perch were not impaired. Several juvenile and adult finfish species avoided the discharge area, especially during periods of high ambient temperatures and high plant loads; whereas yellow perch, pumpkinseed, and gizzard shad were attracted to Crane discharges during periods of low air and water temperatures (72, 81, 82).

• Conclusions

Power plant operation at Crane has a dominant role in defining the salinity and temperature regimes of the receiving water body especially during summer when high temperatures, low freshwater flows, and high generating loads occur. Plant-related discharge effects attributable to thermal loading were frequently detected locally under these conditions. Discharge effects at Possum Point apparently are similar to those observed at Crane and generally do not impact upon Maryland waters. Discharge effects at Vienna are negligible.

Impingement and entrainment losses at Crane did not measurably impact upon local aquatic populations or economic or ecological resources of the region. However at Possum Point and Vienna entrainment affected striped bass and other harvested fish populations. These impacts were small, affecting only a few percent of bay-wide catches. The operations of power plants in the tidal fresh-oligohaline zone thus do not adversely affect resources inhabiting this habitat zone. The additional effects on tidal fresh-oligohaline habitat likely to result from the Perryman facility is not expected to be large provided intake and discharge structures are designed to minimize environmental effects. The Perryman site is not located in a major spawning area for anadromous or semi-anadromous species.

<u>Nontidal Fresh</u>

The two Maryland steam electric stations located on riverine waters are R.P. Smith and Dickerson, both on the Potomac River (Table IV-2a). Each facility uses, at times, a substantial portion of the actual river flow for cooling purposes. The plants are relatively old, of low to medium generating capacity, and located in areas inhabited by typical warm water riverine biological communities (83, 84, 85).

Conowingo Dam on the Susquehanna River is the largest hydroelectric generating station in Maryland. Significant stocks of resident and anadromous fish species inhabit river waters below the dam and historically, large runs of anadromous species occurred in regions of the Susquehanna above the dam (86). Because of the commercial and recreational importance of these fish stocks, the State is conducting a comprehensive program to assess the effects of dam operations on downstream habitats and has intervened in relicensing proceedings for Conowingo before the Federal Energy Regulatory Commission.

Five licensed, small-scale hydroelectric stations presently operate in Maryland and two are under construction (Table IV-2b). Two additional small-scale hydroelectric facilities are believed to be operating without appropriate permits and licenses. Four other facilities are planned and are at various stages of the licensing procedure. Most operating facilities in the state were licensed approximately 20 years ago and are not scheduled for relicensing for approximately ten years. The State is interacting with the developers to insure that designs of new facilities minimize environmental impact. The major environmental impact likely to occur is modification of the natural stream flow. Water quality changes and adverse impacts of construction activity may be of concern at some sites. No field studies to evaluate the impacts at small-scale hydroelectric sites in Maryland have been made.

- Entrainment

Entrainment of phyto- and zoo-plankton are not major problems at steam generating stations located in Maryland's nontidal freshwater habitats (83, 84, 85). However, entrainment of ichthyoplankton may adversely impact local fish populations. Approximately 10 percent of the ichthyoplankton drifting past the Dickerson plant are entrained (83, 84). Ichthyoplankton entrained at the R.P. Smith and Dickerson facilities are mostly forage or rough species; very few are sport fish. Economic and ecological losses due to ichthyoplankton entrainment at riverine plants in Maryland are considered minor (84, 85).

Entrainment losses have not been estimated for the Conowingo hydroelectric plant or for any of the small-scale hydroelectric sites in Maryland. However, turbine-related fish mortalities may be nearly 100 percent under some circumstances (87). Survival depends on the age and size of the fish, as well as type of turbine and its operating characteristics (87).

The restoration of anadromous fish stocks to regions of the Susquehanna River upstream of Conowingo Dam is now being planned. Because virtually all summer river flow passes through the turbines at Conowingo, the probability of entrainment is high for juveniles of anadromous species migrating downstream. Conowingo turbines also entrain juvenile gizzard shad from the reservoir, where the species has undergone recent population increases (88). The trophic effects that introduction of gizzard shad into the lower Susquehanna River and the upper

Chesapeake Bay have on downstream habitats have not been determined.

- Impingement

Impingement at R.P. Smith is negligible in terms of effects on fish populations and the monetary value of the impinged fish (85, 89). Impingement at Dickerson is also negligible except for sporadic high impingement episodes (84).

Because Conowingo and small-scale hydroelectric plants in Maryland use trash racks with openings of several inches to protect internal structures from debris, fish are not impinged at these facilities. Rather they are probably entrained through them.

- Discharge Effects and Habitat Modification

Discharge effects on insects and periphyton were observed at Dickerson but the effects were not large in terms of magnitude or areal extent (84). Several species of fish were attracted to the thermal plume in winter. A few species avoided the plume in warm periods (90). Feeding habits and the condition factor of some fish collected below the discharge differed slightly from those collected from reference areas (91). These differences were probably a consequence of food availability and were not large enough to suggest that changes had occurred in the structure of the food web.

Discharge effects on periphyton and benthic organisms at the R.P. Smith facility tend to be minor (85).

Except for localized impacts in the plume, there are no major river-wide impacts on fish populations.

The discharge and operating regime of Conowingo Dam have significant impact on fish stocks and aquatic biota downstream of the dam. The daily and weekly peaking-generation cycles of the plant produce large fluctuations in downstream flow (0-75,000cfs) and water levels (9 feet or more at the powerhouse). These fluctuations affect downstream water quality (92). During night time and weekend turbine shutdowns, reduced dissolved oxygen concentrations occur in the powerhouse tailrace and areas downstream of the dam. These low dissolved oxygen conditions have been associated with local fish kills.

Dam-induced fluctuations in water level, flow, and water quality affect the abundance of benthic invertebrates and indirectly affect the availability of food for white perch, the dominant fish species in the Susquehanna River below the Conowingo facility (93). During periods of discharge, white perch feed on benthic invertebrates drifting downstream, as well as on zooplankton coming from Conowingo Reservoir. Food sources from the reservoir and possibly invertebrate drift are severely reduced during periods of turbine shutdown. The effect of these fluctuations in food availability on fish stocks in the lower Susquehanna River is currently being evaluated. The dam structure (which lacks a fish passage) limits the access of anadromous fish species to upstream spawning grounds.

In addition to Conowingo, two nuclear power plants, one coal-fired plant, and three hydroelectric plants are located on the lower 80 miles of the Susquehanna River. Once the Susquehanna River enters the chain of hydroelectric impoundments, its velocity and turbulence are greatly reduced, allowing sediment and particulate organic matter to sink to the bottom. In the two largest impoundments (Safe Harbor and Conowingo Reservoirs), much of the settling organic matter decomposes before it reaches the bottom (depleting dissolved oxygen and increasing dissolved nutrient concentrations in the water). Approximately half of the material entering the reservoir (or one million tons) accumulates in the Conowingo reservoir each year. The settling of particulate matter in Conowingo Reservoir also scavenges water-borne radionuclides released by the Peach Bottom Nuclear Power Plant in Pennsylvania, resulting in deposition and long-term burial in sediments (see Chapter V). Conowingo and the reservoirs upstream in Pennsylvania thus prevent the major portion of the sediment and particulate nutrient loads of the Susquehanna River from reaching the Chesapeake Bay, but at the expense of severe localized reductions in water quality.

- Conclusions

In general, entrainment and impingement impacts are small at freshwater facilities and discharge effects are localized. There is no evidence of any cumulative adverse effect of the thermal discharges on the nontidal Potomac River. Environmental effects of the long-term degradation of water quality in the Potomac far exceeds any observed cumulative or long-term power plant effects.

The effects of the Conowingo hydroelectric facility on nontidal fresh spawning and nursery habitats downstream of the dam are severe. Dam operations control water level, flow, and water quality in aquatic habitats downstream of the dam, and also affects the abundance and type of biota that can utilize these habitats. Anadromous fish are denied access to upstream spawning areas. The effects of small-scale hydroelectric facilities on Maryland's rivers is unknown but are currently being evaluated. These effects are anticipated to be small as long as downstream fluctuations in river flow are minimized. State permits required for licensing of small-scale hydroelectric facilities require maintenance of a minimum flow. This should minimize downstream fluctuations in water level and thus environmental impacts.

E. Chlorine Use

The buildup of living organisms on the walls of water boxes and other internal structures in front of condensers is a major problem in the summer at most Maryland power plants. These growths are usually dominated by larger biota, which can slough off and clog condenser tubes, reducing flows and causing plant shut-downs. The buildup of microorganisms on condenser walls reduces the efficiency of heat exchange and affects condenser performance. Seven of the eleven operating power plants in Maryland inject chlorine (a strong oxidizing agent that is widely used as a disinfectant at wastewater treatment facilities) into condenser cooling water to control biofouling. Because chlorine is injected into cooling water just after plant entry, its use adds a chemical stress to entrainment (94).

Studies at Morgantown and Chalk Point indicate that higher plankton mortality occurred during periods of chlorination than when chlorine was not used (24, 30). Laboratory biotoxicity studies further demonstrate that early life stages of most fish and shellfish are particularly sensitive and adversely affected by chlorine and its residuals (30, 94). Mortalities occur at very low concentrations (ppb ranges). Fish kills from excessive use of chlorine were reported at Chalk Point in the 1960's. Chlorine also affects the growth and physiological condition of biota at sublethal levels (94). Some of the chlorine decay products are long-lived, suggesting that adverse effects may not be local (95).

In the Potomac estuary, wastewater treatment facilities account for about 80 to 90 percent of chlorine inputs. Power plants account for most of the remainder (24). The relative importance of power plants as a source of chlorine is probably similar in other regions of the Bay. Thus, power plants are a significant source of chlorine discharges, but are less important than wastewater treatment facilities.

The decay of chlorine in natural waters is a two-phase process (95). The first phase is very rapid, accounting for about 90 percent of the loss of active oxidant. It is so rapid that the second phase begins before passage through the Chalk Point and Morgantown plants has been completed (95, 96). The time for water to pass through these plants is on the order of 4 to 5 minutes. The second phase of chlorine decay generally takes from 1 to 2 hours. Chlorine decay is faster in estuarine water than in freshwater, with maximum rates of chlorine decay occurring at about 10 to 15 ppt salinity (95).

The chemistry of chlorine decay and factors that determine the amount of chlorine required to prevent biofouling in natural waters have been thoroughly studied for Maryland. The amount of organic material in water is the single most important factor determining chlorine decay (95, 96, 97). Other major factors that affect chlorine decay are adsorption on colloidal substances, catalytic decomposition of chlorine by condenser materials, and volatilization.

Two economically feasible chemical alternatives to chlorine -- bromine chloride and ozone -- are also strong oxidizing agents that have chemical properties and environmental consequences similar to chlorine (96, 98). Chemical removal of chlorine from effluents (dechlorination) will reduce the levels of active oxidant in the discharge area and hence reduce toxicity there (99). However, dechlorination will do little to reduce the mortality of entrained organisms since they would be exposed to free available chlorine. At present, the amounts of active oxidant released to the environment at Maryland power plants is low, and dechlorination has not been shown to eliminate longlived chlorine decay products. Discontinuing the use of chlorine and replacing it with mechanical cleaning methods would be expensive. In addition, mechanical cleaning methods, designed to control biomass buildup on condenser tubes (i.e., Amertap), do not control biomass buildup on the walls of water boxes and intake and discharge conduits, which are a serious problem affecting long-term plant operations.

Ultrasound has been shown to control biomass buildup on glass slides in laboratory tests, but this technology has not been developed enough to be seriously considered for implementation at operational power plants (100). Although ultraviolet light is a suitable alternative to chlorine for small wastewater treatment facilities, the large volumes of water required for once-through condenser cooling at power plants render this technology unsuitable. Backwashing with heated water has been used in other states to control biofouling (101). This technology has not been seriously evaluated for Maryland waters, because the high levels of fouling in discharge canals and conduits of most Maryland power plants suggest fouling organisms in Chesapeake Bay can tolerate temperatures between 40 and 45 C (30, 35). The T and temperature needed to make thermal backwashing a viable biofouling control technology would thus be large and may have their own adverse environmental consequences. Retrofitting of thermal backwash to existing facilities would also probably be prohibitively expensive. A promising new technology for the control of biofouling, especially on water boxes, is the use of antifouling coatings, particularly organotins, such as tributyltinfluorides and tributyltinoxides (102). At present, insufficient data are available on the effectiveness of these coatings and their long-and short-term environmental consequences to determine if they are reasonable alternatives to chlorine use (102, 103).

In summary, chlorine injection probably will continue to be used to control biofouling on internal plant structures in Maryland, at least for the next decade. This is because chemical alternatives to chlorine have environmental consequences similar to those of chlorine, and most other alternatives are either expensive or are not sufficiently developed for implementation. The allowable chlorine discharge limits at Maryland power plants has recently been lowered from 0.5 ppm to 0.2 ppm or less, and use of Amertap in condenser tubes is strongly recommended when continuous chlorination is required. The need for continuous chlorination must also be justified using field tests. These new discharge requirements are sufficiently strict so that spawning and nursery habitats should be protected and ecosystem integrity should be preserved.

F. Best Available Technology (BAT)

Previous discussions indicate that entrainment and impingement mortalities are the primary mechanisms through which power plant operations adversely impact Maryland's aquatic habitats. Numerous technologies have been developed for reducing the entrainment and impingement impact of intake structures (104). These structures fall into two basic categories: those which reduce actual rates of entrainment or impingement and those which reduce mortality following entrainment and impingement. These two types of BAT's can be further classified into three basic categories (Table IV-9). These are:

- Physical barriers such as intake screens or nets which prevent withdrawal of organisms
- Behavioral barriers which cause fish to actively avoid intake flows
- Methods that collect fish after contact with intake structures, and then displace them to other areas with minimal harm.

These devices are often used in combination.

Physical barriers are the most effective method for excluding eggs and early life stages of fish from entrainment, as well as for reducing impingement levels. However, fouling biota rapidly grow on physical barriers and retard flows. Biofouling is especially a problem when the mesh of physical barriers is small enough to exclude fish eggs and larvae. Behavioral barriers are effective at reducing impingement for schooling fish, but are ineffective at deterring planktonic organisms, including ichthyoplankton, because these biota generally lack sufficient swimming ability to react to the stimuli provided. Collection of organisms after impingement is only partially effective at reducing impingement losses. Some of the organisms

Table IV-9. Three Categories of Best Available Technology for Intake Structures

Physical Barriers	Behavioral Barriers	Devices that Reduce Post-Impingement Mortality
Vertical Travelling	Air bubble curtains	Fish pumps Screens
Wedge wire screens	Hi-jet water curtain	Ristroph screens
Vertical angled travelling screens	Chains or cable	Screenwash relocation
Horizontal angled travelling screens	Electrical screens	Continuous screen rotation
Single entry-double exit screens	Flashing lights	
Double entry-single exit screens	Loud sounds	
Infiltration beds	Louvers	
Rotating drums	Odor	
Gabion dam	Velocity caps	
Radial wells		
Barrier nets		

collected, particularly early life stages and juveniles, are very sensitive to handling and abrasion and suffer high mortalities.

Two intake control technologies that appear to be particularly promising for Maryland applications have been identified. These are barrier nets and wedge-wire screens (105, 106, 107). Barrier nets reduce impingement levels by denying fish access to intake areas. Their installation generally is comparatively economical and barrier nets have been shown to reduce impingement levels at power plants outside Maryland (107). Wedge-wire screens are cylindrical wire drums that can be constructed of various materials and wire spacing. They are usually placed with their axis perpendicular to the natural currents. Wedge-wire screens reduce entrainment of planktonic life stages and impingement of juveniles and adults because velocities over most of the screen are low relative to the natural currents (105, 106).

Testing of a barrier net at Morgantown in 1980-1981 was unsuccessful because jellyfish and ctenophores clogged the net and caused it to collapse (108). Preliminary findings of a barrier net test currently being conducted at Chalk Point suggest they can be used to exclude large fish and blue crabs from the intake area, thereby reducing impingement as well as auxiliary pump entrainment levels. Biofouling was overcome at Chalk Point by frequent cleaning and changing of nets. A barrier net is also being tested at the power plant intake of the Bethlehem Steel facility in Baltimore Harbor.

Results of field and laboratory tests indicate that wedge-wire screens are effective at reducing both impingement and entrainment by acting as both physical and behavioral barriers. Over 95 percent of the striped bass eggs that would normally have been entrained through a 1-cm mesh traveling screen were excluded by a 1-mm mesh wedge-wire screen in flume tests. The mortality rate of striped bass eggs impinged on 1-mm wedge-wire screens was low (<2%), and most eggs that contacted the screens were rapidly washed off by relatively weak currents (67). Essentially all striped bass larvae greater than 11 mm were able to avoid entrainment through 1-mm wedge-wire screens in flume and field tests. Approximately 40 percent of striped bass larvae smaller than 11 mm were entrained through 1 mm screens. Most of this entrainment occurred at locations on the screen where intake velocity exceeded 15 cm/s. Field tests of wedge-wire screens also indicated that entrainment of ichthyoplankton, other than striped bass, and large invertebrates was reduced by 50 to 100 percent (105). Species evaluated by these tests included bay anchovy, naked goby, isopods, mysid shrimp and small crustaceans. However, the number of zooplankton entrained was not reduced (105). Essentially no juvenile or adult fish and no crabs were impinged during the above mentioned wedge-wire screen field tests (67, 105). The efficiency of screen operations was related to intake velocities and mesh-size (67, 105, 106).

Biofouling of wedge-wire screens was identified as the major problem that would affect long-term operations (104). At the Vienna and C&D canal, the most suitable method to overcome biofouling was determined to be mechanical cleaning and backflushing with air (67). Preliminary results of present studies evaluating backflushing with air to reduce biofouling are promising.

In summary, a wide variety of work is currently being conducted in Maryland to identify technologies that reduce impingement and entrainment levels. Two technologies (barrier nets and wedge-wire screens) are currently being field tested. Both look promising. Biofouling is the major operating problem which must be overcome before these technologies can be recommended for application at new facilities or retrofit to old ones. Ristroph screens have been approved for installation at the BRESCO facility in the Harbor.

G. Long-Term Effects of Power Plant Operations on Water Bodies in Maryland

Most power plants in Maryland are designed for 20-40-year operation, and such long-term operation may have cumulative effects on the biota of receiving water bodies. For example, continual low-level cropping of entrainable life stages may result in long-term population declines, or the continual low-level release of copper may build up to toxic levels. Because of the potential long-term consequences of power plant operations, PPSP and the utilities have initiated long-term monitoring programs in mesohaline and riverine habitats (36, 90). To date these programs have produced the following results.

A preliminary assessment of long-term power plant effects on the benthos at Calvert Cliffs found higher standing stocks and more successful recruitment of some populations at thermally affected locations than at reference areas (36). Lower abundances in the vicinity of plant discharges occurred for only a few species. Thermal discharges caused shifts in the timing of reproduction of one or two benthic species. The largest source of variation in abundance for most species was natural seasonal fluctuations. Large year-to-year differences in stocks occurred for almost all species, much of which was associated with natural salinity fluctuations. Natural sources of variation far outweighed any long-term changes from power plant operations. The relationship between long-term power plant effects and year-to-year changes in plant operating conditions and climatic factors is currently being investigated by PPSP.

Results of studies assessing the long-term effects of power plant operations on benthic and fish communities in fresh-water Potomac are not yet available. However, from findings of earlier studies (1956-1975) at Dickerson, it was concluded that long term changes in the makeup of diatom and benthic communities in the vicinity of plant discharges have occurred since 1968 (84). However, these changes were not restricted to the thermally affected area but were riverwide, indicating that they were due to perturbations other than power plant operations. The only consistent long-term power plant effects observed at Dickerson were enhanced diatom growth and slight reduction in the number of diatom species at the thermally affected stations relative to control sites (84).

The large amounts of data collected over many years at Chalk Point and Calvert Cliffs and in the Potomac also lend themselves to evaluation of long-term power plant effects (2, 21, 30). The composition of fish communities at these sites have varied from year-to-year. The most notable change in fish communities has been the appearance of spot as a dominant fish during the early 1970's, with a corresponding decline in the abundance of white perch. This pattern occurred throughout Chesapeake Bay and was not limited to the vicinity of power plants. Thus, the decline apparently is not related to plant operations (2, 21, 55). Although entrainment of sensitive life stages of forage fish at Chalk Point could potentially affect long-term abundances of adult populations, standing stocks of forage species in the Patuxent have increased by an order of magnitude since power plant operations began (30, 55). Benthic biomass of the Patuxent has also increased by an order of magnitude since Chalk Point operations began. Both of these long-term changes are riverwide and are not restricted to thermally affected areas. Thus, they cannot be attributed to power plant operations. Rather, they are thought to be associated with long-term fluctuations in nutrient and sediment loadings from upstream sources (109).

In summary, power plant operations have long-term effects on the biota in the immediate discharge area of several power plants. These changes generally are localized and frequently consist of increases in production rather than decreases. Relative to natural variation or long-term changes associated with other perturbations, long-term power plant effects are small and do not appear to have any adverse consequences on system stability or food-web dynamics.

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