SUPPLEMENTAL APPENDIX FOR

A geospatial analysis of naloxone distribution patterns in the Massachusetts Overdose Education and Naloxone Distribution Program (MA OEND)

Contents

Naloxone service area clustering algorithm 2

Number of kits distributed per encounter 3

Massachusetts Overdose Education and Naloxone Distribution Program – Blank Intake Form. 4

Massachusetts Overdose Education and Naloxone Distribution Program – Blank Refill Form. 6

Supplemental Figure 1. Sample of refills and rescue attempts in the MA OEND program (2018-2019) 8

Supplemental Table 1. Demographic characteristics of Massachusetts Overdose Education and Naloxone Distribution (MA OEND) program participants (2018-2020), including observations with missing data 9

Supplemental Table 2. Ratios of naloxone dispensing events to opioid overdose deaths (2018-2020) by geographic areas, including municipality of occurrence 12

Supplemental Figure 2A. Residence municipalities of participants reporting rescue attempts occurring in Boston, overlayed by Bureau of Substance Abuse Services (BSAS) regions (2018-2020) 14

Supplemental Figure 2B. Residence municipalities of participants reporting rescue attempts occurring in Boston, overlayed by Massachusetts Bay Transportation Authority commuter rail lines (2018-2020) 14

Supplemental Figure 3. Location of rescue attempts in Boston, by ZIP code (2018-2020) 15

Supplemental Figure 4. Naloxone referral region hubs clustering algorithm results 16

Naloxone service area clustering algorithm

1) We ranked each municipality by the number of naloxone distribution encounters, highest to lowest, and kept municipalities that had greater than 1% of the total distribution events in the state (across the entire study period, 2018-2020)
2) Starting at the top of the list, if one of a top-ranking municipality's first-order land neighbors (i.e., those that share a common border over land or small waterways) was a municipality lower on this list, we consolidated the lower-ranking municipality into the dominant cluster. For example, Boston (#1 distributor of naloxone for 2018-2020) is a first-order neighbor with Cambridge (#9) and Quincy (#12), making the Boston-Cambridge-Quincy cluster hub. Because of this consolidation, hubs may include one or more municipalities (i.e., individual hub and cluster hub, respectively).
3) Similarly, if two municipalities on the list were not first-order neighbors but shared two or more first-order land neighbors, we subsumed the lower-ranking municipality into the higher-ranking one.
4) We kept going until all municipalities that contributed greater than 1% of the total naloxone distribution were either members of a hub with multiple municipalities or an individual hub.

Hubs serve a geographically broader NSA. Each municipality within the NSA gets the majority of its naloxone from the titular hub. We characterized NSAs through the following steps:

1) We counted the number of distribution events made among residents of each municipality in the dataset.
2) Of these, we counted the number of distribution events by the distribution location (e.g., among town X residents, how many distribution events took place in Hub A, Hub B, etc.)
3) We determined the proportion of each municipality's distribution events that occurred through each identified hub (if not at a hub, then elsewhere [including missing location data]).
4) We then ranked and identified the top naloxone-contributing hub for each municipality. For example, for each municipality that belongs to the Boston-Cambridge-Quincy NSA, the highest contributor of naloxone to the residents of that municipality (2018-2020) was the aggregation of Boston, Cambridge, and Quincy (rather than Worcester and Westborough).

Number of kits distributed per encounter

Variable	Missing	Total	Percent Missing
doses_dist~b	60,706	88,085	68.92

# of doses distributed

	Percentiles	Smallest		
1%	2	0		
5%	2	0		
10%	2	0	Obs	27,379
25%	2	0	Sum of Wgt.	27,379
50%	2		Mean	2.472369
		Largest	Std. Dev.	4.10243
75%	2	100		
90%	2	100	Variance	16.82993
95%	4	200	Skewness	44.15221
99%	10	400	Kurtosis	3526.637

879

Overdose Prevention & Naloxone Enrollment Form

Date: m m / d d / y y y y Staff: _____ Site: ☐☐ Location: ☐☐

NEP Code (all progs) ☐☐☐-☐☐☐☐☐☐-☐ BSAS Code: ☐☐☐☐

Participant is (check one): (NOTE: All staff are Non-Users)
1☐ Active User 2☐ In Treatment 3☐ In Recovery 4☐ Non-User

You plan to use overdose education for (check all that apply):
1☐ Friend 1☐ Partner 1☐ Client 1☐ Self 1☐ Family 1☐ Other: _____

What is the zip code where the enrollee lives? ☐☐☐☐☐

Race:(check one)
1☐ American Indian
2☐ Asian
3☐ Black/African American
4☐ Hawaiian/Pacific Islander
5☐ White
6☐ Other: _____

Latino/Hispanic
2☐ No 1☐ Yes

Gender:
1☐ Female
2☐ Male
3☐ MtF
4☐ FtM

ALL PARTICIPANTS:

How many times have you **witnessed** an overdose in your life? #_____
(Write in the **NUMBER**. Never = 0.)

# of Single Step Doses given _____

# of Intramuscular needles given _____

Naloxone Lot # ☐☐☐☐☐☐☐ Expiration Date: m m / y y **# of Multistep doses given** _____

ACTIVE USERS, IN TREATMENT,OR IN RECOVERY:

During the last thirty (30) days, did you use any of the following substances? (Write in the **NUMBER** of days used. No use in past 30 days = 0)

Heroin #_____
Methadone #_____
Suboxone/Subutex / buprenorphine #_____
Benzos/Barbituates (Klonopin, Xanax, Ativan, Valium, Librium, Phenobarbital, Fiorinal, etc) #_____
Clonidine #_____
Cocaine/Crack #_____
Alcohol #_____
Methamphetamine #_____
Any other opioid (Percocet, OxyContin, Oxycodone, Vicodin, Darvocet, Fentanyl, etc) #_____
Other: _____ #_____

During the past year how many times did you:
(Write in the **NUMBER**. "Not in the last year" & "never" = 0)

Visit the emergency room? #_____
Visit your primary care doctor? #_____
Get released from jail or prison? #_____
Go to inpatient Detox #_____
Start a methadone Program #_____
Start a suboxone program #_____
Start residential treatment #_____
Start outpatient / intensive outpatient treatment #_____

Go to self-help meetings
1☐ Not in last year 2☐ 1-10x 3☐ More than 10x

Spend the night on the street or in a shelter?
1☐ Not in last year 2☐ 1-10x 3☐ More than 10x

How many times have you overdosed **in your life**? (Write in the NUMBER. Never = 0) #_____

Did you **ever** receive naloxone? (may check more than one box)
1☐ No
1☐ Yes, from non-medical person
1☐ Yes, from medical personnel (ER/EMT/ Paramedics)

What drugs were **taken the last time**? (may check more than one box)
1☐ Heroin 1☐ Benzos/Barbituates 1☐ Cocaine/Crack 1☐ Clonidine
1☐ Methadone 1☐ Suboxone 1☐ Any other opioid 1☐ Methamphetamine
1☐ Alcohol 1☐ Other: _____

STAFF ASSESSMENT OF ACTIVE USERS ONLY :

Is client interested in referral to treatment?
2☐ No/Not Appropiate 1☐ Yes, but not today 3☐ Yes, today 4☐ Did not discuss

Notes/Comments:

OD Management & Naloxone Review

38770

Staff Initials

	Refill and Follow-Up Orientation Refills available at the program distributing naloxone Come to the van to tell us of your experiences
	Overdose prevention techniques **Educate those you use with!** Purity testing, tie-release, gradual injecting, know the source Risk factors: mixing drugs, abstinence, using alone.
	Signs of Overdose Slower/Stopped breathing; Not responsive to verbal or physical stimulation; Turning blue **Call 911**
	A&B of life: airway and breath Airway: remove gum, food, anything in mouth Breath: if stopped or slowed breathing, **you must breathe for them(rescue breathing)** If you must leave the person, call 911 and place in **recovery position**
	Rescue Breathing On back Lift chin to straighten airway Clear mouth Pinch nose Seal mouth over theirs Two breaths to begin, then one every five seconds
	Naloxone Store away from light and at room temperature Keep naloxone with your works Spray about half up each side of the nose Breathe for them until it starts working If not working after five minutes try another dose If second dose doesn't work in five minutes, something else is wrong: **call 911**
	Return of Overdose Naloxone lasts 30-90 minutes Heroin overdose could last two hours Methadone overdose could last 24 hours: **get to a hospital** Multi-drug OD (alcohol, benzos, cocaine) could be more dangerous: **get to a hospital**
	Kit Assembly Enrolled individual can assemble naloxone kit for use during overdose

Location Codes:

[01] Needle Exchange Program
[02] Medical clinic (OBOT or Health Center)
[05] Drug/Alcohol Detox Center
[06] Emergency Department
[07] Inpatient Hospital
[08] Homeless Shelter
[10] Community meeting (at Church, Community Center, etc)
[11] Home Visit
[12] Other (please specify on the form)
[13] Drop-in-Center
[14] Methadone Clinic
[15] Intensive Outpatient Program
[16] Residential Treatment/Halfway House
[17] Street Outreach
[18] Correctional Setting

Site Codes:

[01] AHOPE
[02] ASGCC
[03] Health Innovations
[04] AAC
[05] Seven Hills
[06] Tapestry Health
[07] BAMSI
[09] CSI/Praxis
[11] Boston Medical Center ED Streets
[14] South Shore Hospital ED
[15] St. Anne's Hospital ED
[17] Lowell Community Health
[18] Lawrence Family Health Center
[19] Holyoke Health Center
[20] AIDS Project Worcester
[21] Learn to Cope
[22] Manet Community Health Center
[23] BPHC
[24] North Suffolk Mental Health
[25] Center for Human Development
[26] Lowell House
[27] Boston Living Center

Codes and Abbreviations:

FtM	Female to Male transgender
MtF	Male to Female transgender
NEP Code	First three letters of mother's first name+ date of birth (mm/dd/yy) Ex: GER053077)
BSAS Code	First & third letters of first and last name Ex: Joseph "Joe" Francis Blow=JSBO

Overdose Report-Back & Naloxone Refill Form

64881

Date: ☐☐ / ☐☐ / ☐☐☐☐ (m m / d d / y y y y) Staff: ☐☐☐☐☐☐☐☐ Site: ☐☐ Location: ☐☐

NEP Code (all progs) ☐☐☐-☐☐☐☐☐☐☐-☐ BSAS Code: ☐☐☐☐

Reason for refill:

1☐ Used during an OD 2☐ Lost 6☐ Stolen 9☐ Other
4☐ Given away/Sold 7☐ Confiscated 8☐ Expired

# of doses Multi-Step Nasal Supplied ☐☐

# of doses Single-Step Nasal Supplied* ☐☐

# of IM Needles Supplied* ☐☐

Naloxone Refill Lot # ☐☐☐☐☐☐☐ Expiration Date: ☐☐ / ☐☐

Regarding the overdose experience:

Date of Overdose: ☐☐ / ☐☐ / ☐☐☐☐ (m m / d d / y y y y)

Naloxone obtained from: *(DPH pilot program site codes are on the back of the form)*
1☐ DPH pilot program, Site code: ☐☐ 2☐ Friend/family 3☐ Pharmacy with prescription
4☐ Pharmacy without prescription 5☐ Other: ☐☐☐☐☐☐☐☐ 6☐ Unknown

Note: If "Don't know" is checked or a question is unanswered, please explain in the comments section

Who overdosed? *(check one)* 1☐ Friend 7☐ Partner 4☐ Client 8☐ Family 3☐ Stranger 5☐ Self → Explain in comments

Gender of the person who overdosed? 1☐ Female 2☐ Male 6☐ Other: ☐☐☐☐☐☐☐☐

Overdosed on what drugs? *(check all that apply)*

1☐ Heroin 1☐ Methadone 1☐ Alcohol 1☐ Gabapentin/Johnnie's 1☐ Don't know
1☐ Fentanyl (Illicitly Made) 1☐ Suboxone 1☐ Clonidine 1☐ K2/Spice 1☐ Other: ☐☐☐☐☐☐☐☐
1☐ Any other Opioid 1☐ Benzos 1☐ Cocaine/Crack 1☐ Methamphetamine

What type of naloxone was used? Check all that apply. (See reverse side for reference.)

1○ Single-Step Nasal: ☐ # of Doses 1○ Multi-Step Nasal: ☐ # of Doses 1○ Intramuscular: ☐ # of Doses

Did the naloxone work? 1☐ Yes 2☐ No → if naloxone did not work, explain in comments

→ If naloxone worked, how much total time did it take since the first dose was given?
1☐ Less than 1 min 2☐ 1-3 min 3☐ 3-5 min 4☐ >5 min

Where did it occur(zip code)? ☐☐☐☐☐ If the person doesn't know zip, city/town ☐☐☐☐☐☐☐☐

What setting did it occur in? 1☐ Private(apt/house) 2☐ Public (park, subway, bathroom, car, hospital)

Did the person live? 1☐ Yes 2☐ No 3☐ Don't know

Was 911 called? 1☐ Yes 2☐ No 3☐ Don't know

Were Police/EMTs/Firefighters present? 1☐ Yes 2☐ No 3☐ Don't know

→ If YES, was the interaction: 1☐ Positive 2☐ Neutral 3☐ Negative

Did you stay with the person until the naloxone wore off and/or the person got medical attention? 1☐ Yes 2☐ No

What else was done? *(check all that apply)*
1☐ Slap 1☐ Ice/Water 1☐ Salt/Cocaine shot 1☐ Recovery Position 1☐ Other: ☐☐☐☐☐☐☐☐
1☐ Sternal/Lip Rub 1☐ Rescue Breathing → If Yes, was a barrier used? 1☐ Yes 2☐ No 3☐ Don't know

Any post-naloxone withdrawal symptoms? *(check all that apply)*

1☐ None 1☐ Physically Combative 1☐ Irritable or Angry 1☐ Vomiting
1☐ Dope Sick (e.g. nauseated, muscle aches, runny nose, and/or watery eyes) 1☐ Other: ☐☐☐☐☐☐☐☐

Notes/Comments:

9538

Code and abbreviations:	
NEP Code	First three letters of mother's first name + date of birth (mm/dd/yy) Ex: GER053077
BSAS Code	First and third letters of first and last name Ex: Joseph "Joe" Francis Blow= JSBO

Staff Initials

Location Codes:

[01] Needle Exchange Program
[02] Medical clinic (OBOT or Health Center)
[05] Drug/Alcohol Detox Center
[06] Emergency Department
[07] Inpatient Hospital
[08] Homeless Shelter
[10] Community meeting (at Church, Community Center, etc)
[11] Home Visit
[12] Other (please specify on the form)
[13] Drop-in-Center
[14] Methadone Clinic
[15] Intensive Outpatient Program
[16] Residential Treatment/Halfway House
[17] Street Outreach
[18] Correctional Setting
[19] Program Office

Site Codes:

[01] AHOPE
[02] ASGCC
[03] Health Innovations
[04] AAC
[05] Seven Hills
[06] Tapestry Health
[07] BAMSI
[09] CSI/Praxis
[11] Boston Medical Center ED Streets
[14] South Shore Hospital ED
[15] St. Anne's Hospital ED
[17] Lowell Community Health
[18] Lawrence Family Health Center
[19] Holyoke Health Center
[20] AIDS Project Worcester
[21] Learn to Cope
[22] Manet Community Health Center
[23] BPHC
[24] North Suffolk Mental Health
[25] Center for Human Development
[26] Lowell House
[27] Boston Living Center

NALOXONE FORMULATIONS FOR YOUR REFERENCE:



Multi-Step Nasal



Single-Step Nasal

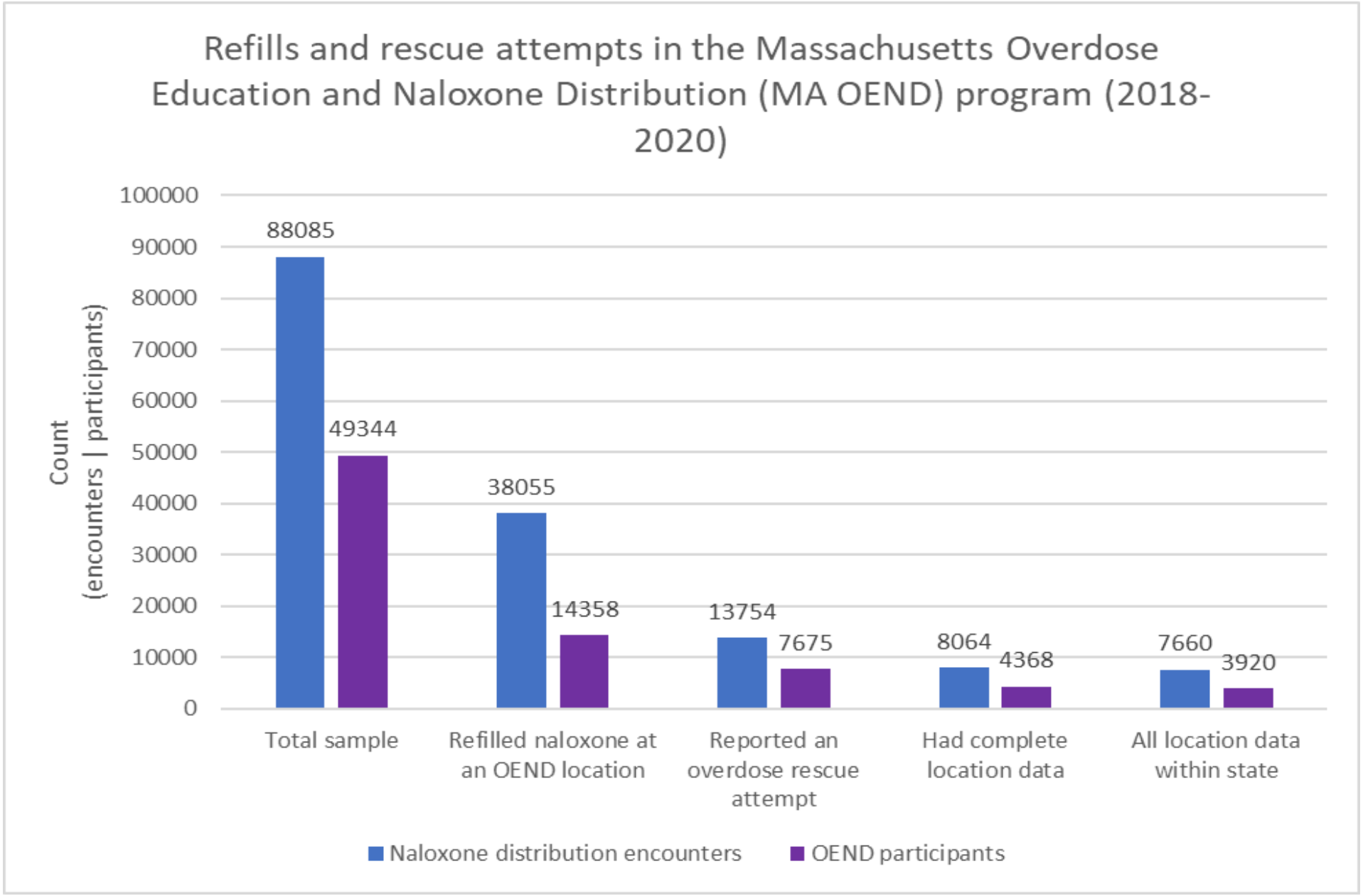


Auto Injector



Intramuscular

Supplemental Figure 1. Sample of refills and rescue attempts in the MA OEND program (2018-2019)



Supplemental Table 1. Demographic characteristics of Massachusetts Overdose Education and Naloxone Distribution (MA OEND) program participants (2018-2020), including observations with missing data

	Total Sample of Individuals (100% of total)			**Never report an overdose rescue attempt** (84.4% of total)			**Report an overdose rescue attempt upon naloxone refill** (15.6% of total)			χ^2
	n	Column %	Average number of visits	n	Column %	Average number of visits	n	Column %	Average number of visits	
Overall	49,344	100	1.74	41,669	100	1.30	7,675	100	4.17	
Ethnicity										1012.8 p<0.001
Latino	5,394	10.9	1.82	4,765	11.4	1.32	629	8.2	5.65	
Non-Latino	31,641	64.1	1.83	27,616	66.3	1.31	4,025	52.4	5.37	
Missing	12,309	25.0	1.48	9,288	22.3	1.23	3,021	39.4	2.27	
Race										934.8 p<0.001
American Indian	305	0.6	1.83	263	0.6	1.27	42	0.6	5.33	
Asian	346	0.7	1.28	336	0.8	1.14	10	0.1	6.00	
African-American / Black	3,707	7.5	1.68	3,334	8.0	1.26	373	4.9	5.42	
Hawaiian / Pacific Islander	63	0.1	2.38	52	0.1	1.40	11	0.1	7.00	
White	29,242	59.3	1.86	25,361	60.9	1.32	3,881	50.6	5.38	
Other Race	1,936	3.9	2.01	1,642	3.9	1.40	294	3.8	5.39	
Multi-Racial	862	1.8	1.36	821	2.0	1.14	41	0.5	5.76	
Missing	12,883	26.1	1.48	9,860	23.7	1.23	3,023	39.4	2.30	
Age Group										1663.0 p<0.001
19 years or younger	674	1.4	1.85	593	1.4	1.30	81	1.1	5.86	
20-29 years old	10,432	21.1	2.09	8,829	21.2	1.39	1,603	20.9	5.94	
30-39 years old	11,116	22.5	2.00	9,498	22.8	1.37	1,618	21.1	5.69	
40-49 years old	6,957	14.1	1.74	6,088	14.6	1.28	869	11.3	5.00	
50-59 years old	5,854	11.9	1.38	5,429	13.0	1.22	425	5.5	3.52	
60 years or older	3,002	6.1	1.23	2,887	7.0	1.13	115	1.5	3.63	
Missing	11,309	22.9	1.48	8,345	20.0	1.23	2,964	38.6	2.21	

Gender										1352.0 p<0.001
Female	18,558	37.6	1.75	16,463	39.5	1.28	2,095	27.3	5.43	
Male	18,741	38.0	1.89	16,155	38.8	1.34	2,586	33.7	5.35	
Other	159	0.3	1.91	147	0.3	1.55	12	0.2	6.33	
Unknown/refused	613	1.2	1.42	589	1.4	1.97	24	0.3	6.79	
Missing	11,273	22.9	1.49	8,315	20.0	1.23	2,958	38.5	2.21	
BSAS[a] region of residence										1261.4 p<0.001
Boston	6,358	12.9	2.21	5,251	12.6	1.32	1,107	14.4	6.47	
Central	5,065	10.3	1.60	4,566	11.0	1.27	499	6.5	4.66	
Metrowest	4,060	8.2	1.92	3,528	8.5	1.30	532	6.9	6.10	
Northeast	5,174	10.4	1.82	4,465	10.7	1.29	709	9.2	5.18	
Southeast	8,228	16.7	1.73	7,135	17.1	1.28	1,093	14.3	4.67	
Western	7,809	15.8	1.74	7,156	17.2	1.40	653	8.5	5.51	
Missing	6,358	25.6	1.47	9,568	22.9	1.22	3,082	40.2	2.24	
How many overdoses have you survived										1233.0 p<0.001
Zero	8,762	17.8	1.47	8,296	19.9	1.27	466	6.1	5.20	
1-5	5,696	11.5	1.67	5,151	12.4	1.30	545	7.1	5.20	
6-15	1,016	2.1	2.04	896	2.2	1.37	120	1.6	7.09	
>15	220	0.4	2.26	185	0.4	1.57	35	0.5	5.89	
Missing	33,650	68.2	1.81	27,141	65.1	1.30	6,509	84.8	3.95	
Person who uses drugs?										2406.2 p<0.001
Uses drugs	24,271	49.2	2.12	20,160	48.4	1.42	4,111	53.6	5.55	
Does not use drugs	14,208	28.8	1.32	13,563	32.6	1.16	645	8.4	4.82	
No enrollment information	10,865	22.0	1.45	7,946	19.1	1.22	2,919	38.0	2.09	
Any addiction treatment in last year?										1162.3 p<0.001
Yes	7,593	15.4	1.65	6,993	16.8	1.33	600	7.8	5.40	
No	6,517	13.2	1.55	6,033	14.5	1.25	484	6.3	5.26	

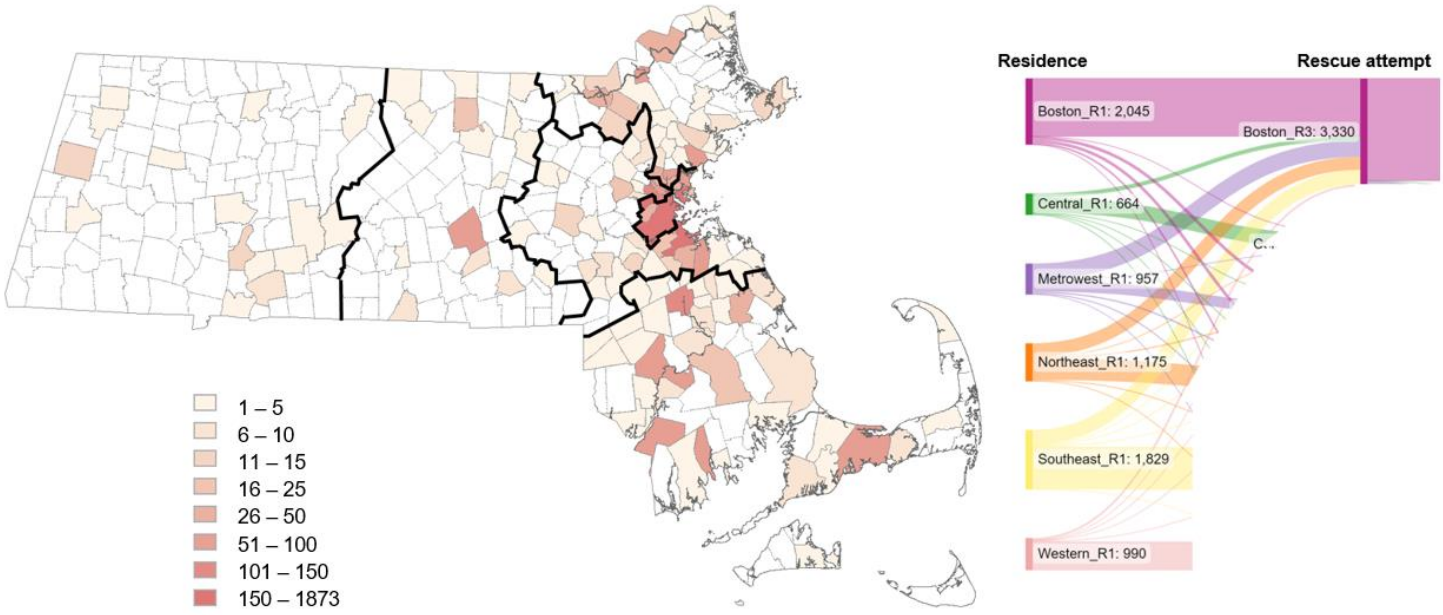
Unable to collect information	1,516	3.2	1.49	1,503	3.6	1.21	83	1.1	6.48	
Missing	34,247	68.2	1.81	27,421	65.1	1.30	6,809	84.8	3.95	
Released from jail / prison in past year										1170.7 p<0.001
Yes	3,055	6.2	1.73	2,780	6.7	1.32	275	3.6	5.95	
No	11,000	22.3	1.57	10,196	24.5	1.29	804	10.5	5.11	
Unable to collect information	1,641	3.3	1.50	1,555	3.7	1.22	44	1.1	6.62	
Missing	33,648	68.2	1.81	27,420	65.1	1.30	6,811	84.8	3.95	
Experienced homelessness in last year										1198.3 p<0.001
Yes	5,240	10.6	1.47	4,715	19.9	1.36	525	7.3	4.61	
No	8,841	17.9	1.83	8,283	11.3	1.26	558	6.8	6.05	
Declined / unable to collect	1,523	3.1	1.49	1,451	3.5	1.22	72	0.9	6.90	
Missing	34,339	68.4	1.81	27,502	65.3	1.30	6,821	85.0	3.95	

Supplemental Table 2. Ratios of naloxone dispensing events to opioid overdose deaths (2018-2020) by geographic areas, including municipality of occurrence

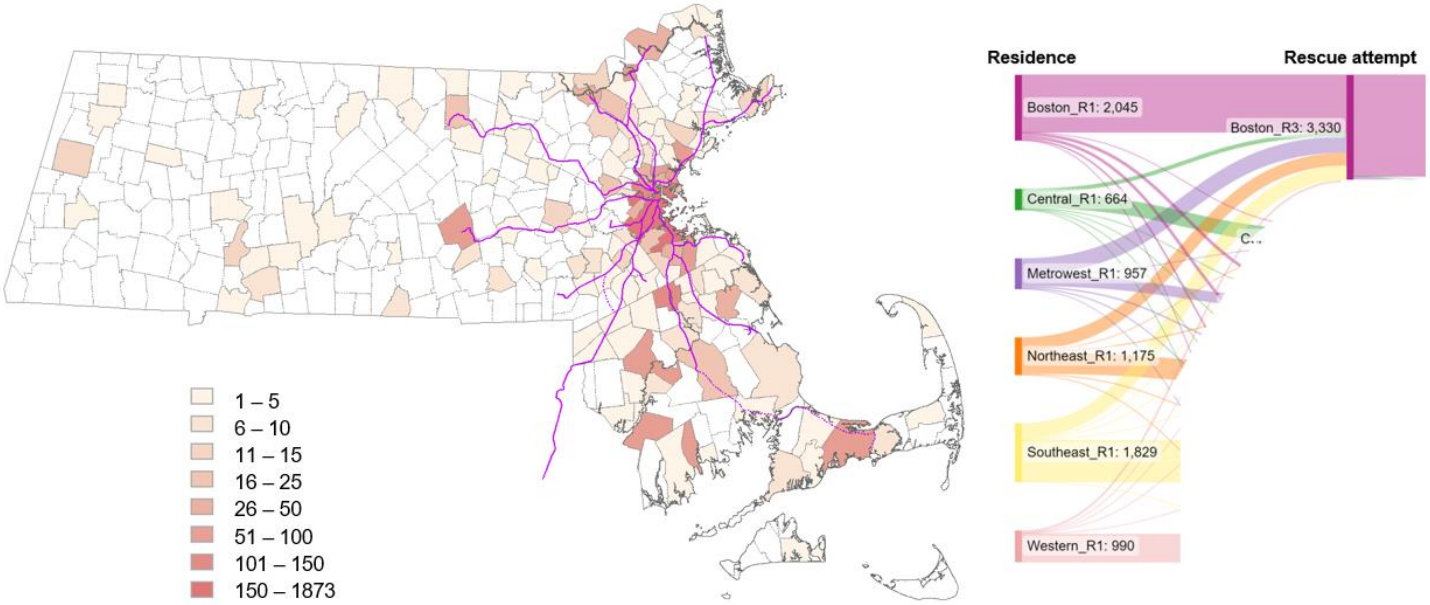
Geographic areas	Total naloxone dispensing events	Opioid-related overdose deaths			
		By municipality of residence		By municipality of occurrence	
		Total	Ratio to naloxone dispensing events (x : 1)[a]	Total	Ratio to naloxone dispensing events (x : 1)[b]
Top naloxone dispensing clusters[c]					
1 Boston – Cambridge – Quincy	24,491	1,812	13.5	1,859	13.2
2 Springfield – Holyoke – Northampton	8,086	737	11.0	741	10.9
3 Fall River – New Bedford	4,627	504	9.2	491	9.4
4 Worcester – Westborough	4,541	528	8.6	549	8.3
5 Lowell – Lawrence – Tewksbury	3,914	504	7.8	497	7.9
6 Pittsfield	2,848	106	26.9	114	25.0
7 Brockton	2,329	194	12.0	230	10.1
8 Lynn	2,233	174	12.8	131	17.0
9 Barnstable	1,304	75	17.4	110	11.9
10 Greenfield	1,267	46	27.5	40	31.7
11 Taunton	966	97	10.0	95	10.2
12 Fitchburg	926	85	10.9	46	20.1
13 North Adams	902	28	32.2	24	37.6
BSAS Regions[d]					
1 Boston	21,462	730	29.4	905	23.7
2 Central	5,863	856	6.8	860	6.8
3 Metrowest	5,888	838	7.0	802	7.3
4 Northeast	7,893	1,263	6.2	1,231	6.4
5 Southeast	11,950	1,457	8.2	1,359	8.8
6 Western	13,932	944	14.8	944	14.8
TOTAL State[e]	85,085	6,109	13.9	6109	13.9

a) Ratio = number of kit distribution events in geographic area/overdose deaths by residence in geographic area
b) Ratio = number of kit distribution events in geographic area/overdose deaths that occur in geographic area
c) Clusters were algorithmically derived: 1) select and sort by highest volume naloxone distributing municipalities (must account for >1 % of all distributing events in state for study period; 21 municipalities); 2) identify first order / nearest neighbors by land border; 3) if one of the nearest neighbors is a municipality lower on the list, subsume it and its first order neighbors (include it in cluster name); 4) if municipality shares 2 first order neighbors with another municipality on the list, combine it and its first order neighbors into one cluster (include it in cluster name); 5) once a town in a first order neighbor of a municipality, it cannot be counted as a first order neighbor of a municipality lower on the list; 6) if a town is cut off from all other land neighbors by cluster, include town in cluster.
d) Massachusetts Bureau of Substance Abuse Services-defined operating regions
e) Columns do not sum to total given dispensing events occurring outside of clusters, missing location data, and locally suppressed overdose deaths; totals are from MDPH data.

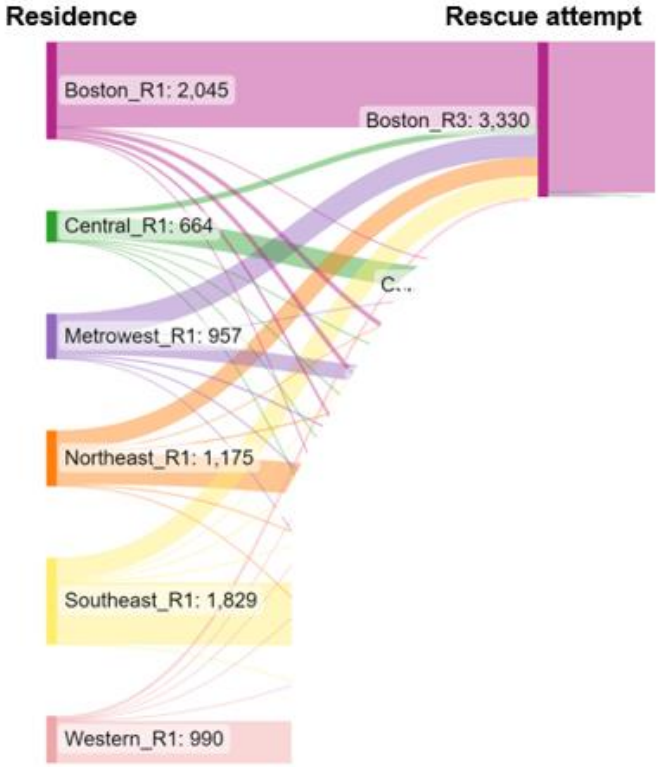
Supplemental Figure 2A. Residence municipalities of participants reporting rescue attempts occurring in Boston, overlayed by Bureau of Substance Abuse Services (BSAS) regions (2018-2020)

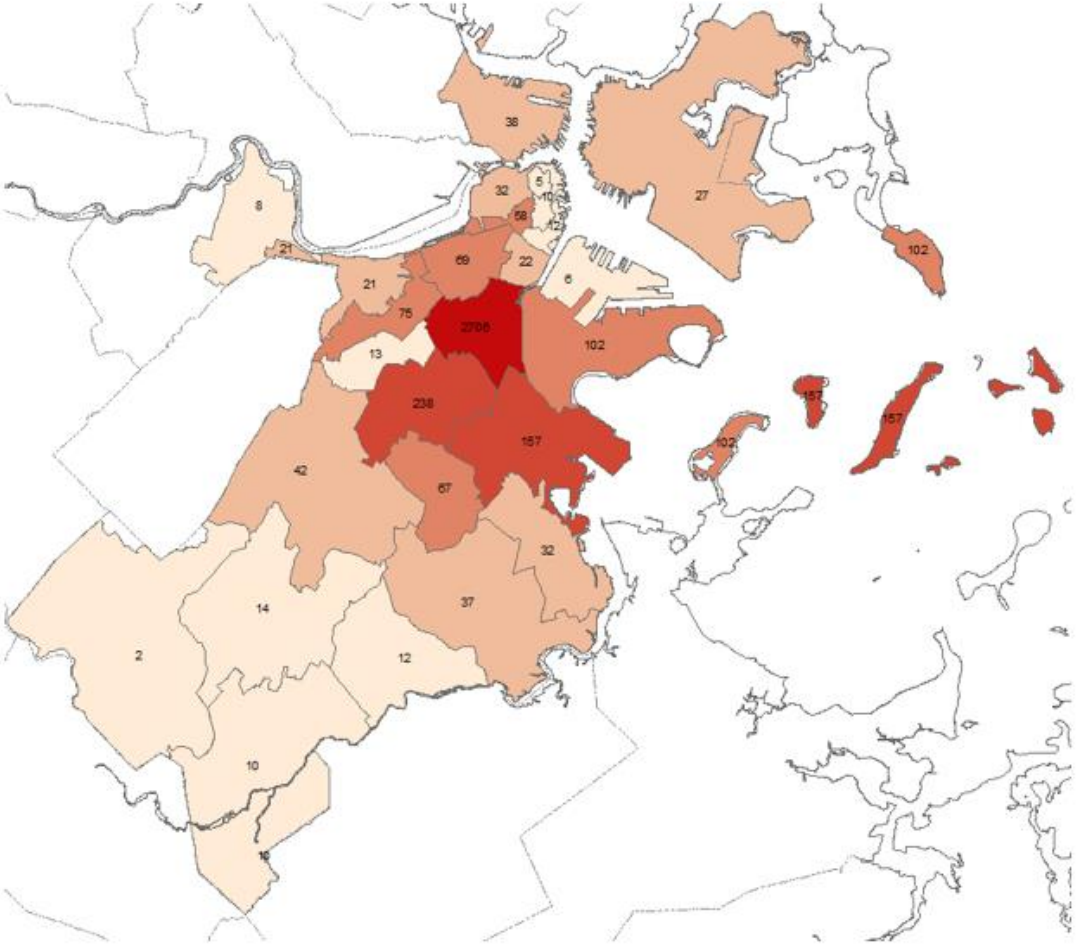


Supplemental Figure 2B. Residence municipalities of participants reporting rescue attempts occurring in Boston, overlayed by Massachusetts Bay Transportation Authority commuter rail lines (2018-2020)



Supplemental Figure 3. Location of rescue attempts in Boston, by ZIP code (2018-2020)





Supplemental Figure 4. Naloxone referral region hubs clustering algorithm results

Municipalities ranked by naloxone distribution events

Rank	Municipality	Count (distribution events, encounters)	Percentage
1	BOSTON	20944	23.78
2	WORCESTER	3629	4.12
3	SPRINGFIELD	3614	4.10
4	HOLYOKE	3565	4.05
5	PITTSFIELD	2848	3.23
6	FALL RIVER	2508	2.85
7	BROCKTON	2329	2.64
8	LYNN	2233	2.54
9	CAMBRIDGE	2209	2.51
10	NEW BEDFORD	2119	2.41
11	LOWELL	1704	1.93
12	QUINCY	1338	1.52
13	BARNSTABLE	1304	1.48
14	GREENFIELD	1267	1.44
15	LAWRENCE	1267	1.44
16	TAUNTON	966	1.10
17	TEWKSBURY	943	1.07
18	FITCHBURG	926	1.05
19	WESTBOROUGH	912	1.04
20	NORTHAMPTON	907	1.03
21	NORTH ADAMS	902	1.02
22	WAREHAM	637	0.72
23	FRAMINGHAM	591	0.67
⋮			
231	WILMINGTON	1	0.00
	TOTAL NON-MISSING	66988	100.00
	MISSING	21097	
	TOTAL	**88085**	

Algorithmically derived distribution hubs

Rank	Municipality	Count (distribution encounters)	Percentage
1	BOSTON - CAMBRIDE - QUINCY	24491	27.80
2	SPRINGFIELD - HOLYOKE - NORTHAMPTON	8086	9.18
3	FALL RIVER - NEW BEDFORD	4627	5.25
4	WORCESTER - WESTBOROUGH	4541	5.16
5	LOWELL - LAWRENCE - TEWKSBURY	3914	4.44
6	PITTSFIELD	2848	3.23
7	BROCKTON	2329	2.64
8	LYNN	2233	2.54
9	BARNSTABLE	1304	1.48
10	GREENFIELD	1267	1.44
11	TAUNTON	966	1.10
12	FITCHBURG	926	1.05
13	NORTH ADAMS	902	1.02
	ELSEWHERE	8554	9.71
	MISSING	21097	23.95
	TOTAL	**88085**	100.00

Legend:
- First order neighbors
- Not first order neighbors, but shared two or more first order neighbors
- Combination

Algorithm:
1) We ranked each municipality by number of naloxone distribution encounters, highest to lowest, and kept municipalities that had greater than 1% of the total distribution events in the state (2018-2020)
2) Starting at the top of the list, if one of a top-ranking municipality's first-order land neighbors was a municipality lower on this list, we subsumed the lower ranking municipality into the dominant cluster. For example, Boston (#1 distributor of naloxone for 2018-2020) is first order neighbors with Cambridge (#9) and Quincy (#12), making the Boston-Cambridge-Quincy cluster hub.
3) Similarly, if two municipalities on the list were not first order neighbors but shared two or more first-order land neighbors, we subsumed the lower ranking municipality into the higher ranking one.
4) We kept going until all municipalities that contributed greater that 1% of the total naloxone distribution were either members of a cluster hub or individual hubs.