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Hawai‘i Childhood Lead Poisoning Prevention Program (HI-CLPPP) Risk System Evaluation

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Table of Contents

Executive Summary

Lead exposure can cause severe damage to a child's health and development. Identifying, controlling, and removing lead hazards safely from a child's environment is critical to preventing childhood lead poisoning. Currently, the Hawai'i Childhood Lead Poisoning Prevention Program (HI-CLPPP) recommends using a lead exposure surveillance questionnaire to screen all children who are six months to six years of age. The questionnaire includes questions about Medicaid coverage; residence in high-risk zip codes; old housing built before 1978; and other lead sources/risk factors of lead poisoning such as jobs, hobbies, food, and water with possible exposure to lead hazards. The state of Hawai'i also recommends testing all immigrants, international adoptees, and refugee children.

This report presents the results of an evaluation of the HI-CLPPP risk system which screens and identifies children at risk for lead exposure. The focus was to evaluate the current method used for identifying high-risk zip codes and propose alternative methods to current procedures. The current method identified 57.3% of children with elevated blood lead levels (EBLLs) living in 55 high-risk zip codes. This method can be improved by updating risk factor data and using a census tract-level analysis. The latter improvement is consistent with procedures used across the nation and is also more precise than the current approach based on 35 primary care service areas.

Four new geographic targeting methods were developed and tested as possible alternatives to the state's current method for identifying high-risk zip codes. These analyses used the 2016-2020 HI-CLPPP lead surveillance database, the 2011-2015, 2012-2016, 2013-2017, 2014-2018, and 2015-2019 American Community Survey (ACS) five-year population estimates, and 2017 and 2021 SmartParcels® real property data.[1] All analyses were conducted using census tract-level data. The alternative methods included, respectively, 1) an absolute threshold based on housing age; 2) a composite risk score based on housing and poverty rates; 3) a composite risk score based on housing, poverty, immigration status, speaking a language other than English at home, and educational attainment; and 4) a composite risk score based on housing, poverty, and children's blood lead test results. Among the four alternative methods, Method 4 was the best because it identified the highest number of children with EBLLs even though the testing rate was the lowest among the three composite risk score methods. A series of sensitivity analyses were also conducted to test the sensitivity of the results to changes in the definition of risk factors and EBLL. Specifically, we used different cutoff years to define old housing, different weights for risk factors, and different thresholds to define EBLL. Most of the sensitivity analyses did not produce better results compared to the four alternative methods.

None of the four methods tested were fully satisfactory. Possible reasons for this finding include, but are not limited to the following: a) risk factors used in the geographic targeting methods were not the only primary sources of lead exposure for children in Hawai'i; b) children living in high-risk areas had not been screened or had missing or

invalid addresses in the HI-CLPPP lead surveillance database; and c) risk factors measured at the level of the census tract did not capture individual-level risk.

Although lead paint in older housing is considered the most common source of lead exposure in the literature, other sources such as magnets and fishing sinkers may be prevalent. Since these sources are not associated with geographic locations, a risk system targeting locations may not effectively identify children with EBLLs, which also speaks to the benefits of adopting universal testing in the state.

Records with missing or invalid addresses in the HI-CLPPP lead surveillance database were excluded from the analyses. Missing data, in general, may negatively affect the effectiveness of data analyses and the reliability of their results. We believe improving the quality of the lead surveillance database is crucial to understanding the state's efforts to reduce childhood lead poisoning in Hawai'i.

Additionally, key informants from Hawai'i and six other states were interviewed. The interviews complement the quantitative data analyses by providing expert informants' perspectives on the advantages and disadvantages of varying existing systems and the desired qualities of an ideal risk system. Consistent with these data analysis results, key informants identified weaknesses with all targeted risk methodologies. Of particular concern was the imprecision inherent in risk modeling, i.e., that these methods often over- or under-predict the actual EBLL rates in different geographic areas. Informants spoke to the advantages of universal testing and shared examples of infrastructure, case management practices, regulatory frameworks, interprofessional collaboration, and coalitions that increase the success of lead poisoning prevention efforts.

The report concludes with recommendations based on the evaluation, including the following:

- Consider universal testing.
- If a target risk system is desired, modify the current high-risk zip code method. Specifically, replace the current method with the proposed method S12. Periodically adjust the system as needed to reflect changing demographics and lead sources.
- Improve the quality of lead surveillance data.
- Take steps to increase screening and testing rates.
- Improve case management infrastructure.

Overview

Lead exposure can cause severe damage to a child's health and development. It can harm the brain and nervous system; slow growth and development; and cause behavioral, hearing, and speech problems. Identifying, controlling, and removing lead hazards safely from a child's environment is key to preventing childhood lead poisoning.[2] Currently, the Hawai'i Childhood Lead Poisoning Prevention Program (HI-CLPPP) recommends using a questionnaire to screen children who are six months to six years old for their risk of lead exposure. The questionnaire includes questions about Medicaid coverage; residence in high-risk zip codes; living in or receiving childcare in housing built before 1978; and other lead sources/risk factors of lead poisoning such as jobs or hobbies, food, and water with possible lead hazards. In addition to the federal testing requirements for Medicaid-enrolled children, a blood lead test is recommended when a parent answers *yes* or *do not know* to any question in the questionnaire, or for all children who live in a high-risk zip code for lead exposure. Hawai'i also recommends testing all immigrants, international adoptees, and refugee children.[3]

This report presents an evaluation of HI-CLPPP's risk system to screen and identify children at risk of lead exposure. The focus was on evaluating the current method of identifying high-risk zip codes and proposing alternative methods to current procedures. Interviews of key informants were also conducted to complement the data analyses to provide a collective perspective on the advantages and disadvantages of varying existing systems and the desired qualities of an ideal risk system. The report includes three sections: 1) a comparison of HI-CLPPP's current high-risk zip code method and alternative methods for identifying high-risk geographic areas in the state of Hawai'i; 2) a summary of interviews of local key informants and CLPPPs in six other states; and 3) a summary of the report and recommendations based on data analyses and the interviews.

Geographic Targeting

Hawai'i's current targeting risk method was developed in 2018.[4] High-risk zip codes for geographic targeting were determined using a composite score method based on three factors: 1) percentage of children screened with elevated blood lead levels (EBLLs) ≥ 5 micrograms per deciliter (mcg/dL); 2) percentage of population below 100% of the federal poverty level; and 3) percentage of housing structures built before 1960. For each factor, a standardized risk score was computed for each of the Primary Care Service Areas (PCSA).[5] For each PCSA, a composite risk score was computed by adding the standardized scores for all three factors. High-risk areas were any PCSAs with a positive sum of the standardized risk scores. Zip codes with overlapping areas with any part of a high-risk PCSA were considered high-risk zip codes.

The current method identified 55 high-risk zip codes (59.1% of all Hawai'i zip codes; see Table 1). Among the 606 children with EBLLs in the analytical sample, 347 (57.3%) lived in these high-risk zip codes. These 55 zip codes overlapped with the residential

areas of 156 (48.0%) census tracts. Only a very small proportion (0.45%) of all children under age six living in these tracts had EBLLs.

Table 1. Hawai'i's current zip code method, EBLL defined as ≥ 5 mcg/dL

	Hawai'i's current method
High-risk zip codes	
# of zip codes (A)	55
% of zip codes (A/93)	59.1%
# of children tested in these zip codes (B)	21,907
# of children with EBLLs (C)	347
% of children with EBLLs among those tested (C/B)	1.6%
% of state total EBLLs from high-risk zip codes (C/606)	57.3%
Census tracts that overlap with high-risk zip codes	
# of census tracts (D)	156
% of census tracts (D/325)	48.0%
Estimated # of children living in these tracts (E)	79,000
# of children tested in these tracts (F)	22,858
# children with EBLLs (G)	354
% of children tested (F/E)	28.9%
% of children with EBLLs among those tested (G/F)	1.5%
% of children with EBLLs among all with EBLLs statewide (G/606)	58.4%
% of children with EBLLs among all children living in the tracts (G/E)	0.45%

Source: 2016-2020 HI-CLPPP lead surveillance database and 2011-2015, 2012-2016, 2013-2017, 2014-2018, and 2015-2019 ACS 5-year population estimates.
Notes: Children referenced in this table were those under the age of six. The total number of Hawai'i zip codes was 93 and the total number of census tracts was 325 after nearshore coastal areas that did not cover any land were removed. The total number of children with EBLLs (≥ 5 mcg/dL) in the sample was 606. The number of children living in the tracts that overlap with high-risk zip codes in 2015-2019 was estimated as those who were under age six at any point during the period of 2015 through 2019. See the Testing Rate section of the Technical Report for more details about the child population estimation.

The current method for geographic targeting may be improved in several ways. For example, while the selection of the risk factors used in the current method is evidence-based, they can be fine-tuned. According to the Council on Environmental Health, house paint used before 1978, and especially before 1960, is a common source of lead exposure.[6] According to the U.S. Environmental Protection Agency, about 24% of homes built from 1960 to 1977 contain lead-based paint, whereas 69% of homes built from 1940 to 1959, and 87% of homes built before 1940, contain lead-based paint.[7] Therefore, the selection of risk factors may consider multiple cutoffs based on housing age. Hawai'i can also consider additional risk factors used by other states. For example, Arizona and Ohio included risk factors such as language used at home and education in identifying high-risk zip codes, as research has shown that a language other than English spoken at home and low educational attainment were positively associated with lead exposure and poisoning.[8] Additionally, instead of using PCSAs, a census tract-level

analysis would show how risk is distributed among geographic communities at a finer level. Given that all other factors (e.g., housing, poverty, education) were estimated at the level of the census tract, the choice of analysis unit is especially critical. This approach may capture variation in risk distribution within each PCSA.

These considerations were incorporated in the following analysis to identify geographic areas where children were at high risk of lead exposure; the zip code method used to identify high-risk areas in the state was evaluated; and the current zip code method was compared with alternatives.

Data Sources

The analysis was based on three data sources: the HI-CLPPP lead surveillance database with children's lead testing results; American Community Survey (ACS) five-year estimates from the U.S. Census Bureau (census data); and SmartParcels® real property data which included the year the property was built. The companion Technical Report describes more details of the variables included in each data source and the process of data cleaning and preparation.

HI-CLPPP Lead Surveillance Database

The HI-CLPPP lead surveillance database included patient information (e.g., date of birth, sex, street address); blood test information (e.g., blood lead level, blood sample collection date); and additional information (e.g., funding source, race/ethnicity). Records from 2016 to 2020 with valid geocoded Hawai‘i addresses and non-missing valid blood lead test results for children under six years of age were used. If a child had multiple records during this period, the record with the highest blood lead level was retained. When there were scores with the same highest value, the most recent records were chosen: this resulted in a sample of 45,543 unique records. The sample size of 45,543 represents the unique head count of young children tested during the five-year time window. See the comparison Technical Report for details of data cleaning and reduction.

Census Data

The 2011-2015, 2012-2016, 2013-2017, 2014-2018, and 2015-2019 American Community Survey (ACS) five-year estimates were used to obtain selected population, social, economic, and housing characteristics. The HI-CLPPP lead surveillance database was matched with census data at the census-tract level.

Real Property Data

We used 2017 and 2021 SmartParcels® property data, which included information such as the year the property was built. The property data were matched with children's residential addresses from the HI-CLPPP lead surveillance database. Individual housing data is a useful complement to ACS estimates of census tract-level housing stock age.

The property data with housing unit information were also used to capture overlapping residential areas between census tracts and zip codes.

Unit of Analysis

All analyses in this report were conducted at the census tract level. The census tract was chosen as the unit of analysis primarily because population data on risk factors were available at census tract level.

After high-risk census tracts are identified, it is customary to convert them into overlapping zip codes and use these zip codes in a screening tool; this is because neither physicians nor parents can easily identify census tracts. However, the conversion is not straightforward because census tract and zip code boundaries are not always well aligned. This is particularly troublesome when a zip code has only minimal overlap with a high-risk census tract. We developed a procedure to identify and exclude zip codes with no housing units in the area of overlap. See the companion Technical Report that describes the conversion from census tracts to zip codes.

One caveat is that it is crucial not to assess the quality of a method for identifying high-risk areas based on results at the zip code level when analyses are performed at the census tract level. When a census tract is converted into overlapping zip code(s), the boundaries are redefined; it is often the case that overlapping zip codes include areas not initially included in the target tract. Therefore, zip code-level results can be misleading.

Sample Description

Our analytical sample of 45,543 children consisted primarily of young children under age three (86.71%, Table 2). A total of 606 children (1.33%) had EBLLs.

Table 2. Age distribution

Age	# of records	%
0	12,809	28.13
1	13,278	29.15
2	13,403	29.43
3	3,158	6.93
4	2,208	4.85
5	687	1.51
Total	45,543	100

Source: HI-CLPPP lead surveillance database.

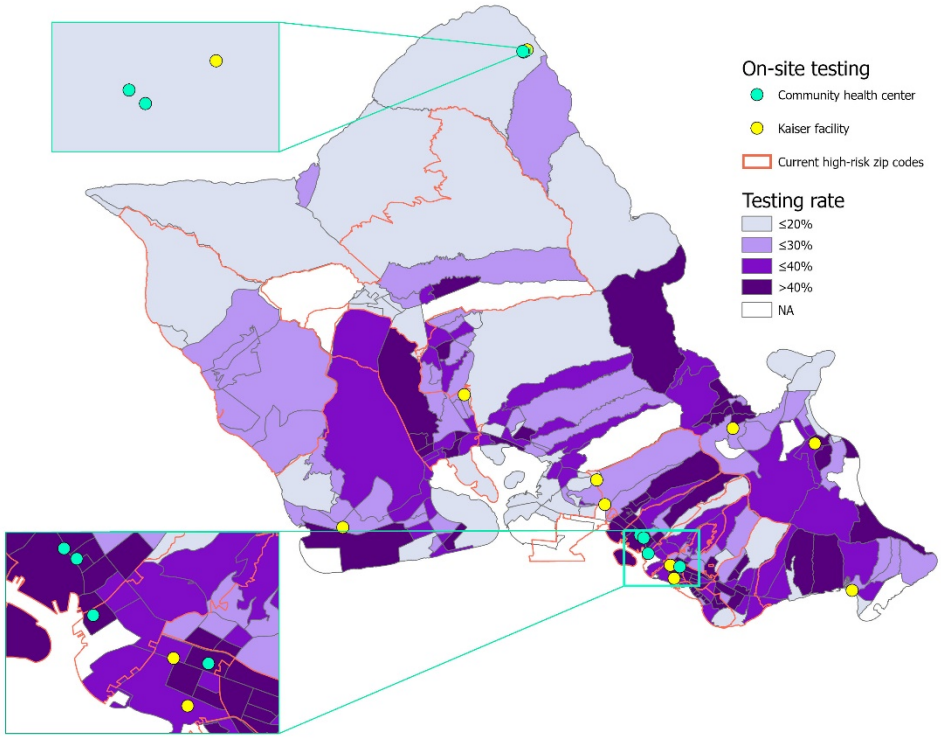
Testing Rate

The blood lead testing rate was calculated using the number of children with valid blood lead test results divided by the estimated number of children living in a census tract.[9]

Figures 1a and 1b illustrate testing rate quartiles by census tract, with a darker color indicating higher testing rates. These two figures show the geographic variation of testing rates by county and census tract. For example, in Honolulu County, areas with high testing rates included communities such as the Waipahu, Kalani (urban East Honolulu), and Castle (Windward) areas.

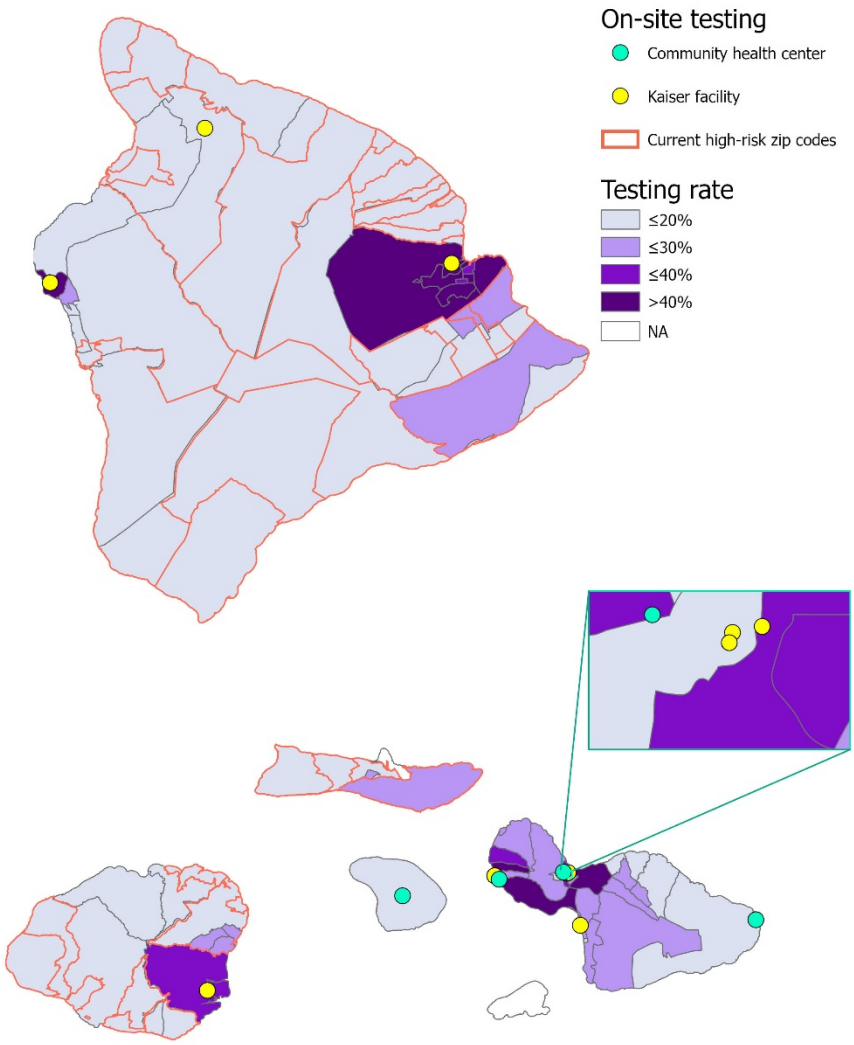
One possible reason for the geographic variation is the proximity to facilities that provide onsite blood lead testing. Research has shown that onsite testing reduces the barriers to screening.[10] Figures 1a and 1b display Kaiser Permanente facilities (yellow dots) and community health centers (aqua dots) with onsite testing. With a few exceptions, the areas with higher testing rates were located near those facilities. Further, those figures also show that high-risk zip code areas in the current risk questionnaire (i.e., orange-outlined areas) did not fully match those with high testing rates.

Figure 1a. Testing rate of children by census tract in Honolulu County



Notes: NA denotes census tracts with blood lead test data but an estimated child population of zero. Possible reasons include: 1) ACS estimates of child population may not capture recent housing development in these areas (e.g., Census tract 39 in the Kaka'ako area); and 2) Census tract boundaries are not very precise in some areas, so some houses in a census tract may be counted in adjacent tracts.

Figure 1b. Testing rate of children by census tract in Hawai‘i, Maui, and Kaua‘i Counties



Notes: NA denotes census tracts with blood lead test data but an estimated child population of zero. Possible reasons include: 1) ACS estimates of child population may not capture recent housing development in these areas (e.g., Census tract 39 in the Kaka‘ako area); and 2) Census tract boundaries are not very precise in some areas, so some houses in a census tract may be counted in adjacent tracts.

Children with Elevated Blood Lead Levels (EBLLs)

Geographic variation existed in the number of children with EBLLs and the percentage of children with EBLLs among those children tested. Figures 2 and 3, respectively, show the number and percentage of children with EBLLs by quartiles for each county and census tract. A darker color indicates higher numbers of children with EBLLs. Note that EBLL rates for a census tract may change dramatically with one or two positive tests when the denominator is small.

Identifying High-risk Areas

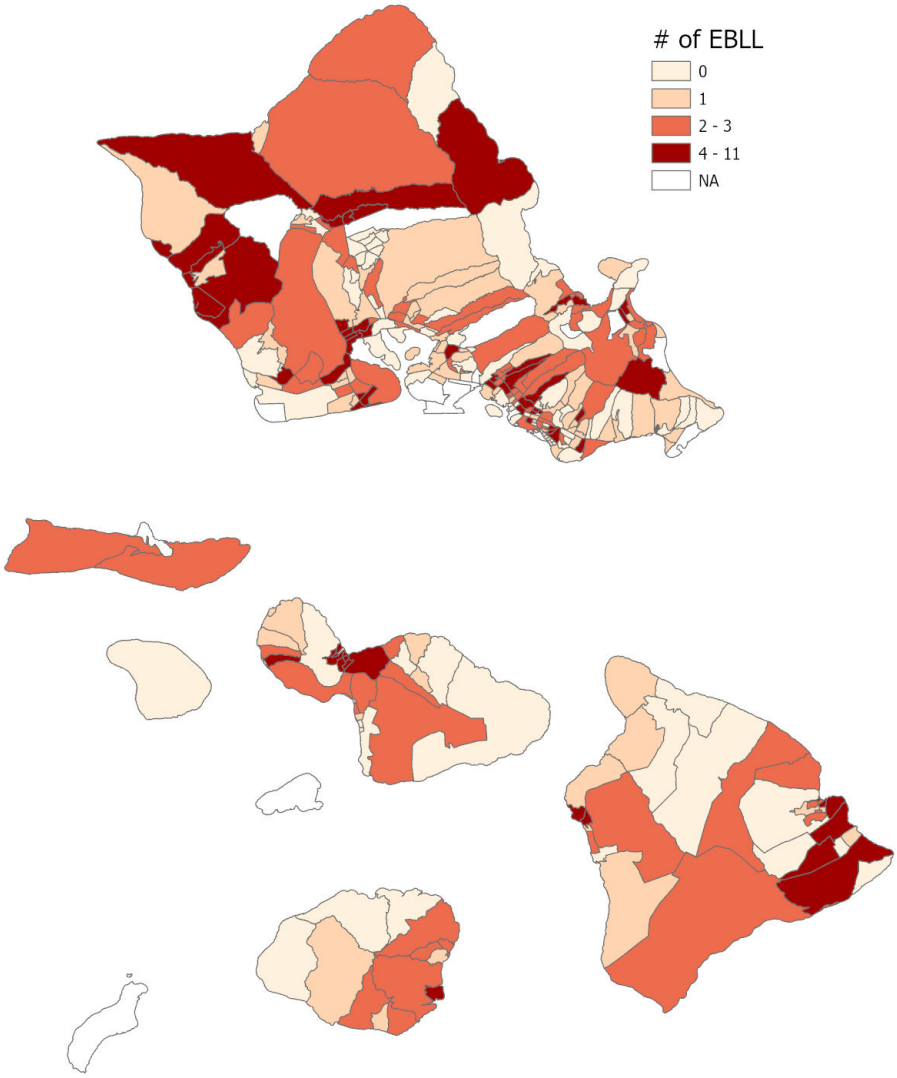
To validate the current zip code method, four alternative methods for identifying high-risk areas using census tract-level analyses were tested. The first method (M1) used a single risk factor and an absolute threshold to define high risk (i.e., any census tract with ≥ 27% of pre-1950 housing was considered high risk). The next three methods (M2-4) used a composite risk score based on multiple risk factors such as old housing and poverty. High-risk census tracts were those in the top quartile of the composite risk score.

A useful predictive method to identify high-risk areas should satisfy two potentially competing criteria: to capture the geographic areas expected to include the majority of at-risk children while simultaneously minimizing the number of children to be tested. There is no gold standard for selecting the most appropriate method. Utility was considered in terms of a) the total child population identified as high risk; and b) whether each method included the majority of children with EBLLs in the HI-CLPPP lead surveillance database. The number of high-risk census tracts or zip codes identified was not used as a criterion because this count reflects neither land area nor population density.

While known EBLLs were used to validate our methods, it should be kept in mind that these surveillance data have limitations as a criterion measure. If some groups of lead-exposed children are systematically under- or over-tested, the surveillance database may not be representative of the true distribution of EBLL in the state.

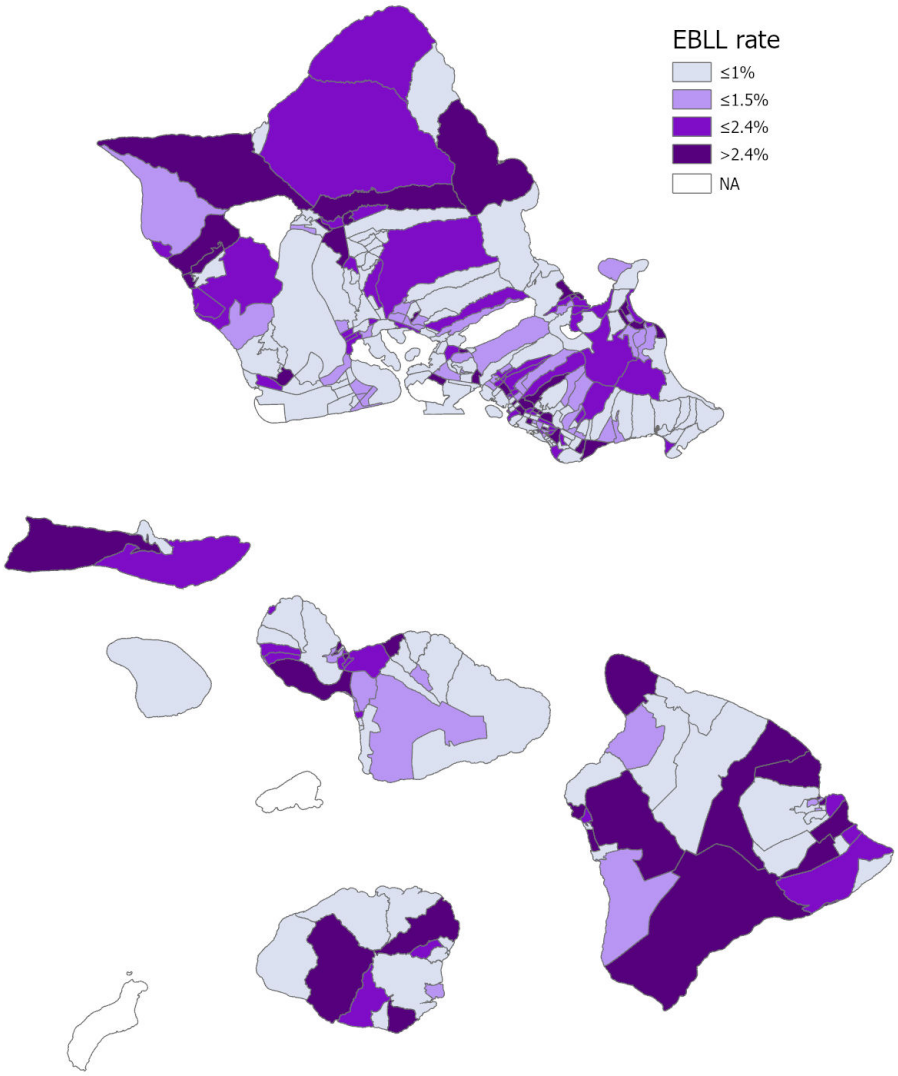
Table 3 presents a summary of the high-risk areas identified using each of the four alternative methods. The table includes the number and percentage of high-risk census tracts identified by each method; the number and percentage of zip codes that overlap with these high-risk tracts; and the number of children, testing rates, and percentage of children with EBLLs in high-risk areas.

Figure 2. Number of children with EBLLs by census tract



Note: NA denotes tracts without valid blood lead test data in the 2016-2020 HI-CLPPP lead surveillance database. EBLL is defined as ≥ 5 mcg/dL.

Figure 3. Percentage of tested children with EBLLs by census tract



Note: NA denotes tracts without valid blood lead test data in the 2016-2020 HI-CLPPP lead surveillance database. EBLL is defined as ≥ 5 mcg/dL.

Table 3. High-risk areas and children in these areas by identification method, EBLL defined as ≥ 5 mcg/dL

	M1: ≥ 27% pre-1950 housing	M2: Pre-1960 housing and poverty	M3: Pre-1960 housing, poverty, immigration status, non-English speaking, and < high school	M4: Children with EBLLs, pre-1960 housing, and poverty
High-risk census tracts				
# of high-risk tracts (A)	18	82	81	79
% of high-risk tracts (A/325)	5.5%	25.2%	24.9%	24.3%
Estimated # of children living in high-risk tracts (B)	7,489	34,650	39,414	39,131
# of children tested (C)	1,641	11,628	14,216	11,649
# of children with EBLLs (D)	27	193	234	270
% of children tested (C/B)	21.9%	33.6%	36.1%	29.8%
% of children with EBLLs identified among those tested (D/C)	1.6%	1.7%	1.6%	2.3%
% of state total EBLLs from high-risk tracts (D/606)	4.5%	31.8%	38.6%	44.6%
% of children with EBLLs identified among all children living in high-risk areas (D/B)	0.36%	0.56%	0.59%	0.69%
Zip codes that overlap with high-risk census tracts				
# of zip codes (E)	19	47	43	59
% of zip codes (E/93)	20.4%	50.5%	46.2%	63.4%
# of children with EBLLs (F)	234	488	466	530
% of state total EBLLs from these zip codes (F/606)	38.6%	80.5%	76.9%	87.5%

Source: 2016-2020 HI-CLPPP lead surveillance database and 2011-2015, 2012-2016, 2013-2017, 2014-2018, and 2015-2019 ACS 5-year population estimates.
Notes: Children referenced in this table were those under age six. The total number of census tracts was 325 and the total number of zip codes was 93. The total number of children with EBLLs (≥ 5 mcg/dL) in the sample was 606. Converting high-risk census tracts into zip codes can overestimate the originally identified high-risk area. More details were provided in the Unit of Analyses section.

Method 1

For the first method (M1 in Table 3), we used old housing as the single risk factor to define high-risk areas, as house paint is the known primary source for lead exposure.[11] A census tract was considered high risk if it included at least 27% of housing built before 1950. This threshold was chosen per the CDC's recommendation for universal

screening.[12] This criterion has also been used to define high-risk areas in other states such as Texas and Florida.[13]

Method 1 identified 18 (5.5%) high-risk census tracts. Among the 7,489 children living in these tracts, 1,641 (21.9%) were tested for blood lead level, and 27 (1.6%) of tested children had EBLLs in 2015-2019. Among the 606 children statewide with known EBLLs, 4.5% lived in these high-risk census tracts. These 18 high-risk census tracts overlapped with 19 (20.4%) zip codes (marked with an asterisk in Table 4), compared with the 55 zip codes listed on the current risk questionnaire.

Table 4. High-risk zip codes in the current questionnaire (55 in total) and identified by M1 (19 in total), EBLL defined as ≥ 5 mcg/dL

High-risk zip codes in Hawai'i's current questionnaire:								
O'ahu		Hawai'i			Moloka'i	Kaua'i		Maui
96786*	96819*	96704	96743	96774*	96729	96703	96754	
96792	96822*	96710	96749	96776*	96748	96705*	96756	
96797	96826	96718	96750	96777	96757	96741	96765	
96813*	96848	96719	96755	96778	96770	96746	96769*	
96815*	96854	96720*	96760	96780*		96747	96796	
96816*	96857	96726	96764*	96781		96751		
96817*		96727*	96771	96783		96752		
		96728	96772	96785				
		96737	96773*					
Zip codes that overlap with high-risk tracts identified using M1 but not included in Hawai'i's current questionnaire:								
96734*						96716*		96763*

Note: * marks zip codes that overlap with high-risk census tracts identified by M1.

Method 2

Poverty was added as a risk factor for the second method (M2 in Table 3) because children living in poverty and residing in old housing are at the greatest risk of lead exposure.[14] Specifically, the percentage of old (pre-1960) housing and the percentage of people below 100% of the federal poverty level (FPL) were used to construct a composite risk score for each census tract.[15] High-risk census tracts were those with composite scores in the highest quartile. The year 1960 was chosen as the cutoff for old housing and the percentage of people below 100% FPL was used to be consistent with the definitions of old housing and poverty in the current zip code method.

This method identified 82 (25.2%) high-risk census tracts. Among the 34,650 children living in these tracts, 11,628 (33.6%) children had valid blood lead test results and 193 (1.7%) of tested children had EBLLs. Among the 606 children with EBLLs in this study's sample, almost a third (31.8%) lived in the high-risk census tracts identified by M2. These 82 high-risk tracts overlapped with 47 (50.5%) zip codes marked with an asterisk in Table 5, including 34 zip codes listed on the current risk questionnaire. Table 5 lists high-risk zip codes in the current questionnaire, as well as zip codes that

overlapped with high-risk tracts identified in M2 but not included in the current questionnaire.

Table 5. High-risk zip codes in the current questionnaire (55 in total) and identified by M2 (47 in total), EBLL defined as ≥ 5 mcg/dL

High-risk zip codes in Hawai'i's current questionnaire:								
O'ahu		Hawai'i			Moloka'i	Kaua'i		Maui
96786*	96819*	96704*	96743*	96774*	96729*	96703	96754	
96792*	96822*	96710*	96749*	96776*	96748	96705	96756	
96797*	96826*	96718*	96750	96777*	96757*	96741	96765	
96813*	96848	96719	96755	96778*	96770*	96746	96769	
96815*	96854	96720*	96760*	96780*		96747	96796	
96816*	96857	96726	96764*	96781*		96751		
96817*		96727*	96771*	96783*		96752		
		96728*	96772*	96785*				
		96737	96773*					
Zip codes that overlap with high-risk tracts identified using M2 but not included in Hawai'i's current questionnaire:								
96701*	96791*					96722*		96779*
96706*	96814*							96793*
96707*	96818*							96732*
96734*	96821*							
96782*								

Note: * marks zip codes that overlap with high-risk census tracts identified by M2.

Method 3

For the third method (M3 in Table 3), in addition to pre-1960 housing and poverty, immigration status, a language other than English spoken at home, and less than high school education were included to create a composite risk score for each census tract. High-risk census tracts were those with composite scores in the highest quartile.

This method identified 81 (24.9%) high-risk census tracts. Among the 39,414 children living in these census tracts, 14,216 (36.1%) had blood lead tests, and 234 (1.6%) of tested children had EBLLs. Among the 606 children with EBLLs in the analytical sample, about 38.6% lived in identified high-risk census tracts. These 81 high-risk tracts overlapped with 43 (46.2%) zip codes marked with an asterisk in Table 6, including 31 listed on the current risk questionnaire. Table 6 lists high-risk zip codes in the current questionnaire and zip codes that overlapped with high-risk tracts identified by M3 but not included in the current questionnaire.

Table 6. High-risk zip codes in the current questionnaire (55 in total) and identified by M3 (43 in total), EBLL defined as ≥ 5 mcg/dL

High-risk zip codes in Hawai‘i’s current questionnaire:								
O‘ahu		Hawai‘i			Moloka‘i	Kaua‘i		Maui
96786*	96819*	96704*	96743*	96774*	96729	96703	96754	
96792*	96822*	96710*	96749*	96776*	96748	96705*	96756	
96797*	96826*	96718*	96750	96777*	96757	96741	96765	
96813*	96848	96719	96755	96778	96770	96746	96769*	
96815*	96854	96720*	96760*	96780*		96747	96796	
96816*	96857	96726	96764*	96781*		96751		
96817*		96727*	96771*	96783*		96752		
		96728*	96772*	96785				
		96737	96773*					
Zip codes that overlap with high-risk tracts identified using M3 but not included in Hawai‘i’s current questionnaire:								
96701*	96818*					96716*		96732*
96706*								96761*
96707*								96763*
96782*								96779*
96814*								96793*

Note: * marks zip codes that overlap with high-risk census tracts identified by M3.

Method 4

In the fourth method (M4 in Table 3) pre-1960 housing, poverty, and the percentage of children with EBLLs were used to calculate a composite risk score for each census tract. Again, high-risk census tracts were defined as those with composite scores in the highest quartile. Note that M4 included the same risk factors used by HI-CLPPP to determine the state’s current high-risk zip codes. By design, M4 was the most similar to what was done in the past. M4 did not yield an exact match to the state’s current list of high-risk zip codes for several reasons: M4 was based on more recent population and EBLL data, M4 was calculated using census tracts rather than PCSAs, and a different composite score threshold was used to define high-risk census tracts.

Method 4 identified 79 (24.3%) high-risk census tracts. Among the 39,131 children living in these census tracts, 11,649 (29.8%) had valid blood lead test results and 270 (2.3%) of these children had EBLLs. Among the 606 children statewide with EBLLs, about 44.6% lived in these high-risk tracts. The 79 high-risk census tracts overlapped with 59 (63.4%) zip codes marked with an asterisk in Table 7, including 42 zip codes listed on the current risk questionnaire. Table 7 lists high-risk zip codes in the current questionnaire and zip codes that overlapped with high-risk tracts identified by M4 but not included in the current questionnaire.

Evaluation of the Four Alternative Methods

Among the four alternative methods (M1-4), the first method using old housing as the sole risk factor identified the lowest number of children with EBLLs living in high-risk tracts.

One possible reason for this result is that a sizeable number of at-risk children living in old housing were either never screened or were not included in this analysis due to missing or invalid addresses or missing test results. This possibility was explored by further examining the 18 high-risk census tracts identified by M1. Table 8 lists the number of children tested, children with EBLLs, testing rate, and the estimated number of children living in each census tract. A few census tracts have low testing rates. For example, census tract 73.02 covers the Joint Base Pearl Harbor-Hickam area with primarily military families. It is likely that children's blood lead test records of these families were not included in the HI-CLPPP lead surveillance database as military families tend to use military medical facilities. One possibility for the low testing rates in other areas such as census tracts 220, 221.02, and 408, is that they were not close to facilities with onsite blood lead testing.

Table 7. High-risk zip codes in the current questionnaire (55 in total) and identified by M4 (59 in total), EBLL defined as ≥ 5 mcg/dL

High-risk zip codes in Hawai'i's current questionnaire:								
O'ahu		Hawai'i			Moloka'i	Kaua'i		Maui
96786*	96819*	96704*	96743*	96774*	96729*	96703*	96754*	
96792*	96822*	96710*	96749*	96776*	96748	96705*	96756*	
96797*	96826*	96718*	96750*	96777*	96757*	96741	96765	
96813*	96848	96719*	96755*	96778	96770*	96746*	96769*	
96815*	96854	96720*	96760*	96780*		96747	96796	
96816*	96857	96726	96764*	96781*		96751		
96817*		96727*	96771*	96783*		96752		
		96728*	96772*	96785*				
		96737	96773*					
Zip codes that overlap with high-risk tracts identified using M4 but not included in Hawai'i's current questionnaire:								
96701*	96782*	96725*				96716*		96732*
96706*	96791*	96740*						96761*
96707*	96818*							96779*
96717*	96821*							96793*
96730*								
96734*								

Note: * marks zip codes that overlap with high-risk census tracts identified by M4.

Among the three methods using composite risk scores (M2-4), M4 was the best method, although all three were not fully satisfactory in capturing high-risk children. Even with the lowest testing rate (29.8% for M4 vs. 33.6% for M2 and 36.1% for M3; see Table 3), M4 identified the highest number of children with EBLLs (270 for M4 vs. 193 for M2

and 234 for M3). Among the 104,037 children under age six in Hawai‘i, 606 had EBLLs, which is 0.58% of the state's population under age six. Compared to this state average rate, all four alternative methods identified higher percentages of at-risk children living in high-risk census tracts (0.36% for M1, 0.56% for M2, 0.59% for M3, and 0.69% for M4). High-risk tracts identified by M4 captured the highest percentage of children with EBLLs among all children under six living in these tracts. Since children's lead test results were included as a risk factor in creating the composite risk score, it is not surprising that M4 identified the highest number of children with EBLLs living in high-risk areas (i.e., census tracts with risk scores in the highest quartile).

Table 8. High-risk areas identified by M1, EBLL defined as ≥ 5 mcg/dL

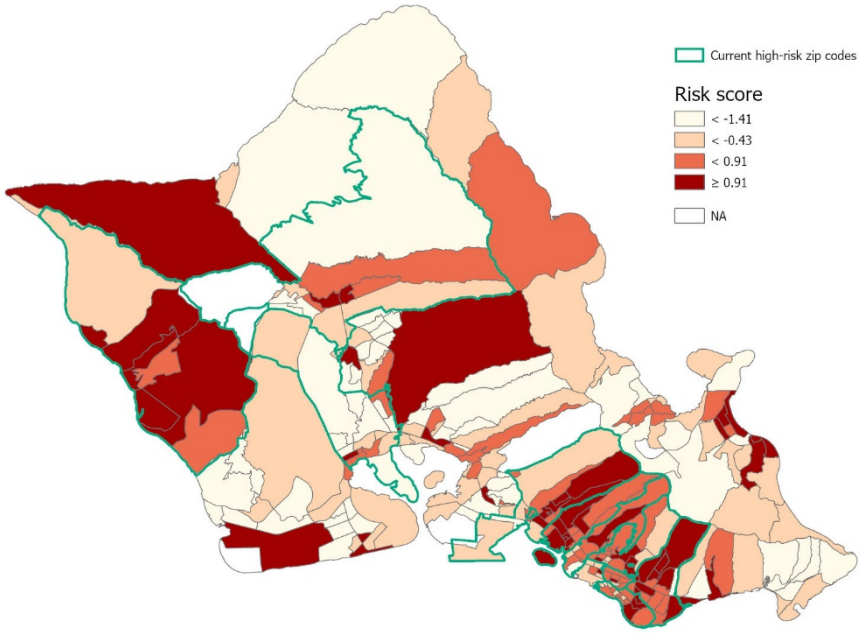
Census tract #, county	Estimated # children	# children tested	# children with EBLLs	Testing rate
220, Hawai‘i	445	12	0	3%
221.02, Hawai‘i	184	4	2	2%
8, Honolulu	158	100	1	63%
9.02, Honolulu	310	120	1	39%
13, Honolulu	223	120	0	54%
15, Honolulu	171	127	3	74%
16, Honolulu	324	144	0	44%
28, Honolulu	314	91	1	29%
30, Honolulu	388	116	1	30%
44, Honolulu	692	237	7	34%
46, Honolulu	339	137	2	40%
48, Honolulu	804	281	5	35%
73.02, Honolulu	1,898	64	0	3%
95.04, Honolulu	393	32	2	8%
112.02, Honolulu	60	38	1	63%
319, Kalawao	0	1	0	--
408, Kaua‘i	504	9	1	2%
316.01, Maui	282	8	0	3%

Source: 2016-2020 HI-CLPPP lead surveillance database and 2011-2015, 2012-2016, 2013-2017, 2014-2018, and 2015-2019 ACS five-year estimates.
Note: High-risk census tracts were defined as those with at least 27% pre-1950 housing. The number of children was estimated as those who were under age six at any point between 2015 and 2019.

Figures 4a and 4b visualize high-risk areas captured by M4 versus the zip code method used in the current risk system. Specifically, the two figures illustrate the distribution of the composite risk score in quartiles using M4 for each county and census tract with the boundaries of high-risk zip codes in the current questionnaire marked by green lines. In Honolulu and Maui Counties, high-risk census tracts with scores in the highest quartile were not fully captured by high-risk zip codes in the current questionnaire. For example, parts of the Waialua, Pearl City, and Kapolei areas in Honolulu County and the Hāna

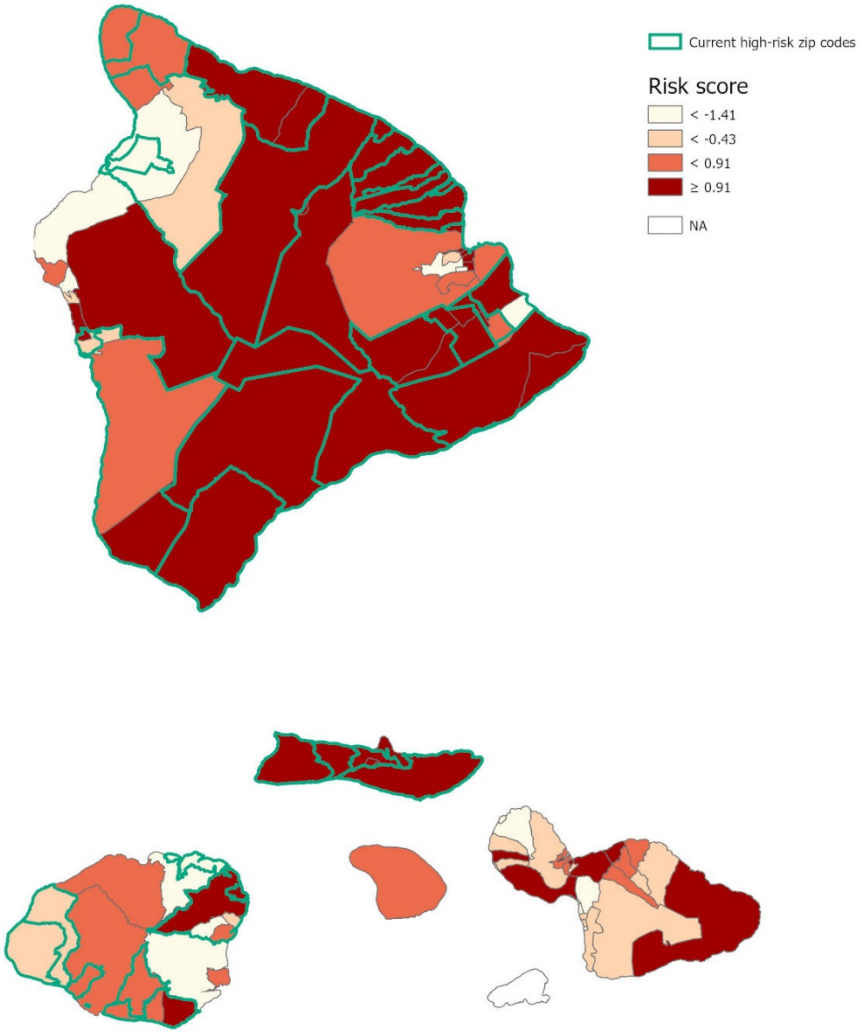
area in Maui County were not listed as high-risk zip codes in the current questionnaire. In Hawai‘i County and Moloka‘i, however, most of the high-risk tracts identified by M4 were captured as high-risk zip codes in the current questionnaire. The different high-risk zip codes identified by M4 versus the current zip code method might result from the use of different years of data, levels of analyses (census tract vs. PCSA), and definition of high-risk areas (the highest quartile of the composite risk score vs. positive values on the composite risk score).[16]

Figure 4a. Composite risk score (M4) by census tract in Honolulu County



Notes: NA denotes census tracts with an estimated child population of zero. EBLL used to define the composite risk score is defined as ≥ 5 mcg/dL.

Figure 4b. Composite risk score (M4) by census tract in Hawai'i, Maui, and Kaua'i Counties



Notes: NA denotes census tracts with an estimated child population of zero. EBLL used to define the composite risk score is defined as ≥ 5 mcg/dL.

Sensitivity Analyses

Sensitivity analyses were conducted: a) using different years as the cutoff to define old housing stock; b) including weights in composite risk score methods; and c) using two different thresholds to define EBLL. The purpose of the sensitivity analysis was twofold:

a) to check how sensitive our results were to changing the definition of high-risk areas and EBLL; and b) to investigate why high-risk census tracts did not include the majority of children currently identified with EBLL in the HI-CLPPP lead surveillance database.

Different Year Cutoffs for Old Housing

In M1, a single risk factor (housing built before 1950) was used. Using 1950 as a cutoff is a common practice by other states and recommended by the CDC. However, this method captured only 4.5% of children with EBLLs in high-risk areas among 606 with EBLLs in the sample. As a next step, using 1950 as the cutoff year to define old housing was examined to see if it would still be appropriate in Hawai'i. First, the number and percentage of all the children in our sample by the year that their residence was built was tabulated, then sensitivity analyses were conducted using different years as cutoffs. Table 9 indicates that only 8.0% of children under age six lived in housing built before 1950; 17.7% lived in pre-1960 housing; and 55.5% lived in pre-1978 housing. Since only 8.0% of children lived in pre-1950 housing, it is not surprising that M1 identified only a small proportion of children with EBLLs as lived in high-risk areas.

Table 9. Children living in housing of different ages

Year cutoff to define old housing	Housing that children live in	# of children	% of children
1950	Pre-1950	2,983	8.0%
	Since 1950	34,158	92.0%
1960	Pre-1960	6,571	17.7%
	Since 1960	30,570	82.3%
1978	Pre-1978	20,625	55.5%
	Since 1978	16,516	44.5%

Source: 2016-2020 HI-CLPPP lead surveillance database and 2021 property data.
Note: The housing information on property data was missing for 8,401 children from the total sample of 45,543.

Different years were then tested as the cutoff to define high-risk areas. Table 10 reports the number of high-risk areas and the number of children living in these areas by housing age cutoff. Among the 606 children with EBLLs, about 28.5% lived in areas with at least 27% pre-1960 housing (S1 in Table 10); and about 89.9% of children with EBLLs lived in areas with at least 27% pre-1980 housing (S2 in Table 10). Although the method using at least 27% pre-1980 housing to define high-risk areas captures the most children with EBLLs, this method identified a large majority of all census tracts as high risk. Specifically, it identified 261 high-risk census tracts (80.3% of 325 tracts), which overlapped with 80 zip codes (86.0% of 93 zip codes). When most of the state's geographic areas are considered high risk, universal screening may be warranted instead of targeted screening based on zip codes.

Table 10. Children in high-risk areas by old housing definition, EBLL defined as ≥ 5 mcg/dL

	M1: 27%+ pre-1950 housing	S1: 27%+ pre-1960 housing	S2: 27%+ pre-1980 housing
High-risk census tracts			
# of high-risk census tracts (A)	18	82	261
% of high-risk tracts (A/325)	5.5%	25.2%	80.3%
Estimated # of children living in high-risk tracts (B)	7,489	34,983	130,685
# of children tested (C)	1,641	10,933	37,874
# of children with EBLLs (D)	27	173	545
% of children tested (C/B)	21.9%	31.3%	29.0%
% of children with EBLLs identified among those tested (D/C)	1.6%	1.6%	1.4%
% of state total EBLLs from high-risk tracts (D/606)	4.5%	28.5%	89.9%
% of children with EBLLs among children living in the tracts (D/B)	0.36%	0.49%	0.42%
Zip codes that overlap with high-risk census tracts			
# of zip codes (E)	19	37	80
% of zip codes (E/93)	20.4%	39.8%	86.0%
# of children with EBLLs (F)	234	411	603
% of state total EBLLs from these zip codes (F/606)	38.6%	67.8%	99.5%

Source: 2016-2020 HI-CLPPP lead surveillance database and 2011-2015, 2012-2016, 2013-2017, 2014-2018, and 2015-2019 ACS 5-year population estimates.
Notes: Children referenced in this table were those under six years of age. The year 1980 was used as the cutoff instead of 1978 because the census data only provided relevant information in 10-year intervals. The total number of census tracts was 325, and the total number of zip codes was 93. The total number of children with EBLLs (≥ 5 mcg/dL) in the sample was 606.

Weighting

According to the Council on Environmental Health, house paint used before 1978,—and especially before 1960—is a common source of lead exposure.[17] The prevalence of lead hazards is higher in older housing.[18] The U.S. Environmental Protection Agency data show that, while only 24% of housing built from 1960 to 1977 contained lead paint hazards, the prevalence of lead hazards increased to 69% of housing built from 1940 to 1959, and 87% of housing built before 1940.[19] Therefore, multiple cutoffs were included based on housing age (i.e., pre-1940, 1940-1959, and 1960-1977), and housing age was weighted by the prevalence rate of lead hazards in a composite score method. This method (S3 in Table 11) identified 78 (24.0%) high-risk census tracts, which overlapped with 37 (39.8%) zip codes. Among the 606 children with EBLLs, 162 children (26.7%) lived in the high-risk tracts.

For the initial analyses (M2-4) it was assumed that each risk factor carries the same weight in creating a composite risk score. This assumption, however, may not be valid. To best approximate the amount of risk attributable to the composite score, the state of

Washington assigned different weights to poverty and old housing (0.42 and 0.58, respectively).[20] Further, the prevalence rate of lead hazards of different housing ages was incorporated in weights. The companion Technical Report includes details about weighting. This method (S4 in Table 11) identified 79 (24.3%) high-risk census tracts, which overlapped with 48 (51.6%) zip codes. Among the 606 children with EBLLs, 189 children (31.2%) lived in high-risk tracts.

Compared to the methods without weights (S1, S2, and M2), the methods incorporating weights (S3 and S4) produced no better results and did not identify more children with EBLLs living in fewer high-risk areas.

Table 11. Children in high-risk areas based on composite risk scores with weights, EBLL defined as ≥ 5 mcg/dL

	S3: Composite score based on pre-1940, 1940-1959, and 1960-1979 with weights	**S4: Composite score based on poverty and old housing (pre-1940, 1940-1959, 1960-1979) with weights**
High-risk census tracts		
# of high-risk census tracts (A)	78	79
% of high-risk tracts (A/325)	24.0%	24.3%
Estimated # of children living in high-risk tracts (B)	31,326	33,109
# of children tested (C)	10,536	10,577
# of children with EBLLs (D)	162	189
% of children tested (C/B)	33.6%	31.9%
% of children with EBLLs identified among those tested (D/C)	1.5%	1.8%
% of children with EBLLs identified among all children with EBLLs (D/606)	26.7%	31.2%
% of children with EBLLs among children living in the tracts (D/B)	0.52%	0.57%
Zip codes that overlap with high-risk census tracts		
# of zip codes (E)	37	48
% of zip codes (E/93)	39.8%	51.6%
# of children with EBLLs (F)	443	452
% of state total EBLLs from these zip codes (F/606)	73.1%	74.6%

Source: 2016-2020 HI-CLPPP lead surveillance database and 2011-2015, 2012-2016, 2013-2017, 2014-2018, and 2015-2019 ACS 5-year population estimates.
Notes: Children referenced in this table were those under age six. The total number of census tracts was 325, and the total number of zip codes was 93. The total number of children with EBLLs (≥ 5 mcg/dL) in the sample was 606.

EBLL Threshold

Instead of using the "reference value" of 5 mcg/dL as the threshold, EBLL was defined as a blood lead level of at least 10 mcg/dL to see if the principal results still hold. This blood lead level was chosen because the previous "blood lead level of concern" was 10 mcg/dL before the "reference value" was updated to 5 mcg/dL.[21] The higher threshold (≥ 10 mcg/dL) identified 135 children with EBLLs in the analytical sample, compared

to 606 children with EBLLs using the lower threshold (≥ 5 mcg/dL). Among these 135 children with EBLLs, only four children with EBLLs lived in high-risk census tracts when the high-risk tracts were defined based on at least 27% pre-1950 housing (S5 in Table 12); 42 children with EBLLs lived in high-risk tracts defined based on poverty and pre-1960 housing (S6 in Table 12); 53 children with EBLLs lived in high-risk tracts defined based on tract-level poverty, pre-1960 housing, immigration status, speaking a language other than English at home, and less than high school education (S7 in Table 12); and 87 children with EBLLs lived in high-risk tracts defined based on poverty, pre-1960 housing, and children's blood lead test results (S8 in Table 12). Although fewer children with EBLLs were identified living in high-risk areas using the higher EBLL threshold, the percentages of children with EBLLs living in these areas were close to those using the lower threshold to define EBLLs in all methods, except for the fourth method when children's test results were included in the composite risk score (3.0%, 31.1%, 39.3%, and 64.4% for M1-M4, respectively, using 10 mcg/dL in Table 12, vs. 4.5%, 31.8%, 38.6%, and 44.6% using 5 mcg/dL as the threshold to define EBLL in Table 3).

Table 12. Children in high-risk areas by identification method, EBLL defined as ≥ 10 mcg/dL

	S5: ≥ 27% pre-1950 housing	S6: Pre-1960 housing and poverty	S7: Pre-1960 housing, poverty, immigration status, non-English speaking, and < high school	S8: Children with EBLLs, pre-1960 housing, and poverty
High-risk census tracts				
# of high-risk census tracts (A)	18	82	81	80
% of high-risk tracts (A/325)	5.5%	25.2%	24.9%	24.6%
Estimated # of children living in high-risk tracts (B)	7,489	34,650	39,414	42,036
# of children tested (C)	1,641	11,628	14,216	12,614
# of children with EBLLs (D)	4	42	53	87
% of children tested (C/B)	21.9%	33.6%	36.1%	30.0%
% of children with EBLLs identified among those tested (D/C)	0.2%	0.4%	0.4%	0.7%
% of state total EBLLs from high-risk tracts (D/135)	3.0%	31.1%	39.3%	64.4%
% of children with EBLLs among children living in the tracts (D/B)	0.05%	0.12%	0.13%	0.21%
Zip codes that overlap with high-risk census tracts				
# of zip codes (E)	19	47	43	56
% of zip codes (E/93)	20.4%	50.5%	46.2%	60.2%
# children with EBLLs (F)	34	106	103	126
% of state total EBLLs from these zip codes (F/135)	25.2%	78.5%	76.3%	93.3%

Source: 2016-2020 HI-CLPPP lead surveillance database and 2011-2015, 2012-2016, 2013-2017, 2014-2018, and 2015-2019 ACS 5-year population estimates.
Notes: The total number of census tracts was 325, and the total number of zip codes was 93. The total number of children with EBLLs (≥ 10 mcg/dL) in the sample was 135.

The CDC has recently adopted the recommendation from the Lead Exposure and Prevention Advisory Committee to update the reference value to 3.5 mcg/dL.[22] Therefore, in the next set of sensitivity analyses, EBLL was defined as a blood lead level of at least 3.5 mcg/dL. As expected, the new lower threshold (≥ 3.5 mcg/dL) resulted in many more children having positive test results. The new threshold identified 1,777 children with EBLLs in the statewide analytical sample, compared to a total of 606 children with EBLLs using the lower threshold (≥ 5 mcg/dL). Table 13 summarized the results of the four methods using 3.5 mcg/dL as the reference value.

Table 13. Children in high-risk areas by identification method, EBLL defined as ≥ 3.5 mcg/dL

	S9: ≥ 27% pre-1950 housing	S10: Pre-1960 housing and poverty	S11: Pre-1960 housing, poverty, immigrant status, non-English speaking, and < high school	S12: Children's test result, pre-1960 housing, and poverty
High-risk census tracts				
# of high-risk census tracts (A)	18	82	81	79
% of high-risk tracts (A/325)	5.5%	25.2%	24.9%	24.3%
Estimated average # of children living in high-risk tracts (B)	7,489	34,650	39.414	36,668
# of children tested (C)	1,641	11,627	14,215	10,580
# children with EBLLs (D)	99	540	638	629
% of children tested (C/B)	21.9%	33.6%	36.1%	28.9%
% of children with EBLLs identified among those tested (D/C)	6.0%	4.6%	4.5%	5.9%
% of state total EBLLs from high-risk tracts (D/1,777)	5.6%	30.4%	35.9%	35.4%
% of children with EBLLs among children living in the tracts (D/B)	1.32%	1.56%	1.62%	1.72%
Zip codes that overlap with high-risk census tracts				
# of zip codes (E)	19	47	43	59
% of zip codes (E/93)	20.4%	50.5%	46.2%	63.4%
# children with EBLLs (F)	647	1,407	1,332	1,519
% of state total EBLLs from these zip codes (F/1,777)	36.4%	79.2%	75.0%	85.5%

Source: 2016-2020 HI-CLPPP lead surveillance database and 2011-2015, 2012-2016, 2013-2017, 2014-2018, and 2015-2019 ACS 5-year population estimates.

Notes: The total number of census tracts was 325, and the total number of zip codes was 93. Two additional records (i.e., "<2; 4", and "<5") were excluded from the analysis as it was unclear if the actual test results were higher or lower than the reference value (i.e., 3.5 mcg/dL). The exclusion resulted a sample of 45,541 records with 1,777 children with EBLLs (≥ 3.5 mcg/dL) in the sample.

Although the lower threshold identified more children with EBLLs statewide, the revised percentages of the statewide total children with EBLLs living in high-risk areas, i.e., the accuracy of high-risk methods in capturing children with elevated test results, was quite similar. This pattern held for three of the four methods (See Table 14, M1-M3 compared to S9-S11). For the fourth method, a composite risk score including test results, a smaller percentage of children with EBLLs were from the high-risk areas using the lower blood lead threshold (M4 vs. S12).

Table 14. Children with EBLLs in high-risk areas by the reference value and identification method

EBLL defined as		# of children with EBLLs statewide (A)	# of children with EBLLs in high-risk tracts (B)	% of statewide children with EBLLs in high-risk tracts (B/A)
≥ 5 mcg/dL	M1: ≥ 27% pre-1950 housing	606	27	4.5%
	M2: Pre-1960 housing and poverty	606	193	31.8%
	M3: Pre-1960 housing, poverty, immigration status, non-English speaking, and < high school	606	234	38.6%
	M4: Children with EBLLs, pre-1960 housing, and poverty	606	270	44.6%
≥ 3.5 mcg/dL	S9: ≥ 27% pre-1950 housing	1,777	99	5.6%
	S10: Pre-1960 housing and poverty	1,777	540	30.4%
	S11: Pre-1960 housing, poverty, immigrant status, non-English speaking, and < high school	1,777	638	35.9%
	S12: Children's test result, pre-1960 housing, and poverty	1,777	629	35.4%

Source: 2016-2020 HI-CLPPP lead surveillance database and 2011-2015, 2012-2016, 2013-2017, 2014-2018, and 2015-2019 ACS 5-year population estimates.

Key Informant Interviews

Purpose and Methods

Key informant interviews were used to gather insights from local and national experts on the strengths and weaknesses of the different risk systems used in Hawai‘i and elsewhere. Ten individuals from six states comprised the interview sample. (See the acknowledgments section for their names and titles.)

This purposive sample included practicing physicians and agency staff from Arizona, Hawai‘i, Maryland, Massachusetts, Ohio, and Texas. States were selected to include those implementing different approaches to defining target zip codes, as well as those

using universal testing. The Hawai'i State Department of Health provided introductions to in-state physicians and out-of-state CLPPP coordinators. Almost all persons contacted agreed to participate.

Interviews were conducted online, led by two Center on the Family (COF) staff. Participants received an interview guide in advance of their meeting, and the interviewers prepared by reviewing and summarizing the relevant documents available on each state's website. The interview questions varied for each state. However, the general structure was to discuss a) the strengths and challenges of each state's risk system; b) any recent changes in approach; c) thoughts on what an ideal risk system would look like; and d) feasible suggestions for improving Hawai'i's current approach. Interviews lasted 45-60 minutes. Each interviewer performed an independent review of session transcripts and then generated an initial list of themes. After comparison and discussion, a final list of themes and key quotations were derived.

Results

In addition to addressing the pros and cons of different risk system approaches, participants shared advice on practical issues related to implementing the larger public health process of combating lead poisoning—from public awareness to risk surveillance, case management, housing abatement, regulations, and political will. Four themes emerged regarding risk systems per se, along with six themes regarding implementation (see Table 15). Each theme is summarized below.

Table 15. Interview Themes

Theme
Risk systems should reflect the changing nature of lead poisoning
All risk identification methods are flawed
Unknown prevalence is the bane of everyone's existence
Universal testing is preferable
Benefits of a robust reporting and monitoring infrastructure
The importance of housing abatement
Innovative use of funds
Benefits of strong policies
Overcoming barriers with education and awareness
Partnerships and coalitions strengthen implementation

Risk Systems Should Reflect the Changing Nature of Lead Poisoning

Since the 1980s and 1990s, all states increased the number of children tested while also seeing a precipitous decline in lead poisoning rates. Per each state's website, roughly 1-2% of young children have blood lead levels of 5-9 mcg/dL, and 0.25-1% have levels of 10 mcg/dL or higher. This contrasts with historical figures where up to 18% of children had elevated blood lead levels (EBLLs). One interviewee spoke about their state's success:

> "Despite a significant increase in the number of tests, we have not seen a significant increase in the number of kids with severe lead poisoning…. That suggests we've done a very credible job of removing a lot of the previous sources of exposure that led to very high lead levels in kids."

Risk systems may need to evolve as the frequency and causes of lead poisoning change. Given the current low base rate, states may want to consider whether different screening strategies are effective for relatively frequent vs. rare conditions. The changing nature of exposure sources may also have implications for risk screening. Paint remains the leading source of EBLLs, but its predominance is declining as older homes are renovated or abated, and newer housing stock is built. Some states are finding that sources now vary by county. For example, the housing may be the primary cause in some counties, while foodstuffs or foreign travel are the key sources in other parts of the state. States still rely on geography-based risk systems, which may become less useful as unpredictable, idiosyncratic sources start to arise.

> "One of the things we are seeing as we've expanded the number of kids [tested] is a shift in the sources of exposure…. It's more difficult to figure out whether it's a single exposure [or] a cumulative exposure from a number of different sources…. As you get newer housing stock and remediate the older stock, causes are becoming more diffuse and idiosyncratic. Would that require a real change in strategy? We're in the midst of an evaluation right now on that very topic."

At this time, it is not clear what an alternative risk assessment system should look like. It is clear that states are devoting more attention to identifying idiosyncratic sources as part of case management:

> "[We suffered from] tunnel vision because we have such an older housing stock…. Our community health workers [now] have an in-depth questionnaire…that gets into behavioral issues, utensils, food, spices, Ayurvedic medicines, travel outside the U.S.,…pressure cookers, aluminum cookware,…religious amulets, and jewelry…. It's definitely something that we're going to be working on over the next couple of years."

All Risk Identification Methods Are Flawed

Most participants were generally satisfied with the risk identification method used in their own state. At the same time, there was unanimous recognition of the inherent limitations of each approach.

Screening surveys. Most states have a lead exposure risk survey that is administered to parents, similar to the one used in Hawai'i. Survey questions address housing age, known exposure in the household or peer group, whether the child lives in a high-risk zip code, and individualized risk factors such as parent occupation, imported household items, and foodstuffs. The individualized risk factors showed quite a bit of regional variation. The key advantages of risk surveys are their low cost, relative ease of administration, and coverage of individualized risk factors that are not geography-based. Screening surveys are also the main route for identifying at-risk children who do not receive Medicaid or who live outside of high-risk zip codes.

Practical concerns related to survey use included administration time, social desirability bias in parents' answers, and whether parents might find the survey intimidating. All participants questioned whether physicians administer screening surveys to the intended children on the intended schedule, and whether they even used their state's survey. Surveys are most useful for identifying at-risk children who are not on Medicaid or living in high-risk zip codes. No states track the actual administration rates of screening surveys, nor which survey item(s) led to a particular testing referral.

> "On these EPSDT[23] forms,…[you check that] yes, you were doing lead screening. But the lead screening could either be, I've assessed it by talking to people, or I've ordered a blood test. There isn't any rigor around how you chose to do those two things."

> "[Our survey is] probably the thing we struggle with the most…. I don't think it's widely utilized. I think the high-risk zip codes in the Medicaid status are what generally get physicians to test. [The physicians] that test groups beyond that are asking good questions about where maybe somebody lives, like their specific apartment or home.... There's a lot of people questioning the effectiveness of those [surveys] these days, especially now."

The most glaring drawback of risk surveys is whether they are actually useful in identifying at-risk children, especially given national research that suggests low correspondence with measured blood levels.[24] As one respondent framed the issue:

> "Questionnaires are [helpful] at the point of was your house built before this or do you spend time there. But that only goes so far. If that's not the major risk factor in the community where you live, then [a survey is] never going to adequately screen people…. The kids that I took care of who were lead poisoned, it was somebody in the household making lead fishing sinkers, fishing weights, or a car battery left to corrode next to the house, or a particular piece of some kind of ceramic or jewelry…. You can't have enough pictures and a long enough list to capture all those things. That's the fallacy of the questionnaire. There is research that shows that no

questionnaires are better than chance at identifying kids with high lead levels…. [Our survey] doesn't actually help identify who needs to be tested. So why are we doing it?"

Target zip codes. Absolute thresholds, composite scores, and statistical modeling approaches to identify target zip codes were all represented among the states interviewed. Interviewees from the four states that use target zip codes were moderately satisfied with their own state's approach. Most interviewees were not involved in defining their state's high-risk zip codes and had limited insight on how and why past decisions came to be, especially when the target zip code method was developed by an outside contractor.

The CDC recommends the use of target zip codes on the assumption that this approach increases the identification of children with EBLL while reducing unnecessary testing in low-risk areas. Zip code methods were seen as most helpful when sources are clearly localized, e.g., a populous urban area with a high density of older, poorly-maintained housing stock. Zip codes are less useful when sources are not geographically based and/or when children move:

"A zip code is helpful if your lead source is something that is fixed in a geographic way. So if it's the pipes, the water source, something toxic in the soil from the past, if it's something about the housing, exposure to exhaust from cars on a highway when we have leaded gasoline, then zip code is helpful. If it's related to some imported food, imported toy, imported jewelry, imported ceramic, antiques, all of these other kinds of things, then zip code is never going to help."

An additional complication arises when mailing addresses are different from residential addresses, e.g., a PO box, because medical records usually include only the former. Finally, target zip codes need to be revised periodically to reflect changes in population estimates and testing data.

Ideally, a more precise geographic unit, such as census tracts, was preferred. Zip codes are widely used because they are feasible. Identifying a residential census tract was considered too challenging for parents and physicians, but almost everyone knows his or her zip code. One state tried using high-risk census tracts instead of zip codes, but was not successful. Another state has an online map to help families identify their zip code, especially for those in areas without street addresses.

Informants had issues with the accuracy of the zip code method. Some so-called high-risk zip codes have low tested EBLL rates, while some low-risk zip codes have concerning levels of EBLL. The issue of over- and under-identification was especially salient to one state. Because that state is highly diverse, agency staff hoped modeling based on extensive demographic data at the census tract level would reduce the likelihood of overlooking children in rural areas. However, after comparing several years of surveillance data to modeled predictions, it was determined that revisions were in order. At the time of our interviews, the new modeling study was under embargo, so the details of these changes were not available. This informant also emphasized that public

health staff should work closely with statisticians to ensure they understand real-world conditions:

> "[Our size and diversity is] the main reason we always thought a model was best for our state…. [Parts are] quite rural…, then we have big cities…. [We worried that] those small towns and small cities, and maybe [regions] were not well-represented in the data, and so we thought modeling would solve that…. [However, we found areas] designated as high-risk that probably shouldn't have been…. We're not seeing the high number of elevated kids in [two industrial cities with larger minority populations]…. [The modeling also] doesn't consider areas of the state that don't have a high predicted probability, but the data itself show there's probably a bigger problem there. Something we talked about a lot in the new model is making sure that we want to select zip codes where the predicted probability is high, but also those where there's high observed [EBLL]. That sounds so common sense now, saying it out loud, but it's not something we considered during the initial work with [our contractor]…. With a disconnect between our knowledge of what's actually going on and the contractor who's just in the numbers and the stats, sometimes things are lost."

Another state was able to develop demographic models that did a good job of identifying high-risk zip codes, i.e., zip codes with a high percentage of EBLL among children tested.[25] However, the two models that offered a good statistical fit to the data used a stringent criterion to define high risk. Specifically, the two best models defined a high-risk zip code as one where either 9% or 17% of children tested had blood lead levels of 5 mcg/dL or above. (At the time, these thresholds corresponded to the 75th and 90th percentile ranks of the percentage of tested EBLL for all zip codes). Although defensible on statistical grounds, these models would leave many children undetected simply because they live in a zip code with a more typical rate of EBLL.

Finally, a fallacy underlies all targeted zip code methods. Existing surveillance data are the gold standard for validation, yet it is shaped by zip code classifications. If surveillance data were representative of children in the state and within each zip code, these data would be an excellent criterion. Because testing is more common in high-risk zip codes, more children in these areas will be identified, and documented EBLL rates are more likely to be accurate. Non-risk areas may have exposed children who remain undetected primarily because their zip code does not trigger a mandated test. With scant testing, a zip code may erroneously remain in non-risk status. That zip code's surveillance data may also not be representative due to unknown factors that initiate a rare testing event. As one informant said:

> "You can identify where your hot spots are based on the known results. But you're potentially missing hotspots where kids just haven't been tested."

The lack of representative surveillance data leads to the next theme below.

Unknown Prevalence is the Bane of Everyone's Existence

One interviewee focused on the fact that few states have good data on the prevalence of what is an increasingly rare event. This person saw an urgent need for well-designed epidemiology studies to fill this gap. Good prevalence data could also improve clinical practice:

> "The prevalence of childhood lead poisoning, the distribution of it, and the cause of it is something that is unknown nationwide. There aren't good prevalence studies. We're still going to be flying blind until we actually understand the patterns of lead poisoning, elevated lead levels, and lead risk in our state. Until we know what that is, we can't design a better system…. Say for a year we make a concerted effort to test every single 15-month-old child everywhere in our state…. Then for everybody who has an elevated lead level, really put effort into [identifying the source]. Was it corroding car batteries in the yard? Is it peeling paint? Is it mom's jewelry? Is it grandma's antique bowl that she serves the [food] in?
>
> We might learn that in fact lead is geographically distributed in our state. But we might learn that [our state] is very, very different and the majority of our lead poisoning cases are these sporadic exposures. That's a completely different beast to try to control than geographic distribution…. [If] we tested 100% or 90% of the 15-month-olds and we found that 5% of them had elevated levels, then we could redesign our advice to pediatricians…. [If] we really know there are [geographic] pockets, we can go in and try to mitigate that. [Or we might identify] particular sources that we need to be worried about. We could do a big educational campaign on [confirmed common causes] and educate pediatricians, as well as others."

Universal Testing is Preferable

Informants felt that universal testing is the best approach—at least in theory. Given the consequences of undetected lead poisoning, no child should be overlooked. Ideally, lead testing would be a mandatory component of routine pediatric care, similar to childhood vaccinations:

> "Universal testing is the only way to ensure everybody gets the screening done. Targeting is not working because even in the targeted areas, they're not testing all the kids. We know that only 50% of kids are being tested."
>
> "It should be covered as part of well-child care. Right now, only under Medicaid is it routinely covered. So [universal testing] would require working with the insurance companies."

Obstacles to universal testing include many of the same practical concerns that result in low compliance under targeted testing models: parent reluctance to have their child undergo the procedure; physician perception that lead poisoning is not a problem; lack of follow-through getting children to a lab; and a convenient infrastructure for data submission. (See *Overcoming barriers with education and awareness.*) Challenges specific to

universal testing include mandated insurance coverage, the cost-benefit ratio of targeted vs. universal screening, and political will.

> "Roadblock number one: every insurance company would have to pay for it, with no parent co-pay. The second roadblock is convincing pediatricians to order it, because a lot still don't think lead is very high risk or they don't think it applies to their [patient] population. I think pediatricians could be brought around, especially if there is insurance coverage for it.... Another barrier is that you really need to do a venipuncture blood test."

Two respondents felt universal testing is ideal, but did not see it happening in their states. The two states with universal testing both had historically high rates of lead poisoning and high proportions of old housing stock. One of these states has had universal testing for decades; the other started universal testing as a pilot after modeling studies suggested the benefits of widespread detection outweighed the increased expense. The latter state experienced a perfect storm of conditions that led to the adoption of universal testing: the aforementioned empirical study, strong inter-departmental relationships, an active CLPPP coalition, and allowing point-of-care (POC) testing.

Although the transition to universal testing may seem daunting, once the system is in place, testing gradually becomes less of an issue. If all children of a certain age are tested, physicians are relieved of the burden of tracking which of their patients need a screening survey or need to be tested:

> "Surprisingly, there were a lot of providers and managed care organizations that were relatively happy to see universal testing happen. Although people don't say it explicitly, it's so much easier if you don't have to worry about whether they're in the high risk zip code, out of the zip code, if they've moved, where they lived before, et cetera."

It must be noted that even the two so-called universal states do not achieve universal testing. Rates did increase, but plateaued at about 50% and 70% of all children. Geographic pockets with relatively low testing also still exist.

Pushback regarding cost was seen as less about absolute cost and more about the best use of public health dollars. One respondent from a state with universal testing felt it is important to continually assess whether CLPPPs allocate resources to maximum advantage:

> "[Initially] people had concerns about the cost and the follow-up. I would say it was less about the cost, and most about efficiency. People asked a totally valid question: If you have X dollars, do you want to spend it testing a very large number of kids, or do you want to focus and increase the number of kids in those higher risk areas? It's a very good thing for departments to look at their lead testing strategies and think about where the biggest equity bang for the buck is. [What is the] best approach in terms of healthcare dollars, in terms of doing investigations, in terms of preventive actions, and in terms of health equity? That's a challenging order."

Informants familiar with Hawai'i's circumstances felt universal testing was feasible. It would require sound data to justify the need, mandated insurance coverage, getting electronic medical records (EMR) systems in smaller medical offices, an effective public education campaign, and political will:

> "It's not often that Hawai'i actually gets out in front and is on the cutting edge. But being a small state has its advantages. In the same way that we have been a leader in COVID, this may be a place where there's an opportunity for us to be a leader. So yes, we could do this."

Benefits of a Robust Reporting and Monitoring Infrastructure

Robust reporting and monitoring systems are key for successful CLPPP implementation. CLPPP requires more comprehensive and sophisticated data systems to connect or the integration of lead surveillance data with other databases such as case management and housing abatement. For these systems to be effective, reporting compliance—from physicians to labs to case management—must be enforced. When done well, this allows for accountability and transparency at all levels.

The soup to nuts system. One state stood out as having an exemplary database built to align with state law that includes clinical laboratory licensing, lead surveillance, case management, and housing information, and also generates user reports. As this state's respondent pointed out, such a comprehensive and tailored data system requires political will and funding investments not only to build, but also for ongoing improvements.

> "When an elevated confirmed venous sample result comes through, [the system] opens a case on the child. We have hundreds of users in probably 60 to 80 different health departments across the state that are providing direct services to families. They document all their activity in the system. We try to make it easy for our investigators to document their activity, generate their reports and letters from the system, and do all the work they need to do. The new system tells you all your assigned investigations, and then you can look individually at each one of those and see where it's at.
>
> [The system] is tailored to [our state's] law, so for us it works perfectly. We can run reports to see how well we're doing it, responding to families; it is all in the system. We manage and monitor our labs through the system as well…. So the lab reporting, the home visiting, the investigation work, the orders, the notices of [housing] non-compliance, lifting the orders off the properties once they have been fixed—that's all managed in the system down to the legal documents. Everything is saved there.
>
> With our system, it's just hard to not do the work now because someone's going to see, including the highest levels of our leadership within our agency. So, it's a lot more transparent, it's a lot more manageable. Just being able to track everything in an online system, I don't know how to do without it at this point…. But it took us a long time to get there. We've had help since 2009, but it really didn't do everything we needed

it to until 2012. We have an IT project almost every year where we do enhancements and upgrades and bug fixes and get more reports, more letters that we can generate from the system to make it as good as possible for our users."

Data infrastructure that allows for feedback loops. Data systems should also provide feedback that helps doctors monitor their own screening of patients. This "feedback loop" is key to identifying children who fall through the cracks (e.g., those not receiving screening surveys or ordered tests, and where timely follow-up is needed). Integrating lead screening reminders and test results into physicians' own electronic medical record systems is seen as an effective and easy way to help providers do their part:

"We're on auto pilot [with our] electronic medical records. Every time a child comes in for any visit—urgent care or well-check—[the system checks] whether they need any vaccines, their BMI checked. Lead will come up if they haven't had their lead level where they were supposed to. The EMR triggers when the child comes in, [so we can say] hey, you're here for a wart, but while you're here, why don't you go to the lab and get your lead level? "

Integrating physicians' EMR systems with the lead surveillance system can enhance surveillance success by engaging providers and incentivizing consistent screening. Several respondents either wished for these linkages or expressed satisfaction with having them in place. For example:

"[You need to] know whether that child went through the system, got blood drawn, and the result came back to you. You would see the result if it came back, but there wasn't any flag that says you ordered this and it was never done until the child comes back to you next time and you see there's no result."

"The more you can integrate the EMR and clinical decision support, the better. Make it easier for the providers to be reminded on an ongoing basis of the need to do that lead test and regular feedback on how they're doing that. We are looking very seriously at developing focused reports back to providers on how they are doing individually [in terms of screening rates]. That I think is a very strong incentive."

Importance of data quality. Regardless of what data system is in place, getting complete and accurate surveillance data into these systems often presents challenges. Data quality issues include missing data, submission of test results conducted in physician offices, and the accuracy of the tests themselves.

All states report that physicians and labs may simply not submit test data, fail to submit in a timely manner, or submit incomplete information. It is possible to fix some of these gaps, but this work is staff intensive. One state publishes the rates of missing fields (i.e., lead level, age, address, ethnicity, and assigns staff to track down incomplete data). Another requires labs to contact physicians within a short time window and obtain complete records for patients with missing addresses.

Although point-of-care (POC) testing is a boon for parents, this method presents reporting burdens for physicians and health departments. Since the freestanding test devices lack connectivity, physician offices must submit data via direct online access to the surveillance system, populate data spreadsheets to forward to the surveillance office, or simply fax individual reports. As a result, delayed or missing reporting is common. One state estimated that 30% of their data are from POC testing; handling this volume of manual data entry requires dedicated staff.

> "Point-of-care testing is a real advantage for patients. [But] the lack of a simple electronic interface between the point-of-care test and the electronic record is a real obstacle to facilitating quick reporting and feedback to the provider. This has to do with instrument design and incentives, both at the FDA and at the CDC and in the marketplace, to get electronic reporting about the point-of-care testing integrated."

Finally, there is concern about the accuracy of certain testing equipment and/or capillary draws. POC capillary testing is not highly accurate. One state compared capillary results with confirmatory venous levels and found false positive rates as high as 70%. Part of this inaccuracy was determined to be the result of improper washing of children's fingers before collection. Another state regulates the kind of test equipment labs can use and requires venous confirmation of all elevated capillary tests.

The Importance of Housing Abatement

Three states spoke proudly of their success in reducing lead paint exposure. As mentioned earlier, this was seen as the main reason EBLLs have dropped nationwide. The informants saw abatement as the most important strategy to pursue:

> "If I had to pick one goal, I'd be screening properties instead of kids. Get everyone on board about getting their properties de-leaded."

> "Some really, really bad houses have either been demolished or renovated.... Money to target neighborhoods with that historic burden to have lead control work done is the best thing we could do to really lower the EBLL rate."

> "I think I could speak for every single person that works in Childhood Lead Poisoning. We'd all rather see prevention be the focus and make sure kids don't get poisoned in the first place through very strong housing laws."

Success came from a combination of strong regulations, public posting of affected properties, adequate abatement funding, and collaboration with state housing departments. These states require owners and landlords to abate paint hazards. Failure to comply can result in orders to vacate the property. Public postings help prospective renters and buyers avoid tainted properties. In some states, these lists highlight at-risk homes; in at least one state the listing is of homes deemed to be safe. While abatement is often triggered as a part of an EBLL case investigation, at least one state takes a preventive approach, requiring abatement of all pre-1978 properties with a resident child under age 16.

Since abatement can be an overwhelming burden for owners, these states combine multiple sources of financial support. To assist homeowners from different economic strata, one state uses HUD, Medicaid, or state tax credits, depending on homeowner eligibility. (Also see the section *Innovative Use of Funds*.) One informant noted that homeowners may overestimate the cost of abatement, even though the cost can be a crisis for certain properties:

> "Sometimes people think [abatement] is super expensive, and it's really not. Negative connotations and perceptions can stop people from doing the right thing."

Innovative Use of Funds

A number of respondents discussed their innovative use of various funding streams to support their CLPPPs rather than solely depending on CDC or even state funding. Examples include the use of Medicaid and Title V funds to support and improve surveillance data systems and case management, and the use of administrative CHIP funds for lead abatement in homes with qualifying children. Ideas about braiding funds might be especially useful for Hawai'i.

> "Medicaid also supports our systems. Like the help system we have, they've paid for almost all the work on that. I'm sure IT work is expensive in Hawai'i as it is here, and we spend a lot of money on that, hundreds of thousands of dollars a year. Without Medicaid, we would most likely be using the CDC's [health surveillance software].... We [also] negotiate with Medicaid to be reimbursed for Medicaid-eligible children for the [case investigation] work that we do. We bill all the costs of those investigations to Medicaid. So it's a great source of funding."

> "We have one innovative program here…, our Medicaid CHIP program for lead abatement, which uses the administrative component of CHIP funds under a health services initiative to fund lead abatement for families who are either enrolled in or eligible for CHIP here, which is probably about 40% of kids."

Benefits of Strong Policies

Successful CLPPPs are supported by strong and comprehensive laws. State statutes can empower lead prevention programs and/or affiliated agencies with a range of authority, from the timing and frequency of screening and testing to reporting compliance, approval, and oversight of laboratory facilities; from case management procedures and timelines to oversight of lead abatement and enforcement of orders to vacate properties.

Examples of strong policies include the following: One state places prominent statements on its website and parent screening education materials that lead screening is "the law". This state also holds testing labs responsible for correcting missing data. One state regulates the types of acceptable test equipment and environmental investigations cannot start before an elevated blood sample is confirmed using approved

devices. Another state requires managed care contractors to document sufficiently high testing rates:

> "Meeting lead measures is part of [our state's] values-based purchasing criteria for the MCOs. They have a vested financial interest in making sure lead testing rates are as high as possible."

As mentioned in the section above, strong housing statutes induce owners to undertake the task of abatement.

> "I believe our law is probably one of the more stringent ones.... As far as enforcement—the teeth of the law—I know that varies greatly from one state to the next.... Something that may be unique about [our state] is that we issue orders to vacate properties and then the property owner is responsible to vacate them.... We actually put all our properties that are marked for notice of noncompliance order to vacate on the web, on the [state] Public Health Data Warehouse. We put that information out to the public. It updates every night. So if a property comes on the list, it will show up, or if it comes off the list. [It] has interactive maps and all that good stuff."

The most stringent housing statutes are preventative in nature, as described by one informant:

> "The statute in a nutshell is primarily preventative, which means that if a property was built before 1978 and there's a child under 16 in residence, that property, regardless of whether it's a rental property or an owner-occupied property, and regardless of what the child's blood level is, needs to be in compliance with the law. So it's not predicated upon an inspection being done and it's not predicated upon a child being exposed. It doesn't matter whether it's an owner-occupied or rental property. It's a very strong statute that's been in effect since 1971."

Overcoming Barriers with Education and Awareness

Consistent with other local work that addresses childhood lead poisoning perspectives in Hawai'i,[26] respondents across states face a number of barriers to testing and screening children.

Overcoming provider-level barriers. At the provider level, there is sometimes a perception that lead poisoning is no longer a problem in their area. There is limited time to address lead screening during patient exams, especially if the visit is timed with other screening and vaccine protocols. Family practitioners may be less aware of lead issues as compared to pediatricians, leading to fewer testing orders. Some physicians feel screening is not worth their time given low reimbursement rates for this service.

Exploring and identifying the specific barriers in each state is key to generating thoughtful and purposeful provider education and outreach strategies to overcome barriers. These might include direct follow-up with providers, outreach and

presentations to managed care groups, and partnering with professional associations at the local level to share messaging and education.

> "We do need a lot more education.... For example, a lot of people believe that because we are a fairly new state, meaning a lot of our population growth has happened in the last few years…, there is this misconception, 'Oh, that's just an East Coast problem. That's just a New York or Chicago problem. All of our houses are new here. There's no old houses."

> "[We are] looking at the best way to communicate with physicians. Whether it's through smaller groups utilizing the MCOs to do some education, utilizing their associations and then, just when we have them on the phone, hopefully trying to educate them and their staff."

> "The message coming from their peers is always going to be better received. So we really try to work with the medical community on anything related to the medical world because we're not from that world, we're from public health. Us telling them what to do just doesn't seem right from my perspective, let alone theirs. That's why we have them involved in every single thing related to testing, because we want that buy-in through their professional organization."

Overcoming parent-level barriers. Parents are often unwilling to have their child tested for lead. Reasons include not understanding the consequences of lead poisoning, not wanting to put their young child through a needle procedure (i.e., especially when the visit is timed with vaccinations), and not having the time or resources to travel to a lab for testing when the testing lab is not conveniently located. If providers take the time, a simple pitch may be an effective way to reduce parents' concerns. For example:

> "What I would be saying to the parents is, 'Your child is at an age where we know they put their hands and their toys in their mouths. We know that there's a lot of lead in our environment in many different places…. and it's very, very hard to identify the risk on an individual basis. It's inconvenient to get a blood test on your child, but it lets us know whether or not your child is getting too much lead. And if he or she is, that can cause permanent brain damage, decrease their IQ, and have health impacts for the rest of their lives. So it's worth it to get a blood test now to know. Chances are it's fine and then you'll know that you don't need to worry about it. If it's not fine, we will work with you to figure out where it's coming from and to get that out of your child's environment so that no more damage happens.' Period. And I think that minute would be a much better use of time and resources than getting somebody to answer this [screening questionnaire]."

Another strategy includes engaging with the early childhood education (ECE) community as natural partners, given their expertise in brain development and access to parents of young children. With direction from licensing divisions, ECE providers can educate parents on the importance of and encourage screening and, in essence, "do the work" for CLPPP Programs.

"We pick up the most lead poisoned children in July, August, September. I think kids are… getting screened because they're trying to enroll in daycare and we're picking up these kids…. It's just a good relationship with EEC, our licensing and our daycare providers. I do traveling road shows to daycare providers and licensors to say, this is why it's so important, and they do that work for us—before they enroll those kids, they check to make sure that they've been screened. What I say to them is, if you identify a pediatrician or a provider that isn't screening multiple kids for your daycare because they tend to be in the same area, let me know and I'll do outreach to that provider and explain to them why it's really important that they screen their kids."

Partnerships and Coalitions Strengthen Implementation

Partnerships, collaboration, and coalition development are key to successfully implementing and evolving Childhood Lead Poisoning Prevention Programs (CLPPPs).

Working across agencies. Respondents discussed several examples of how they have worked across state agencies and divisions to leverage resources and expand program implementation capacity. As discussed above, inter-agency partnerships with ECE licensing divisions may lead to increased parental awareness and screening of children. The preschool enrollment process could be leveraged as an opportunity to ensure children who might have otherwise fallen through the cracks at earlier ages get screened. Many states, including Hawai'i, include lead screening in the health history collected for preschool enrollment. CLPPPs could work more purposefully and in partnership with ECE licensing divisions and providers in their state to make sure lead screening is actually *required*, and compliance with testing is enforced as a part of enrollment. Besides providing an additional touchpoint to screen children, the strategy of requiring and enforcing lead screening compliance as a part of ECE enrollment also takes some of the burden of convincing hesitant parents off of physicians.

"It's not just the lead program and it's not just the pediatricians, but we're also saying for those other agencies or nonprofits that are somehow influenced by or dealing with childhood health, wellness, [and] education [that they] are basically functioning as a check for us. To enroll in daycare, they need to see that that child's been screened."

"Lead tests in [our state] are a prerequisite for admission to a public licensed daycare, pre-K, kindergarten, or first grade, although enforcement is challenging. In many cases, we know there are kids who have not been tested before age six who are admitted when they should not be. That and engagement with the state department of education to reinforce that message—that's something we also worked very hard on."

Collaborating with HUD programs to develop housing registries is another example of inter-agency collaboration:

"We have another little fit that works with our HUD grantees in [our state], where HUD grantees are required as part of their grant to provide proof of a registry of all the homes they helped de-lead. We have a lead safe registry. So [HUD] basically works with us for the lead safe registry and we publish [it]. Again, it's that relationship,

trying to figure out those places where you can naturally build those bridges and help other people do your work is really helpful."

Another state described coordinating with the Medicaid office to identify Medicaid-enrolled children. Should a Medicaid child not appear in the lead surveillance database, physicians and/or parents could then be reminded to obtain the needed testing.

Professional partnerships. The healthcare provider voice in the development of procedures and changes to CLPPPs is especially critical to securing their buy-in for implementation. However, as one respondent cautions, professional silos should also be avoided; partnerships and coalitions should include representation from the health, housing, environmental protection, and early childhood fields.

"So, it's really been engagement over time with the providers that's made the big difference. We have a representative from the American Academy of Pediatrics on our lead poisoning commission."

"You need to have a coalition with your pediatric providers and your family healthcare providers. You need to talk to them from the beginning and you need to make sure that they care about lead poisoning because if this isn't on their radar…it's not going to happen…. I would talk to them first about [whether] they believe in this. Do they think this is necessary? And if so, then how would you structure things to get that? What do they think the regulation should look like? If you want to make the health argument first, you get the white paper with the pediatricians and the folks on board about why it's a concern. And then you present that to the other stakeholders with a strong public health argument to the insurance providers, the parents, early education and childcare [providers], and other family advocates to say, 'This makes a difference. This is a really important issue.'"

"If there are others, not [just] healthcare providers, that you can bring along in the beginning who might have practical input about what this would look like and what folks can do, you should include them. It's those silos..., you've got people who are only in the environmental piece and then you've got the people [who] are only in the health piece, and it's really important to bring them together for that practical approach to figure out what the best options are."

Partnerships and coalitions are key to building political will. Finally, investments in CLPPPs, whether to build data systems, change guidelines, or shift to universal screening, require political will and leadership. Garnering political will often depends on coalition building to advocate for issues and build the case for expanded efforts and funding.

"Yes, we could do [universal testing]. We could decide it statewide. It would take some political will to do. Unfortunately, I think people are going to say, 'Yeah, we'll pay for it if you prove to us that it's a problem, but we don't know that it's a problem.'"

"Starting with the water crisis, we had a lot of interest in lead in our state from our state legislature, from our governors. Our newest governor has really made children's

health, and childhood lead poisoning specifically, a huge focus for his administration. So we have a lot of funding that we've never had in the past coming right from state income tax dollars and other sources. There's a lot of attention on everything lead...and our governor really tasked us to all work together. He's put out a series of recommendations for us all to work together on. In the past it was just, 'the Department of Health will figure out all this stuff'. Now he's saying, 'everyone's required to work on this, and you better report back that…you have a plan.'"

Recommendations

The focus of this evaluation was to assess the effectiveness of Hawai'i's current method for determining target high-risk geographic areas and propose alternative approaches that might be preferable. The current method identified 55 high-risk zip codes (59.1% of all Hawai'i zip codes). Based on 2016-2020 lead surveillance data, 57.3% of children with known EBLLs lived in these target zip codes. Several issues may be raised about the existing method. First, the ACS estimates and EBLL rates used to compute composite risk scores were outdated; at a minimum, risk scores should be updated using the most current data. Second, composite scores were computed at the level of 35 PCSAs. Creating risk scores for each census tract is standard practice and offers greater precision in differentiating geographic locales. Third, the current target method may not have the intended effect on clinical practice. If the target method is effective, testing rates should be systematically higher in targeted zip codes. However, such results were not observed in Hawai'i (see Figures 1a and 1b).

Four alternate targeted geography methods using different risk factors and census tract-level data were proposed. The alternate methods either did not capture the majority of the children with known EBLLs or identified a large number of high-risk areas, which would require screening in most of the geographic locations in the state. For example, when high-risk areas were defined based on a composite score of old housing, poverty, immigration status, a language other than English spoken at home, and adults with less than a high school education (Method 3, Table 3), only 38.6% of children with EBLLs lived in high-risk census tracts, which overlapped with 43 zip codes. When high-risk census tracts were defined as those with at least 27% pre-1980 housing (Method S2, Table 10), this method captured the vast majority of children with EBLLs (89.9%). However, at the same time, most areas in Hawai'i (80.3% of all zip codes) were identified as high risk. When so much of the state is deemed to be high risk, it would be a relatively small step to instead employ universal testing.

None of the methods tested were fully satisfactory. Possible reasons for this include: 1) risk factors used in the alternative methods were not the primary sources of lead exposure for children in Hawai'i; 2) children living in high-risk areas had not been screened or had missing or invalid addresses in the HI-CLPPP lead surveillance database; and 3) risk factors measured at the level of the census tract may not capture individual-level risk. In regard to the first reason, although lead paint in older housing may still be the primary source of lead exposure, other sources[27] such as magnets and

fishing sinkers may be common. Since these sources are not associated with geographic locations, a risk system targeting locations might not help identify children with EBLLs.

With existing data, we could not pinpoint the reason for the lack of a strong association between high-risk areas and children with EBLLs. It could be due to the ineffectiveness of targeted screening by geographic locations, or because children living in high-risk areas had not been screened or had missing or invalid addresses in the HI-CLPPP lead surveillance database. High quality testing data of all children in the state are necessary to rule out the latter and help identify whether children living in high-risk geographic areas do indeed tend to have elevated blood lead levels.

Recommendations based on the evaluation results are provided below.

- **Consider universal testing.**

Given the inherent limits of targeting methods and the consequences of missing even one exposed child, universal testing merits serious consideration. Other states have successfully transitioned to universal testing, and it is widely seen as the most desirable approach.

Given that Hawai‘i is a small state and 26% of its young children are already tested,[28] universal testing seems to be an achievable goal. Several things would need to be in place to enable this change: a) strong, broadly-based professional and community support; b) a data-based justification; c) funding and transition plans, d) mandated insurance coverage, and e) good advocacy to shepherd needed policy changes through the legislature. If point-of-care (POC) capillary testing is encouraged to reduce parent resistance and physician burden, a more accurate venous follow-up confirmation should be required for elevated screens. Small practices could be offered grants to purchase POC test equipment. HI-CLPPP could consult with states that have made the transition to get feedback on building political will, successful phase-in strategies, and lessons learned. While universal testing is a desirable approach, we need to keep in mind that even states with long-term universal screening/testing have not been successful in testing all children.

A pilot of several years duration could be done to assess the feasibility and acceptance of universal testing. This would also establish a sound baseline of test data that could serve multiple purposes. First, several years of universal testing data—including source identification—would give a definitive answer about the scope and causes of lead exposure in the state. These data would be invaluable in improving preventive education and risk abatement strategies. Second, baseline data would confirm whether lead exposure is geographically based. If exposure is strongly localized, target risk screening methods may be warranted. If pilot procedures require the administration and submission of the lead exposure risk survey (perhaps with a sample of parents), this would be an ideal way to validate the survey for possible future use. It may also be possible to design a prevalence study that answers these same questions using a representative sample of young children.

- **If a target risk system is desired, modify the current high-risk zip code method. Specifically, replace the current method with the proposed method S12. Periodically adjust the system as needed to reflect changing demographics and lead sources.**

Of the alternate methods tested, Method S12 using poverty, old housing, and children's blood lead test results was the most promising. This method identified the highest percentage of children with EBLLs among all children under age six living in the high-risk census tracts (see Table 13). Among the three composite risk score methods (S10-12), S12 identified the highest percentage of children with EBLLs among those tested even though the testing rate was the lowest.

Hawai'i can consider replacing the current zip code method with S12 using a census tract-level analysis, which presents the risk distribution across geographic communities at a finer level. This would require changes to current HI-CLPPP materials and educating physicians and parents about newly defined high-risk zip codes.

The state should also periodically update risk score calculations to reflect changes that could affect the designation of high-risk zip codes. For example, more recent data should be used to capture changes in housing developments, population characteristics, and children's blood lead test results in the HI-CLPPP lead surveillance database. Finally, if the primary sources of lead exposure in our state change over time, the risk system should be adjusted accordingly. Changes could include factors used to determine each area's composite risk score and/or specific items on the screening survey.

- **Improve the quality of lead surveillance data.**

The HI-CLPPP database had a fairly high rate of missing, incomplete, or incorrect information. While addresses were the most problematic field, cases with reported lead levels instead of exact scores (e.g., < 10 mcg/dL) were also an issue. Strategies used in other states to improve data accuracy and quality include dedicating agency staff to data cleaning and collecting POC test results, and statutes (backed by fines) that require clinical labs to obtain missing information from physicians within a short time period.

- **Take steps to increase screening and testing rates.**

Since federal law requires mandatory blood lead screening tests for all children receiving Medicaid; efforts to increase screening rates could start with this population. A data sharing agreement with Medicaid would allow tracking and enforcement of screening for all mandated children. Financial incentives for reaching targeted testing rates could be included in MedQUEST contracts and/or all insurance companies could be required to publish screening and testing rates. Physician education and support has been effective in some states. This includes a) publishing area-based testing and EBLL rates, b) identifying and providing personalized coaching to physicians who are not referring children as expected, and c) partnering with the American Academy of Pediatrics and other professional associations to prioritize peer education and awareness. Early childhood educators are also strong allies for parent education. Childcare, pre-K and

kindergarten enrollment provides a natural gateway for checking children's testing status. Consider lobbying to make lead testing a requirement for enrolling in early childhood programs.

Other strategies for increasing testing rates would incur greater costs. One local managed care organization expects universal testing by their physicians and provides automated screening reminders and test results through their electronic medical records system. A possible reason for Hawai'i's generally low testing rates is lack of access to onsite testing.[29] Grants to small practices could support the purchase of POC testing equipment. Other incentives could be developed to encourage more clinical labs to open in underserved areas and/or co-locate at medical centers or sites with multiple group practices.

- **Improve case management infrastructure.**

Hawai'i lacks good data on lead exposure sources. The Hawai'i State Department of Health has recently established a case management position to oversee the follow-up of children with EBLLs. Resources and/or additional positions should be provided as needed to ensure all cases are investigated and resolved in a timely manner. Other states speak highly of the advantages of good case management data systems for improving clinical care and abatement activities. Integrating source data with the surveillance database would lead to a better understanding of the varied sources of exposure and their possible geographic distribution.

Citations and Endnotes

[1] Instead of using the 2016-2020 ACS data that would match the time period of HI-CLPPP data, we used data of earlier years because 2016-2020 ACS five-year estimates were not released at the time of analysis.
[2] Centers for Disease Control and Prevention. (2021). *Prevent children's exposure to lead*. Retrieved from https://www.cdc.gov/nceh/features/leadpoisoning/index.html
[3] Hawai'i recommends testing for blood lead upon arrival to the United States and Well Child Visits for immigrants (including international adoptees). Hawai'i also recommends testing blood lead for refugee children age 6 months to 16 years and repeating blood lead testing 3 to 6 months after refugee children age 6 months to 6 years are placed in permanent residences. Hawai'i State Department of Health. (2021). *Hawai'i childhood lead poisoning prevention*. Retrieved from https://health.hawaii.gov/cshcn/childhood-lead-poisoning-prevention/health-care-providers/
[4] Per the HI-CLPPP staff, the development of the zip code maps and questionnaire began in 2017 but were not finalized until 2018.
[5] In the early 1990s, Primary Care Service Areas (PCSA) were selected to describe the delivery of primary health services in the state of Hawai'i with stakeholder inputs. The purpose of clustering neighborhoods into these PCSA is to provide information below the county or island level with demarcation between adjacent neighborhoods.
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[9] The numerator was the unduplicated head count of children who were under age six and had least one valid blood lead test during the time window of 2016 through 2020. The denominator was the estimated unduplicated head count of children who were under age six at any point from 2015 through 2019. See the Testing Rate section of the Technical Report for details.
[10] Kemper, A.R., & Clark, S.J. (2005). Physician barriers to lead testing of Medicaid-enrolled children. *Ambulatory Pediatrics*, *5*(5), 290-293.
[11] Centers for Disease Control and Prevention. (2021b). *Sources of lead exposure*. Retrieved from https://www.cdc.gov/nceh/lead/prevention/sources/paint.htm
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[13] Florida first identified a high-risk census block group with ≥ 27% pre-1950 housing or ≥ 74% pre-1970 housing and then identified high-risk zip codes that contained one or more high-risk census tracts. Texas considered a census tract high risk if the percentage of children ages 1-2 years with a BLL ≥ 5 mcg/dL was ≥ 3% among those tested in 2016, or the percentage of housing built before 1950 was ≥ 27%.
[14] Centers for Disease Control and Prevention. (2021a). *Populations at higher risk*. Retrieved from https://www.cdc.gov/nceh/lead/prevention/populations.htm
[15] For each census tract, we computed a composite risk score by adding the standardized scores for all risk factors.
[16] Based on the distribution of the composite score, states used different cutoffs to determine high-risk zip codes. For example, Hawai'i defined high-risk areas as those with a positive sum of the standardized risk scores, whereas Colorado defined high-risk areas as the top 30% of the distribution, and Arizona defined high-risk census tracts in the top two quartiles with a risk score greater than or equal to 0.41.
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[28] The percentage of children under age six tested was calculated using the number of children under six in the analytical sample from the HI-CLPPP lead surveillance database (i.e., 45,543) divided by the estimated number of children under six at any point between 2015 and 2019 (i.e., 175,129, estimated based on 2011-2015, 2012-2016, 2013-2017, 2014-2018, and 2015-2019 ACS five-year estimates, Table B17024). Since records with missing or invalid addresses or missing blood lead test results were excluded from the analytical sample, the percentage calculated here was an underestimate of the actual percentage of children under six tested in the state.
[29] Kemper, A.R., & Clark, S.J. (2005). Physician barriers to lead testing of Medicaid-enrolled children. *Ambulatory Pediatrics*, 5(5), 290-293.

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