



# Estimating Nantucket's Effective Population

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## Abstract

This paper extends demographers' traditional approaches to estimating local populations using symptomatic data. We augmented those approaches in order to track one community's de facto population—both its permanent residents (“Census population”) and other sojourners—and assorted others in residence for shorter spells of time (“impermanent residents”). We illustrate how a new type of mobility data—the anonymous “pings” emitted by people's personal mobile devices—can unveil the presence and mobility patterns of de facto populations within a community by month, week, and day. We use these data to gauge the seasonal ebb and flow of population on Nantucket Island, MA, a seasonal resort community whose *effective* population far outnumbers its “Census population.” We distinguish the following factors: (1) *Permanent Residents*, for whom Nantucket is their “usual place of residence” and where one votes and files one's tax return; (2) *Commuting Workers*, who reside off-island and regularly commute to jobs on-island via high-speed ferry or air taxi; and (3) *Sojourners* of three types: (a) *Seasonal residents*, most occupying a second home they either own or rent; (b) *Seasonal workers*, present for several months to fill many hospitality, landscaping, and other temporary jobs from April through September; and (c) *Visitors*, present for shorter stays, as vacationers or on business. For each segment, we highlight the estimation methodologies we devised and evaluate their strengths and limitations. Our research exemplifies the evolution of traditional demographic methodologies to address practical concerns at local community scales using “Big Data.” Resort communities and winter “snowbird” destinations in Sunbelt locales experience regular annual influxes of visitors and/or seasonal residents in particular months. Just as daytime urban populations strain downtown infrastructure and transportation, such impermanent residents—however, brief or lengthy their stay—impose seasonal strains on local infrastructure and public services.

**Keywords** Seasonal residents · Tourist population · De facto population · Resort community · Snowbirds · Mobile device data · Cellphone data · Community data platform · Nantucket

## Introduction

This paper extends demographers' traditional approaches to estimating local populations using symptomatic data. We augmented those approaches in order to track one community's de facto population—both its permanent residents (“Census population”) and other sojourners—and assorted others in residence for shorter spells of time (“impermanent residents”). We illustrate how a new type of mobility data—the anonymous “pings” emitted by people's personal mobile devices—can unveil the presence and mobility patterns of de facto populations within a community by month, week, and day.

In this paper, we show how these data can gauge the seasonal ebb and flow of population on Nantucket Island, MA, a seasonal resort community whose *effective* population far outnumbers its “Census population.” Situated 30 miles off the Massachusetts coast, Nantucket's geographic separation from the US mainland makes it ideal for our study. It is a self-contained Massachusetts county that is accessible only by ferry, aircraft, or private boat. People necessarily arrive and depart through its two ferry terminals or single airport (excluding those few who come and go on private sailboats and yachts). Their comings and goings vary dramatically during the year, because Nantucket is a seasonal resort community. During peak summer months, people *in residence* vastly outnumber those who are residents.

Nantucket County (excluding undevelopable land set aside in public trust) comprises roughly the same land area (23 sq. mi.) as Manhattan, NY. For each island, an ever-changing mix of sojourners and permanent residents constitutes its de facto population. Manhattan's typifies the daily urban influx and outflow of commuters. Nantucket's comprises a broader mix of impermanent residents, reflecting more than just the daily ebb and flow of urban commuters.

## Symptomatic Indicators

Traditional demographic methods for estimating the permanent resident population count of a place rely upon time-tested indicators of human presence—the number of occupied housing units, active electric utility meters, and other established indicators of peoples' ongoing presence. Such indicators are first anchored to the latest complete Federal census enumeration (here, April 1, 2010). Thereafter, subsequent change reflects more or fewer people and translates statistically into an estimate of the population count. The underlying logic (detailed in Morrison 1971) is simple and intuitive: Each symptomatic indicator is like a statistical contrail, roughly scaled to the number of people who were (or are now) present in a place. A 25% increase in occupied housing units, active electric utility meters, or trash collected implies 25% more people.

This “symptomatic indicator” approach has undergone successive refinement over decades. Now, the advent of “Big Data” expands possibilities exponentially. The underlying logic of this approach can accommodate any contrail-like data consistently related to people's temporary presence somewhere.

## Mobile Device Data

Our focus is on a new type of symptomatic data that could greatly expand how demographers in the future might characterize local populations: the “pings” emitted by personal mobile devices running voluntarily downloaded applications (apps)—those location-based services (LBS) that use one’s location to provide services (Ratti et al. 2006).

StreetLight Data, a private company, uses a proprietary algorithm and methodology to turn trillions of these anonymous “pings” into useful data. They specialize in people’s movement, especially useful for traffic management and real-time information for commuters on congested highways. These data are especially well suited to our needs, given Nantucket’s geographic isolation. They furnish relative counts of devices entering and leaving specific geofences that encompass the Island’s ferry docks and airport. A geofence is a virtual geographic boundary, defined by GPS or RFID technology, that enables software to trigger a response when a mobile device enters or leaves a particular area.

Using mobile devices as proxies for people vastly increases the possibilities for estimating a population’s size within a geofenced place and tracing its members’ comings and goings over time.

StreetLight’s reports allow clients to know the origins, workplaces, and travel patterns of people based upon apps that deliver anonymized data. The company assigns home and regular work locations by analyzing the patterns of where the devices have spent their nights and days over the preceding 30 days. Researchers access just *index values* of individual devices or their owners, not unit counts. A given index value gauges just the *relative* size of a given “crowd”—for example, showing that the number of mobile devices (MDs) that passed through Nantucket’s ferry terminals between 7 am and 9 am on a Monday was 150% of the corresponding number that passed through on a Tuesday.

With just these relative metrics, one needs some benchmark to gauge the actual size of such crowds: an actual count of arriving passengers. If Monday morning’s actual count was a known 450 passengers, then we can relate index values to implied counts of arriving passengers (no. of passengers = index value times MDs). In general, we find a reliable relationship between StreetLight’s relative index values and the independent trip-level passenger counts we obtained for ferries bringing people to and from Nantucket. Based upon our studies, we are refining ways to (1) estimate the number of people present on Nantucket on any given day, (2) track people’s movement around the island, and (3) distinguish specific population segments of particular interest in this seasonal resort community. Our objectives are to construct credible estimates of the **average daily peak number** of persons present on Nantucket, from the wintertime lows through the seasonal peaks, and to trace their **changing demographic characteristics** across months and seasons of the year.

## Conceptualizing an “Effective Population”

Nantucket is an exemplary case of a community whose de facto population count differs markedly from its official permanent resident count. Like other resort communities and winter “snowbird” destinations, Nantucket experiences regular annual influxes of visitors and/or seasonal residents in particular months. Just as daytime urban populations strain downtown infrastructure and transportation, such impermanent residents—however brief or lengthy their stay—impose seasonal strains on local infrastructure and public services.

Whether its permanent residents total 17,000 (Nantucket) or 1.7 million (Manhattan), neither Nantucket nor Manhattan is the same “population” throughout the year. Each is a gradual procession of people coming and going throughout the year. Nantucket’s is a well-defined seasonal procession of comings and goings. For every hundred permanent residents, the Island hosts hundreds more persons *in residence* on a typical summer day.

We refer to this entire population of permanent and impermanent Nantucket residents as its *effective population*. The Census Bureau’s 2010 decennial census and subsequent postcensal population estimates refer to just the permanent resident component of this effective population.<sup>1</sup>

Being able to distinguish a seasonal resort community’s permanent “census population” and its population of sojourners *in residence* for various spells of time is fundamentally important. To illustrate this, at noon, a ferry may deliver 400 arriving passengers and accommodate 400 other departing passengers within an hour, leaving Nantucket’s estimated daily population unchanged in size. Yet the 800 different members of its *effective* population generate a noontime spike in local congestion and downtown fast-food business.

To advance this perspective, we distinguish analytically five segments of Nantucket’s effective population:

1. *Permanent residents* are persons who regard Nantucket as their usual place of residence and where they may register to vote. This concept closely approximates the Census Bureau’s “usual residence” definition, without necessarily being anchored to a specific date (April 1 or July 1). It is one’s legal residence—where one lives, votes, and files one’s tax return.
2. *Commuting workers* are persons who reside off-island and travel regularly (e.g., daily or weekly) to jobs on the island—analogue to suburbanites who commute to downtown jobs. Many are in the construction trades, traveling primarily by high-speed ferry or air taxi.
3. *Sojourners* are persons who stay on Nantucket for a period of time, mostly during the warmer months. They may be *seasonal residents* occupying a second home

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<sup>1</sup> Ours is not the first effort to address the challenging problem of defining and gauging so-called non-permanent populations (see Smith 1989; Bell and Ward 2000; Swanson and Tayman 2011). We have adapted a conceptualization (Jackson Hole Conservation Alliance 2013) remarkable for its analytic simplicity.

they own (i.e., nonresident taxpayers) or renting a private home or other long-term local accommodation (typically from mid-June through mid-October); *tourists* staying for days or a week; *seasonal workers* in residence seasonally to fill the many hospitality, landscaping, and other seasonal jobs during the April–September high season, or short-stay *visitors* on Nantucket, as vacationers or on business.

In the following sections, we describe methodologies we devised to estimate each population segment, the input data we used, and our evaluation of mobile device data for estimating a community's effective population across the year.

## New Methodologies

Nantucket lacks a well-ordered measure of its *effective population*, which expands and contracts in size and whose membership changes across seasons. Strengthening measurement is an essential first step in promoting evidence-based decisions about scaling infrastructure to meet public needs and strengthening businesses catering to so many different people during the year. Lacking a suitable off-the-shelf methodology, we undertook to devise new ones and validate them in this one community, hoping that other communities—and possibly the Massachusetts State Data Center—can build upon what we have learned.

The population size of Nantucket is measured by census enumerations, supplemented by annual estimates of population based upon symptomatic indicators of people's presence. Each Massachusetts town must conduct an annual town census for the purpose of maintaining the town's official street list of its residents. This responsibility is vested in an independently elected town clerk. Our approach builds upon the strengths of the Nantucket Town Clerk's annual *Street List of Residents*. We supplement this List with information from (1) various symptomatic measures whose performance characteristics we understand and can validate and (2) standard sources of individual and household demographic characteristics (ESRI Demographics and published block-group data from the American Community Survey).

## Nantucket's Town Street List and Annual Town Census

Our starting point is an **anchor population**. This is a precisely calibrated measure of the number of permanent Nantucket residents at a particular time, which is sufficiently accurate and reliable to serve as the benchmark for calibrating other symptomatic indicators. Below, we (1) overview the Town Clerk's Street List and official Annual Town Census, used ahead as the source of our anchor population and (2) clarify their distinctive advantages and known limitations for measuring an anchor population. (See "Appendix" for further technical detail and documentation.)

All Massachusetts town clerks annually prepare a town street list (TSL) furnishing the names and addresses of all persons ages 17 years or older who officially reside in that town (Massachusetts Town Clerk's Association (1984); also <https://malegislature.gov/Laws/GeneralLaws/PartI/TitleVIII/Chapter51/Section6>.) This

TSL is published and is publicly available. Nantucket's Town Clerk also maintains a confidential master street list (MSL), which includes the names of all persons under age 17 plus certain individuals and family members (e.g., law enforcement personnel) whose addresses are not publicly released. This confidential MSL is updated continuously based upon (1) residents' daily in-person transactions with the Town Clerk's office, (2) statewide-reported vital events by place of residence, and (3) an official annual Town Census, which serves to reconfirm and update the names of all known household members currently shown on the street list.

The Town Clerk's MSL functions as a continuously updated *population register*.<sup>2</sup> Unlike a census of population, which enumerates a population at a given time point, a population register can be queried on any day for the then-current count of residents.

To validate the street list for our purposes, we compared available historical TSL data (for 2001, 2010, and 2011–2017) with corresponding Census Bureau data (see Table 1). We were able to compare two successive decennial census enumerations (April 1, 2000 and 2010) and seven postcensal estimates (July 1, 2011–July 1, 2017). We also show the two-year trailing average since 2011. These comparisons underscore three noteworthy points:

1. Census 2000 counted 9520 persons as Nantucket residents vs. the closely comparable June 2001 TSL count of 9695 (i.e., 2% more only 14 months after the April 1, 2000 census). The close agreement here suggests that the June 2001 TSL registered permanent residents about as completely as the 2000 decennial census did (under the plausible assumption that the annual rate of population increase was about 1.8%).
2. The corresponding comparison a decade thereafter shows a July 1, 2010 estimate (based on the April 1, 2010 census count) of 10,164 persons vs. the TSL June 2010 count of 11,219. The TSL counted 10% more residents as of the same time (mid-year 2010).
3. Comparing Census Bureau postcensal estimates for 2011 through 2017 with each year's mid-year TSL count thereafter reveals a widening gap over the next 7 years. The official Census Bureau estimate understates the TSL count by 14.2% in 2012 and by 16% in 2016. The two-year trailing average since 2011 supports the conclusion that this gap has tended to widen between 2011 and 2017.

Our further comparisons of household counts and estimated average household size revealed substantial disparities between Census data and TSL data. The 2010 Census counted 4229 occupied households vs. TSL's 6151 (i.e., 45% more). Average

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<sup>2</sup> The term **population register** denotes a list of persons who are citizens or residents of a country or a sub-national region. A "population register" as defined in *Methodology and Evaluation of Population Registers and Similar Systems* is "an individualized data system [for] the continuous recording ... of selected information pertaining to each member of the resident population of a country in such a way to provide the possibility of determining up-to-date information concerning the size and characteristics of that population at selected time intervals... [It] is the product of a continuous process ... of updating... all changes so that the characteristics of individuals in the register remain current."

**Table 1** Comparison of town street list count of residents and Census Bureau's postcensal estimates of residents

	2000/01	2010	2011	2012	2013	2014	2015	2016	2017	2018
Town street list count	9695	11,219	11,596	12,007	12,058	na	12,602	13,202	12,967	13,473
Census Bureau estimate	9520	10,164	10,124	10,300	10,548	10,795	10,901	11,089	11,229	na
Underestimate (%)	- 1.8	- 9.4	- 12.7	- 14.2	- 12.5	-	- 13.5	- 16.0	- 13.4	-
2-year trailing average (%)		-	- 11.0	- 13.5	- 13.4	-	-	- 14.8	- 14.7	-

household size was 2.39 persons (2010 Census) vs. 1.82 persons (2010 TSL). These disparities are likely interdependent and may arise from an implicit difference in how the term “household” is defined by each source.<sup>3</sup>

Beyond these quantitative comparisons are further considerations suggested by the influx of foreign-born persons who have made Nantucket their home in recent years. There is ample evidence that Nantucket has evolved into a miniature immigrant entry port and is a microcosm of demographic transformations elsewhere in the USA. Its counterparts are found in such urban immigrant entry ports as Fresno and Santa Clara, CA; Yakima and Pasco, WA; and Chelsea and Lowell, MA. All display the common hallmarks of an immigrant entry port: circular migration, rising proportions of foreign-born residents, and increasing numbers of English Language Learners (ELLs) in public schools (Morrison 2000). Nantucket Public Schools (NPS) enrollment trends support this interpretation.<sup>4</sup> ELL enrollment counts have increased from 39 in fall 2005 to 282 by June 2017.

Based upon all the above considerations, we chose to adopt the confidential master street list (MSL) as our anchor population. First, it is an actual *count* of persons who are officially resident, enhanced by successive annual Town Censuses (as distinct from a postcensal estimate). Second, the MSL appears to be more accurate than the Census Bureau’s postcensal estimates of that resident population, as extrapolated from the 2010 decennial census (see Table 1). We conclude that the Census Bureau’s standard methodology does not fully account for the dynamics of change in Nantucket’s permanent resident population, especially in the out years like 2016 and 2017.

Apart from its apparent superior accuracy, the MSL offers several advantages going forward. First, we could anchor successive estimates of the effective population to specific chosen dates instead of being tied to the Census Bureau’s July 1 annual postcensal estimate date. Second, it will be possible for the Town Clerk to query the MSL on a regular periodic basis throughout the year (e.g., semiannually), broadening possibilities for exploiting the MSL as a population register. For example, an extract on date *i* could be used to anchor the component elements of the Town’s effective population. A time series of annual extracts at date *i* could be used to calculate key parameters of change from one year to the next, e.g., demographic components of change (births, deaths, in-migrants, and out-migrants), changes in household size and composition, and comparative characteristics of in-migrants and out-migrants.

## Gauging the “Ebb and Flow” of Effective Population Segments

Like the tides surrounding this small island, the population of Nantucket ebbs and flows across the year. This effect is apparent on a weekly basis in summer, with high

<sup>3</sup> The Census Bureau’s definition of a “household” allows for the possibility of one or more families and/or unrelated individuals occupying one household. The TSL (relative to Census) counts 45% more street address “households” but only 10% more occupants of such households. We suspect that the TSL’s street address “household,” as applied here, approximates what the Census Bureau would term a “family;” “subfamily;” and “unrelated individual” who might inhabit one occupied housing unit.

<sup>4</sup> Source: Nantucket Public Schools, “English Learners at Nantucket Public Schools: Report to the Nantucket School Committee” PowerPoint presentation, June 20, 2017.



populations on Saturday and low populations on Wednesday, and seasonally with high tide in summer and low tide in winter. In 2017, we registered the peak population (44,000) in the early evening on July 3 and the low population (13,600) at noon on March 4. In this section, we focus on estimating the components of this ebb and flow of Nantucket's effective population.

Our approach is premised on several necessary assumptions: (1) we completely account for all members of each component (e.g., all sojourners); (2) individual components are mutually exclusive (e.g., we do not count a commuting worker also as a visitor, or vice versa); and (3) our measure of each separate component is "well-behaved" (statisticians' shorthand for a measure that does not veer off course at one or another extreme<sup>5</sup>). Most importantly, the three types of sojourners we distinguish must not exceed the total number counted as coming and going via established transportation modes (ferries and aircraft) to and from the island.

Strictly speaking, none of these assumptions will be perfectly valid; we only want to guard against those that are categorically invalid. For example, "visitors" and "seasonal residents" can be difficult to distinguish, since each may masquerade as the other. A seasonal homeowner who "visits" Nantucket intermittently in between monthly rentals of that home may be impossible to distinguish from a succession of one-time tourists who have left the same contrail (home is off-island, stayed on Nantucket for a week, then returned home). Alternatively, a family that rents a home for the summer season may include one member who appears to visit Nantucket repeatedly (arriving from Boston each Friday and departing each Monday morning). This commuting breadwinner might be hard to distinguish from a succession of weekend tourists. Furthermore, we have no satisfactory method (as yet) for estimating the number of economically invisible persons residing within Nantucket's varied communities of origin.

In the following sections, we summarize methodologies we have developed to date to estimate the size of individual segments of Nantucket's effective population.

## Permanent Residents

We estimate the permanent resident population by combining three components: (1) the MSL register maintained by the Town Clerk; (2) all other persons identified as residents of Nantucket on the basis of voting, banking, and other records; and (3) the estimated number of children living with the adults in groups (1) and (2).

Thus far, we have used an edited "public" version of the MSL current as of September 2017. It included all 10,798 nonconfidential persons ages 17 and older as of that time point. To this, we added 3392 additional adult residents not on the MSL as of September 2017, identified as officially resident on Nantucket based upon data from financial institutions, voting records, and other sources. These 3392 additional adult residents were identified by Civis Analytics, a private firm which compiles data from financial institutions, voting records, and other sources to identify place of residence. They appear to be persons who had not yet self-identified as residents to the Town Clerk.

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<sup>5</sup> For example, the relationship between people's height and weight would likely not be "well-behaved" where applied to a population of sumo wrestlers.

Neither our “public” MSL nor Civis data identifies children. To estimate this under-17 population, we grouped adults into residential units based on their common street address. For our purposes, each set of adults sharing a street mailing address defines a “residential household.” Next, we assigned an estimated number of children to each such residential household, based on the ratio of children to adults shown in the US Census Bureau’s American Community Survey Public Use Microdata Sample (ACS PUMS) for Massachusetts. ACS PUMS is a 1% representative sample of data well suited to this specific task: estimating the presence of children based on the age and gender of adults residing at the same address. We judged the statewide sample data as likely to be a reliable reflection of Nantucket’s population. In this way, we estimated that 2972 children are members of the “permanent residential household” population—a grand total of 17,162 estimated permanent residents as of early 2018.

### Year-Round Commuters

We estimated the number of year-round commuters using the fast ferry passenger records for the months of February and March of 2017. Commuters favor the fast ferry, which takes 60 min each way (compared with 135 min on the slower car ferry). We chose the February–March period because visitor traffic is at a minimum, and year-round commuting workers have resumed work routines after the December holidays. Interviews with experienced commuters informed us that during these months, 90% of passengers on the 6 am boat and 50% of those on the 9 am boat are commuting workers, for a daily average of 265 daily commuter trips to Nantucket.

Some commuters ride the ferry daily; others arrive on Monday and depart on Thursday, working four 10-hour days. To estimate weekly commuters, we calculated “excess” arrivals on Monday (compared with the mid-week average). We observed that 149 extra passengers arrive on Monday compared to mid-week, and we estimate 100 of them are weekly commuting workers who stay on the island through Thursday. Finally, we looked at the “deficit” of arrivals on Friday to estimate the daily commuters who work for  $4 \times 10$  days. We noted that mid-week counts are higher than Friday by 60 at 6 am and by 31 at 9 am. From this, we estimate that 69 are traveling four times per week rather than 5, leaving 196 total commuters present for the five-day work week. Since each arriving worker makes a return trip, we calculate the total number of trips by commuters as twice the number of arrivals.

A total of 2712 ferry trips per week are attributable to 365 commuting workers. An additional small number of commuting workers come and go via a brief air taxi flight from Hyannis or New Bedford. Presently, we lack adequate data for estimating their numbers, but we know they are small relative to ferry arrivals. Three 9-passenger flights per weekday (a plausible upper limit on average weekday air taxi passenger arrivals) would account for barely 10% of the 365 daily commuters arriving by ferry.

By combining the permanent resident population and the commuter population, we can estimate that the year-round weekend population is 17,162 and the year-round weekday population is 17,527. These figures provide the foundation for estimating the ebb and flow of the sojourners.

## Sojourners

We have defined sojourners to be the effective population in excess of the year-round population. This group is exceptionally diverse. It includes many foreign seasonal workers, affluent second homeowners who stay for months, and visitors present for a week, a weekend, or a single day (“day trippers”). Every sojourner enters Nantucket through one or another of the geofences to register arrivals by ferry or aircraft. Initially, every arriving sojourner registers as a “visitor” in our mobility metrics—that is, someone whose mobile device spent most of the preceding month somewhere else before entering one or another of our arrival area geofences. Only after one’s device has been present on Nantucket for several weeks do StreetLight mobility algorithms classify that device as “living” on to Nantucket. Likewise, upon departure, a Nantucket resident’s device is indistinguishable from any year-round resident’s device (since its “home” is estimated on the basis of only the past month).

*Seasonal workers* are especially difficult to count or estimate, for several reasons. First, there was no way to detect them through the StreetLight platform. They come as visitors and leave as apparent residents. Additionally, many seasonal workers who originate from abroad leave little or no detectable economic footprint that Civis Analytics could uncover (e.g., a bank account, credit card, or other transactional data indicating “home” as a Caribbean island or an Eastern European country). Some unknown number may well operate on a cash basis, relying upon a trusted family member for noncash transactions. These considerations make it likely that seasonal workers overlap with and confound our estimates of visitors.

All these complexities limit one’s ability to distinguish subtypes of sojourners—seasonal workers, seasonal residents, and visitors. We continue to experiment with various possible approaches (see Nantucket Data Platform reference for details and updates). It appears that we must look beyond StreetLight data to other vendors offering more detailed “residence history” data on personal mobile devices.

*Visitors* account for most of the variation in Nantucket’s effective population throughout the year. Whether one considers the average population count during a given week in August or the total number of different faces who were present during that week, it is visitors coming and going who outnumber most everyone else. Conceptually, we define a “visitor” as anyone who is briefly present on the island, for part of a day or for a weekend, or any continuous stay up to 10 days. In order to quantify “visitors,” we must distinguish other sojourners who do not fit our definition of a “visitor.” Our preliminary estimate suggests that visitors average about 15,500 of all sojourners on an average August weekend and 12,200 on August weekdays. Visitors appear to be fewest in February (less than 500 per day).

## Discussion

Applied demography is a field of research driven primarily by practical problems, not the pursuit of knowledge. Our research exemplifies the ever-expanding scope of this field and the evolution of methodologies for addressing practical concerns at local community scales. Resort communities and winter “snowbird” destinations in

sunbelt locales experience regular annual influxes of visitors and/or seasonal residents in particular months. Just as daytime urban populations strain downtown infrastructure and transportation, such impermanent residents—however, brief or lengthy their stay—impose seasonal strains on local infrastructure and public services.

Until now, demographers have drawn upon various symptomatic measures to estimate people's presence in a community. For example, the Census Bureau's State Data Centers apply variants of the "housing unit method." The location-specific "pings" emitted by anonymous populations of mobile devices introduce transformative possibilities for estimating the ebb and flow of people. Being able to gauge the precise weekly or seasonal ebb and flow of such populations is important to seasonal resort communities, be they winter ski resorts or summer/fall recreation havens. The common denominator is a tourist economy, accompanied by the need to scale up a local hospitality workforce for a seasonal window of economic opportunity followed by a lengthy dormant period.

The US Census Bureau enumerates people by their "usual residence" for the eminent purpose of reapportioning political power once every decade. To do so, it aims to "count every person once, only once, and in the right place."<sup>6</sup> Determining usual residence is straightforward for most people. However, "given our nation's wide diversity in types of living arrangements, the concept of usual residence has a variety of applications. Some examples of these living arrangements include people experiencing homelessness, people with a seasonal or second residence, people in group facilities, people in the process of moving, people in hospitals, children in shared custody arrangements, college students, live-in employees, military personnel, and people who live in workers' dormitories." (Accessed 12/13/2019 at [https://www.census.gov/programs-surveys/decennial-census/2020-census/about/residence-rule.html?eml=gd&utm\\_medium=email&utm\\_source=govdelivery](https://www.census.gov/programs-surveys/decennial-census/2020-census/about/residence-rule.html?eml=gd&utm_medium=email&utm_source=govdelivery).) Yet other purposes predominate. It is people's presence on Nantucket—however lengthy or temporary—that invigorates the local economy, meets the hospitality industry's workforce needs, drives public service demands, shapes human service needs, and generates tax revenues.

## Conclusions

This paper extends demographers' traditional approaches to estimating local populations using symptomatic data. The "symptomatic indicator" approach has endured and undergone refinement for decades. With the advent of "Big Data," new possibilities have expanded exponentially. The anonymous "pings" that people's personal mobile devices emit register people's presence and mobility patterns within a community. Used as general-purpose symptomatic indicator, these data are, in effect, a statistical contrail roughly scaled to the number of people who were (or are now) present in a county (or any defined place). Like any symptomatic indicator, such contrail-type data bear a consistent relationship to the presence of people.

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<sup>6</sup> "The Census Act of 1790 established the concept of "usual residence" as the main principle in determining where people should be counted, and this concept has been followed in all subsequent censuses. 'Usual residence' has been defined as the place where a person lives and sleeps most of the time. This place is not necessarily the same as the person's voting residence or legal residence.

We have broadened and augmented this approach, using such mobility data to track a community's de facto population—both its permanent residents and other sojourners who may be present or in residence there for spells of time. Nantucket's geographic separation from the US mainland makes the island an ideal community for our study: a self-contained Massachusetts county, accessible only by ferry, aircraft, or private boat.

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## Appendix A: Nantucket Master Street List: Technical Details

Nantucket's Town Clerk maintains a confidential master street list (MSL), which includes the names of all persons under age 17 plus certain individuals and family members (e.g., law enforcement personnel) whose addresses are not publicly released. This confidential MSL is updated continuously based upon (1) residents' daily in-person transactions with the Town Clerk's office, (2) statewide-reported vital events by place of residence, and (3) an official annual Town Census, which serves to reconfirm and update the names of all known household members currently shown on the street list. Each January, the Town Census is mailed out to each household on the town street list in early January of that year. Each recipient household is required to verify and update all information on household membership and return the census form via mail or in person.<sup>7</sup> Most returned census forms reach the Town Clerk's office within a month of being mailed out. Thereafter, returns fall off, trickling in through April; a few arrive much later in the year.

The Town Clerk estimates that about 80% of all forms *ever* returned arrive by late April (the rest trickle in over the remaining months of the year).<sup>8</sup> Furthermore, she

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<sup>7</sup> The Town Clerk estimates that about 4 in 5 census forms arrived by mail; 1 in 5 are delivered in person.

<sup>8</sup> This lengthy tail is partly attributable to residents who spend winter months elsewhere and have mail forwarded to them only periodically. The "80%-by-April" estimate affords a rough multiplier for an advance estimate of the eventual response rate: (10/8) \* No. of census forms returned as of April 30.

estimates that about 20% of all census forms mailed out are never returned, which implies a behavioral response rate of 80% (this rate excludes census forms returned by the Post Office as “undeliverable,” typically because of no forwarding address).<sup>9</sup>

The Town Clerk’s master street list functions as a continuously updated population register.<sup>10</sup> Unlike a census of population, which enumerates a population at a given time point, a population register can be queried on any day for the then-current count of residents. Upon request, the Town Clerk can release the aggregate count of all persons who are officially listed as Nantucket residents on that day (including persons under age 17 and several hundred adults whose names and addresses are suppressed for reasons of confidentiality).

A noteworthy feature of the Town Clerk’s street list is that it is continuously updated. Updating is accomplished through several ongoing procedures: (1) well-defined, consistently enforced transactions whereby motivated persons can establish themselves officially as Nantucket residents; (2) protocols for reporting of vital statistics (births and deaths) by place of residence; (3) voting list address verification whenever a registered voter signs in to vote; and (4) an annual census, which serves to reaffirm and also update the master street list.

These continuous flows of information, complemented and reaffirmed annually by a census, establish a robust updating process that supports a de facto population register:

- *Establishing residence* One must present several forms of identification which together offer convincing proof of residence. Among these are a driver’s license, passport, federal tax return, or tax bill establishing one’s official home address; monthly residential utility bills, showing one’s Nantucket address; etc. The Town Clerk is the ultimate arbiter of what document(s) constitute convincing proof of residence. A noteworthy consideration is that would-be Nantucket residents are incentivized to be officially listed as such, in order to register to vote in Nantucket elections and to be eligible for discounted passage on the Steamship Authority car ferry (which entitles one to save several hundred dollars on a roundtrip with a vehicle).
- *Vital statistics reporting* The Commonwealth of Massachusetts forwards a copy of the birth certificate for any birth that occurs within the state to the Town Clerk where the mother officially resides.<sup>11</sup> Death certificates reach the Town Clerk from the State Voter Registration System.

<sup>9</sup> The Town Clerk can obtain an extract of census forms mailed out that were returned as undeliverable.

<sup>10</sup> The term **population register** denotes a list of persons who are citizens or residents of a country or a sub-national region. A “population register” as defined in *Methodology and Evaluation of Population Registers and Similar Systems* is “an individualized data system [for] the continuous recording ...of selected information pertaining to each member of the resident population of a country in such a way to provide the possibility of determining up-to-date information concerning the size and characteristics of that population at selected time intervals... [It] is the product of a continuous process .... of updating... all changes so that the characteristics of individuals in the register remain current.”

<sup>11</sup> The Town Clerk estimates that fewer than two percent of all TCSL-registered mothers giving birth do so out-of-state, meaning the newborn would remain invisible until subsequently listed on a Town census.

- *Voting list address verification* Each registered voter appearing in person to vote in an election must first verify one's current address to be issued a ballot. Any voter reporting an address differing from the street list address is directed to change his/her address with the warden or clerk before the ballot is issued. If a voter does not appear on Nantucket's list of voters but swears that he/she has not lived or registered anywhere else, that person must then complete an "Oath of Continuous Residence" to receive a ballot.
- *Annual reaffirmation and updating by a census* The Town Clerk's official annual Town Census is mailed out around early January to all households on the "master" street list that have a valid mailing address. The Town Census provides a separate annual update to the "master" street list by responding households themselves. The responding household member is required to write in the name of a new household member not listed; to identify any listed household member who no longer resides there; and to correct any other information (e.g., a person's age, occupation, and so on). Although these self-reported annual additions, deletions, and corrections do not promptly reach the Town Clerk,<sup>12</sup> they serve over time as an independent reaffirmation and update to the master street list, enhancing its value as a population register.

## Appendix B: Using StreetLight Mobility Data to Gauge Population Size and Mobility

### Transportation Data

We have used the most current available transportation data, which collectively account for an estimated 79% of all personal transportation to and from Nantucket. Transportation data are in the form of trip-level passenger counts obtained from major ferry operators. These counts document (by the minute) the number of passengers arriving or departing by vessel. Trip-level ferry data were acquired from The Steamship Authority (SSA) and Hyline Cruises, detailing passenger counts between Nantucket Island, Martha's Vineyard (seasonal service), and the U.S. mainland. Monthly passenger data were acquired for Seastreak and Freedom Cruise Line.

We used StreetLight to determine the relative volume of people arriving or departing by minor ferry operations and by private boat. We did this by measuring the total activity at the entrance to Nantucket's harbor and subtracting the volume of passengers who arrived or departed by major ferry operations. We estimate that up to 5% of the ebb and flow of people on island is attributable to vessels other than major ferries. We also accounted for very short day trips, which would masquerade

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<sup>12</sup> First, not all census forms mailed out are returned. Overall, response rates average roughly 80%, some unknown proportion of which is attributable to forms returned by the Post Office as undeliverable ("no forwarding address"). Second, a small fraction of households opts to have mail delivered to a postal delivery box; the Town Census is delivered only to valid street delivery addresses. Third, since compliance is not strictly enforced, nonresponding household members do not risk an audit or civil penalty but such a person may be removed from the active voter list and purged entirely if the person does not vote in two successive State elections.

as departure–arrival pairs occurring within just several hours. Lastly, we modeled an additional 14% of the data based on monthly facts and figures or publicly available statistics on aggregate major-carrier airport activity. For that 14%, we estimated the daily distribution based on daily statistics provided by Nantucket Memorial Airport and Cape Air, which is the second largest carrier serving the airport.

We estimate that 2% of activity is, as yet, unmeasured. It includes people who come and go by private aircraft or charter carriers.

## Estimating Counts for Transportation Zones

We tabulated monthly passenger arrivals and departures at each of Nantucket’s two ferry terminals. For the lower-traffic winter months, we calculated 3-month windows to capture sufficient StreetLight activity data for analysis. (As with US Census Bureau sample data, StreetLight activity data are released only where they meet minimum absolute numerical thresholds, to protect privacy.) Thus, users focusing on very small areas or time intervals that register low activity counts must run analyses on multiple consecutive months to aggregate sufficient data for public release.

Since not everyone uses a smartphone with LBS enabled, StreetLight captures only a sample of people in any geofenced zone. Their algorithm converts raw sample data into an activity index (AI). Although not an actual count, this AI is scalable. Thus, if one AI value is 200 (at a given place and time) and another is 400 (at that same place but a different time), the latter registers twice as much activity as the former. *The prospect of scaling comparisons according to time and place are the key to exploiting the symptomatic information that AI values can provide for time intervals and geofenced places of our choice.* Coupled with this flexibility is an important caveat: AI values reflect “touches,” not individuals. One AI value twice as large as another could reflect the same people entering the geofence twice, instead of everyone entering just once.

We have drawn geofenced zones to encompass the entire area a traveler would inhabit and thereby minimize overlap with non-travelers. Our aim here was to confine measured activity to arriving and departing travelers and exclude family, friends, or taxis that pick up or drop off travelers at ferry terminals or the airport.

We report the StreetLight activity indices as average daily AIs. We normalized the AIs to average daily trip counts (ADTCs). We regressed ADTCs for each time frame to estimate a predictive model for each geofenced transportation zone. The length of the time frames varied according to the time of year. Winter months required a 3-month window to generate an output, while most of the summer months had enough activity for weekly output. The composite model combines the observations from all time frames and both ferry terminals into one model. The observations across the year had enough variation to account for a range between 400 and 3000 ADTCs. Seasonality variables included in our initial regressions proved insignificant at  $p < 0.05$  and so they were omitted. The AIs and ADTCs were tested for autocorrelation using the Durbin–Watson statistic. The results were negative using  $\alpha = 0.05$ . Analyzing each transportation zone individually yielded the following equations:



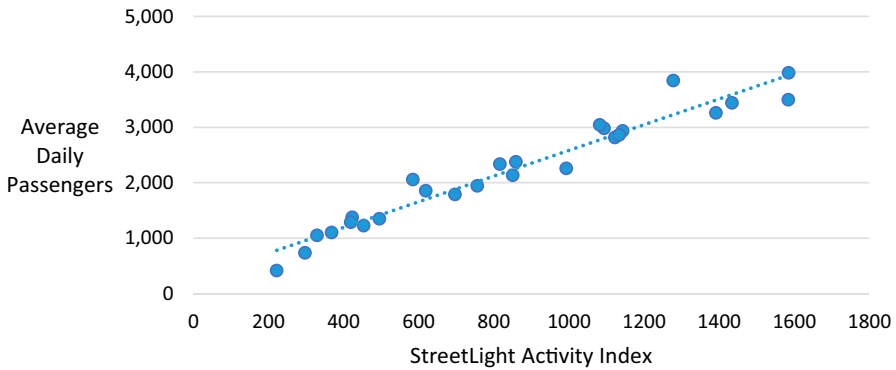


Fig. 1 Composite StreetLight model

Without constant:

Hyline terminal:  $y = 2.4257x, R_2 = 0.97, N = 14$

SSA terminal:  $y = 2.3021x, R_2 = 0.96, N = 14$

Composite model:  $y = 2.3653x, R_2 = 0.96, N = 28$

With constant:

Hyline terminal:  $y = 2.1832x + 280.91, R_2 = 0.99, N = 14$

SSA terminal:  $y = 2.2711x + 33.32, R_2 = 0.96, N = 14$

Composite model:  $y = 2.2334x + 147.25, R_2 = 0.97, N = 28$

where  $y$ =average daily count and  $x$ =StreetLight Zone Activity Index.

The equations show how the models differed between the inclusion and exclusion of the constant. The higher value of the Hyline constant could indicate the existence of non-Hyline traffic in that zone with some regularity. Although we noted the tighter fit with the constant, we chose to implement models without a y-intercept since the zone activity is intended to be a simple scale. While informative to see both ways, the first set of equations fit the phenomenon the best in practice. With our goals being eminently practical, we proceeded with the simple scale.

Using the composite model, each increase of 1 in the AI implies 2.37 more travelers. Assuming accurate counts, the results show that the travelers at the SSA Terminal use LBS at a slightly higher rate than those at the Hyline Terminal. Nonetheless, the scales are very similar to each other.

We can use this composite model (see Fig. 1) where the actual number of people moving through a geofenced area is unknown. Given just the AI for a geofence, this model estimates the daily average number of people who move through that zone. This model was key in estimating the number of people who arrive and depart from Nantucket by private boat. We were able to geofence the entrance to the harbor, observe the AI for all passengers traveling through this

zone, calculate the ADTCs for all boats, and subtract the number of ferry passengers from that total.

The smaller ferry companies provide another example of the usefulness of this model for NDP. Companies sending ferries to and from New Bedford and New York City did not respond to participation in the study. However, with known time schedules and docking locations, we can query StreetLight for the AI within those zones, apply the model, and estimate ADTCs of those ferries.

## Permanent Population

Permanent residents are people who make the island their primary home year-round. We estimate the permanent resident population by combining three components: (1) the annual town street list register maintained by the Town Clerk; (2) persons identified by Civis Analytics as residents of Nantucket based upon voting, banking, and other records; and (3) an estimated number of children living with the adults in groups (1) and (2).

The Town Clerk, in accordance with Massachusetts law, maintains a list of all Nantucket town residents. Updates to this list derive from the official annual Town Census as well as continuous updates throughout the year whenever a person reports (and documents) being a permanent resident at a street address. We obtained from the Town Clerk an edited “public” version of this list, current as of September 2017. At that time, it included 10,798 nonconfidential adults in the register.

We contracted with Civis Analytics to match all persons that Civis identifies as residents of Nantucket County against these street list adult residents. Civis compiles data from financial institutions, voting records, and other sources to create profiles on US residents. This effort identified 3392 additional adults not on the street list as of September 2017 whom we believe should be classified as permanent Nantucket residents. Both sources together appear to furnish a more complete current list of the adult resident population by including persons yet to self-identify in person to the Town Clerk as residents as of September 2017.

For confidentiality reasons, neither source identifies children. Accordingly, we have estimated the number of children who reside with the adults whom we identify as permanent residents. First, we grouped adults into “residential units” based on their common street address. This residential unit serves as an operational definition and is entirely distinct from the Census Bureau’s standard definitions of households and their occupants (e.g., family and nonfamily members). For each street address occupied by one or more adults, we assigned an estimated number of children based on the ratio of children to adults shown in the US Census Bureau’s American Community Survey. We used the Public Use Microdata Sample (ACS PUMS) for Massachusetts, a 1% representative sample of data well suited to this specific task: estimating the presence of children based on the age and gender of adults residing at the same address.

We judged the statewide PUMS sample to be the most reliable reflection of Nantucket’s population, based on comparisons documented in Table 2. PUMS data are available for a single sub-area (“PUMA”) that encompasses Nantucket County, Dukes County, and a portion of Barnstable County on Cape Cod. However, the Barnstable

**Table 2** Nantucket county and selected other geographies (American Community Survey 2016)

	Under 18 (%)	Over 65 (%)	White (%)	Black (%)	Latino (%)
United States	23	15	76	14	17
Massachusetts	21	15	82	9	11
Nantucket Co	20	14	89	8	12
Barnstable Co	16	28	94	3	3
Dukes Co	18	20	92	8	8

County portion, which accounts for most of this PUMA population, differs markedly from Nantucket. Residents are older and racially less diverse. For example, the national, State, and Nantucket percent over 65 is around 15% (vs. 28% for Barnstable County). Nantucket also has proportionately more Black and Latino residents than the rest of the local PUMA, with the greatest ethnic discrepancy in the Latino population.

Using Massachusetts ACS PUMS data, we grouped adults in each household by age (18–24, 25–29, 30–34, ... 70–74, and 75 +). We grouped households according to the number of adults in each. For households with one or two adults, we estimated the number of children to be the mean number of children in households in the PUMS that match the gender and binned age of the adults in the household. For example, a Nantucket household with a 36-year-old male and a 33-year-old female was estimated to have the average number of children shown for PUMS households with a 35–39-year-old male and a 30–34-year-old female (and no other adults). The total number of children residing in the household was used regardless of the relationship between the child(ren) and adult(s) present.

For the larger-size households, there are both more possible combinations of adults and smaller samples for estimating the average number of children in each. These constrain the range of combinations we can estimate. We used a linear regression model of number of children present, based on the number of adults and the number of adults of each gender–age group combination. We fit the model based on all of the three-plus-adult households in the Massachusetts PUMS sample, applied the model to each of our three-plus-adult Nantucket households, and used the predicted value as the estimated number of children for that household. When the age or gender of one or more household adults is unknown, the number of children in the household is estimated as 0.26 times the number of adults, based upon the overall reported number of children per adult for Nantucket.

Table 3 shows the number of households and the estimated number of children in each of these groups for households from the street list and households from Civis' added records. Individuals identified by Civis are more likely to be single adult households than are individuals from the Street List (35% vs 25%) and are less likely to be in male–female households (11% vs 19%) or three-plus-adult households (4% vs 16%).

Table 4 shows the total number of estimated permanent residents by record source and age. Our methods yield an estimated total of 14,190 adults and 2972

**Table 3** Number of children and households of each type by source of adult records

Household type	Civis	Street List	Total
Single			
Children	141	528	669
Households	1202	2659	3861
Man and woman			
Children	75	695	771
Households	182	1172	1354
Two men			
Children	5	24	29
Households	100	334	434
Two women			
Children	10	67	77
Households	66	380	446
3+ adults			
Children	34	1261	1296
Households	64	1470	1534
Unknown			
Children	0	131	131
Households	0	95	95
Total			
Children	265	2707	2972

**Table 4** Summary of permanent resident population by source

	Adults	Children	Total
Street list	10,798	2707	13,505
Civis	3392	265	3657
Total	14,190	2972	17,162

children for a grand total of 17,162 permanent residents, which we round to an official estimate of 17,160.

### Year-Round Commuters

Year-round commuters reside off-island and work at regular jobs on Nantucket during the work week. Some come and go daily; others with access to local housing (typically paid by employers) stay overnight, commuting weekly from and to their off-island homes.

We estimated the number of year-round commuters by using fast ferry passenger records for the months of February and March of 2017. We chose this time period for several reasons: (1) only one fast ferry operates during these months, (2) visitor traffic is at a minimum, and (3) year-round commuting workers have resumed work routines after the December–January holidays. A convenience sample of interviews

**Table 5** Total ferry trips per week attributable to commuting workers

Trips per week	Number of commuters	Total trips
2	100	200
8	69	552
10	196	1960
Total	365	2712

with experienced commuters informed us that during this time, about 90% of passengers on the 6 am boat and 50% of those on the 9 am boat are commuting workers, for a daily average of 265 daily commuter trips to Nantucket.

Some commuters ride the ferry daily. Others arrive on Monday and depart on Thursday, working four 10-h days. To estimate weekly commuters, we calculated “excess” arrivals on Monday (compared with the mid-week average). We observed that 149 extra passengers arrive on Monday compared to mid-week, and we estimate 100 of them are weekly commuting workers who stay on the island through Thursday. Finally, we looked at the deficit of arrivals on Friday to estimate the daily commuters who work four 10-h days. We see that mid-week counts are higher than Friday by 60 at 6 am and by 31 at 9 am. From this, we estimate that 69 are traveling four times per week rather than five, leaving 196 total commuters present for the five-day work week.

Each worker must make a return trip for each arrival, so the total number of trips made by commuters can be calculated as twice the arrivals. Table 5 shows that a total of 2712 ferry trips per week are attributable to 365 commuting workers. An additional small number of commuting workers commute to Nantucket via a brief air taxi flight from Hyannis or New Bedford. We currently lack adequate data for estimating their numbers, but we know they are small relative to ferry arrivals. Three 9-passenger flights per weekday (a plausible upper limit on average weekday air taxi passenger arrivals) would account for barely 10% of the 365 daily commuters arriving by ferry. As we acquire more data from airline carriers, we plan to survey both commuters and airport personnel to better estimate the volume of regular worker commuting via air taxis.

**Seasonal Workers**

A seasonal worker is someone residing on Nantucket for a period of time (typically several months) who fills one or several seasonal jobs created by tourism and the presence of many seasonal residents. Seasonal workers are especially difficult to count or estimate, for several reasons. First, although they are not permanent Nantucket residents, the StreetLight data report Nantucket as their “home” within a month (based upon where their mobile devices reside most days and nights of the prior month during their seasonal presence). Second, upon first arriving on Nantucket, seasonal workers mimic visitors on our metrics: their mobile devices previously resided off-island. Third, upon departing months thereafter, these same seasonal workers appear (on our metrics) to be Nantucket residents leaving home: their mobile devices (having registered Nantucket as where

they “live”) register their departure. Finally, many seasonal workers who originate from abroad leave little or no detectable economic footprint for Civis Analytics to discover: no bank account, credit card, or other transactional data indicating that “home” is a Caribbean island or an Eastern European country. Some unknown number may operate on a cash basis, relying upon a trusted family member for noncash transactions. All these considerations together make it likely that seasonal workers overlap with and confound our estimates of visitors and other effective population segments.

To determine the number of seasonal workers, we started by calculating demand. The first step was to quantify the local labor force available to help fill these positions. The local labor force is defined here as the number of permanent residents between the ages of 18 and 65. We found 9754 adults on our permanent resident list that qualified. Next, we sought to estimate the number of potential jobs that had to be filled each month. The federal Bureau of Labor and Statistics (BLS) and the Bureau of Economic Analysis (BEA) track the number of jobs across the nation. BLS tabulates their data by state unemployment insurance programs, so the universe measured by these data is persons covered by unemployment insurance. BEA uses this tabulation as a starting point for its figures. Several industries and nonprofits do not participate in unemployment insurance programs. BEA captures those, as well as college student jobs, interns, and various forms of independent contracting. Although the BEA data encompass a broader universe of jobs, BEA report those data only annually whereas BLS does so monthly.

To explore these two alternative data sources, we first analyzed the distribution of jobs reported monthly by the BLS for Nantucket (using the current “preliminary 2017” numbers). The index value presented in Table 6 shows how the BLS monthly employment varies from the average for each observation.

The BEA has not yet reported 2017 numbers. To project a BEA number, we calculated the average annual BEA growth shown for Nantucket for the most recent 3 years, then applied that growth to 2016 in order to project a 2017 annual average. Finally, we applied the BLS monthly to the BEA figures to estimate the monthly BEA distribution of jobs for Nantucket.

Next, we compared the monthly total jobs to the number of adults in the local labor force, taking account of unemployment. During winter 2017, the number of persons in the labor force exceeded the number of jobs. During the 2017 July–August peak season, this imbalance sharply reversed, with almost 8000 more jobs than workers to fill them (and concurrently, a very low measured rate of unemployment). The equations below show how the number of seasonal jobs was estimated using all the employment information at hand:

$$\text{Total work force} = \text{local labor force} + \text{commuters} - \text{unemployment}$$

$$\text{Seasonal jobs} = \text{monthly total job estimate} - \text{total work force}$$

It is common knowledge that many Nantucket residents hold more than one job year-round to afford the high local cost of living. This pattern becomes more commonplace during the summer, as housing costs spike and employment opportunities

**Table 6** Projected BEA monthly estimates based upon BLS data

Time period	Preliminary BLS employees	Index	Projected BEA employees	Projected BEA proprietors	Monthly total job estimate
January	5118	0.69	5458	3212	8670
February	5081	0.69	5419	3189	8608
March	5251	0.71	5600	3295	8896
April	6132	0.83	6540	3848	10,388
May	7364	1.00	7854	4621	12,475
June	9393	1.27	10,018	5895	15,913
July	10,551	1.43	11,253	6622	17,874
August	10,558	1.43	11,260	6626	17,886
September	8795	1.19	9380	5520	14,899
October	7593	1.03	8098	4765	12,863
November	6467	0.88	6897	4059	10,956
December	6116	0.83	6523	3838	10,361
Average Annual	7368	1.00	7858	4624	12,482

materialize. A 2013 study conducted in Jackson Hole, WY, found that the average worker in the Tetons worked 1.2 jobs. We have applied that scale in Table 7 to complete our seasonal worker estimate.

For now, we are unsure whether the average Nantucket seasonal worker holds 1.2 jobs (we have only unsubstantiated “guesstimates” as alternatives). To strengthen and refine these estimates, we plan to conduct interviews on this population.

### Seasonal Residents

A seasonal resident is a homeowner (or a tenant) who resides on Nantucket for only part of the year. For our purposes, a seasonal resident appears to be a permanent resident while on the island, staying continuously (albeit for a finite extended stay) as opposed to visiting for short stays, e.g., frequent weekend visits.

We first singled out all the residential parcels with a dwelling subject to Town real estate property tax. Next, we scrutinized the reported mailing address on the tax roll. There were 5149 such residential parcels for which the tax bill is mailed to an off-island address. We anticipated that some of these owners use a proxy with an off-island address to handle their financial affairs. To remove false positives (i.e., actual local homeowners whose tax bills would erroneously indicate only seasonal residence), we compared this parcel list against Civis Analytics records. This comparison revealed 593 owners who qualified as apparent permanent residents despite an off-island mailing address. This correction reduced our list from 5149 parcels above to 4556. We then removed duplicate owner names, for a final total of 4254 homeowners, including 602 residential parcels registered to business names, typically LLCs. We geocoded the mailing addresses to determine the origins of this group. Each unique owner was attributed a household size based on the average household size of their census block group of origin. The overall average household

**Table 7** Estimated number of seasonal workers by month (2017)

Time period	Monthly total job estimate	Local labor force	Unemployed	Commuters	Total work force	Seasonal Jobs	Seasonal worker estimate at 1.2 jobs each
January	8670	9754	630	365	9489	–	–
February	8608	9754	608	365	9511	–	–
March	8896	9754	514	365	9605	–	–
April	10,388	9754	287	365	9832	556	463
May	12,475	9754	213	365	9906	2569	2141
June	15,913	9754	195	365	9924	5989	4990
July	17,874	9754	166	365	9953	7921	6601
August	17,886	9754	144	365	9975	7911	6593
September	14,899	9754	152	365	9967	4932	4110
October	12,863	9754	150	365	9969	2894	2412
November	10,956	9754	213	365	9906	1050	875
December	10,361	9754	301	365	9818	543	453



size was 2.4. This average was attributed to all addressees with a non-US mailing address. Based on these figures, we estimate that if every seasonal resident were on the island at once, they would number just under 11,000 people.

We attempted to use LBS data sources to determine when seasonal residents were present on Nantucket. It proved possible to model only those seasonal residents who stay for an extended time. This captured second homeowners who behave like residents during their seasonal stays. We are continuing to refine our methodology here, leveraging alternative mobility data sources.

### Visitors

We define a visitor as anyone who is briefly present on the island, for part of a day, a weekend, or for any continuous stay up to 10 days. This definition aligns with StreetLight data, which designates a visitor as anyone who spends most nights of that calendar month somewhere other than Nantucket.

Visitors account for most of the variation in Nantucket's effective population throughout the year. Whether one considers the average population count during a given week in August or the total number of different faces present during that week, it is visitors coming and going who outnumber most everyone else.

To quantify "visitors," we first had to define each of the other population segments of Nantucket's effective population that contribute to its variation. When entering via ferry or aircraft, everyone except a permanent resident or year-round commuter from off-island looks at first like a visitor. That is, StreetLight data identify them as people arriving on Nantucket who reside and work someplace else. Their mobile device cannot register any preexisting intent to stay longer than 10 days. In short, anyone with an off-island home passing through one of our geofenced transportation turnstiles is a "visitor" unless designated otherwise. Since we have an almost complete picture of trips to and from Nantucket, we are moderately confident to have captured visitors and seasonal residents in aggregate.

**Table 8** Top 10 origin metro areas of residence of Nantucket summer visits

Metropolitan area	Visits
Boston–Cambridge–Quincy, MA–NH	141,200
New York–Northern New Jersey–Long Island, NY–NJ–PA	58,700
Barnstable Town, MA	54,800
Providence–New Bedford–Fall River, RI–MA	34,400
Bridgeport–Stamford–Norwalk, CT	26,300
Washington–Arlington–Alexandria, DC–VA–MD–WV	13,600
Hartford–West Hartford–East Hartford, CT	13,200
Philadelphia–Camden–Wilmington, PA–NJ–DE–MD	12,500
Worcester, MA	11,700
Miami–Fort Lauderdale–Pompano Beach, FL	8500
New Haven–Milford, CT	6400
Springfield, MA	6000

The largest source of error traces to the fact that our airport trip data, of necessity, are largely modeled. With the cooperation of the Nantucket Memorial Airport and Cape Air, we were able to allocate monthly reported data across days of the month for other airlines servicing Nantucket only seasonally (e.g., Jet Blue and Delta). This allocation is premised on the plausible assumption that flights come and go in the same daily rhythm (reflecting variations across weekdays in passenger demand for air transportation). By our estimate, the airport accounts for less than 15% of Nantucket's daily population turnover, so modest estimation errors are tolerable.

**Table 9** Average daily peak weekday population, 2017

	Daytime population	Permanent resident	Commuters	Seasonal residents	Seasonal workers	Visitors
January	17,640	17,160	365	–	–	115
February	17,050	16,685	365	–	–	–
March	17,470	17,105	365	–	–	–
April	17,820	16,992	365	–	463	–
May	20,720	17,160	365	–	2141	1054
June	27,470	17,160	365	590	4990	4365
July	38,440	17,160	365	5710	6601	8604
August	38,270	17,160	365	5610	6593	8542
September	26,010	17,160	365	2040	4110	2335
October	22,040	17,160	365	–	2412	2103
November	20,180	17,160	365	–	875	1780
December	18,670	16,575	365	–	453	1277

**Table 10** Average daily peak weekend population, 2017

	Daytime population	Permanent resident	Commuters	Seasonal residents	Seasonal workers	Visitors
January	18,600	17,160	–	–	–	1440
February	16,410	16,410	–	–	–	–
March	16,370	16,370	–	–	–	–
April	18,680	17,160	–	–	463	1057
May	23,570	17,160	–	–	2141	4269
June	28,780	17,160	–	590	4990	6040
July	39,670	17,160	–	5710	6601	10,199
August	40,750	17,160	–	5610	6593	11,387
September	30,000	17,160	–	2040	4110	6690
October	23,720	17,160	–	–	2412	4148
November	20,290	17,160	–	–	875	2255
December	19,850	17,160	–	–	453	2237

During February and March, we detect a negligible number of visitors; during the summer, by contrast, there are sojourners more than double the population of the island. StreetLight gives us home locations for people who come from the lower 48 states. From those data, we note that Nantucket visitors originate in all lower 48 states. We estimate that about 141,200 visits to Nantucket are by Boston area residents and about 58,700 are by New York City residents. Table 8 shows the top 10 origins of Nantucket visitors between April and October.

These numbers denote *visits*, not different *people*. For example, 10 visits could be one person coming and going 10 times, or 10 people coming and going just once. Accordingly, we cannot track or identify individuals, only the trends in the ebb and flow of visitors (whether first-time or repeated). We have only begun to understand this procession of people coming and going. We look forward to strengthening and deepening our understanding of each of these five population groups in the future.

### Summary Estimates of Average Weekday Population by Month, 2017

Tables 9 and 10 presents our consolidated estimates of the five segments of Nantucket's Effective Population on average weekdays and average weekends.

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