Introduction

Background

Florida is experiencing tremendous population growth. The environmental and social consequences of this growth on Florida’s marine resources are not well understood. The Florida Blueways initiative seeks to clarify these consequences (Florida Marine Research Institute, 1999). The Florida Blueways initiative considers management needs through the application of ecological principles to characterize and assess human-environmental interactions for the management and stewardship of coastal resources. An evaluation of human and natural system dynamics is predicated on characterizing important human uses of coastal resources. Recreational boating-related activities, which include fishing, anchoring, pleasure cruising, and nature viewing, are considered to be important human-uses of Florida’s coastal resources (Bell, 1994; Antonini, Bell, Kampert, Sidman, Swett, and Tupper, 1997; Swett, Fann, Antonini, and Alexander, 2000).

One high-density boating area is Southwest Florida - (Manatee, Sarasota, Charlotte, Lee, and Collier counties). Today there is an estimated 97,628 registered pleasure boats in this region (Florida Bureau of Economic and Business Research, 1990). This represents a 405 percent increase since 1970. According to 1998 boat registrations almost one-half (44,026) of the recreational boats in Southwest Florida are registered in the current Blueways study area of Charlotte and Lee counties, the two counties surrounding Charlotte Harbor.

One of the objectives of Blueways is to identify and map high-use areas that could be interpreted as hotspots. Hotspot is a general term that is specified depending upon the characterization’s objective, typically in terms of some attribute greatly exceeding the average. For example, Prendergast, Quinn, Lawton, Eversham, and Gibbons (1993a) defined diversity hotspots as the top five percent of record-containing 10-km squares that were ranked by the number of species per square. Other applications include species richness, taxonomic criteria like concentrations of endemic species, or the extent of threats present (Prendergast, Wood, Lawton, and Eversham, 1993b; Myers, 1990). Blueways extends the list of applications to include concentration and diversity of human uses, human-use conflicts, and temporal human-use patterns. More specifically, in this study we considered concentrations of boats and areas where crowding is perceived.

Characterizing recreational boating is complex. Activities, vessel types, and attitudes of boaters vary considerably, each uniquely contributing to the spatial and temporal boating pattern. Therefore, in this study three sampling procedures were implemented, each focusing on unique aspects of boating. The first, aerial reconnaissance, is a well-established way to map boat locations (Ashton, 1971; Gorzelaney, 1998). Aerial surveys provide a “snapshot” of boat locations, source data for calculating boat densities. Second, workshops were used to delineate high-
use areas for specific boating-related activities because many boating activities cannot be identified from the air. Third, telephone and mail surveys of a random sample of boaters in the area were used to ascertain favorite destinations, perceived crowding, activities, and motivations behind the observed spatial patterns (West, 1982; Feitelson, 1991). The three methods provide a "value-added" blend of objective observation, independent local knowledge, and behavioral information.

**Goals and Objectives**

The goal of this study was to utilize several survey methods to generate spatial and temporal recreational boating use and activity profiles for Charlotte Harbor, Florida, that can be interpreted in terms of use hotspots and potential for crowding. Specific objectives include: (1) mapping boat locations using aerial surveys; (2) identifying areas where specific recreational boating activities occur by interviewing local boating experts and resource managers; (3) estimating boat densities in expert-defined activity areas; (4) identifying primary activities and temporal usage through a telephone survey of area boaters; and (5) identifying favorite boating locales, identifying reasons for selecting travel routes and favorite locales, and estimating crowding potential through a mail survey of area boaters.
Methodology

Survey Methods

Three methods were selected to provide complementary information for characterizing recreational boating and identifying areas of highest use and crowding potential. Aerial reconnaissance was selected to map the location of individual boats on selected dates and times. Workshops brought together local boating experts to identify areas where recreational boating and associated activities typically occur. A combined telephone/mail survey was implemented to identify favorite boating areas, seasons, and areas of perceived crowding. This section describes how each survey procedure was carried out.

Aerial Surveys

The aerial surveys provided a series of “snapshots” of boating in Charlotte Harbor that was integrated with expert-defined activity areas for visualizing densities in areas where specific activities were believed to predominate. As of the submittal of this report, four aerial surveys were completed for the Charlotte County portion of the study area: March 30, April 18, April 29, and May 17, 2000 (three weekdays, one weekend day). Two were morning flights, and two were afternoon. Aerial surveys for the Lee County portion of Charlotte Harbor were flown in 1998 (Gorzelany, 1998). Aerial surveys for Charlotte Harbor are continuing in order to complete one year of flights, which is necessary for capturing the seasonal variability of boating and to match the sampling protocols used by Gorzelany for Lee County.

Surveys in Charlotte Harbor were flown over all navigable waters in a Cessna 172 aircraft at an altitude of 500 feet. A single observer/videographer was seated in the right front seat of the survey aircraft. An image-stabilizing digital Hi8-mm Sony camcorder with date and time stamp recorded all vessels in-use while flying a standard flight path. Starting and ending locations in Charlotte County were varied for each survey.

Once completed, each vessel observed on the video footage was plotted and recorded on ArcView® GIS 3.2 survey maps. Attribute data included vessel type, size, whether the boat was moving or not, direction of travel (if any), and a unique alphanumeric code for each vessel observed. Vessels were classified either as big powerboats, small powerboats, sailboats, or personal watercraft (PWC). Additionally, environmental conditions, including weather, wind speed and direction, and Beaufort sea-state value were recorded.

Workshops

The objective of the workshops was to have local boating experts draw areas on a map of Charlotte Harbor and characterize each area with respect to boating
activities (jet skiing, sailing, fishing, cruising, nature touring, diving), crowding, and nighttime use. Six meetings were held over two days. Three two-hour meetings were held at the Regional Planning Council Building in North Fort Myers on May 9, 2000 and three meetings were held at the Charlotte Harbor Environmental Center in Punta Gorda on May 10, 2000. Twenty-four of the 66 experts invited attended the meetings. Affiliations included representatives from estuary programs, regional planning councils, marine industries, fishing clubs, guides, captains, the West Coast Inland Navigation District, Florida Sea Grant, county government, Florida Department of Environmental Protection, dive clubs, and environmental organizations.

Each two-hour session began with a half-hour overview of the project, instructions for the participants, and a short question/answer period. During the remaining time the experts drew activity areas on maps (see Appendix B for an example of the survey map) and described each area by filling out an accompanying data sheet. Specifically, participants described each area for its primary boating activity, secondary boating activities, times of greatest crowding (times of the day, days of the week, months of the year, etc.), and the number of boats present that, in their opinions, would constitute crowding. The primary activity was defined as the experts’ perspective of a predominant boating-related human use occurring within the delineated area. Only one primary activity could be selected per area, and all attributes describing the area were related to the primary activity. Secondary activities were those, in addition to the primary activity, that the expert considered to be noticeable or “likely to be observed.” High crowding was defined as the number of boats that would lead to a change in boating pattern, such as leaving an area earlier in the day than usual (Drogin, 1991). Moderate crowding was defined as more boats than one would prefer, but would not lead to a change in boating pattern.

Telephone and Mail Surveys

The objective of the telephone and mail surveys was to identify popular boating activities, reasons for selecting travel routes and destinations, favorite boating areas, and areas of perceived congestion (Heatwole and West, 1982). The telephone survey elicited information regarding boat type, draft, length, common activities (including fishing, anchoring, nature-viewing, and cruising), and the day and time that outings took place. Telephone respondents were asked if they would be willing to participate in a follow-up mail survey (Dillman, West and Clark, 1994). Respondents who agreed to participate were mailed a detailed map of Charlotte Harbor, depicting 35 boating regions and the locations of marinas and boat ramps, along with a questionnaire. The mail survey elicited information regarding where boaters go (destinations and travel routes), areas of greatest congestion, reasons for selecting travel routes, and attitudes toward other boaters. The mail survey was used to characterize boater attitudes toward congestion and the motivation behind boating decisions, as a complement to aerial and telephone surveys (see Appendix B for copies of the telephone and mail surveys and associated correspondence).
A stratified random sample of 500 recreational boaters in Charlotte and Lee counties was selected from the 1998 Florida Vessel and Title Registration System (VTRS), which is currently being updated and maintained by the Florida Department of Transportation. The sample size of 500 provides better than a +/- 5 percent margin of error with a 95 percent confidence level based on the entire boating population (roughly 44,000 boat registrations in Charlotte and Lee Counties). A boat class -- (a) kayak, row, canoe, (KCR); (b) sail; (c) power boats; (d) big powerboats; (e) personal watercraft (PWC) -- was assigned to each of the records, based on an interpretation of the "make," "model," and "length" fields contained in the VTRS. The random sample was drawn first by county in proportion to the total two-county boat population. This was followed by a sample allocation by boat class that was proportionate to the number of owners who live in each respective county (Table 1). Names and addresses were used to obtain telephone numbers for the sample.

Telephone and mail surveys were administered using established survey procedures (Dillman, 1978, 1991). The telephone survey was pre-tested by a sample of Charlotte County boaters who had participated in a prior survey (Antonini et al., 2000). Telephone interviews were conducted in May and June 2000 by the Florida Survey Research Center (FSRC), in the Department of Political Science University of Florida.

<table>
<thead>
<tr>
<th>boat class</th>
<th>Lee</th>
<th>Charlotte</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>all records</td>
<td>% class total</td>
</tr>
<tr>
<td>KCR</td>
<td>1095</td>
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</tr>
<tr>
<td>Sail</td>
<td>1509</td>
<td>0.60</td>
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<tr>
<td>Power</td>
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</tr>
<tr>
<td><strong>Big Power</strong></td>
<td>1007</td>
<td>0.65</td>
</tr>
<tr>
<td>Jet Ski</td>
<td>3233</td>
<td>0.74</td>
</tr>
<tr>
<td>Totals</td>
<td>29228</td>
<td>331</td>
</tr>
</tbody>
</table>

*KCR is Kayak/Row/Canoe. ** Big powerboats are > 26 feet long and have a draft >= 3 feet.

**Table 1. Sample Breakdown by Boat Class.**

Mail surveys were pre-tested by local boating experts and resource managers at workshops held in Fort Myers and Punta Gorda. The names and addresses of participants who agreed to complete the mail survey were supplied to us on a weekly basis by the FSRC. Survey packets were promptly mailed and included a postage-paid envelope and a copy of "A Historical Geography of
Southwest Florida Waterways: Volume One, Anna Maria Sound to Lemon Bay' (Antonini et al., 1999). A reminder card was mailed in late June to those individuals who had not yet returned questionnaires. The FSRC conducted reminder calls in conjunction with the reminder mailing.

Five hundred individuals participated in the telephone interviews and 354 agreed to complete a mail survey. Two hundred and fifteen usable mail surveys were returned (Table 2). A proportionate ratio of the mail sample to the telephone sample of both Charlotte and Lee counties was maintained for all boat types except the jet-ski category (under-represented by 4%) and the sailboat category (over-represented by 3%).

<table>
<thead>
<tr>
<th>Telephone Surveys Completed</th>
<th>Mail Surveys Sent</th>
<th>Mail Surveys Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lee</td>
<td>Charlotte</td>
</tr>
<tr>
<td>Jet Ski</td>
<td>23</td>
<td>13</td>
</tr>
<tr>
<td>*KCR</td>
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<td>8</td>
</tr>
<tr>
<td>**Power</td>
<td>266</td>
<td>149</td>
</tr>
<tr>
<td>Sail</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>TOTAL</td>
<td>317</td>
<td>183</td>
</tr>
</tbody>
</table>

*KCR is Kayak/Row/Canoe. **The power category includes the big powerboat class.

Table 2. Breakdown of Telephone and Mail Survey Completions.

Mapping High-Use Areas

This section describes methods selected to map data obtained from each of the three survey methods. Methods used to integrate data also are presented.

Mapping Relative Boat Densities from Aerial Survey Data

Boat location data for each survey date and county were combined and partitioned into weekend and weekday data layers. Differences in the sampling intensity between the two counties were not considered. Relative boat density was computed using a Voronoi diagram (also called Thiessen polygons), which is an expression of natural neighbor relationships in two dimensions (Boots and Getis, 1988; A Okabe, Boots, Sugihara, Chiu, and M Okabe, 2000). The Voronoi diagram was constructed using the Arc/Info THIESSEN command (Environmental Systems Research Institute, Redlands, Cal.). Voronoi polygons were converted to a raster data layer of 25x25 meter cell size. Each cell was classified according to the size of the polygon from which it was derived.
Voronoi polygons were generated to estimate boating densities by calculating areas around boats interpreted from aerial videography. In this type of analysis, greater concentrations of boats result in a dense Voronoi diagram (small polygons), whereas low concentrations of boats generate large Voronoi polygons, indicating greater vessel dispersion. Areas of highest vessel concentration were mapped according to the polygon size. Class intervals were defined as Voronoi polygons less than 1000 cells (highest relative boat density; greatest vessel concentration); polygons from 1000 to 4999 cells (moderate relative boat density); and those polygons 5000 cells or more (lowest relative boat density; greatest vessel dispersion). The Voronoi representation of boating-use (Figure 1; page 12) identifies areas of highest relative boating density and serves as one interpretation of high-use areas or use-hotspots in exclusion of the other methods.

Mapping Expert-Defined Fishing Areas

The primary intention of the workshops was to have experts define areas for which boating densities could be calculated. Fishing was the primary use most selected by experts so subsequent analyses focused on fishing. Areas of greatest overlap (expert consensus) could be interpreted as predominant fishing locales (hotspots). Each boating area identified by an expert was digitized into Arc/Info and assigned a unique number that linked it with attributes on a corresponding data sheet (Appendix A). Expert-defined fishing areas were selected out and combined in Arc/Info. Areas of greatest primary fishing-area overlap reflect greatest expert consensus (Figure 2; page 13). Mapping intervals reflect equal division of the data range (least to greatest expert consensus).

Mapping Favorite Fishing Areas Identified by Mail Survey Respondents

Mail survey recipients were asked to identify their favorite boating destinations ("Place an X at your favorite boating areas") on a map provided with the survey (Appendix B, Map A). Survey maps contained a detailed shoreline and a one-second grid to help respondents locate their favorite destinations as accurately as possible.

Each favorite location was digitized using a bathymetric map that included the shoreline and a one-second grid for orientation, to ensure the most accurate interpretation and digitization of survey data. Boaters' favorite spots were classified according to their favorite activity (Figure 3; page 15). Fishing was also the primary activity most selected by boaters, so this analysis also focused on fishing. The DENSITY command in ArcView was used to generate a GRID interpreted as being favorite fishing areas. An output grid with a cell size of 400 feet and a search radius of 3000 feet was a density map that most accurately reflected the distribution of favorite fishing areas. Areas of highest density reflect popular destinations and one interpretation of fishing hotspots (Figure 4; page 16).
Mapping High-Use Areas Through Data Integration

The three methods selected were chosen to provide complementary types of boating data. Each method can be used independently as the basis for identifying hotspots. However, data from aerial surveys, workshops, and telephone and mail surveys also can be integrated for more robust characterizations.

First, weekend boating densities in expert defined fishing areas (fishing hotspots) are mapped by integrating results from workshops and aerial surveys. Weekends were selected to better portray peak-use periods (telephone and aerial survey results show weekends as being peak-use times). Aerial survey data for Lee and Charlotte counties were combined into a single Arc/Info coverage. This data layer was then split into weekend and weekday flights. Expert-defined fishing areas were stored as individual data layers, one layer per expert. A program was written that calculated the frequency, total number, mean density, standard deviation, and maximum value of activities and boat types observed for each expert-defined region for both weekends and weekdays. Weekend vessel counts were aggregated within expert-defined fishing areas for mapping high-use fishing areas according to relative densities (Figure 5; page 18).

A second integration involves combining expert-defined fishing areas with favorite fishing spots identified by mail survey respondents. Each expert-defined fishing area was combined such that areas containing the greatest overlap (expert consensus) received higher values. Areas were converted to grids and reclassified by equal interval to identify low, medium, and high consensus. A similar procedure was used to classify boater-defined favorite fishing areas. The two grid layers were combined to reveal a multi-overlay composite that also identifies high-use fishing areas (Figure 6; page 19).

Use Profiles for Boaters and Regions

A profile of boaters offers insight into motivations that underlie observed/mapped boating patterns. A clustering technique (Kachigan, 1986) was used to profile boaters and regions within Charlotte Harbor. Due to the preponderance of small powerboats in the sample (the sample was weighted to survey a representative number of boaters by county and type), this type was analyzed separately from the other boat types (big power, sail, Personal Watercraft (PWC), and kayak/row/canoe (KRC).

Cluster analysis is a statistical procedure used to group and/or classify individual observations in a data set according to their similarities. Individual observations that are deemed "similar" are grouped together to form clusters of observations (that can be differentiated from other observations or clusters). The K-mean, also called K-group, cluster method used in this analysis combines observations with respect to K-means (or average cluster position). Initially, the number of clusters (K) is set at a minimum (in this case 3) and increased iteratively
until the procedure ceases to produce large and significantly different clusters. Significantly different clusters are based upon the relationship between the total sum of squares (TSS), the within-group sum of squares (WSS), and between group sum of squares (BSS), where \( TSS = WSS + BSS \).

First, the TSS for all variables selected (i.e., boat type versus favorite time of day, favorite boating location, etc.) is computed identifying three initial clusters. More clusters are added, one at a time, until there is no significant decrease in WSS. Next, the mean for each cluster is computed. Individual observations are then assigned to a cluster based upon Euclidean distance from the TSS mean. Individual observations are therefore assigned to a cluster for which the TSS distance is smallest: (i.e., WSS is minimized and BSS is maximized).

An analysis of variance (ANOVA) is performed on each run to determine the overall statistical significance of the cluster configuration(s) using the F-statistic to highlight the amount of total variation accounted for by the BSS. A cluster profile is revealed, identifying outcomes that best differentiate one cluster from another.

Dependent variables included boat type and location. Independent variables included: time(s) of day; day(s) of week; month(s) of year of preferred usage; favorite activities; favorite reason for selecting a destination or travel route; and the most congested time(s) of day, day(s) of week, and month(s) of the year. The boater profile is based on the following five boat types: Power, big power (powerboats greater than 26 feet in length and having a draft of greater than 3 feet), sail, personal-watercraft (PWC), and kayak/row/canoe (KRC).

To meet minimum observation requirements the cluster analyses required that the original 35 boating areas depicted on the mail questionnaire (Appendix B) be collapsed to 10 regions. Summary statistics were used to corroborate cluster analyses results.

**Perceived Crowding**

Perceived crowding was addressed through the use of a mail survey that included a map identifying 35 boating regions (Appendix B, Map B). Boating regions where crowding is perceived to exist are identified by summarizing responses to the following survey question:

*In which areas, if any, (identified on Map B) have you experienced the greatest amount of boat congestion? Congestion refers to the presence of more boats than you prefer.*

___________ Most congested area.

___________ Second most congested area.
Areas of perceived crowding are mapped as a function of the standard deviation from the mean number of mail survey respondents who selected a particular region (identified on Map B, Appendix B) as being the first or second most congested (Figure 7; page 22). Crowding is more likely to occur within regions that exhibit a 2 to 3, or > 3 standard deviation higher than the average. Perceived crowding is also addressed by identifying changes in behavior. For example, mail survey respondents were asked if they had, in the past year, avoided or left their favorite areas because there were too many boats there, or if they had tolerated too many boats in their favorite areas.

Crowding can also be a function of the diversity of proximate activities. Boaters' favorite activity spots (Figure 3; page 15) were used to identify areas that contain the greatest activity diversity. Proximate activities included anchoring, cruising, sailing, fishing, and nature viewing. Activity diversity is measured by the number of proximate activities located within one square mile of each other. Areas that contained the greatest activity diversity were compared with regions of greatest perceived congestion (Figure 7) to identify possible crowding hotspots (Figure 8; page 23).