Assessment of Techniques for Estimating Beach Attendance

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Summary

Oil spills and other environmental incidents often result in lost recreational use of beaches and coastal waterways. Under the Oil Pollution Act of 1990 and other environmental liability laws, the public can be compensated for lost beach use from the time of the incident until beach use is restored to the conditions that existed but-for the incident conditions (baseline). Often it is difficult to conduct a census of an entire beach for an extended time period, thus quantifying lost beach use generally involves calculating estimates of beach attendance based on survey techniques. This paper focuses on three onsite survey techniques to estimate beach attendance: all day counts, periodic counts, and helicopter overflights. The results from these different techniques are discussed and some conclusions on the related merits are drawn.

All day counts involve counting everyone who arrives onto the beach via a specified access point for one day. Periodic counts involve taking snapshot counts of specified beach zones at designated times. Helicopter overflights provide a snapshot of the entire beach at a particular point in time. For each technique, sampling designs are used to determine which access points or beach zones will be counted, and at what times the counts will occur.

The technique assessment study occurred August 23rd - 25th, 2002 at Dewey Beach, Delaware. Dewey Beach is a multiple access point beach, with footpaths that provide beach access interspersed along the length of the beach. The sampling design resulted in counting people arriving through a subset of the access points each day for the all day counts, conducting periodic counts at specific times and zones, and

conducting two helicopter overflights each day. Attendance estimates were calculated by adjusting number of observed beach users by the probability that they were observed in a count. Standard errors of the estimates were calculated using a variant of the jackknife method, though the method is analytical and not a true replication method.

Results suggest that, generally, attendance estimates from all three techniques are comparable, as most estimates fall within 95% confidence intervals of each other. Additionally, the estimates rely on a sample of the beach population being able to accurately report their total trip duration and the number of times they re-enter the beach. Sensitivity analyses results show that relatively small errors in the reporting of trip duration and re-entry can have considerable effects on the attendance estimates, and convergence of estimates can occur after modifying trip duration and beach re-entry by relatively small magnitudes. The variances of trip duration and beach re-entry would include the changes required to converge attendance estimates.

Periodic counts are shown to be the most cost-effective method for estimating beach attendance, as 25% of the effort and cost required for all day counts was required for periodic counts that produced comparable estimates. Given the estimate sensitivity to trip duration and re-entry, there appear to be few trade-offs other than cost that render one technique superior to the others.

Introduction

Beach Attendance Estimates

Oil spills and other environmental incidents involving coastal resources often result in lost recreational use of beaches and surrounding waterways. Under the Oil Pollution Act of 1990 and other environmental liability laws, designated that Natural Resource Trustees may claim damages to restore affected beaches and compensate the public for the interim lost use during the process of restoration. To compensate the public in cases involving beach degradation or closures, Trustees must be able to calculate the interim losses incurred. This calculation requires estimates of beach attendance that would have occurred but for the incident. Often this estimate is made by estimating beach attendance both before and after the incident. In some cases, beach attendance data may be available from existing sources, such as lifeguard counts; however, these counts are often not taken according to a representative sampling plan and may produce biased estimates. In natural resource damage cases that involve litigation more accurate data, collected using a sampling plan with additional interviews conducted with beach users, is generally needed. In addition to their use in natural resource damage assessments, estimates of beach attendance may also be useful for other types of analyses. For example, attendance estimates may help determine the size of the beach patrol required to guard a beach, which can in turn affect city or town budget allocations. Further, attendance estimates may be useful for studies involving tourism impacts or other economic analyses.

For attendance estimation, a beach is typically categorized as either a limited access or multiple access beach. Limited access refers to beaches with one or relatively few entry points. Beaches within state and national parks are often limited access beaches, with obvious points of entry such as parking lots or a few trails coming onto the beach. Survey techniques for limited access beaches generally involve the use of an observer at each entry point counting the number of people entering the beach throughout the day. Typically all entry points are counted during a survey of a limited access beach.

Multiple access refers to beaches with enough entry points to prohibit all points being surveyed. One example of a multiple access beach is a beach with a boardwalk along the edge, where a person can step onto the beach at any point along the boardwalk. Other multiple access beaches may not have boardwalks but may have a large number of entry points along the beach. Sampling designs that designate where counts will occur are generally employed to survey multiple access beaches.

Onsite Survey Techniques for Multiple Access Beaches

The underlying objective of most beach attendance surveys is to estimate the number of distinct visits to a beach during a given time period. This implies weighting each observation (person counted) by the probability that they were captured in the count. For all techniques, part of this probability is determined by the sampling design. However, a second component of the probability of being captured in a count depends on the type of survey technique employed. Three techniques that have previously been used to estimate beach attendance (Hanemann 1996; Torangeau and Ruser, 1999; Deacon and Kolstad 2000) are discussed here: all day counts, periodic counts, and helicopter overflights.

All day counts involve selecting a subset of entry points and stationing an observer at each point to count each person who enters the beach throughout the day. The probability that someone was captured in a count is reflected by the probability that the entry point they walked through was selected to be surveyed. However, it is possible for someone to leave and re-enter the beach in the same day and be double counted, artificially increasing the probability of being captured in a count. A more accurate representation of the probability of being captured in a count is a function of both the sampling probability and the number of beach re-entries. Previous beach use studies have included sub-sampling interviews of beach users to determine the average number of times a person re-enters the beach (Hanemann 1996) and adjusting the sampling probability accordingly.

Periodic counts are counts taken at selected times throughout the day. Rather than counting people entering the beach through an entry point, periodic counts count the number of people in a pre-defined zone of the beach. Sampling designs are used to select both the zones to be counted and the times of day for conducting the count. The length of time required to conduct the periodic count is primarily determined by the number of people in the zone, but the time should be limited to a relatively short period to avoid double counting people who walk out of and back into the zone. For this technique, beach re-entry is typically not a problem; however, the length of time someone stays at the beach does affect their probability of being captured in a count. Similar to the all day counts, sub-sampling interviews can be conducted to determine beach trip duration, and the sampling probability can be adjusted accordingly. Torangeau and Ruser (1999) use this technique to estimate beach attendance at Florida beaches.

Helicopter overflights provide a means to conduct a sweep survey of the entire beach, theoretically counting every person on the beach at a specific point in time. Overflights can be thought of as a periodic count where the predefined zone is the entire beach, and the sampling design determines the time of the count. Similar to the periodic counts, the probability of being captured in a helicopter count is a function of the sampling design and the duration of a beach visit. Clearly, for all types of survey techniques, additional sampling observations will should increase the accuracy of the estimate.

Goal and Objectives

The goal of this paper is to compare beach attendance estimates from all day counts, periodic counts, and helicopter overflights, and to provide general insight concerning the advantages and problems of each survey technique. The primary objectives of the paper are to (1) estimate beach attendance using all day counts, periodic counts, and helicopter overflights, (2) compare analytical procedures for estimation within a technique, (3) address issues relating to the accuracy of each technique, (4) assess the cost-effectiveness of each technique, and (5) assess the efficiency changes from decreasing the number of observations in the estimate.

Study Area

The study was conducted at Dewey Beach (Figure 1), located on the southern Atlantic shore of Delaware, approximately 95 miles south of Wilmington. The town of Dewey Beach is 22 blocks long (approximately 1.2 miles), with a winter population of 350 and a summer population of 30,000. The Dewey Beach Patrol is on duty from the Friday before Memorial Day until the Sunday after Labor Day, from 9 AM until 5 PM daily. Dewey Beach was chosen as the study site for several reasons. First, the beach is a known size with designated northern and southern boundaries that are easily distinguishable both on the ground and from an aerial view. This helped to ensure that the overflight counts were conducted within the same area as the on ground counts. Second, the Dewey Beach Patrol and the Delaware State Police provided significant assistance during the study design and throughout the implementation. Third, access to Dewey Beach is primarily via twenty footpaths that lead from the street to the beach. The area of beach lying between two consecutive footpaths created a zone which could be counted during a periodic counts, and the footpaths themselves served as entry points to be surveyed.

Dewey Beach is bounded on the south end by Collins Avenue and on the north end by Chesapeake Street, although technically the beach extends about 400 feet beyond Chesapeake Street to the north. North of West St. there are no hotels on Route 1, and vacation and rental properties in this area tend to be less densely distributed than those south of West St. Additionally, there are no restaurants or shops in this area, as there are along the rest of Route 1. The area from St. Louis St. to Read St. has a high concentration of hotels with some rental units, and south of Read St. there is a mix of hotels and rentals. Lifeguards from the Dewey Beach Patrol suggested that the extreme northern and southern ends may receive slightly less use than the rest of the beach. Lifeguards also suggested that weekends received higher use than weekdays, and that use on Fridays is somewhere between a weekday and a weekend day.

Access to Dewey Beach is via footpaths that begin at the end of each street, creating twenty-one entry points. There are few hotels where guests can walk directly onto the beach from the hotel without using a footpath, and small sand dunes are present in areas where there are no hotels or rental units. Thus nearly all visitors access Dewey Beach via the footpaths.

Methods

Overview

The study was conducted from Friday August 23 to Sunday August 25, 2002. The sampling day went from 6:30 or 7:00 AM to 6:30 or 7:00 PM, with the start time selected randomly on Friday and alternating on subsequent days. On each day periodic counts, all day counts, and helicopter overflights were conducted. Additionally, a sub-sampling effort was undertaken each day to collect data on trip duration and beach re-entry. The sampling design, including sub-sampling, required thirteen observers per day to simultaneously conduct all of the sampling methods. The design and procedural methods are described below.

Sampling Design

<u>All day counts</u>

A systematic sampling approach was used to select 4 of the 20 streets between and including Chesapeake and Collins for all day counts. After one street was randomly selected, every 5th street became a subsequent sampling location. This sampling approach was used rather than a purely random sample to ensure that, for each sampling day, sampling locations were distributed throughout the length of the beach (Roger Torangeau, personal communication).

<u>Periodic Counts</u>

Dewey Beach was divided into 20 zones for the periodic counts. Each zone was identified as the area between the two consecutive streets, e.g. zone one would consist of the area between Chesapeake St. and Carolina St. The sampling day was divided into 13 time periods of one hour each. Both the zone and time period for the periodic count were selected randomly from a grid consisting of 260 cells (20 zones x 13 time periods). A training session was given to observers on Friday morning from 6:30 to 9:30 before any counts began. Because of the training, the first 60 cells, e.g. any zone/time between 6:30 and 9:30, were blocked and not included in the sample selection. Thus the sampling grid for Friday consisted of 200 cells. Twelve cells from the sampling grids were randomly selected each day for periodic counts, with two observers conducting six counts each.

Helicopter Overflights

The Delaware State Police provided two overflights of Dewey Beach every day. Flight times were dependent on police schedules and were not randomly selected; however, efforts were made to conduct flights in the late morning and afternoon. One observer was present during each flight.

Sub-sampling

Sub-sampling consisted of short in-person interviews conducted by observers to collect information on beach re-entry and trip duration. To ensure that all sub-sampling was not concentrated during any part of the day, a stratified random sampling approach was used to select sub-sample times in a morning, afternoon, and evening time block. While each day had the same number of sub-sampling occasions, the number of people interviewed during each sub-sampling occasion varied, depending on the observer, the people being interviewed, and the number of people in a zone. For the all day counts the stratified approach resulted in eight sub-samples between 6:30 and 10:30, sixteen between 10:30 and 4:30, and four between 4:30 and 6:30, for a total of twenty-eight sub-samples per day. For the periodic counts each observer sub-sampled after three of the counts, for a total of six sub-samples per day.

Procedural Methods

All day counts

The all day counts were broken into three shifts: (1) 6:30 - 10:30, (2)10:30 - 4:30, and (3) 4:30 -6:30. For each sampling location the first and third shifts were covered by one observer and the second shift was covered by a second observer. Observers counted and recorded all people arriving onto the beach from the footpath for ½ hour (see Figure 2), and were then given ½ hour off. Observers noted anyone arriving onto the beach with surfboards or kayaks. This procedure continued for the thirteen hour sampling day, with sub-sample interviews conducted during selected "½ hour off" periods. Half-hour counts were doubled to obtain arrivals for the sampling day.

Periodic Counts

Zone boundries were constructed by envisioning a line that extended the wooden fences, which distinguished the footpaths coming off the streets, to the rest of the beach and into the water. This was intended to create a zone between two consecutive streets. Observers then counted the number of people within the zone boundaries (see Figure 3). Because many zones were crowded and difficult to count from one stationary point, observers walked a pattern from the back of the beach to a mid-point, counting people in front of them. On average counts took 5 minutes.

Helicopter Overflights

Overflights were conducted twice per day. On each flight the helicopter flew from the north end of Dewey Beach to the south end, approximately a 5 minute flight. The helicopter flew at an altitude of approximately 150 feet and stayed close to the shore line. The speed was controlled so that conditions were optimal for filming the beach. The beach and water were filmed through an open door using a Canon XL1 Digital Camera.

Sub-sampling

During selected periods observers conducted interviews after their counts. The interviews were intended to be short and to collect information pertaining to beach re-entry and trip duration. Appendix 1 contains the interview guide. Interviews were conducted in the zone where the count was taken. If everyone had already been interviewed in a particular zone, the interviewer moved on to an adjacent zone. The procedure for conducting interviews is outlined below and illustrated in Figure 4. All random variables were generated for observers prior to initiation of the study on Friday.

Procedure for Conducting Sub-sample Interviews

1. Randomly pick a starting end - either the hotel end or the water end - to begin interviews.

2. Randomly pick either the Northern or Southern boundary to begin interviews.

3. Randomly pick a number to determine how many people to skip before you begin interviewing.

4. Randomly pick a number to determine how many people to skip in-between interviews.

5. Walk in a perpendicular line to hotels/water (US1) and conduct interviews.

6. When finished with the first line, start a second line approximately 15 feet from the first line and continue interviewing for ½ hour, or until the entire segment was completed.

Results

Beach Conditions

Temperatures during the study were moderate, with highs reaching the low 80's in the afternoons. Both Friday and Sunday were partly to mostly sunny throughout the day. Saturday was mostly cloudy in the morning with clearing in the late morning and early afternoon and thunderstorms developing in the late afternoon. At approximately 3:30 PM on Saturday the Dewey Beach Patrol cleared the beach due to thunderstorms. The beach remained cleared until the lifeguards left at 5 PM, and after that time several spot checks showed that there were very few people on the beach. All counts taken on Saturday ceased after 3:30.

Beach Re-entry and Trip Duration

Beach re-entry and trip duration were estimated from the sub-sampling interviews. Table 1 shows average re-entry and trip duration for each day. To examine whether people who arrive at the beach in the morning tend to stay longer than people arriving later in the day, separate estimates for trip duration are given for those people who arrived in the morning versus early afternoon.

Table 1. Estimates of Beach Re-entry and Trip Duration

	Friday	Saturday	Sunday
Average Beach Re-entry (number of times)	1.59 (0.06) n=216	1.32 (0.06) n=107	1.45 (0.06) n=176
Average Trip Duration (hours)	4.56 (0.16) n=209	3.06 (0.18) n=102	4.83 (0.18) n=174
Average Trip duration of arrivals between 6:00 and 10:00 AM	6.69 (0.37) n=51	3.80 (0.46) n=31	6.38 (0.34) n=66
Average Trip duration of arrivals between 10:00 AM and 2:00 PM	4.44 (0.15) n=121	2.94 (0.14) n=63	3.94 (0.14) n=105
Average Trip duration of arrivals between 2:00 PM and 7:00 PM	2.03 (0.14) n=37	bad weather cleared beach at 3:30	only 3 arrivals in this time period

All day counts

Arrival distributions from the four zones selected for counting are shown in Figures 5-7. Beach attendance estimates from all day counts were derived from Equation (1), where

n_z is the zone count,

f_z is the zone sampling probability,

r (bar) is average beach re-entry,

e_z is the number of people already present in the zone at the beginning of the first count.

Counts for Friday from 6:30 to 9:30 AM were based on projections made from arrival distributions for Saturday and Sunday. Estimates are shown in Table 3.

$$A = 2\sum_{z=1}^{Z} \frac{n_z}{f_z}\left(\frac{1}{\bar{r}}\right) + \sum_{z=1}^{Z} e_z \qquad (1)$$

Periodic Counts

Results of the periodic counts are shown in Figures 8-10. Attendance estimates from periodic counts were derived using Equation (2) (Torangeau and Ruser 1999), where all notation is the same as (1) and d (bar) is average trip duration.

$$A = \sum_{z=1}^{Z} \frac{n_z}{f_z}\left(\frac{1}{\bar{d}}\right) \qquad (2)$$

Both equations (1) and (2) weight each observation by the probability that it was captured in a count. An alternative method to estimate attendance from periodic counts is to make use of the information on arrival-dependent trip duration and specific times the counts occurred. Table 1 shows that trip duration varies depending on arrival at the beach, and generally people who arrive later stay fewer hours. Thus rather than use the average trip duration for the entire day to adjust estimates, the sampling day can be segmented into *p* segments and trip durations for each segment can be used to adjust each segments estimate. Estimates from each segment can then be summed to represent the entire day (Equation 3) Estimates derived from (2) and (3) are presented in Table 3.

$$A = \sum_{p} \sum_{z}^{Z} \frac{n_{pz}}{f_{pz}} \left(\frac{1}{\bar{d}_p} \right) \qquad (3)$$

Overflight Counts

Digital tape was downloaded and analyzed using Adobe Premier software, which allowed frame by frame counts of people on the beach and in the water. Three counts were taken from each tape segment, and average of the three counts was used. Attendance estimates from overflight counts can be calculated in a similar fashion as periodic counts - by summing observations and dividing by the probability of being captured in a count. Like the periodic counts, the sampling day can be segmented according to flight times and trip durations calculated for specific segments of the day. Table 2 shows the flight counts for each day, with the standard error in parentheses. Equation (3) can then be used to estimate attendance for the entire day. Note that the estimate for Saturday is calculated based on the average trip duration for the day up until 3:30 PM, as only one flight was conducted due to beach closure.

Table 2. Overflight Counts

Friday 1:00 PM	1,430 (81.75)
Friday 5:00 PM	824 (23.84)
Saturday 12:00 PM	482 (58.53)
Sunday 9:45 AM	498 (17.85)
Sunday 1:00 PM	2,561 (366.01)

Variance of the Estimates

In calculating the variance of the attendance estimates one must account for the fact that the estimates contain several sources of variance. Sampling error is present in both the zone counts and the sub-sampling, and different observers introduce an additional source of error. Software packages such as SUDAN and WesVarPC allow variance estimation of complex data via replication procedures, where sub-samples are selected repeatedly from the whole sample, variance is calculated on the sub-sample, and variability among the sub-samples is used to calculate the variance of the full sample. However, replication procedures require a minimum sample size, generally 30 or more observations. In this study, the largest sample size was 12 observations per day, from the periodic counts. Arrival counts had 4 observations per day, and the overflight counts had 1 to 2 observations per day. These sample sizes were not large enough to use replications procedures such as jacknifing, thus the variances of the beach attendance estimates (Table 3) are calculated based on a variant of jackknifing (Equation 4) (Full 2002).

$$Var_{JACK} = \frac{Z-1}{Z}\sum_{s=1}^{S}\left(\hat{Y}_{\bullet s}^{as} - \hat{Y}_{\bullet s}^{a}\right)^2 \qquad (4)$$

where

Z = the number of zones selected from the sampling design

S = the sample observation

$\hat{Y}_{\bullet s}^{as}$ = the estimate with observation S deleted

$\hat{Y}_{\bullet s}^{a}$ = the estimate with the full sample

Table 3. Beach Attendance Estimates

	A1 All day counts (Eq. 1)	**A2 Periodic Counts (Eq. 2)**	**A3 Periodic Counts: (Eq. 3)**	**A4 Overflight Counts: (Eq. 3)**
Fri. (se)	5,665 (584)	4,507 (184)	6,753 (358)	4,144 (1,236)
Sat. (se)	4,000 (568)	3,562 (297)	3,867 (261)	NA
Sun. (se)	7,349 (1,445)	4,351 (302)	4,571 (485)	5,928 (1,901)

Standard errors were used to calculate the 95% confidence intervals around the estimate (Table 4). Given the large standard errors, all estimates with the exception of Friday A2 and A3 fall within the overlap of the 95% CI. However, the standard errors were calculated based on a theoretical framework for a variant of jackknifing and not using a true replication procedure, thus inferences made only from the standard errors should be taken with precaution.

Table 4. 95% Confidence Intervals

	A1	A2	A3	A4
Fri.	5,665 (4,497 - 6,883)	4,507 (4,139 - 4,875)	6,753 (6,038 - 7,468)	4,144 (1,672 - 6,616)
Sat.	4,000 (2,864 - 5,136)	3,562 (2,968 - 4,156)	3,867 (3,347 - 4,387)	NA
Sun.	7,349 (4,459 - 10,239)	4,351 (3,748 - 4,954)	4,571 (3,775 - 5,367)	5,928 (2,126 - 9,730)

Discussion

The estimates derived from periodic counts, A2 and A3, were generated from two observers, while estimates derived from all day counts required eight observers, or 400% more effort. If the cost per observer per day is approximately $300, including meals and lodging, the difference in cost between the two techniques is $5,400 for the three day period. Because both the A1 and A2 estimates were within the 95% confidence intervals of each other, the additional observer effort and cost required for all day counts seems inefficient. Additionally, while a larger percentage of the sampling grid was covered with all day counts than with periodic counts, e.g. 20% versus 5%, the number of zones sampled with periodic counts was greater. This can improve daily estimates in situations where temporal patterns of beach use are known but the spatial use patterns are less clear. Further, if observer effort for the periodic counts had been equal to effort for the all day counts, e.g. 8 observers, 18% of the sampling grid would have been covered. To ensure that periodic counts are conducted in every time block a systematic, rather than a completely random, sample can be drawn.

One disadvantage with periodic counts is the definition of zone boundaries. Based on observer feedback, it was fairly easy to determine zone boundaries and conduct the counts during most of the study. However, when the beach became extremely crowded periodic counts became difficult, as more people moved into and out of the boundaries and the counts were generally more time consuming. Additionally, the fences that extended onto the beach from the footpaths likely facilitated observers ability to create zone boundaries. This may not be the case for other beaches. Boundary determination was less of an issue for the all day counts at Dewey Beach, as the footpath entry points were distinct and spaced far apart. However, other beaches, for example beaches with boardwalk access, may not have distinct entry points, and thus some boundary definition will be required for conducting all day counts.

Helicopter overflights seem to be the least cost-effective technique, as the estimates derived from the overflights are within the 95% confidence interval of all other estimates except the Friday A3 estimate and the technique is generally the most expensive of the three. Expenses of overflights would generally include the cost of the video camera rental ($300 for the total study period), one observer to film and one observer to conduct sub-sample interviews ($1,800 for the total study period), and the cost of the helicopter, estimated at $1000 per trip, totaling $7,100 for the study. Additional observations would be preferable to the two conducted for the current study, which would likely increase the cost.

Analyzing the digital tape from the overflights proved to be inexpensive for this study, primarily due to the free labor provided for making counts from the tapes (about 15 labor hours) and the free access to Adobe Premier computer software. Without this software, a graphics lab would be required to download the digital tape and make enlargements of specific frames, costing between $100 to $300. Helicopter counts could be made directly from the camera viewer or by connecting the camera to a monitor; however, this eliminates the ability to enlarge specific frames. Further, stopping or pausing the tape in the camera viewer or on a monitor creates blurred images, making it extremely difficult to count. However, even with the ability to download the digital tape to computer and count frame by frame, the ability to make counts from the digital tape was reduced considerably during crowded times. Enlarging specific frames that were crowded helped somewhat, though the resolution is compromised by the pixel limit on digital video, which is the same for most types of digital video. To increase the film resolution and sharpen enlargements, analog film can be shot, transferred to digital, and enlarged with a greater resolution than film shot originally in digital. However shooting analog film would generally require the use of a videographer, at $1,000 per day. Additionally, when people are behind umbrellas, other people or structures, or in dark shadows on the beach neither enlarging nor improving the picture resolution will increase the ability to get an accurate count. Given the comparability of the overflight estimates and estimates of the other techniques, overflights do not provide a cost-effective method for estimating attendance.

Although Equation (4), as opposed to a true replication method, was used to calculate the variance of the attendance estimates, the ability to estimate a variance using jacknifing or another replication procedure comes at the expense of obtaining additional sampling observations. For example, generating a sufficient number of observations to estimate the variance of the arrival counts using a replication procedure would result in a beach census, as the 30 observations that are generally required is greater than the number of entry points (20) throughout the entire beach. In cases like this, researchers need to evaluate the trade-offs between the precision of the variance estimate (and most likely a reduction in variance with the additional observations) and the cost. It would be useful in a future study to obtain enough observations from a single technique to simulate a variance and compare that to a variance estimated from Equation (4). Such a study would povide more general information on the standard errors of beach attendance estimates as well as speak to the cost-effectiveness of estimating variance through replication procedures vs. an analytical solution such as Equation (4).

Sub-sampling to determine beach re-entry and trip duration worked well, however, two points related to sub-sampling warrant attention:

1) For periodic counts trip duration was used to adjust the estimates However, a better adjustment would use the amount of time spent on the beach, as opposed to trip duration. Given the way the interview questions were asked, a person could provide an estimate of trip duration that included time spent off the beach eating lunch, dinner, etc... However, only the time spent on the beach itself reflects the probability of being captured in a count, therefore, the correct adjustment is the time spent on the beach.

2) Given the way the interview questions were asked, beach re-entry was calculated only up to the interview point. Respondents were not asked to project how many more times they would re-enter the beach, thus any re-entries that the respondent made after the interview were not included, unless they were intercepted by an interviewer at a later time. Therefore, the average beach re-entry is likely a conservative estimate.

Given the two points above, it is useful to examine what a change in average trip duration and beach re-entry estimates would have on the attendance estimates. This information is presented below:

Friday

- If average trip duration was one hour shorter, e.g. an hour spent off the beach having lunch is included when someone answers questions about trip duration (meaning that they have overstated their actual time on the beach by one hour), the periodic estimate is 5,772 (all day estimate 5,665).
- If average beach re-entry increased by approximately 0.5, e.g. half of the respondents entered one more time than they reported (either before or after the interview), the all day estimate is 4,504 (periodic estimate 4,507).
- Adjusting both figures, the estimates converge when trip duration is about 20 minutes shorter than the average and approximately 25% of the sub-sample respondents re-enter the beach one additional time.

Saturday

- If average trip duration was thirty minutes shorter the periodic estimate is 4,258 (all day estimate 4,000).
- If about 20% of the sub-sample respondents re-enter the beach once more than reported the all day estimate is 3,520 (periodic estimate 3,562).
- Adjusting both figures, the estimates converge when trip duration is about 18 minutes shorter than the average and approximately 15% of the sub-sample respondents re-enter the beach one additional time.

Sunday

- If average trip duration was about two hours shorter the periodic estimate is 7,426 (all day estimate 7,349).

- If all sub-sample respondents re-enter the beach once more than reported the all day estimate is 4,292 (periodic estimate 4,351).
- Adjusting both figures, the estimates converge when trip duration is about one hour shorter than the average and approximately 50% of the sub-sample respondents re-enter the beach one additional time.

With the exception of average beach re-entry on Sunday, all of the changes that would result in convergence or near convergence fall within the variances of trip duration and beach re-entry. Recognizing that people cannot predict precisely how long they will stay at the beach and the shortcoming of the estimate of average beach re-entry, the attendance estimates from all techniques are within reasonably close range.

Conclusions

The general conclusions from the study are summarized below:

1. In general, given the large standard errors of the estimates, the three techniques produced relatively comparable daily attendance estimates.

2. Given the standard errors and the estimate convergence with relatively small changes to trip duration and beach re-entry, the cost-effectiveness of periodic counts is superior to both all day and overflight counts. Cost per daily estimate is calculated at about $600 for periodic counts, $2,400 for all day counts, and approximately $2,700 for the overflight counts, excluding travel to the study site. Further, for the current study, if observer effort was doubled for the periodic counts it would cost approximately $1,200 per daily estimate and the standard errors would be expected to decrease.

3. Overflight estimates produce the largest standard errors and the technique is the most costly of the three. In crowded conditions making counts from the overflight tape was extremely difficult, and two sampling observations are probably not sufficient to calculate a reliable daily estimate.

4. Without the appropriate software it is difficult to estimate the increased accuracy additional observations will produce with any

technique. If the number of access points to the beach is small and an additional observation adds a significant amount of coverage of the sampling grid, all day counts may provide better estimates. However, an additional all day observation in this study, which would require 13.5 person hours of labor, would only increase the coverage by 5%. For large multiple access beaches it may be better to cover more zones using periodic counts and sacrifice the continuous time coverage, particularly given the large standard errors.

5. The sampling design for periodic counts should be stratified by time blocks to ensure that observations are distributed throughout the day.

6. Sub-sample interviews should obtain data concerning the total time a respondent is on the beach versus the more general estimate of trip duration to better reflect the probability of being captured in a count.

7. The estimates are sensitive to people's ability to predict their trip duration and to beach re-entry. On average, incorrect predictions of trip duration by as little as thirty minutes can significantly change attendance estimates, as can one unreported re-entry to the beach, though it is likely to be more difficult for respondents to estimate how many times they will re-enter the beach during the day than to give an approximate beach departure time. Some possible ways to improve estimates of beach re-entry and trip duration include

refining the questions in the sub-sample interviews, further stratifying the sub-sampling times, and possibly intercepting people as they are leaving the beach for what appears to be the end of their day trip. The latter may result in more precise information on trip duration and re-entry.

These conclusions are based on the study at Dewey Beach. As mentioned previously, Dewey Beach has well defined entry points for conducting all day counts, and has physical structures on the beach, e.g. wooden fences, that may assist in defining boundaries for periodic counts. For other beaches some of these conclusions may not be applicable. For example, for extremely crowded beaches periodic counts may be difficult to conduct, particularly if physical structures aren't present to define boundaries, which may ultimately lead to inaccurate estimates. In this case it may be more cost effective to cover a large proportion of entry points and estimate attendance using all day counts rather than periodic counts.

Conclusions that suggest overflights are not an efficient survey technique to estimate attendance should hold for most types of beaches, for several reasons. First, at least two, but ideally more, flights are needed throughout the day because of the temporal variation of beach use. This is true regardless of how crowded a beach is, and renders the technique very expensive. Second, because there are always people behind umbrellas or other structures, overflight footage from any beach that is more crowded than Dewey Beach will be difficult to count accurately. Third, even if the temporal patterns of beach use are well established and the beach is uncrowded so that accurate counts from the tapes can be made, overflights will still be less cost effective than periodic counts, as the accuracy of periodic counts will increase under these conditions as well.

The conclusions concerning estimate sensitivity to beach re-entry and trip duration should hold for most beaches, as re-entry and duration rely on one's ability to recall or predict characteristics about their beach visit. Theoretically, this ability should not depend on the type of beach one visits. Given the attendance estimate sensitivity to re-entry and duration, future research may want to explore different interview methods. For example, interviews could be conducted off the beach near an exit point. People leaving the beach could be questioned about the length of their trip and the number of times they left the beach, and also asked if they are leaving the beach for the day at the point of the interview. If they are leaving for the day, then the concern about a re-entry not being counted if it occurred after the interview is no longer relevant. It also may be worthwhile to compare estimates from on and off beach interviews.

This study has demonstrated that beach attendance can be estimated by counting the number of people who walk through a given entry point for the entire day, by counting people in selected zones at specific time periods, and by conducting helicopter overflights and subsequently analyzing videotape of the beach recorded during the flight. As mentioned above, Dewey Beach has several specific features that facilitated both arrival and periodic counts. Therefore, in addition to drawing on the conclusions of this study to choose a survey technique to estimate attendance, researchers should also consider the type of beach, crowd levels at the beach, any special features of the beach, and cost that can be allocated to the study.

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