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Quantifying Recreational Use of an Estuary: A Case Study of Three Bays, Cape Cod, USA

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Abstract

Estimates of the types and number of recreational users visiting an estuary are critical data for quantifying the value of recreation and how that value might change with variations in water quality or other management decisions. However, estimates of recreational use are minimal and conventional intercept surveys methods are often infeasible for widespread application to estuaries. Therefore, a practical observational sampling approach was developed to quantify the recreational use of an estuary without the use of surveys. Designed to be simple and fast to allow for replication, the methods involved the use of periodic instantaneous car counts multiplied by extrapolation factors derived from all-day counts. This simple sampling approach can be used to estimate visitation to diverse types of access points on an estuary in a single day as well as across multiple days. Evaluation of this method showed that when periodic counts were taken within a preferred time window (from 11am-4:30pm), the estimates were within 44 percent of actual daily visitation. These methods were applied to the Three Bays estuary system on Cape Cod, USA. The estimated combined use across all its public access sites is similar to the use at a mid-sized coastal beach, demonstrating the value of estuarine systems. Further, this study is the first to quantify the variety and magnitude of recreational uses at several different types of access points throughout the estuary using observational methods. This work can be transferred to the many small coastal access points used for recreation across New England and beyond.

Keywords

Estuarine recreational use; Coastal access; Cape Cod; Water quality benefits; Visitation

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Introduction

Coasts and estuaries are critical resources for communities as they provide food, recreational opportunities, spiritual value, and more to residents and visitors. Estuaries are highly valued for these resources, and as a result, coastal communities surrounding estuaries are often densely populated and can be greatly impacted by human development and use. These human impacts, along with reduced water circulation within embayments, can lead to diminished water quality in estuaries, often more so than at open ocean beaches or in offshore waters (Lotze 2010). The proximity to communities and sheltered environs also make them desirable for recreation through the availability of wind-protected harbors and the perception that estuarine beaches are less dangerous than open-ocean beaches (Lepesteur et al. 2008). Estuaries in the northeastern United States are popular for beachgoing, shellfishing, fishing, boating, kayaking, and more. While coastal recreation, in general, has been identified as providing significant economic value to coastal states and communities (for a review, see Pendleton 2008), little emphasis has been made on accurately measuring the use of estuaries.

Cape Cod (“The Cape”; Barnstable County) consists of 15 towns within Massachusetts that are heavily dependent upon their estuarine and coastal systems. Coastal tourism and its associated industries are major drivers of the local economy, and many residents and visitors have expressed deep connections to the Cape’s 52 embayments. While they are used recreationally for a variety of different activities, there is no existing quantification of the recreational use of Cape Cod’s estuaries. Here, we present an approach for calculating recreational use of an estuary for a single day using simple, onsite observations. We create factors to relate easy-to-take counts of cars at given times to recreational visits totals. Important distinctions between the methods presented in this study and other established methods are 1) the focus on quantifying use at public recreation access points that range in size and popularity common in estuaries, 2) the consideration of multiple forms of recreational use common in estuarine waters, 3) the estimation of visitation without the use of intercept or mail surveys, and 4) estimates of accuracy based on actual all-day observations rather than across sampling methods. We applied the methods in a case study of the Three Bays estuary system on Cape Cod, Massachusetts, to demonstrate how these methods could be applied for other smaller embayments in New England and elsewhere.

Literature Review

Recreational opportunities are important benefits provided by the ecosystem services of estuarine waters. As communities and states work to improve water quality, restore habitat, and maintain access, quantifying the number of users who benefit from improvements or are affected by those policies provides critical information to coastal decision-makers. The recreational use studies resulting from the Deepwater Horizon oil spill, for example, demonstrate the utility of collecting and maintaining baseline visitation data to allow for future damage assessments or calculations of the value of water quality improvements (English et al. 2018; Tourangeau et al. 2017).

Visitation data are critical for estimating non-market values for recreation (e.g., Hayes 1992; Freeman 1995) to know how many people are affected by policies or management actions. Water quality improvements can be costly; so even baseline counts of recreational users, without monetary valuation, can improve understanding of the potential magnitude of the ecosystem service benefits or potential damages (Tourangeau et al. 2017). Quantifying recreational use can also provide information about which sites are used most heavily, and the activities for which they are used. This information can support a better allocation of resources and improved spatial planning for environmental management, facilities siting, and safety purposes (Dwight et al. 2007; Pendleton 2008; Morgan 2016).

Counts and other data on the volume of recreational use for estuarine areas is limited. The 2000 National Survey on Recreation and the Environment (Leeworthy and Wiley 2001) provided national-scale data on participation in all types and locations of saltwater recreation, including in estuarine systems. The survey found that more than 43 percent of the civilian, non-institutionalized U.S. population had participated in at least one of 19 marine outdoor activities from 1999 to 2000. While that study reveals notable participation in multiple types of saltwater recreation, it does not distinguish between estuarine or open ocean beach use. Furthermore, as this kind of information is often unavailable at the local level or irrelevant to smaller estuarine access points. The accuracy and utility of existing recreational use information tends to be limited (De Cantis et al. 2015). There has been some focus on the spatial distribution of use of an estuary to contribute to marine spatial planning efforts to manage conflicting uses (Dalton et al. 2010; Patroliia et al. 2017). Although these studies were interested in where people go within a waterbody, they did not quantify how many people were present throughout a day.

Other estuarine recreation research focuses on the economic value of a recreation day for a person going to an estuary (e.g., Greene et al. 1997; Kline and Swallow 1998; Lipton and Hicks 1999; Lipton and Hicks 2003). The studies are heavily dependent on phone, mail, or intercept surveys to identify specific locations and frequency of use (e.g., Fesenmaier et al. 1989; Hayes 1992; Johnston et al. 2002). While survey-derived visitation estimates are common in the recreation demand literature, large discrepancies have been found between estimates made by onsite counts and visitation derived from surveys that ask participants to recall their experience after the fact. Surveys, which can be expensive and time intensive, have been found to overestimate visitation by up to double in some cases (Tourangeau et al. 2017). In addition, the survey-based approaches typically do not help in estimating use on a finer scale such as daily visits. Lastly, many economic valuation studies provide a value of use per person for a waterbody but are not able to provide the total economic value of all recreational visitors for an estuary, usually due to a lack of good, available visitation data.

Other methods for generating visitation estimates for coastal areas are often restricted to beaches or large parks. They are often targeted as study areas because visitation records are either easier to obtain or easier to estimate because these locations have discrete entrance points and enough visitors to justify user fees. Benefit transfer valuation studies rely on user records within the study region or other existing sources of visitation data (Deacon and Kolstad 2000; Palm-Forster et al. 2016). Primary studies in these larger recreational settings have quantified recreational use by using a variety of sampling strategies to estimate

visitation. Methods include onsite observations (all-day or periodically), lifeguard visitor counts, parking lot receipts, electronic counters, or aerial photos (e.g., Deacon and Kolstad 2000; da Silva 2002; Dwight et al. 2007; Harada et al. 2011; King and McGregor 2012; Garcia and Smith 2013; Kreitler et al. 2013; Morgan 2016; Lyon et al. 2018). Other research available on the volume of specific types of recreation and transportation (e.g., biking and walking; (Nordback et al. 2013; Hankey and Lindsey 2016) depend on the availability of continuous counts, which are not widely available for coastal areas.

The National Forest Service, National Park Service, and National Oceanic and Atmospheric Administration (NOAA) carried out studies and developed guidelines to improve the accuracy of visitation estimates (English et al. 2000; Wallmo 2003; Leggett and Curry 2011; Zarnoch et al. 2011; Leggett 2017; Horsch et al. 2017). However, these studies all rely on large-scale, costly survey data. For example, the National Marine Fisheries Service of NOAA conducts national phone, mail, online, and intercept surveys to estimate total participation and effort for coastal recreational fishing, including estuaries. This data estimates the number of anglers expected at thousands of sites at different times throughout the year (NOAA 2019). Vølstad et al. (2006) also calculated recreational angling effort for the Delaware River using both access surveys of recreational anglers and periodic aerial counts. Many of the methods mentioned above are for only a single activity, require a survey or complex analysis, or are resource intensive to implement and not readily transferable to estuaries. More recently, visitation to larger study regions such as the thousands of lakes in Minnesota and Iowa was estimated using geotagged images from the photo-sharing website Flickr (Keeler et al. 2015).

Each method proposed for estimating visitation has advantages and disadvantages for estimating recreational use of various natural areas. Smale (2011) argued that most methods described above lack validity and reliability because it is difficult to compare predicted estimates to the actual number of visitors. This is because there are often no data on actual visitation to many recreation sites. Therefore, Smale (2011) compared various systematic sampling strategies to actual visitation to test for accuracy among sampling procedures. Results indicated the difficulty in accurately estimating visitation to a large, urban park because of the challenges in obtaining a sample that accurately represented the entire park. Similarly, King and McGregor (2012) studied the differences in their daily visitation estimates, calculated using periodic counts (e.g., “snapshots” at a period in time; Banzhaf 1996) and sub-sampling surveys, to official agency counts (e.g., lifeguard visitor counts, parking lot receipts, parking lot counters, etc.). Based on their comparison of the different methods, they concluded that the official agency counts tended to overestimate use, especially at smaller beaches (King and McGregor 2012). Wallmo (2003) compared onsite counts (periodic and all-day) to that of helicopter overflights. These techniques were found to be reasonably comparable in estimating daily visitation to a beach, suggesting that the recommended technique for a comparable beach should be based on efficiency and cost-effectiveness rather than accuracy. Periodic counts were identified as the most economical technique in the Wallmo paper. Vølstad et al. (2006) compared access-point intercept surveys and aerial surveys for use in calculating recreational catch effort. They found that a combination of the efforts (aerial-access surveys) was both most cost-effective and accurate. However, each of these studies lacked actual observations for the number of daily visitors

they sought to estimate with their sampling methods. In our study, we include estimates of the accuracy of our methods based on actual observations of visitation as opposed to across sampling methods.

This study adapts some of the methods described above into a practical approach for accurately capturing daily visitation to estuaries with many small access points and with varying types of use other than just beachgoing. The current dependence on survey methods or the use of a dedicated sampling plan like lifeguard counts or entrance fees are outside the scope of many organizations managing smaller estuaries or coastal access areas. For example, many towns do not collect parking fees or attendance information for smaller access points that are common at larger beaches and are without the technical expertise to implement a survey of participants. Lacking the commonly used data and expertise, it is difficult to estimate recreational use of an estuary through multiple smaller access points without employing more estuarine-specific methods. In this paper, we outline an approach that is not dependent on the use of survey data or attendance information and that can be used to estimate participation at all types of access points commonly found in estuary systems. The approach we present produced extrapolation factors by comparing periodic onsite observations to counts of actual daily visitation via all-day counts at diverse types of access points. Therefore, a periodic count of parked vehicles can be translated to estimate the number of visitors at a site for a day (Figure 1). These factors could be applied in other estuaries (with consideration of the limitations of the method, discussed within) to estimate efficiently daily or multi-day site visitation. The methods are intentionally simple to allow for replication in other small estuaries. Further, this study also elucidates the variation in number and type of recreational uses at different types of access points throughout an estuarine system.

Study Location

Three Bays is a 1,251-acre embayment system in Barnstable, Massachusetts, USA that gets its name from its three connected, primary bays (Cotuit Bay, West Bay, and North Bay), along with several smaller sub-estuary systems. We conducted counts at eleven public access points for Three Bays: three beaches, four boat ramps, two sandy landings, one town dock, and one end-of-the-road way to water (Figure 2). Two additional public access points were excluded from this study due to the difficulty of distinguishing between public and private use at these sites where public access occurs next to and largely integrated with private marinas. We quantified public access points to capture a range of beneficiaries of the embayment, but do not capture visitation from private access such as those who live directly on the coast or have private access through marinas, moorings, or beach clubs. All public access points on Three Bays are open and free of charge to anyone who can access the water without having to park in a space. However, “public access” for most of these sites is limited to town residents or property owners because resident parking permits are required for almost all parking spaces at these sites. This study’s focus on public shoreline access underestimates overall recreational use of the estuary because it does not quantify users that accessed the area by boating from private access points or from outside of Three Bays, which is colloquially a large contributor of use.

Like many other coastal embayments in New England, the Three Bays embayment system is affected by excess nutrients and bacteria loadings from septic systems and stormwater runoff. The Massachusetts Estuaries Program listed Three Bays as impaired due to both high nitrogen concentrations and pathogen loads (State of Massachusetts 2013). This estuary and other similar waterbodies are currently under active management efforts to manage nitrogen through the Cape's planning process to update its Section 208 plan as a part of the Clean Water Act (Cape Cod Commission 2017). We quantify public recreation use of Three Bays to provide baseline information about those who could be affected by future water quality improvements or degradation. We also introduce the utility of this method for use in other small estuaries.

Methods

Quantifying visitation to a public resource such as an estuary is challenging because of the size and spatial complexity of the area within the estuary available for recreation. Unlike a typical open-water beach where recreational users can be directly observed on or near the beach, estuaries often have large unobservable areas and multiple recreational entrance points. Similar to the use of a park, visitors may stay near the access points or they may continue to other parts of the estuary where they are no longer visible. Therefore, to quantify recreational use in a complex, estuarine system, we must directly observe public visitation as visitors funnel through the multiple access points.

The approach described below adapts existing sampling methods to the complexity of an estuary to estimate daily visitation to 11 individual public access points. Our approach produces extrapolation factors and demonstrates how they can be applied to simple, instantaneous onsite observations of parked cars ("cars" used here to represent any personal, non-commercial vehicles including sedans, SUVs, trucks, and vans) to produce the estimates of daily public visitation. We recognize that, within an estuary, there are also many private access points, either from private homes or clubs. Therefore, estimates of recreational use derived from public access points alone will understate total recreational use of the estuary.

Below, we explain the theoretical model of visitation we used, followed by the two types of onsite counts used in this study (all-day counts from sunrise to sunset and periodic counts of parked cars) and the development of extrapolation factors for estimating visitation to multiple access points on a single day.

Theoretical Model

The easiest way to conduct onsite observations is to count periodically the number of people present at a single access point at different points in time throughout the day. However, these counts (hereafter referred to as "periodic counts") need to be translated to total visitation for the day because they are simply a snapshot in time of recreational use. Banzhaf (1996) first developed a conceptual approach that established a relationship between periodic counts and the total number of visitors to a site. His working paper has been cited frequently because it emphasizes the practicality of using periodic counts translated to total visitation for the day (e.g., King and McGregor 1996; Leggett 2017). We used periodic count methods to estimate

visitation to the public access points of Three Bays, and followed Banzhaf's (1996) framework closely, summarizing and explaining our application below.

We establish a relationship between periodic counts and total number of visitors for a day by first creating a distribution of use throughout the day. The hypothetical distribution of use curve (Figure 3) shows the number of recreational users at any given moment at a site. This is considered the “stock” of recreational users and is based on the flow of arrivals and departures through the day. The stock of visitors at any time is the difference between the cumulative arrivals and departures up to that time (Equation 1).

$$s(t) = \int_{t=0}^t a(t) - d(t) \, dt \quad \text{Equation 1.}$$

Stock of recreational users derived from arrivals and departures.

Where,

$s(t)$ – stock at time t

$a(t)$ – arrivals at time t

$d(t)$ – departures at time t

Using all-day counts to observe actual recreational use from sunrise to sunset, we developed a similar distribution curve to show use throughout the day for access points on Three Bays. Counting all day at a recreation site allows for tracking arrivals and departures to calculate the stock ($s(t)$) present at any point in the day. However, because these all-day counts are resource intensive, our objective was to develop a method to estimate total arrivals ($\int a(t)$), or equivalently total departures ($\int d(t)$), by only observing the stock ($s(t)$) at various points in the day through periodic counts. The arrival and departure functions give the number of recreational users, but also can be thought of as the probabilities of a single recreational user arriving and departing at a given time. By thinking of them as probabilities, we can connect periodic counts to the stock curve of unique visitors through a day. As explained by King and McGregor (2012), the chance that we observe a recreational user, j , who visited sometime throughout the day in a periodic count, C_t , is the probability they arrived before the count and left at any time, T , after the count.

$$P(j \in C_t) = \int_{t=0}^t a(t)dt \quad * \quad \int_t^T d(t)dt \quad \text{Equation 2.}$$

Probability of observing a recreational user.

These probabilities differ for each time, t given the changing pattern of arrivals and departures throughout the day, creating the probability of a user being present during a specific time period, P_t . We therefore weight the count of each person, C_t , during a specific

time period by the chance of them being present in a count to estimate visitation for the day, V .

$$V = \int a(t) = \frac{1}{P_t} C_t \quad \text{Equation 3.}$$

Visitation for the day based on the observation of an individual during a periodic count.

We refer to the term $\frac{1}{P_t}$, as the “extrapolation factor” for that time, t . As it is derived using the stock curves developed from the all-day counts, this can be used to extrapolate visitation for a whole day from a periodic count at any one time.

Observations and Sampling Plan

While Banzhaf (1996) developed a general framework, the applications of the framework have thus far relied on interviews or surveys to elicit arrival and departure times and/or trip durations. Conducting surveys can be a constraint in many cases where it is a challenge to obtain approval to survey the public or to avoid interrupting a person’s recreational visit to the water. Our approach provides an alternative. Horsch et. al (2017) describe methods and best practices for obtaining visitation observations for more general coastal recreation at larger beaches. Our methods are similar but adapted for the types of access points found in estuaries. We developed stock curves and associated extrapolation factors using onsite observations to document arrivals and departures. We utilized two types of onsite counts, all-day and periodic, which we discuss below. From these we calculated the relationships between the periodic counts and the actual total visitation for that access point throughout the day using all-day counts. This produced extrapolation factors that can be applied going forward to just one periodic car count to estimate visitation at a public access site in a single day. This is a simple and cost-effective alternative to surveys and all-day observations.

All-Day Counts

We used all-day counts to record actual visitation at access points for the day. These counts consisted of recording arrivals and departures of both recreational users and cars at an access point for an entire day. For each of these all-day counts, we kept track of the arrivals, $a(t)$, and departures, $d(t)$, in 15-minute increments. We used the arrivals and departures to calculate the stock curve for the day, $s(t)$ (Equation 1). In the results, we grouped the 15-minute increments into hour blocks for simplicity to create the stock curves and extrapolation factors by hour. We also recorded the primary recreational activity of each person based on their activity on arrival to the access point.

We conducted 16 all-day counts at the 11 sites over the span of seven days during the summer of 2017 (June-August), sampling two or three sites on each of the seven days. We used stratified random sampling to capture use on weekdays and weekends as well as by month to cover June, July, and August with at least two days per month. A team of two or three researchers was stationed at each site, with an additional two researchers moving from site to site conducting periodic counts. The randomized sampling allowed us to capture use

for different weather conditions and times of the season. We randomly selected sites by access point type (beach, boat use, and landing or way to water¹) to ensure there were at least two different types of access sampled on any given date. We conducted at least one all-day count at each access point.

We created zones for each access point to differentiate between people “using” the public access point and those accessing the bay through private access or quickly passing by. We mapped each access point and outlined lines of demarcation for determining whether someone should be counted (see Figure 4 for an example of a zoning map for cars at Loop Beach). We created zones separately for counting cars and recreational users², and utilized the zoned maps for both the all-day observations and periodic counts to ensure consistency between counting methods and among researchers.

To quantify recreation for a range of activities, not just beachgoing, we estimated visitation from sunrise to sunset. This captured use of the estuary during the tail ends of the day when some of the different types of activities tend to occur (e.g., fishing and shellfishing). Because sampling each of the seven days from sunrise to sunset was outside the scope of this study, we randomly selected three days to sample from sunrise to sunset and sampled the remaining four days from 9am to 4pm. The 9am to 4pm time frame was chosen based on the assumption that, because the town of Barnstable collects parking fees during these hours at nearby major beaches, that window represents the normal hours of peak recreational use for a day. In later analyses and when describing visitation for a day, we adjusted each estimate to represent visitation from sunrise to sunset based on the ratio of visitation between normal hours and the tail ends of the day.

Although these all-day counts directly obtained the needed information to quantify visitation for one day for a single access point, they were fairly resource intensive and time consuming. The all-day counts would also be difficult to conduct at all 11 access points in the estuary at once, as each access site needed two or three observers to count people and cars. Therefore, we conducted complementary periodic counts to develop a method to more efficiently estimate visitation for the estuary on a given day. While these all-day observations were used to calculate extrapolation factors, they were also used as actual visitation numbers to determine the accuracy of visitation estimates derived from the periodic counts.

Periodic Counts

The periodic counts (C_t in Equation 2) recorded the instantaneous count of parked cars at a site within a given zone at a specific time. Given the difficulty of observing recreational users at a public access point, we determined periodic car counts were a better measure. This is because people may enter through an access point but often travel outside the

¹The types of access defined in this article are based on the town’s recognized public access points. Boat use includes the town dock and boat ramps, designated by the town of Barnstable. A landing is defined as foot access to the water for small boats and launching of canoes or kayaks. “Ways to water” is the term used to define any other points of public access.

²Zoning maps might be different when counting cars and recreational users because some access points had parking spaces farther away from the site or we found that people would park their car but not use the public access point for recreation. These zones allowed us to differentiate between recreational users and non-recreational users.

observational area (e.g., kayakers, sailors, or other boaters) which could lead to an underestimate of recreational users for the day if we only used the number of people directly visible at the public access point from our periodic counts. Therefore, we refer to “periodic counts” as the number of parked cars observed at the access point for an instantaneous “snapshot” of time. These car counts were used to extrapolate to total visitation for the day (Banzhaf 1996). Periodic counts of cars are much easier to conduct than all-day counts and can be done quickly for multiple access points at various times in a single day. This method is similar to roving creel surveys presented in the fisheries management literature (e.g., Rasmussen et al. 1998; Soupir et al. 2006), where observers drive or fly between each access point, record the observations and move to the next. We took isolated periodic counts at least twice per day (morning and afternoon) at all 11 access points on each sampling day when the all-day counts were conducted (n= 170). Observers responsible for the all-day counts at the randomly selected access point also conducted periodic instantaneous counts at the top of each hour for five of the seven observation days (n=128; total periodic counts n=298). The same designated zones we used in the all-day counts of each access point were used to put bounds on which cars were included in the periodic counts.

Relationship between All-day and Periodic Counts

The probability of seeing a car during a periodic count is related to the distribution of cars in a day. Using the stock of cars throughout the day is theoretically the same as estimating the arrivals and departures of recreational users explained in Banzhaf’s theoretical model. We fit our extrapolation factors using the stock of cars for each hour block, S_t , and the all-day counts of visitation, V . Therefore, our extrapolation factors, E_t (Equation 4), internalize both the sampling weights, $\frac{1}{P_t}$, and car-to-people ratios into the extrapolation factors by hour.³ In more intuitive terms, this allows us to answer the question “how many recreational user visits for an entire day does one car in the parking lot at a given time represent?”

We calculated an extrapolation factor relating one car observed at a site during a periodic count to the actual visitation (number of people) observed from all-day counts at that site during that hour.

$$E_t = \frac{1}{\frac{1}{n_t} \sum \frac{S_{dt}^i}{V_d^i}} \quad \text{Equation 4.}$$

Average extrapolation factor by hour.

Where,

E_t – the extrapolation factor for hour t

³Similarly, we could have translated the total visits from car to people terms using a fixed ratio found from our observations. However, by estimating an extrapolation factor for each hour as we do above, it allows for differences in the car to people ratio by hour.

n_t — the number of observations made in hour t across all sites and days

V_d^i — total number of recreational users from all-day counts for sites i on day d

S_{dt}^i — stock of cars for sites i on day d in hour t

To estimate visitation for an entire day, we then applied the average extrapolation factors for each hour, E_t , to periodic counts taken in that hour to estimate visitation throughout the day to our periodic counts from each individual site across all sampled days.

$$\widehat{V}_{dt}^i = E_t C_{dt}^i \quad \text{Equation 5.}$$

Visitation for a site for the entire day.

Where,

$\widehat{V}_{dt}^i$ — extrapolated total visitation for site i from a periodic count at time t

E_t — average extrapolation factor for time t

C_{dt}^i — periodic count at time t for site i

For those sites where we have overlap between extrapolated visitation, $\widehat{V}_{dt}^i$, and actual visitation based on all-day counts, V_d^i , we estimated an error, $V_d^i - \widehat{V}_{dt}^i$ (equation 6).

$$e_d^i = V_d^i - \widehat{V}_{dt}^i \quad \text{Equation 6.}$$

An error for a site on a day.

Where,

V_d^i — total number of recreational users from all-day counts for sites i on day d

$\widehat{V}_{dt}^i$ — extrapolated total visitation for site i from periodic count at time t

This error estimates the accuracy of applying our extrapolation factors to periodic car counts. For assessing the method overall, we estimate three accuracy measures (equations 7–9). The mean error (ME) gives an estimate of the amount of bias in the estimates. The mean absolute percentage error (MAPE) measures the percentage deviation of our estimates based on periodic counts from the actual measures using all-day counts. The root mean square error (RMSE), or the standard deviation of the errors, provides a commonly used statistical measure of the fit penalizing large errors.

$$\frac{1}{n} \sum_n e_d^i$$
Equation 7.

Mean error.

Where,

n – number of daily visitation estimates made from periodic counts

$$\frac{100\%}{n} \sum_n \left| \frac{e_d^i}{V_d^i} \right|$$
Equation 8.

Mean absolute percentage error (MAPE).

$$\sqrt{\frac{\sum_n (e_d^i)^2}{n}}$$
Equation 9.

Root mean squared error (RMSE).

Because we took multiple periodic counts across multiple sites on any day, we simulated the estimates of accuracy above by creating errors at each location on each day 100 times in R based on randomly selecting a series of periodic counts. We then averaged the estimates of accuracy (ME, MAPE, RMSE) across the 100 simulations to determine the accuracy of the methods when one or multiple periodic counts are taken certain time windows. We conducted this type of simulation to estimate the accuracy of the method is such a way as to mimic how a user of our method would conduct future counts (periodic counts would be taken at various times in different places based on available resources and not necessarily at the same exact time of day in each place).

Estimating Visitation for the Day for the Entire Estuary

To get total visitation for the estuary based on the eleven public access points, we calculated the extrapolated visitation ($\widehat{V_d^i}$) for each site and summed the 11 estimates to get to total recreational use of the bay. Based on the results of the tests of the accuracy of periodic counts taken at different times within the day, we used counts taken within the preferred time window (11:00–4:30pm), explained below, to estimate visitation for Three Bays for each sampling day.

Results

Unlike many other recreational counts that focus solely on a single recreational activity (usually beachgoing), we observed multiple types of recreational use in the estuary (see Figure 5 for the breakdown of types of use). Activities varied across the three different types of access points: 1) beaches were primarily used for spending time by the shore (including swimming or wading), 2) boat ramps and launches were primarily used for launching

motorboats and sailboats, and 3) landings and ways to water primarily served as areas for walking. Across all 11 access points, spending time by the shore made up almost half (47 percent) of all use, followed by boating (16 percent) and walking (16 percent).

We observed considerable use of the Three Bays estuary system throughout the summer season. Use varied based on the type of access point, time within the season, day of the week (weekend versus weekday), weather, and available parking (see Table 1). At Loop Beach, for example, the all-day counts revealed 623 people for the sunny Saturday following the Fourth of July (a U.S. holiday) and only 55 people in the beginning of the summer season on a June Monday with less ideal weather conditions.⁴

Based on the all-day counts of both cars and people, the overall estimated car-to-people ratio across all sites and across the days with different weather is 1:1.70. The ratios for the different types of access points were 1:1.41 for beaches, 1:1.89 for boat launches and landings, and 1:1.82 for landings and ways to water. These ratios are lower than many estimates of recreational participation at larger coastal beaches (for instance, the town of Barnstable uses a 1:3 ratio for its larger, open water beaches; Patti Machado, Leisure Services Director for the Town of Barnstable's Recreation Division, email to author, September 14, 2016). The car-to-people ratios varied widely across the access points and weather conditions, with a high of 1:2.37 at a beach access point (Loop Beach) on a busy, sunny July weekend day to a low of 1:0.64 for the same beach on a rainy day in June⁵. Having a range of car-to-people ratios is consistent with some past studies (e.g., King and McGregor 2012). The lower car-to-people ratio we found could be indicative of how estuaries differ in use from coastal beaches in terms of solo use for fishing, kayaking, etc. and may reflect different uses of those areas under varying weather conditions (e.g., there are fewer people than cars for some of the observations of rainy days because people were not counted if they did not exit their cars).

Distribution of Use throughout the Day

The all-day counts revealed a general pattern of use across the sampled sites (Figure 6). The busiest time for use (when the largest stock of users was present) was in the afternoon from 12 to 4pm. Using the Banzhaf (1996) stock curve concept, as described above in the methods section, the stock of recreational users is the cumulative arrivals minus the cumulative departures up to that point in time. Like Banzhaf's theoretical model, the curve reveals an increase in the stock curve as arrivals outnumber departures until the afternoon, when the total number of users begins to decrease as departures outnumber arrivals.

The average distribution of use curve also captures recreation throughout the day from sunrise to sunset, showing the importance of capturing use of an estuary or other coastal areas during the tail ends of the day. Many recreational visitor counts are based on parking receipts collected for a day or during day counts, which provide data on use only for limited hours. For example, in Barnstable, Massachusetts, parking attendants at the town's open

⁴As noted in the methods section, the all-day counts are adjusted to represent the day from sunrise to sunset based on the visitation across time.

⁵This difference is mainly because we did not count people who parked at the access point, but did not get out of their car (possibly because it was a rainy day).

coastal beaches collect data only from 9am until 4pm. We conducted six all-day counts from sunrise to sunset and ten all-day counts from 9am to 4pm. In our six counts that captured use from sunrise to sunset, we found that only 61 percent of all entries to the access points occurred during the hours of 9am to 4pm. Afternoons and evenings from 4pm on constituted 21 percent of all entries to the access points, and 18 percent of all entries were before 9am.

Extrapolation Factors

Because visitation varies throughout the day (Figure 6), predicting total daily visitation from periodic car counts requires the use of different hourly extrapolation factors (Equation 4 above). Put simply, the number of cars present at one hour of the day may represent a different number of total people for the day than cars present at a different hour within the day (Figure 7). We calculated extrapolation factors for each hour, which are used to translate the number of cars observed at an access point during a particular hour to the total visitors to that access point for the entire day. The extrapolation factors account for both the likelihood of observing a car as well as the car-to-people ratio for the hour in which the periodic count was conducted. The extrapolation factors range throughout the day from a high of 60.84 people per car for 5am to 5:59am to a low of 10.32 people per car for 2pm to 2:59pm. Figure 7 shows the confidence intervals of the extrapolation factors with the highest precision in the afternoon from 2pm to 2:59pm. This corresponds with the higher probability of counting a person in the afternoon because the stock of people is higher in the afternoon than in the early morning or evening.

Estimating Visitation for the Day

We found that total visits for the day can be estimated using single periodic car counts multiplied by our calculated extrapolation factors for each hour block within 44 percent of actual visitation (Equation 5). Using 158 periodic counts that overlapped with all-day count data, we estimated the accuracy between predicted visitation derived from periodic car counts to the actual visitation that we observed from the all-day counts. Table 2 presents the mean error, the mean absolute percentage error (MAPE), and the root-mean-squared error (RMSE). Conducting one random, periodic car count at any point between sunrise and sunset to calculate the total recreational users for the day results in a mean error of 35.87, MAPE of 47.75, and RMSE of 19.26 (Table 2). The accuracy of estimating daily visitation is not markedly increased by conducting two random counts in a day at a site (mean error of 36.26, MAPE of 43.77, and an RMSE of 17.35). However, conducting a single periodic car count within a more strategic window for conducting periodic counts did show an increase in accuracy. Conducting a random periodic car count during the late morning/afternoon (from 11:00am to 4:29pm) did show increased accuracy (mean error 31.28, MAPE of 44.44, and RMSE of 14.42). We chose to create one set of factors for use at any access point in the estuary. The accuracy of the method could be increased by creating access-point or access-point-type specific (e.g., boat ramp or beach) extrapolation factors, for example. However, this increase in accuracy would come with a tradeoff as it would entail more resources to conduct all-day counts in more places as well as a more complicated application by users.

One complication of this methodology is the difficulty in estimating a day's recreational use if the sampled periodic car count is a zero (there are no cars present at that site at the time of

observation). This is like imperfect-detection limitations found in ecological research (for a review, see Banks-Leite et al. 2014). We realistically know that at least one car will likely visit each of the sites every day, but a zero counted during a periodic count would extrapolate to a zero estimate for the day. In our sampling, 16 percent (25 out of 158) of the periodic car counts that overlapped with an all-day car count were zeros. We retained them for the calculation of the extrapolation factors because dropping them would induce bias, as should future users of this method. The mean errors presented in Table 2 are thus based on the predicted visitation for all the periodic counts, including the counts that were zeros. Because the zero counts are included, this leads to an underestimate of visitation. Future researchers using our methods may also encounter zero-count issues. Sampling later in the day, specifically in the preferred window between 11:00am to 4:30pm reduces the number of zeros and increases the accuracy of the estimates.

For each of the seven sampling days, we estimated visitation for the entire Three Bays embayment system based on randomly drawn periodic car counts at all 11 sites (see Figure 8). To do this, we took a random draw for each of the sites from periodic counts taken between 11:00pm and 4:30pm on each sampling day. Figure 8 shows total recreational use of the Three Bays embayment system on each day, by type of site (beaches, boat launches, and landings or way to water). Summed public recreational use for all access points in Three Bays ranged from a low of 289 recreational users on a rainy Monday in early June to 2,332 on a sunny Saturday in July. Due to parking availability and other site attributes (refer to Table 1), Loop Beach and the Oyster Landing town dock contributed most to recreational use in Three Bays.

As described earlier, the sampling dates were randomly chosen to provide a representative set of dates and weather. The relative use across the summer season for Three Bays is consistent with expected coastal use (Lyon et al. 2018), with heavier use on weekends and days with good weather (see Table 1 for weather by date).

Discussion

Our work provides a simple method in which a set of extrapolation factors can be applied to a single periodic count of cars observed at multiple access points on an estuary (Figure 2). Summing visitation across all access points produces a daily estimate of the total number of recreational users at an estuary (with most accurate results from single periodic car counts conducted between 11am – 4:30pm) using a single periodic count of cars. This method produced a lower bound of recreational use for the Three Bays estuary system because we only included use at public recreational access points. Even with this conservative estimate, we observed hundreds to thousands of visitors on each of the seven sampling days randomly chosen across the summer season in one small estuary system on Cape Cod. To date, there has been very little work conducted to understand the recreational value of estuaries, and what has been done has been focused on larger estuaries like Narragansett Bay, the Delaware River, or Chesapeake Bay. This study provides practical methods for generating recreational use information (Figure 1) that can be used to conduct valuation estimates for the many smaller estuaries where visitation data are lacking. These smaller access points, which have been largely ignored in the recreational count literature although they support a significant

amount of use. In this study, the number of recreational users on any given day for the entire Three Bays estuary was greater than the estimated use of any one of the public open water beaches for the town of Barnstable (for estimates of those values, see Figure 5, Lyon et al. 2018). This demonstrates the substantial amount of aggregate use of these smaller public access points for a single waterbody and the value of estuaries for communities. Because this is likely to be true for other estuaries, a significant amount of coastal recreational use may not be accounted for in coastal management decisions.

Estuaries are burdened with many environmental stressors and mitigating those stressors and restoring ecological integrity is neither easy nor inexpensive. Estuaries are also more likely to be affected by degraded water quality than open water beaches, but typically receive fewer resources towards estimating recreational use. Understanding the social and economic value of recreation for an estuary helps to provide insights into the usefulness of investing resources in recovering an estuarine area. Scaling up estimation of recreational use on estuaries to include all public recreation sites on a regional or national scale could provide important information about the value and use of these systems for managers and other environmental decision-makers to consider. Recreational data can also provide important baseline data that would be valuable for estimating the impact of adverse events such as oil spills, beach closures for bacteria, or algal blooms.

The methods in this paper provide information on recreational use for seven specific sampling days, and those days represent a sampling of the distribution of recreational use throughout the summer. This work stops short of providing a precise estimate of the full season's use. A rough estimate of the full season's recreational use can be calculated using the mean of weekday participation (883 recreational users) and mean weekend-day participation (1,479 recreational users) from our sampling days and multiplying by the number of weekdays and weekend-days from June to August (66 and 26 days, respectively). This simple calculation estimates more than 95,000 (96,671) recreational use visits to the Three Bays for the summer season. It is also possible, but outside of the scope of this paper, to more precisely model seasonal visitation of Three Bays using a model of data from other Barnstable beaches with temporal and weather considerations (see Lyon et al. 2018 for more details).

There are a few challenges and limitations to these methods that should be considered when implementing this approach in other areas. First, visitation to public access is highly site specific. The public access points we sampled were much smaller than traditional, open water beaches, and they were often much more incorporated into the surrounding residential zones or roadways. They mostly, unlike many beaches, did not have specific, formal entrances. Additionally, many of the sites had very limited parking availability (see Table 1), so many people parked elsewhere and entered Three Bays by foot or by bike. Decisions sometimes needed to be made about what constituted a visit to the site for recreational use rather than a pass-through; these decisions were greatly assisted by using the maps delineating where to count people and cars (see Figure 4 in the methods section for an example). These maps were critical for carefully demarcating what constituted a car or person as being "in" or "out" of the recreational use zone. The designated yellow dotted lines for each access point (Figure 4) were treated as our formal entrances to Three Bays,

which made the counting process more consistent across researchers. It was assumed that if someone entered Three Bays by other means (for example, by boat), they did not formally use the public access point. The maps allowed the observers to keep track of their counts in a consistent manner, especially on busy days when it became difficult to track the length of time a single person stayed within the zone to determine if they should be counted as a user.

Second, brief visits can be difficult to capture with periodic car counts. Many of these recreation sites are deeply incorporated into the culture of neighborhoods and are used for short visits while out for a walk or for taking a quick look at the water, in addition to the lengthier recreational visits. Town resident permits added another layer of complexity to capturing total visitation by impacting parking behaviors. Non-residents may visit access points fewer times and stay longer, whereas residents who have paid for a permit can more easily visit the shoreline briefly multiple times in the season. These complexities increase the difficulty of capturing more ephemeral visits, particularly when using parked car counts.

Third, extrapolation factors are based on current public access and parking allowances as well current coastal behavioral patterns. Future use of this model assumes that visitors' behaviors do not change in ways that would affect the extrapolation factors used to connect the number of vehicles to the number of people. Changes in the available bike access or parking spots could affect these behaviors as could cultural shifts in engaging in these or other behaviors, so future recounts of the area would be important if shifts occur.

As mentioned above, the demarcated lines for each access point determine when a person or car should be counted as a recreational visit. They also allowed the observers to keep track of their counts in a consistent manner, especially on busy days when it became difficult to track the length of time a single person stayed within the zone to determine if they should be counted as a user. Overall, these limitations are likely to mean that our all-day counts underestimated total recreational use of the estuary. Further, the inclusion of these visitors who stayed for a short time results in reduced probability of capturing their visits in periodic counts, and possibly influenced the calculated mean error (see Table 2) for the predicted visitation from periodic counts to the all-day observations counts.

Overall, these limitations are likely to mean that both our all-day counts and the use of periodic car counts underestimate total recreational use of the estuary. All-day counts were likely low because we chose to exclude certain types of use such as boating near the site and walking, biking, or running by a site. In addition, our inclusion of visitors who stayed for a short time in all-day counts (for example, those who entered a site for only a few minutes to take in the scenery) results in reduced probability of capturing their visits in periodic counts, and possibly influenced the calculated mean error (see Table 2) for the predicted visitation from periodic counts to the all-day observations counts.

There were also challenges and limitations in determining the primary recreational activity of individuals during the all-day observations. For instance, someone may have entered the recreational site to go kayaking but stayed to go swimming, which made it difficult to get the length of stay and number of people at any given time by activity. Because people sometimes engaged in more than one activity during their visit, we could not estimate

different distribution of use curves throughout the day by recreational type. In figures 2 and 5, we recorded the observed activity upon entry to the recreation site as the activity for an individual's visit. The number of boats using a public access point is similarly difficult to track. We did not count recreational users boating near a public access point or entering by boat because often it was impossible to distinguish whether they entered the estuary by sea or from another access point within the estuary. Additionally, people may be miscounted on a boat, especially if people are picked up or dropped at locations other than the public access points we were observing on that sampling date. Counting boats and boat users from land was also difficult when the trailers for the boats became detached from the car due to limited space. For example, a car may detach their trailer in a parking space, leave, and then come back (so would be double counted when re-entering). Even with these complications, the benefit of the methods used for this work enable researchers to calculate recreational use extrapolation factors without the use of intercept surveys, which can limit the feasibility of use studies for many organizations and agencies due to financial, bureaucratic, and technical restrictions.

The methods presented in this paper were designed so they could also be applied in other estuarine recreation spots and may provide helpful shortcuts (i.e., the use of periodic car counts rather than all-day counts) for collecting recreational data more efficiently. Unlike methods that rely on providing estimates solely for larger beaches, our methods are applicable in the diverse recreational settings provided by estuaries. In addition to estuarine beaches, we calculated recreational use for town docks, ways to water, landings, and boat launches, which provide access for a large number of recreational users to estuaries but have thus far been neglected in the literature. Future work for estimating recreational use in coastal areas that compare all-day observations and periodic counts would help provide increased transferability of the methods and findings. The extrapolation factors we calculated were for the Three Bays estuary, and it remains unknown how well those factors would hold for recreation sites in other estuarine systems. As these methods are replicated across other study areas, it may also be possible to provide basic estimates of recreation by just using periodic counts or the number of available parking spots as proxies. Wallmo (2003) found periodic counts to be the most economical method for calculating beach visitation, and conducting periodic counts was certainly a less labor- and resource-intensive approach.

There are several recommendations from this study that may be valuable to other researchers conducting similar work in estuaries. We designed these methods to overcome the need to conduct surveys of recreational users at estuarine sites. Logistically, counting cars rather than people is much easier, especially when using zone maps (Figure 4) to provide important consistency across researchers. If conducting only periodic counts, narrowing the time window of counts to 11:00pm-4:30pm, reduces the estimate's error. If applied to other estuarine recreational sites, the most precise estimates could be developed by conducting a similar combination of periodic and all-day counts.

In this study, we have provided a set of methods for estimating recreational use at public access points in estuaries and other coastal locations. Estimates of recreational users provide some of the basic information needed for more complex economic and social analyses of

impacts, but very little work has been conducted to calculate use of smaller estuaries. Understanding how many people are using these smaller, but numerous, coastal access points is important for understanding the magnitude of impacts from water quality improvements or degradation. This is also useful in other management contexts such as decisions about capital improvements to access points or determining damages from an adverse event such as a hurricane or oil spill. These methods should be useful for estuary managers, local, state, federal or tribal government agencies, and non-governmental organizations that are interested in calculating public recreational use of their estuaries.

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Fig. 1. Descriptive graphic of methods developed and applied in this research.

The approach we present is the use of extrapolation factors that relate the count of cars at certain times to visitation through the whole day. Mean extrapolation factors were calculated by relating periodic, instantaneous observations to actual daily visitation in the form of all-day counts. Multiplying a single periodic car count at a site (sampled at 1 PM, for example) by the extrapolation factor for 1 PM produces an estimate of total visitation to that site for the entire day. Summing total daily visitation across all public access points in an estuary provides a simple method to estimate total daily visitation for an entire embayment.

Fig. 2. Map of Three Bays and the 11 public access points used in this study

Each access point is described by type (i.e., boat ramp, beach, dock, landing, or way to water) and estimated recreational use broken up by types of activities.

*estimated visitation for an average weekend day in the summary, calculated using car counts and broken down by type of activity based on results from all-day observations

Fig. 3. Stock of recreational users

The stock of recreational users at any one time in the day is the difference between the cumulative arrivals and departures up to that time. Adapted from Banzhaf (1996) and Leggett (2017).

Loop's Beach - Car Count Zones

For **all day**, count any cars or cars with trailers that enter the main lot closest to the beach or park in a designated space along the street. Arrivals are counted when either parked in a space or entering the main lot by crossing the yellow dotted line. Departures are counted when the parked cars along the street leave or a vehicle exits the main lot from the yellow dotted line.

For a **periodic count**, include all cars parked in designated parking spots along Oceanview Avenue. Also count all cars in the main parking lot (these cars in the main lot do not need to be parked in a designated spot).

Fig. 4. Sample zone map

We created two maps, one for counting cars (shown in figure) and one for counting recreational users for each of the 11 sampled recreation sites. The demarcated areas determine whether observers should count cars as “in” or “out” of the recreation site. The use of these maps ensured consistency in counting methods across researchers.

Fig. 5. Different types of recreational use on the days of the all-day counts at the 11 different access points on Three Bays embayment system in Barnstable, Massachusetts

As shown in the four pie charts, the proportion of types of recreational use is different at the three types of access points, with the most popular activities as follows by access type: beaches, spending time by the shores; boat launches, boating; and ways to water, walking by. Each of the types of recreation shown in the legend begin in the top right with boating and proceed clockwise in the order displayed in the legend.

Fig. 6. The average distribution of recreational users throughout the day

Stocks and flows from 9am to 4pm are the average of all 16 all-day counts and those along the tails from 5am to 9am and 4pm to 8pm are the average of only the six all-day counts when we observed visitation in those hours.

Fig. 7. Hourly extrapolation factors

The extrapolation factors translate the number of cars counted at a given time to the total people visiting a site in a day. They are presented in terms of people, where one car counted within an hour translates to the number of people shown. The figure shows the average factor by hour and the 90 percent confidence interval (the shaded area). The confidence intervals were estimated based on a gamma distribution fit with method of moments matching to each hour's extrapolation factor from our sample.

Fig. 8. Estimated visitation to Three Bays

These estimates are based on a randomly selected periodic car count for each access point and day during the preferred afternoon hours (11:00 – 4:30pm). Visitation is grouped by type of access point (greens = ways to water and landings; golds = boat ramps and town dock; blues = beaches) and ordered within each access type by level of use.

Table 1.

Recreational use of the 11 access points on the seven sampling dates.

Sampling Date	Max. Temp.	Precipitation	Sky Condition	Public Access Name	Available Parking Spaces	Car Count*	People Count*
Sunday June 4, 2017	72	None	Partly Cloudy	Bay Street Boat Ramp	5–10	51	75
				Ropes Beach	10–15	87	63
Monday June 5, 2017	59	Light Rain	Overcast	Loop Beach	50–55	86	55
				Prince Cove Boat Ramp	5–10	19	27
Saturday July 9, 2017	84	None	Clear	Bay Street Boat Ramp	5–10	62	108
				Loop Beach	50–55	263	623
Friday July 21, 2017	92	None	Clear	Cross Street Beach	5–10	73	151
				Hooper’s Boat Ramp	10–15	40	139
				Ropes Beach	10–15	134	171
Saturday July 22, 2017	83	None	Clear	Cordwood Landing	15–20	32	53
				Little River Landing	<5	43	100
Wednesday August 2, 2017	80	None	Clear	Oyster Place Town Dock	40–45	134	214
				Sea View Way to Water	<5	90	134
Saturday August 12, 2017	72	Rain	Overcast	Bridge Street Boat Ramp	15–20	99	111
				Loop Beach	50–55	102	144
				Prince Cove Boat Ramp	5–10	21	50
Total = 16 all-day counts							

Note:

* The total number of people and cars observed at each access point are based on the total number of arrivals corrected to represent a day from sunrise to sunset.

Table 2.

Accuracy of using periodic counts to estimate daily visitation.

	Mean Error	MAPE	RMSE
1 random count within a single day	35.87	47.75	19.26
2 random counts within a single day	36.26	43.77	17.35
1 random count within a window of the day (11:00– 4:29pm)	31.28	44.44	14.42

Note: The mean error, mean absolute percentage error (MAPE), and the root mean squared error (RMSE) measure accuracy in estimating daily visitation with periodic car counts across a variety of period counting methods.