All in One: Do Single-Stream Curbside Recycling Programs Increase Recycling Rates?

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Abstract There is current debate on the effectiveness and efficiency of residential single-stream curbside collection compared to multi-stream curbside collection. This study investigates whether there is an increase in tonnage of recyclables collected at the curb after switching from a multi-stream to single-stream program and discusses factors that may account for variances in magnitude. This three-case comparative study examined collection data from the cities of Fremont, Livermore, and San Leandro, located in the San Francisco Bay Area, all of which recently switched to single-stream. Recycling coordinators from these cities were able to provide monthly data on tonnages of recyclables and garbage collected at the curb from single-family homes. Multiple regression analyses showed that a single-stream program significantly increases the amount of recyclable materials set out at the curb. The observed differences in the magnitudes of increase between these cities indicate that other factors in the program impact recycling behavior as well. Examination of these curbside programs suggests that educational outreach to residents may be one of the greatest factors in maximizing recycling rates in a single-stream service. This study also found that switching to single-stream may not have a significant impact on reducing the amount of land-filled materials. There are also reasons for doubting the reliability and accuracy of the data, indicating that improvements upon methods of data recording in the recycling field need to be made in order to more accurately assess the efficacy of recycling programs.

Introduction

Around 500 curbside recycling programs provide service to an estimated 28 million Californians (CA Integrated Waste Management Board 2003). The widespread coverage of this service began with the implementation of California's Integrated Waste Management Act of 1989 (AB 939). It created a board to establish a new method of diverting California's waste stream, mandating a 25 percent diversion of waste from disposal for each city and county by 1995, and 50 percent diversion by 2000 (CIWMB 2003). Since the statewide diversion rate is still below 50 percent as of the most recent estimate, it is exceptionally important for the Board to know if these programs are effectively encouraging participation and diverting waste (CIWMB 2006).

Jurisdictions may experience different levels of recycling participation due to a variety of factors. However, previous studies attempting to identify these factors are inconsistent in their conclusions, which suggests that recycling behavior is not generally predictable. A study by Folz (1991) showed that socioeconomic status was not a determinant of recycling, but Schultz's 1995 study contradicts this finding with a conclusion that income is a good predictor of recycling. Schultz's (1995) study also determined that age did not correlate with recycling behavior but Derksen's (1993) study did. Public commitment, normative influence, goal setting, and rewards were shown to result in significant increases in recycling rates (Schultz 1995). A link was also made between behavior change and pleas to recycle and feedback (Schultz 1999). Even social norms may play a part in pressuring some residents to recycle (Carlson 2001).

Recycling program characteristics could play a large role in encouraging residents to recycle but are far less studied (Reinfeld 1992). The variables of the program prior and after implementation of single-stream could affect changes in collection tonnages, including the number of streams, types of materials collected, frequency of collection, volume of containers, and whether or not containers were provided. In addition, some jurisdictions may have focused on educating the public about the new program, sometimes in various languages while others may not have mandated any kind of outreach. There are also many differences in recycling service between jurisdictions such as time of establishment of the program, rate charges to residents for garbage or recycling collection that could affect recycling rates.

In the US, the three-bin collection method was common in the early 1990s (Fig. 1). In this system, residents were responsible for separating recyclables into categories such as newspaper,

mixed paper, and bottles and cans (CIWMB 2003). This strategy of sorting recyclables, whether into bins or split carts, is called source-separated or multi-stream recycling. With advances in technology, many cities throughout the country, including the Bay Area, are switching to single-stream recycling, also called commingled collection, for the potential to collect more materials (CIWMB 2003). In this method, all residential collectables are combined together into one large container to be separated at a materials recovery facility (MRF) (Taylor 2003).

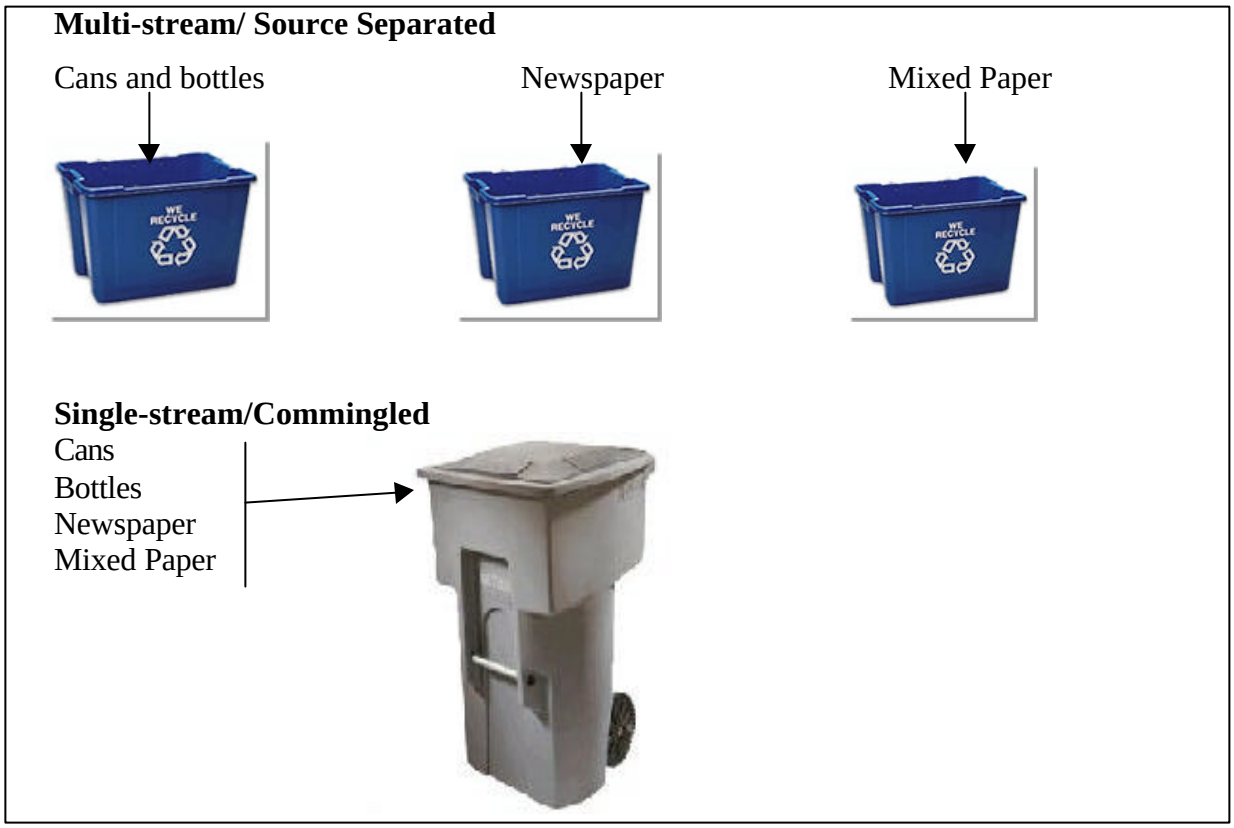

Figure 1. Multi-stream and single-stream curbside separation methods.
Cart: http://www.recy-cal.com/evr4.jpg Bin: https://www.cityofpa. us/pwSolidW.htm

Some previous studies showed that single-stream programs increase the number of participating households and, on average, the quantity of materials collected compared to multiple-stream programs. Stuart Oskamp's (1996) study on cities in southern California concluded that single-stream programs dramatically increase the number of participating households and volume collected due to greater ease of recycling. A short-term study by Eureka Recycling (2001) in St. Paul modeled an increase in participation, though it concluded that this

resulted from the greater capacity of the single bin compared with the three separate bins, rather than ease of recycling.

This study examined three jurisdictions in the San Francisco Bay Area to see what changes in recycling rates occurred due to a switch from multi-stream to a single-stream program. Though previous studies showed that single-stream programs collect more materials than multi-stream programs, this three-case comparative design allowed this study to determine if there were differences in the magnitudes of the changes. If variation is found, this study will discuss the factors that may explain this phenomenon though they were not fully investigated.

The three cities in this study were Fremont, San Leandro, and Livermore, which are representative cities of Alameda County. Recycling rates from single-family homes only were analyzed in this study. These cities switched to single-stream at least two and a half years ago. I hypothesized that there would be an increase in recycling rates due to the switch from multi-stream to single-stream recycling curbside programs. I also hypothesized that these cities will have experienced comparable increases in their recycling rates after their implementation of single-stream because they have similar programs and are all in the same county.

Methods

To examine the changes in recycling rates, I needed to gather data on tonnages of recyclables[1] collected at the curb from single-family homes from cities that switched from multi-stream to single-stream curbside recycling in the past few years. I also needed to gather data on tonnages of garbage collected at the curb from single-family homes. I chose to look only at single-family homes because the recycling dynamics in multi-family dwellings are not comparable to those of single-family homes. One factor that contributes to this is that residents in multi-family dwellings are not usually provided with individual bins for recycling but have communal bins. Previous studies have shown that recycling rates in multi-family dwellings are generally much lower than that of single-family homes due to the lack of space and difficulty of outreach (Stevens 1998). I also needed data on the populations of each city. Data available for the number of households serviced with garbage and recycling collection were not consistently reported.

[1] "Recyclables" in this study refers to materials that are placed in the recycling containers though all those materials may not actually be recyclable.

Because the state and many counties did not have a compiled database of the information I needed, I contacted individual jurisdiction recycling coordinators. The CIWMB website provided contact information for jurisdiction "annual reporting contacts" who were able to assist me themselves or transfer me to someone who could. I contacted over 50 city recycling coordinators in the Bay Area counties of Alameda, Contra Costa, San Mateo, Santa Clara, Marin, and San Francisco. Most of the cities that have switched to single-stream are only in Alameda and Contra Costa counties. Many cities outside of the Bay Area in California started their recycling programs as single-stream or switched so long ago that records were difficult to access while many cities in the Bay Area had switched within the last few months. The three cities in this study, Fremont, San Leandro, and Livermore were selected because single-stream had been implemented more than two years and recycling coordinators were able to provide data from before and after the switch. It was important to study cities that had implemented single-stream for a few years so that long term trends could be observed. I conducted semi-structured interviews with the recycling coordinators about the local curbside recycling programs.

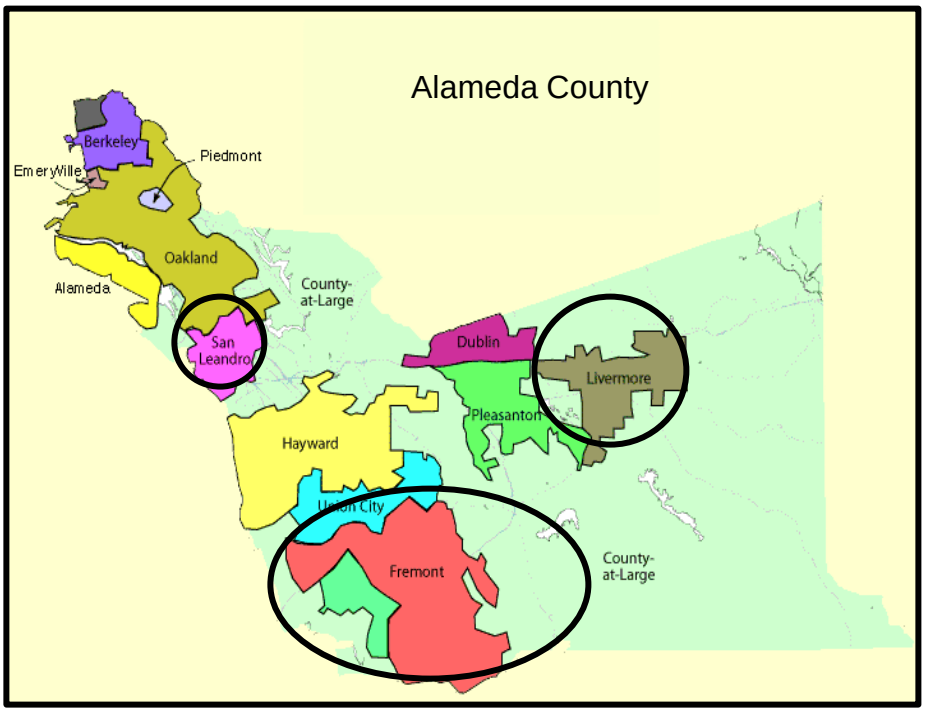

Figure 2. Map of Alameda County depicting study sites in this study.
Map: www.mosquitoes.org/ images/service_map.gif

Study Sites The cities of Fremont, San Leandro, and Livermore are located in the East Bay of the San Francisco Bay Area (Fig. 2). Fremont has a population of about 200,000 residents, San Leandro has about 80,000 residents, and Livermore has a population of 73,000 residents (US Census 2000). These three cities began curbside recycling service in the early 1990's. All had residents sort their recyclables into three 18-gallon bins. Fremont's bins were all one color while Livermore and San Leandro residents received different colored bins to help distinguish each stream. The switches to single-stream occurred for San Leandro in June 2000, Livermore in August 2002, and Fremont in June 2003. The haulers replaced the bins with a single large cart. While Fremont and Livermore residents were given 64-gallon capacity recycling carts as the default, San Leandro residents were presented with 96-gallon carts (Virostko, Erlandson, Longshore 2005-06, pers. comm.). Fremont residents could downgrade their recycling cart to a 32-gallon capacity. Livermore residents could upgrade to 96 gallons free of charge. All three cities have Pay-as-You-Throw rates instead of a flat rate for their garbage collection with recycling service included or for an additional minimal fee. Livermore and Fremont residents were given a 64-gallon capacity garbage cart as the default while San Leandro residents got a 32-gallon cart. All three cities began to collect more materials and there is some variation in what is accepted in each. All programs added plastics #3-7 to their list of acceptable materials (Virostko, Erlandson, Longshore 2005-06, pers. comm.). While Fremont and Livermore provide recycling collection once a week, San Leandro residents have biweekly service. Each city has outreach programs in forms of presentations and printed literature that may be distributed in person at community events or through the mail. Livermore had the most extensive and elaborate educational materials of these three cities including annual colored brochures and quarterly newsletters (Virostko, Longshore, Erlandson 2006, pers. comm.). The single-stream program was highly publicized for a few months prior and after implementation in these three cities. All cities had achieved the AB 939 mandate to reach 50% diversion by 2000 and are now trying to reach the county goal of a 75% diversion rate by the year 2010 (Virostko, Longshore, Erlandson 2006, pers. comm.).

Data Collection I was able to gather monthly total tonnages of recyclables and garbage for years prior to the switch to single-stream and after for single-family homes for each city. [2] The

[2] The city of San Leandro has two haulers that serve different parts of the city. Only data from ACI, that serves 60 percent of the city, is examined in this study.

recycling coordinators obtained this data from their contracted haulers/materials recovery facilities (MRFs). MRFs could measure the tonnages of recycling that come in from each jurisdiction they service or allocate tonnage based on the number of accounts they have for each city (Erlandson 2006, pers. comm.). To improve accuracy, the case cities chosen for this study have collection tonnages based on actual measurements, not extrapolations. Single-family home tonnage data were available separate from multi-family dwellings or businesses. Recyclables in this study include accepted plastics, metals, glass, and paper fibers. Greenwaste was not included in this study.

To be able to normalize the data for population, I gathered yearly population data for each city from the Department of Finance's Annual Statistical Report (Reagents of the UC 2006, elec. comm.). It extrapolates population for each year from US Census, DMV, hospital, and utilities data. This data is not tailored to the residents that contributed to the tonnages collected in this study because it included residents in both multi-family and single-family homes. However, this population data was the best available and relative trends could still be extrapolated though the absolute numbers are not accurate.

Analysis Recycling coordinators provided data on monthly tonnages of recyclables and garbage from single-family homes for each city. Data on tonnages collected for recyclables and garbage were first deseasonalized in attempt to reduce variance due to seasonal fluctuations in the amount of garbage and recyclables residents generate during certain times of the year. These oscillatory effects were normalized so that they do not interfere with observed changes in tonnages at the time of the switch. Deseasonalized data were calculated based on a seasonal index derived from a 12 month moving average, centering this average, and finding the ratio of this centered average to the observed data (Mansfield 1983).

There are many ways to express the amount of recycling though there is no single superior method. In this study, I will present some of them in order to demonstrate many perspectives that may provide more insight into the results. These include examining the changes in total absolute tonnage of recyclables, changes in the fraction of total waste that is recycled, changes in recyclables per capita, and changes in the amount of land-filled waste after a switch to single-stream.

Multiple regression analyses were carried out on these various presentations of recycling rates to measure the impacts from the program change. They were performed to see if there was

significant change in the slope and/or intercept before and after the switch. A change in the slope would indicate that the switch to single-stream had a continuous effect on the recycling rate while a shift in the intercept would indicate an instantaneous effect.

It is extremely important to note that the phrase "switching to single-stream" is used to encompass all changes in the recycling program at that time, not just reducing the number of streams for residents. Changes in the program include increasing the volume of the bins, increasing outreach to publicize the change, increase in acceptable materials, etc.

To better understand inconsistencies in the amount of change observed between cities, various qualitative aspects of each jurisdiction such as population, languages spoken, and affluence were noted. This study also considered the recycling program factors such as types of materials collected, frequency of collection, volume of containers, and presence of education and outreach.

Results

As mentioned before, there are multiple ways that recycling rates can be expressed. Since I was able to gather data on tonnages collected for recyclables and garbage, I will present data as absolute total values of recycling tonnages, as percentages relative to the total waste stream, as pounds collected per capita as well as examine garbage data.

First, by looking at total tonnages, it is apparent that each city collected drastically different amounts of recyclables (Fig. 3). This graph depicts the total amount of recyclables set out per month before and after the single-stream switch for each city of Fremont, Livermore, and San Leandro. The x-axis is labeled in "years since the switch," with "0" marked at the last month before single-stream was implemented. Different ranges of data are presented because each city switched during different years and varied in availability of past data. It is also noticeable that Fremont's tonnages of recyclables vary much more month to month than tonnages collected in Livermore or San Leandro. Variation in total number of collection days each month accounts for variation in recyclable tonnages (Gallegoes 2006, pers. comm.). Since Fremont serves many more residents than the other two cities, this phenomenon was magnified.

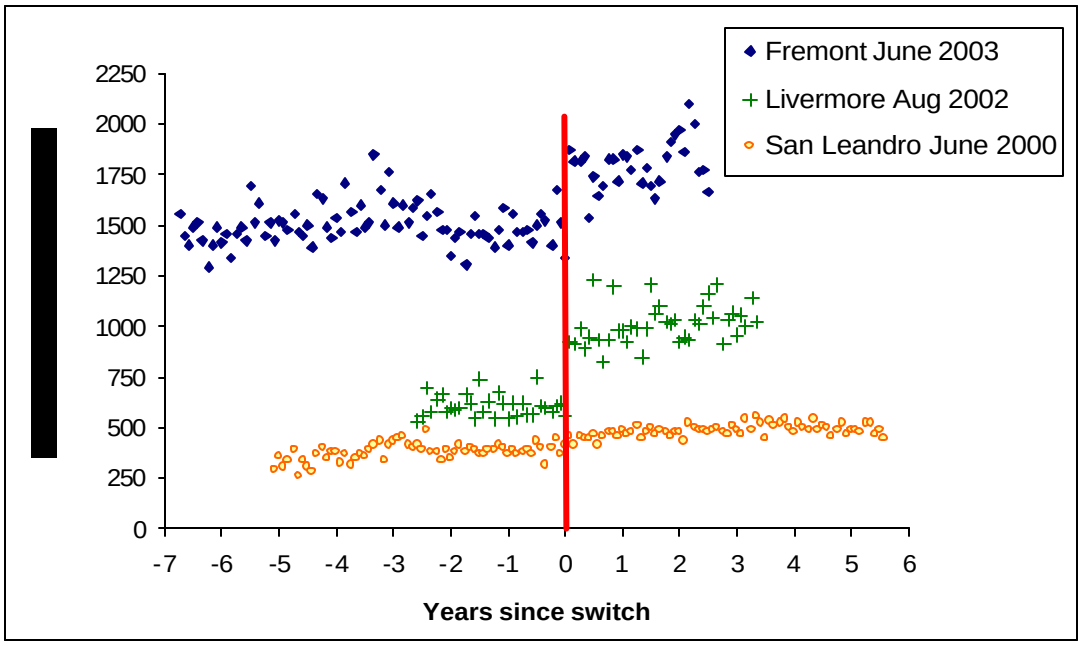

Figure 3. Monthly total tonnages of recyclables collected at the curb.

The following models were used to analyze these and following data:

$$Y = a + b1 *(TIME) + b2 * (SWITCH) + b3 * (TIME*SWITCH) \quad \text{eq 1}$$

$$Y = a + b1*(TIME) + b2 * (SWITCH) \quad \text{eq2}$$

Y is the dependent variable and would represent total tonnage of recycling, total tonnage of garbage, the relative amount of recycling to garbage, or recycling tonnage per capita. TIME is a continuous variable that captures trends in time, such as background population growth, education programs, or changes in general awareness about recycling. Here, TIME is measured in years. Year 0 marked the beginning of the first year of reliable data. SWITCH is a binary variable with SWITCH = 0 when multi-stream was in place and SWITCH = 1 when single-stream was implemented. It is important to note that the SWITCH variable encompasses any program change associated with a switch to single-stream recycling in addition to reducing the number of streams. These include any associated increase in the total volume of the collection container, boost in publicity and education, expansion of materials accepted, etc.

In both equations 1 and 2, the b1 coefficient is a measure of the background rate of change in the dependent variable. The b2 coefficient is a measure of the instantaneous effect of the switch to single-stream and all the factors it encompasses. It shows how much of a change can be

attributed to the switch in the program, after taking into account background rates of change, already captured by b1. The term TIME*SWITCH accounts for change in the slope after implementation of the single-stream program. A statistically significant b3 coefficient indicates an effect on the dependent variable that continues long after the time of the switch, noticed by a change in slope. Equation 2 was used if this variable is found to be insignificant. Most of the regression statistics found in this study are summarized in Table 1.

Table 1. Summary of regression coefficients and statistics.

	b1 (background rate of change)	p-value	b2 (instantaneous change)	p-value
Fremont				
Total Recyclables	Not significant	p>0.05	+278.2 tons	p<0.001
Lbs recyclables/resident	Not significant	p>0.05	+27.2 pounds	p<0.05
Total garbage	+80 tons/year	p<0.001	-512 tons	p<0.01
Lbs garbage/resident	Not significant	p>0.05	-44.5 pounds	p<0.01
Livermore				
Total Recyclables	+33.8 tons/year	p<0.01	+290 tons	p<0.001
Lbs recyclables/resident	Not significant	p>0.05	+77.5 pounds	p<0.05
Total garbage	+42.9 tons/year	p<0.01	-124 tons	p<0.01
Lbs garbage/resident	Not significant	p>0.05	Not significant	p>0.05
San Leandro				
Total Recyclables	+7.48 tons/year	p<0.001	+57.1 tons	p<0.001
Lbs recyclables/resident	Not significant	p>0.05	+26.7 pounds	p<0.01

Multiple regression using equation 1 showed that for every city in this study, there were no statistically significant changes in the slope after the program switch on total tonnage of recyclables. For the city of Fremont, multiple regression using equation 2 indicated that the slope before as well as after the switch was not significantly different ($p>0.5$) from zero (Fig. 4). There was however, a significant ($p<0.001$) instantaneous jump in the total tonnage of recyclables collected after the switch (Fig. 4). In Fremont's case, since there is no background rate of change, we can attribute about a 278 ton increase to the switch in program.

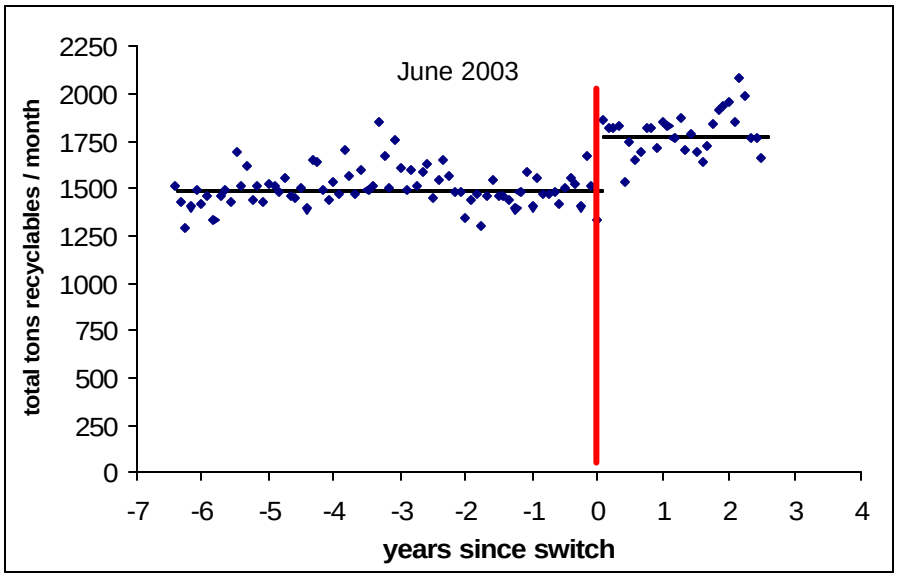

Figure 4. Total monthly tonnages of recyclables collected at the curb for the city of Fremont.

The city of San Leandro on the other hand did show a statistically significant slope in its recyclables data (Fig. 5). Its total recyclables increased at a rate of 7.47 tons per year ($p<0.001$) due to background influences such as increases in awareness or population. In San Leandro's case, there was small, but statistically significant ($p<0.001$) instantaneous effect on the amount of recyclables collected (Table 1).

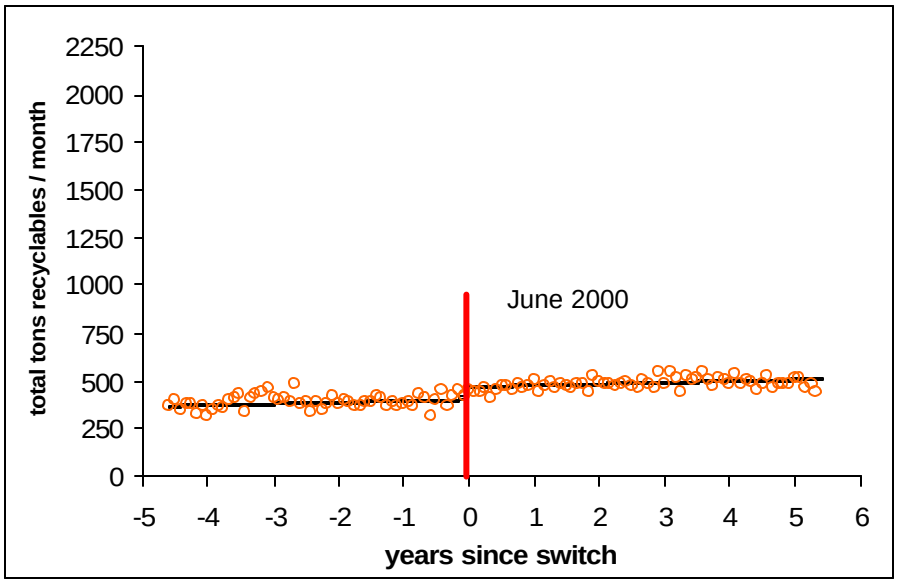

Figure 5. Total monthly tonnages of recyclables collected at the curb for the city of San Leandro.

While an instantaneous effect was barely perceptible for San Leandro, Livermore's data shows a dramatic increase in total tonnages collected after implementation of the single-stream recycling program (Fig. 6). Livermore has a significant slope of 33.82 tons per year ($p<0.01$). This high coefficient may be due to increases in the number of residents in Livermore during that time. Multiple regression concluded that there was an instantaneous increase of 290 tons ($p<0.001$).

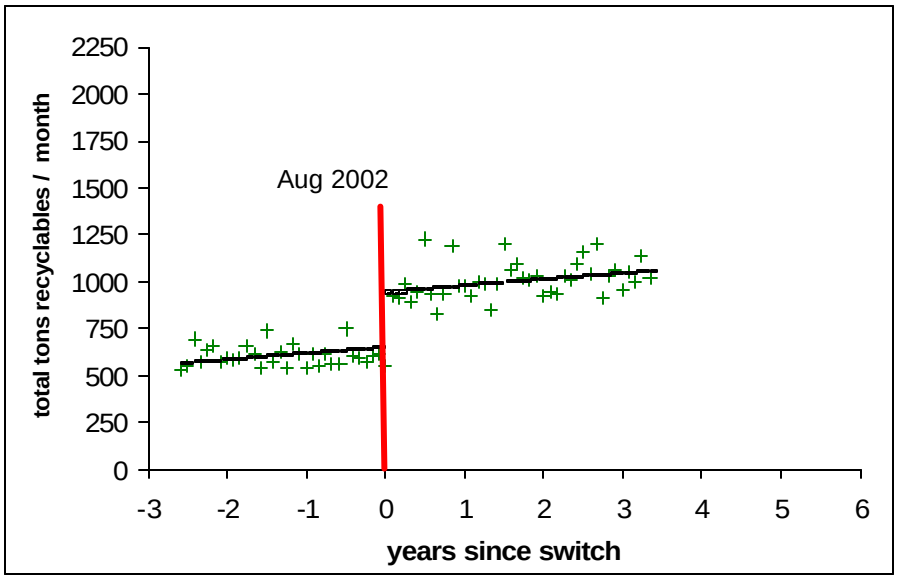

Figure 6. Total monthly tonnages of recyclables collected at the curb for the city of Livermore.

Though it can be gauged that Livermore had the greatest total increase, the data on total tonnage of recyclables were normalized for population to be able to compare the recycling rates across cities at the smallest scale (Fig. 7). Keeping in mind that the population data includes multi- and single-family residents, this data is still useful in evaluating the relative differences between cities.[3] Monthly tonnage data for recyclables were summed up for over the year and divided by the population for each city (Fig. 7). Examining the data from this calculation provides a different perspective than looking at total tonnage. No significant slope was detected before or after the switch for all cities. When the total tonnages of recyclables were normalized for population, each resident in all three cities recycled at comparable rates prior to single-stream. In this method of representation, Livermore still showed the greatest increase in recycling after implementation of the new program (Fig. 7). Multiple regression for these data concluded that the discontinuous increases can be attributed to the change in program. Fremont ($p<0.05$) and San Leandro ($p<0.01$) residents increased recycling by about 27 pounds per person. Livermore residents dramatically increased their amount of recyclables collected per

[3] From CIWMB profiles, Livermore may have a smaller fraction of homes that are multi-family compared to Fremont and San Leandro which have comparable amounts. Also, the fact that the tonnage for San Leandro is for 60% of the city was taken into account when finding total population.

person by more than twice than that of the other two cities. Multiple regression indicated that each Livermore resident increased recyclable setout by about 77 pounds ($p < 0.05$).

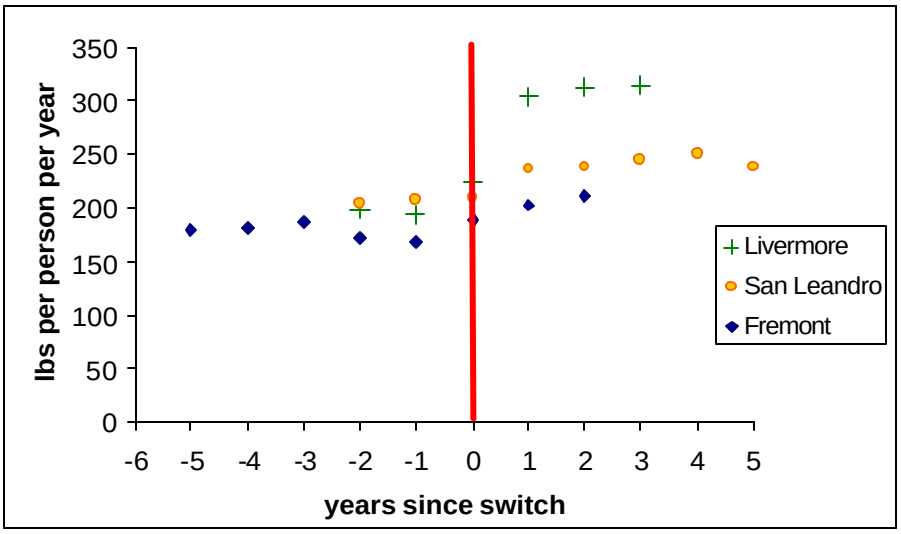

Figure 7. Pounds of recyclables per person per year.

To see if cities were just generating more garbage along with more recyclables, it was useful to look at recyclables as a percentage of the whole waste stream (recyclables and garbage) (Fig. 8). San Leandro's garbage data was incomplete so only the other two cities are included in this analysis. From this perspective, one would expect the fraction of recyclables to increase after implementation of single-stream. No significant change would indicate that residents also increased the amount of land-filled waste at the same rate. Livermore and Fremont data followed expectations (Fig. 8). Prior to single-stream both cities had comparable fractions of recyclables diverted from the waste stream. For Fremont, there was a slight, downward slope prior to single-stream ($p<0.001$). This reflected the fact garbage increased at a positive rate while recycling rates stayed stagnant prior to single stream. Performing multiple regression with Livermore's data concluded that the slope is not significantly different from zero and that there was no significant change in the slope after the program change. Implementing single-stream had different effects for each city. Fremont reacted with a positive slope of about one percent per year ($p<0.01$). This could be explained if Fremont residents are reducing the amount of total waste they are generating though this rate is so small that it might be due to the large variation in either or both recyclables and garbage data. For Livermore, on the other hand, there

was a discontinuous increase in the fraction of recyclables placed out at the curb to the whole waste stream ($p<0.001$). Prior to single-stream the average percentage was 29 and increased to 40 percent after. After single-stream, Livermore diverted more of its total waste stream to recycling than Fremont.

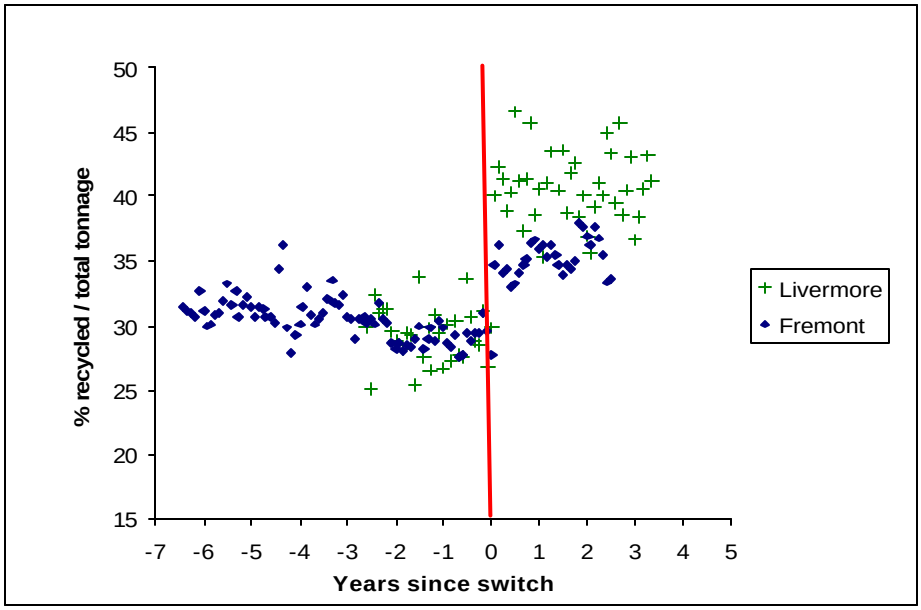

Figure 8. Fraction of total generated waste (recyclables and garbage) that were placed in recycling bins.

From only looking at these increases in the fraction of recyclables in the whole waste stream, the conclusion may be that the single-stream program had achieved its purpose of increasing the amount of recyclables placed at the curb, inferring the diversion of materials from landfills. Implementing the new program should not greatly affect the amount of total waste being generated—more would be allocated to the recycling bin and less to the garbage bin.

For Fremont, the amount of total generated waste (the sum of garbage and recyclables) collected varies dramatically from month to month (Fig. 9). Through the years 1997 and 1998, Fremont had an increasing rate of total materials generated, most likely due to an increase in the population. When multiple regression was performed for the data starting in 1999, there was no statistically significant slope or change due to the single-stream program, which is to be expected (Table 1). Fremont's garbage tonnages show the expected trend in garbage generation after implementation of single-stream (Fig. 9). There had been a steady increase of about 80 tons/year

in total tonnage of garbage ($p<0.001$). (The inconsistency that garbage generation has been steadily increasing but not recyclables or the total material generated may be explained by the high variation in the data.) After implementation, an instantaneous drop in tonnage of garbage was observed and there was no impact on the slope. This drop in tonnage of garbage set-out is predicted to be due to residents diverting it to recycling bins. An instantaneous decrease in garbage of 512 tons for the whole city was attributed to the implementation of single-stream ($p<0.01$) and multiple regression on a per capita level showed a decrease of about 44 pounds of garbage per person in a year ($p<0.01$).

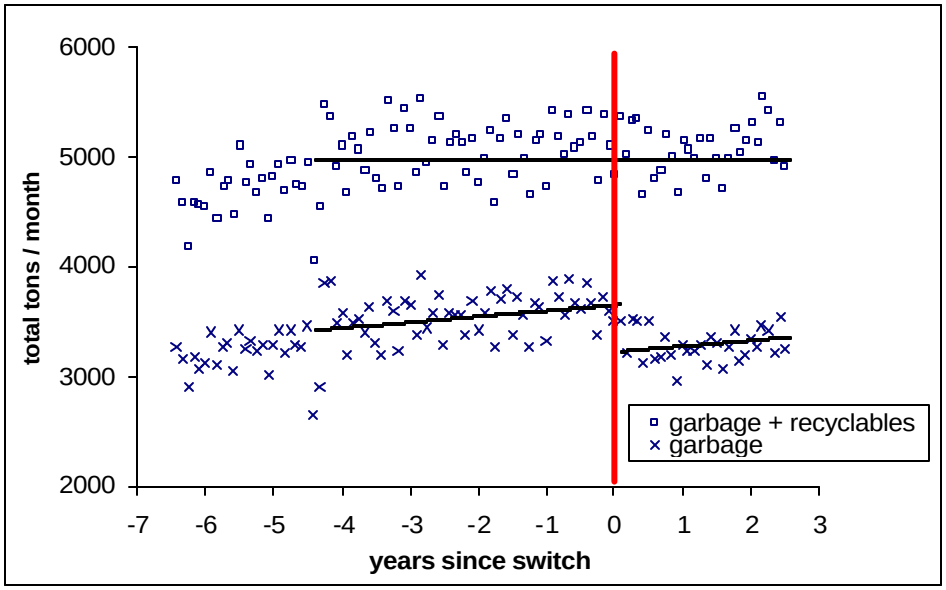

Figure 9. Total monthly tonnage of garbage and recycling and only garbage for the city of Fremont.

Examining Livermore's garbage data resulted in an alternative outcome (Fig. 10). For this city, there is only a slight instantaneous decrease of 124 tons that is placed at the curb after single-stream ($p=0.01$) which is unexpected since the effect on the recycling rate was so great. When this data was normalized for population, it turned out that there was no statistically significant decrease in the pounds of garbage set out per person per year after single-stream. In Livermore's case, the large increase in recycling corresponded with the generation of more total waste. Multiple regression concluded that there was no significant slope in the amount of total waste generated during the multi-stream program of materials. After single-stream, the slope

became about 89 tons/year ($p<0.05$). This means that though Livermore residents were recycling much more, almost the same amount of waste is going to the landfill. Instead of the case where residents were recycling materials that they would have previously thrown in the garbage container like in Fremont, Livermore residents were generating more recyclable material. Normalizing this data for population showed that residents increased the amount of total generated waste by an enormous amount of around 100 pounds per person per year after single-stream (Fig. 11). The fact that the population data used accounts for both multi- and single-family homes means that the increase is actually an underestimation. Some of the increase may be explained if Livermore residents were taking their recyclables to be recycled at a drop-off or buy back center prior to single-stream. Another scenario may be that during multi-stream, scavengers may have been much more prone to taking recyclables from residents, ceasing when desired recyclables were not sorted. The higher variation among the data points after the switch also suggests that there is a difference in the way that the tonnages are measured.

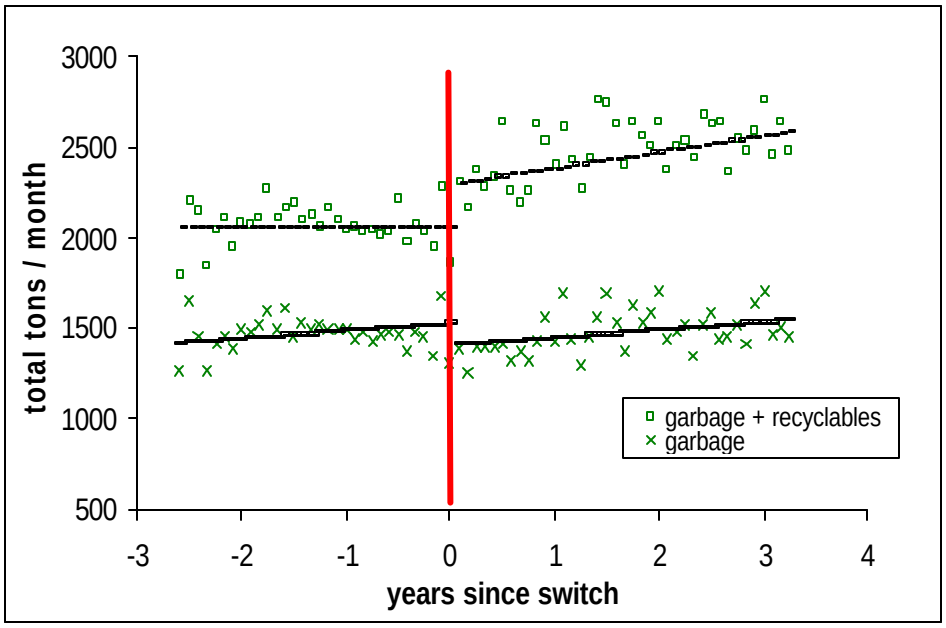

Figure 10. Total monthly tonnage of garbage and recycling and only garbage for the city of Livermore.

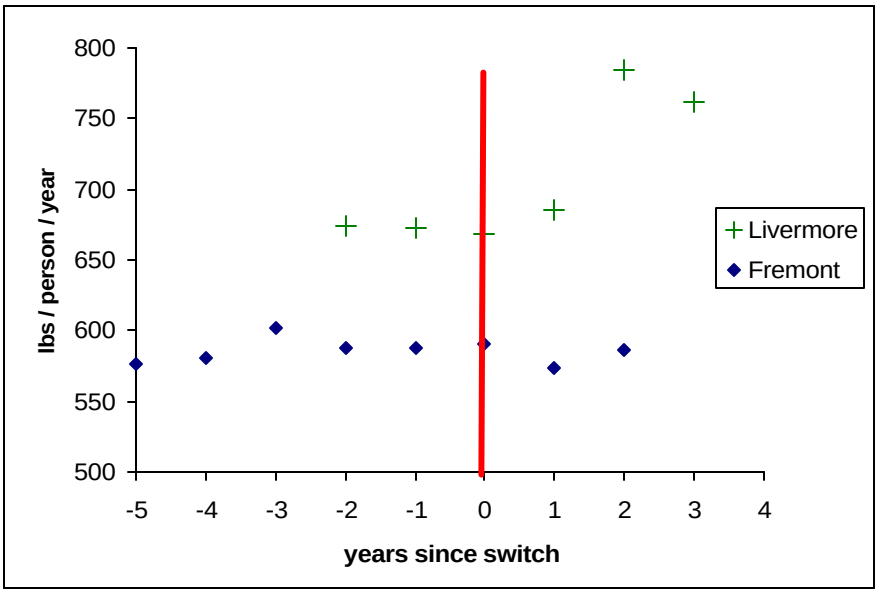

Figure 11. Total waste (recyclables and garbage) in pounds per person per year.

Discussion

My initial hypothesis that single-stream increases recycling rates is proven to be true. Through multiple regression analysis, it was shown that there was a statically significant increase in total tonnages in recycling collected after implementation of single-stream in all three cities. Statistically significant increases were also found at the per capita level. While it was proven that all cities experienced an increase in recycling tonnages collected at the curb, the amount of materials that go through the entire recycling process remain uncertain. Single-stream increases contamination rates so some recyclable materials may be diverted back to the waste stream (CIWMB 2003). In addition, clean materials accepted by the program may still be land-filled because there is no assurance that there will be a strong market for them (Longshore 2006, pers. comm.). All of the cities in this study began to accept #3-7 plastics when they implemented the single-stream switch to ease residents in sorting. However, markets for these plastics wildly fluctuate and haulers might eventually throw these materials back to the waste stream (Longshore 2006, pers. comm.). Thus, the observed increases in collection due these plastics may not increase diversion from landfills if they are diverted there later in the cycle by the manufacturers or sorters. There also has been little assessment in the amount of materials sold overseas that are eventually land-filled (Holtzclaw 2006, pers. comm.).

My second hypothesis that all three cities would experience the same magnitude of increase was refuted. After normalizing total tons of recyclables for population, multiple regression showed that the cities experienced different magnitudes of increase. On a per capita basis, each resident had comparable amounts of recyclables set out at the curb during the multi-stream program. After the switch, Livermore residents increased the absolute amount of recyclables set out in a year (~77 pounds) by more than two times as much as Fremont or San Leandro residents (~27 pounds). This discrepancy indicates that there are other factors to consider in addition to elimination the need for residents to sort that effect recycling rates. Every program alteration in the switch to single-stream may be playing a role in increasing recycling rates. Other program changes include the increasing the total volume of the recyclables container, availability of carts, acceptable materials, and the extensiveness of outreach/publicity.

The larger cart for collecting recyclable materials may have encouraged residents to recycle more. Residents may have gotten the impression that they were expected to sufficiently fill the recycling cart. In these cases, Fremont and Livermore residents had 64-gallon recycling bins but had varied effects on recycling tonnages. San Leandro residents had 96-gallon recycling carts and the smallest garbage bin of 32-gallons but still had comparable tonnages as Fremont. However, San Leandro residents have their recyclables collected biweekly instead of weekly like the other cities. It is conceivable that they may have more to recycle but had reached capacity at end of two weeks.

Another factor in determining amount of increase may be that some residents did not have recycling bins prior to implementing single-stream. Implementing the new program meant that every household, that may or may not have had bins, was provided with a recycling receptacle and they could then participate in recycling. This may not be a significant factor because residents could have readily contacted their respective hauling companies to request replacement bins.

A conceivable factor in increasing recyclables collected would be an increase in acceptable materials. Most of the increase in these cities would be due to the collection of #3-#7 plastics, included in every single-stream program and but not prior to it. Since all three cities had about the same accepted materials before and after but different increases in tonnage, this factor may not play a major role in increasing tonnage.

Overview of each program shows that educational outreach may be an important factor in influencing residents to recycle. All three cities had educational materials that were both sent to residents in the mail and all made the effort to be present at public events to promote recycling. The educational campaigns were more extensive in Fremont and Livermore than in San Leandro. Fremont and Livermore both had newsletters that go out to residents a few times throughout the year as well as bill inserts. After single-stream Livermore had more vibrant educational materials. Quarterly newsletters and yearly brochures were in color and targeted children as well as adults. Fremont also had quarterly newsletters and bill inserts but they were less eye-catching. San Leandro did not have literature sent to residents on a regular basis though reminders were included in the bill (Erlandson 2006, pers. comm.). The disparity between Fremont and Livermore may be due to Fremont's much larger population. Public outreach efforts may not reach the same fraction of people in this city than in Livermore.

Furthermore, city demographic factors may have some effect on recycling rates in addition to program characteristics. Fremont and San Leandro have a greater part of the population who "speak English less than 'very well'" (US Census 2000). While about seven percent of Livermore residents fall into this category, both San Leandro and Fremont have higher rates at about 20 percent (US Census 2000). Outreach efforts in English would not have as much of an impact to those who are most familiar with other languages. Affluence of a community might play a part in how much people recycle because those in a higher socioeconomic status would have a greater capacity to consume more and generate more materials. From examining median house prices and average income of the residents, Livermore and Fremont are similar in this aspect while San Leandro is relatively lower in affluence (US Census 2000). However, looking at these cases shows that higher affluence may not be indicative of higher recycling rates.

While it is important to look at recycling rates and understand factors that affect them, effects on the amount of materials going to landfills must not be assumed. Examining garbage tonnages for Livermore shows that single-stream, though it collects more recyclables, did not have as great an impact diverting waste from landfills as expected. Though Livermore had a much greater increase in recyclables tonnage, Fremont diverted much more waste. On a per capita basis, Livermore residents did not show to have any decrease in garbage generation, though they dramatically increased their production of recyclables. It is uncertain if prior scavenging, change in tonnage measurement methods, an increase in consumption, or some other factor(s) account

for how these materials were generated. Since the goal of diversion is to reduce waste going to the landfill, Livermore would not have achieved this with the implementation of single-stream. It is necessary to look at recycling and garbage rates because it becomes clear that though recycling rates increase, there may not be a corresponding decrease in the amount of materials continuing to be land-filled.

Another indication of program success is the participation rate (number of setouts of the number of potential setouts). Though these data were available for these three cities, they were not included in this report because they seemed to be highly unreliable and were inconsistently reported. Fremont calculated its participation rate based on driver reports for an annual audit. Fremont reported a constant participation rate over many years which shows this data is not reliably collected. While Livermore's data had trends that followed the expected trend of a noticeable increase after the program switch, it had reported participation rates of greater than 99% which is highly unlikely. San Leandro, also reporting extremely high rates, had a trend in which participation dropped from the high 90's to the low 60's after single-stream. It is doubtful that with fewer residents participating, the total tonnage of recyclables would not drop as well but actually increase. Accurate reports of this data are important to see if more people are contributing their recyclables or that the same participants are recycling more.

Information on the influence of education on recycling rates, factors that affect garbage rates, and accurate participation rates, are needed for recycling coordinators to tailor programs to maximize waste diversion. Though these three cities reached 50 percent diversion in 2000 as mandated by the CIWMB, Alameda County mandated the goal of reaching 75 percent by 2010. However, the method for diversion rate calculation used by the CIWMB is questionable in its reliability and accuracy. Diversion rates are calculated from the base rate of land-filled material in 1990. This formula takes into consideration land-filled tonnages and changes in employment, population, and taxes in order to calculate a reduction in waste production; recycling data is not included. This diversion rate is not accurate because Longshore and Erlandson both explained that waste tonnages were not recorded in 1990 (2005-06 pers. comm.). San Leandro and Livermore, like many other cities, have gone back to recalculate this base rate in order to meet the 50% diversion rate mandated by AB 939 (Longshore, Erlandson 2006, pers. comm.). These issues in assessing diversion make it difficult to evaluate the progress of reducing land-filled material.

The assumptions that needed to be made in this study show that improvements on data measurement are necessary in order to evaluate the success of a recycling program. Tonnage reports to the cities are sometimes revised, indicating the possibility of inaccurate data for both recycling and garbage (Erlandson, 2006 pers. comm.). Reliable participation rates would show whether increases in recyclables tonnage are due to more people participating or people placing more recyclables in the carts. Consistent data on the number of households with curbside service for each city are needed to evaluate the effect of program changes at the most accurate scale. Using the estimated population data from the Department of Finance which incorporates multi- and single-family homes resulted in many interesting and unexpected findings. Using more accurate data may, however, result in different conclusions.

In conclusion, this three case comparative study shows that switching from multi-stream to single-stream curbside recycling significantly increases tonnages of recyclable material collected at the curb for single-family homes. The variation in the magnitude of increase for Fremont, San Leandro, and Livermore indicates that other factors affect recycling rates besides reducing the number of streams. Though not extensively researched here, there is some suggestion that going to single-stream and providing extensive outreach and appealing educational materials may maximize recycling rates. This study showed that though recycling rates increased due to the program change, landfill tonnages may not be affected. Improvements upon data collection are needed to be able to assess into greater detail the effectiveness of different curbside recycling programs and the specific factors that influence recycling rates.

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