Quantification of Peak Season Marine Vessel Traffic Pressures
In the San Juan Islands

FINAL REPORT

Pilot Study: August 9 - September 10, 2006

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Abstract: *The marine waters surrounding the San Juan Islands appear to communicate high levels of vessel traffic, especially during the sunny summer weekends of peak vacation season. This perception is corroborated by several factors: 1. international commercial shipping lanes serving two major North American ports; 2. Alaskan Marine Highway, Washington State and several international ferry routes; 3. a plentiful sport and commercial fishery with 4 major game fish providing year round opportunities; 4. an extremely popular yachting and pleasure cruising environment featuring several nature parks accessible only by water; and, 5. Orca pods, other marine mammals, and numerous water-fowl rookeries providing very appealing on-water tourist attractions. However, prior to this study, there have been no published attempts to rigorously quantify vessel pressures in the San Juan Islands. In this pilot study we develop methods for deriving statistics on vessel traffic utilizing spotters and digital photography from fixed wing over-flights during the peak tourist season (August-September 2006). Samples were stratified by weekend/holiday days and week days. Data was collected for 4 week days and 9 weekend/holiday days. Results indicate average total of 963 vessels on water at any given daylight time for weekend/holiday days and 667 for week days. Vessels were also identified by general type as: power, sail, commercial fishing, recreational fishing, whale tours, navy, cargo (of any size) and ferry. Rough location markers were plotted in a GIS yielding relative concentration gradients. Finally, the study also focused on identifying less expensive (land based) data collection methods. At least one promising site on Harney Channel was identified for yielding reliable predictor statistics for total vessel numbers from shoreline observation samples.*

INTRODUCTION

The San Juan Islands provide a seemingly unique setting for high concentrations of marine vessel traffic. The Islands' geography (see map appendix A) tends to force vessel traffic through a few constrained passages. There is only one centralized east-west oriented communication route (locally referred to as the marine extension of State HWY 20). This route is utilized as the primary conveyance for inter-island traffic throughout the archipelago. International commercial shipping lanes, located in near proximity to the Islands, serve as navigation routes for large container and cargo vessels, occasionally accompanied by pilot ships, arriving and departing from the ports of Vancouver, BC and Seattle/Tacoma, WA. Additional navigation routes are provided for ferries transporting people, freight and vehicles between the San Juans, the mainland of Washington, British Colombia's Vancouver Island and several of the major islands within the San Juan archipelago. These routes also form the terminus of the Alaskan Marine Highway with ports stretching along the inner passage between Seward, AK and Bellingham, WA.

(NOAA 2006) Because of the island geography, most goods and construction materials are conveyed via shipping from the mainland and between islands in cargo vessels and construction barges ranging in a wide variety of sizes. Besides providing vital transportation routes, the marine waters surrounding the San Juan Islands support a bountiful commercial and recreational fishery. Four major game and commercially valuable fish provide year around fishing opportunities. These waters also attract pleasure craft enthusiasts from around the region and even the world with world-famous yachting anchorages like Sucia and Stewart Islands and upscale marina resorts like Roach Harbor and Rosario. The archipelago features several nature parks accessible only by water. An abundance of marine mammals, including Southern Resident Killer Whales and several water fowl rookeries, attract nature tourist seeking on-water wildlife viewing possibilities. (Travel, USA Travel) Finally, because many of the San Juan Islands do not have ferry service, and, in part, possibly attributed to the generally perceived "island lifestyle", San Juan County has high per capita ownership of private marine vessels. Washington State issued 3063 boat registrations between April 2006 and March 2007 in San Juan County alone. (WDOT 2007) Since 2001 annual expenditures on pleasure boats and related supplies from Washington State residents have consistently ranked amongst the top ten in the nation. (WDFW 2003) At the same time, population growth estimates forecast nearly doubling of resident populations in San Juan and all coastal counties by 2025. (WOFM 2004) These trends combine to suggest rising numbers of marine vessels in the future.

Many scientific studies point to ecological and sociological impacts from marine vessel pressures. "The environmental impacts from recreational boating can be grouped into four primary areas, says Harrison Bresee, a marina technical advisory specialist for the Virginia Sea Grant Marine Advisory Program at the Virginia Institute of Marine Science: operational hazards (such as habitat damage from propellers and noise), petroleum products, pollutants related to boat maintenance, and sewage." (Fields 2003) Mooring, anchoring, prop scaring and even density of boat traffic causing increased turbidity during daylight hours can significantly degrade sea grass beds. (Murphy & Eaton 1983) (Crawford 1998) Hydro-phonic noise has been shown to hinder communications between whales. (Foote et. Al 2004) Sea vessel traffic, as an obstacle to marine mammal navigation, causes increased surface activity behavior leading to stress. (Bain et. Al 2006) Audio phonic noise from power boats, as well as, wave action, seems to cause nest abandonment in some water fowl. (Burger 1998) Additionally, audio phonic noise from high levels of sea vessel traffic has been attributed to quality of life disturbance for coastal residents. (Fields 2003) Wake action causes disturbance to near shore habitat including erosion. (Wtrwy et. Al 2002) Bilge water flushing is the primary source of small but chronic oil spills introducing significant levels of PAHs into the marine system annually. (Balk et. Al. 1994) In addition to PAHs, resulting from burned hydrocarbons while underway, fuel and oil spills from vessel servicing contribute point source pollutants from several petroleum based products. (Balk et. Al. 1994) Marine vessels also contribute significant amounts of CO, NO2, and other hydrocarbons as airborne pollutants. (Quan et. Al 2002) Ballast water exchange and hull substrate provide transportation means for the import of various non-native macro and micro marine flora and fauna. (Herwig et. Al 2007) Certain bottom paint anti-fouling compounds tend to leach trace amounts of copper and other metals that bioaccumulate in the food chain and attach to marine sediments. (Fields 2003) The introduction of raw untreated sewage into the marine environment from the concentrated contents of just one vessel's head can lead to more nutrient contamination than the dumping of treated affluent from 10,000 households. (Fields 2003) Derelict fishing gear causes wasteful predation of enormous numbers of marine animals and water foul every year. (Cooke & Cowx 2004) Finally, poorly managed fisheries can cause severe pressure on bio-diversity such as the case with Ling Cod and Rockfish. (Coleman et. Al 2004) All research into environmental impact from marine vessels seems to increasing impact with increased vessel density pressure. (Fields 2003) Many of these impacts have been underscored by the recent listing of the Southern Resident Killer Whales under the Endangered Species Act and the announcement from NOAA Northwest Fisheries requesting public comment on proposed sea vessel regulations under its protection strategies.

Faced with declining health of marine life in the San Juan Islands along with increasing human pressures, the San Juan Board of County Commissioners designated the County a Marine Stewardship Area (MSA) with the stated objective: "to facilitate the protection and preservation of our natural marine environment for the tribes and other historic users, current and future residents, and visitors." With this resolution, San Juan County Resolution No. 8-2004 January 2004, the board tasked the Marine Resources Committee (MRC) with delivering the results of a formal study with detailed recommendations for achieving this goal. (Evans & Kennedy 2006) The resulting Marine Stewardship Area Draft Plan identifies several stressors on target ecosystems within the MSA, which are attributed to marine vessel activity, including chronic oil spills, major oil spills, and anchoring in sea grass beds (Slocomb 2005). While there was much concern over environmental impacts from sea vessel traffic within the MSA, apparently there had been no concerted effort to quantify traffic levels throughout the San Juan Islands. SoundWatch has gathered comprehensive data on Whale Watching boats in near proximity to Orca pods. (Koski 2004 & 2006) Other programs in Puget Sound and the Georgia Basin, such as the Ducks Unlimited and the WDFW Puget Sound Ambient Monitoring Program, have gathered some vessel count statistics as ancillary data while performing bird counts. However, none of these data sources offer a comprehensive picture of vessel types, concentrations and movements within the entire San Juan County MSA.

Because marine vessels are not constrained by roadways, as is the case for vehicular traffic, accurate accounting of marine vessel traffic volume can be somewhat problematic. On canals, monitoring of marine vessel traffic has been successfully facilitated with remote motion detection camera techniques often used in vehicular traffic counts. (Bloisi et. Al 006) While this method works on a canal, most published boat surveys seem to focus on five low-tech methodologies: on-water surveying; ground based contact surveys; mail back boater questionnaires; aerial fly-overs; and boat ramp parking lot vehicle counts. (Bosley 2005) Questionnaires and other non-counting methods tend to focus on the sociology of boaters trying to get at carrying capacity densities. (Bosley 2005) Counting methods often utilize visual spotters and seem to be most applicable to enclosed basins such as lakes. (Bosley 2005) Some aerial fly-over surveys have employed high speed digital orthogonal photography in order to successfully predict marine mammal, sea turtle and boating populations with transect/distance derivations. (McClellan 1996) This methodology required an aerial platform of fixed wing aircraft equipped with gyro-mounted geo-corrected belly camera or helicopter with strut mounted camera. Other published studies of marine mammal population estimates have employed a patch occurrence metric whereby snapshot counts are made of a particular habitat patch at predetermined time intervals in order to estimate total population based upon individual spotting. For the following pilot study conducted between August 9 and September 10, 2006, The San Juan County MRC Science Subcommittee was interested to see if aerial high speed digital orthogonal photography could be employed in a cost effective matter in order to gain accurate estimates of marine vessel populations in the San Juan Islands. It was also hoped the pilot study could be utilized to test several methodologies with a goal of determining the least expensive, repeatable and reliable method for determining sea vessel concentration levels on an ongoing basis. Specifically stated, the study objective was two fold: **1. Develop a study design model, which provides rigorous quantification of sea vessels operating within marine basins along coastal San Juan Islands, identifies vessels by type and usage, establishes spatial and temporal distributions, and determines concentration to square kilometer; 2. Develop predictor statistics for estimating future quantities with less rigorous and less expensive sampling.**

METHODS

The study design initially focused on deriving vessel traffic density by means of orthogonal aerial photographs taken along flight transects flown at an altitude of 2,000 feet. With an Olympus dSLR Evolt 500 camera using a 150 mm zoom lens, each photo would cover a maximum ground distance of 1.6 km or approximately .5 miles on either side of the transect. The photos would be rectified into a GIS with landmark registration points. Density estimates could then be made using transect/distance algorithms. The Olympus e500 was chosen because it carries one of the least expensive price points for a digital camera with full size photo sensor and complete SLR functionality. Due to project budget constraints, we could not rent a helicopter or a fixed wing aircraft specifically licensed by the FAA to be equipped with belly-mount camera port. Instead we chartered a fixed wing Cessna 172 from Bellingham Aero Aviation, FAA licensed for flight instruction and scenic aerial photography. This required a photographer in the co-pilot (right-hand) seat to lean out through the window during flight in order to achieve nearly orthogonal positioning of the lens. Photos would be taken as fast as the shutter could be operated with a high speed Compact Flash storage card recording the information.

After the first flight survey, however, we quickly realized that it was not possible to obtain orthogonal, in-focus, data while leaning out the window into a 70 mph head wind. It was also apparent that boats were far too transient and migratory for transect/distance derivations to be useful, even from an altitude of 2000 feet with ground speed of less than 100 mph. Therefore, the sampling method was modified to include the pilot and a co-pilot gathering spot counts while a photographer in the back seat moved from side to side capturing as many vessels as possible with varying oblique angles and focal lengths ranging between 40 and 150 mm. Besides simply counting numbers of vessels, the pilot and co-pilot could also identify vessels as to type based upon 5 general operating categories: Power, primarily motorized pleasure craft greater than 16 feet in length; Sail, primarily wind powered pleasure craft greater than 16 feet in length; Commercial Fishing, powered vessels greater than 16 feet in length and apparently engaged in fishing activity with rigging to operate net gear; Ferry, commercially operating vessels capable of transporting more than 10 passengers; and, Cargo, various sized container vessel, freighter, barge, or pilot boat greater than 16 feet in length and apparently engaged in the transport of commercial goods, construction activities or research. Only vessels underway, at anchor or moored were counted, excluding all vessels which were at dock or in marina slips, under 16 feet in length or paddle-powered.

Sample times were randomly selected from dates spanning the peak summer months of August and September after being stratified by two classes: morning or afternoon and weekend/holiday or weekday day types. Random selection was intentionally weighted in favor of weekend/holiday day type to insure rigorous sampling during times known to convey highest densities. A particular flight required 2 hours to transverse all transects. Each survey start time would have to be separated by at least 2.5 hours to allow for refueling. Operating hours for the pilot and aircraft were limited to between 9 a.m. and 6 p.m. Because further operational restrictions were based upon weather conditions, a complete set of alternative sample times were chosen to be used in the event that a primary sample could not be taken for reasons of low ceiling or high winds. (Flights were not permitted at times when the ceiling was less than 1000 feet or sustained wind velocity exceeded 20 mph.) Thus 26 over-flight surveys were conducted with the following sample regime:

August 9, 2006	9:30 a.m. (no usable data collected)
August 12, 2006	10:15 a.m.
August 12, 2006	3:15 p.m.
August 13, 2006	10:00 a.m.
August 13, 2006	3:30 p.m.
August 15, 2006	11:00 a.m.
August 15, 2006	3:45 p.m.
August 25, 2006	10:30 a.m.
August 25, 2006	3:00 p.m.
August 26, 2006	10:00 a.m.
August 26, 2006	3:00 p.m.
August 27, 2006	9:00 a.m.
August 27, 2006	3:15 p.m.
August 29, 2006	10:30 a.m.
August 29, 2006	3:15 p.m.
September 2, 2006	11:30 a.m.
September 2, 2006	3:15 p.m.
September 3, 2006	10:15 a.m.
September 3, 2006	3:00 p.m.
September 4, 2006	10:00 a.m.

September 4, 2006 4:00 p.m.
September 7, 2006 2:00 p.m.
September 9, 2006 9:30 a.m.
September 9, 2006 4:00 p.m.
September 10, 2006 10:00 a.m.
September 10, 2006 3:00 p.m.
The sample set consisted of 9 weekend/holiday mornings, 9 weekend/holiday afternoons, 4 weekday mornings, and 4 weekday afternoons.

The study area was divided into 9 geographically intuitive regions (see appendix B) in order to facilitate count binning and reduce error from double counting or missed coverage. Spotters were trained to count boats with closing trajectories bringing them into the currently counted region and not count boats near the current region boundary with trajectories out of the region. Nearly complete coverage of marine waters, bounded by the Straits of Juan de Fuca to the south, Sucia Island to the north, U.S.–Canadian border to the west and Lummi Island to the east, could be accomplished in 2 hours at an altitude of approximately 2300 feet. Stewart Island was not typically included due to time constraints and South Lopez was necessarily excluded due to constraints from Whidbey Naval Airspace. Survey methods were additionally amended, beginning with the afternoon flight of August 12, to include free-hand position sighting of vessel locations on data sheets containing aerial maps of each of the 9 geographic regions. (See appendix C) The co-pilot spotters were trained to determine linear quadrate position sightings based upon landmarks evident on the aerial maps. Because the furthest distance between two obvious landmarks in the study area was slightly less than 4 kilometers, free-hand location sightings were deemed to be accurate to within .5 square kilometers. The position markers were further symbolized as to the five general type classifications: Power, Sail, Ferry, Cargo and Commercial Fishing.

Vessel locations and types from the aerial map data sheets were then “heads-up” digitized into point feature GIS layers. The locations and type id’s were further quality checked against data from the aerial photography. This was especially useful in improving the accuracy of position and classification for vessels in the crowded embayments of Sucia Island, Roach Harbor, Fishermen’s Bay, Friday Harbor and Shoal Bay. The photo record was also useful in establishing three additional vessel classes: Recreational Fishing, powered vessels greater than 16 feet in length and apparently engaged in fishing activity without rigging to operate net gear; Whale Tour, commercially operating vessels capable of transporting more than 10 passengers and actively engaged in viewing Orcas; and Navy, identifiable as U.S. Navy ship. Each point layer was then converted to a raster concentration surface utilizing the ESRI 9.1 Point Density Tool with a 50 meter cell size and search radius of .5 kilometers. Cell density values were reported in units of vessels per square kilometer. The cell size was chosen based upon minimum average distance between vessels and the search radius was selected in order to consume our estimated error from the free-hand point location method. The raster surfaces were then averaged in order to report results for: Total Average Density; Total Average Density Weekdays; Total Average Density Weekend/Holidays; Total Average Density Sail; Total Average Density Power; Total

Average Density Commercial; Total Average Density Morning; and Total Average Density Afternoon. These are further explained in the results section that follows. Complete metadata for all GIS layers are contained in Appendix D.

Concurrent with several of the over-flight surveys, ground observers were stationed in eight strategic areas throughout the Islands: Yellow Island looking out over San Juan Channel; Yellow Island looking out over President's Channel; Yellow Island looking out over Sperden Channel; Orcas Island looking across midpoint of East Sound; Orcas Island looking across Harney Channel to Shaw Island; Rocky Point looking over False Bay; Cattle Point observing Cattle Pass; and Andrews Bay looking out onto Horo Strait. The observers were given a standardized data sheet (See Appendix E) and trained to record spot counts for numbers of specific classes of vessels within the full viewable range from their particular location. In addition to spot counts, ground observers also recorded a rate for the number of all vessels, any type, passing a point on the horizon during a specific time interval. All of this data was plotted against over-flight data and analyzed with regression models. Further concurrent ground based data was obtained with the deployment of automated digital cameras from Friday Harbor Labs focused across the main channel entering the harbor. The camera was first set on a timer with photos taken every 2 minutes. Because this method seemed to miss a lot of vessel traffic, the camera was replaced with a system employing a motion detection sensor. This system seemed to greatly reduce the number of missed captures but also captured a lot of erroneous data when the sensor was triggered by light reflections off of waves and wakes. Because of the amount of data contained within this dataset, we are, as yet, unable to report results from the photo sensor collection system. We have, however, developed a method to speed up the analysis by converting the digital still images to video frames. An observer can then record information from visual spot identification of marine vessels types while viewing a video stream that compresses a day into roughly 4 hours. Both quantitative and qualitative information can be derived from the photos with the video enabling a "flow" for speeding up the efficiency in discarding erroneous frames. When time and budget can be made available, data extracted from the photo sensors in this manner can then be rigorously regressed with data from the aerial surveys. Regressions employed for analysis of the concurrent ground based observer data included: Total # OBSERVER ~ Total # Flight Survey; Total # per Type OBSERVER ~ Total # per Flight Survey; Total # OBSERVER ~ Total # Flight Survey for Same Geographic Section; Sum Total # OBSERVERS ~ Total # Flight Survey; Sum Total # OBSERVERS From Same Geographic Section ~ Total # Flight Survey from Same Geographic Section; Rate per Hour OBSERVER ~ Total # Flight Survey; Rate per Hour OBSERVER ~ Total # Flight Survey for Same Geographic Section; Summed Rates per Hour OBSERVERS ~ Total # Flight Survey; Summed Rates per Hour OBSERVERS From Same Geographic Section ~ Total # Flight Survey from Same Geographic Section; Relative Vessel Class Proportionality OBSERVER ~ Relative Vessel Class Proportionality Flight Survey; and Relative Vessel Class Proportionality OBSERVER ~ Relative Vessel Class Proportionality Flight Survey from Same Geographic Section. Linear, Log/Log and Log/Normal regressions were analyzed for each model.

RESULTS

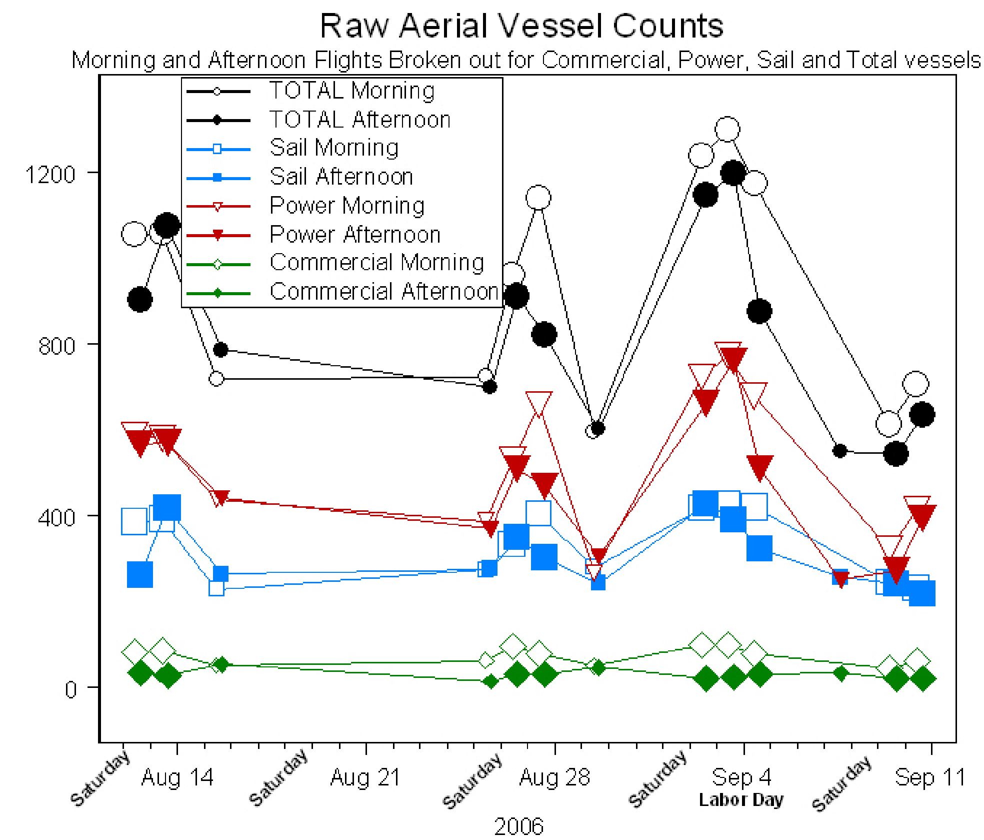


Figure 1: Vessel Counts from each Morning and Afternoon Flight reported by Total and for Power, Sail and Commercial Type classification. The Commercial class represents the sum of Ferry, Commercial Fishing and Cargo classifications.

Figure 1 depicts the spread of data for all aerial surveys over the study period. The proportionality between power and sail boats is an accurate reflection of industry assumed proportions in private ownership. As would be expected, the total vessel numbers, and particularly the number of Power and Sail boats, exhibit spikes during weekend and holiday periods. Conversely, the numbers in the Commercial grouping, a summation of Commercial Fishing, Cargo and Ferry vessels, remain flat over the study period. Vessel densities appear to be slightly greater for morning hours when compared to afternoon hours in general for all categories. The difference in morning and afternoon counts, however, does not seem significant. The data also accurately exhibit an expected trailing-off trend toward the end of “Peak Season”. In general, the data provide an accurate account of most pre-study expectations with the only real surprise possibly found from the total volume reported throughout the day.

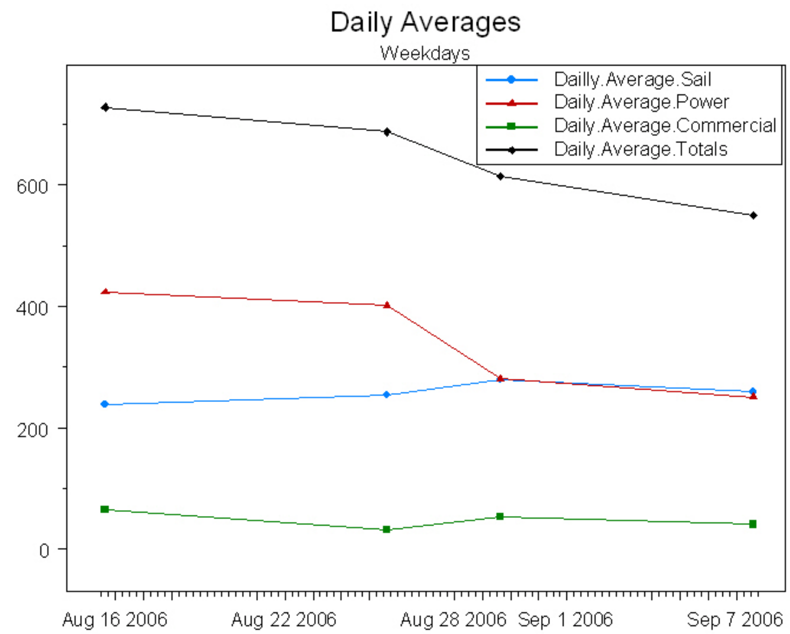


Figure 2: Daily Averages of Morning and Afternoon Counts for Weekday Flights

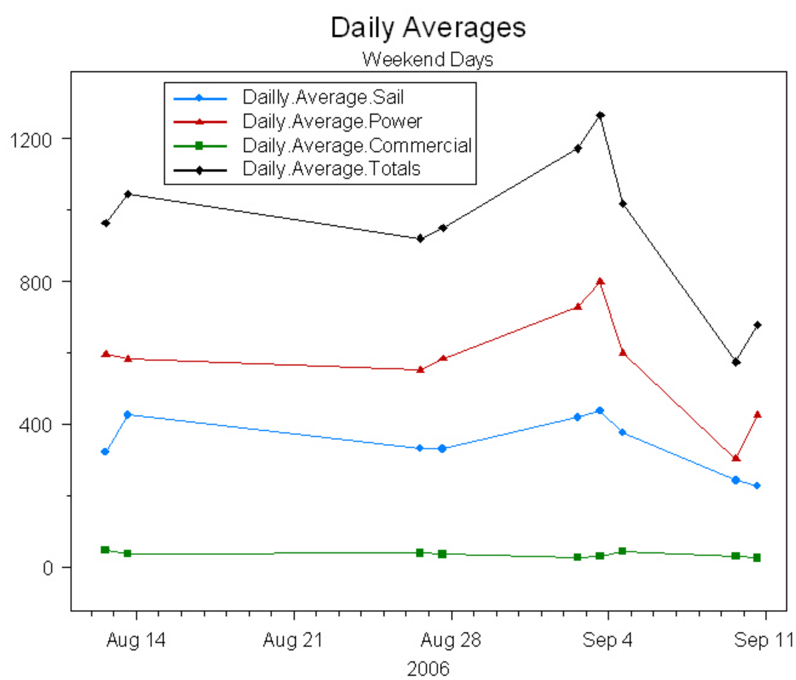


Figure 3: Daily Averages of Morning and Afternoon Counts for Weekend and Holiday Flights.

Figures 2 and 3 represent the daily averaged results for morning and afternoon times plotted separately for weekday flights and weekend/holiday flights. Although two different pilots and five different co-pilot spotters were utilized over the course of the study, the data appear to be precise with little variance between day types other than the expected Labor Day spike and end of season trailing. The only other exception to precision is exhibited in a sharp decline in average power boat counts between the first and second half of the study period. This is possibly explained by a severe surge in gasoline prices during the later part of August, 2006.

2006 PEAK SEASON WEEKDAY SEA VESSEL COMPOSITION
9 A.M. – 6 P.M.

	Power	Sail	Commercial Fishing	Ferry	Cargo	TOTAL
Average	**351**	**260**	**50**	**3**	**3**	**667**
Standard Error	**+/- 29.68**	**+/- 7.17**	**+/- 5.42**	**+/- .56**	**+/- .56**	**+/- 32.43**

2006 PEAK SEASON WEEKEND/HOLIDAY SEA VESSEL COMPOSITION
9 A.M. – 6 P.M.

	Power	Sail	Commercial Fishing	Ferry	Cargo	TOTAL
Average	**554**	**343**	**59**	**4**	**4**	**963**
Standard Error	**+/- 33.88**	**+/- 17.94**	**+/- 9.37**	**+/- .44**	**+/- .53**	**+/- 54**

Figure 4: Average Vessel Compositions for any given time between 9 a.m. and 6 p.m.

Figure 4 breaks out the average snapshot of sea vessel composition on the marine waters surrounding San Juan County separated for weekday and weekend/holiday day types. There were roughly 650-700 boats on the water during any given weekday time between 9 a.m. and 6 p.m. during peak season 2006. For any given similar time reference during weekend and holiday periods, there was a total of approximately 900-1000 boats on the water. Though the number of Commercial Fishing, Ferry and Cargo vessels remained nearly constant throughout the week, there was an average 58% increase in power craft and 32% increase in sail boats over the weekends and holidays. This was the primary contribution to a total average vessel increase of 44% during the weekend/holiday periods. Because the data spread was relatively small for various survey times within a specific day type, we consider this data to be a good representative picture of boats on water during the 2006 Peak Season for any given time within the sample time range for a particular day type. There is some uncertainty here due to the proportion of Standard Error to Mean resulting from relatively few samples. (Total of 25 surveys over 13 days) However, even with a relatively small sample set, the proportion of Standard Error to Mean is generally much less than 10 %. Because this is baseline information, we have no indication of whether or not 2006 was a typical year in comparison with previous years. In fact, one could list several contributing factors which may have made 2006 anomalous, including exceptionally good weather, high gasoline prices, and a strong Canadian dollar. No external factors were taken into consideration while gathering baseline data for this pilot study.

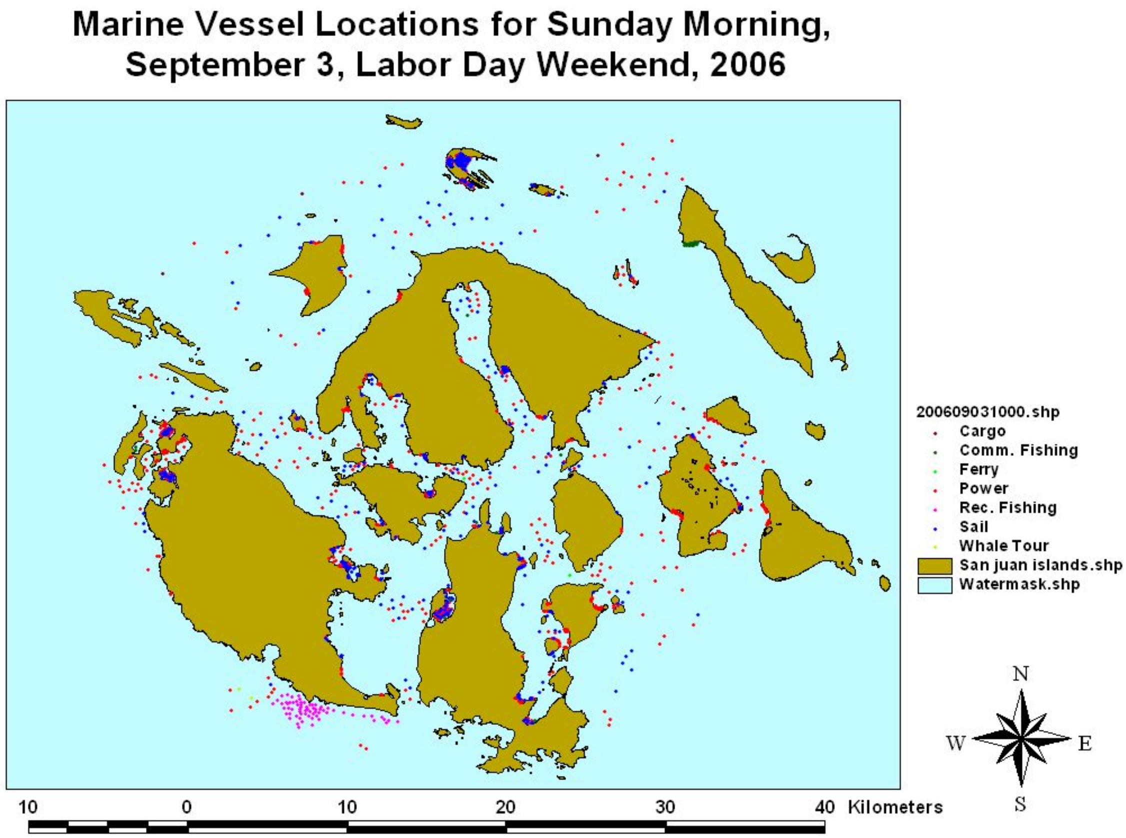
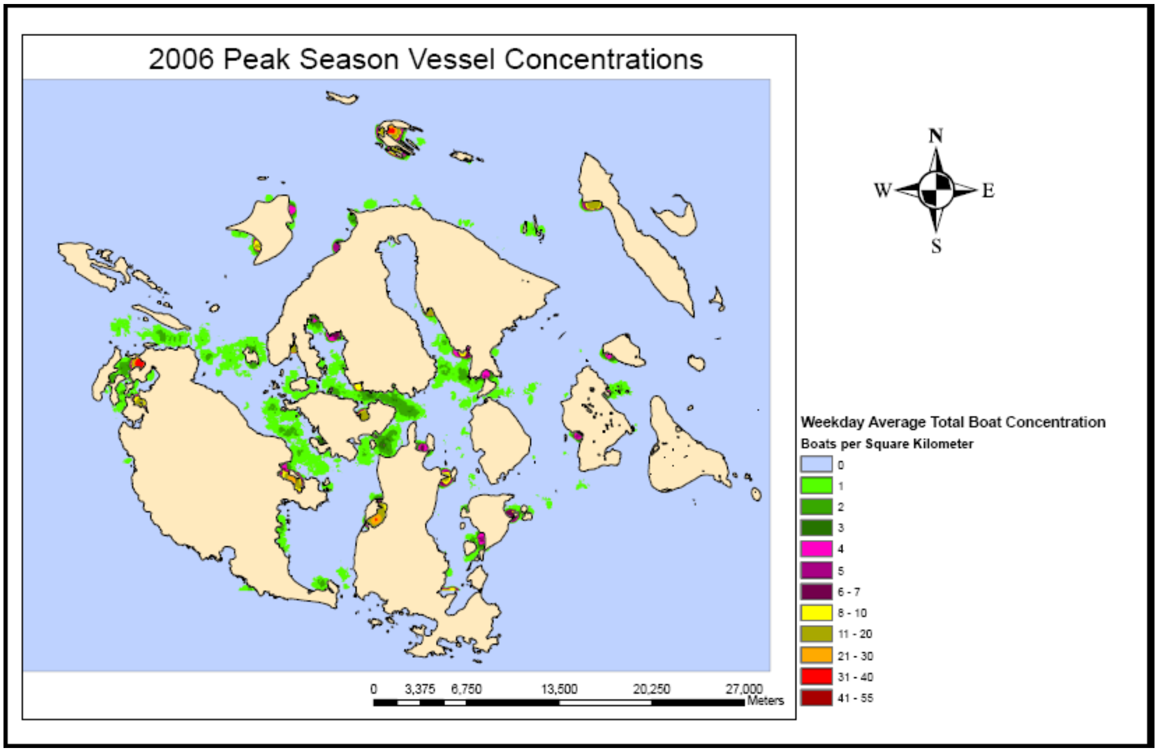


Figure 5: Point Locations for Marine Vessel Types on Saturday morning of Memorial Day Weekend.

Figure 5 maps a typical point feature dataset of marine vessel types and locations generated from the aerial survey data. The Sunday morning flight on September 3rd over the 2006 Labor Day weekend yielded the highest counts of any survey throughout the pilot study period. Though the data reported in this format may be of some use, because of the relatively large associated error, estimated to be +/- .5 square kilometers for individual positions, and because marine vessels are generally highly mobile, we feel much more confident in the usefulness of results from the point density concentration surfaces generated through further spatial analysis of these point feature layers. However, maps of approximate locations from each flight, such as that shown in figure 5, do provide a good picture of the spatial dispersions for each vessel type classification. Additionally, the maps of general locations offer a better understanding of vessel movements in the open water areas. These areas are typically contained in the lowest concentration bin on the density surface maps with concentrations less than 1 vessel per square kilometer. It is also interesting to note from the map in Figure 5, the bays and harbors appear to be dominated by sailing vessels while the open waters appear to be somewhat more populated with power vessels. This particular survey had 7 of the 8 vessel classes represented; displaying Whale Watching in a typical spot along the western coast of San Juan Island and obvious salmon fishing clusters off the southwestern shores of Cattle Point.



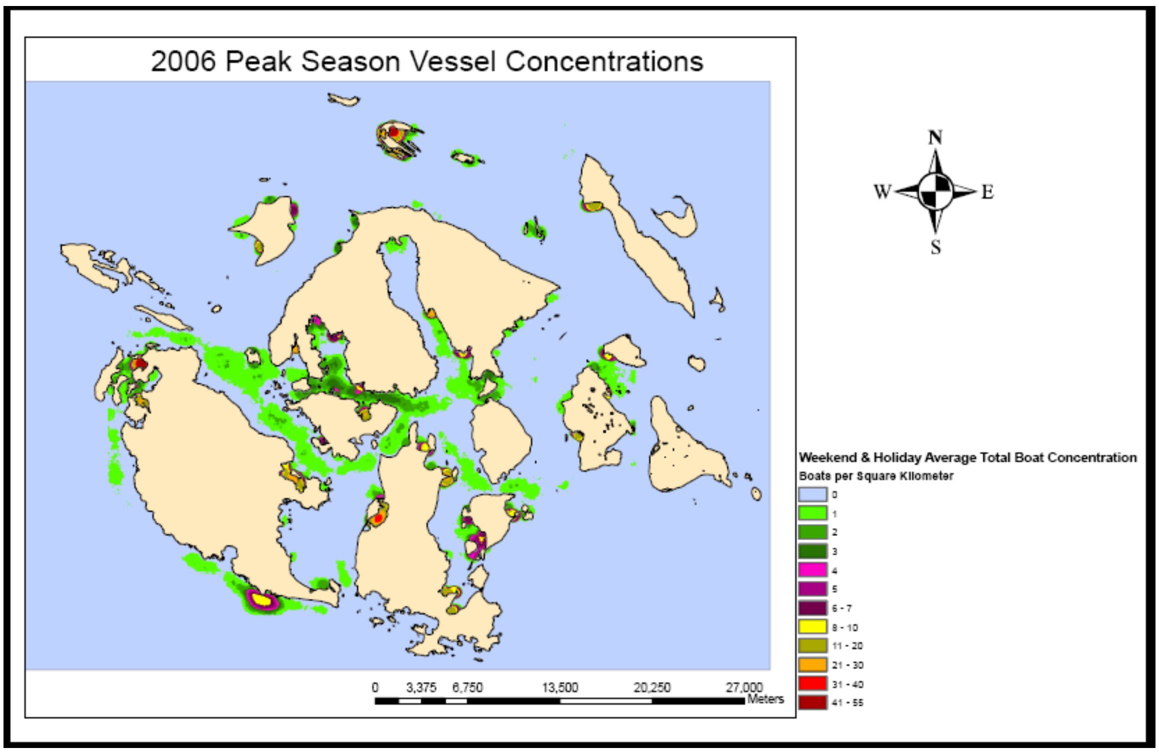
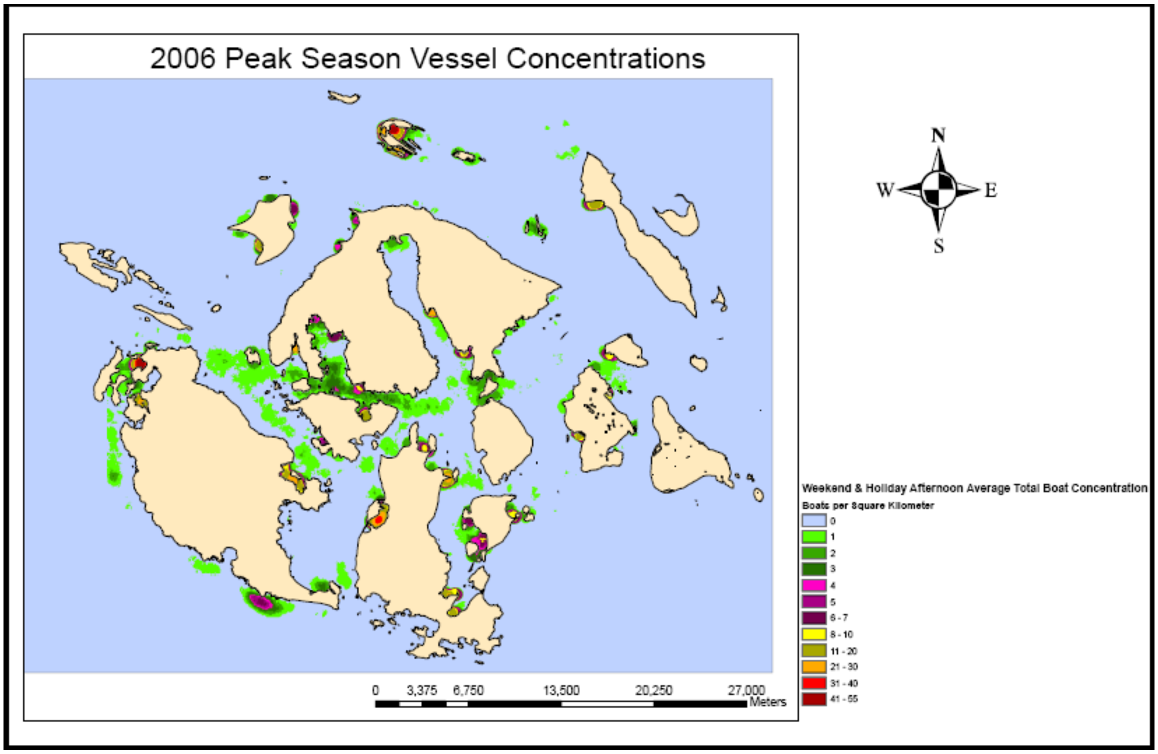


Figure 6: Concentration Surfaces for Average Total Boats during Weekday and Weekend/Holidays

The concentration maps in Figure 6 show how average total boat concentrations for weekend/holiday periods compare with weekday periods. The average total concentration densities for weekend/holidays are higher in most areas than for those same areas on weekdays. There are also more areas of higher densities during the weekend/holiday periods.



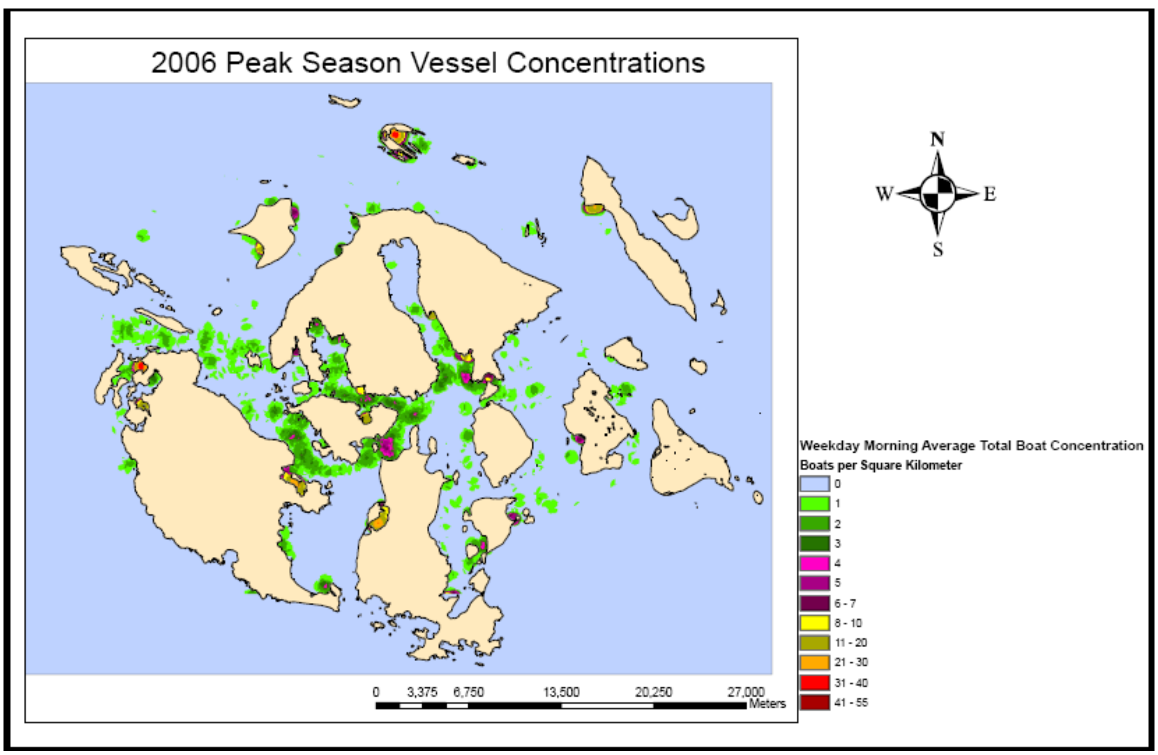


Figure 7: Total Average Boat Concentration Surfaces for Afternoon and Morning Times during Weekend/Holiday Periods

The two concentration maps in Figure 7 on page 13 demonstrate the differences between average total boat concentration densities for mornings and afternoons of weekend holiday periods. Recall that the total numbers of marine vessels counted during morning and afternoon surveys were nearly equal. However, the areas of concentration are apparently quite different between morning and afternoon hours. On average, there appears to be many more boats at anchor and mooring in the bays during the afternoon when compared to the morning. Conversely, on average, there are significantly more vessels underway in the channels during the morning hours. This was also observed when comparing the morning and afternoon concentration distributions for average total boats during weekday periods.

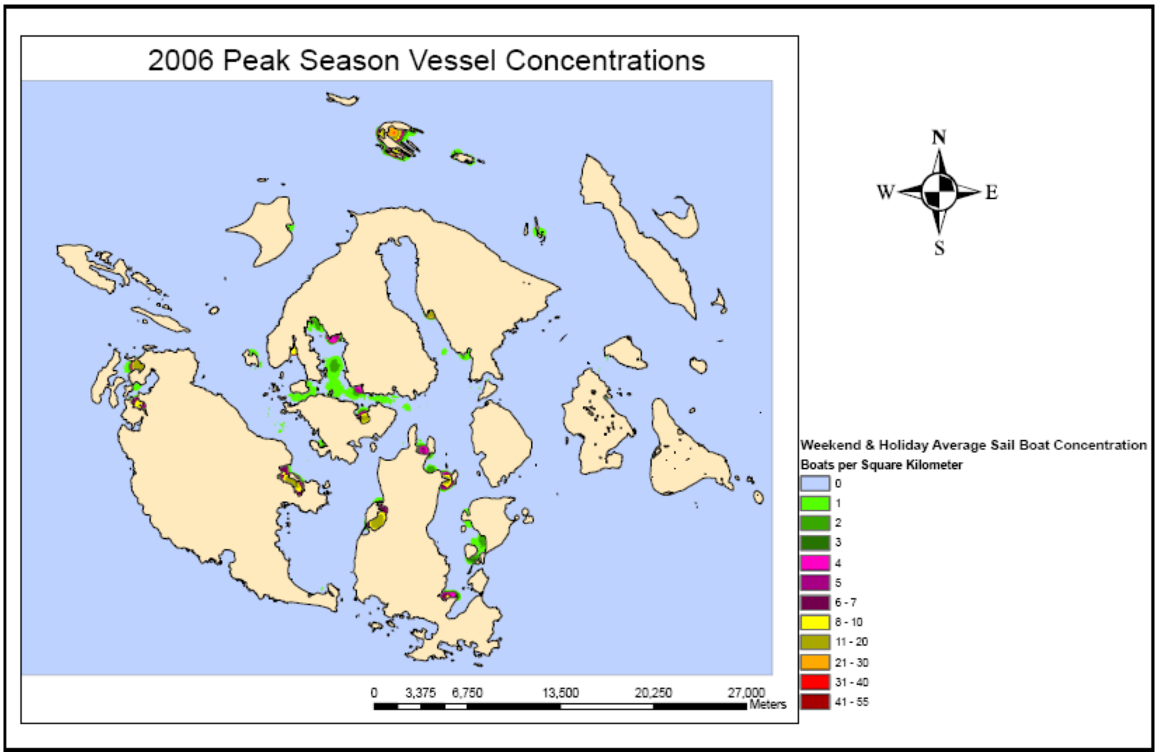


Figure 8: Total Average Sail Boat Concentrations during Weekend/Holiday Periods

The map from Figure 8 above exhibits the concentration surface for average total sail boats during weekend/holiday periods. When compared to the concentration map in Figure 9 on the following page for average total power boats during weekend/holiday periods, sail boat concentration areas appear much less dispersed. Except for concentrations around West Sound at the southwestern tip of Orcas Island, sail boats seem to be spending more time stationary at mooring or anchor. Power boats, on the other hand, are much more transient, contributing high levels of concentration over more widely dispersed spatial cells, especially throughout all of the constrained passes along the south shore of Orcas Island. Both power and sailing vessels are highly concentrated around West Sound and the northern coastline of Shaw Island, causing traffic densities through this constrained pass to remain fairly intense. Similar patterns were observed from concentration layers for average total sail and power boats during weekday periods.

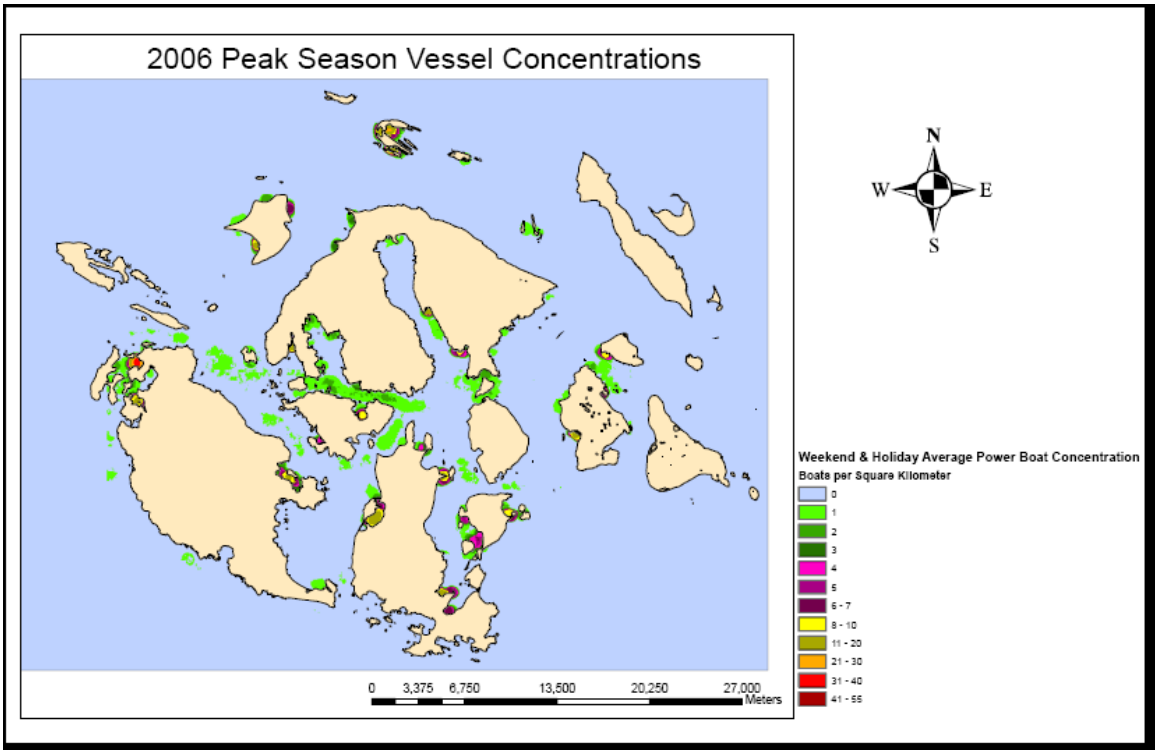


Figure 9: Total Average Power Boat Concentrations during Weekend/Holiday Periods

Finally, we present results for the only promising predictor statistic from analysis of the concurrent ground based observations. After analyzing all ground observation data with the models outlined in the previous Methods section, it was found that only one

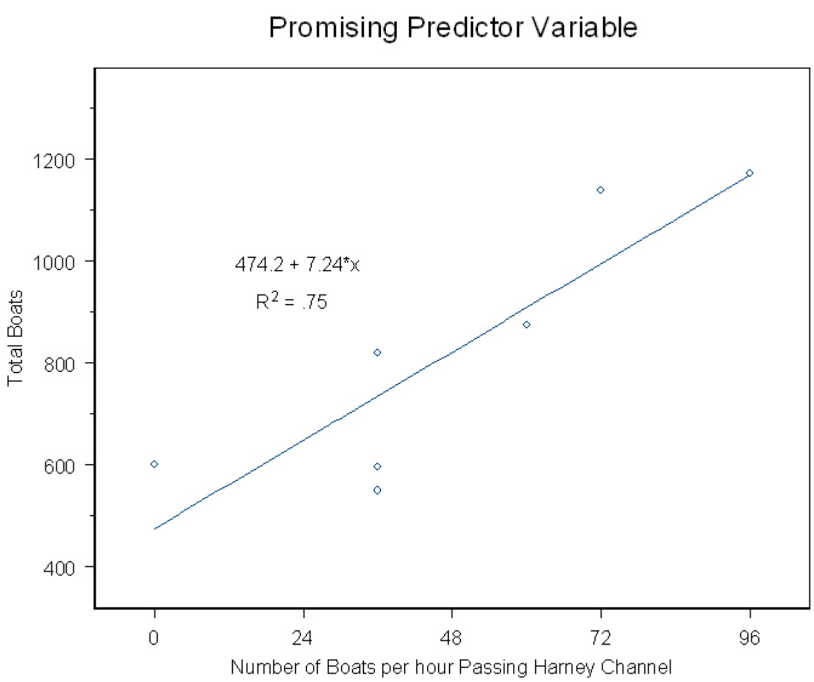


Figure 10: Linear Regression of Rate per Hour OBSERVER (Harney Channel) ~ Total # Flight Survey

location, a house deck on Orcas Island overlooking Harney Channel, yielded results that may have promise for predicting only total number of boats. Figure 10, on the previous page, shows the linear fit for this regression model. The observer sighted a flagpole point on Shaw Island and counted total number of boats crossing that point without note of vessel type. This observed rate does do a fairly good job of predicting total boats on water with an R squared value of .75. The model obviously has more difficulty with predicting total vessels during times of low traffic volume. However, with more samples, the R square should likely increase. This location seems like a logical location from which to derive predictor statistics because of its proximity to the high concentration areas of West Sound and the northern coast of Shaw Island. The location is also situated on a constrained passage along the major east-west conveyance route. Motion detection photography from this location could also yield results for vessel types and relative abundance.

CONCLUSION

The methods for obtaining data on marine vessel traffic in this pilot study appear to yield highly precise and accurate results for both quantity and quality parameters. Information was collected with use of the least expensive charter fixed-wing aircraft available and a digital camera costing less than $900. Vessel quantities spike during weekend/holiday periods of peak summer season due to increased recreational use. Commercial use remains relatively constant throughout the week. There is not a significant difference in on-water traffic volumes between morning and afternoon hours within weekday or weekend/holiday periods. Because environmental impacts from marine vessels are greatly exacerbated by high volume, the number of vessels throughout the peak summer season could be considered significantly high, with particular concern over pressures during weekend/holiday periods. Interpreted spatial data yielded reliable concentration surfaces for vessel densities per square kilometer. The concentration densities further point to increased concerns from environmental pressures over weekend/holiday periods. Average total vessel densities for weekend/holiday periods were typically twice as high in the bays when compared to the densities in popular bays during weekdays, ranging from greater than 20 boats per square kilometer on weekdays to greater than 40 boats per same unit area during weekend/holiday periods. This data should be very useful for managers adopting strategies for identifiable hot spots within the San Juan County MSA. Managers should also consider results pointing out the differences between concentration patterns for the morning and afternoon hours. Though, traffic volume remained nearly constant throughout the day, the consequence of higher concentrations in the channels during morning hours and, conversely, higher concentrations in the bays during afternoon hours must be taken into consideration for any strategic management plan. Additionally, because different vessel types imply various environmental pressures, results for vessel density by type should guide management strategies for protection of sensitive ecosystems within the MSA. Finally, it does appear likely, with a bit more experimentation, ground based photography with motion detection sensors can be utilized to predict vessel traffic for quantity and possibly quality parameters.

FURTHER STUDY

In the pilot study we have been able to test and refine several study methodologies. We have also gathered good baseline data for the peak summer season with spatial analysis pointing out high concentration areas for specific vessel types. We have found some of the ground based observations to be good predictors for Total marine vessel traffic volume. This leads us to believe that further ground-truthing with motion detector cameras at better strategically placed ground locations may eventually result in a county-wide survey completely constructed from the ground. Also, from our pilot study, we have a much better handle on the spread of the data and realize that our flight surveys do not need to be as intensive. Obviously, however, we need to continue an abridged regiment of aerial photo and count surveying in order to refine ground observation and automated remote photography strategies. We believe trend analysis to be very valuable in getting at the question of carrying capacity and policy management, Therefore, it is essential to expand seasonal coverage in our baseline data, continue research into the development of statistics that can predict concentration levels from ground based observations alone, and gather further observations for the next peak season data point on the trend line. With fewer required flights and less flight data to analyze, the next phase of the study can devote more resources to analyzing and gathering more ancillary data, such as the auto-generated photos from FHL, web-cam photos, marina information, DOT mooring information, marine gasoline sales, State parks visitor information, boater surveys, etc. Additionally, several more specific questions have arisen out of the pilot study: "What is the proportion of boats anchoring related to those mooring in the embayment areas?"; "What areas might be most prone to concerns from noise pollution?"; "How might regulations for the protection of Orcas affect overall vessel traffic flows?" The next phase of the study can concentrate on gathering data to try and answer these and other more specific questions in addition to the more general questions of trend and carrying capacity.

In summary, I believe the next phase of the Marine Vessel Traffic Study should be funded with goals for:

1. Expanding Seasonal Coverage;
2. Gathering data for trend analysis;
3. Further refining data gathering techniques;
4. Further researching the development of predictor statistics derived solely from ground based observation;
5. Expanding analysis of more ancillary data sources;
6. Developing the study of several other more specific questions, i.e. anchorage pressures, noise pollution pressures, whale watching pressures, traffic hazards for paddlers, etc.

All baseline results gathered from the pilot study were obtained with the most minimal budget and a 100 % match of volunteer to paid hours. Future studies must be more adequately funded so that the quality of the work is not so directly tied to the quality of available volunteers.

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Jim Slocomb, MRC Vice-Chair, GIS and information system consultant
Ken Sebens, Director, UW Friday Harbor Laboratories
Michael Durland, Owner/manager, Deer Harbor Boat Yard
Tina Whitman, MRC Member, Science Director, Friends of the San Juans
Terrie Klinger, UW School of Marine Affairs, Friday Harbor Laboratories
Phil Greene, Yellow Island Steward, The Nature Conservancy
Rowann Tallmon, WSU Beach Watchers

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Don and Marilyn Majors, Friends of the San Juans, 10 hours
Phil Greene, Yellow Island Steward, The Nature Conservancy, 25 hours
Rowann Tallmon, WSU Beach Watchers, 11 hours
A R Weisbrod, WSU Beach Watchers, 17 hours
Jacki Riley, WSU Beach Watchers, 12 hours

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Jonathan Riley, Western Washington University Senior in Geography, 350 hours
Tom Clark, Western Washington University Senior in Engineering Technology, 5 hours
Jennifer Hauer, Western Washington University Senior in Environmental Science, 5 hours

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Milo Stevens
Matt Manson

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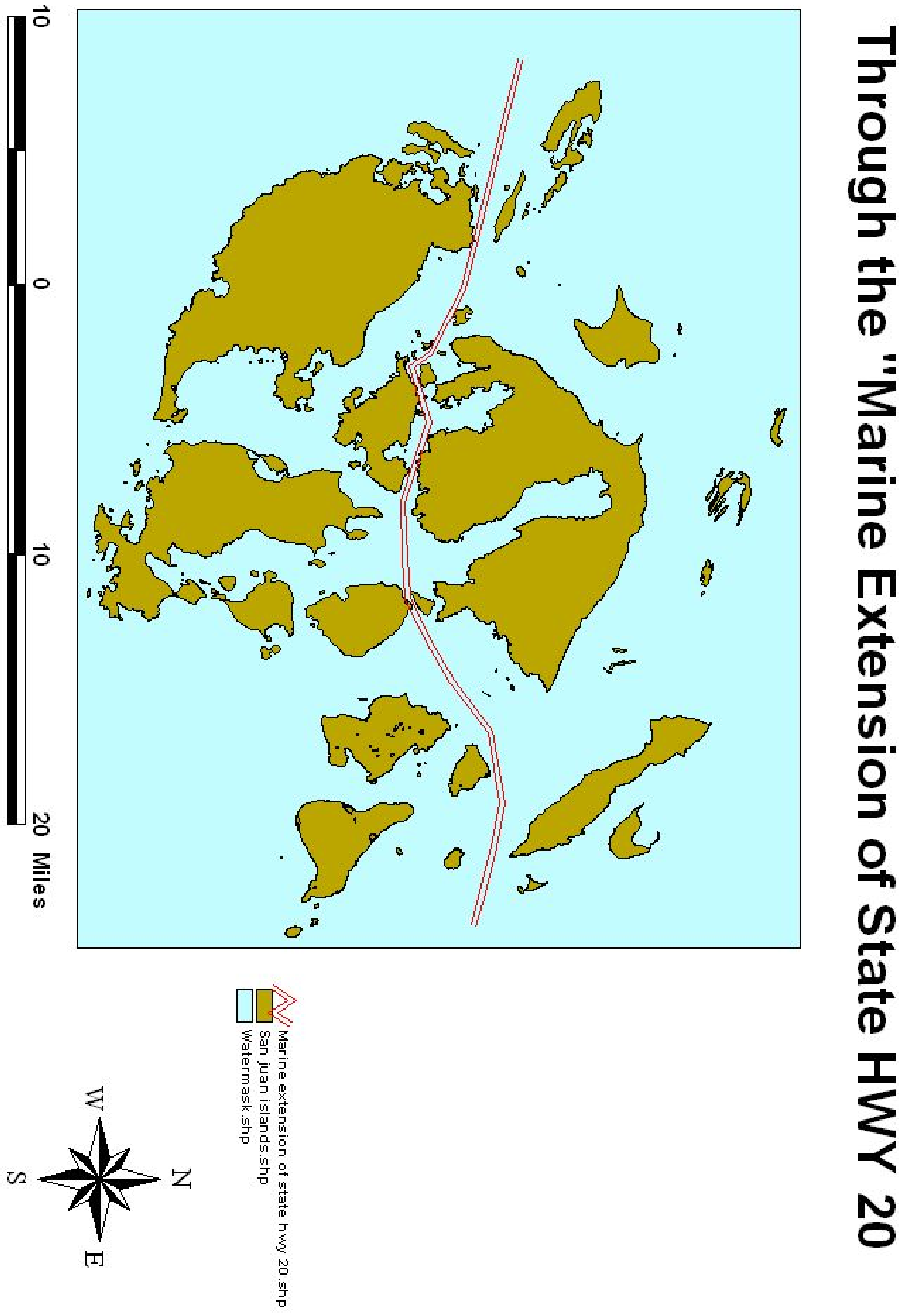
Appendix A


San Juan Islands with
Several Constrained Passes
Through the "Marine Extension of State HWY 20
10
0
10
20 Miles
Marine extension of state hwy 20.shp
San juan islands.shp
Watermask.shp
N
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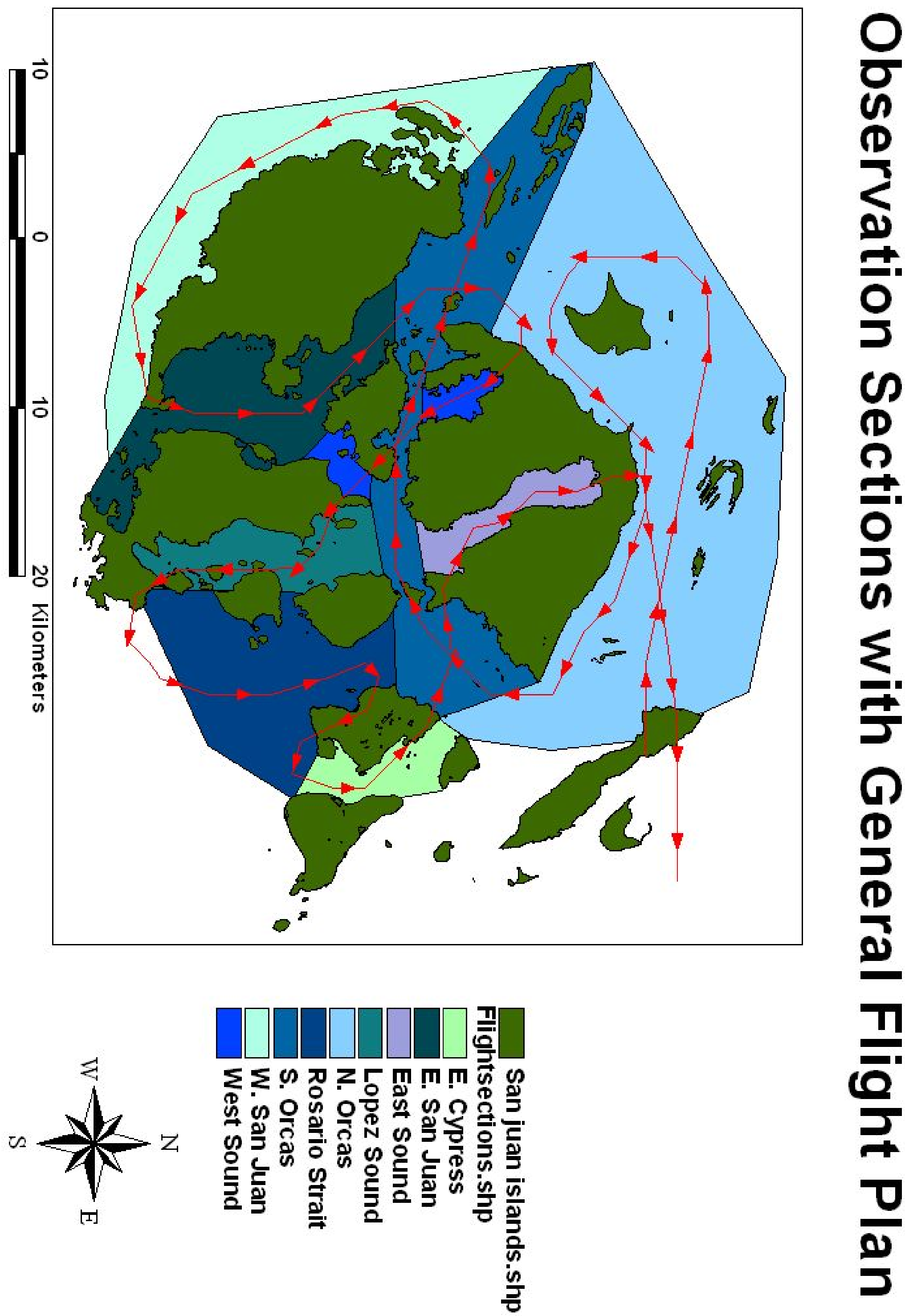
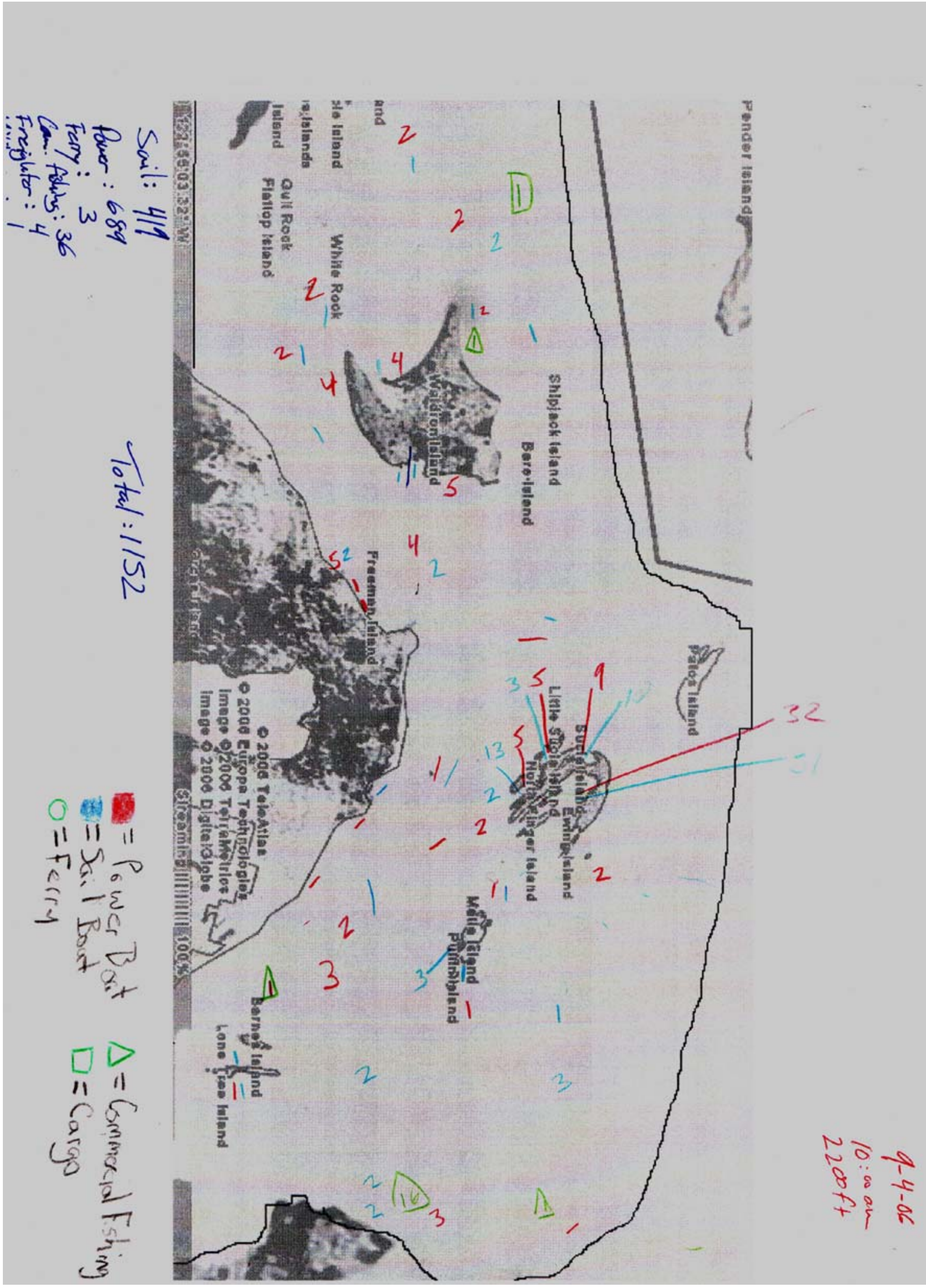
S
W

Appendix B



Observation Sections with General Flight Plan
10
0
10
20 Kilometers
San juan islands.shp
Flightsections.shp
E. Cypress
E. San Juan
East Sound
Lopez Sound
N. Orcas
Rosario Strait
S. Orcas
W. San Juan
West Sound
N
S
E
W

Appendix C


Pender Island
Shipjack Island
Bare Island
Waldron Island
White Rock
Quil Rock
Flattop Island
Freeman Island
Patos Island
Sucia Island
Little Sucia Island
Ewing Island
Matia Island
Puffin Island
Barnes Island
Lone Tree Island
© 2006 TeleAtlas
Sail: 419
Power: 689
Ferry: 3
Com. Fishing: 36
Freighter: 1
Total: 1152
= Power Boat
= Sail Boat
○ = Ferry
△ = Commercial Fishing
□ = Cargo
9-4-06
10:00 am
2200 ft

Appendix D

Marine Vessel Survey
GIS Layers Metadata

<u>ArcView Projects:</u> There are two APR files titled San Juan Islands Vessel Study Area Sections and San Juan Island Marine Vessel Locations. These can most easily be opened by placing the folder, GIS Layers, in the root directory of a drive named C. The former project contains a polygon theme of the San Juan Islands and a polygon theme demarcating 9 sections dividing the entire study area into sample bins. There is also a layout in the project denoting the general flight path by which the sections were surveyed. The latter project contains point themes for each aerial survey depicting general marine vessel locations symbolized as to vessel type utilizing template legend files, “legend1” and “legend2”. This project also contains a layout with a full extent map of survey results from the morning of Memorial Day 2006.

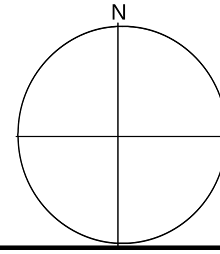
<u>Shape Files:</u> All shp files are projected in UTM NAD 1927. Except for a polygon coverage of the Islands, a polygon mask used for point density analysis and a polygon coverage of the divided study sections, all other shp files are digitized point locations from aerial survey observations. Each of these point files represents one flights data and the files are titled according to naming convention “yyyymmddhhmm” on a 24 hour time scale: example file 200609041000.shp contains spatial data for the 10 a.m. survey on Memorial Day 9/4 of 2006. The points were digitized based upon visual estimations of vessel locations hand recorded onto aerial photo maps by flight crew observers. The observers were trained to locate individual vessels and vessel clusters by quad rating distance between real world geographic features then transferring markers onto the aerial photo maps for each of the study sections. Markers also contained information as to general vessel type. Therefore, in addition to spatial information, the point layers for each flight also contain attributes for “Type” “Section” (Strings) and “Date” “Time” (Integers). Type consists of values for “Power”= power cruising boats and power yachts over 16 feet in length, “Sail”= day sail cruisers and sailing yachts over 20 feet in length, “Comm. Fishing”= power vessels with obvious rigging for commercial fishing activity, “Rec. Fishing”= power vessels appearing by activity, location and movement to be engaged in sport or recreational fishing, “Ferry”= WA State Ferries, BC Ferries and private charter Ferries, “Cargo”= any vessel obviously engaging in commercial activity other than commercial fishing, including ocean going container and cargo vessels, barges of all size and pilot ships, “Whale Tour”= charter tour boats obviously engaged in active whale watching, and finally the self explanatory “Navy”. Section contains values for the 9 arbitrary study sections named “N. Orcas”, “S. Orcas”, “W. San Juan”, “E. San Juan”, “West Sound”, “Lopez Sound”, “Rosario Strait”, “E. Cypress”, and “East Sound” with respective boundaries indicated in the Sections polygon shape file. The Date and Time fields simply contain integer values for “YYYYMMDD” and “HHMM” respectively and are included mainly for data QAQC and indexing. Because actual location points for individual vessels were digitized based upon “eyeballed” observations, and because boats are highly mobile, there is a great deal of error associated with an individual vessel location. However, due to observers being trained to accurately quadrate locations between distance spanning geographic features and because the furthest distance between geographic features in the study area is less than 4 Km, we estimate the maximum location error at +/- 500 meters. In addition to the point location shape files for each flight, the data was further subdivided into shape files for _power, _sail, and _commercial with _power containing points with Type = “power”, _sail containing points with Type = “sail” and _commercial containing points with Type = “Comm. Fishing”, “Rec. Fishing”, “Cargo”, “Ferry”,

Appendix E

Ground Based Observations
Standardized Data Sheet

San Juan County MRC Boat Survey Data Sheet

Sample #:	Weather:	Pilot:	Shade Horizon View
Date:	Sea Cond.:	Airspeed:	N
Area:	Time:	Altitude:	
Observer:	Latitude:		
Platform:	Longitude:		
Power of Mag:			
Comment:			



VESSELS							
Pleasure		Fishing		Commercial		Tour Operators	
Sailboat (Single Mast)		Private		Charter Ferry		Whale Watching	
Power Cruiser		Charter Party		Cargo Container Ship		Diving	
Power Yacht		Commercial		WA State Ferry		Other/Unknown	
Sailboat (Multi Mast)		Unknown		Research Ship			
Kayak (paddle power)				Government			
Other/Unknown				Unknown			
Total Pleasure		Total Fishing		Total Commercial		Total Operators	

Comment: Comment: Comment: Comment:

Total Vessels