ADAPTING THE E.P.A. RAPID BIOASSESSMENT PROTOCOL FOR USE ATTAINABILITY STUDY IN THE CAPE FEAR RIVER

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Abstract. Water quality of the lower Cape Fear River below Lock and Dam No. 1 (about 60 km upstream of the City of Wilmington) has long been considered affected by a large number of industrial and municipal waste discharges. However, few detailed water quality and biological investigations have been conducted to assess these impacts in this portion of the tidally influenced freshwater river. The area is difficult to study because of tidal effects, channel characteristics (relatively narrow and deep), and high seasonal flows.

Detailed seasonal aquatic biological investigations of habitat characteristics, benthic macroinvertebrates, and fisheries were completed using a modified Rapid Bioassessment Protocol (RBP). The biological studies were conducted as part of a use attainability assessment to determine if industrial discharges on this portion of the river were reducing dissolved oxygen (DO) to levels that caused deleterious effects on the aquatic biota. The habitat characteristics of the Cape Fear River related to basin hydrology and historical dredging were determined to be the primary factors affecting the variability in biological characteristics in the river. The results of the biological studies, however, indicated that the aquatic life uses of the river were not impaired by the industry.

The significance of the biological data showing that water quality and attainable use were not affected by Federal's discharge were consequential for the North Carolina Division of Environmental Management (DEM) in establishing appropriate waste load allocation limits for the Cape Fear River.

INTRODUCTION

National laboratory-derived water quality criteria were published as guidance under Section 304(a) of the Clean Water Act (CWA) for the purpose of enabling states to derive site-specific water quality criteria for the protection of local aquatic life and stream uses (EPA, 1983a). In addition to these water quality guidance criteria for protection of designated aquatic uses, EPA established guidance (i.e., "Water Body Survey and Assessment Guidance for Conducting a Use Attainability Analysis") to determine if an aquatic protection use is being attained for a given water body (EPA, 1983a and EPA, 1983b). More recent guidance, "Rapid Bioassessment Protocols for Use in Streams and Rivers," was developed, providing states with a practical technical reference for conducting cost-effective biological assessments of lotic systems (Plafkin et al., 1989).

The RBP was developed by consolidating procedures in use by various state water quality agencies. During the development of the RBP, field methods in common use were evaluated in an effort to identify successful bioassessment methods that use different levels of effort. For example, the highest level protocol (RBPIII) incorporates certain aspects of the methods used by the North Carolina DEM.

The DEM has an interest in developing a site-specific RBP or a similar method as a standard for monitoring aquatic life and attainable use. Through the 305b monitoring program and other aquatic monitoring projects in the state, the DEM updates a regional water quality data base of lotic systems that represent uncontaminated waters for use with the RBP. This regional aquatic system data base represents the best attainable physical habitat, water chemistry, and biological parameters for establishing specific environmental conditions and aquatic life uses for reference comparison.

The RBP advocates an integrated assessment, comparing habitat and biological measures with a range of empirically derived reference conditions. The goal of the comparison is to understand the relationship between habitat and biological potential. Once this relationship is understood, water quality impacts can be objectively distinguished from habitat effects, and control efforts can be focused on the most important source of impairment.

For the RBP to be used for effective comparison of a distressed area to measure water quality degradation and attainable use, a regional data base of habitat, water quality, and biotic conditions from unimpaired systems is required. This paper describes a modified RBP procedure in which the RBP parameters were used, under the guidance of the DEM, to determine if the designated use on a section of the Cape Fear River was being attained. The RBP method was modified in this work, because the reference data base for unaffected tidally influenced freshwater systems was not established in this region of North Carolina.

BACKGROUND

The study area is located on a 60-km reach of the lower Cape Fear River below Lock and Dam No. 1 to the City of Wilmington, North Carolina (Figure 1). The DO in this reach of the Cape Fear River has been considered marginal by the DEM because of both natural and anthropogenic factors. Extensive water quality modeling for DO under various hydrological conditions on this reach of the river has been conducted by the state and industries discharging to the Cape Fear. A comparison of model results predicting DO concentrations with and without industrial and municipal loads indicated that DO in the Cape Fear River, during warm water and low flow conditions, is reduced below 5.0 mg/l.

The Federal Paper Board Company, Inc., paper and pulp mill (Federal), located about 5 km below Lock and Dam No. 1, was considered to be a major contributor to the biochemical oxygen demand (BOD) load lowering the river DO. However, when the DO models were run without the Federal sources, the BOD apparently causing the reduction in DO was due to natural sources emanating from Hood Creek and the Black River located approximately 30 km below Lock and Dam No. 1. Both of these rivers are black water systems affected by drainage from hardwood swamps that produce natural organic loads sufficient to reduce the DO below 5.0 mg/l in the lower reach of the Cape Fear River. In addition, the watershed drainage below the confluence of Hood Creek and the Cape Fear is also affected by runoff from large forested swamps, compounding the organic load to the Cape Fear River. This is in contrast to drainage

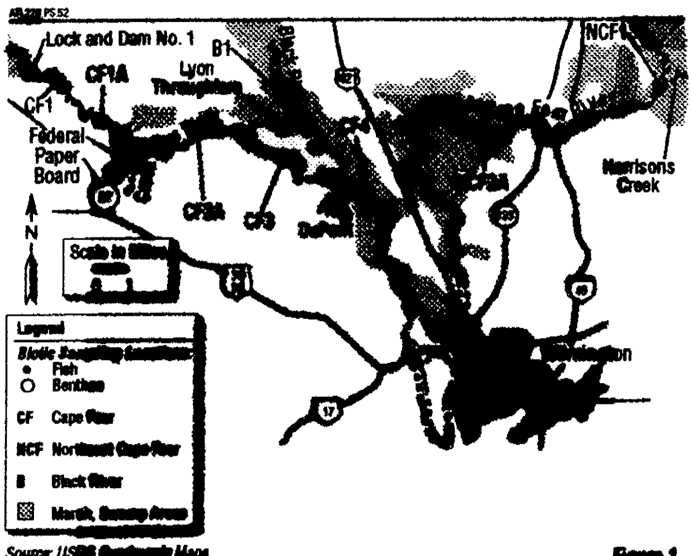

Figure 1
Federal Paper Board Biological Assessment Study Area

from mostly upland watershed sources in the reach of the Cape Fear River above the confluence of Hood Creek and Black River. Although the models indicted that DO could be reduced below 5.0 mg/l due to natural conditions, the DEM proposed NPDES water quality based permit limits for BOD to protect aquatic use in the lower Cape Fear River by maintaining a river DO concentration of at least 5 mg/l.

The DEM also recognized the natural effect of organic enrichment on the DO regime of rivers influenced by swamp drainage and developed a use classification of "Swamp" to indicate that the water may have natural water quality characteristics (e.g., DO) at levels outside the range of other freshwater Class C Systems. The DEM further recognized that the complicating influence of the organic drainage from natural systems can affect the reliability of using the DO models to conclude that attainable use was degraded because of the Federal discharge alone. Because of this uncertainty, DEM agreed that better decisions about DO oxygen management strategies could be made if there were a better understanding of the relationship between water quality conditions and the aquatic communities in the Cape Fear River.

STUDY OBJECTIVES AND APPROACH

The objectives of the biological investigations were to determine: (1) whether Federal's effluent significantly affected the aquatic communities of the Cape Fear River, (2) whether the state-designated use of the Cape Fear River was being attained, and (3) if the use was being affected, the likely cause of the effect. The study focused on measuring the fish and benthic community in the affected reach of the Cape Fear River to determine if aquatic life uses were being attained. This analysis of attainment was based on comparison with unaffected reference stations. The approach differed from Plafkin's (1989) RBP methods in that the metrics were evaluated without weighted scores. In addition, site-specific metrics suggested by DEM (Lenat, 1991) were included in the evaluation. This modified approach was coordinated with the DEM prior to initiation of field sampling.

METHODS

Station Selection

Selection of sampling stations was based on two primary criteria: (1) relevance of the stations to the influence of the Federal effluent, and (2) comparability among stations. The biological study included sampling fish and benthos at two stations upstream of Federal's discharge, at three stations below the discharge, and at three stations on adjacent rivers with similar habitat characteristics. The stations were selected to minimize variation among habitats so that measured differences in the aquatic community structure would be more likely related to water quality and the effects of Federal's discharge (Figure 1). Stations CF1 and CF1A were the two upstream reference stations. Stations CF2A, CF3, and CF4 were stations on the Cape Fear River downstream of the Federal discharge. Stations B1 (Black River), NCF1, and NCF2A (Northeast Cape Fear River) were reference stations not on the Cape Fear but in the same watershed. Seasonal surveys were conducted at these stations to incorporate the variable effects of seasonal water temperature and rainfall (i.e., discharge) on community structure relative to Federal's effluent. Because of significant changes in seasonal flows, station locations were adjusted either upstream or downstream, or stations were added to account for variability in habitats and to provide sampling at sites most representative of the stream reach being studied.

Table 1. Parameters Evaluated for Comparing the Various Sampling Stations.

Physical Parameters:
- Predominant surrounding land use
- Local watershed nonpoint source pollution
- River depth and width
- High water mark
- Velocity
- Dams
- Channelization
- Canopy cover
- Sediment odors
- Sediment oils
- Substrate texture
- Aesthetics

Water Quality Parameters
- Water odors
- Surface oils
- Turbidity
- Stream type and state class

Habitat Parameters:
- Substrate cover for aquatic organisms
- Embeddedness
- Flow
- Channel alternation
- Bottom scour/deposition
- Run/bend ratio
- Bank stability
- Bank vegetation
- Streamside cover
- Undercut banks
- Bank slope

Table 2. Comparison of Total Scores for Habitat Assessment of the Cape Fear Affected by Federal's Discharge and Unaffected Reference Sites

Affected Stations	April	Months June	August
CF2A	108	114	102
CF3A	108	108	99
CF4A	79	81	81
Reference Stations			
CF1	104	104	98
CF1A	104	107	102
NCF1	81	81	78
NCF2A	83	81	78
B1	82	81	78

CF = Cape Fear River Stations
B = Black River Station
NCF = Northeast Cape Fear River Stations

Data Collection

The RBP scoring assessment was used to estimate the habitat quality and conditions for comparison of the eight sampling stations on the Cape Fear River (Plafkin et al., 1989). The habitat quality evaluation was accomplished by comparing scored RBP physicochemical and habitat feature parameters at river stations influenced by Federal's discharge to unaffected reference stations. Table 1 is a list of the physical, water quality, and habitat RBP parameters evaluated at each station.

Benthos and fish were sampled at each station using standard techniques for benthos (Ponar grabs, kick-nets, hand collections, and artificial substrates) and for fish (gill nets, hoop nets, minnow nets, trawling, and electroshocking). Sampling strategies, using the various types of gear, included as many diverse habitats as possible, and were designed to be representative of benthos and fish communities inhabiting the study sites.

RESULTS

Habitat Comparison

Results of the RBP ranked habitat assessment are shown in Table 2. Based on the evaluation of the habitat assessment, the Cape Fear River had a distinctly different bank structure and river morphometry from that of the Northeast Cape Fear and Black Rivers. Bottom sediments consisted largely of sandy material at all sites. With the exception of Station CF4, located below the confluence of the Black River, the Cape Fear River channel morphometry was more "U" shaped with steep banks, no littoral zones, and less stabilizing bank vegetation than the Northeast Cape Fear and Black Rivers. These latter two reference rivers were generally wider, with some emergent vegetation and littoral zone habitat. The flood plain characteristics also differed between the upper reach of the Cape Fear and the Black and Northeast Cape Fear Rivers. The Black, Northeast Cape Fear, and Cape Fear below the Black River confluence had significant drainage from forested swamps, whereas the watershed above the Black River confluence was mostly upland pine. The differences in channel shape and depth were partially attributed to the frequent maintenance dredging and channelization in the Cape Fear River.

Benthos

The robustness of the comparison of RBP parameters between the biological conditions at the affected sites and at the references sites is limited by the number of samples collected and the number of RBP parameters used. For the benthos assessment, three potentially affected locations below the Federal discharge were compared with five reference sites using eight RBP metrics. To provide representative sampling of as many habitats as possible, multiple methods were used - throughout the year-long sampling program. These methods included Ponar grabs of sediments (three per station), hand collection (six per station) from snags, leaf packs, and shoreline substrates, and artificial substrates using Hester-Dendys (12 per station) at representative areas in each station. The total number of benthos samples collected for these habitat types was 651 distributed over the eight stations and during four seasons. These benthos data were evaluated seasonally as quantitative (Ponar and Hester-Dendy) and qualitative (hand and net) samples. The results of these analyses averaged by season are shown in Table 3; a brief description of each RBP parameter is provided at the end of the table.

All but one of the Cape Fear stations (CF4) had similar habitat features. The habitat for Station CF4 on the Cape Fear River was more like the reference stations on the Black (B1) and Northeast Cape Fear (NCF1 and NCF2A). Table 3 illustrates the wide variation in numbers of individuals and species that were collected from the different habitats for each method used. The important differences in habitat features affecting the community structure among the stations included bank morphometry and microhabitats for benthos such as snags and woody debris. A Jaccard Coefficient of Similarity and an Analysis of Variance calculation showed that, with the exception of Station CF4, the benthic community structure among the Cape Fear River stations was generally similar but differed when compared to the adjacent river reference stations (CH2M HILL, 1992).

Although the results of the community analysis showed differences in benthic community structure among the stations, particularly between the adjacent river reference stations and the Cape Fear River, the indices of water quality were very similar. The DEM has developed a species-specific biotic index (BI) for benthic organisms inhabiting rivers and streams in North Carolina (Lenat, 1991). This BI was used with the EPT indices on the suggestion of the DEM to compare the relative water quality conditions between stations. A BI factor change of 0.4 units is considered by the DEM to be indicative of differences in water quality. The results of the BI, shown in Table 3, indicate that there were no significant differences in BI. It was concluded from these results, and concurred with by the DEM, that there was no discernible difference in water quality among the stations.

Fisheries

There were 13 RBP fish protocols applied for this study: catch per gear type, catch per unit effort, total number of species, total number of individuals, number of insectivore species, number of sunfish species, number of minnow species, number of intolerant species, proportion of tolerant species, proportion of freshwater individuals, proportion of omnivore individuals, proportion of insectivore individuals, and proportion of carnivore individuals. For brevity in this paper, only 4 of the protocols, (taxa, numbers captured, diversity, and evenness), which measure community structure, are presented. The reader is referred to CH2M HILL (1992) for details of the other fish RBP metrics, which are measures of trophic structure and catch rates. Table 4 summarizes the fisheries data for these protocols among the eight stations. Because of the mobility of fish and differences among habitats, a high degree of variability was observed in the number and kinds of fish collected among the stations.

Although the species composition was different, there was no discernible difference in species diversity, as shown in Table 4. Since the community data (type of fish, number of species, number of individuals) indicated a balanced and diverse fish population in the Cape Fear River typical of the area, although different from the reference stations, it was concluded that water quality was not a factor in this difference. The DEM agreed that habitat and natural mobility of fish in a dynamic, tidally influenced river accounted for the observed variability of the fish data.

REGULATORY ACTION

Normally, when regulatory agencies develop wasteload allocations, they rely heavily upon water quality modeling to provide the framework for permit requirements. In this case, the DEM was reluctant to use water quality modeling as the primary basis for establishing BOD discharge limits because of the influence on the Cape Fear River DO from natural sources in the watershed. The significance of the biological data showing that water quality and attainable use were not affected by Federal's

Table 3. Seasonal Results of the Benthic Macroinvertebrate Metric Analysis for Characterization of the Biological Integrity of the Cape Fear River

RBP Parameters	NCF1	NCF 2A	B1	CF1	CF1A	CF2A	CF3	CF4
	Reference Stations						Affected Stations	
Species Richness								
Ponar	25.8	12.8	18.5	10.3	13.3	14.8	13.8	15.0
Qualitative	58.0	33.8	52.5	37.8	49.0	38.0	35.0	41.8
Hester-Dendy	20.0	17.0	19.0	26.0	19.0	22.0	14.0	24.0
Total Number Individuals								
Ponar	404.5	185.8	342.3	299.0	165.7	982.0	469.3	393.8
Qualitative	4268.5	1370.3	2682.0	1391.3	1790.3	2569.5	2049.0	2849.3
Hester-Dendy	530.0	747.0	622.0	1687.0	1290.0	1300.0	965.0	1071.0
Biotic Index								
Ponar	3.2	3.4	3.5	3.7	3.4	3.5	3.2	3.4
Qualitative	3.4	3.4	3.3	3.4	3.4	3.5	3.3	3.3
Hester-Dendy	2.7	3.3	3.0	3.2	3.1	3.3	3.2	3.2
Ratio of EPT and Chironomid Abundances								
Ponar	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.5
Qualitative	0.6	0.2	0.3	0.2	0.2	0.3	0.4	0.2
Hester-Dendy	0.7	0.3	1.2	0.5	0.6	1.2	0.8	0.8
ETP Index								
Ponar	4.0	0.5	1.3	0.5	0.3	1.8	0.3	0.0
Qualitative	8.8	3.8	9.0	6.5	9.0	5.3	5.3	5.5
Hester-Dendy	4.0	5.0	5.0	7.0	7.0	6.0	4.0	7.0
Percent Dominant Taxa Contribution								
Ponar	66.8	73.8	60.0	84.8	71.0	82.5	69.0	73.5
Qualitative	69.8	74.3	39.5	56.5	42.3	59.8	45.8	68.3
Hester-Dendy	87.0	77.0	74.0	69.0	79.0	74.0	81.0	73.0
Diversity Index H'								
Ponar	2.7	2.6	3.3	2.3	2.4	2.2	2.3	2.7
Hester-Dendy	2.4	2.4	2.7	2.8	2.3	2.9	2.3	2.7
Evenness J'								
Ponar	2.0	0.7	0.6	0.7	0.6	1.2	0.6	0.7
Qualitative	0.5	0.6	0.7	0.7	0.7	0.6	0.7	0.6
Hester-Dendy	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6

Notes:
Taxa Richness: The health of the community can be determined by measurement of the variety of taxa present. The premise for using this metric is that the taxa richness increases with increasing water quality, habitat diversity, and/or suitability (Plafkin et al., 1989).
EPT INDEX: This index value represents the number of ephemeroptera, plecoptera, and trichoptera present, which generally increases with increasing water quality (Plafkin et al., 1989).
Percent Contribution of Dominant Taxa: The percent contribution of the numerically dominant taxa to the total number of organisms is an indication of the community balance at the lowest taxonomic level. The greater the percentage value, the lower the habitat quality (Plafkin et al., 1989).
NCDEM Biotic Index (BI): Each organism is assigned a site-specific tolerance value (TV) (Lenat et al., 1991). The BI is equal to the sum of the relative number of individuals (i.e., scaling factor) times the TV, divided by the total number of scaling factors used. The index was developed as a means of assigning a single value to summarize the pollution tolerance of benthos and the relative water quality. The greater the value, the greater the tolerant species composition and the poorer the water quality (Plafkin et al., 1989).
Diversity Index: Species Diversity (H') is an expression of community structure based on number of individuals and number of species. The greater the H' value, the more diverse the community. Diversity is sometimes used as a measure of habitat quality (Magurran, 1988).
EPT/Chironomidae Ratio: The ephemeroptera, plecoptera, trichoptera (EPT) and chironomidae (C) abundance ratio (EPT/C) uses these indicator organisms as a measure of community balance and quality. The greater the ratio value, the greater the community imbalance (Plafkin et al., 1989).
Evenness: Species evenness is a measure of how the abundance data are distributed among the species. The index value of J' decreases toward zero as the relative abundance of the species diverges away from evenness (Magurran, 1988).

Table 4
Indices of Community Structure Based on Combined Fisheries Data Collected During Season Sampling

METRIC	REFERENCE STATIONS					DOWNSTREAM STATIONS		
	NCF1	NCF2A	B1	CF1	CF1A	CF2A	CF3	CF4
Taxa Richness[1]	23	18	17	18	14	14	10	22
Number of Individuals[2]	214	89	76	187	76	84	34	165
Species Diversity[1]	3.21	2.27	2.50	2.04	2.07	1.90	1.85	1.83
Evenness[1]	0.60	0.68	0.90	0.69	0.73	0.75	0.86	0.46

[1] See Table 3 for definition of metrics.
[2] NUMBER OF INDIVIDUALS: The evaluation of the total number of fish is a measure of community structure. A reduction in the number of individuals is usually an indication of reduced habitat conditions (Plafkin et al., 1989).

discharge were consequential for the DEM to establish appropriate wasteload allocation limits for the Cape Fear River.

CONCLUSION

The variability of benthos and fish data was attributed primarily to habitat differences rather than water quality. DEM agreed that the modified RBP results indicated that the aquatic life uses in the lower Cape Fear River were not being degraded by the current BOD load from the paper and pulp mill effluent. The relevance of this study to water quality assessments relates to the paucity of quantitative data available in most states for evaluating societal impacts to streams.

For example, Wharton (1978) suggests that there are 39 different hydric systems in Georgia. Until a data base for habitat, chemistry, and biota of unaffected aquatic environments is developed for these 39 systems, the modified RBP approach can be used as a management tool to:

- Characterize the existence and severity of use impairment
- Identify sources and causes of use impairment
- Evaluate the effectiveness of control actions in impaired systems
- Support use attainability studies
- Characterize regional biotic components of lotic systems

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