thicker and greener.

CONCLUSION

I – Water Sampling

In the Tiláran region—where Leaves and Lizards is located—the months with the warmest temperatures of the year are March, April and May, which are incidentally also the rainiest months of the year (Coen, 1983). Due to the heavy amounts of rainfall, we were able to locate two water stream points that would have otherwise been pretty dry. From the results we obtained with the HOBO thermometer devices it is clear that there is a trend both in air and water temperature that has a direct correlation to the climate. A basic definition of climate says it is the sum of the weather conditions for a particular region, which is determined by solar radiation (Coen, 1983). Our results show that in hours when the sun is not completely out, that is when the HOBO devices were least susceptible to solar exposure, the temperature was cooler than when sunshine was more prominent. Also, we observed a trend in rainfall that caused the temperature readings to fluctuate. Heavy rainstorms consistently happened in the late afternoon (~4pm and later), which is also when the temperature readings began to drop. As compared to data from 2008, the same general trends in air and water temperature measured by the HOBO device seemed to occur in 2009.

While rain activity affected the temperature readings in a non-destructive way, heavy rainfall created an obstacle for flow rate measurements. The day before our first trial had little rainfall and we were able to take the flow rate successfully. That afternoon there was heavy rainfall, which prevented us from obtaining a second set of flow rate measurements because it left debris in the stream that in turn made the current static. In order to leave the experiment the same we decided to try again the next day. However, another heavy rainfall only left more debris in the stream, which was again static. From this we determined that there must be a strong current well beneath the surface of the water because on the opposite side of the debris dam the surface current was flowing. Therefore, by mere observation we can say there is stream flow.

II – Soil Sampling

Leaves and Lizards lies on soils from steeply dissected to mountainous relief, which developed from volcanic ash deposits, are dark, deep, rich in organic matter, medium-textured, moderately fertile, and excessively drained (Vásquez Morera, 1983). From our samples, we were able to confirm all these characteristics. A general trend on the property is that the points from higher elevation are drier than those at lower levels. This helps explain the vast growth in vegetation from 2008 to 2009 because there is more plant life at areas where the soil is most moist. Also, the pH across the property is fairly neutral therefore reforestation has great prospects. The general soil type on the property is a silt loam, which has components that are good for cultivating.

What this means for the Leaves and Lizards property is that reforestation efforts have great potential for further growth and development on that land. If they continue planting green plants and trees in the areas with more moist soils they will see good results. As for flowers and other ornamental plants, those gardens will likely flourish in the soils with higher elevation. Nevertheless, because the pH is so neutral, plant life will probably grow well all around the property.

Intermountain valleys are progressively more deforested than the lush peaks of the surrounding mountaintops. The volcanoes that mainly surround the site still retain rain forest (Stiles, 1989). The soils we sampled from external locations showed the same silt trend as in Leaves and Lizards. The soils that came directly from the Arenal Volcano site had more sand in them, but the area still has lush forests. The soils from the nearby primary forest resembled the soils collected in the water points at Leaves and Lizards. This helps to explain the dense forest surrounding the spring streams.

III – Vegetation Qualification

According to the Holdridge Life Zones, Leaves and Lizards lie in a tropical premontane rain forest where vegetation is very dense (Hartshorn, 1983). We can confirm this statement with the panoramic photographs we took of the various points around the property. From 2008, there is significant growth of vegetation in most areas, especially average height of trees and forest density. Our observations show that the Leaves and Lizards site has the right qualities for reforestation seen in the developments during the past year. Each photograph shows a positive change in the environment such as more abundant or verdant plant life.

In 2008 the students outlined vegetation parameters. The table with the information they documented offers a more qualitative analysis of the property. Since then, the updated table shows that significant changes did indeed occur in vegetation growth. The average height of trees doubled in most plots and the percent grass decreased. This shows that there is now richer plant life in the plots. Perhaps with the water and soil data obtained this term Leaves and Lizards will be able to enhance their reforestation efforts and continue to successfully cultivate the tropical rain forest.

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Table 1

Water Data May 2009
Flow Rate

Water Data - May 2009

Leaves & Lizards Water Points

Flow Rate in m^3/s

Length = 2m
Width = 70cm
Depth = 5cm

Cross-Sectional Area = (1/2)(width)(depth) = (1/2)(70)(5) = $175m^2$

Velocity = distance/time

Flow rate = Area x Velocity = c x v

Spring Stream 1, 27 May 2009

Try 1	1:17:18	Velocity = 2/77.18 = 0.026s
Try 2	1:11:99	Velocity = 2/71.99 = 0.028s
Try 3	1:33:46	Velocity = 2/93.46 = 0.021s

Flow rate - Try 1 = ($175m^2$)(0.026s) = $4.55m^3/s$
Flow rate - Try 2 = ($175m^2$)(0.028s) = $4.9m^3/s$
Flow rate - Try 3 = ($175m^2$)(0.021s) = $3.68m^3/s$

Average flow rate = $4.38m^3/s$

Table 2

Soil Samples May 2009
Leaves and Lizards - Bird and Water Points

Soil Samples - May 2009

Leaves & Lizards: Bird Points A-N and Water Points

Point	pH	Moisture	Chroma	Value	Hue	Sand/Silt/Clay	Type
A	7	6.4 - A	5yr	3/2	dark reddish br	47/53/0	silt loam
B	7.1	5.9 - B	5yr	3/3	dark reddish br	42/58/0	silt loam
C	7	5.9 - B	7.5yr	2.5/2	very dark brow	48/52/0	silt loam
D	7	6.8 - A	7.5yr	3/2	dark brown	44/56/0	silt loam
E	7.1	6.3 - A	10yr	2/2	very dark brow	50/50/0	sandy/silt loam
F	7.7	6.4 - A	7.5yr	3/2	dark brown	42/58/0	silt loam
G	6.9	6.4 - A	7.5yr	2.5/1	black	58/37/5	sandy loam
H	6.9	6.9 - A	5yr	3/1	very dark grey	35/65/0	silt loam
I	7	6.1 - B	7.5yr	2.5/1	black	45/50/5	silt loam
J	7	6.2 - A	7.5yr	2.5/2	very dark brow	38/62/0	silt loam
K	7	6.8 - A	7.5yr	3/3	dark brown	53/47/0	silt loam
L	6.9	5.4 - B	7.5yr	2.5/2	very dark brow	53/47/0	sandy loam
M	7	5 - C	7.5yr	2.5/1	black	35/65/0	sandy loam
N	7	7 - A	7.5yr	3/2	dark brown	44/48/4	silt loam
Spring Stream	6.4	3.9 - D	2.5y	4/4	olive brown	0/100/0	silt
Spring Stream	7.1	5.1 - C	10yr	3/2	very dark grayi	33/67/0	silt loam
Spring Confluei	6.7	4.6 - C	2.5yr	4/4	dark yellowish	0/100/0	silt
Spring Mix	7	3.9 - D	2.5y	4/4	olive brown	17/83/0	silt loam

Table 3

Soils Samples May 2009
Arenal Volcano Site and Orlando's Jungle Forest Samples

Soil Samples - May 2009

Arenal Volcano Site and Orlando's Forest Jungle

Sample	pH	Moisture	Chroma	Value	Hue	Sand/Silt/Clay	Type
Arenal 1	n/a	n/a	7.5yr	2.5/1	black	83/17/0	sandy loam
Arenal 2	n/a	n/a	10yr	3/1	very dark grey	30/70/0	silt loam
Interior Forest	n/a	n/a	7.5yr	2.5/3	very dark brown	36/64/0	silt loam
Exterior Forest A	n/a	n/a	7.5yr	3/2	dark brown	76/17/7	sandy loam
Exterior Forest B	n/a	n/a	5yr	4/6	yellowish red	11/89/0	silt loam

Table 4 Vegetation Qualification May 2009

Vegetational Parameter Characterizations - May 2009

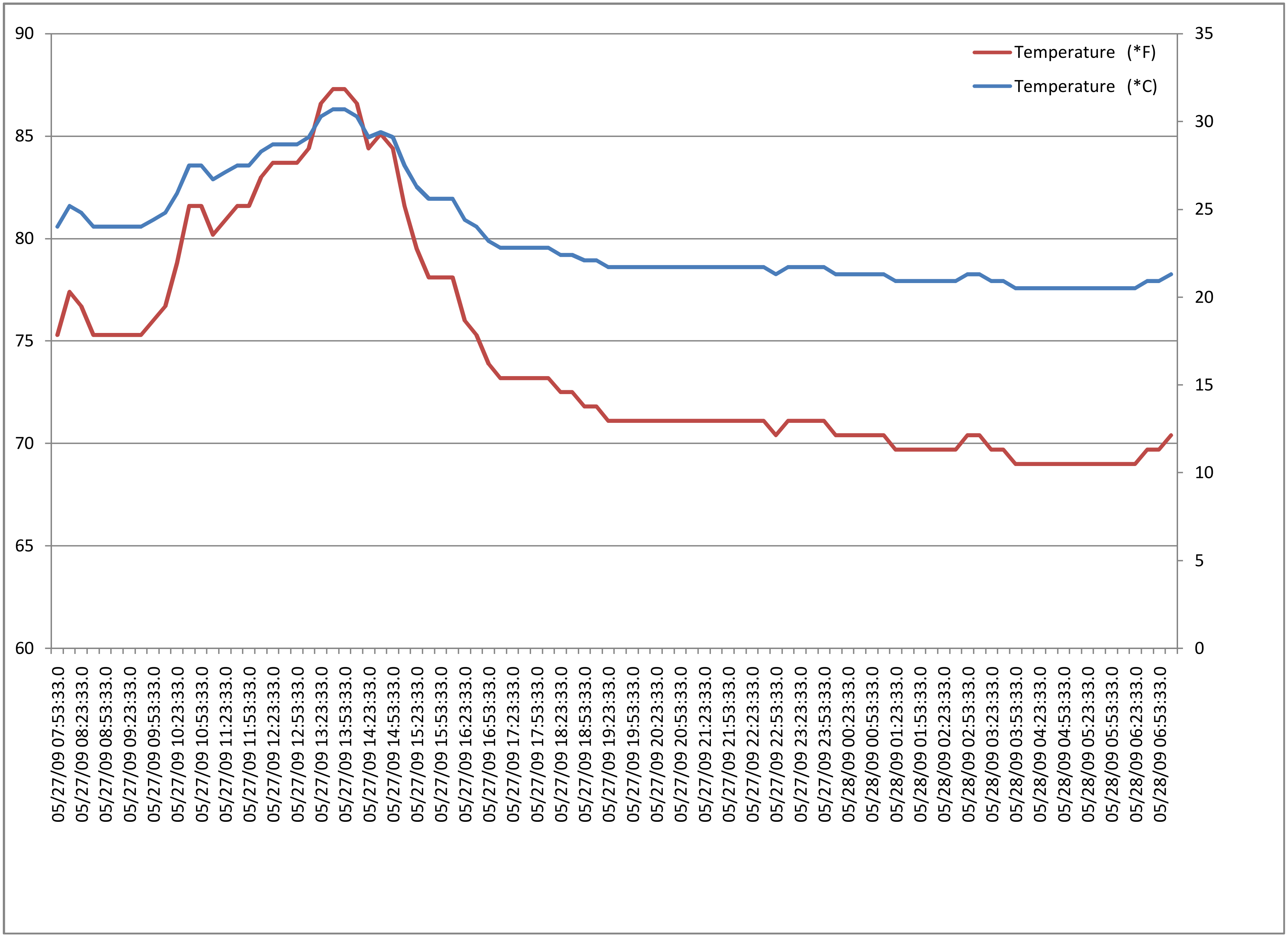
Characterization of the fifteen vegetation areas at Leaves & Lizards

Plot Name	Plot Type	Disturbance	% Grass 2008	% Grass 2009	Dominant Tree	Avg. Tree Height (m) 2008	Avg. Tree Height (m) 2009	Distance b/t Trees (m) 2008
Almendro 1	mixed	mowed	70%	50%	DIVA	1	4	3.3
Cabins	ornamental	cabins, path	20%	20%	N/A	1	2	0.25
Mixed 1	mixed	none	40%	30%	DIVA	1.5	2	2
Mixed 2	mixed	none	40%	10%	DIVA	1.8	4	4.3
Mixed 3	mixed	mowed, path	70%	30%	VOGU	1.5	2	4
Mixed 4	mixed	none	10%	10%	VOGU	2	2.5	3.6
Patch 1	monoculture	mowed, path	100%	30%	LAUR/VOCH	4	8	3.55
Patch 2	mixed	mowed	70%	50%	VOGU	1	4	3.5
Patch 3	mixed	mowed	70%	70%	MELI	4.5	7	3.3
Sloth Valley	mixed	none	80%	80%	COAL	30	40	10.5
Steve & Debbie'	ornamental	none	80%	25%	N/A	N/A	N/A	N/A
Teak 1	monoculture	none	25%	25%	TEGR	2.5	8	3.5
Teak 2	monoculture	mowed, path	10%	30%	TEGR	2.5	8	3.5
Teak 3	monoculture	path	90%	70%	TEGR	2	6	4.95
Teak 4	mixed	mowed, path	75%	40%	TEGR	1	6	3.7

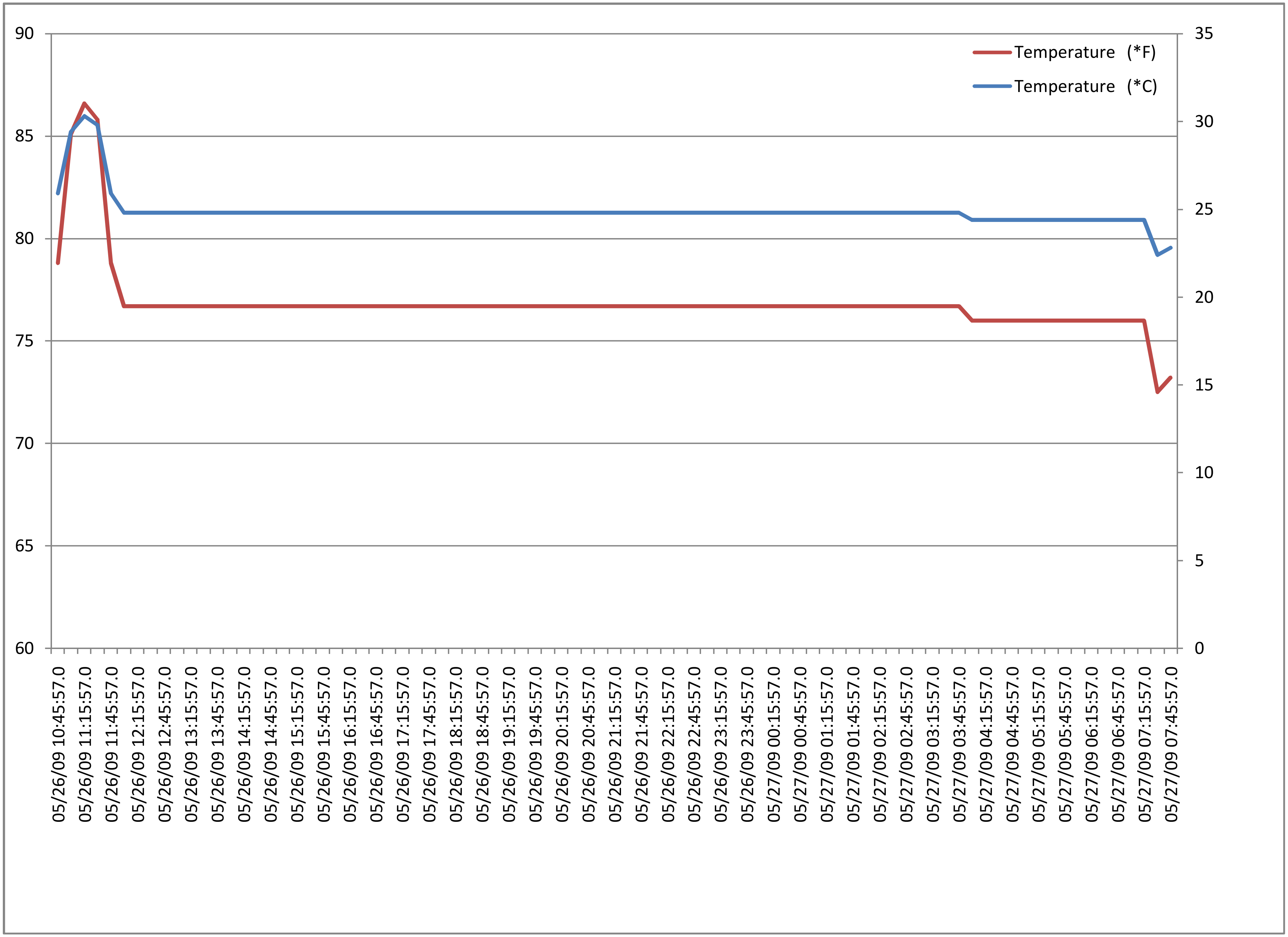
Table 4 Vegetation Qualification May 2009

Distance b/t Trees (m) 2009
1
0.25
2
2
4
1.8
3.55
3.5
3.8
20
N/A
3.5
3.5
4.95
3.7

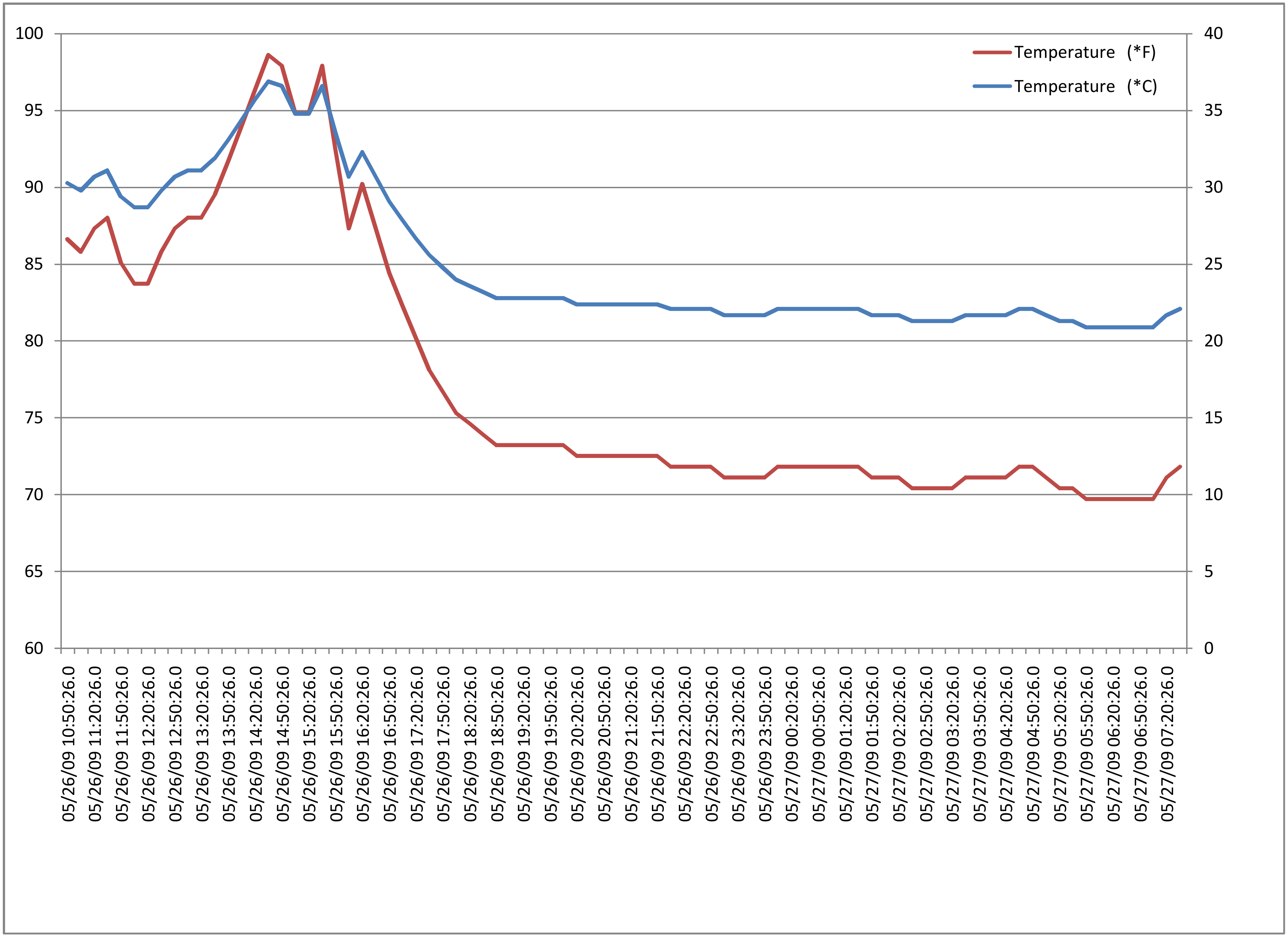
Spring2Air52709GRAPH FIGURE 2



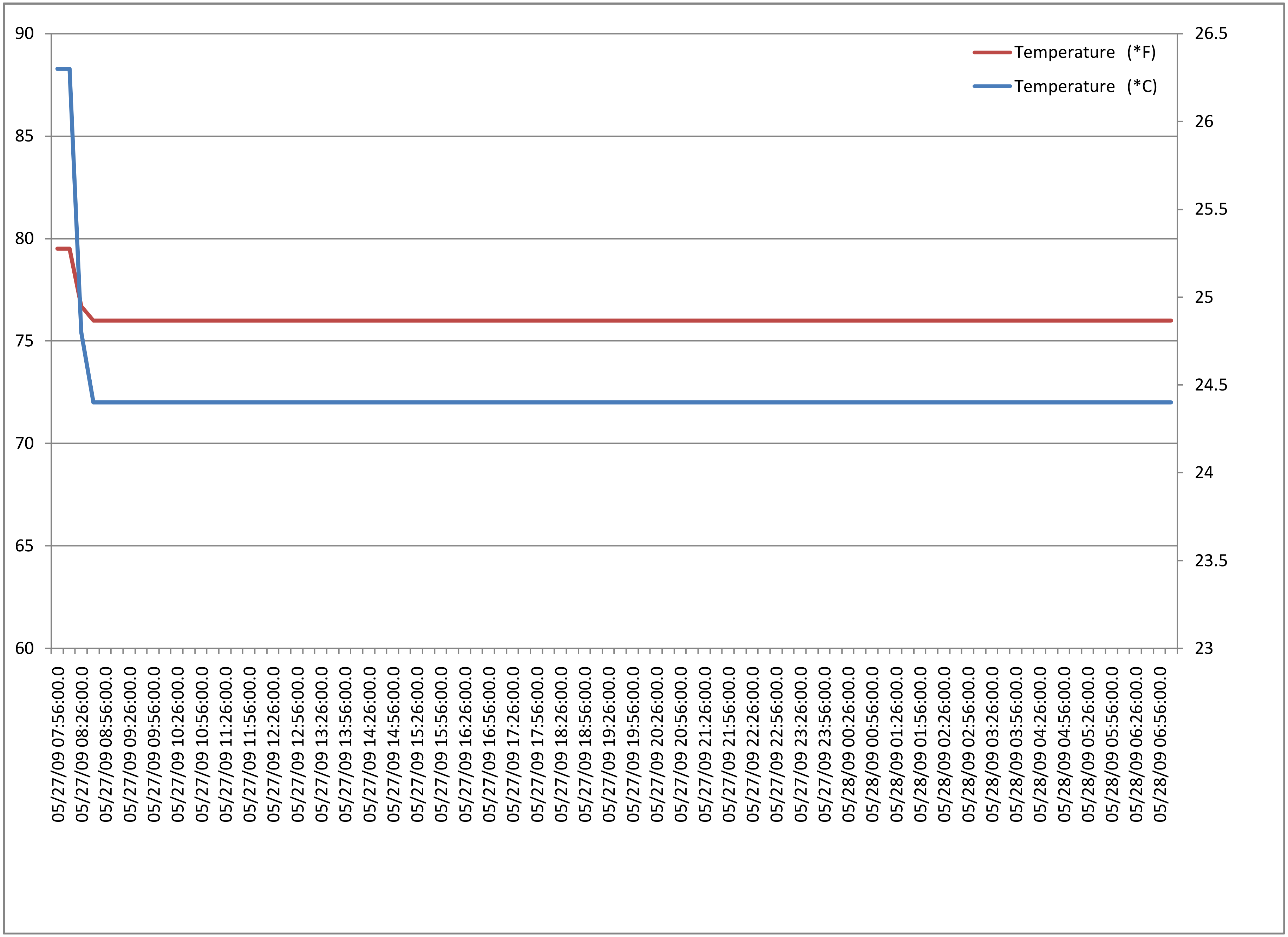
Spring2Water52709GRAPH FIGURE 3



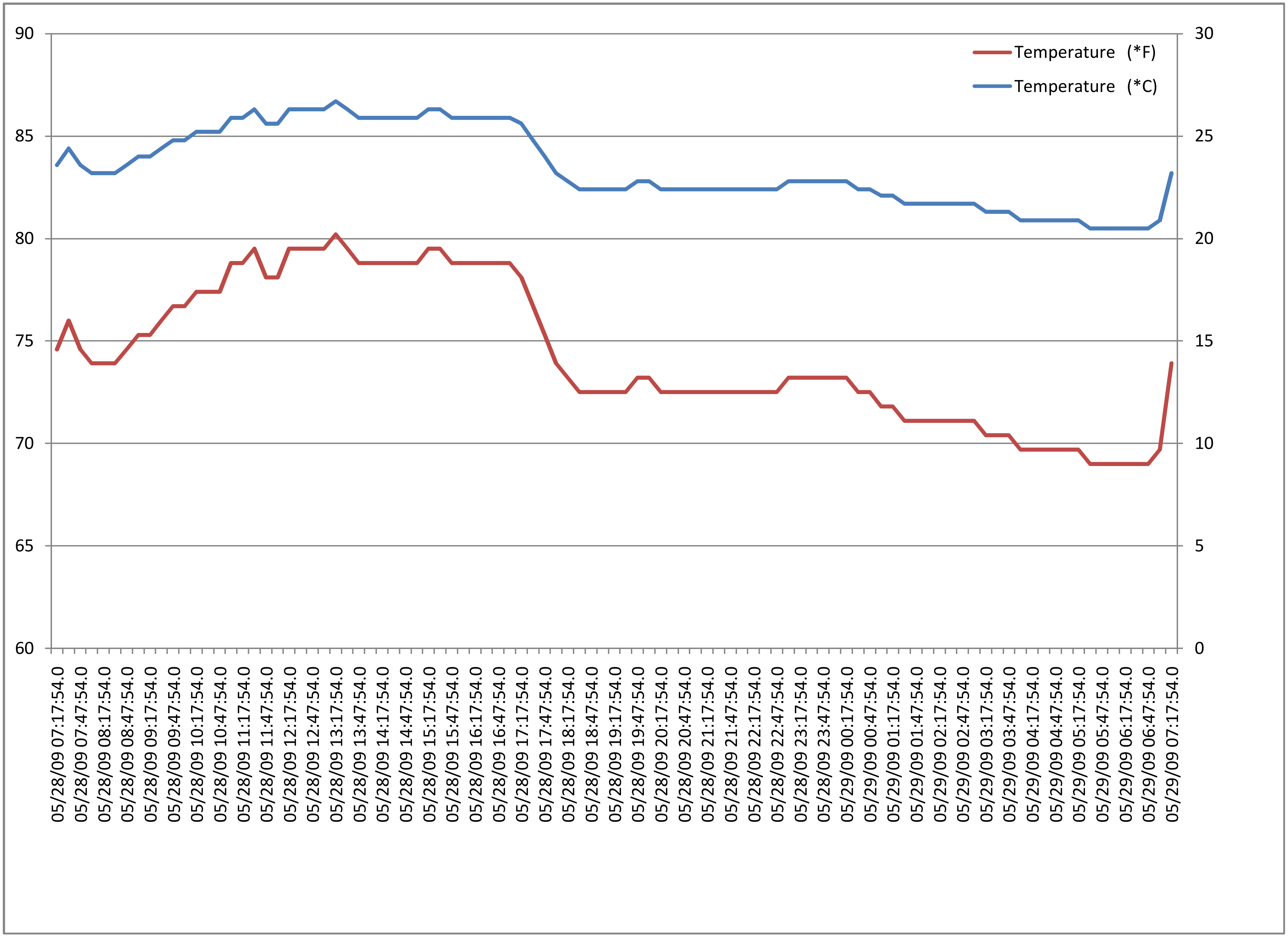
Stream2Air52709GRAPH FIGURE 4



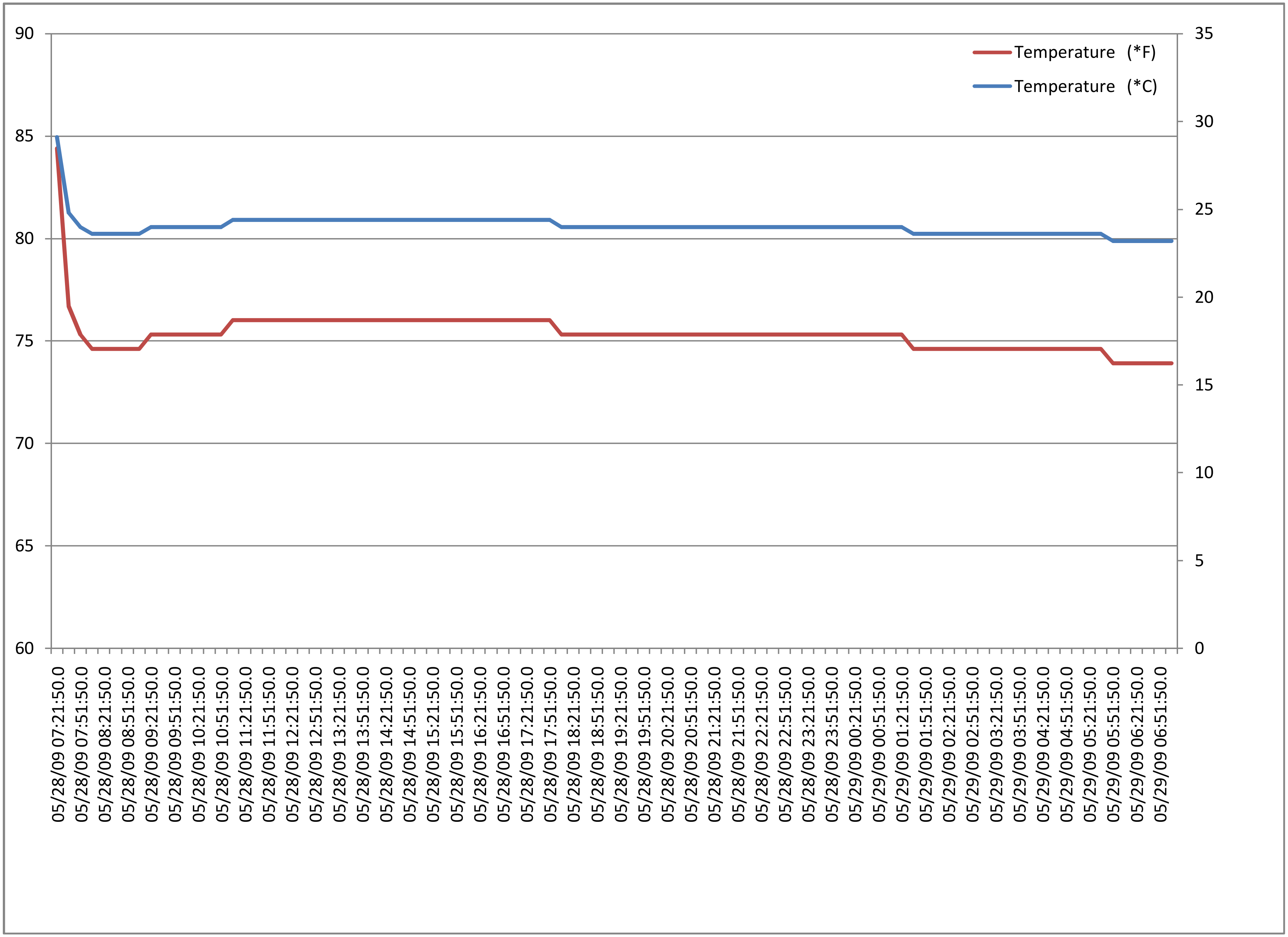
Stream2Water52809GRAPH FIGURE 5



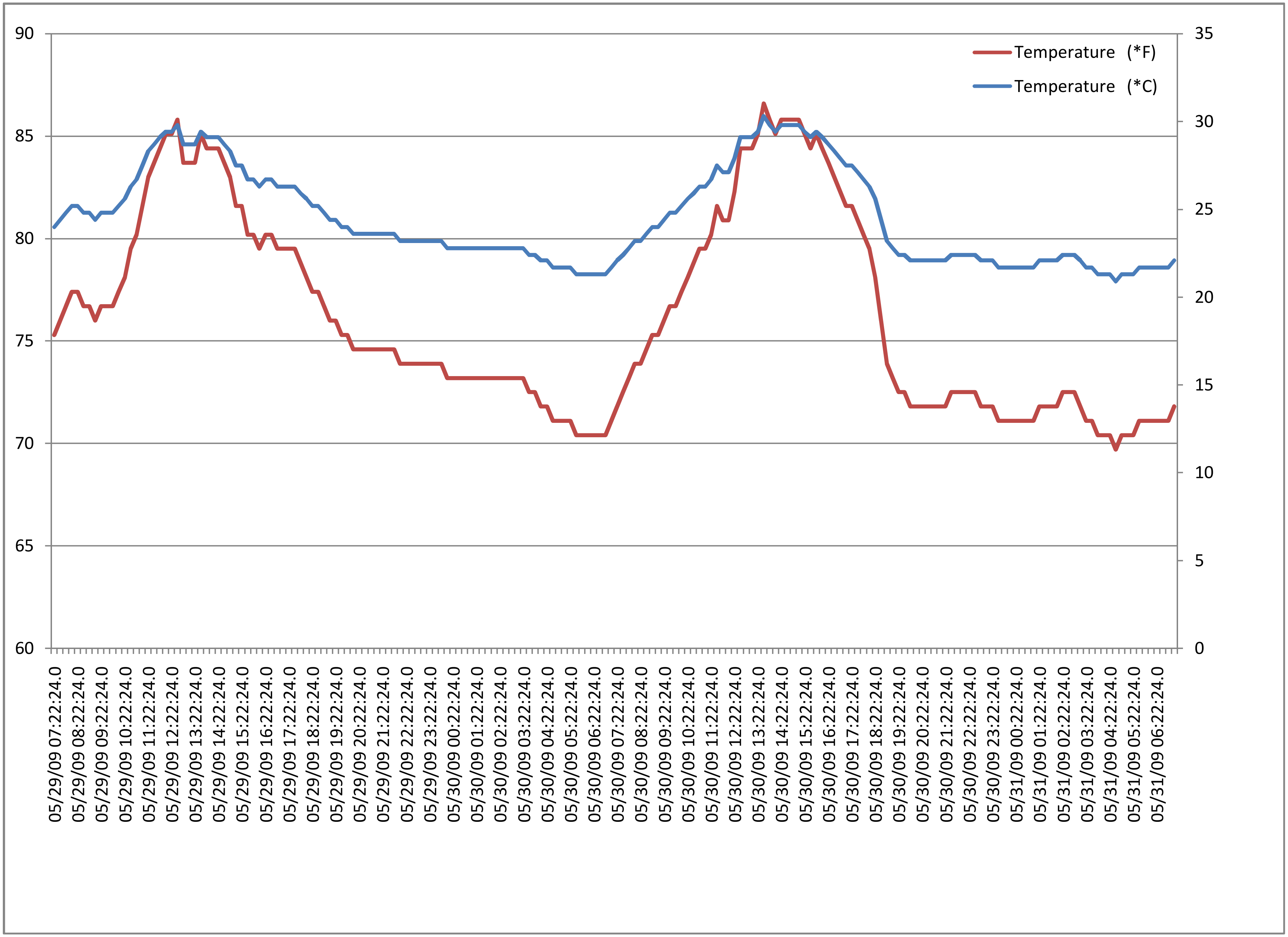
Spring1Air52809GRAPH FIGURE 6



Stream1Water52809GRAPH FIGURE 7



Spring1Air52909GRAPH FIGURE 8



Stream1Water53109GRAPH FIGURE 9