ABSTRACT

A means of predicting and graphically illustrating degraded water quality in estuaries was developed using various SAS statistical procedures and SAP/GRAF software. Expected water quality conditions, as represented by a series of discrete and identifiable "pollution profiles", are illustrated with CONTOUR and G3D. Geographical orientation is provided by configuring SASMAP data sets as ANNOTATE data sets and overlaying with the data-generated pollution isobars or response surface. Mean conditions for each discrete profile are illustrated, along with standard errors. This allowed easy identification of potential "trouble zones" of consistently high pollution levels, plus areas with high variability which may require concentrated sampling efforts in the future.

INTRODUCTION

In an effort to identify contaminated waters from which oysters may not be legally or safely harvested, a method for predicting and illustrating water quality trends along the Louisiana coast was developed using SAS software. Several SAS statistical procedures were applied in the identification of discrete pollution "profiles". A profile was defined as a system-wide, instantaneous pattern of pollution, or thumbprint, which appeared to reoccur over time. These major recurrent profiles could then be predicted based on the concurrent environmental conditions which were assumed to elicit the profile.

Once identified, the set of profiles was illustrated with SAS/GRAF software. Isobars from CONTOUR and the response surface from G3D were superimposed over customized ANNOTATE map data sets to provide geographical orientation of the pollution conditions. This allowed more efficient identification of estuarine areas which might exceed the legal water quality standards for shellfish harvesting.

The graphing technique is described, with examples of two of the pollution profiles obtained for the Barataria Bay region of coastal southeastern Louisiana. These examples represent two of over twenty-five such profiles provided to state agency personnel to assist regulation of oyster harvest from privately leased coastal waterbottoms.

METHODS

Identification of Profiles

The first step in illustrating the major pollution profiles was, of course, to identify and characterize them. Historical water quality data, measured in Most Probable Number (MPN) fecal coliforms/100cm³, were received for over 100 stations within the Barataria Bay system. Local environmental data (rainfall, air temperature, river discharge, wind direction and speed, etc.) were compiled for the same time period. The environmental variables were assumed to potentially impact the water quality conditions over the area in question. Input from point sources was assumed constant.

Briefly, identification of the major recurrent profiles was accomplished by clustering units of time for which the spatial pattern of coliform levels throughout the bay system was similar. Seven such dominant profiles were obtained for the Barataria Bay system. Each profile was then characterized by the conditions, both environmental and water quality, present during the time periods which clustered together. The idea was to then discriminate between the pollution profiles on the basis of the environmental conditions that were associated with them. This was accomplished through discriminant analysis. The resultant discriminant functions can then be used to predict which pollution profile should be present in the bay system, given the existing set of environmental conditions. This in turn aids the decision of state resource managers whose duty is to regulate oyster harvest according to current minimum legal water quality requirements. The technique is described in more detail in Geaghan and Millard (1986).

Illustration of Profiles

Our objective was to depict the proposed boundary between "safe" and "unsafe" harvesting areas, as defined by existing federal regulations (NESSF, 1965). Further, it was felt that the graphical results could aid optimization of future sampling strategies by illustrating areas with highly variable water quality conditions. These areas would then merit increased sampling frequency to keep abreast of their status. Conversely, areas which tend to exhibit consistent water quality conditions could be sampled less often with little loss of information.

G3GRID (Fig. 1) was used as one method of depicting fecal coliform concentrations present in the system for each of the profiles. Mean MPN's per station (and their standard errors) were calculated, with each station associated with an X,Y (latitude/longitude) pair. G3GRID was employed to generate a sufficient rectangular grid of data points for the contouring algorithm. Because of the approximation methods used by G3GRID, areas remote from real station data but within the data grid sometimes received values which were extreme and unreasonable. These values were reset via a DATA step to logical minimums and maximums. This also maintained a reasonable scale for response variable resolution. Each isobar represents a MPN level that is significant to the resource manager. (For the purpose of illustrating the technique, it is
The NOLABELS option was used to increase the effective plotting area, and contour levels (MPN levels) of particular interest to the managers were specified via a GCONTOUR option. Each of the seven profiles for the Barataria Bay area would then result in a graph of the type shown in Figure 1; each with a different pollution profile and each associated with a particular set of environmental conditions. Standard errors of MPN samples are depicted in the same manner.

A highly effective visual interpretation of pollution levels over the study area was provided by the G3D procedure (Fig. 3). The mean MPN and standard errors were again the response variables plotted on the Z axis. Geographical orientation of the 3-D surface was added by annotating the study area map below the surface, via an artificial and constant Z coordinate assigned to the ANNOTATE observations. This Z value corresponded to the ZMIN value given in the G3D option. The entire graph was then optimally tilted and rotated to enhance the perspective. The NOLABEL option was invoked to delete unnecessary labeling of the X and Y axes. Z-axis tickmarks and labels were added via ANNOTATE. As with the GCONTOUR graphs, unreasonable values generated by G3GRID (e.g. negative standard errors) were reset to logical minimums and maximums. Figure 4 shows an example of code used to generate the G3D graphs.

The contours of pollution concentration corresponding to the major profiles should be quite robust since they are based on a range of environmental data thought to produce a similar contamination pattern. In using this method,
DATA ANNO; SET IN!.ANNO;
PROC SORT; BY STATION;
DATA STAT; SET IN!.PROFS;
PROC SORT; BY STATION;
DATA BOTH; MERGE STAT ANNO; BY STATION;
IF CLUSTER=
IF (1.565000<=X<=1.572800) THEN DELETE;
IF (.500000<=Y<=0.516000) THEN DELETE;
PROC GPRESS DATA=BOTH 011T=PROJLAj
ID COUNTY SEGMENT;
****
BEGIN GRID DATA SET FORMATION. ****
Call in SAS coordinates
with station coordinates
and pollution statistics for
sampling stations.
Merge stats with coordinates *
Choose profile to graph*
Trim X & Y radians to optimize*
up-scaling of area of interest *
Project station and map *
coordinates *
DATA COLIF; SET PROJLAj IF HAPS=' STATION' ;
Subset station records and *
stats for gridding purposes *
PROC SORT; BY STATION;
PROC G3GRID DATA=COLIF 011T=GCOLIF;
GRID Y*X=1fEAN1 SPLINE AXIS1= -.00334046 TO .00354325 BY .000236
AXIS2= -.00338691 TO .00338581 BY .000225;

Procedure 30 X 30 GRID **;
NOTE: Above axis of output grid data set are determined by *
Minimums and maximums needed to bracket the map of *
the area of interest. *
Intervals chosen to provide reasonable grid resolution *

DATA GCOLIF; SET GCOLIF;
IF MEAN > LOG(1700) THEN MEAN=6.0*
Reset unreasonable extr""s *
ELSE IF MEAN < LOG(1.1) THEN MEAN=0.6*
generated by G3GRID *
DATA ANN03S; SET nfl.ANNO;
Call in map annotat .. data set *
TITLE1 F=SIHPLEX C=BLACK H=1.4 'MEAN CONDITIONS SPRING AND EARLY SUMMER PROFILE';
PROC G3D DATA=GCOLIF ANNOTATE=ANN03S 011T=OUT .COLIF;
PLOT Y*
X = MEAN!ZMIN= -1.0 ROTATE=20 Tilt=70 ZTICKNUM=O YTICKNUM=O XTICKNUM=O NOLABEL ZHAX=7.0
CTOP=C1AN CBOTTOM=RED CAXIS=BLACK;
NOTE: ZHIN above corresponds
with Z coordinate given to ANNOTATE data set. *
This places map "below" the 3-D surface and gives perspective.
GCONTOUR generated as above .., except with no Z coordinates involved.*

Fig. 4. Example of code used to generate G3D plots of pollution profiles.

however, we are not receptive to new profiles arising from hydrologic changes and new pollution point sources. The contours are also insensitive to the complexity of the coastal hydrology. Thus, the assumption that areas intermediate of contour lines exhibit intermediate pollution levels may not always hold. Hydrologic barriers may give two proximate stations entirely different source waters. We believe however, that this effect is not important at the sensitivity level of our models. In any case, it provides a warning that the contours should be viewed as approximations.

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LITERATURE CITED


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APPENDIX I. Examples of GCONTOUR and G3D plots of mean MPN and standard errors for pollution profiles in Barataria Bay, LA.
APPENDIX I (contd). Examples of GCONTOUR and G3D plots of mean MPN and standard errors for pollution profiles in Barataria Bay, LA.