TUESDAY—NOVEMBER 14, 1967

Chairman—JOHN S. GOTTSCHALK, *Bureau of Sport Fisheries and Wildlife, Washington, D. C.*

The Protection of Maryland's Estuarine Areas[1]

L. EUGENE CRONIN
Chesapeake Biological Laboratory
Natural Resources Institute
University of Maryland
Solomons, Maryland

Abstract

Maryland's portion of the Chesapeake estuarine system includes the enormously valuable low-salinity half. By nature, this region is highly productive of oysters, clams, crabs and fish, with special advantages as a spawning and nursery region for a wide variety of fish and as a production area for oysters.

By use, this region is a major waterway for commercial shipping, the burgeoning center of a wide variety of water-related recreation, the waste-receiver from 4 million people and a vast industrial complex, and one of the traditional seafood centers of the nation.

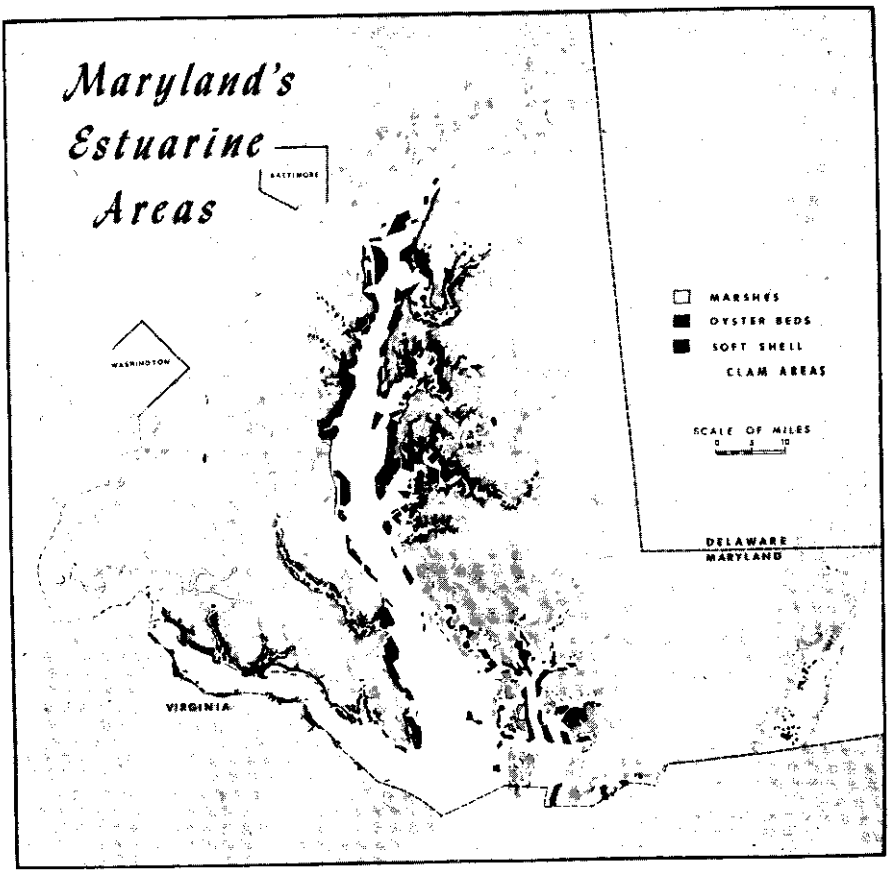
Until recently, uses have developed without rational efforts toward long-term balance within the limits of the system. There are now, however, several highly constructive activities underway which hold promise.

At the administrative level, Maryland has improved its management of oysters and other seafood, adopted stringent water pollution regulations, begun to study an entirely new concept in the control of domestic and industrial wastes, participated in basin-oriented coordination and control, and acquired substantial areas of marshland and other important watershed sites.

Research has been, is, and will be of special value in protecting and enhancing the uses of the Chesapeake. Special emphasis has recently been placed on studies of thermal pollution from power plants, the effects of spoil disposal from channel dredging, the probable dispersion of wastes at alternative sites, possibilities of eutrophication from domestic wastes, the possibilities of safe control of noxious species, and identification of the environmental requirements of major species.

MARYLAND, A SMALL STATE of 12,303 square miles, has 2,416 square miles of estuarine water, about 400 square miles of associated wetlands, and a total

[1]Contribution No. 339, Natural Resources Institute, University of Maryland.



tidal shoreline of 4,433 miles. It includes the upper half of Chesapeake Bay, the lower portion of the Susquehanna River (largest on the East Coast of the United States) and of the Potomac River, and many lesser tributaries. The salinity ranges from 0 parts per thousand (ppt) at the head of estuaries to about 20 ppt at the Maryland-Virginia line. The Bay averages about 20 feet in depth, with a maximum of 175 feet. It is the largest estuary in the United States, and probably the most valuable.

Maryland also owns part of the coastal lagoon series along the Middle Atlantic region, including Assawoman Bay, Sinepuxent Bay and about two-thirds of Chincoteague Bay. Thirty-one miles of Atlantic Ocean coast faces an estuarine portion of the continental shelf, strongly affected by Delaware Bay.

USES OF THE ESTUARY

The human uses of these estuarine areas are varied, intensive, expanding—and often conflicting. It would not be appropriate to review all of them now (see Cronin, 1967), but it is pertinent to illustrate briefly the nature and mag-

nitude of those uses, with emphasis on destructive changes and threats.

Fisheries

Commercial fisheries, principally for oysters, crabs, soft clams and striped bass, yield 80-85 million pounds per year, with a product value of $40 million (Manning, 1967). Maryland's catch of oysters, soft-shell clams and striped bass is the highest in the world, and the blue crab yield is among the best.

Recreational fisheries are not as well measured but apparently take several million pounds of fish and involve the expenditure of tens of millions of dollars.

Indirect support of other fisheries may be as important as the direct yield. These low salinity areas are heavily used by at least 30 species of freshwater, estuarine and marine species for spawning and nursery grounds (Flemer et al., 1967). This portion of Maryland includes the most productive spawning grounds of striped bass in the world and supplies much of the Atlantic Coast stock (Mansueti and Hollis, 1963). Other species present as juveniles include white perch, hogchoker, bay anchovy, winter flounder, naked goby, several silversides, croaker, spot, weakfish, menhaden and American eel (Flemer et al., 1967). No estimate is now possible for the value of these nursery grounds, but they support a very large portion of the more than 500 million pounds of fish catch attributed to the Chesapeake Bay.

Transportation

Baltimore receives about 5 thousand ocean-going vessels each year, and military and private boat traffic is very heavy. Increase is highly probable, and there is an almost insatiable demand for dredging to create and maintain channels.

Recreation

About 100 thousand private boats use the tidal waters of Maryland, and swimming, skiing, boating, beaching and fishing are all popular. Rapid expansion is certain, despite problems of pollution, sea nettles, sea weeds and limited public access to the shore.

Maryland's wetlands provide one of the most important over-wintering areas for waterfowl along the Atlantic Coast and also support substantial resident populations. Hunting is intensive.

Waste Disposal

Maryland's population of 3.1 million in 1960 may nearly double by the year 2000 (Md. Department of Planning, 1963), and most of the domestic wastes reach the estuary. Most of this receives some degree of treatment, but none of the nitrates and phosphates are now removed. Doubling of phosphates may approach the capacity limits of the upper Bay (Pritchard, 1966).

Industrial wastes are present but restricted to relatively small areas. Gross pollution does not appear to be threatening, but subtle pollution from a tremendous variety of agricultural, domestic, metropolitan and industrial areas may create new and difficult problems.

Thermal pollution from the giant generating stations proposed for the Chesapeake area may substantially modify local areas (Mihursky and Kennedy, 1967).

Industrial and Residential Development

Baltimore City, Washington, D. C., and many lesser communities cluster

around the estuary, and this is one of the fastest growing areas in the East. Data on the loss of estuarine areas to the rapid expansion of these centers are incomplete, but a preliminary survey indicates the destruction of 11 thousand acres in 10 years on the Western Shore and upper Eastern Shore. This was about 14 percent of the total and the rate of change is accelerating (Vaughn et al., 1966).

Silt invades every tributary, but the worst loading is in the Potomac, where 2½ million tons are carried into the estuary annually, and one-quarter of this arises from urban "development" in the Washington, D. C. area (Wark and Keller, 1963).

EFFORTS TO PROTECT AND ENHANCE THE ESTUARINE AREAS

Maryland, like most coastal states, began on the estuary. The bays are an important part of the environment of most residents, and there is a public wish to protect and improve these areas. The supplies of water, marshland and seafood long seemed inexhaustible, but decline and visible local degradation have brought efforts to improve.

Fisheries

Legislative action has created a strong non-political management agency, provided it with professionally-trained leadership, and given it increasing regulatory authority. As a result, valueless restrictive controls are being slowly eliminated, and productive management, especially for the oyster, is increasing. Bi-state management in the Potomac River has also been successful in improving the yield of oysters.

The development of the Maryland soft-shell clam industry provides an unusual case of constructive action. Invention of the escalator hydraulic dredge in 1951 was followed by (a) rigid restriction; (b) research; (c) regulation based on findings; (d) rapid expansion; and (e) promotion (Manning, 1959, and Cronin, 1966). The results have been dramatic, with the development of a large and relatively stable new industry producing about 700 thousand bushels of clams each year.

Sports fishing has been encouraged by removal (except during the spawning season) of a unique upper-size limit of 15 pounds for striped bass caught by hook and line, by a broad program of information to fishermen and a trophy-fish citation competition.

The nursery value of the upper Bay and tributaries has been illuminated by extensive, but still incomplete, studies of the distribution and ecological requirements of the estuarine and transient species. Support has been given by Dingell-Johnson funds, by the operating budget of the Chesapeake Biological Laboratory and by the Maryland Department of Chesapeake Bay Affairs. Valuable additional data have been obtained as a by-product of studies of the effects of spoil disposal effects in the upper Bay (Flemer et al., 1967).

Research on fisheries is continuous. The Department of Chesapeake Bay Affairs conducts various management studies and the Chesapeake Biological Laboratory carries out many research projects, some of which are supported by contracts. The Chesapeake Bay Institute of Johns Hopkins University and the Oxford Biological Laboratory of the Bureau of Commercial Fisheries also undertake appropriate projects.

Recreation

Recreational users of the estuary have been given considerable encouragement by the State in recent years. Three bay shore parks provide access, and an increasing number of boat launching ramps have been provided. Several small fishing "reefs" have been established. An unusually fine "Guide for Cruising Maryland Waters," containing maps, safety instructions, navigational information and a summary of marine laws, is now in its fourth edition at $5.00 (Matthews, 1967). Basic boating courses are available under some circumstances. A trained force of marine police, equipped with modern vessels and other facilities, provides both aid to all who use boats and enforcement of the growing number of regulations.

Research has recently begun on the troublesome summer sea nettle, *Chrysaora quinquecirrha*. In some years this medusa is abundant enough to discourage swimming, although it is only irritating, never fatal. The research at the Chesapeake Biological Laboratory is directed toward (a) understanding the biology of the species and its relation to the rest of the estuarine community; (b) searching for possible methods of reducing the damage from nettles without destroying desirable species or conditions; and (c) developing and testing any such biological, chemical, physical and mechanical method which shows promise (Blair, 1966, and Cargo and Schultz, 1966, 1967). With state and matching federal funds under PL 89-720, the program will be expanded and speeded.

An aggressive program of wetlands protection is underway. It was triggered by concern over damage to wildfowl habitat from filling, ditching, dredging and other activities, but now has vigorous support from all agencies under the Board of Natural Resources, which coordinates activities by the several resource departments.

The older phase of the program is based on acquisition of a significant portion of Maryland's extensive marshlands. By long-term efforts, using primarily federal-aid funds, the Maryland Game and Inland Fisheries Commission has obtained about 37 thousand acres of wetlands. The tracts are placed under various appropriate patterns of management to yield hunting as well as long-term protection. There are still, however, unresolved conflicts between optimal management for wildlife production and for mosquito control. In addition, it is important to note that there is very little knowledge available to guide the optimal management of such areas for the benefit of seafood species and other organisms affected by the wetlands.

Recently, the Maryland Department of Game and Inland Fish, with important assistance from the Maryland Planning Department and U.S. Bureau of Sport Fisheries and Wildlife, has initiated a project to inventory all wetland areas, estimate the value of each, record losses, determine the extent of pollution in these areas, and recommend a program for their protection and preservation.

For this purpose, wetlands include all areas from 6 feet below mean low water to the highest regularly wetted sites. Sixteen classes have been established, and a comprehensive data sheet is being developed for each site. It will include physical description, vegetative type, uses by wildfowl, mammals and aquatic species, assessment of value for various uses, and estimates of the vulnerability of the tract to construction, public works, pollution, erosion and other modifications.

The wetlands program is a difficult task. Previous limited surveys located 2,782 areas, including 361,465 acres (Maryland Game and Inland Fish Commission, 1956). Two-thirds of this acreage is linked to the estuaries.

The program is already of constructive value, even before total new figures are available. The data obtained on several sites have been used as the strong factual basis for recommendations to protect areas from proposed destructive changes. Eventually, the state hopes that rational consideration can be given to all of the present and potential values of such areas.

Waste Disposal

Like all of the other states, Maryland has recently adopted new water quality criteria and specific water quality standards (Maryland Water Resources Commission, 1967). High general criteria were established, six water use categories were identified, and standards were set for each use. Then, the present desirable water uses were listed for each of 411 water areas. These uses now control the standards to be applied to each area.

These standards in Maryland are ambitiously high and set excellent targets. In addition, the burden of proof has been placed on those who might wish to have exceptions permitted in order to use public waters for waste disposal. Achieving and enforcing compliance is a formidable task, but these are now both state and federal regulations, and the public will is in favor of this major effort to enhance and protect the waters of the state.

Several important waste disposal problems are the subjects of intensive research. Three of these merit brief attention — heat from power plants, the optimal location of waste discharges, and deposition of spoil from channel dredging.

Power plants are crowding into the estuarine area to take advantage of the large volume of low-salinity water for cooling their condensers. Such utilities usually obtain land and carry construction to a rather advanced point before seeking permission from the state agencies to use, heat and discharge water. Modern plants need up to 3 million gallons per minute (gpm) and elevate that quantity by 10-12°F. The Chesapeake Biological Laboratory has studied one smaller plant (500 thousand gpm elevated 11.5°F during summer) located along the Patuxent River estuary. The study began 2 years before plant operation and continued until the end of summer in 1967, about 2 years after completion. Extensive and frequent field observations have been combined with detailed laboratory studies of the thermal responses of estuarine species. About 40 scientists from a dozen agencies and institutions have contributed to an informally coordinated program. The most interesting results indicate the following effects (Mihursky et al., 1966, 1967a, 1967b; Roosenburg, 1967):

a. There has been heavy mortality among some of the planktonic species entrained in the condenser cooling water. However, the effects of mechanical damage, chlorination and thermal injury cannot yet be sorted and evaluated.
b. Oysters have been killed in the outfall and have accumulated large quantities of copper near the outfall area.
c. The availability of fish near the plant outfall apparently increased during winter and declined during the summer, as compared with pre-plant periods.

d. Phytoplankton productivity appears to be lower in the area near the plant.
e. River water is sometimes heated all the way across the river, and temperature increase is noted for at least 3 miles up and down the tidal river.
f. Several important estuarine species *(Mya arenaria, Crangon septemspinosus, Neomysis americana* and others) are near their thermal tolerance limits under normal summer maximum temperatures, so that even small additions may be deleterious.

The results have already been sufficient to guide the establishment of new and much stricter standards for the release of heat in Maryland waters. They have also stimulated consideration of possible constructive uses of these great quantities of thermal energy. There may be promising opportunities in estuaries for the use of such heat in aquiculture (Mihursky, 1967).

Very recently, the Maryland Board of Natural Resources has recommended legislation which would require public agency approval *prior* to the construction, installation or operation of any such facilities. The applicant would also be required to provide sufficient data to permit reasonable estimates of the effects on natural resources, or pay the costs of obtaining such data by an agency which is acceptable to the Board. If enacted, this will correct the present faulty time sequence and place the burden of providing suitable data on the potential polluter.

The Chesapeake Bay Institute of the Johns Hopkins University contributed much to the development of the Rhodamine B dye method for examining water movement and studying flushing rates (Carpenter, 1961). With financial help from the Maryland Department of Health, they have used this technique to examine proposed sites for sewer outfalls and for power plant discharges. The results, which they interpret with high competence, have been useful both in preventing the overloading of sluggish tributaries and in identifying locations where excellent natural circulation can most quickly dilute pollutants.

The central floor of the Chesapeake Bay is surfaced with fine silts and clays (Ryan, 1953). Dredging for the creation and maintenance of deeper shipping channels produces fine-grained spoil which must be deposited elsewhere. About 45-90 million cubic yards will be thus handled in Maryland in the next 10 years.* Since the state must agree to the method and site of disposal, officials are aware of and deeply concerned about the dangers which may be involved.

Intensive studies of shallow-water spoil release are being made by the Chesapeake Biological Laboratory under a contract with the U.S. Bureau of Sport Fisheries and Wildlife, using funds from the U. S. Army Corps of Engineers. Pumping of about 1.4 million cubic yards of sediment had no gross observable effect on algal productivity, zooplankton, fish eggs, larvae or adults. The spoil did, however, spread over an unexpectedly wide area, smothering some of the benthic fauna (Biggs, 1967; Flemer et al., 1967; Cronin, Biggs and Pfitzenmeyer, 1967). Additional observations are underway.

The state has demonstrated its willingness to support such estuarine research by continuing appropriation and by provision of funds for contractual support of specific studies.

An imaginative new concept of waste disposal is now under consideration. A select committee has suggested that a state-wide Waste Acceptance Service be established to accept all municipal and industrial wastes. Producers would

*U.S. Army Corps of Engineers. Personal communication.

be charged on the basis of volume, strength and treatability of waste. If fully effective, this system would assure adequate treatment, allow use of all of the options for treatment, permit central effective decisions in contrast to action by hundreds of local centers, and still protect local control of zoning, development and land use. The plan is now under study for costs and feasibility. Many of the local estuarine pollution problems would be effectively corrected. Problems remain in treating mixed effluents and in placing outfalls for the large quantities of effluent. Such centralized collection might, however, be highly advantageous for the efficient removal of the fertilizing chemicals which now constitute one of the greatest threats to the estuary.

Development

Zoning for the control of future development is emerging in the tidewater areas of Maryland, but it is far from adequate. The Baltimore region has been particularly aggressive, and most of the counties have established zoning boards.

There is no broad pattern of planning and zoning for the entire estuarine area. Decisions are usually made at the local level, and no mechanisms yet exist for complete monitoring of the present and potential uses and value of the estuarine areas, for establishing the optimal balance of uses for those areas, or for guaranteeing that future developments will not irretrievably destroy some of the human uses of those areas.

Two Compacts, a Model and Cooperative Research

Maryland has entered into negotiations with neighboring states and with the federal government to work toward interstate-federal compacts for basin-wide management. The Susquehanna Basin Compact has been approved by New York and Maryland and by one legislative house in Pennsylvania. A draft of a Potomac River Basin Compact, drawn up by the states, has recently been published and is under discussion in Maryland, Pennsylvania, Virginia, West Virginia and the District of Columbia. Supporters are highly optimistic.

Each compact would create a Commission, with one representative from each signatory body. The Commission would complete comprehensive water resource plans; develop a balanced program to meet water needs; promote sound water management practices; review and approve water projects; operate major water facilities if necessary; regulate withdrawals; and seek to assure compatability between developments and the scenic, historic and environmental value of the basin. Each will augment, not replace, existing state and federal agencies, and actions affecting a state must usually be approved by the representative of that state.

Both compacts recognize the vast effects which water management throughout the basin has upon the estuarine areas. Both intend to meet the needs for river flow into the estuary, or at least give those needs full value in rationing the water supply and in planning improved management.

Unfortunately, it is not yet possible to provide such management agencies with accurate estimates of the optimal patterns of seasonal river flow for the benefit of estuarine resources. At present, recommendations are limited to insisting that river flow patterns are of vast importance to estuarine uses, that diversions or other major modifications in the river be approached conservatively, and that appropriate research be encouraged and fully supported.

The U.S. Army Corps of Engineers is authorized to construct a hydraulic model of the Chesapeake Bay. The model will occupy about 11 acres and

contain 645 thousand gallons of water. Horizontal scaling will be 1:1000, vertical scaling 1:100, and time scaling will be 1:100. The model will be in Maryland, and the pertinent agencies of the state are advising and assisting in planning for the facility and its programs. The model, which cannot operate before 1972, will make essential contributions to knowledge of the hydrographic effects of variation in river flow, the potentials of various possible outfall sites for hot water and waste effluents, and many other questions. It cannot directly answer biological problems, but it can indicate the areas of profitable research on many of those problems.

The large body of field data required for planning and verifying the model will probably be obtained through the Chesapeake Research Council, an informal association of three permanent research agencies with academic affiliation — the Chesapeake Bay Institute of the Johns Hopkins University, the Chesapeake Biological Laboratory of the University of Maryland and the Virginia Institute of Marine Science. The Council exists to encourage exchange among the staffs of the agencies and to facilitate cooperative research programs. The Council is probably the largest cooperating group of estuarine scientists in the world, comprising about 110 trained people, of whom 40 hold doctorates.

For the model, the Council has divided the Chesapeake into three areas, and each laboratory will conduct surveys of salinity, temperature, currents and tidal changes. About 200 stations will be occupied for at least 13 hours, and all data will flow into compatible computer systems. Each laboratory is independent and free to use any techniques or instrumentation which will yield the requisite accuracy, but plans are well coordinated. The field studies are scheduled for completion by April of 1969.

THE SUMMING UP

Where, then, does Maryland stand in her efforts to protect and enhance the vast estuarine areas which are essential to her future? She has made imaginative and effective progress on many fronts. These include improved fisheries management, high water quality standards, better recreational opportunities, inventory and acquisition of wetlands, partial zoning, basic and applied research, and interstate-federal efforts to manage large watersheds. Public interest has been stirred and the state government aggressively supports these positive accomplishments. Especially, Maryland has placed capable professionals in the pertinent state departments and expects them to act with vigor. They do. This is a fine record, not matched by many, if any, other small governments.

Are these efforts sufficient? The policy guide "Developing and Managing Estuaries" (Atlantic States Marine Fisheries Commission, 1966) provides a check-list of recommended state actions. Against these criteria, even more must be done in public education on estuaries; analysis and correction of legal problems; firm interim control of the destructive uses of estuarine areas; full inventory of present and future values and losses; adequate monitoring of water quality; acquisition of related land areas; clear enunciation of objectives and policies for estuarine management; sufficient support of research to obtain answers to the flood of new problems; and full coordination of all of the governmental agencies involved in estuarine use and management.

This is indeed a formidable list of jobs yet to be completed. Even with many evidences of excellence, Maryland has far to go to assure the continuing optimal uses of the estuarine areas. But so has every other state with large coastal areas. The estuarine zone of the United States is one of our most useful and vulnerable national resources.

LITERATURE CITED

ATLANTIC STATES MARINE FISHERIES COMMISSION
1966. Developing and managing estuaries. A statement of policy and guidelines for effective action. 8 p.

BIGGS, R. B.
1967. Overboard spoil disposal. I. Preliminary analysis of environmental effects. Proc. Nat. Sympos. Estuarine Poll. Am. Soc. Civil Engineers. Stanford Univ. (in press).

BLAIR, E. T.
1966. A new attack on sea nettles. Md. Conservationist *43*(1):16-22.

CARGO, D. G. AND L. P. SCHULTZ
1966. Notes on the biology of the sea nettle, *Chrysaora quinquecirrha*, in Chesapeake Bay. Chesapeake Sci. *7*(2):95-100.

CARGO, D. G. AND L. P. SCHULTZ
1967. Further observations on the biology of the sea nettles and jellyfishes in Chesapeake Bay. Chesapeake Sci. *8*(4):209-220.

CARPENTER, J. H.
1961. The Chesapeake Bay Institute Study of the Baltimore Harbor. Proc. Md. Del. Water and Sewage Assoc., 33rd Ann. Conf: 62-78.

CRONIN, L. E.
1966. An effort to promote a resource — Maryland's soft shell clam. Atl. States Mar. Fish. Comm. (Appendix to minutes). Nat. Res. Inst., Univ. Md., Ref. 66-107.

CRONIN, L. E.
1967. The condition of the Chesapeake Bay. Proc. 32nd. N.Amer. Wildl. Nat. Res. Conf. (in press).

CRONIN, L. E., R. B. BIGGS, AND H. T. PFITZENMEYER
1967. Relations of spoil disposal to shellfish areas. Nat. Shellf. Assoc. (in press).

FLEMER, D. A., W. L. DOVEL, H. T. PFITZENMEYER, AND D. E. RITCHIE, JR.
1967. Overboard spoil disposal. II. Preliminary analysis of biological effects. Proc. Nat. Sympos. Estuarine Poll., Am. Soc. Civil Engineers. Stanford Univ. (in press). NRI Contr. 329.

MANNING, J. H.
1960. Commercial and biological uses of the Maryland soft clam dredge. Proc. Gulf Caribb. Fish. Inst. 12th Ann. Session (1959): 61-67.

MANNING, J. H.
1967. A summary report on Maryland's commercial fisheries 1957-1966. Md. Dept. Ches. Bay Affairs. Mimeo, 10 p.

MANSUETI, R. J. AND E. H. HOLLIS
1963. Striped bass in Maryland tidewater. Nat. Res. Inst., Univ. Md., and Md. Dept. Tidewater Fish, 28 p.

MARYLAND DEPARTMENT OF PLANNING
1963. Newsletter, Vol. XVI, No. 7. 4 p.

MARYLAND GAME AND INLAND FISH COMMISSION
1956. Wetlands of Maryland. Job completion report, Pittman-Robertson Project No. W-30-R. Mimeo, 68 p.

MARYLAND WATER RESOURCES COMMISSION
1967. Water resources regulation 4.8. General water quality criteria and specific water quality standards. Water Res. Comm. Dept. Water Res. 30 p.

MATTHEWS, W. B.
1967. Guide for cruising Maryland waters. Dept. Ches. Bay Affairs. 4th Ed. 58 p. $5.00.

MIHURSKY, J. A.
1967. On possible constructive uses of thermal additions to estuaries. BioSci. *17*(10):698-702.

MIHURSKY, J. A. (WITH OTHERS)
1966. Progress report, 30 June 1966, Patuxent Thermal Studies. Nat. Res. Inst., Univ. Md.

MIHURSKY, J. A. (WITH OTHERS)
1967a. Progress report, 1 July 1966—31 December 1966, Patuxent Thermal Studies. Nat. Res. Inst., Univ. Md.

MIHURSKY, J. A. (WITH OTHERS)
1967b. Progress report, 1 January 1967—30 June 1967, Patuxent Thermal Studies. Nat. Res. Inst., Univ. Md.

MIHURSKY, J. A. AND V. S. KENNEDY
1967. Water temperature criteria to protect aquatic life. Amer. Fish. Soc. Spec. Publ. 4:20-32.

PRITCHARD, D. W.
1966. Fisheries vs. the exploitation of the nonextractive resources in estuaries. Ches. Bay Inst. ms. report, 9 p.

ROOSENBURG, W. H.
1967. Final report (and supplement) on "A study of the effects of thermal pollution on *Crassostrea virginica (Gmelin)* in the Patuxent River Estuary" Project 3-25-R1, Comm. Fish. Res. & Devel. Act., Nat. Res. Inst., Univ. Md. Mimeo, 5 p.

RYAN, J. D.
1953. The sediments of Chesapeake Bay. Md. Dept. Geol., Mines and Water Res. Bull. 12, 120 p.

VAUGHN, G. F., V. D. STOTTS, E. H. HOLLIS, AND R. C. HAMMER
1966. Wetlands committee report to Md. Board Natural Res. 4 p. and appended Inventory by Stotts. Mimeo.

WARK, J. W. AND F. J. KELLER
1963. Preliminary study of sediment sources and transport in the Potomac River Basin. Interstate Comm. on the Potomac River Basin. Tech. Bull. 1963-11:1-28.