Spatial Accuracy Assessment of Wetland Permit Data

Nina M. Kelly

ABSTRACT: A collection of permits granted for alterations to coastal wetlands in North Carolina from 1984 through 1992 was examined to determine the spatial accuracy of the data. Each permit site for which a precise location existed in its associated permit file was surveyed using a Global Positioning System, and the error was identified between the location described in the permit file and the true location. The error was analyzed with respect to direction of error, accompanying map type, and time. Results suggest that the spatial error found in the Permit Record for coastal North Carolina was too large to perform spatial analysis. Only 50 percent of the permit sites were found within 250 meters of their true location, and the rest were in error by as much as 45 kilometers. Errors were uniformly distributed in direction and not biased in any direction. The inclusion of maps with greater detail did not significantly reduce error in locating the permit site. There was a slight decrease in error over time, but the fit was not sufficiently strong to indicate an improvement in accuracy over time. The results suggest a need for better standards for gathering future data and call for more stringent spatial data quality controls on environmental permit data of this kind.

Introduction

An important aspect of coastal management in the United States continues to be wetland management. Despite federal, state, and local legislation designed to limit the alteration of wetland habitat, wetland loss continues because of substantial urban development along the coast (USGS 1996). Measures of the change in wetlands vary, as they are often confounded by different methods of measurement and the resulting different estimates of wetland extent (Rolband 1995; Shapiro 1995). One method of measuring change to wetlands is to analyze the permits that are filed when a wetland is altered. The record of permit activity in an area provides an underutilized source of information on wetland change, which might be used in environmental analysis to determine spatial patterning of wetland alteration—an important predecessor to understanding cumulative impacts of individual wetland alteration (Kelly 1996). This research examines in detail the spatial accuracy and precision of sample Permit Records in coastal North Carolina. The paper presents overall accuracy measures and attempts to account for error by reviewing it with respect to three factors: the direction of the error, the scale of the map accompanying each permit, and the date of permit filing. I also suggest a method to assess the utility of the dataset for spatial environmental analysis and recommend methods for improving the quality of locational data inclusion.

Nina Kelly is associate professor at the University of California—Berkeley, Ecosystem Sciences Division, Department of Environmental Sciences, Policy and Management, Berkeley, CA 94720-3110. Tel.: 510.642.7272; Fax: 510.642.1477. E-mail: <mkelly @nature.berkeley. edu>.

The Permit Record as a Tool for Wetland Management

Since the late 1970s, proposals to alter the natural environment in the United States have required a federal permit, issued following an evaluation of that permit request by relevant governmental agencies. The primary law governing wetland management is Section 404 of the Clean Water Act, which was passed in 1972 and was recently re-authorized. Section 404 regulates the deposition of fill material in wetlands (Dennison and Berry 1993) and requires a permit to be filed with the U.S. Army Corps of Engineers (Corps) prior to any wetland alteration (with some exemptions). In the southeast United States, these permits have since 1978 been collected in the offices of the relevant reviewing agencies and now serve as a record of wetland alterations in the country over nearly two decades. These files—hereafter called the Permit Record—serve as a useful management tool in several ways. First, while the acreage figures in the Permit Record are only estimates, they have been used to create inventories of wetland change that are a crucial part of the picture of a changing environment (Mager and Thayer 1986; Field et al. 1988; Mager and Rackley 1991; Kentula et al. 1992; Montana

Audubon Society 1993). These studies make note of the fact that estimates of change from these files can be influenced by inadequate measures of wetland loss included in some permit cases, and by difficulties early in the Clean Water Act process of defining a wetland (Tiner 1994). Because of these difficulties, wetland inventories are only estimates of change. Second, the information contained in the Permit Record—which includes such information as location, amount of change, and notes from habitat specialists regarding the condition of the habitat—could serve many important environmental and coastal management applications. For example, the spatial information contained in the dataset could be used to aid in mitigating siting and restoration planning by highlighting areas where excessive amounts of wetlands have been altered. Wetland mapping projects could be focused in areas that have experienced large wetland changes. Third, the analysis of cumulative impacts of piecemeal alterations requires accurate location of historic wetland site alterations (Kelly 1996). While the intent of the information contained in the permit file was not originally provided to assist in cumulative impact assessment, it is often suggested as useful in this regard. The accuracy of these datasets is unknown, and a complete analysis of the quality of the data is needed.

Map Error and Map Accuracy

If we consider the Permit Record to be a digital geospatial dataset for the analysis of wetland change, it is relevant to review it according to the standards designed for that purpose by the Federal Geographic Data Committee (FGDC). These standards suggest the reporting of data quality in each of the following five categories: attribute accuracy, logical consistency, completeness, positional accuracy, and lineage (Federal Geographic Data Committee 1998). Of primary importance to coastal managers are attribute accuracy, completeness, and positional accuracy; the last of these is investigated in this paper. Attribute accuracy was not estimated for the dataset, but staff at the Habitat Conservation Division in Beaufort, North Carolina, indicated that all the wetland permits for the time covered by this research are for actual or "jurisdictional" wetlands. Dataset completeness is difficult to verify, as there are no historical records of altered wetland sites that did not go through the permit process. Nevertheless, the Army Corps of Engineers staff I spoke with indicated that this dataset covers all anthropogenic wetland activity described in Section 404 of the Clean Water Act in the area for the time period considered. A thorough investigation of positional accuracy is both necessary and possible.

Analysis of the positional accuracy of digital datasets used for environmental analysis has advanced in the last 10 years, as many statistical error measures and map accuracy standards have been tested for use (Openshaw 1989; Bolstad and Smith 1995; Federal Geographic Data Committee 1998; Burrough and McDonnell 1998). Spatial accuracy can be expressed in terms of various measures including mean error, standard deviation of error, and root mean squared error (RMSE). From these measures, scale-dependent accuracy standards that express confidence limits on data have been developed. An example of these standards is the Circular Map Accuracy Standard (CMAS), which requires that 90% of the points on a map fall within scale-dependent limits. While wetland permit data do not require any of these measures to be reported, this paper presents the accuracy of the data according to the standards set up by the FGDC standards committee, and attempts to account for error by reviewing it with respect to direction, accompanying map type, and date.

The Study

The Permit Record

Under the Clean Water Act, proposed activities that would place dredge or fill material into a wetland require prior issuance of a Section 404 permit. In North Carolina, all permits—both state and federal—authorizing wetland impacts must receive Section 404 certification under the joint permit filing guidelines. Section 404 permit applications received by the Corps office in Wilmington for wetland activities in the coastal counties of North Carolina are sent to the National Marine Fisheries Service (NMFS) Habitat Conservation Division Office in Beaufort, North Carolina, and to other federal agencies for review of the potential environmental impacts to fisheries of each proposed action. The Habitat Conservation staff in Beaufort maintains both a digital database of permit applications and the paper files for each permit. The permit tracking system records information on project identification: the permit identification number, the applicant, state, county, nearest associated major and secondary water body, and important dates such as the date of application, date of

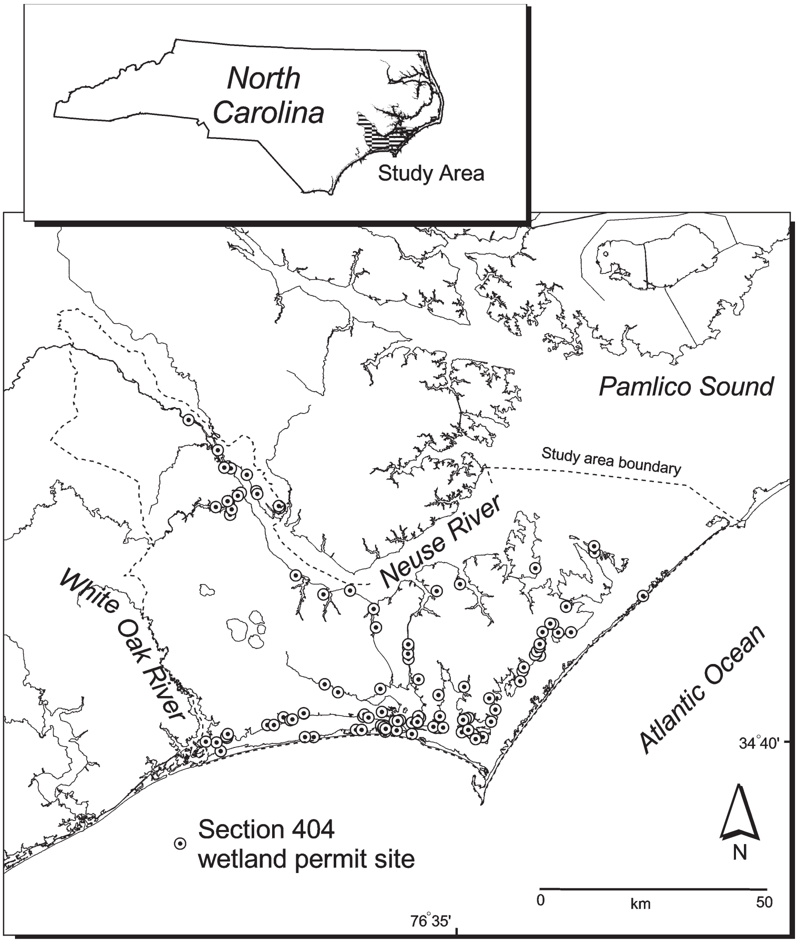

Figure 1. The study area in eastern North Carolina.

The research was conducted in the coastal region of North Carolina, in 22 sub-watershed basins of the White Oak watershed and 22 sub-watershed basins of the Neuse River watershed (Figure 1). The study area covers most of two coastal counties (Carteret and Craven). It extends some 100 kilometers from the coast inland and contains extensive acreage of estuarine, riparian, and palustrine wetland. The area is typical of coastal North Carolina in that it contains extensive coastal wetlands, and it has been changing rapidly with urban growth (Schafale and Weakley 1990; Holman and Childres 1995; USGS 1996). Population increase in Carteret and Craven counties has been mirrored by an increase in the number of Section 404 permits that have been requested and granted in the study area (Kelly 1996).

comment, and date of issuance. Data include the kind of activity involved and the habitat affected (dominant habitat, using the Cowardin system (Cowardin et al. 1979), subsystem, class, and subclass). Acreage measures are also provided, including the acreage proposed by the applicant, the acreage recommended by the NMFS, and the acreage permitted by the Corps. Again, these data provide a host of potentially useful information for important analysis of wetland change and management success.

The digital Permit Record and the paper files differ in one important aspect—location information. The Corps requests information on the exact location of the wetland site prior to the issuance of the permit. The paper file includes an exact site location, but such information is not included in the digital database at a level of spatial precision beyond county level. Therefore, spatial analysis of the digital Permit Record is impossible at resolution greater than the county level. Exact permit locations for each permit site are only found in the paper files; thus, an examination of those files was necessary.

Method

Creating the Digital Geo-referenced Permit Record Database

The Permit Record was converted to a digital geospatial dataset using the Geographical Information System (GIS) software Arc/INFO (ESRI 1997). The Rbase digital database maintained by the Habitat Conservation staff in Beaufort, North Carolina, was transferred to the Arc/INFO data structure by first defining an INFO file with fields corresponding to those in the Rbase format. A spatial and temporal search of the INFO file yielded all permits that were granted by the Corps within Carteret and Craven counties between September 1984 and October 1992. The paper version of these 122 permits was examined for location information.

Location Information

Location information was provided in every permit application in the study area, but the quality and characteristics of the data varied. Spatial data encoding took the form of one or more of the following—precise location expressed in either latitude and longitude or stateplane (found in 95 percent of permits), as a map (81 percent of permits), or as a text address (3 percent). Permits often contained more than one type of location information. Each permit site was visited with a Global Positioning System (GPS) unit to verify the accuracy of the location information.

Various location information sources were used to find each permit site. The process of finding the sites was not straightforward in every case and often required using all of the sources of information provided. For example, if a map was included in the file, it was used to locate the general neighborhood of the permit site. Then local interviews and visits were used to determine that the correct site had been found. If there was not a map included in the permit file, an address was used, or if that was not possible, discussions with permit review staff were conducted, and the site determined. Ultimately, the permit site was found in all cases.

GPS is a positioning and navigation system, accurate in time, velocity and in all three dimensions of position—latitude, longitude, and altitude (Trimble Navigation Limited 1994; August et al. 1994). Real Time Differential Correction (RTDC) was employed to remove error contributed by reflection, atmospheric noise, inclement weather, and Selective Availability (S/A). Corrected data can achieve accuracy from one to five meters, which was accurate for this study. Permit site locations were determined using the RTDC method (a Trimble Pro XL unit and the Fort Macon Base Station located in Atlantic Beach, North Carolina). Each site was visited with a GPS unit, and GPS data on location of one point on the site were gathered. No attempt was made to delimit the site or to gather spatial information defining the shape of the site. Of the 122 total permits, 109 were within the study area boundary and contained precise locational information that could be subsequently compared to the known GPS location. Thirteen permits were within county boundaries but outside the study area and were, therefore, excluded from the analysis.

Projection Information

The projection and datum of each dataset need to be understood prior to comparison to avoid the calculation of spurious error caused by an unintended datum shift (Welch and Homsey 1997) or mislabeled projections. The GPS locations were taken using the WGS83 datum, UTM projection (Parameters: UTM Zone 18, meters). The permit file locations were expressed in either stateplane or latitude/longitude coordinates, using the NAD27 datum. All locations were subsequently changed to the NAD83 Datum.

There is a slight difference between the ellipsoids of either datum: the polar axes of NAD83 and WGS83 differs by one meter. This accounts for a negligible difference in ground coordinates when datums are shifted between WGS83 and NAD83 (Doyle 1997). Reprojection of the stateplane co-ordinates and latitude/longitude coordinates found in the permit files was performed using the PROJECT routine in Arc/INFO, producing a collection of coordinates in the UTM projection system based on the same parameters noted above.

Analysis of Error

Creating Error Vectors

For each of the 109 sites that had a precise permit location and a corresponding GPS location, the magnitude and direction of discrepancy were calculated based on simple geometry. For the following description, refer to Figure 2. For each pair of locations (the x and y variable found in the paper permit files and the x and y variables derived from GPS), an angle ß, and magnitude h were calculated such that:

$$\tan ß = a_x - b_x / a_y - b_y$$

$$\tan ß = b / a$$

Calculating ß:

if $\Delta x > 0$, and $\Delta y > 0$; then $ß = \arctan(\tan ß)$

if $\Delta x > 0$, and $\Delta y < 0$; then $ß = \arctan(\tan ß) + \pi$

if $\Delta x < 0$, and $\Delta y < 0$; then $ß = \arctan(\tan ß) + \pi$

if $\Delta x < 0$, and $\Delta y > 0$; then $ß = \arctan(\tan ß) + 2\pi$

Calculating h:

$$h = (a^2 + b^2)^{1/2}$$

The vector component of direction can be expressed with an x variable of hcosß and a y variable of ysinß. A mean vector length r was calculated:

$$r = 1/n\,((\Sigma \cos ß)^2 + (\Sigma \sin ß)^2)^{1/2}$$

The length of this mean vector will indicate the dispersal of vectors.

Measuring the Error

The series of error vectors of direction and magnitude was analyzed in several ways. In all cases, simple statistical analysis was performed. First, the magnitude of error was calculated and related to map accuracy standards. The effect of rounding on this measure, and the presumed effect of typographical mistakes, were examined. Second, the directional bias of the error was tested using Raleigh's test for circular distribution (Batschelet 1981; Ebdon 1994) to determine if any consistent

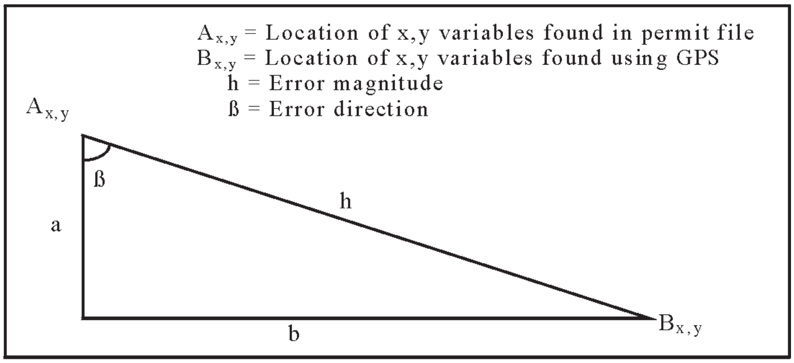

Figure 2. Triangle expressing geometric relations used in calculating magnitude and direction of discrepancies between permit files and GPS readings.

mistakes were being made in the recording of location information. Third, the magnitude of error was examined with respect to the type of map included in the permit to examine if a given type of map, when used to determine the location, yielded a smaller error. And fourth, the magnitude was examined with respect to year to determine if location estimates improved over time. The third and fourth of these analyses require further explanation.

Several types of maps are accepted as spatial locator guides in the permit review process. Differing scales and levels of spatial accuracy can hinder location of potential wetland alteration site, and may account for errant location information found in the permit files. Table 1 lists types of maps accepted by the Corps in the wetland permit review process, and Figure 3 gives examples of four types of maps used. The analysis of error by map type was performed to test a hypothesis stating that the most accurate, largest scale standard map (the USGS 1:24,000 topographical quadrangle, also known as the 7.5-minute quadrangle) would be associated with the smallest error, and conversely, the sketch map, providing no scale and limited detail would be associated with the largest error.

Although it was not clear that in every case the map was used to determine the latitude and longitude coordinate of the site, this test was performed to determine if the use of a highly detailed, large-scale map yielded more accurate location information. A simple regression of the log of the magnitude of error versus time was performed to test the strength of any trend toward decreasing error over time. Determination of yearly improvement is important to test whether or not the error found in the data is an aberration, or if a trend of improvement in locating projects can be seen.

Results

Magnitude of Error

The amount of error found in the spatial location information of the permit files is clearly demonstrated by a map of the error vectors. Figures 4 (a) and (b) show the error found in the entire study area and that found in a subset near Beaufort, North Carolina. This geographic display reinforces the conclusion that the use of the original dataset for accurate and precise mapping of wetland alteration is limited. The largest errors seem to be in cardinal directions, implying typographical blunders in either the latitude or longitude coordinate in the original permit file creation, but errors persist throughout and are revealed at larger scales. The contribution of typographical mistakes was difficult to ascertain statistically, and the best indication of a few typographical mistakes was in the evidence provided by the map. Several larger errors are in the northerly direction, suggesting a missed digit in the latitude, but a combination of typographical mistakes in both latitude and longitude can produce a vector aligned in any direction.

Type of Map	Scale	Permits in Study Area
Sketch	Various	41
Engineering drawings	Various	29
7.5-minute quadrangles	1:24,000	16
North Carolina Department of Transportation maps	1:300,000	14
Miscellaneous	Various	7
National Oceanic and Atmospheric Administration charts	1:70,000	2

Table1. Map types accepted by the Corps of Engineers in their Section 404 permit review process.

Descriptive statistics of the magnitude of direction are presented in Table 2. The distribution of magnitude of error was negatively skewed, with a mean of 15,647 meters. Map accuracy standards assume a normal distribution. Even without meeting this requirement, the information contained in the dataset was clearly not adequate for locating these sites, or for spatial analysis. Examining the percentile distribution in Table 3, it is clear that 10 percent of the permits were located 53 meters away from their true location, 20 percent were located within 95 meters of their true site, 75 percent were located within 981 meters of their true site, and 90 percent were located within 30 kilometers of their true location. These results indicate that, in 50 percent of the cases, a permit could be anywhere within a search area of 17 hectares. A search radius is also presented within which one might have to search to locate each permit site given its locational error.

The Circular Mean Accuracy Standard (CMAS) sets 90 percent confidence limits on the distribution of a set of points. For a map of 1:24,000-scale (a commonly used map scale in the permit review process), the CMAS requires that 90 percent of the points sampled fall within 12.7 meters of their real location. Regardless of the negative skew in this distribution, this dataset obviously fails any of the most lenient map accuracy standards.

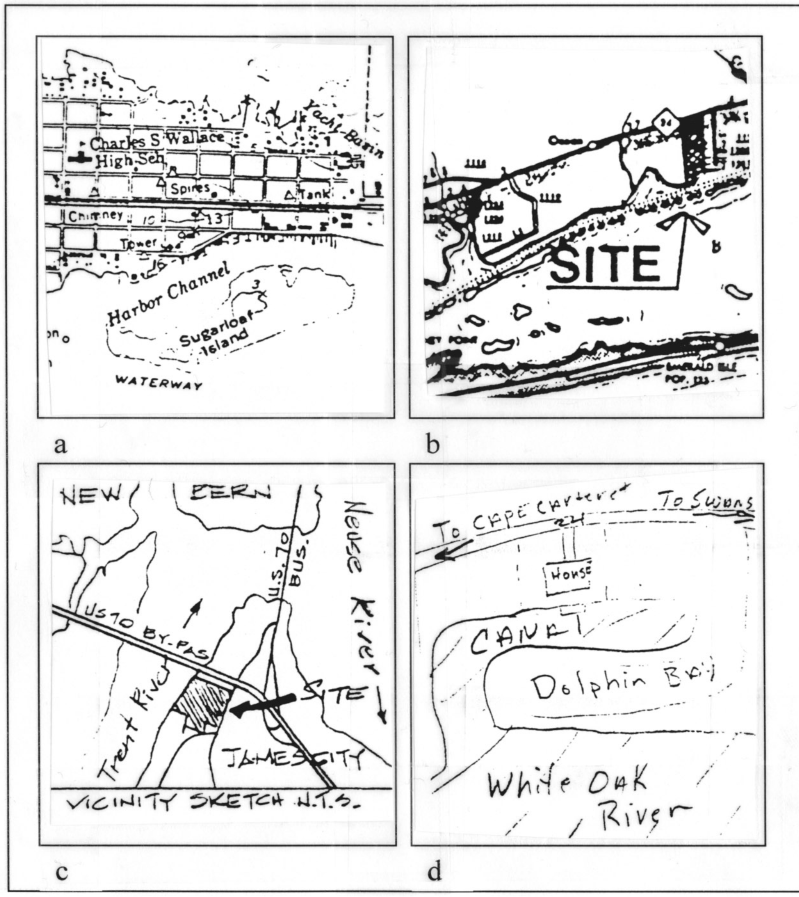

Figure 3. Types of maps included in the paper permit files: a) 1;24,000-scale 7.5-minute topographic quadrangle; b) 1:300,000-scale Department of Transportation map; c) engineering drawing; and d) hand-drawn sketch map.

Count	95 permits
Minimum	15.26 meters
Maximum	445,021.62 meters
Mean	15,647.52 meters
Standard Deviation	66,193.68 meters

Table 2. Descriptive statistics of the magnitude of error.

A Word on Precision

Some of the error found in the data might be the result of the Corps' habit of maintaining location information in "degrees, minutes, and seconds," which results in an inherent rounding of the location information to the nearest second. At latitude 35° and longitude 77°, the center of the study area, one second of longitude and one second of latitude are equivalent to 27 and 33 meters, respectively. This is the best spatial precision that can be expected from the location data recorded in this way. One minute of latitude at this location is roughly equivalent to 1,850 meters, while one minute of longitude is equivalent to 1,500 meters. Only three permits fall within these limits. Clearly, precision and rounding did not account for the error.

Direction of Error

The direction of error was examined for bias. Simple geometry allows for the computing a directional variable that has magnitude removed: the x variable of hcosß and the y variable of ysinß are plotted against each other in Figure 5. A mean

Percentile	Distance (meters)	Cumulative Number of Permits within Percentile Range	Search Area (hectares)
10	53.0	7	0.8
20	95.0	23	2.8
50	232.0	45	16.9
75	981.0	68	302.2
90	29,347.0	81	264,074.5

Table 3. Percentiles for magnitude of error.

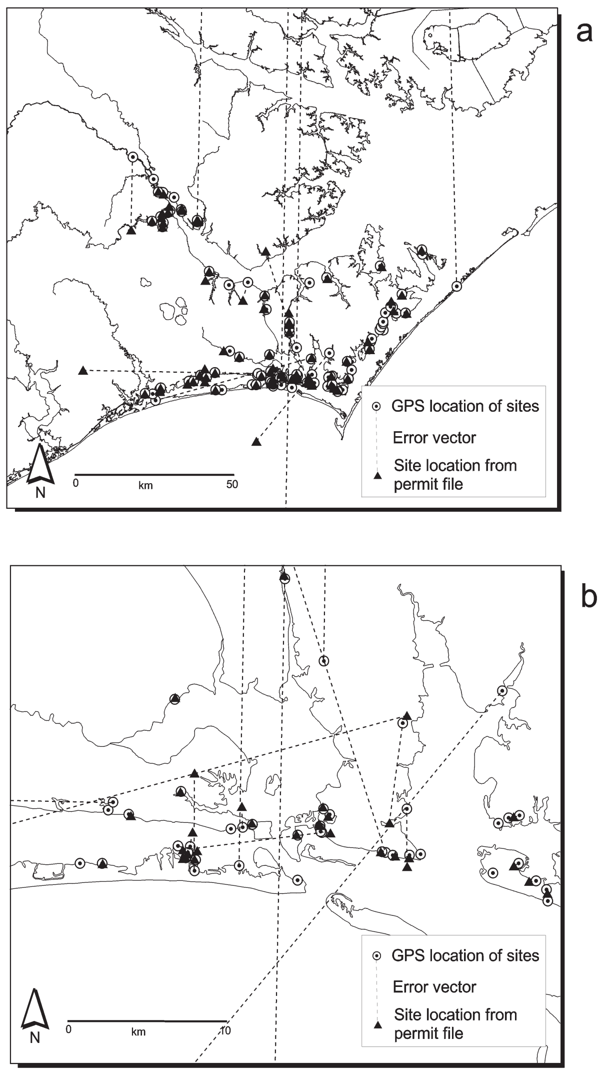

Figure 4. Error vectors showing the difference between the Corps location and GPS location in a) the study area, and b) in Beaufort, North Carolina.

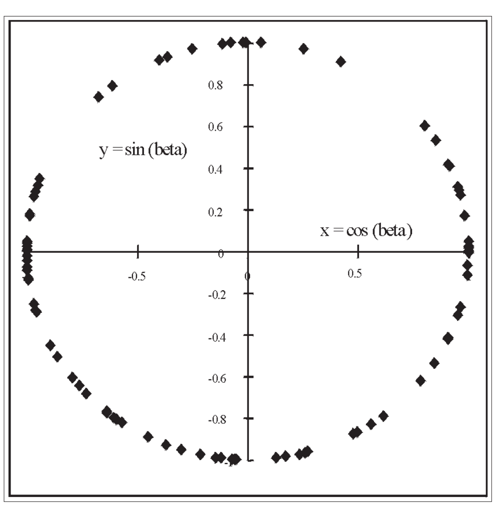

Figure 5. The directional distribution of error vectors displaying no significant clustering by direction.

vector length r was calculated; the length of the mean vector indicated the dispersal of vectors and was tested using Raleigh's test for circular distribution (Batschelet 1981; Ebdon 1994). For this test H_o stated that the parent population was uniformly distributed. A statistic P was determined from a table designed for this test, based on r and n. If the test statistic P was less than α, H_0 would be rejected. The results indicate n = 95, r = 0.1227, and P = 0.237, with α = 0.05. The value for P was greater than α, thus H_o was accepted, and it was determined that the population was distributed uniformly. Therefore, errors occurred in all directions regardless of magnitude, and typographical errors did not account for the majority of the errors.

Map Type

The hypothesis tested stated that the use of maps of high accuracy and precision in the permit application process (such as the 1:24,000-scale 7.5-minute quadrangle series maps that contain sufficient detail to locate a typical permit site) would provide location data closer to the real permit site than would the use of inaccurate maps. The distribution of error with respect to map type was investigated for the following four map types: 7.5-minute quadrangles, North Carolina Department of Transportation maps, engineering drawings, and sketch maps. Table 4 displays the magnitude of error classed by map type. Prior to running the ANOVA tests on these four groups, the variance for each group was compared to the variance of the other groups in order to insure that the variances were sufficiently similar to proceed. An F_{max} test was performed, and the variances of the four groups were not significantly different (Ebdon 1994).

A paired ANOVA post hoc test comparing magnitude of error with map type was performed. Table 5 displays the tabular results. The results are surprising if one assumes that the inclusion of a highly accurate and precise map would assist a user in determining a position location. The engineering drawings yielded the smallest error, but the collection of sketch maps also yielded a low error, and the 1:24,000-scale 7.5-minute quadrangle provided slightly more error. No map type provided significantly less error than all the other types. For the two ANOVA tests computed, Fisher's PLSD and Scheffe, most of the comparisons between the difference in magnitude of error provided by the maps, were not significant at the 5 percent level. The Fisher's test found the error associated with the County Department of Transportation 1:300,000-scale scale map significantly higher than that provided

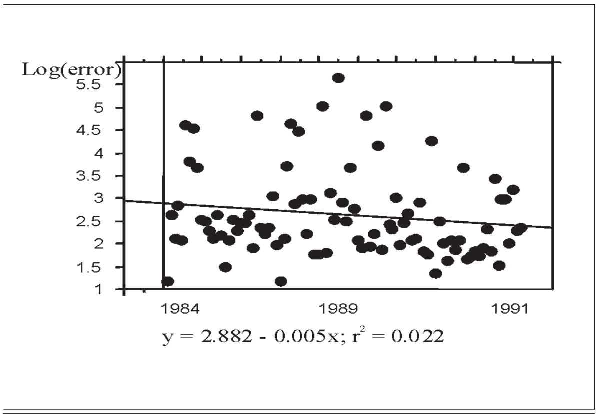

Figure 6. Regression plot: Log(Error) vs. time.

by the engineering drawings and the sketch maps, but no map type yielded significantly lower levels of error than any other. The 1:24,000-scale map did not give better than an average error.

Time

The log of the magnitude of error was regressed versus time to establish any trend in error through time. An ANOVA was not possible because of the greatly differing variances found within each year. Figure 6 shows the regression plot. A weak regression ($r^2 = 0.022$) can be fitted, indicating a declining error through time. This was not a strong fit however, and a convincing argument of decreasing error could not be made.

Discussion

The permit process in the Corps district covering coastal North Carolina was clearly inadequate for use in spatial analysis. This kind of inattention to spatial fidelity is not confined to wetland management; inadequate spatial information is found in other environmental management datasets, and any analysis based on the locations found in these databases is suspect. The location information in the files examined here exhibited some typographical errors, many map reading errors, and errors resulting from careless checking.

On balance, a person wishing to check the status of a site might find himself or herself anywhere from 15 meters to 45 kilometers away from the site if they used the location information found within the Permit Record. An argument might be presented that while the specific location information was lacking, the supplemental map locator found in many of the files was adequate to guide the observer to the correct site. This was true for certain individual sites; however, anecdotal address information was in no way adequate for precise location. In addition, the use of accurate maps in the permit process did nothing to reduce error in locating the site. The sketch type of map, which contains several maps of dubious spatial integrity, yielded better overall results. These results suggest that the map type and location information are not related, or rather that a map was not used in the generation of the latitude and longitude coordinates that are entered in the permit itself, an unfortunate disregard for the relevant and useful spatial information that can be found on the 7.5-minute quadrangle series.

While some might argue that the location information is getting better, discussions with habitat conservation staff in the NMFS office at Beaufort, and an examination of the quality of location information found in current permits, both imply that this is a problem of procedure and not one that can be remedied by time. Thus, if there is need or desire to follow up on a permit after a wetland alteration, management agencies probably would be unable to accurately locate many sites and thus the financial cost of follow-up would be exacerbated.

A New Accuracy Standard

Applying the Map Accuracy Standards to wetland permit locations was not altogether ideal. These standards were developed for cartographic precision, but the location of wetland permits seem to necessitate a less precise standard. I propose a permit mapping accuracy standard that defines requirements for the mapping of wetland permit locations on paper. This standard would apply to all data gathered relevant to each permit and to the display of permit data on paper maps.

The new standard requires that points are within 2 mm of their true location on a 1:24,000-scale map, or within 48 meters

Map Type, Ranked by Mean Error	Count	Mean Magnitude of Error (meters)	Standard Deviation of the Magnitude of Error (meters)
North Carolina Department of Transportation	14	46,990.87	133,355.02
7.5-minute quadrangle	16	11,155.21	30,799.94
Sketch map	41	6,185.56	19,589.88
Engineering drawing	29	5,825.09	16,097.88
Other	9	788.54	1,434.83

Table 4. Descriptive statistics of the magnitude of error by map type.

				Fisher's PLSD[2]	Scheffe
First map group	Second map group	Mean Difference (meters)	Critical Difference (meters)	P-Value	*P-Value*
7.5-minute quadrangle	NC[1] Department of Transportation	-35,835.654	41,229.183	0.0875	0.3984
7.5-minute quadrangle	Engineering drawing	5,330.118	34,412.581	0.7587	0.9924
7.5-minute quadrangle	Sketch	4,969.654	32,494.677	0.7616	0.9926
NC Department of Transportation	Engineering drawing	41,165.773	37,258.652	*0.0308	0.1932
NC Dept. of Transportation	Sketch	40,805.308	35,494.866	*0.0248	0.1645
Engineering drawing	Sketch	-360.464	27,281.233	0.9791	>0.9999

1 NC = North Carolina.

2 For each test, an asterisk indicates significance at the stated significance level. Comparisons in this table are not significant unless the corresponding p-value is less than 0.05.

Table 5. Comparison of magnitude of error by map type using ANOVA tests , Fisher's PLSD and Scheffe.

of their true location. This distance is adequate for locating a permit site in the field in the permit review process. This permit accuracy standard is an improvement over the present process which requires the inclusion of maps in permit files, yet does not require the use of those maps, even highly precise, large- scale maps, in locating the target permit sites. The standard could be met without the use of digital map coverages, but would be strengthened with their inclusion.

A New Method for Permit Review

In the permit process, better standardization by the Corps and reviewing agencies in gathering location information and in checking the veracity of the input spatial data could limit the problem of locational error. The first recommendation is to use 7.5-minute quadrangle series maps in locating the permit site on the map, not just including them in the permit file. The 7.5-minute quadrangle series maps provide standardized, readily available maps at a scale that is useful for depicting and locating permits. A 2.0-millimeter wide arrow on a 1:24,000-scale map is sufficient to locate a permit site within 48 meters, which is an acceptable level of precision for locating the permit site in the field. The acceptability of these maps is supported by fieldwork; site maps that used 7.5-minute quadrangles were by far the most helpful in finding sites in the field. Once a site visit has been made, a GPS unit should be used. A digital spatial database could be employed to gather, store, and analyze relevant geospatial data.

In the future, as digital data becomes easier to gather and visualize, it is conceivable that a digital dataset could be used for the entire request, logging, and tracking system. Relevant ancillary data could be included to aid in the decision process. Historic site alterations, aerial photography of specific target areas, National Wetland Inventory (NWI) maps, and many other types of relevant spatial information could be included. This could be a spatial database in the truest sense, with spatial information providing the data management, display, and user interface: a spatial decision support system (Walsh 1993).

Conclusions

There has been recent movement toward the use of GIS in coastal resource management in general, and in wetlands management in particular (Welch et al. 1992). GIS has been recommended for locating possible mitigation banking sites, locating ideal restoration sites, characterizing and evaluating wetland resources, and updating wetlands maps (Wuenscher 1994; Brown and Stayner 1995; Lyon and McCarthy 1995, South Carolina Department of Natural Resources 1996). But there is a lack of corresponding discussion regarding the implementation of geospatial technologies in the wetland permit process. The spatial information contained in the Corps Permit Records is insufficient for cumulative impact analysis or spatial analysis other than county level estimates of change. Results of cumulative impact analysis and precise spatial analysis of change provide valuable knowledge to inform the environmental management process. In an age of digital record keeping, where resource monitoring, change analysis and impact assessment technologies rely on precise digital location information, a move toward standardized and accurate methods of location information gathering cannot be ignored.

The permit accuracy standard, and the new approach to the wetland permit review process described in this paper are particularly relevant in view of the Essential Fish Habitat (EFH) mandates of the Magnuson-Stevens Fishery Conservation and Management Act of 1996 (Schmitten 1999). This Act requires federal agencies to consult with the Secretary of Commerce (as represented by NMFS) on all actions, proposed, authorized, funded, or undertaken by the agency, which may adversely affect EFH. Alterations to wetlands might be such an adverse action, and , in this respect, precise information on the location of the impact will be crucial.

Ideally, the investigation of future wetland impacts (and consequent impacts on essential fish habitat) should be informed by previous wetland change. A digital version of the Permit Record, with adequate spatial accuracy, could help insure a better wetland management process. Management of wetlands using accurate spatial information might include, for example:

- Siting wetland mitigation and restoration projects in areas where excessive amounts of wetlands have been altered;
- Targeted updates of wetland mapping efforts that focus on areas of multiple wetland alterations; and
- Analysis of cumulative impacts in the wetland landscape.

These important research and management goals could be better served with accurate spatial information in the wetland permit process.

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From the Editor

As the new editor of CaGIS, I would like to encourage readers to submit papers appropriate for publication in CaGIS. Traditionally, papers appearing in CaGIS have had a cartographic emphasis, even those papers oriented toward GIS. Although the bulk of papers in CaGIS will continue to have a cartographic emphasis, I also invite readers to submit papers that might be labeled as "pure" GIS. I am hoping that such papers will allow our readership to become aware of important theoretical developments that are taking place in GIS. I am also interested in receiving papers in the budding area of geographic visualization (GVis). In recognition of this, a forthcoming issue of CaGIS edited by Alan MacEachren and Menno-Jan Kraak will focus on research issues in GVis. Other special issue topics that are being considered include generalization, history of 20th century cartography, visualization (covering completed research as opposed to research issues), geocomputation, cognition, internet-based teaching materials, community-based mapping, OpenGIS, and GIS and public health. If you are interested in getting involved in one of these special issue topics, please contact me and I will forward your name on to those who have already expressed an interest in the topic.

When submitting a paper to CaGIS, please follow the "Instructions for Contributors", which will appear in a forthcoming issue. If your paper should be accepted for publication, please pay special attention to the guidelines for submitting digital material. Graphics must not be imbedded in word processing files; rather digital files for graphics should be submitted separately, ideally as either Encapsulated PostScript (EPS) or Tagged Image File Format (TIFF) files. Following such guidelines will help to insure the high quality of graphics that our readership expects.

I am pleased to announce my associate editors and the members of my editorial board. Many of these people have already been busy reviewing papers for me, and I sincerely thank them for all of their hard work.