

Evaluating the Benefits  
of Reducing the  
Frequency/Magnitude of Algal Blooms

Roland C. Steiner, PhD PE

and

Kathleen B. Hogan, PhD

ICPRB Report 86-16

October 1986

Interstate Commission on the Potomac River Basin  
6110 Executive Boulevard, Suite 300  
Rockville, Maryland 20852-3903

## Acknowledgement

The completion of the work leading to this report was accomplished with the assistance of many others. Blair T. Bower, noted resource economist, took an early interest in the project and offered valuable advice. Dr. Ann Fisher and Peter P. Caulkins of the U.S. Environmental Protection Agency Office of Policy Analysis provided useful reference material and technical comments. Curtis M. Dalpra, ICPRB Public Information Officer, provided advice on the location of appropriate sailing marinas and help in surveying providers of recreation facilities. Acknowledgement is also extended to the many people in the Potomac River community who gave their answers to the survey questions.

This report has been prepared by the Interstate Commission on the Potomac River Basin. Funds for this report are provided by the United States Government, the U.S. Environmental Protection Agency, and the signatory bodies to the Interstate Commission on the Potomac River Basin: Maryland, Pennsylvania, Virginia, West Virginia, and the District of Columbia. The opinions expressed are those of the authors and should not be construed as representing the opinions or policies of the United States or any of its agencies, the several states, or the Commissioners of the Interstate Commission on the Potomac River Basin.

# Evaluating the Benefits of Reducing the Frequency/Magnitude of Algal Blooms

## EXECUTIVE SUMMARY

The Potomac Strategy State/EPA Management Committee, convened after the algae bloom of 1983, developed a work plan which includes implementation of its Expert Panel's recommendations and other tasks. The survey of benefits described in this report is among the other tasks set forth in the work plan.

The objective of this study is to evaluate the potential for increased benefits which might accrue from reducing the frequency and/or magnitude of algal blooms in the estuary. Although the estuary is used for commercial fishing and transportation, the dominant use is that of recreation (U.S. Army Corps of Engineers, 1986). Methods for identifying recreational benefits are reviewed and the use of these methods by other researchers examining benefits of improved water quality are discussed. The types of water quality benefits which may be realized within the Potomac estuary are reviewed. Although recreational benefits constitute the bulk of all benefits and are the emphasis of this study, some discussion of the other categories is provided in order to emphasize that additional benefits do result from improved water quality, albeit ones that are more difficult to quantify. This is not intended to provide a basis for benefit-cost analysis of water quality improvement in the Potomac; but to provide some sense of the direction in value derived from improvement.

It was determined that this project could not produce adequate data to support the development and use of a formal model. Instead, the result of this study is a qualitative impression of demand for reduced algal presence gleaned from direct contact with recreation providers and participants. The main thrust of questions to the business community was to determine the effect of algae on their trade. Those actually using the estuary were asked how the presence of algae affected their use and enjoyment of the water.

The study concludes that there exists significant evidence suggesting that recreational benefits would accrue from further abatement of algal blooms. This evidence is provided in part through research performed by other investigators in the region who consistently relate water quality improvements with increased demand for recreation. Additional support is provided by the interviews detailed in this study.

The focus on recreational impacts, although perhaps dominant, is only one of several potentially important areas of concern. Therefore, the finding of some demand, in this limited study, for reduced algae in recreation activities can be considered to represent just the tip of the iceberg of potential benefits.

## INTRODUCTION

During the summer of 1983, the upper estuary of the Potomac River was covered with a bloom of blue-green algae. Blooms of this magnitude in the Washington metropolitan area had not been seen in about a decade and were thought unlikely to occur again because of continually more stringent wastewater treatment programs and improving water quality.

The recurrence of the massive algae bloom in 1983 was so unexpected that area officials joined with the U.S. Environmental Protection Agency to form the Potomac Strategy State/EPA Management Committee and assemble the Algal Bloom Expert Panel to identify possible causes of the problem. In its report (1985) the panel made some recommendations on maximum levels of chlorophyll-a in the estuary that would result in various probabilities of recurrence of a bloom. Specifically, the following two goals were presented:

1. reduce the occurrence of chlorophyll-a concentrations exceeding 100 ug/l, the level believed to result in nuisance conditions, especially in the embayments, and
2. reduce the occurrence of only the more massive blooms where chlorophyll-a levels exceed 250-300 ug/l.

These goals were thought to reflect the major risks of recurrence associated with the type of algal bloom observed in 1983. In addition to these goals, the panel stated that with each type of risk, "a balance must be achieved between the relative costs of various control actions to achieve a specific level of phytoplankton concentration and the relative benefits associated with reduced occurrences of nuisance conditions".

Achieving this balance requires information with regard to the costs of control actions for both point and nonpoint sources of nutrient loadings into the estuary and with regard to the benefits derived from abatement of the blooms. The Potomac Strategy State/EPA Management Committee developed a work plan which includes implementation of the Expert Panel recommendations and other tasks. The survey of benefits described in this report is among the other tasks set forth in the work plan. Currently, only the costs of controls for the point source loadings are available. The Blue Plains Feasibility Study (BPFS) (Greeley & Hansen, 1984) examines a range of treatment levels at wastewater treatment plants discharging to the Potomac Estuary and its embayments. The costs of capital improvements range from less than \$1/4 billion

to more than \$ 1/2 billion (1982 dollars) for sewage flows expected in the year 2005. The least-cost plan would relax the phosphorus concentration in effluent limits to .35 mg/l and require no added nitrification. The most expensive would require more stringent phosphorus and nitrogen limits than currently required by the NPDES discharge permits. A wide range of nutrient concentrations is possible and depends upon the treatment alternatives selected. In the BPFs, these nutrient levels have been related to the development of algal blooms and in particular to the potential for blue-green varieties to dominate.

Nonpoint sources must also be considered. The BPFs found that algal blooms may occur as a result of unusual hydrometeorological conditions regardless of the level of treatment. It is possible that high alkalinity concentrations promote the release of phosphorus from the sediments. Therefore, a potentially unlimited reservoir of phosphorus may exist under particular flow, temperature and water quality conditions. The Interstate Commission on the Potomac River Basin is working with the Metropolitan Washington Council of Governments on another task to address this issue by investigating the potential frequency of hydrometeorological conditions which favor the growth of algae.

Given that nutrient levels can be partially controlled and that the costs of reduced algal blooms are at hand, it is necessary to assess what the residents of the region feel is an acceptable level of water quality with regard to algal blooms. For example, if a massive bloom were to occur only once every 10 years, would it drastically affect people's uses of the river? Would it change their current perception that the quality of the Potomac River is generally good, and that previous and future expenditures are worthwhile?

The objective of this investigation is to examine local impacts of recent algal blooms and thereby the benefits of reducing their frequency and/or magnitude. Methods for identifying benefits are reviewed and the use of these methods by other researchers examining benefits of improved water quality are discussed. The types of water quality benefits which may be realized within the Potomac estuary are reviewed. While recreational benefits constitute the bulk of all benefits and are the emphasis of this study, some discussion of the other categories is provided in order to emphasize that additional benefits do result from improved water quality, albeit ones that are difficult to quantify. This is not intended to provide a benefit-cost analysis of water quality improvement in the Potomac; but to provide some sense of the value derived from improvement. The results of a limited survey of operators of recreational facilities and users of recreational facilities are presented in detail.

## RELATED RESEARCH

The issue of benefits derived from water quality improvements has been addressed in both the general sense, and with regard to the Potomac in particular. A good short description of motivation and methods is provided by Kneese (1984). The Water Resources Council (1973) established Principles and Standards for Planning of water and land related resources. The enhanced quality of the environment was one of only two objectives.

"This objective reflects society's concern and emphasis for the natural environment and its maintenance and enhancement as a source of present enjoyment and a heritage for future generations."

This is a strong motivation for continued pollution abatement measures. Unger, et al. (1973) indicate that benefits resulting from continued water pollution control will be publicly demanded as long as they are perceived to exceed their costs. Economic benefit studies directed at reducing algae include that by Reiling, et al. (1973) in their study of Upper Klamath Lake in Oregon. This analysis of benefits started with the assumption that all blue-green algae would be removed from the lake. The results indicated that significant benefits would result. Peter Caulkins, et al. (1986) use a lake water quality classification index (LCI) developed by Uttormark and Wall (1975) which is based on four water quality parameters including the extent of algae growth. Of the four parameters, algae growth is given the most weight; accounting for up to 9 points of a potential total of 23. Two models developed by Caulkins et al. indicated that a 16% or 12% increase in day trips for recreation would result for each point of water quality improvement in the LCI. Notwithstanding the subjectivity of the LCI, recreation benefits are seen to respond significantly to improvements in water quality.

Cronin (1982) studied households' willingness to pay for improved water quality in the Potomac River near Washington, D.C. His concern in the study was to provide information appropriate to the selection of the economically efficient level of water quality. The survey asked the willingness to pay for the present level of water quality in the river and three higher levels. Six water use parameters were grouped in each level, and among the characterizations of the parameters was mention of algae in and on the water. An important finding of the study was that; although for the lower levels of treatment, the users of the river expressed more willingness to pay than non-users, at the highest level, the relationship was reversed. Estimated income elasticity of willingness to pay for improvements in

water quality ranged from 0.32 to 0.57 for the four alternate water quality levels offered. Strand et al. (1986) developed benefits models from recent surveys around the Chesapeake Bay. The Bay includes at least part of the Potomac estuary; and swimming, fishing, and boating users in the Washington, D.C. and surrounding counties area were found willing to pay from \$45 to \$95 per year.

### BENEFITS OF WATER QUALITY IMPROVEMENTS

Aquatic Protection and Recreation are the areas of major impacts associated with benefits affected by water quality decisions in the Potomac estuary (as delineated by EPA (1982)). This is also shown in the findings of the U.S. Army Corps of Engineers (1986) regarding the dominant use of the upper Potomac estuary; their report assessed and ordered by importance the many uses of the Potomac estuary.

Various methodologies have been developed to quantify recreational benefits. Analogous methodologies do not exist for for evaluating the benefits accrued from the protection of aquatic life, an area in which significant benefits do exist. The numerous negative impacts of blue-green algae on the aquatic environment were discussed by the Expert Panel (1985). Among them were: difficult water treatment problems with taste and odor, oxygen depletion with resulting decline or elimination of desirable flora and fauna, fish kills and diseases, and illness, disease and death among vertebrate consumers of affected waters. Thus, the present focus on recreation impacts, although perhaps dominant, is only one of several potentially important areas of concern. Therefore, the finding of any demand for reduced algae in recreation activities can be considered to represent just the tip of the iceberg of potential benefits.

Typically, the available methods of measuring (recreation) benefits are not precise because environmental commodities (e.g. water quality) are not bought and sold in ordinary markets. However, formal models of benefits, including those previously cited, have been developed. The EPA (1982) presents the subject of benefits valuation in detail, including descriptions of the more often used methods:

1. Travel Cost Models - which compare the the expense of getting to (and into) alternate use areas. Data required include: point of trip origin, round trip mileage, cost per vehicle mile, implicit time cost, length of stay, access fees, and if the trip satisfies other objectives.

2. Contingent Valuation Models - which derive willingness to pay for alternate choices of site characteristics. Data required include: design of a representative survey of the affected population, and clearly defined and consistently presented alternatives.

3. Recreation Participation Models - which rely on surveys of the recreation activities of the general population, and result in the degree of participation in identified activities. Data required include: representatively designed survey of general population, socio-economic information, residential location, recreational activities and locations, quality and capacity measures of activity sites.

In most cases, the data requirements are substantial if significantly reliable results are to be expected. It was determined that this project could not produce adequate data to support the development and use of a formal model. Instead, the result of this study is a qualitative impression of demand for reduced algal presence gleaned from direct contact with recreation providers and participants. The main thrust of questions to the business community was to determine the effect of algae on their trade. Those actually using the estuary were asked how the presence of algae affected their use and enjoyment of the water.

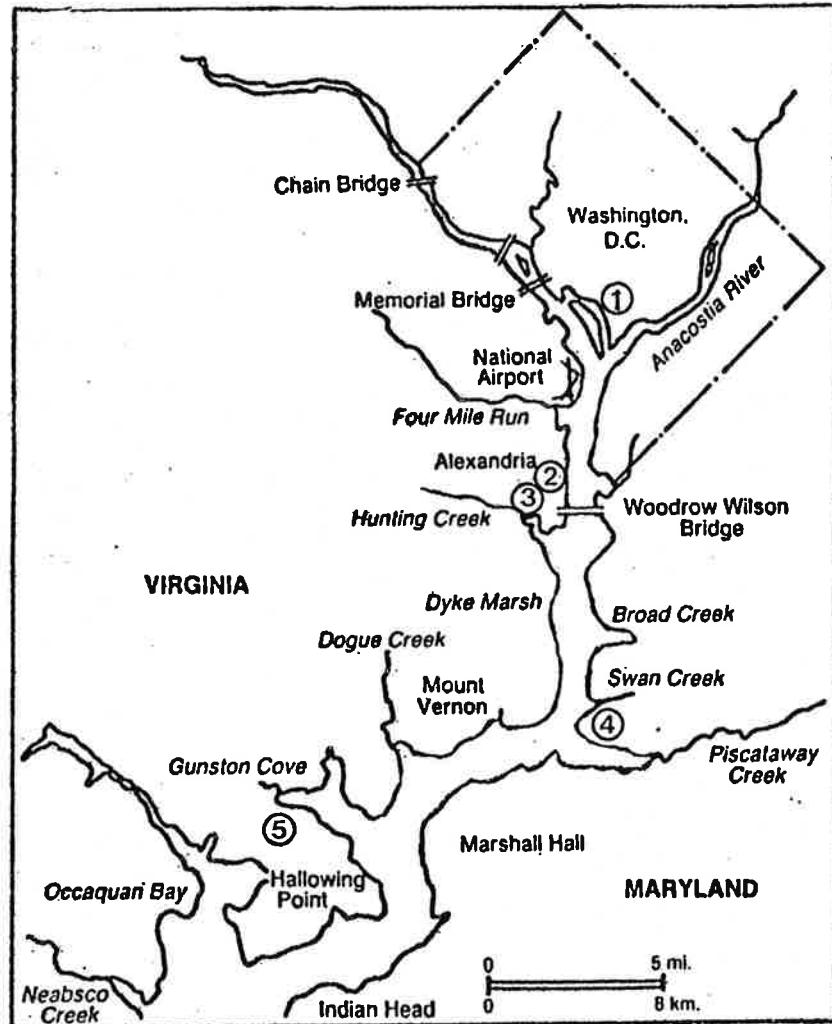
### SURVEY RESULTS

The potential beneficiaries of activities related to the presence of algae were divided into two major categories: providers of recreation facilities (those in the business), and users of those facilities and the river. In both categories, features unique to the individual made further sub-classification difficult; although they are interesting and may be described in general terms. For example, it is useful to note the degree of contact which the user has with the water: the extremes ranging from several yards above the water surface on a tour boat, to the physical immersion of a wind surfer. It is also interesting to note the degree of mobility of boaters; whether they operate powerboats and are independent of wind speed and direction, or whether they are fairly constrained to (and must tolerate) a local area.

The providers of recreation facilities were surveyed on a weekday: Friday, August 22, 1986, so as to avoid the greater potential distractions on weekend days. Those using the estuary



MAP OF POTOMAC SURVEY LOCATIONS



- (1) Water Street
- (2) Belle Haven
- (3) Alexandria
- (4) Ft. Washington
- (5) Pohick Bay

were surveyed on Sunday, August 24, 1986, under the supposition that the broadest cross-section of recreationists would be active on a weekend day. The questions used in the survey are reproduced in the Appendix.

#### Responses of Recreation Providers

- a. Gangplank Sailing Association, Water Street, Washington, D.C.  
Rick Morris, Dock Master

Thought that recreation on the Potomac competed with activities at state and federal parks. People, when confronted with algae in some areas, would continue to use the river by seeking other less affected areas; thus experiencing the inconvenience of increased "travel time" to the recreation site. People would not want to water ski or go swimming; algae would wash off boat hulls as they sailed or motored through cleaner water; therefore, no direct economic cost. Not particularly aware of problems because they did not occur at the marina.

- b. Washington Boat Lines, Water Street, Washington, D.C.  
James Rooney, Operator

Operates relatively large boats, meaning that customers are well above the water and any algae that may be in or on it. Algae has not been particularly noticeable. All ages and groups of people ride Washington Boat Lines for the river scenery, onboard entertainment, and transportation to Mt. Vernon. The number of passengers has not been noticeably affected by algae blooms in the recent past. Perhaps if blooms were a regular occurrence, ridership would decrease.

- c. Belle Haven Marina, Fairfax County, Virginia  
George Stevens, Operator

The dense algae blooms of recent past years affected the water contact sports side of this marina's business. The rental of sail boards, sun fish and other light recreation equipment diminished as the algae became dense, and ceased altogether during floating blooms of the blue-green species. Wind surfing and sailing lessons offered at the marina stopped because customers did not want to come into contact with algae in the water. The loss of income from diminished lessons and light craft rentals was up to \$2,000 per week. Power boating is not much affected, either by those who use the launch ramp or those who rent slips at the marina. However, wake trails left in the

floating algae did disturb boaters, and the general feeling was that the algae was disgusting. The cause of the algae (and the present hydrilla) was attributed to nutrients discharged in the effluent from Blue Plains Sewage Treatment Plant.

d. Old Dominion Boat Club, Alexandria, Virginia  
James Robey, Dock Master

Members of this club include a wide range of ages and pursue the usual boating activities: skiing, swimming, fishing and pleasure boating. In addition, they participate in many joint and club-sponsored activities. The older members have generally known the Potomac for a number of years and have seen long-term improvement in its water quality. They are apparently willing to accept the occasional algal nuisance. It does pose a problem, however, by sticking to the sides of boat hulls and, if allowed to dry, is difficult to remove. Therefore, after coming into contact with spray containing dense algae, boaters must wash down their hulls. Also, there is an unpleasant smell when boats travel through and stir up water with dense or floating algae.

Responses of Recreationists

a. Boating couple with cabin cruiser moored at Ft. Washington Marina, Prince George's County, Maryland

Algae did not affect their boating activities. They seemed to have only a vague idea of what algae in the water even looked like. They pointed to hydrilla and described problems with it getting clogged in marine engine cooling water systems, and that it was a greater problem than algae.

b. Sport fishing couple with cabin cruiser moored at Ft. Washington Marina, Prince George's County, Maryland

They take their boat out onto the river most weekends. Their principal activity is fishing, although they also water ski and swim. They believe people with small boats are more affected by algae than those with larger ones. They had a good understanding of the spatial and temporal distribution of algae. They would not swim or ski where algae was dense or floating, and think dense algal blooms are bad for fishing. With regard to alternate activities, they had their boat and would use it to find areas where algae was not present rather than pursue a non-water-based activity. Thus, they would experience the inconvenience of looking for areas free of algae.

c. Fisherman with trailered bass boat launched at Ft. Washington Marina, Prince George's County, Maryland

This young man owned a fairly sophisticated open boat with both a gasoline powered outboard motor (for quick access to fishing areas) and an electric motor (for use while fishing). He had been fishing in the Potomac since boyhood. He had noticed swirls of algae in the water which affected where, not whether, he chose to fish.

d. Owner of cabin cruiser moored at Ft. Washington Marina, Prince George's County, Maryland

This middle-aged man seldom uses his cruiser for boating, preferring instead to enjoy it moored in its slip which is provided with an electrical hook-up. He does not like algae in the water, yet is unlikely to change how and when he uses his boat. He has noticed that trailer-drawn boaters turn and leave the marina after arriving to find dense algae present.

e. Young boating family with trailered outboard cruiser, Pohick Bay Regional Park, Fairfax County, Virginia

This couple with young child(ren) uses its boat for water skiing, access to swimming locations and general boating pleasure. They would continue to use their boat if there was dense or floating algae, but would not ski or swim.

f. Jet-skier, Pohick Bay Regional Park, Fairfax County, Virginia

This young man on a jet ski has skied in dense algae and would do so again, although he prefers cleaner water. He feels he has a \$3,000 machine and he would not let algae get in the way of his use of it. He indicated that boaters would launch their craft at ramps into water containing dense algae, but would then sail or motor to areas where algae was less apparent. He seemed to appreciate that algae was a non-toxic plant and thus not threatening to his health, whereas he did say that if he felt that toxic chemicals were noticeable in the water he would go elsewhere. He expressed his support for continued clean-up of the river. The ramp launching fee is \$6 (\$65 for the season), beach launch fee is \$4 (\$40 for the season), and access to the park is \$4 for out-of-county residents (free to residents).

g. Group of wind-surfers, Pohick Bay Regional Park, Fairfax County, Virginia

This small group of young men and women were taking advantage of a rare windy weekend in August. They said that they would surf in water containing dense algae if the wind was adequate, but would try not to fall off their boards into it. They put the price of boards in the range of \$400 to \$2,000 and were subject to the beach launching fee. While they use Pohick Bay with its present frequency and intensity of algae, they also expressed their support for continuing the clean-up of the river. They indicated that they preferred to use the river where there was algae rather than where the effluent from Blue Plains Waste Water Treatment Plant was more evident. In addition, they noted the convenient location of Pohick Bay and would not travel two hours to Lake Anna, Virginia for cleaner water.

h. Sailing couple with trailered boat, Pohick Bay Regional Park, Fairfax County, Virginia

This couple indicated that it was the good sailing weather which attracted them to the river, and that the presence of algae would only somewhat diminish their enjoyment.

Note: of the perhaps 200 vehicles in the launchers-only parking lot at Pohick Bay Regional Park, only about half a dozen displayed license plates from states other than Virginia.

i. Park spokesman, Potomac Overlook Park, Virginia

The spokesman indicated that the algal influence on opacity of the water diminished the ability of fish-eating birds to see and catch their prey. It can be deduced that birdwatchers' enjoyment of the estuary is reduced when algae is present and water fowl are scarce. Personally, the spokesman was more concerned about the presence and concentration of chemicals (including lead) from sewage treatment plants and military installations.

The following set of general observations summarize the interviews.

1. The responses to the limited survey discussed in this report did indicate support for continued expenditure on further reducing the frequency or magnitude of algal blooms.

2. Lessons and rentals of sail boards and other light sailing craft diminished during periods when algae was dense in the river. This may reflect the reluctance of less experienced or committed wind surfers and sailers; whereas, those who owned their equipment appeared to be more determined to pursue these activities notwithstanding the potential for water contact.

3. Those people who would not water ski or swim during periods of dense or floating algae might eventually join a private swimming (country) club or install a pool on their property.

4. Types and locations of activities pursued are functions of water quality. Motor boaters might be equipped to water ski, fish or be prepared to just sight-see. These activities and where they are pursued may be flexible. Boaters may launch at a sight where there is dense algae present, then move off to find clearer water. Thus, they would experience the inconvenience of looking for areas without algae.

5. Recreation on the Potomac estuary is changing; wind surfing and jet-skiing are now common on parts of the river and its embayments, having not been nearly so popular in earlier years. Therefore, the impact of algae on the general picture of recreation and water sports may be changing.

6. Although not strictly a finding of the survey, the concept of pride in the quality of one's local water body was discernable. Also, it could be surmised that there may be the benefit of increased civic pride in improved environmental quality among the general local population of non-users.

More detailed observations are difficult to provide at present for several reasons each related to the fact that a major bloom has not occurred in the Potomac estuary for a year or two. First, hydrilla has been introduced to the estuary and has dominated the water quality scene most recently. Facility operators and the users of the marinas were more eager to express their displeasure with this year's hydrilla than with algae several years back. Second, people's perceptions seem to dull with time. Several operators could recall the blooms of 1983 and 1984 but could not recall the effects. Users of the river thought back to the blooms but seemed to focus more on the water quality conditions of the current year. These responses do not adequately reflect the degree of concern which was present during the 1983 bloom.

Finally, the recreational industry experiences change. Both operators and recreationists enter and leave the area. Therefore, the blooms of 1983 and 1984 do not exist in the memories of some of the people currently active in the estuary. New users may be a particularly important group for this type of analysis since they will be less forgiving of degraded water quality conditions, not having observed the improvements over the last decade.

### CONCLUSIONS

There exists significant evidence suggesting that recreational benefits would accrue from further abatement (in magnitude and/or frequency) of algal blooms. This evidence is provided in part through research performed by other investigators in the region who consistently relate water quality improvements with increased demand for recreation. Additional support is provided by the interviews detailed in this study.

The focus on recreational impacts, although perhaps dominant, is only one of several potentially important areas of concern. Therefore, the finding of some demand, in this limited study, for reduced algae in recreation activities can be considered to represent just the tip of the iceberg of potential benefits.

### FURTHER WORK

The results of this study are useful in preparing a method for further quantification of recreational benefits resulting from fewer and less severe algal blooms. Noting that perceptions are tempered with time and that the recreational demands are changing with time, it seems necessary to perform an investigation in the estuary prior to and during an actual bloom event. The objective would be to relate water quality characteristics (chlorophyll-a, extent of algal mass) to the use of the river by different types of recreationists. Monitoring water quality and demand for recreation prior to an event would provide a baseline specific to that year. With the onset of high chlorophyll-a concentrations and algal growth the monitoring should increase to include surveys of the users. This would more accurately capture peoples' responses to the algal bloom. Records of revenues at recreational facilities and of activity levels could be obtained and compared to the water quality records and the surveys. The resulting information, describing recreational benefits, would be a lower bound on the benefits of further abatement of algal blooms.

## REFERENCES

Algal Bloom Expert Panel: Robert V. Thomann, Chairman, et al., The 1983 Algal Bloom in the Potomac Estuary, Potomac Strategy State/ EPA Management Committee, March 1985.

Caulkins, Peter P., Richard C. Bishop and Nicolaas W. Bouwes, Sr., The Travel Cost Model for Lake Recreation: A Comparison of Two Methods for Incorporating S Quality and Substitution Effects, American Journal of Agricultural Economics, Vol. 68, No. 2, May 1986.

Cronin, Francis J., Valuing Nonmarket Goods through Contingent Markets, for U.S. Environmental Protection Agency, by Pacific Northwest Laboratory, Richland, Washington, September 1982.

Environmental Protection Agency, Water Quality Standards Handbook (Draft), Office of Water Regulations and Standards, Washington, D.C., October 1982.

Greeley and Hansen, Blue Plains Feasibility Study, Final Report, District of Columbia, Department of Public Works, Water and Sewer Utility Administration, Office of Engineering Services, Design and Engineering Division, August 1984.

Kneese, Allen V., Measuring the Benefits of Clean Air and Water, Resources for the Future, Inc., Washington, D.C., 1984.

Reiling, S.D., K.C. Gibbs and H.H. Stoevener, Economic Benefits from an Improvement in Water Quality, Project 16110 FPZ, Office of Research and Monitoring, U.S. Environmental Protection Agency, January 1973.

Strand, Ivar E., Nancy E. Bockstael and Catherine L. King, Chesapeake Bay Water Quality and Public Beach Use in Maryland, University of Maryland, Conference on Economics of Chesapeake Bay Management II, Annapolis, Maryland, May 28-29, 1986.

Unger, Samuel G., M. Jarvin Emerson and David L. Jordening, State-of-Art Review: Water Pollution Control Benefits and Costs, Volume I, Office of Research and Monitoring, U.S. Environmental Protection Agency, October 1973.



U.S. Army Corps of Engineers, Hydrilla in the Potomac River and Tributaries, Final State Design Memorandum and Environmental Impact Statement, Baltimore District, February 1986.

Uttormark, Paul and Peter Wall, Lake Classification - A Trophic Characterization of Wisconsin Lakes, Corvallis, Washington, U.S. Environmental Protection Agency, Environmental Research Laboratory, 1975.

Water Resources Council, "Water and Related Land Resources, Establishment of Principles and Standards for Planning", Federal Register, Vol. 38, No. 174, September 10, 1973.

## APPENDIX

### SURVEY QUESTIONS

The questions developed for the survey were not all asked verbatim; instead they provided an outline of subjects to be covered in a more casual conversation with respondents. In this way, clarification could be sought, and more detail gathered when appropriate.

Survey Questions to Recreation Service Providers

Survey Questions to Recreationists

The Effect fo Algae on the Recreational Value of the Potomac Estuary

Questions for Water Recreation Service Providers:

What activities does water-based recreation on the Potomac Estuary compete with?

What alternate water-based activities (and locations) do consumers prefer when the Potomac Estuary water is high in algae?

What water-based activities are pursued by customers, normally? when there are various levels of algae in the water?

Where do customers come from, normally? when there are various amounts of algae in the water?

What age groups of customers pursue what activities? Does this change with respect to different amounts of algae?

Where and when were various levels of algae noticeable in the past? In what way physically, visually, smell?

What activities do various levels of algae interfere with, and how? Do people go away, stay away, how long?

Which weeks or months of the year are usually affected by various levels of algae?

What are the start-up costs and how much money do customers spend in a day at your business, for what activities?

What is your pattern of business (how many customers) through the week, the year?

What are typical costs for your services?

What state and/or federal agencies have you dealt with in water-based recreation?

How is business affected by various levels of algae in the water?

What is your estimated fraction of the market for your services on the estuary?

What is the dollar amount of your average annual turnover (total business, not profit)?

Name and phone for follow-up:

The Effect of Algae on the Recreational Value of the Potomac Estuary

Questions for Water Recreationists:

1. Does algae (green Water) interfere with the way you use the Potomac? how? why?

What is it about algae that (might) bother you? sticks to things? smell? looks bad?

How much algae does it take to bother you? (picture)

If it bothers you and you do something else for recreation, what is that? where? how much does that cost?

What weeks or months are your activities affected by algae?

What do you in a day on the river and how much does it cost?

Note age, sex, group, etc.