A Methodology for Delineating a Primary Service Area for Recreational Boaters Using a Public Access Ramp: A Case Study of Cockroach Bay

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Introduction

The delineation of a market service area for recreational boaters using a given public access ramp is essential to answer the question of where boaters come and examine the extent to which there is variability in the geographic distribution of use intensity within a ramp's market area. This paper presents a methodology for identifying and mapping the primary service area (PSA) of a public access ramp—the predominant market area from which ramp patrons are drawn—by taking into account directional variability and the distance-decay properties of ramp use. This involves the identification of the market boundary of the PSA; something that is known to vary by location and direction.

Conventional approaches to delineating market service trade areas include radial ring-based studies, drive-time analyses, and the use of gravity models. Radial ring studies are performed by evaluating various market demographics, using census information aggregated to tract, block, or block-group level; identifying those areas that fit a pre-selected profile and fall within a pre-defined radial distance from a given location. This approach commonly depicts service/trade areas as circular, and typically does not consider the behavioral, spatial, or physical conditions that can promote or restrict patronage in various directions (Thrall and McMullen, 2000; Thrall, 2002). Variability in the spatial distribution and density of prospective patrons, their willingness to travel, the tyranny of distance and separation, lo-
cation accessibility as defined in terms of the transportation infrastructure, and the physical characteristics of the coastline can all play important roles in influencing the size and shape of market service areas. These considerations are widely overlooked in radial ring studies, as is the fact that accessibility to a given a site will vary across a region (or ring) in accordance with population density and the physical layout of the road network and related capacity and travel constraints. **Drive-time analyses** delineate market service areas based on geographic locations that fall within pre-defined travel times to a given site (Thrall et al., 2002). This method, however, does not account for variability in willingness-to-travel, consumer preference, knowledge and experience, perceptions, and spatial-use patterns that are affected by competition and/or intervening opportunities from alternative sites that are deemed as substitutable from the perspective of patrons.

**Gravity or 'spatial interaction' models** have also been applied to delineate market service or trade areas (Fotheringham, 1981, 1983; Huff, 1964). Gravity frameworks assume that patrons are “distance minimizers”, and that there is a distance-decay property to patronage with respect to a given site. In short, the farther prospective patrons reside from a particular site/location, the less likely those patrons are to visit or frequent that site/location. Gravity-type formulations, however, are more difficult to implement than the radial ring method or drive-time analyses within a Geographic Information System (GIS). Nonetheless, gravity models can be very effective in exposing directional trends in patronage and the spatial distribution of demand. Used in conjunction with pie-shaped wedges, sectors, or transects that extend outward from a central point or location (Thrall, 2002), the gravity model can be used to derive irregularly shaped market areas that capture directional differences in market share and geographic reach based on observed travel patterns and distance-decay properties.

The wedge-casting approach applied in this study has its roots in both the gravity model tradition and the retail market-area capture rate established by Applebaum (1965; 1966). Applebaum (1966) suggested that **a primary service area encompass a geographic area**
that accounts for between approximately 75 and 80 percent of the users or consumers within that market. This market capture rate will be used as a benchmark to assess the validity of a primary service area generated from the gravity model. A series of gravity models will be run to estimate direction-specific distance-decay parameters and corresponding threshold travel distances.

The Data

Ramp patron data for N=31 ramps in the Tampa and Sarasota Bay area were collected as part of a unified two-year effort initiated by the Florida Fish and Wildlife Conservation Commission’s Fish Wildlife Research Institute (FWRI) and Florida Sea Grant. The underlying objective of this data collection effort was to determine where boaters travel from in order to access ramps, as well as other information including where they travel to on the water (favorite destinations) and on-water travel routes. During 2003 and 2004, personnel from FWRI, FSG, and Hillsborough County visited area ramps and collected 6,088 unique license tag numbers (FL tags, excluding repeat visitors) from tow vehicles/trailers in ramp parking lots. License tag information was compared to the state’s Vessel/Vehicle Title Registration System (VTRS), maintained by the Florida Department of Highway Safety and Motor Vehicles, yielding a subset of N=3,089 name and address matches.

Approximately 51 percent of the trailer license numbers observed at the ramps did not have a corresponding VTRS name and address match. The high rate of unmatched records can be partially explained by fact that many boaters requested that the DHSMV not make their personal information available to the public. Boater names and mailing addresses were used to conduct a mail survey questionnaire and for determining the location coordinates of name/addressed matched users. The \( \{x,y\} \) coordinates \{longitude, latitude\} for geo-coded observations were then compiled as a GIS point/data layer and mapped.

For this analysis, only the sample data for ramp patrons of Cockroach Bay were utilized. This sample was combined with a supplementary database of Cockroach Bay ramp patrons from a study.
conducted by FWRI in 2004. The combined databases yielded a sample of \( n = 504 \) geo-coded/address mapped observations of ramp patrons that launched a boat from Cockroach Bay during the 2003 and 2004 boating seasons.

**Delineation of a Primary Service Area: A wedge-casting approach**

A wedge-casting approach is used to delineate the primary service area (PSA) of the public access ramp located at Cockroach Bay. The method employed in this analysis is similar to the one used by EdgeMap GIS for the delineation of a market service area (see Thrall and Casey, 2002; Thrall, et al. 2002). The approach adopted in this paper, however, is more modeling oriented. As with all gravity-type formulations, it is assumed that use-intensity declines with increasing distance from a given ramp; i.e., that there is a distance-decay characteristic to ramp patronage. Furthermore, it is expected that the rate of decline and the subsequent “reach” of a ramp (and its draw) will vary depending on geographic location and direction. Directional variability in ramp use may be attributable to many factors including (a) variations in accessibility related to the location of the ramp relative to the spatial distribution of boaters; (b) established patterns of use and user preferences; (c) the physical features of the study region and coastline and the ease at which a ramp (and/or preferred on-water destinations) are accessible from various locations or launch sites; and (d) the layout of the regional transportation network along which boaters must travel to access various ramps.

To capture directional variability in ramp use intensity, point distributions of ramp patrons were mapped using latitude and longitude coordinates for geo-coded observations from the aforementioned sample. A series of wedges, centered about each ramp, was drawn within the GIS at equally spaced intervals of 15 degrees (i.e., from 0 to 360 degrees) to cover all of the possible land-based origins of boaters that were observed using the ramp (see Figure 1). Grid cells of a fixed and predetermined size were superimposed over the study region. Distance estimates, in miles, were then calculated between the centroid of each grid cell and the boat ramp. Note that distance estimates may also be obtained using travel mileage or travel times to the
ramp assuming the shortest route along a superimposed transportation network. Use-intensity per unit area (Ul) was measured simply by summing the number of geo-coded ramp patrons observed within each grid cell. Only cells with non-zero entries (i.e., with at least one geo-coded ramp patron address) were used in this analysis. Some wedges were also combined to side-step problems associated with limited sample size.

Wedge casting allows for the extraction of statistically derived wedge-specific estimates of threshold distance. Threshold distance may be defined as the distance from a ramp that marks the outer boundary of the primary service area for a given wedge (or along a transect) – the distance from a ramp at which ramp patronage falls to a level that is significantly below the average within a wedge (see Figure 2). Note that (a) the size of the grid cells, (b) the chosen angle
Figure 2. Estimation of threshold distance using a distance-decay function.

Threshold distance is \( d_A^* \), where use intensity (UI) falls to a value that is significantly less than the mean use intensity (\( UI_m \)) observed within a \( j \)-th wedge. To find the threshold distance, set use-intensity or wedge size, and (c) the orientation of wedges (via rotation of the axes) can be altered to allow sensitivity testing of threshold distance estimates. A grid cell size of 2.5 square miles was used in this analysis, given that it produced a distribution of values that ranged from a minimum of 0 to a maximum of 14 ramp patrons/points per cell from the sample data. This provided an adequate number of non-zero cell entries (and degrees of freedom) to allow estimation of the distance-decay function. The total number of non-zero entry cells equaled 272, with an average (median) patron/point count of approximately 2.4 (2.0) patrons/points per cell.
equal to the lower limit of the (1-\(a\)) x 100\% confidence interval for mean use intensity within the wedge and solve for \(d^*\), where \(a\) is a chosen significance level (in this analysis \(a = .01\), implying a 99\% confidence level). The distance-decay property of ramp patronage can be expressed as a negative-exponential function, with use-intensity (\(U_I\)) defined as a decreasing function of distance (\(d\)):

\[
U_I = f(d) = \theta \cdot \exp(\beta(d)) \mu,
\]

and \(E(\beta) < 0\) (i.e., there is a negative distance-decay parameter). The estimation procedure involves a semi-logarithmic transformation of (1), yielding

\[
\ln(U_I) = \ln(\theta) + \beta(d) + \varepsilon,
\]

where \(\ln(\theta)\) is a constant term, \(\beta\) is the “friction-of-distance” parameter (with the expectation that \(\beta\) will be less than zero), and \(\varepsilon = \ln(\mu)\) a random, log-normal error term. Estimates for the model’s constant term and the distance-decay parameter (\(\theta^*, \beta^*\)) may be found by using ordinary Least Squares regression under the usual limiting assumptions. Note that estimation of the constant term requires recovering the “anti-log” of \(\ln(\theta)\), where \(\exp(\ln(\theta)) = \theta^*\). Hence, once parameter estimates are recovered, estimated use-intensity \(U_{I0}\) at a given distance \(d_0\) (where \(d_0 < d_{\text{max}}\)) may be defined as

\[
U_{I0} = \theta^* \cdot e^{\beta^*(d_0)}
\]

and \(d_{\text{max}}\) is the observed “outer range” -- the greatest distance from which a patron is observed using a given ramp. A threshold distance (\(d^*\)) can then be identified for each wedge, where at distances \(d > d^*\) use intensity will fall to a value that is significantly less than the “mean use intensity” (\(U_{I_{m}}\)) observed within that wedge. To find the threshold distance, set use-intensity equal to the lower limit of the (1-\(a\)) x 100\% confidence interval for mean use intensity and solve for \(d^*\).
Thus, we may define $U_1^* = 0^* \cdot e^{\beta^*(d^*)}$, where

$$U_1^* = U_{1_m} \cdot \left\{ t_{w2} \cdot (\sigma^*/\sqrt{n}) \right\} \quad (4)$$

for a chosen $\alpha$ value, standard deviation estimate $\sigma^*$, and sample size $n$ – defined as the number of cells with non-zero observations/point totals within a given wedge. Equations (3) and (4) are then used to solve for the threshold distances associated each wedge, thereby revealing a geographic representation of PSA.

Logarithmic transformation and algebraic manipulation of equation (3) yields $\ln(U_1^*/\theta^*) = \beta^*(d^*)$. Hence, a wedge-specific threshold distance estimate $d^*$ may be found for any set of estimated values associated with a $j$-th wedge $\{U_1^*, \theta^*, \beta^*\}_j$, where

$$d^* = \ln \left\{ \left[ U_{1_m} + t_{w2} \cdot (\sigma^*/\sqrt{n}) \right] / \theta^* \right\} / \beta^*$$

$$= \ln \left\{ U_1^* / \theta^* \right\} / \beta^*.$$

(5)

If $U_1^* < 1.0$, then set $U_1^* = 1$ to solve for $d^*$ -- the distance where use intensity $U_1$ falls to 1.0 ramp patrons per cell using the estimated distance-decay function parameters.

Should the regression model fail to produce a distance-decay parameter estimate $\beta^*$ that is significantly different from zero (i.e., if one fails to reject the null hypothesis that $\beta^*=0$) then a reasonable estimate of $d^*$ must be found. This can be achieved by calculating either the median distance value ($d_{\text{median}}$) or the upper value of the confidence interval for the median distance value. The use of the median distance value provides a useful alternative when the distance-decay function cannot be estimated due to problems associated with (a) small sample size or limited degrees of freedom; (b) zero variance in use-intensity values within a given wedge or sector; and (c) poor fit due to the presence of “outliers” or extreme observations.

Another option is to combine wedges, should the spread of points be similar in a given direction over a broader range or reference angle. Combining wedges is useful in helping to overcome problems of small sample size (and limited degrees of freedom), yet it provides
Table 1. Regression Results for Cockroach Bay: estimated distance-decay parameters ($\beta^*$) and estimated threshold distances ($d^*$).

<table>
<thead>
<tr>
<th>wedge(s)/degrees</th>
<th>distance-decay $\beta^*$ (prob.)</th>
<th>threshold distance $d^*$</th>
<th>cells</th>
<th>points</th>
<th>d.f.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 0-15°</td>
<td>na</td>
<td>25.22**</td>
<td>18</td>
<td>21</td>
<td>--</td>
</tr>
<tr>
<td>2 15-30°</td>
<td>-.03309 (.0256)</td>
<td>33.60</td>
<td>25</td>
<td>37</td>
<td>22</td>
</tr>
<tr>
<td>3 30-45°</td>
<td>-.03035 (.0441)</td>
<td>31.38</td>
<td>41</td>
<td>100</td>
<td>38</td>
</tr>
<tr>
<td>4 45-60°</td>
<td>-.01634 (.0003)</td>
<td>43.76</td>
<td>76</td>
<td>182</td>
<td>73</td>
</tr>
<tr>
<td>5 60-75°</td>
<td>-.01440 (.0442)</td>
<td>47.32</td>
<td>48</td>
<td>84</td>
<td>45</td>
</tr>
<tr>
<td>6 75-90°</td>
<td>-.04346 (.0004)</td>
<td>50.51</td>
<td>19</td>
<td>33</td>
<td>16</td>
</tr>
<tr>
<td>7-8 90-120°</td>
<td>-.01505 (.0741)</td>
<td>50.41</td>
<td>13</td>
<td>17</td>
<td>10</td>
</tr>
<tr>
<td>9-12 120-180°</td>
<td>na</td>
<td>11.38**</td>
<td>6</td>
<td>7</td>
<td>--</td>
</tr>
<tr>
<td>13-14 180-210°</td>
<td>na</td>
<td>8.26**</td>
<td>12</td>
<td>12</td>
<td>--</td>
</tr>
<tr>
<td>15-18 210-270°</td>
<td>na</td>
<td>--</td>
<td>0</td>
<td>0</td>
<td>--</td>
</tr>
<tr>
<td>19-22 270-330°</td>
<td>na</td>
<td>12.11**</td>
<td>7</td>
<td>3</td>
<td>--</td>
</tr>
<tr>
<td>23-24 330-360°</td>
<td>na</td>
<td>27.17**</td>
<td>7</td>
<td>8</td>
<td>--</td>
</tr>
</tbody>
</table>

Note: Estimated threshold distances shown in miles; six of the 12 regression runs produced significant results at the 90% confidence level or higher (shown in bold, with probability estimates in parentheses); r-square values ranged from .11 to .40; na – means not applicable; ** “fail to reject” $H_0$: $\beta = 0$ at 90% confidence, with $d^*$ estimates based on observed median distance value within wedge/sector.

less accurate results when estimating direction-specific threshold distances.

Once wedge-specific threshold distance estimates are compiled, the general shape of the PSA will be revealed. This same procedure can then be applied to all ramps in a given study area using a hypothetical or “average” launch location (based on the average {x,y} coordinates for all ramps in the study area) and the observed point distribution of the origins of ramp patrons observed launching from those ramps. This analysis will reveal a regional service area (RSA) – the predominant regional market area that represents the locations from which ramp patrons are drawn taking into account variations in the directional orientation of travel patterns and estimated distance-decay parameters. Mapping the RSA will allow an individual ramp’s market draw potential to be compared to the draw potential of all ramps in the study region.
The Results

The regression results for Cockroach Bay are shown in Table 1. In cases where a fairly large number of non-zero entry cells were available, the model did quite well in terms of producing a statistically significant estimates of the distance-decay parameters and threshold distances. Note that the regression models for wedges 2 through 7-8 yielded probability values $<.10$ for $\beta^*$. Notice also that some of the 15-degree wedges were combined to increase the number of cells where point densities were low. In these cases, estimates of threshold distance were based on the median travel distance value. The outer boundary of the primary service area for Cockroach Bay is shown in Figure 3.

Note that this modeling approach did quite well in terms of estimating threshold distances and capturing areas with the highest density of points (areas where ramp use intensity is high based on the observed point distribution). This is especially true for the wedges associated with ramp patrons located along the northern, northeastern, and eastern sections of the service area. The wedges along the southwest, however, seem to be over-estimated. This is undoubtedly tied to a relative small sample size and the presence of distant or outlying points. All in all, the wedge-casting approach provided an adequate representation of the PSA for Cockroach Bay. Points/patrons that are located beyond the outer boundary of the PSA, but within the state or region, may be thought of as being part of the ramp’s “secondary service area” (SSA). Note that the PSA for Cockroach Bay accounted for roughly 77% of its ramp patrons; a value that is acceptable in terms of Applebaum’s targeted market capture rate for a PSA.

A similar regression-based approach was taken to delineate the regional service area (RSA) using the entire point distribution for all $N=31$ ramps in the Tampa Bay and Sarasota Bay regions. The results are based on the average launch location (from ramp coordinates) and the entire sample point distribution of ramp patrons in sample. The average ramp location is the representative geographic center from which a typical boater would launch (hypothetically), and the RSA represents the primary service area for all ramps within the
Figure 3. The Primary Service Area (PSA) for the Cockroach Bay ramp.

Cockroach Bay Ramp
Patron Locations and Derived Primary Service Areas

Tampa Bay and Sarasota Bay boating regions.

The general outline of the RSA is shown in Figure 4. Note that the RSA retains a shape that is similar to that of the PSA for
Figure 4. The Regional Service Area (RSA) for N=31 public access ramps in the Tampa and Sarasota Bay area.
Cockroach Bay, particularly for wedges along the northern and western portions of the study region. The RSA, however, extends farther out (as would be expected), especially along the northeastern sectors of the study area. This is no surprise given that the locations associated with this area contain the largest number of VTRS boats per unit area. Note that the estimated regional service area (RSA) accounted for approximately 79% of all ramp patrons in the sample. Statistical results for both the PSA and RSA yielded market capture rates that were in line with criterion established by Applebaum.

Draw Potential and Use Intensity

A ramp's draw potential (RDP) may be found by comparing the size of the PSA (coverage in square miles) to the size of the RSA. The RDP essentially describes the geographic "reach" or draw of a given PSA using the RSA as a benchmark. The greater the area associated with a PSA, the greater the geographic reach of the ramp’s service area when compared to the reach all ramps within the study region. RDP can be thought of as a measure of relative spatial coverage of a ramp’s predominant market area, and to what extent it might be localized or regionalized. It can be used to identify ramps that draw users from proximate versus more distant locations. The RDP for Cockroach Bay is approximately .47 (or 1,249sq. mi. / 2,686sq. mi.). This reveals that the PSA for Cockroach bay is roughly half of the size of the RSA, suggesting that it draws from a fairly large geographic area.

Ramp patrons in each wedge of the PSA are known to contribute to a ramp’s use. Hence, a wedge-specific user potential (WSUP) index may also be calculated. For an i-th ramp or PSA, let \( p_{ij} \) denote the number of observed geo-coded points/patrons in wedge j, and let \( A_{ij} \) denote the total area within wedge j that is known to contain a boating population (prospective ramp users). The boat/boater "supply area" of a wedge can be defined as the geographic area where VTRS records are observed for trailer-able boats (i.e., boats less than 26 feet in length), excluding areas where such boats/boaters do not reside, based on the geo-coded address information from Flor-
ida’s VTRS and “buffered” areas that encompass the boating population.

A wedge-specific user-potential (WSUP) index for an i-th PSA and a j-th wedge may be defined as:

$$WSUP_{ij} = \{ \frac{m_j}{[p_{ij} / S \ p_{ij}]} / [A_{ij} / S \ A_{ij}] \},$$

where $p_{ij}$ is the number of patrons observed in a j-th wedge, $A_{ij}$ is the total area within a j-th wedge associated with VTRS boats, and $m_j$ is the total number of wedges/sectors that define an i-th PSA. Note that this index is similar in design to a “location quotient” in terms of its structure. It is a ratio of ratios, an index that contrasts the percentage of points found within a wedge to the percentage of boating area from which patrons are likely to be drawn. Unlike the location quotient, the WSUP index is a use-intensity measure that highlights the proportion of users associated with a given wedge (on a per unit area basis) taking into account only those areas in which there is a resident boating population as established from VTRS records. In other words, the WSUP index is a relative measure of inter-wedge use variability that highlights the degree to which ramp patrons located within a given wedge account for ramp use controlling for the uneven density and distribution of the boating population within the PSA itself.

WSUP index values for the Cockroach Bay ramp are highlighted in Figure 3 (see shaded wedges). The values are broken down into three categories: low, medium, and high use-intensity based on equal intervals. WSUP values ranged from a minimum of approximately 1.5 to an observed maximum value of approximately 6. Notice that the big contributors to ramp use are associated with the northeasterly wedges. It is no surprise that these wedges run along the western side of Florida’s I-4 and major transportation corridors as they make their way toward the Tampa Bay area. Notice also that ramp use intensity as measured by the WSUP index is shown to decline with increasing distance from the major transportation corridors. This pattern is also consistent with the spatial distribution of VTRS boats and the high density of boats/boaters located along areas that
run parallel to the transportation arteries found within the study region. This suggests that the geography of VTRS boats and the regional transportation network play important roles in influencing the demand for the public access ramp located at Cockroach Bay.

In order to better reflect the geographic area from which boaters are drawn to a given ramp, the PSA may be “fine-tuned” in accordance with the observed use intensity values that are found within the PSA and the use intensity found outside the PSA. In short, the PSA may be optimized to better reflect the spatial distribution of use intensity. This can be accomplished by applying a cell-based procedure (post PSA estimation), deleting cells within the PSA with use intensity values that fall significantly below the average value and augmenting the PSA to have it include cells in the secondary service area where use intensity is not significantly different from that which is observed with the PSA itself. This would require evaluation of the underlying trend surface of ramp use (i.e., modeling use probabilities) and a cell-based demand analysis. Directions for future research also include a complimentary water-side analysis to uncover the spatial distribution of on-water destinations that are associated with particular ramps to test the hypothesis that boaters are “distance minimizers” with respect to favored on-water destinations (i.e., boaters choose ramps that are both close to home and close to their favorite on-water site).

**Concluding Remarks**

The wedge-casting approach for estimating a ramp’s PSA and the accompanying descriptive indices offer tremendous potential for highlighting spatial patterns of ramp use intensity. Future applications must involve large sample sizes (where the sample size exceeds, say, 1000 observed ramp patrons per public access ramp) to ensure adequate representation of the spatial distribution of demand. The analysis in this paper may be expanded to generate *probability estimates* that represent the likelihood of ramp use from various locations within the study region. In addition, inspection of favored on-water destinations may shed light on the patterns of ramp use and what estuarine areas users are likely to impact once boaters launch from a
given ramp. Moreover, the methods applied in this study could be useful in helping to locate additional public access ramps within the study region (based on existing and/or projected demand, the distance-decay properties of ramp patronage, use intensity measures, and VTRS information). The empirical findings in this study are consistent with results from a previous boater survey in the Tampa and Sarasota Bay area (Sidman, et. al 2004), in which boaters were characterized as "distance minimizers" with respect to ramp choice. The ramp-use patterns for Cockroach Bay also reveal a primary service area with use intensities and an outer boundary that is highly influenced by the regional transportation system and the spatial distribution of registered boats.

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