Stepwise Proportional Weighting Algorithm for Single-Race Population Estimation Using Hawai‘i Census Data

Masako Matsunaga PhD; Kyle M. Ishikawa MS; Chathura Siriwardhana PhD;
Hyeong Jun Ahn PhD; John J. Chen PhD

Abstract

Many health and health disparities studies require population prevalence information of various race groups, but the estimation of single-race population sizes using the US Census data has been challenging. For each Census race group, Census only provides the counts of those reported being single race ("race alone") and those reported of that specific race regardless of whether the individuals were multiracial or not ("race alone or in (any) combination"). The issue of how to classify Census multiracial individuals is especially important for the state of Hawai‘i due to its large multiracial population. The current study developed the Stepwise Proportional Weighting Algorithm (SPWA) for single-race population estimation using US Census data for major race groups in the Census and their nested detailed races. Additionally, given that "partial Native Hawaiian" has often been treated as "Native Hawaiian" in health disparities studies in Hawai‘i, the algorithm can also adjust for the unique partial Native Hawaiian race categorization. This paper describes the estimation process with the SPWA and demonstrates its ability to estimate single-races for the 5 most common race groups in Hawai‘i. This new methodology addresses an important concern regarding how to classify multiracial individuals to strengthen health and health disparities research in Hawai‘i.

Keywords

population estimates, algorithm, Censuses, Hawaii, racial group, Native Hawaiians, Public Health

Abbreviations

AIAN = American Indian and Alaskan Native
API = Asian and Pacific Islander
NCHS = National Center for Health Statistics
NH = Native Hawaiian
NHOPI = Native Hawaiian or Pacific Islander
POL = Polynesian
SEER = Surveillance, Epidemiology, and End Results Program
SOR = Some Other Race
SPWA = Stepwise Proportional Weighting Algorithm

Introduction

Hawai‘i has the highest percentage of multiracial residents among the 50 states in the United States (US). According to Hawai‘i Census data, individuals who self-identified with more than 1 race accounted for 21.4% of the population in 2000 and 23.6% of the population in 2010, which is substantially higher than the national averages (2.4% and 2.9%, respectively).[1]

In both the 2000 and 2010 Censuses, the US Census Bureau collected and tabulated race and ethnicity data based on the *Revisions to the Standards for the Classification of Federal Data on Race and Ethnicity Office of Management and Budget*, issued in 1997. [2] The revisions increased federal major race categories from 4 [White, Black or African American (Black), American Indian and Alaska Native (AIAN), and Asian and Pacific Islander (API)] to 5 [White, Black, AIAN, Asian, and Native Hawaiian or Other Pacific Islander (NHOPI)]. In addition, it allowed the Census Bureau to use a sixth category – Some Other Race (SOR). The revisions also required federal data collection programs to allow respondents to select more than 1 race category when responding to a query on their racial identity.[3]

Since 2000, the US Census Bureau started to report counts of "*race alone*" and "*race alone or in (any) combination*" for the major races and their nested detailed races in compliance with the revised 1997 standards.[4] The updated reporting guidelines created an analytical challenge for determining and reporting race-specific statistics, such as disease prevalence by race group.[2] To meet this challenge, the regression bridging method was developed to derive single-race population estimates for the 4 major races,[5,6] which has been widely used in surveillance systems, such as the National Center for Health Statistics (NCHS) National Vital Statistics System[7] and the Surveillance, Epidemiology, and End Results Program (SEER) of the National Cancer Institute.[8] Due to concerns about the undercounted Native Hawaiian population in past Censuses, the Native Hawaiian estimates reported by SEER were adjusted by increasing API count and decreasing the White count.[8] However, SEER only provides estimates for the 6 major Census races and the methodology of estimation requires additional data external to the Census.

Several studies have determined single-race population estimates for the most common races in Hawai‘i,[9-13] such as White, Filipino, Japanese, Chinese, and Native Hawaiian (NH). However, there has not been a suitable method available for the population estimation for all common races in Hawai‘i. In addition, vital records and health surveys in Hawai‘i often categorize partial Native Hawaiians as NH. Thus, estimates for other race populations would need to be adjusted accordingly for this increased NH population estimate. A previous study proposed a proportional weighting approach allowing the single-race population estimates for the 5 most common races in Hawai‘i.[13] It determined weights for allocating multiracial individuals to individual single-race categories and obtained the single-race estimates by summing the count of single-race individuals and a proportion of the count of multiracial individuals. However, this approach did not take into consideration the nested structure of the Census races. As a result, population estimates for many of the detailed race groups in Hawai‘i could not be properly determined. The current study aims to expand the approach in a stepwise manner to account for the nested Census data structure (Stepwise Proportional Weighting Algorithm (SPWA)), with and without the adjustment for the count of partial NH. This paper describes the SPWA's estimation steps and demonstrates its utility with the estimation for the 5 most common racial groups in Hawai‘i. Lastly, the limitations and strengths of the SPWA are discussed.

Methods and Results

Hawai‘i Census Data

The current study utilized race data for Hawai‘i from the most recent decennial Census at the time of analysis (2010 Census).[14] **Figure 1** illustrates the nested structure of Census race data. The 6 Census major races (White, Black, AIAN, Asian, NHOPI, and SOR) were denoted as Level-1 races, using index *i*. The Census' detailed races under AIAN, Asian, and NHOPI were denoted as Level-2 races, using index *j*. The nested relationship between an *i-th* Level-1 race and a *j-th* Level-2 race was expressed using parentheses as *i(j)*. Detailed races under Level-2 races were denoted as Level-3 races, using index *k*. The nested relation of a *k-th* race of its upper-level races was expressed as *i(j(k))*. This system of indices and notations to denote nested races were used throughout. For instance, NH, a Level-3 race under Level-2 Polynesian (*POL*), which was under Level-1 NHOPI, was denoted as *NHOPI(POL(NH))*.

Census data provided both counts of "*race alone*" and "*race alone or in (any) combination*" for each race unless the actual count was less than 100 in which case a missing value was reported. The data also included the counts of "*Two or More*

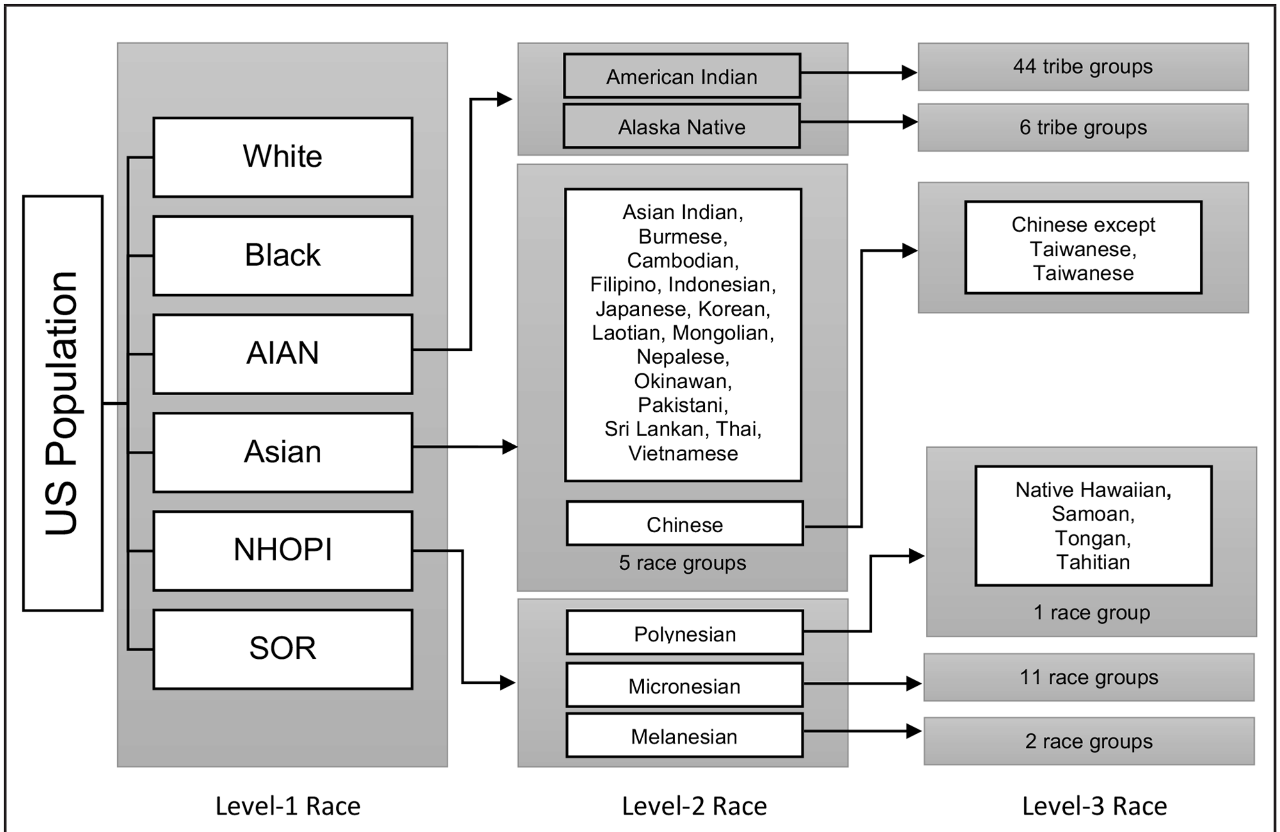

Figure 1. US 2010 Census Population Structure, Highlighting Race Groups for Single-Race Population Estimation for Hawai‘i[a]

AIAN = American Indian and Alaska Native. NHOPI = Native Hawaiian and Other Pacific Islander. SOR = Some Other Races.

[a] Race groups in the white boxes were estimated. Estimates for other race groups in the dark shading were not obtained due to the lack of data required for the estimation.

Races," which were the numbers of multiracial individuals associated with the major races.[4] In this paper, the counts of "*race alone*" and "*race alone or in (any) combination*" were referred to as *alone* counts and *combination* counts, respectively. The "*Two or More Races*" count was referred to as the *multiracial* count for Level-1 races. After excluding races with missing alone counts, the Hawai'i Census data included *alone* and *combination* counts for 31 common races, which are shown in the white boxes of **Figure 1**.

Proportional Weighting Approach

The proportional weighting approach uses *alone, combination*, and *multiracial* counts to obtain single-race population estimates for the 5 most common races in Hawai'i (White, Filipino, Japanese, Chinese, and NH).[13] For a given race *i*, the *difference* count, denoted as T_i^{2+}, is the difference between the *alone* count (T_i^1) and the *combination* count (T_i^2) (Equation 1), representing the count of multiracial individuals associated with race *i*. The total *multiracial* count for all races, denoted as *M*, is the total population count minus the sum of the total alone count (Equation 2). The *weight* (w_i) for race *i* is obtained by dividing T_i^{2+} by the sum of all the *difference* counts (Equation 3). The *single-race estimate* for race *i* (T_i) is calculated by adding a fraction of the *multiracial* count (*M*), as determined by w_i, to the *alone* count of race *i* (Equation 4).

$$T_i^{2+} = T_i^2 - T_i^1 \quad (1)$$

$$M = T - \sum_{i=1}^{I} T_i \quad (2)$$

$$w_i = \frac{T_i^{2+}}{\sum_{i=1}^{I} T_i^{2+}} \quad (3)$$

$$T_i = T_i^1 + (M \times w_i) \quad (4)$$

where T_i^1 is the *alone* count,

T_i^2 is the *combination* count,

T_i^{2+} is the *difference* count,

T is the total population count,

w_i is the *weight* for multiracial individuals,

M is the *multiracial* count,

and T_i is the single-race population estimate for race *i.*

The Stepwise Proportional Weighting Algorithm (SPWA)

Estimation without Adjustment for Multiracial Native Hawaiians

To account for the nested structure of the Census race categories, the SPWA estimated single-race population size in a stepwise manner from Level-1 to Level-3 races (**Figure 1**). Equations 1-4 were used for the estimation of Level-1 races. The denominator for the *weight* was the sum of the *difference* counts for Level-1 races. The *multiracial* count (*M*) for Level-1 races was the "*Two or More Races*" count. For Level-2 races (*i(j)*) estimation, the algorithm was applied similarly (Equations 5-8). The *multiracial* count (M_i) was derived from the single-race estimates of the Level-1 races (Equation 6). For instance, the *multiracial* count for Level-2 races under *Asian* (M_{Asian}) was obtained by subtracting the sum of these races' alone counts from the single-race estimate of Asian. The denominator for the weight was the sum of the *difference* counts of these Level-2 races (Equation 7).

$$T_{i(j)}^{2+} = T_{i(j)}^2 - T_{i(j)}^1 \quad (5)$$

$$M_i = T_i - \sum_{j=1}^{J} T_{i(j)} \quad (6)$$

$$w_{i(j)} = \frac{T_{i(j)}^{2+}}{\sum_{j=1}^{J} T_{i(j)}^{2+}} \quad (7)$$

$$T_{i(j)} = T_{i(j)}^1 + \left(M_i \times w_{i(j)}\right) \quad (8)$$

where $T_{i(j)}^1$ is the *alone* count,

$T_{i(j)}^2$ is the *combination* count,

$T_{i(j)}^{2+}$ is the *difference* count,

$w_{i(j)}$ is the *weight* for multiracial individuals,

M_i is the *multiracial* count,

and $T_{i(j)}$ is the single-race population estimate for a race *i(j)*.

The Level-3 races under Polynesian and Chinese were estimated with similar steps.

Estimation with Adjustment for Multiracial Native Hawaiians

Under the NH adjustment, all partial NH were treated as NH, ie, using the *combination* count for NH as its adjusted estimate, which included both single-race NH and multiracial NH. As a result, estimates of the other races affected by this NH adjustment needed to be modified accordingly. First, the following adjustment elements at the 3 race levels were determined sequentially:

$$NH_{level3} = T^{2+}_{NHOPI(POL(NH))},$$

$$NH_{level2} = NH_{level3} - \left(T^{1}_{NHOPI(POL)} - \sum_{k=1}^{K} T^{1}_{NHOPI(POL(k))}\right),$$

$$NH_{level1} = NH_{level2} - \left(T^{1}_{NHOPI} - \sum_{j=1}^{J} T^{1}_{NHOPI(j)}\right),$$

where NH_{level3} is the *multiracial* NHs not included in the NH *alone* count,

NH_{level2} is the *multiracial* NHs not included in the Polynesian *alone* count,

NH_{level1} is the *multiracial* NHs not included in the NHOPI *alone* count.

Next, the *alone* and *difference* counts for NHOPI and Polynesian were adjusted. For the Level-1 races, the following equations were used.

$$T_i^{1\,adj} = \begin{cases} T_i^1 + NH_{level1} & \text{if } i = NHOPI \\ T_i^1 & \text{otherwise} \end{cases}$$

$$T_i^{2+\,adj} = \begin{cases} T_i^{2+} - NH_{level1} & \text{if } i = NHOPI \\ T_i^{2+} & \text{otherwise} \end{cases}$$

$$M^{adj} = T - \sum_{i=1}^{I} T_i^{1\,adj} - NH_{level1}$$

$$T_i^{adj} = T_i^{1\,adj} + M^{adj} \times w_i^{adj}$$

where $T_i^{1\,adj}$ is the adjusted alone count for a Level-1 race,

$T_i^{2+\,adj}$ is the adjusted difference count for a Level-1 race,

M^{adj} is the adjusted *multiracial* count for Level-1 races,

w_i^{adj} is the adjusted *weight* calculated with the adjusted *difference* counts,

and T_i^{adj} is the adjusted single-race estimate for race *i*.

The Level-2 and -3 race estimates could be adjusted similarly.

Sensitivity Analysis of the SPWA Estimates

The sensitivity of the SPWA estimates was assessed following a Monte Carlo simulation, by perturbing the calculated weights in the estimation.[15] For Level-1 race *i,* a random weight was generated uniformly from a range with lower and upper limits defined by a perturbation limit (*a*%), $[w_i(1 - a), w_i(1 + a)]$, where w_i is the original weight for race *i*. This sampled weight is denoted as $w^p_{i,a,s}$, where *s* is the *s-th* iteration, with , where n is the number of simulations. For a given *s*, due to the randomness of the perturbation, the summation of the sampled weights for the Level-1 races was likely not equal to 1. Therefore, these sampled weights were scaled at each iteration in order to constrain the summation to be 1, with the scaled weights denoted as $w'_{i,a,s}$. Next, $w'_{i,a,s}$ was used to calculate a perturbated Level-1 single-race estimate, $T_{i,a,s}$, as $T_{i,a,s} = T_i^1 + (M \times w'_{i,a,s})$. Accordingly, these perturbated single-race estimates for Level-1 races were then used to determine the single-race estimates for Level-2 and Level-3 races.

A custom value of 1000 was used as the number of simulations for the sensitivity analysis. The minimum and maximum values of the 1000 simulated estimates for each race was reported as the sensitivity interval for the estimate. The current study used custom values of 1% and 5% perturbation limits for the sensitivity analysis.

Illustration of the SPWA Single-race Population Estimates

The SPWA was utilized to derive the population estimates of the 5 most common race groups in Hawai‘i: White, Filipino, Japanese, Chinese and NH, with and without partial NH adjustment. All calculations were conducted with R version 4.2.0.[16]

Table 1 presents unadjusted and adjusted estimates and the sensitivity analysis results for these races. White had the largest estimate without adjustment, accounting for 31.7% of the Hawai‘i population (n = 1 360 301). Filipino was the second largest race group (18.0%), followed by Japanese (16.7%), NH (12.3%), and Chinese (7.6%). With the partial NH adjustment, NH estimate increased in rank from fourth to second among the 5 most common races, accounting for 21.3% of the total Hawai‘i population. White remained the largest race group, however, its percentage decreased to 28.3%. At the same time, the percentage for Filipino, Japanese, and Chinese decreased to 16.8%, 15.6%, and 6.4%, respectively.

Figure 2 shows the distributions of unadjusted and adjusted estimates generated with 1% and 5% weight perturbation limits. The distributions were found to be symmetric. Not surprisingly, the 5% sensitivity intervals were wider than those of the 1%, but both intervals were relatively narrow compared with the population estimates, indicating the stability of these single-race estimates. For example, the intervals for unadjusted White ranged from 430 485 to 432 754 for the 1% weight perturbation limit and from 425 960 to 437 377 for the 5% weight perturbation limit.

Table 1. Single-Race Population Estimates using the Stepwise Proportional Weighting Algorithm (SPWA) with and without Adjustment for Multiracial Native Hawaiians: Hawai‘i 2010 Census			
	SPWA Estimate (%[a])	**1%[b] Sensitivity Interval**	**5%[b] Sensitivity Interval**
Without Adjustment			
White	431 635 (31.7)	430 485, 432 754	425 960, 437 377
Filipino	244 730 (18.0)	243 936, 245 466	240 664, 248 936
Japanese	227 165 (16.7)	226 528, 227 793	223 896, 230 467
Native Hawaiian	166 944 (12.3)	165 953, 167 961	161 967, 172 145
Chinese	103 600 (7.6)	102 750, 104 324	99 212, 107 288
With Adjustment			
White	384 300 (28.3)	383 790, 384 790	381 818, 386 780
Native Hawaiian	289 970 (21.3)	- c	- c
Filipino	227 973 (16.8)	227 514, 228 382	225 782, 229 986
Japanese	212 422 (15.6)	212 012, 212 839	210 366, 214 387
Chinese	86 422 (6.4)	86 000, 86 835	84 121, 88 638

[a] Percentage of the total Hawai‘i 2010 Census population (n=1 360 301). [b] Percentage weight perturbation limit.
[c] With adjustment, all multiracial Native Hawaiians were treated as Native Hawaiians.

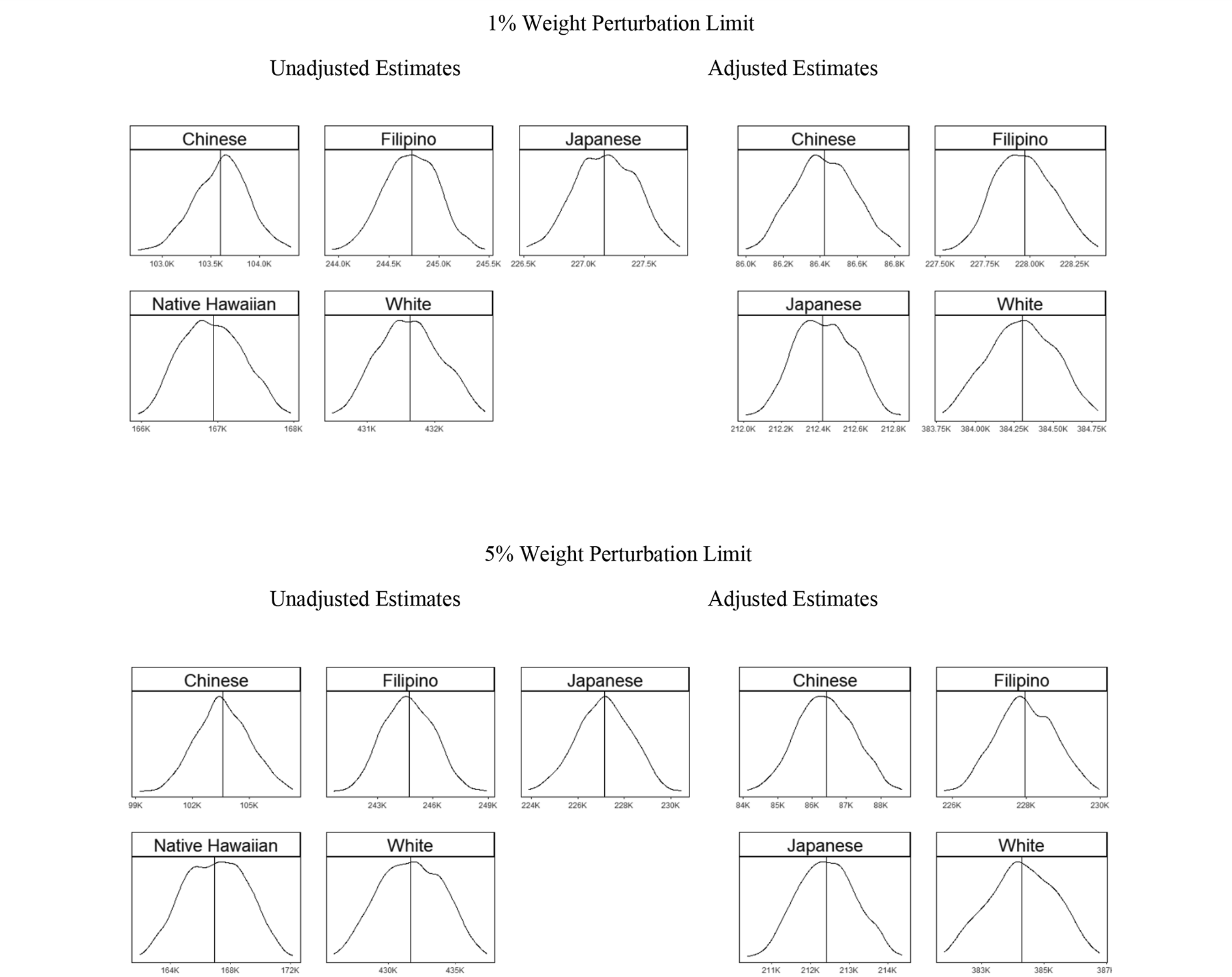

Figure 2. Stepwise Proportional Weighting Algorithm (SPWA) Sensitivity Analysis: Distribution of 1,000 Simulations of Unadjusted and Adjusted Single-race Estimates with 1% and 5% Perturbation Limits for the Most Common Races in Hawai‘i

Notes: 1. With adjustment, all partial Native Hawaiians were treated as Native Hawaiians. 2. The vertical line in each plot indicates the SPWA single-race estimate.

Discussion

Single-race population sizes are essential parameters for health statistics, public health policy-making, and health disparities research, such as assessing ethnic-specific disease prevalence or developing new public health initiatives. The SPWA proposed in the current study allows for the systematic bridging of multiracial Census data into single-race population estimates. The algorithm takes into consideration the nested structure of the Census data and applies the proportional weighting approach in a stepwise manner, which allows for the estimation of all major and detailed Census race groups. The classification of partial NH as NH, a common practice in Hawai‘i, can be easily accommodated in the SPWA by introducing a multiracial NH adjustment. The sensitivity analysis suggests that the SPWA single-race estimates are quite stable given the perturbation limits used in the simulations.

For the 5 most common race groups in Hawai‘i, the single-race estimates show substantial increases from the *alone* counts. This is not surprising given the high percentage of multiracial residents in Hawai‘i, but the increased rates varied significantly among the race groups. For example, White increased by 28.2% (unadjusted = 431 635) from its *alone* count (n = 336 599). Among the 5 races, the largest increase was found for NH (108.0%, unadjusted count: 166 944, *alone* count: 80 337), whereas the smallest increase was found for Japanese (unadjusted count: 197 497, *alone* count: 166 944). NCHS also provides population estimates[7] based on the regression bridging method, which accounts for person- and county-level factors.[5,6] Based on the estimates using the 2010 Hawai‘i Census, White accounted for 30.1% of the Hawai‘i population, which increased by 21.9% from the *alone* count. Compared to the estimates in this study, the NCHS estimate for White has a slightly smaller increase from the *alone* count.

This study found that the impact of the multiracial NH adjustment varied across the race groups. Among the 5 most common race groups, a dramatic increase was found for NH, while substantial reductions were found for Chinese and smaller reductions were observed for White, Filipino, and Japanese. These observations seem to imply that more multiracial Chinese in Hawai‘i also self-identified as NH. SEER also included Hawai‘i adjustments in their estimates.[8] SEER estimates, based on the 2010 Census, were 24.7% for White.[8] The Hawai‘i Health Survey also categorized partial Hawaiians preferentially as Hawaiians. Their 2011 estimates showed that White accounted for 19.7% of the Hawai‘i population.[17] The Hawai‘i proportions for White based on the SEER and Hawai‘i Health Survey estimates were smaller than the NCHS's estimates (30.1%). The proportion for White based on adjusted estimates in this analysis was also smaller (28.3%) than the NCHS's estimate. The discrepancy among these estimation methods could be more apparent when comparing single-race counts rather than percentages. Therefore, researchers should be aware of the method used to generate single-race population estimates and how multiracial individuals, such as partial NH, were classified. This is critical to the appropriate interpretation of the analyses.

There were several limitations to the current study. The SPWA was developed to take into consideration the nested structure of the Census race data and applied the proportional weighting approach in a stepwise manner. Although the SPWA will likely reduce bias in the determination of the weights for multiracial individuals, it could still result in some overestimation due to missing data. Since population sizes for many Asian races were remarkably smaller than Filipino, Japanese, and Chinese, the impact on the estimation of these other races was considered minor. Another limitation was that the estimation could not consider the actual genetic compositions of each multiracial individual. For example, a multiracial individual with 3 races could be genetically comprised of 50% race *a*, 25% of race *b*, and 25% of race *c*. However, there was no way to identify the true race profile of each multiracial individual (eg, the number of races reported, parents' races). Even though the proportionality assumption may not always reflect the reality, it seems a sensible assumption overall. For this reason, the SPWA assigned equal race proportions for each multiracial individual. For example, one-third were assigned to each race if 3 races were reported. Another limitation is that the race data are self-reported. Individuals may not know their full ancestry or may only report it partially. The race categories included in the 2010 Census questionnaire generally reflect a social definition of race recognized in the US and are not an attempt to define race biologically, anthropologically, or genetically.[4] Also, 2010 Census surveyed race and Hispanic origin as 2 separate questions. In the current study, we focused on only the 2010 Census race categorization data.

Strengths of the SPWA include: (1) relatively straightforward calculations so complex statistical models are not needed; (2) external data are not required for the estimation; (3) single-race estimates can be determined iteratively for various races; (4) can be easily adapted to the adjustment for multiracial NH; (5) race estimates are, in general, relatively stable under the perturbations to the weights assigned in the estimation process; and (6) the approach could easily be applied to any future Census data to update these single-race estimates. The presenting estimates were computed using the 2010 decennial Census. The estimates will be updated when the 2020 Hawai‘i Census data become available.

Potential applications of the SPWA single-race population estimates are broad, including the determination of reference counts for race-based resource allocation, the justification for public policy decision-making, the denominator determinations of health services analysis, and the compiling and reporting of public health and other vital statistics. The SPWA fills an important methodology need for public health and health disparities research in Hawai‘i.

Conflict of interest

None of the authors identify a conflict of interest.

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Authors' Affiliation:
- Department of Quantitative Health Sciences, John A. Burns School of Medicine, University of Hawai'i, Honolulu, HI

Corresponding Author:
John J. Chen PhD; Email: jjchen@hawaii.edu

References

1. Jones NA, Bullock J. The two or more races population: 2010. *2010 Census Briefs.* Published September 2012. Accesed April 5, 2022. https://www2.census.gov/library/publications/cen2010/briefs/c2010br-13.pdf
2. Office of Management and Budget. Provisional guidance on the implementation of the 1997 standards for the collection of Federal data on race and ethnicity. Accessed April 5, 2022. https://www.ofm.wa.gov/sites/default/files/public/dataresearch/pop/asr/re_guidance2000update.pdf
3. US Census Bureau. Decennial Census of Population and Housing Questionnaires & Instructions. U.S. Department of Commerce, Economics and Statistics Administration. Published 2021. Accessed April 5, 2022. https://www.census.gov/programs-surveys/decennial-census/technical-documentation/questionnaires.2010_Census.html
4. US Census Bureau. 2010 Census Summary File 2 - Technical Documentation. US Census Burea. Published 2011. Accessed April 4, 2022. https://www2.census.gov/programs-surveys/decennial/2010/technical-documentation/complete-tech-docs/summary-file/sf2.pdf
5. Ingram DD, Parker JD, Schenker N, et al. United States Census 2000 population with bridged race categories. *Vital Health Stat 2.* 2003(135):1-55.
6. Parker JD, Schenker N, Ingram DD, Weed JA, Heck KE, Madans JH. Bridging between two standards for collecting information on race and ethnicity: an application to Census 2000 and vital rates. *Public Health Rep.* 2004;119(2):192-205.
7. National Center for Health Statistics. Bridged-Race Population Estimates - Data Files and Documentation. Published 2021. Accessed April 11, 2022. https://www.cdc.gov/nchs/nvss/bridged_race/data_documentation.htm#april2010
8. National Cancer Institute. US County Population Data - 1969-2020. The Surveillance, Epidemiology, and End Results program of the National Cancer Institute. Published 2022. Accessed April 6, 2022. https://seer.cancer.gov/popdata/
9. Wu Y, Braun K, Onaka AT, Horiuchi BY, Tottori CJ, Wilkens L. Life expectancies in Hawai'i: A multi-ethnic analysis of 2010 life tables. *Hawaii J Med Public Health.* 2017;76(1):9-14.
10. Gomez SL, Noone AM, Lichtensztajn DY, et al. Cancer incidence trends among Asian American populations in the United States, 1990-2008. *J Natl Cancer Inst.* 2013;105(15):1096-1110.
11. Liu L, Noone AM, Gomez SL, et al. Cancer incidence trends among native Hawaiians and other Pacific Islanders in the United States, 1990-2008. *J Natl Cancer Inst.* 2013;105(15):1086-1095.
12. Research and Economic Analysis Division of the Department of Business Economic Development & Tourism: State of Hawaii. Demographic, Social, Economic, and Housing Characteristics for Selected Race Groups in Hawaii. Published 2018. Accessed April 11, 2022. http://files.hawaii.gov/dbedt/economic/reports/SelectedRacesCharacteristics_HawaiiReport.pdf
13. Ahn HJ, Chen JJ. Proportional weighting algorithm for single-race population estimation using multiracial census. *Population Review.* 2018;57(1).
14. US Census Bureau. American FactFinder. Published 2019. Accessed March 13, 2019. https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml
15. Saltelli A, Ratto M, Andres T, et al. *Global Sensitivity Analysis. The Primer.* 2008. John Wliey & Sons. West Sussex, England.
16. R: A language and environment for statistical computing [computer program]. R Foundation for Statistical Computing, Vienna, Austria. 2022.
17. Hawaii Health Survey. Hawaii Health Survey 2011. State of Hawaii, Department of Health. Updated July 31, 2015. Accessed April 11, 2022. https://health.hawaii.gov/hhs/