

Monitoring Wetland Area Change in the Conterminous United States Utilizing Statistical Methods

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SUMMARY

The U. S. Fish and Wildlife Service has been monitoring Wetland losses in the United States since the late 1970's. This is accomplished by a stratified random sampling of the conterminous United States. Monitoring wetland and related land use change in the U.S. using remotely sensed data is a formidable task. There continue to be improvements to the study design and techniques being used as the project is continually being modified to meet the information needs of policy makers and resource managers. The overriding goal however has remained to produce statistically valid estimates of wetland area in the U.S. To date these efforts have yielded data sets to estimate total wetland area, rate of loss over time, and provide information for various wetland categories as they increase or decrease over time. This presentation describes these past efforts, presents existing challenges and outlines ongoing activities for future work.

I. Introduction

Wetlands are among the most diverse and valuable ecosystems in the world. They provide a filtration system for both natural and human induced pollutants in the water supply, critical habitat for hundreds of species of plants, birds and animals, and flood and erosion control by slowing the movement of water (Mitsch and Gosselink 1993). Even with all of these values, wetlands in the United States have been destroyed at the alarming rate of 1/2 hectare per minute for the past 200 years (Dahl 1990).

The United States Fish and Wildlife Service (USFWS) began monitoring wetland loss in 1979. At that time it became apparent that data describing wetland status and trends in recent years would be important and useful to resource managers and policy makers alike. The United States is a large (7,827,000 square kilometers encompasses the 48 conterminous states) and very ecologically diverse country. Prior to 1979, a comprehensive study addressing all wetland types and sizes across the country had not been attempted. The best estimate of wetland area to that point in time had been compiled by Shaw and Fredine (1956). The USFWS has undertaken

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a full coverage mapping effort of the United States' wetlands, this will be the most complete inventory of the wetlands to date, however this project will not be finalized until the late 1990's and area summaries may not be completed until some time after that date. This necessitated a sampling approach to develop the information needed on wetland status in the United States so that more timely policy decisions could be made.

The USFWS, working with a group of statisticians, developed a statistical random sampling procedure, designed to produce area status information for selected wetland categories. Using this approach, a report was released in 1983 that estimated total area and the average annual net loss of wetlands in the conterminous United States from the 1950's to the 1970's to be 185,000 hectares (458,000 acres) (Frayner 1983). In 1991, an updated report estimated that the average annual net loss of wetlands from the mid 1970's to the mid 1980's had dropped to approximately 117,000 hectares (290,000 acres) (Dahl 1991a). The statistical method used to obtain these estimates is discussed below:

II. Sample Design and Development

Wetlands are not evenly distributed across the landscape (Figure 1). Topography, hydrology and land use play important roles in the location of large wetland areas. The conterminous United States has large concentrations of wetlands in the Coastal Plain region of the southeast and the glaciated north central states. The Rocky mountains and the desert southwest regions are not as conducive to wetland ecosystems. Migratory waterfowl rely heavily on wetland areas to provide

Figure 1. Distribution of wetlands in the conterminous United States. (from Mitsch and Gosselink 1993, after Dahl 1991b.)

food, cover, and nesting and brooding habitat as well as areas for staging and resting during migration. Resource managers are keenly interested in reducing wetland loss in these key areas within the migratory flyways, as this loss has a direct impact on the populations of migratory waterfowl.

Estimates of the wetland loss within key regions was desirable to help illustrate the need for wetland protection. This prompted the use of a stratified random sample to estimate the wetland trends in various regions. Strata were derived from state boundaries and physical subdivision lines as described by E. G. Hammond (1970). Additional strata were added to encompass areas dominated by estuarine wetlands along the eastern seaboard and Gulf of Mexico to help further describe the trends in this vital region. Figure 2 illustrates the 210 strata used to sample the conterminous United States.

Figure 2. Strata derived from Hammond's physical subdivisions and state boundaries.

Each stratum was subdivided using a grid overlay with cells measuring 3.218 square kilometers (4 square miles). The population of possible sample sites within a stratum was calculated by dividing the area within the stratum by the area within each grid cell (3.218 square kilometers). Sample plots, equivalent to one grid cell were then chosen by a simple random selection process from the population of available plots.

Sample sizes were determined based on the wetland area estimation made by Shaw and Fredine (1956), using an estimated percentage of wetland coverage per stratum. Therefore, strata with a high wetland concentration were sampled more heavily than areas with a lesser concentration (Figure 3). A total of 3629 sample plots were located throughout the 210 strata. This sample yielded the results contained in the 1950's-1970's report as well as the mid 1970's-mid 1980's report.

Figure 3. Sample plot distribution for the state of North Carolina. Coastal areas with a suspected higher wetland density are more intensively sampled than mountainous areas.

III. Data Collection and Analysis

The sample plots were analyzed using manual interpretation of aerial photography for each era included in the studies (1950's, 1970's and 1980's). Each sample plot was classified using a scheme of seventeen (17) possible land use/land cover categories - 14 wetland and 3 upland types this scheme has been modified to include fifteen (15) wetland and 5 upland land use categories (Table 1 - a modified version of the wetland classification system by Cowardin et al. 1979). The interpreted sample plots were area measured and using a combination of manual and automated procedures the proportion of each category type within the sample plot was calculated. The data was held in a matrix of first era category types and second era category types. Estimates of wetland area change calculated by a FORTRAN program that evaluated the proportion of each sample plot that changed categories were used to estimate the trends in wetlands across the United States.

This program evaluates each sample plot to give the proportion of the plot area that has changed from one category to another. The final output of the program estimates national, and state wetland trends. Results show wetland gain or loss, land use change by type, and wetland change by type. For example, the mid 1970's - mid 1980's report estimated that 821 hectares (2029 acres) of estuarine intertidal emergent were converted to urban land use, and 396,248 hectares (979,116 acres) of palustrine forest were converted to agriculture land use (Dahl 1991a). Once all plots were evaluated, estimates could be made with 90% confidence on national trends in wetland losses.

Table 1. Trend Categories - Based on a modified version of "Classification of Wetlands and Deepwater Habitats of the United States". (Cowardin et al. 1979).

Marine Intertidal

Estuarine Subtidal

Estuarine Intertidal Emergents

Estuarine Intertidal Scrub Shrub/Forest

Estuarine Intertidal Unconsolidated Shore/Rocky Shore

Estuarine Intertidal Aquatic Bed

Palustrine Forested

Palustrine Scrub Shrub

Palustrine Emergents

Palustrine Unconsolidated Shore

Palustrine Unconsolidated Bottom

Palustrine Aquatic Bed

Palustrine Farmed *

Lacustrine

Riverine

Upland Agriculture

Upland Urban

Upland Forested Plantation *

Upland Rural Development *

Other Uplands

* denotes categories added following the 1970's to 1980's update.

IV. Problems

Many aspects of the study present problems to the final outcome. Three of the most influential problems are that of sample size determination, the normalization of photography dates and procedural error.

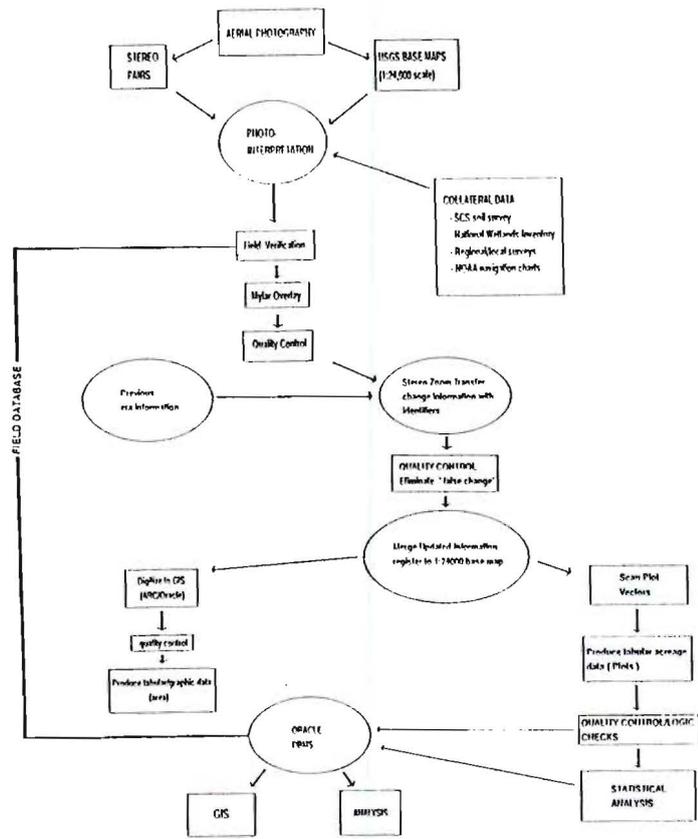
The original assignment of sample plot amounts to each strata was based on data from Shaw and Fredine (1956), data that presented wetlands as important waterfowl habitats. This may have left out many types of wetlands not utilized by waterfowl such as bogs, fens and vernal pools. The result may be under sampling in certain areas. An example of this would be the state of Maine (the northern most Atlantic coast state), an area dominated by northern peat bogs and coastal shore

wetlands was sampled with only 27 sample plots out of the possible 7000 plus plots in the state. Shaw and Fredine estimated wetland area for Maine to be 154,312 hectares (381,300 acres). The current estimate for wetland area in the state of Maine is 2.1 million hectares (5.1 million acres) (Dahl 1990).

The problem of the photography date is most apparent when trying to calculate an average annual wetland loss rate. Since the rate of change for each plot was not normalized to the photo date there was inherent error in simply dividing the total area change by the average number of years. For example, the mean date of photos in the mid 1970's to mid 1980's study was 1974 and 1983. However the photo dates ranged from 1969 to 1986. This broad range of photography date requires a normalization procedure to reduce error in estimating average annual wetland loss.

Manually interpreting aerial photos, drafting to a map by hand and attributing a scanned image are all processes used in the data collection. The trend analysis procedure takes each sample plot through many phases of production (Figure 4). Each of these steps is followed by at least one quality control check and the critical steps are checked twice. The biologists analyzing the photos utilize any available collateral information (e.g. field verification, soil maps, topographic maps, and existing wetland maps). These quality control checks are designed to minimize error however aerial photography has limitations of scale, season, and types of emulsion. This procedural error needs to be considered in the confidence interval of the entire study.

Figure 4. Flow chart illustrating trend analysis procedures.



V. New Directions

The release of "Wetlands Status and Trends in the conterminous United States Mid 1970's - Mid 1980's" (Dahl 1991a), received Congressional committee attention and sparked interest in having data be more current and frequent. Consequently the USFWS has gone to a continuous data collection mode. Ten percent (10%) of the 3629 sample plots are evaluated each year. Ideally, this would be random, but will coincide with the National Aerial Photography Program (NAPP) schedule of acquisition. NAPP flies new photography for each state every ten years. Having the trend study coincide with available photography should allow for less variance in photo dates as well as more timely data. Programming is now underway at Colorado State University to update the statistical process that estimates wetland trends. The previous method will have to be changed to allow reliable annual reports on wetland loss in the conterminous US to be released based on evaluating 10% of the sample plots and projecting the results to the nation utilizing a model from the two previous trends studies.

The ecological diversity across the United States was not adequately described using fourteen (14) wetland categories and three upland categories. The USFWS has decided to broaden the description of the land in its Wetland Status and Trends reports. Wetland categories were increased by 6 types shown in Table 1. The upland categories were perhaps the most strategic to include. The "other uplands" category needed to have further definition, policy makers felt that certainly the United States had more than two defined upland categories that could be easily discerned on the landscape. The categories added, Upland Forested Plantation and Upland Rural Development were chosen for their historical proximity to wetlands.

The recent public concern and current legislation in the area of wetland loss has indicated that procedures and data analysis for estimating wetland loss could be highly scrutinized. The USFWS is responding with an intensification of the sample plots used to estimate wetland loss. The repeated requests for regional estimates along with increased public concern has led to regional studies that estimate more precisely regionally specific trends. These two objectives are being accomplished by increasing the sample size of the strata to 10% of the total population of sample plots within the strata, 15% if the strata is an area of critical concern.

Several areas are the most important where current and reliable data is needed. They can be established by many criteria, including previous trend studies showing accelerated loss in the area, population gains beyond normal birth/death rate growth and concern by federal, state, local or private organizations. If the area is small enough a blanket coverage analysis can be conducted finding actual areas of wetland loss and land use change. If these areas are large like the coastal zone, lower Mississippi River floodplain or the prairie potholes, an intensified trend study along with the annual update can be conducted to estimate the wetland loss and land use change. The first region presently being completed is the coastal zone from Texas to Delaware Bay. Other regions will be estimated in the near future, Lower Mississippi Alluvial Plain and the Prairie Potholes.

Satellite imagery is another possibility to overcome the photography date problem. This could also allow for greater than 10% of the plots to be updated in the

continuous data collection mode and give more accuracy to the estimations. However the satellite technology needs to improve before this would be a strong data source. The pixel size on the most accurate satellite image usable for wetland classification is 15 meters. Discussion has begun with the United States military to use some of the imagery that has been obtained by military satellites that has greater accuracy for wetland classification.

VI. Interagency work

The United States Environmental Protection Agency (EPA) has developed a program to evaluate and monitor the condition (health) of the wetlands of the United States. Due to the similar design of the EPA's wetlands program and the USFWS' Status and Trends study, pilot studies are now underway to try to combine the sampling areas and therefore share costs of both studies. EPA uses a hexagon grid sample scheme and selects a target wetland type from within each hexagon to field sample. In combining the two studies, wetlands within sample plots within hexagons are being field sampled. This will be beneficial to both organizations to have the information supplied by the combined studies. Surrounding land use can have a direct adverse affect on the condition of a wetland, a stormwater sewer system draining directly into an estuarine saltmarsh can degrade the wetland by introducing contaminants from the overland flow as well as reducing the halinity. Conditions of wetlands can directly affect the productivity, wildlife value, and therefore legal protection may falter and finally permits may be given to dredge, fill or otherwise alter the extent of the wetland.

VII. Conclusion

The USFWS is responsible for releasing timely data for the use of policy makers, planners and environmental managers. The latest estimate is that 117,363 ha. (290,000 acres) of wetlands are lost annually, primarily due to agriculture expansion. While new legislation restricts wetland loss and/or degradation, the estimation process plays a vital role in monitoring progress to curb wetland losses and needs to evolve with the information needs to remain effective. The stratified random sample has been an efficient method to make estimations for various sizes of regions. High cost and technological constraints must be balanced with demands for more accurate data collection (less procedural error). The USFWS continues to make improvements in the process and strives to release accurate and timely data.

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