Student Waste Habits in Carleton Residential Halls

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Where are students missing the opportunity to recycle and compost?

Introduction and Background

Carleton College prides itself as an institution that actively values sustainability. Carleton has committed itself to fulfill the President's Climate Commitment and achieve carbon neutrality by 2050 by developing Climate Action Plan (CAP). The CAP establishes a framework for reducing campus greenhouse gas emissions by simultaneously addressing five focus areas: energy supply and demand, land management, transportation, procurement, and waste management (Carleton CAP, 2011). Carleton has achieved remarkable success in reducing campus energy consumption, increasing the number of LEED certified buildings, founding and managing the Cowling Arboretum, constructing a commercial-sized wind turbine, and providing opportunities for members of the Carleton community to participate and spearhead a wide variety of projects related to sustainability (Carleton CAP, 2011).

There are many opportunities for the college to make further progress in the waste management focus area. Carleton first implemented a recycling program in the mid-1980s and introduced composting around 2005. Carleton's Custodial Services and the Office of Sustainability have experienced difficulty in promoting recycling and composting across campus (Carleton CAP, 2011). Although Carleton invested in a campus wide recycling and compost program a number of years ago, Custodial Services and other members of the Carleton community have noticed that students and faculty are not taking full advantage recycling and compost bins. With a minimal amount of effort and attention, one can see that standard trash bins, recycling bins, and compost bins are widely cross-contaminated with trash that belongs in another type of receptacle.

Custodial Services has started a number of initiatives that are aimed at improving the infrastructure of waste management of Carleton. Custodial Services has expanded resources for composting and recycling in academic and residential buildings. Waste Busters, a community of concerned custodians, has worked to monitor and centralize waste output to reduce the cost of waste hauling. Custodial Services is currently negotiating with the campus waste hauler to commence a monthly recycling and compost reporting system (Carleton CAP, 2011).

Beyond the internal progress being made by Custodial Services, the current challenge is to improve communication and education about what is recyclable, compostable, and waste. In 2012 Custodial Services and the Student Sustainability Assistants piloted a new Carleton Community Waste Program that features centralized and standardized waste stations in academic and public buildings like Sayles-Hill and the Library (Carleton CAP, 2011). There has been anecdotal praise for the reduction of cross-contamination and greater public clarity of which type of receptacle different waste types belong in. Custodial Services is currently considering expanding the centralized bin system to residential halls, but uncertainties about student waste habits across structurally unique residential halls calls into question the value of standardizing waste management in all campus living environments.

Student waste handling in dormitories remains a huge problem. The degree of cross-contamination is visibly severe, and students still experience confusion over where to place their waste without the aid of posters and other resources. This study pilots a new waste monitoring program in residential halls that quantifies cross-contamination of waste receptacles in six dorms: Myers, Goodhue, Watson, Cassat, James, and Nourse.

The research questions of this study are:

RQ1. Is there a significant difference in average bin fullness and cross-contamination index between dorms?

RQ2. Which types of contaminants are most abused by students and which dorms do these take place?

RQ3. Do student waste habits vary at different times during the term? Is there variance in average bin fullness and cross-contamination when controlled by day of the weekend and weekend number observed (i.e. Saturday 7th weekend)?

This study hopes to better inform Custodial Services of waste distribution in dorms, contribute recommendations that speak to the Campus Community Waste Program, and use waste data as a tool for planning a targeted outreach program during Green Wars in winter term.

Data Collection

The unit of analysis for this study was a floor within a particular residential hall. Floors were not randomly sampled. Every floor in Myers, Goodhue, Watson, Cassat, James, and Nourse was visited between 9 AM and 12 PM on every Saturday and Sunday morning of fall term 2013. Data on these dorms speak for themselves, but as they consist of the majority of campus dormitories, they can be used to extrapolate on general student waste handling habits in Carleton dormitories. On each floor, a student waste monitor recorded the total number of waste bins (not recycling or compost, only waste to be sent to a landfill), the total number of cross-contaminated bins, the total number of empty bins, and the average bin fullness of all waste bins present. Most importantly, student waste monitors tallied incidents of cross-contamination by cross-contaminant type in all waste bins.

Student waste monitors examined the entire volume of each waste bin and recorded the presence of the following contaminants:

-Organic Waste (W); waste that should be compostable including paper towels and food

- Pizza Boxes (D); are compostable

-Coffee Cups (F); should be composted

- Sayles boxes (B); to-go food boxes distributed at Sayles, should be composted

- Recyclable Plastic (P); includes plastic bottles, but not candy wrappers.

-Cardboard and Paper (R); can be recycled

-Aluminum (A); can be recycled

- Glass (G); can be recycled

- Plastic Solo-cups (S); associated with parties and drinking activities, can be recycled

Many of these contaminant types are highly. Contaminant types like Solo-cups and pizza boxes were measured because they are commonly misplaced items that could benefit from being examined and treated individually during planned targeted outreach in winter term of 2014. Although this report does not analyze these individual contaminant types and instead generalizes to the scope of compostable and recyclable contaminants, there is definitely the intention to address all of these contaminant types before conducting targeted outreach.

For the sake of simplifying the data collection process, bin fullness was consistently rounded to proportions of 0.0, 0.25, 0.50, 0.75, or 1.

The following metrics were calculated using raw data:

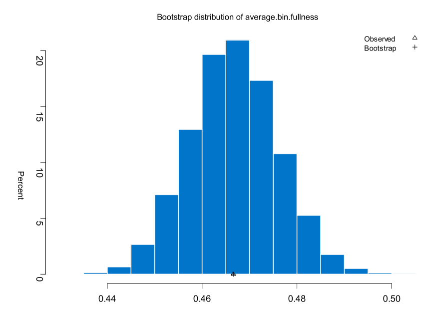
-Total Contamination Score - the total number of contamination incidents recorded on the floor.

-Contamination Index - the Total Contamination Score divided by the number of contaminated receptacles. This metric is a measure of cross-contamination diversity, not the magnitude, severity, or quality overall cross-contamination.

-Compostable Item Misplacement Index - this index equals the total number of incidents of compostable cross-contamination (Organic Waste, Dominoes, Coffee Cups, Pizza Boxes) divided by the total number of bins on each floor.

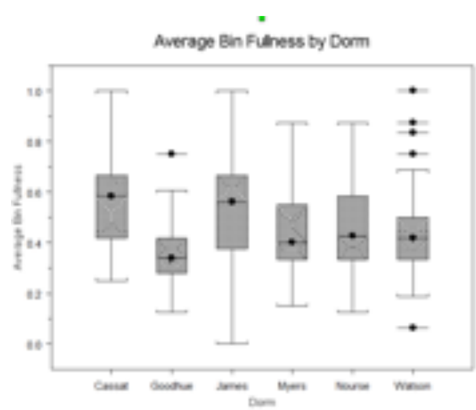
-Recyclable Item Misplacement Index - this index equals the total number of incidents of recyclable cross-contamination (Plastic, Aluminum, Glass, Solo-cups) divided by the total number of bins on each floor.

Analysis and Results

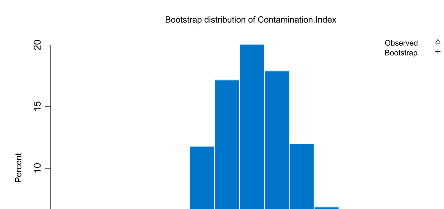


RQ1. Is there a significant difference in average bin fullness and cross-contamination index between dorms?

The average bin fullness of all floors in Myers, Goodhue, Watson, Cassat, James, and Nourse during fall term was 0.46655. The standard error of the bootstrap distribution for average bin fullness is 0.00931. I am 95% confident that the average bin fullness of all observed floors is between 0.4485655 and 0.4849012.



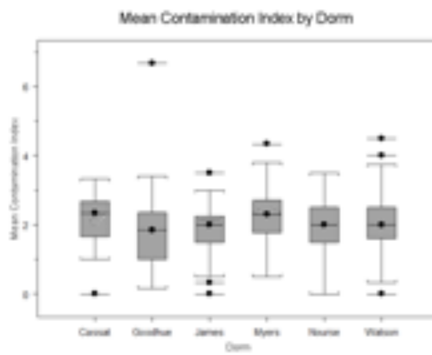
To test if there is any significant difference in average bin fullness across dorms, I conduct a fixed affects One-way ANOVA test. The null-hypothesis is that there is no difference across any of the observed dorms in average bin fullness. The alternative hypothesis is that at least two dorms are significantly different in average bin fullness. The reported p-value for the ANOVA is 5.812351e-012, which suggests that there



are statistically significant differences in average bin fullness across dorms at the 1% level.

The mean cross contamination index of all floors in Myers, Goodhue, Watson, and Cassat, James, and Nourse during fall term was 2.03155. The standard error of the bootstrap distribution for cross-contamination index was 0.03971. I am 95% confident that the mean cross-contamination index for all observed floors is between 1.954103 and 2.109536.

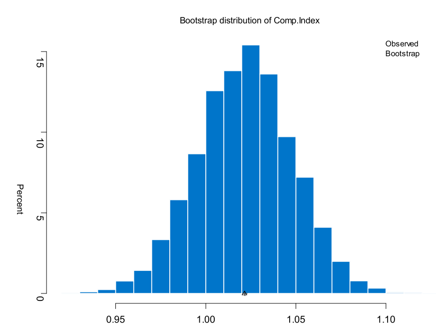
To test if there is any significant difference in cross-contamination index across dorms, I conduct a fixed affects One-way ANOVA test. The null-hypothesis is that there is no difference across any of the observed dorms in cross-contamination index. The alternative hypothesis is that at least two dorms are significantly different in cross contamination index. The reported p-value for the ANOVA is 0.1569641, which suggests that there are statistically significant differences in mean cross-contamination index across dorms at the 5% level.



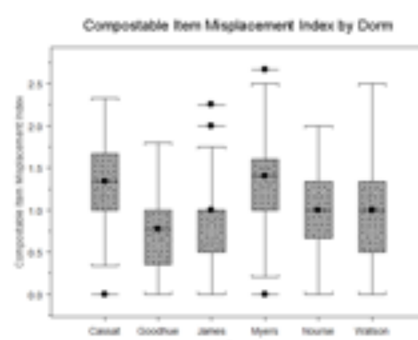
There is strong evidence that suggests that both floor average bin fullness and mean contamination index varies significantly across different dormitories.

RQ2. Which types of contaminants are most abused by students and which in dorms do these take place?

The mean compostable item misplacement index in Myers, Goodhue, Watson, Cassat, James, and Nourse during fall term was 1.0215. The standard error of the bootstrap distribution for average bin fullness is .02645. I am 95% confident that the mean compostable item misplacement index of all observed floors is between 0.9696157 and 1.072536.

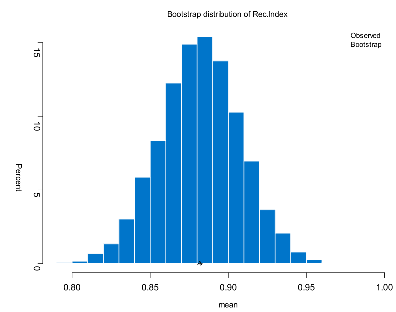


To test if there is any significant difference in the mean compostable item misplacement index across dorms, I conduct a fixed affects One-way ANOVA test. The null-hypothesis is that there is no difference across any of the observed dorms in the mean compostable item misplacement index. The alternative hypothesis is that at least two dorms are significantly different in the mean compostable item misplacement index. The reported p-value for the ANOVA is 9.121874e-10, which suggests that there are statistically significant

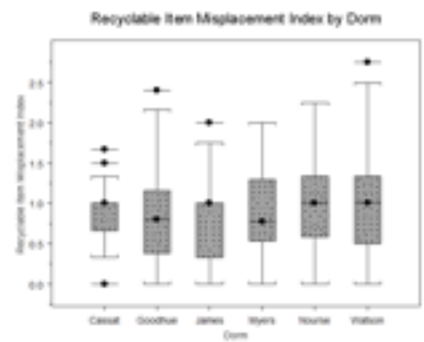


differences in in the mean compostable item misplacement index across dorms at the 1% level.

The mean recyclable item misplacement index in Myers, Goodhue, Watson, Cassat, James, and Nourse during fall term was 0.88172. The standard error of the bootstrap distribution for average bin fullness is 0.02585. I am 95% confident that the mean recyclable item misplacement index of all observed floors is between 0.8311244 and 0.9336903.

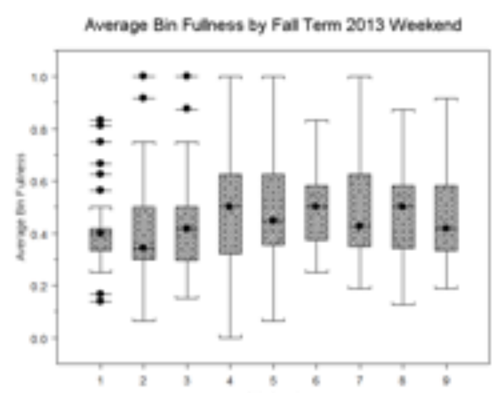


To test if there is any significant difference in the mean recyclable item misplacement index across dorms, I conduct a fixed affects One-way ANOVA test. The null-hypothesis is that there is no difference across any of the observed dorms in the mean recyclable item misplacement index. The alternative hypothesis is that at least two dorms are significantly different in the mean recyclable item misplacement index. The reported p-value for the ANOVA is 0.5359937, which does not provide sufficient evidence to reject the null-hypothesis.



The results suggest that compostable items are more often misplaced in Carleton dormitories than recyclable items. The ANOVA tests inform us that we can compare and contrast the misplacement of compostable items across dorms. However, there is not strong enough evidence to warrant a claim that the misplacement of recyclable items varies across Carleton dorms.

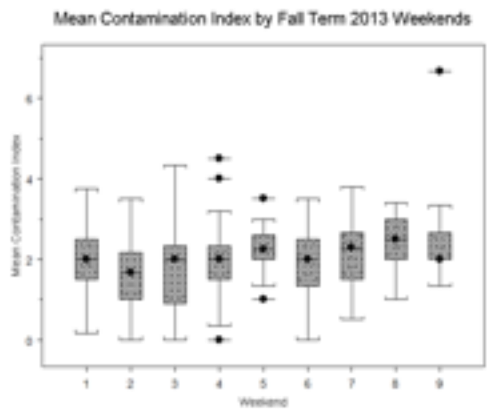
RQ3. Do student waste habits vary at different times during the term? Is there variance in average bin fullness and cross-contamination when controlled by day of the weekend and weekend number observed (i.e. Saturday 7th weekend)?

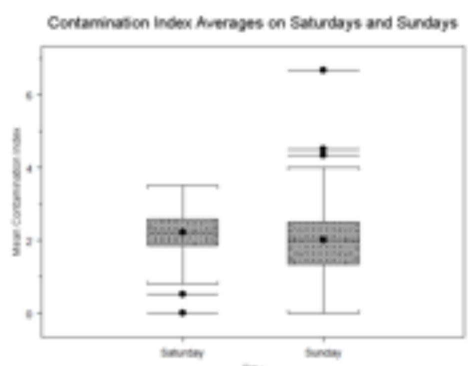


To test if there is any significant difference in **average bin fullness** in observed dorms across different weekends throughout the term, I conduct a fixed affects One-way ANOVA test. The null-hypothesis is that there is no difference across any of the observed weekends in average bin fullness. The alternative hypothesis is that at least two weekends are significantly different in average bin fullness. The reported p-value for the ANOVA is 0.2100771, which does not provide strong enough evidence to reject the null-hypothesis.

The sample mean of average bin fullness values observed on Saturday was 0.4776196, whereas the sample mean of average bin fullness values observed on Sunday was 0.4579759. **To test if average bin fullness varied significantly depending on the day of the weekend it was observed**, I conducted a Two-Sample t-Test. The null-hypothesis is that there is no difference Saturday and Sunday observations of average bin fullness. The alternative hypothesis is that Saturday and Sunday observations are significantly different in average bin fullness. The reported value for the t-Test is 0.2961, which does not provide strong enough evidence to reject the null-hypothesis.

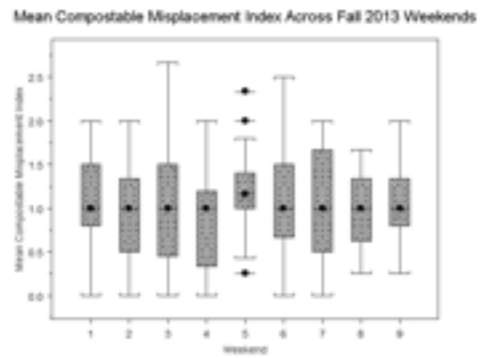
To test if there is any significant difference in **mean cross-contamination index** in observed dorms across different weekends throughout the term, I conduct a fixed affects One-way ANOVA test. The null-hypothesis is that there is no difference across any of the observed weekends in mean cross-contamination index. The alternative hypothesis is that at least two weekends are significantly different in mean cross-contamination index. The reported p-value for the ANOVA is 5.15.8112e-006, which provides strong evidence to reject the null-hypothesis. However, the figure to the right does not show any obvious trend in mean contamination index as the term progressed, so this analysis provides little practical significance.



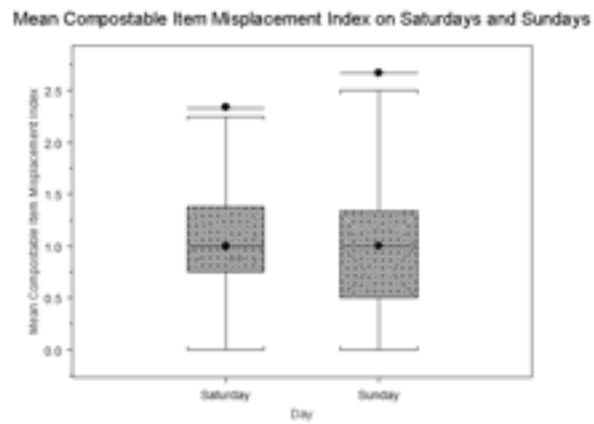


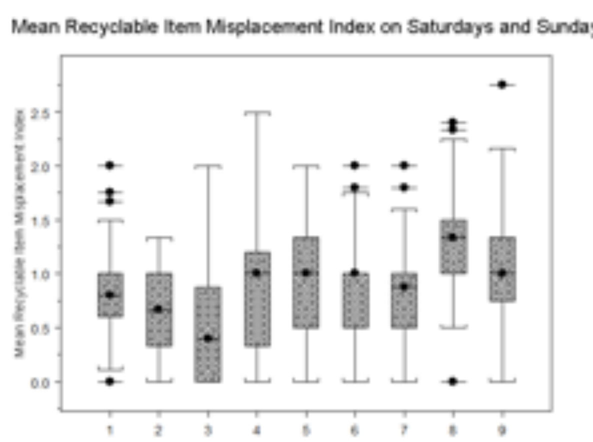
The sample mean cross-contamination index values observed on Saturday was 2.1699163, whereas the sample mean of average bin fullness values observed on Sunday was 1.9237448. To test if **mean cross-contamination index varied significantly depending on the day of the weekend** it was observed, I conducted a Two-Sample t-Test. The null-hypothesis is that there is no difference between Saturday and Sunday observations of mean cross-contamination index. The alternative hypothesis is that Saturday and Sunday observations are significantly different in mean cross-contamination index. The reported value for the t-Test is 0.001, which provides strong evidence at the 1% level to reject the null-hypothesis that Saturday and Sunday observations on mean cross-contamination index do not differ. Although Saturdays have a higher mean cross-contamination index, the interquartile range of Sunday cross-contamination indices is larger than Saturday (1.16667 vs. 0.7142857) and Sunday has a higher maximum than Saturday (6.666 vs 3.5). This shows that high cross-contamination indices (relative to the mean of 2.0315) are observed on both days of the weekend.

To test if there is any significant difference in **mean compostable item misplacement index** in observed dorms across different weekends throughout the term, I conduct a fixed affects One-way ANOVA test. The null-hypothesis is that there is no difference across any of the observed weekends in mean compostable item misplacement index. The alternative hypothesis is that at least two weekends are significantly different in mean compostable item misplacement index. The reported p-value for the ANOVA is 0.01824392, which provides strong evidence to reject the null-hypothesis at the 5% level.



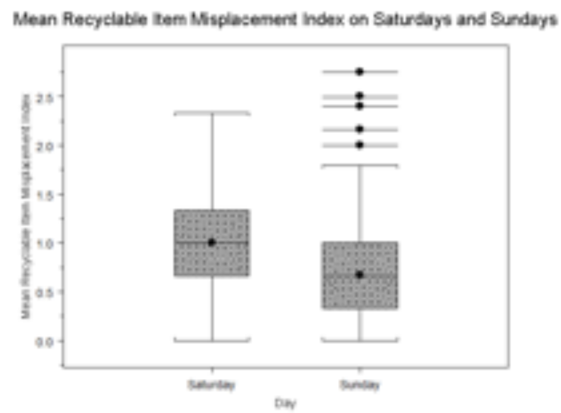
The sample mean of compostable item misplacement index observed on Saturday was 1.085746, whereas the sample mean of compostable item misplacement index observed on Sunday was 0.9758487. **To test if mean compostable item misplacement index varied significantly depending on the day of the weekend it was observed**, I conducted a Two-Sample t-Test. The null-hypothesis is that there is no difference between Saturday and Sunday observations of mean compostable item misplacement index. The alternative hypothesis is that Saturday and Sunday observations are significantly different in mean compostable item misplacement index.. The reported value for the t-Test is 0.0316, which provide strong evidence to reject the null-hypothesis at the 5% level. The Saturday mean is slightly beyond the 95% confidence interval of mean compostable item misplacement index (1.085746 vs 1.072536), which suggests some practical significance despite the ubiquitous appearance of the graph to the right.





To test if there is any significant difference in

mean recyclable item misplacement index in observed dorms across different weekends throughout the term, I conduct a fixed affects One-way ANOVA test. The null-hypothesis is that there is no difference across any of the observed weekends in mean recyclable item misplacement index. The alternative hypothesis is that at least two weekends are significantly different in mean recyclable item misplacement index. The reported p-value for the ANOVA is 1.10388e-006, which provides strong evidence to reject the null-hypothesis at the 1% level.



The sample mean of recyclable item misplacement index observed on Saturday was 1.000849, whereas the sample mean of recyclable item misplacement index observed on Sunday was 0.7928188. **To test if mean recyclable item misplacement index varied significantly depending on the day of the weekend it was observed**, I conducted a Two-Sample t-Test. The null-hypothesis is that there is no difference between Saturday and Sunday observations of mean recyclable item misplacement index. The alternative hypothesis is that Saturday and Sunday observations are significantly different in mean recyclable item misplacement index. The reported value for the t-Test is 0.000, which provide strong evidence to reject the null-hypothesis at the 5% level. The Saturday mean is greater than the 95% confidence interval of mean recyclable item misplacement index (1.000849 vs 0.9336904), which suggests that the difference between Saturdays and Sundays is practically significant.

Table Summary of P-Values

	Dorm	Weekend	Day
Average Bin Fullness	***5.812351e-012	.2100771	.2961
Cross-Contamination Index	0.1569641	***5.15.8812e-006	***0.001
Compostable Item Misplacement Index	***9.12187e-10	**0.01824392	**0.0316
Recyclable Item Misplacement Index	0.5359937	***1.10388e-006	***0.000

Mean Proportions of Waste Types in All Observed Floors In Fall 2013

Waste Tye	W	P	R	G	A	D	S	F	B

Proportion of All Bins Contaminated	**0.606±0.033**	**0.431±0.032**	**0.369±0.032**	0.016±0.007	0.102±0.019	0.058±0.013	0.069±0.017	**0.317±0.03**	0.155±0.022

For example, 60.6% of all waste bins in east side dorms are contaminated with organic waste. (W) = organic Waste; (P) = Recyclable Plastic; (R) = Cardboard and Paper; (G) = Glass; (A) = Aluminum; (D) = Pizza Boxes; (S) = Solo Cups; (F) = Coffee Cups; (B) = Take-away Food Boxes.

Table Summary of Confidence Intervals and Dorm Means

	Average Bin Fullness	Cross-Contamination Index	Mean Compostable Item Misplacement Index	Mean Recyclable Item Misplacement Index
95% Confidence Interval for all Dorms	(0.4485655, 0.4849012)	(1.954103, 2.109536)	(0.9696157, 1.072536)	(0.8311244, 0.9336904)
Myers Mean	0.4383999±0.038 −	2.2712054±0.167 +	1.2857887±0.127 +	0.8932292±0.123
Goodhue Mean	0.3540252±0.028 −	1.8383185±0.254 −	0.7305928±0.103 −	0.8093440±0.137 −
Watson Mean	0.4340320±0.03 −	2.072642±0.152	0.9847619±0.107	0.9560317±0.112 +
Cassat Mean	0.5733617±0.051 +	2.1153846±0.148 +	1.2410256±0.115 +	0.8897436±0.101
James Mean	0.5483077±0.056 +	1.8410256±0.186 −	0.8948718±0.127 −	0.8102564±0.136 −
Nourse Mean	0.4697422±0.044 +	2.0222222±0.197	1.0305556±0.133	0.9±0.14

* Plus and minus symbols show whether the mean of each dorm was above or below the population mean confidence interval of the four dependent variables

Discussion and Conclusion

This data provides some valuable insights into how student waste habits differ across different dorms. The statistically significant difference in average bin fullness across dorms (p-value < 0.000) speaks to the heterogeneity of waste bin availability and student needs in different dorms. From my hands on experience as a waste monitor, James and Cassat floors have fewer and narrower waste bins than dorms like Goodhue and Watson. Therefore, James and Cassat have exceptionally high average bin fullness on their floors. This information is valuable to Custodial Services, who is considering an investment of standardized waste cabinets in residence halls. These waste cabinets feature narrow, roofed bins, which will have a smaller carrying capacity than many current waste bins. A potential negative outcome of this decision is an overflow of compostable and recyclable items into waste bins. This raises the question of whether high average bin fullness is associated with cross-contamination indices. Cassat and James exhibit opposite associations between average bin fullness and cross-contamination indices (see table summary of confidence intervals and dorm means). Further analysis of this current dataset using a regression model controlled by dorm could address this question.

The statistically significant difference in mean compostable item misplacement index across dorms allows us to interpret which residence halls manage compostable materials relatively well and which residence halls can improve the most. James and Goodhue residents seem to manage compost relatively well compared to the other dorms, while Myers and Cassat have a mean compostable item misplacement index that are exceptionally higher (higher than the 95% mean confidence level) than the other dorms. During Green Wars, composting outreach should be targeted at floors in Myers and Cassat. It is also important to acknowledge good performance, so James and Goodhue should be credited for their stewardship.

It is important to remark that the mean compostable item misplacement index is not an ideal measure of compost mismanagement. In the data collection process, only sub-units, (food waste, coffee cups, pizza boxes, and sayles boxes) of compostable materials were recorded. It would have been ideal to directly tally the number of compostable materials (aggregate the subunits) on each floor and calculate the true proportion of bins on each floor contaminated by compostable items. However this was not done so an index was the only possible solution. This is an issue which can be corrected during the next phase of monitoring winter term.

It is surprising that there were no statistically significant differences in mean recyclable item misplacement index across residential halls (p-value = 0.5359937). This implies that all dorms have similar issues that limit better student handling of recyclable materials. Similar to the compostable item misplacement index metric, recyclable item misplacement index is not an ideal metric. These two metrics attempt to speak to problem of forgone opportunities for recycling and composting. A more in depth analysis of the proportion of each observed waste type in contaminated bins can provide a much more precise understanding of which waste items students are not handling properly. This dataset can easily accommodate such an analysis.

Although there were statistically significant relationships between weekend number and all three cross-contamination indices, the observed relationship provides little practical value. These relationships were analyzed with the possibility in mind that bin fullness and cross-contamination might be exceptionally high during certain times in the term, such as during mid-term break or the last week of the term. There is no clear temporal trend in any of these indices.

The statistically significant relationships between day of the weekend and all three cross-contamination indices is more likely to be useful as a monitoring quality control measure than an indicator of actual differences in student habits. Each day of the weekend has different student monitors on the job. I personally work on Saturday with occasional assistance by Jason Magaziner, whereas Jackson Van Fleet leads monitoring on Sundays with the assistance of Ryan Wegner. For all three cross-contamination indices, mean values were higher on Saturdays than on Sundays. This may very well reflect that I am a stingier monitor than my Sunday colleagues. While it is possible that students may empty a lot of their trash on Friday afternoons to freshen up for the weekend, the stark differences between Saturday and Sunday mean values suggest the presence of sampling bias. This shows us that student monitors need to practice sampling together to refine monitoring protocol and improve the accuracy and consistency of the waste monitoring project.

It is important for a reader of this report to understand what exactly each cross-contamination indices mean. The cross-contamination indices created in this study are measures of the diversity and spread of cross-contamination, not the magnitude or severity of cross-contamination. One small apple core in a waste bin will qualify the bin as cross-contaminated. While these may not seem like useful metrics, in the case of community waste management, the community is as strong as the weakest link. Although a few ignorant students might spoil the data for a whole floor, their actions have costly consequences on the sorting and handling of waste after it leaves campus. These metrics measure the potential for floor communities to become more educated on proper waste monitoring habits. Even if the future outreach program “preaches to the choir”, the outreach will hopefully energize floor communities to be more aware of waste management as an important component of sustainability and educate their neighbors when they witness cross-contamination.

This dataset shows that organic waste, plastic, cardboard, and coffee cups are the most frequently misplaced waste types, and should be most strongly emphasized by Carleton's Community Waste Program. Further analysis of this dataset can provide information on the proportion of waste bins contaminated by each waste type on the scale of individual dorms and floors.

This report has not fully realized the potential of this dataset. However, it provides a baseline for planning education and outreach activities in the future. The next obvious step is to conduct two-way ANOVAs of dorm and floor number on cross-contamination indices. This step will allow monitors to zoom in on particular floors that are problematic and exceptionally responsible, providing the specific information that monitors will need to start visiting and consulting with floor communities. This information also has potential utility for Custodial Services and the Sustainability Office, which work hard to accommodate sustainable behavior and make Carleton's waste stream more efficient.