The major conclusion from an analysis of the 304(l) listing process was that inadequate data exist to determine whether power plants are regularly discharging toxic chemicals at concentrations exceeding criteria. Since plants are not required to sample effluents for priority pollutants on a regular basis, data that were used to place plants on the preliminary C list were as much as four years old. Although more recent data were obtained to place facilities on the final list, it is not known how well these data represent long-term average concentrations.

Conclusions

Atmospheric contaminants such as heavy metals and PAHs tend to concentrate in the surface microlayer of the Chesapeake Bay and its tributaries. However, power plants were not implicated as a major source of these contaminants. Levels of arsenic and mercury were measured in water, sediments, and fish from ponds in the vicinity of the Chalk Point, Dickerson, and Morgantown plants. Concentrations of mercury were elevated in fish from these ponds relative to a control pond removed from power plants but were not greatly elevated above levels measured in Potomac River fish.

Coal leachates have been characterized as acidic iron sulfate solutions that contain environmentally hazardous concentrations of metals. Laboratory exposures of mummichogs to neutralized Chalk Point coal leachate resulted in decreased spermatogenesis. Field studies indicated that spermatogenesis in mummichogs near the Brandon Shores, Chalk Point, and Morgantown plants and several miles upstream from these plants was lower than at a control site away from these plants. Impact assessment studies at the Vienna Fly Ash Disposal Site did not indicate that bioaccumulation of toxic metals occurred in local fish. An *in situ* bioassay study at the Faulkner Ash Disposal Site indicated poor larval yellow perch survival in Zekiah Run. Since both upstream and downstream areas were similarly impacted, the effects are apparently not site-related. The practice of storing leachates in containment ponds and neutralizing leachates with carbonates should minimize impacts to receiving systems.

Chlorine use adds a chemical stress to entrainment; studies at Chalk Point have indicated higher entrainment mortality during periods of chlorination. No local depletions of benthic populations have been observed in the vicinity of power plant discharges following extended periods of chlorine use. In the past, copper released from condenser tubes was found to bioaccumulate in oysters in the Chalk Point discharge area. The installation of titanium condenser tubes at Chalk Point has eliminated this problem.

MDE has initiated a biomonitoring program, which requires effluent toxicity testing at several power plants and the use of these tests in compliance monitoring. Results of these studies indicate that the effluents were not acutely toxic. The Brandon Shores and Vienna plants were placed on Maryland's Clean Water Act section 304(l) list of toxic dischargers due to effluent copper concentrations that exceeded Maryland criteria. However, an analysis of the

304(l) listing process indicates that inadequate data exist to determine whether power plants are regularly discharging toxic chemicals at concentrations exceeding criteria.

H. Control of Biofouling

Maryland power plants inject chlorine into condenser cooling water to control biofouling (Morgan 1968). Chemical removal of chlorine from effluents (dechlorination) reduces the levels of active oxidant in discharge water, thereby decreasing its toxicity in the receiving waterbody (Hall *et al.* 1981). At present, the amounts of active chlorine oxidant discharged to Maryland receiving waters from power plants are low; therefore, dechlorination of power plant discharges is not necessary and would not be cost-effective (Breisch *et al.* 1984).

Information on the effects of chlorine use on aquatic biota was summarized in the previous section. The problem of biofouling, and the impacts of dechlorination procedures and alternatives to chlorine, were discussed in CEIR-6. This section summarizes that information.

The buildup of living organisms on various plant structures and equipment is a major engineering problem at most estuarine power plants (Diaz-Tous and Miller 1983). Biogrowth within condenser tubes, as well as growth that has sloughed off parts of the intake structure, can clog condenser tubes, reducing condenser performance and causing plant shutdowns. Colonial species, such as bryozoans and hydroids, which grow rapidly, are the major species that adversely affect power plant operations. Some tube building worms, crustaceans and barnacles are also of concern. Tubes constructed by free living invertebrates can clog fine-mesh intake screens and frequently serve as precursors for the attachment of colonial forms on clean surfaces (Weisberg *et al.* 1984b). Different groups of biofouling organisms are of concern in the different salinity zones. Biofouling growth mainly occurs from early spring to late fall; however, it is most rapid from June to September (Weisberg *et al.* 1984b).

Historically, biofouling has not been a problem at power plants located on Maryland freshwater habitats. However, the Asiatic clam, *Corbicula fluminea*, has recently invaded freshwater habitats throughout the United States, including Maryland, and has characteristics (e.g., rapid growth, high fecundity, planktonic developmental stages) that can severely impede freshwater power plant operations (Mattice 1983). The zebra mussel, *Dreissena polymorpha,* which has recently invaded the Great Lakes, is also a potential threat to riverine power plants in Maryland if it spreads to freshwater habitats in the state.

As discussed in Section G, many Maryland power plants use continuous chlorination to control biofouling of internal plant structures (Bongers *et al.* 1975; MMES 1985a). However, biofouling growth at some power plants can be controlled by periodic application, which reduces the amount of chlorine discharged to the environment and minimizes cost. Therefore, Maryland utilities are required to conduct studies to demonstrate the need for continuous chlorination. Studies at Chalk Point indicate that intermittent chlorination is not effective during the peak fouling season (PEPCO 1987). The first year of a three-year chlorine minimization study has been completed at the Morgantown plant. The first year studies are intended to determine the minimum effective concentration of chlorine when used continuously. In the second and third years, trials of intermittent chlorine use will be conducted at Morgantown and Chalk Point.

A number of alternatives to chlorine are available for controlling biofouling, but many have similar environmental consequences or other disadvantages. Economically feasible chemical alternatives to chlorine for power plant application include bromine, chloride and ozone (Breisch *et al.* 1984). Both are strong oxidizing agents, and both have environmental consequences similar to those of chlorine (Bongers *et al.* 1977, Mangum and McIlhenny 1974).

Mechanical cleaning systems, such as the commercially available Amertap system, and backwashing with heated water, can remove biofouling from condenser tubes. Ultrasonic vibrations or ultraviolet light theoretically kill fouling organisms before they enter the plant. The success of these antifouling technologies is limited either due to their restricted applicability to portions of the intake structure, or their reduced effectiveness with Chesapeake Bay fouling species and large volumes of intake cooling water. Thirty-day field tests indicate that the backflushing of wedge-wire screens with air is a cost-effective way to control biofouling (Weisberg *et al.* 1984b), although no Maryland power plants presently utilize wedge-wire screens.

Another effective technology for the control of biofouling is the use of organotin-based antifouling paints (Gitlitz 1981; Hall *et al.* 1983; Waldock and Thain 1983; Beaumont and Budd 1984); however, concern about environmental impacts of tributyl tin (TBT, the most common organotin antifouling pain additive) has led Maryland and Virginia to pass legislation prohibiting the use of TBT for biofouling control. Other antifouling coatings include the various types of nontoxic "slick-paints", which make surfaces too smooth to permit attachment of biota. Preliminary findings on the effectiveness of some of these paints are promising.

Because of the disadvantages or uncertainties involved with other antifouling methods, chlorine injection will continue to be used to control biofouling of internal power plant structures in Maryland in the near future. Other chemical additives have environmental consequences similar to those of chlorine, and most other biofouling control technologies are either expensive or not sufficiently developed for implementation. Spawning and nursery habitats of RIS will probably be protected, and ecosystem integrity preserved, as long as regulatory discharge limits for chlorine are maintained. Nontoxic means of controlling biofouling are being evaluated and developed for power plant applications. These materials may prove to be a viable solution to a major problem common to power plants.

I. Best Available Technology and Operating Procedures

Numerous technologies, including both intake technologies and modifications of operating practices, have been developed for reducing entrainment and impingement impacts (Cannon *et al.* 1979; Weisberg *et al.* 1984a; MMES 1985a).

Intake Technologies

Intake technologies can be classified into three categories: physical barriers, behavioral barriers and collection. Physical barriers have proven most successful to date.

- Physical Barriers

Physical barriers, such as intake screens or nets, reduce withdrawal of organisms. They are very effective in reducing entrainment of early life stages of fish and in preventing impingement of adults and juveniles. However, biofouling of the barrier is generally a problem when the mesh size of physical barriers is sufficiently small to exclude fish eggs and larvae (Weisberg *et al.* 1984a).

Two promising intake control technologies for Maryland applications are barrier nets and wedge-wire screens. Barrier nets generally are economical to install and maintain, particularly for retrofitting to older plants, and effectively reduce impingement in both estuarine and freshwater habitats (Haymes and Patrick 1984; MMES 1985a). Physical site limitations may prevent their retrofit to some Maryland power plants such as Morgantown and Calvert Cliffs (Wietz 1982).

Wedge-wire screens are cylindrical wire drums that are constructed of wire mesh over frameworks of various other materials, usually placed with their axis perpendicular to the natural currents. Natural currents rapidly wash away organisms that accumulate near or on them into by-pass flows (Hanson 1977). Their fine mesh spacings (1 to 3 millimeters) generally keep entrainment of early life stages low.

In field and laboratory tests, wedge-wire screens reduced entrainment of ichthyoplankton and large invertebrates by 50 to 100 percent but did not reduce the number of zooplankton entrained (Weisberg *et al.* 1984a). Essentially no fish or crabs were impinged on the screens during the field tests (Weisberg *et al.* 1984a). Some fish larvae may avoid the complex flow patterns near the surface of the screens, but most appear to be physically excluded by the fine mesh wire spacing (Weisberg *et al.* 1984a). Wedge-wire screens are moderately expensive to retrofit into operational power plants or install into new plants. However, they are most cost-effective and can approach the effectiveness of closed-cycle cooling (MMES 1985a).

- Behavioral Barriers

Behavioral barriers (e.g., air bubble curtains, sound) are designed to cause fish to avoid intake flows. These barriers are not effective at reducing impingement of non-schooling fish or at reducing entrainment and impingement of early life stages and most older schooling fish (ASCE 1982; Cannon *et al.* 1979). Most fish simply do not respond to the stimuli provided.

- Collection

Collection of organisms after impingement is only partially effective at reducing impingement losses. Some of the organisms collected, particularly early life stages and juveniles, are sensitive to handling and abrasion and suffer high post-impingement mortality (Tatham *et al.* 1977).

Operating Practices

Because of relatively low capital costs, modification of plant operations is frequently the most cost-effective approach to reducing many environmental impacts. Three power plant operating practices that have been evaluated in Maryland are intake screen wash cycles, use of auxiliary tempering pumps, and, as described previously, continuous chlorination.

- Intake Screen Wash Cycles

Most Maryland power plants rotate intake screens every eight hours to clean them of impinged organisms and debris (Bongers *et al.* 1975; MMEC 1980; EA 1981c; MMES 1985a). Estimation of annual impingement loss has led generally to the conclusion that the 8-hr screen wash cycle losses were less than those associated with shorter cycles, but other factors may have made these estimates deceptively low for longer cycles. Some Maryland utilities are now performing studies to estimate the magnitude of loss due to decay, falling off, and predation, which will help to optimize screen wash cycle times.

- Auxiliary Tempering Pumps

As previously discussed, auxiliary tempering pumps were used at Chalk Point to temper thermal and chemical effects in the discharge canal and nearby by pumping additional water into the discharge (MMES 1985a). However, studies by both PEPCO and PPRP showed that turning off the pumps would reduce entrainment and impingement while not significantly increasing downstream mortalities (Loos 1987; Cadman and Holland 1986). PEPCO has now discontinued use of the pumps.

Conclusions

Two intake control technologies that are applicable to Maryland, barrier nets and wedge-wire screens, have been identified and field tested, and appear to be effective. In addition to physical alterations of power plants, changes in operating practices have also helped to minimize power plant impacts on aquatic resources.

J. Long-Term Effects of Power Generation on Maryland's Benthic Resources

PPER has used benthic monitoring as an integral part of its monitoring program to assess long-term environmental impacts of power plant operations in Maryland since 1972. In 1984, PPSP combined its estuarine benthic monitoring with that of the Maryland Department of Health and Mental Hygiene-Office of Environmental Programs, which is now the Maryland Department of the Environment. The joint monitoring program, which samples throughout the Maryland portion of the Chesapeake Bay, is an important element of Maryland's effort to determine the state of the Bay and to track the effectiveness of Baywide pollution abatement and water quality management actions. In 1983, PPRP expanded its activities, establishing a benthic monitoring program in the riverine portion of the Potomac River. Sampling is concentrated in areas potentially affected by the R.P. Smith and Dickerson power plants.

The PPER long-term benthic monitoring programs are based on the concept that the composition of benthic communities is largely determined by ambient sediment and water quality. Therefore, the variety, abundance, and productivity of benthic organisms are good indicators and integrators of water and sediment quality impacts of power plant operations. Benthic organisms are good indicators for other reasons. Because they generally complete their life cycles within specific regions of the Bay or rivers, their responses to power plant operations and pollution abatement activities are region-specific and may be quantified and evaluated. Since benthos are an important intermediate link in the food web, their responses to power plant operations are likely to be representative of the responses of other living resources.

The PPER studies compare and contrast spatial and temporal characteristics of benthic population and community properties in thermally affected areas with those of reference areas to assess power plant effects. Such comparisons may also be made at different times to assess the effects of actions or events (Holland *et al.* 1986; Holland *et al.* 1989). Benthic sampling locations in estuarine waters encompass the range of salinity and sediment types that occur throughout Maryland (Holland *et al.* 1989). Sampling locations in the freshwater reaches of the Potomac River span the Piedmont and the Ridge and Valley regions of Maryland (Vannote and Sweeney 1985; Shaughnessy and Holland 1989). The relevant physical and chemical properties of the water and sediments are also measured at each sampling location. Sampling occurs throughout the year, most intensively during periods of highest abundance and rapid growth.

Power Plant Effects on Estuarine Benthos

As most power plant impacts on benthos were discussed earlier in the chapter, they are very briefly reviewed here. Although large numbers of planktonic life stages of benthic organisms are entrained and killed by power plants, these losses do not adversely affect nearby or regional benthic populations (Holland *et al.* 1979, 1985a; Holland and Hiegel 1981; Heck *et al.* 1981; MMES 1985a; Holland *et al.* 1989). Power plant discharges often contain measurable amounts of chlorine and copper, which are toxic to benthic organisms at extremely low levels (Bongers *et* *al.* 1975; Brungs 1976; ANSP 1983a), but the consequences of such discharges to environmental quality also prove to be minimal. Only at Chalk Point did releases of chlorine and copper have any potential long-term cumulative impacts (MMES 1985a), and the effects of copper discharge there have recently been eliminated completely with the installation of titanium condenser tubes to replace the copper-nickel tubes. Chlorine discharges have not been actually observed to cause depletions of benthic populations in the vicinity of power plant discharges, even following extended periods of chlorine use (MMES 1985); moreover, the concentrations of the most toxic forms of chlorine in power plant discharges are within acceptable limits (Sugam and Helz 1977; Helz 1981). This is because chlorine decays rapidly to relatively nontoxic forms in estuarine waters.

High-velocity discharge systems at Morgantown and Calvert Cliffs have altered sediment characteristics in their immediate discharge regions by removing softer sediments, leaving no suitable habitat for burrowing benthos. However, fouling organisms, generally more abundant in scoured areas, have approximately the same resource value as burrowing organisms, resulting in no net loss. Power plants with low-velocity discharge systems (e.g., C.P. Crane and Chalk Point) neither strongly influence nearfield sediment characteristics nor adversely affect nearfield habitat characteristics (EA 1981b; MMES 1985a).

Thermally affected areas near Maryland power plants promote population growth and earlier reproduction in some benthic species (ANSP 1983a; MMES 1985a; Holland *et al.* 1985a; Holland *et al.* 1985b). Power plant discharges, however, have not excluded any species or caused out-of-season reproductive failure. In general, thermal discharges at Maryland power plants do not exceed thermal tolerances of benthic organisms except within the discharge canals of the Chalk Point, C.P. Crane, and Morgantown facilities (ANSP 1977; TI 1981; MMES 1985a).

Intake water at both Calvert Cliffs and Morgantown is withdrawn from deep offshore layers, raising the salinity and lowering the DO concentration of the waters receiving their discharges (Holland *et al.* 1985b). However, because plant effluents are quickly mixed and flow into wide portions of the receiving water bodies, changes in water quality are not detectable beyond the immediate discharge region (Bongers *et al.* 1975; MMEC 1980; MMES 1985a), and local benthic populations are not adversely affected. In summary, macrobenthos do not have high discharge mortalities at estuarine power plants in Maryland because plant-related changes do not exceed the physiological tolerances of most of the indigenous macrobenthos (Holland *et al.* 1989).

Long-term Trends and Regional Distributions of Estuarine Benthic Communities

Factors other than power plants have significant impacts on benthic communities. Over the 14 years of PPER's long-term benthic monitoring program in the Chesapeake Bay, benthic populations have fluctuated greatly. They also fluctuate seasonally, as shown in Figure 4-6. Most of the observed long-term changes in abundance are associated with the effects of long-term increases in salinity (Holland *et al.* 1989). The estuarine salinity gradient is also a major factor controlling regional distributions of benthos. In general, changes in benthic distribution associated with power plant operations are small and localized compared to the impacts of long-term or regional variations in salinity.

During summer, salinity and temperature differences between surface and bottom waters retard vertical mixing, and the available dissolved oxygen in deeper waters of the Bay is consumed by natural metabolic processes. Summer low-DO conditions have been recorded in deeper (> 10m) water habitats of Chesapeake Bay since the 1950s (Taft *et al.* 1980; Officer *et al.* 1984; Seliger *et al.* 1985; Holland *et al.* 1988a; Holland *et al.* 1989). Much of the recent increases in the duration and severity of summer anoxia are associated with increases in nutrient loadings and excessive algal production. Changes in agricultural practices and development of the Bay's watersheds are major causes for increased nutrient inputs to the Bay watershed that have been identified (EPA 1983).

Power Plant Effects on Freshwater Benthic Organisms

Distinct changes have occurred in benthic communities in the vicinity of power plants operating in the freshwater portion of the Potomac River. Macrobenthic responses to power plant discharges included decreased abundances of dominant species and reduced occurrence of rare species. Few species were favored in power plant discharges. Sublethal power plant effects on macrobenthos, such as changes in growth rates or size class distributions, were not detected. Impacts associated with power plants were greatest and most severe during summer months and low-flow years. Severity of impact was also affected by the size of the power plant discharge, and by annual variations in the timing of maximum temperatures. Additional data must be evaluated to define the significance of these power plant impacts compared to natural sources of variation. A modified study design was implemented in 1989 with the objective of defining the spatial extent and magnitude of power plant impacts on benthos in riverine systems (Shaughnessy and Holland 1989).

Conclusions

PPER's long-term benthic monitoring studies have demonstrated a number of important facts. The impact of low-DO water on bottom habitats is difficult to measure directly, but is clearly evident in benthic communities. However, in terms of this and other water quality parameters, power plant operations in the Bay generally influence benthic abundance and biomass less than do water quality changes associated with natural processes. Power plant effects (long-term and short-term) on estuarine benthic organisms are small, probably because plant-related alterations to water and sediment quality are small and do not exceed the macrobenthic physiological tolerances.

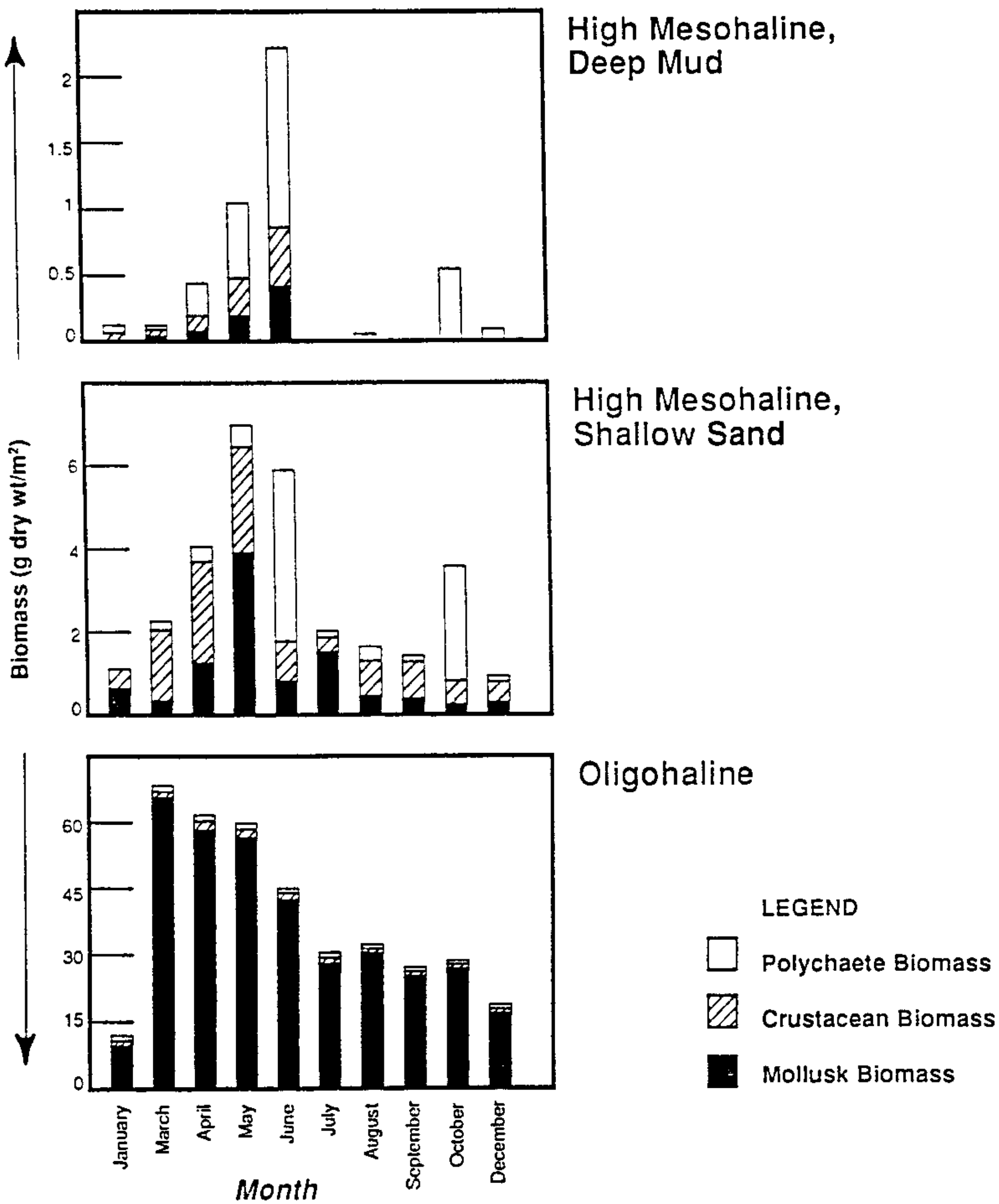

Figure 4-6. Annual cycle of benthic organism biomass in three representative habitats found in Chesapeake Bay (Note: Biomass scale is different on each graph)

K. Summary

Steam Electric Facilities

The major direct aquatic impacts of steam electric facilities are the result of cooling water withdrawals and thermal/chemical discharges. Availability of water for cooling is generally good in Maryland, and consumptive use of water by power plants is fairly small. However, the gradual replacement of once-through cooling systems with closed-cycle cooling towers means an increase in consumptive use, which could impact freshwater availability in the future, especially during drought years. In general, studies have shown that entrainment and impingement impacts have been localized, and there has been no evidence thus far of any long-term consequences to the aquatic biota in the state's surface water bodies. However, the significance of entrainment losses of forage fish such as the bay anchovy remains a major unresolved issue, and future synergistic interactions of power plant impacts with other environmental insults to the receiving water bodies cannot be ruled out.

Thermal and chemical discharges have affected surface water quality in the vicinity of several power plants, although no regional effects have been detected. Fish and crabs are variously attracted to or repelled from plant discharges, but fish migration, spawning activity, and growth do not seem to have been adversely affected. Benthic abundance and productivity are generally higher in thermally affected areas; however, increases in overall productivity have not impacted local or regional food web dynamics to a detectable level. Changes in biota due to the long-term degradation of water quality attributable to chemical discharges are negligible compared to changes due to other sources. Power plants to date have not been implicated as major sources of atmospheric contaminants to the Chesapeake Bay and its tributaries. Coal leachates from power plants likewise do not seem to have measurable impacts on aquatic systems near the plants. Toxicity testing of power plant effluents indicate that they are not acutely toxic. Brandon Shores and Vienna were placed on the list of toxic dischargers as required under section 304(l) of the Clean Water Act because effluent copper concentrations exceeded Maryland water quality criteria. However, inadequate data exist to determine whether power plants are regularly discharging toxic chemicals at concentrations exceeding criteria.

Specific aquatic impacts from withdrawals and discharges are summarized below by Bay region and by power plant:

- Potomac River

Entrainment and impingement impacts are small at the Dickerson, Morgantown, and R.P. Smith plants, and discharge effects are localized. No long-term cumulative impacts have been identified from operation of these facilities.

- Nanticoke River

Entrainment of plankton is estimated to be low at Vienna and impingement of juvenile and adult fish is negligible. Discharge effects also appear to be insignificant.

- Patuxent River

Chalk Point has the greatest potential for entrainment impacts to plankton (including small fish) and for discharge effects compared to other plants in the mesohaline salinity zone. Regional ichthyoplankton populations of several representative important species (RIS) may be adversely affected at Chalk Point. Net losses of bay anchovy due to entrainment are estimated to range from 8 to 56 percent annually, with the most probable annual loss 10 to 20 percent. Impingement at Chalk Point has declined substantially since PEPCO installed a dual barrier net system in 1985 and is not expected to affect commercial or recreational landings of fish and crabs. The impacts of Chalk Point's thermal effluents are localized. Fish and crabs are attracted to or excluded from the discharge region depending on season, but fish migration routes are not blocked. Thermal effluents do not adversely affect the growth and reproduction of fish or other biota.

- Chesapeake Bay

Entrainment losses to planktonic stages of benthic organisms occur at Calvert Cliffs but do not result in local population depletions. Projections of potential entrainment losses of certain fish populations suggest that they may be marginally affected at this plant, although causing little change in net system productivity. Entrainment losses apparently do not result in nearfield depletions in ichthyoplankton populations. No consistent discharge effects on plankton or fish have been measured there, although the high-velocity discharge has modified the benthic habitat and resulted in localized depletions of benthos.

Entrainment losses at C.P. Crane do not affect regional RIS populations, even though ichthyoplankton losses are large in the receiving water body. A significant number of organisms are impinged there, but losses appear to be too small to have a detectable effect on regional stocks of fish or crustaceans. Local thermal effects are frequently detected at Crane, especially during summer when high temperatures, low freshwater inflows, and high generating loads occur. Nevertheless, power plant operations do not significantly affect biotic resources on a regional basis.

- Baltimore Harbor

Entrainment impacts of the six plants (Brandon Shores, BRESCO, Gould Street, Riverside, Wagner, and Westport) have not been directly measured. No estimates of the regional impacts of entrainment have been made because of insufficient baseline information on ichthyoplankton that use the harbor area as spawning and nursery grounds, but no local depletions have been found that can be attributed to power plant operations. Impingement losses are not expected to affect commercial or recreational landings of fish or crabs in the area at the present time. Discharge impacts of these plants are difficult to separate from those of other industries in the harbor, although they are not expected to cause any additional adverse impacts. However, improvements in environmental quality may make Baltimore Harbor more important as a spawning and nursery area for RIS, and reevaluation of biotic impacts may be required in the future.

Hydroelectric Facilities

The development and operation of hydroelectric facilities can cause three major types of impacts: flow cessation and fluctuation of water levels, alterations of water quality, and prevention of fish passage.

- Conowingo

By far the largest hydroelectric facility in Maryland is Conowingo; its effects are summarized below.

Flow Cessation and Fluctuation of Water Levels

In the past, releases of water from the dam were based primarily on power demand requirements. Consequently, flows were commonly reduced to virtually zero for extended periods (typically nights and weekends). This resulted in loss of viable aquatic habitat in the Susquehanna River below Conowingo Dam. As part of a settlement agreement between PECO and the State of Maryland, a minimum flow was instituted for the period March through November. By providing more food and available habitat, the minimum flow has helped fish populations below the dam to become healthier and more productive. Flows during the winter months are currently being studied to determine if the biological resources at risk during those months require continuous flows.

Reduction of Water Quality

Stratification of Conowingo Pond during low-flow summertime conditions can result in releases of hypoxic water from the dam that can be of significant harm to aquatic life for several miles downstream. Hydroelectric releases have violated the State's water quality standard for dissolved oxygen in the past. Physical modification of the dam is underway to improve the situation and preliminary results indicate that turbine venting is an effective aeration technique which should permit compliance with the DO standard. Studies are underway to evaluate the effectiveness of turbine venting and other techniques to add oxygen to the turbine discharge.

Prevention of Fish Passage

The physical presence of the dam has denied anadromous fish access to spawning areas upstream. Final design plans for a permanent fish lift facility have been approved, and construction is to begin in 1990. Completion is anticipated in spring 1991 before that year's run of American shad. Until fish passage can be provided around the upstream dams, fish must be sorted and trucked upstream. Studies are continuing to investigate the movement patterns of adult fish through the lower four impoundments and the behavior and success of outmigrating juveniles.

- Small-Scale Facilities

Field work and modeling studies are being conducted by the State and Penelec to assess the impact of current operation of the Deep Creek hydroelectric facility on Deep Creek Lake and downstream in the Youghiogheny River. These studies will be used help determine measures that could be taken to minimize impacts. Work is continuing at the Brighton Dam and Potomac Dam No. 4 projects to evaluate possible mitigation of impacts at those sites as well.

L. References

Abbe, G.R. and C.W. Hart, Jr. 1974. Growth and mortality of tray-held oysters in the Patuxent River, Maryland. Proc. Nat. Shellfish Assoc. 64:1.

ANSP (Academy of Natural Sciences of Philadelphia). 1977. Morgantown Station and Potomac estuary: A 316 environmental Demonstration. Prepared by the Academy of Natural Science of Philadelphia, Benedict Estuarine Research Laboratory, Benedict, MD, for the Potomac Electric Power Company, Washington, D.C.

ANSP. 1983a. Chalk Point station 316 demonstration: Technical reports, Vols. I-IV. Prepared by the Academy of Natural Sciences of Philadelphia, Benedict Estuarine Research Laboratory, Benedict, MD, for the Potomac Electric Power Company, Washington, D.C.

ANSP. 1983b. The effects of condenser replacement at the Chalk Point SES on nearby tray-held oysters, May-December 1982. Prepared by Benedict Estuarine Research Laboratory, Academy of Natural Sciences of Philadelphia, Benedict, MD, for the Potomac Electric Power Company, Washington, D.C. ANSP Report No. 85-3.

ASCE (Committee on Hydraulic Structures, Hydraulics Division, American Society of Civil Engineers). 1982. Design of Water Intake Structures for Fish Protection. New York: ASCE.

Beaumont, A.R., and M.D. Budd. 1984. High mortality of the larvae of the common mussel at low concentrations of tributyltin. Marine Pollution Bulletin 15:402-405.

BG&E (Baltimore Gas and Electric Company). 1989. Certificate of Public Convenience and Necessity Environmental Review Document for the Perryman Power Plant.

Bongers, L.H., T.P. O'Connor and D.T. Burton. 1977. Bromine chloride: An alternative to chlorine for fouling control in condenser cooling systems. Prepared by the Martin Marietta Environmental Center, Baltimore, MD, and the Academy of Natural Sciences of Philadelphia, Benedict Estuarine Research Laboratory, Benedict, MD, for the U.S. Environmental Protection Agency. EPA-600-17-77-053.

Bongers, L.H., T.T. Polgar, A.J. Lippson, G.M. Krainak, R.L. Morgan, A.F. Holland, and W.A. Richkus. 1975. The impact of the Morgantown power plant on the Potomac Estuary: An interpretive summary of the 1972-1973 investigations. Prepared by the Martin Marietta Environmental Center, Baltimore, MD, for the Maryland Department of Natural Resources, Power Plant Siting Program, Annapolis, MD. PPSP-MP-15.

Bowman, M.L., and S.B. Weisberg. 1985. Use of multiple unequally-sized turbines to reduce flow fluctuations below hydroelectric dams. Presented at the Small Hydro/Fisheries Symposium, May 3, 1985, Denver, CO.

Breisch, L.L. D.A. Wright and D.M. Powell. 1984. Chlorine and the Chesapeake Bay. University of Maryland Sea Grant, College Park, MD. UM-SG-TS-84-02.

Brungs, W.A. 1976. Effects of wastewater and cooling water chlorination on aquatic life. Prepared for the U.S. Environmental Protection Agency, Washington, D.C. EPA Ecological Research Series. EPA-600-3-76-098.

Burton, W.H., A.E. Pinkney and J. Gurley. 1990. Yellow perch larval survival studies and the potential effects of an ash storage facility in the Zekiah Swamp Watershed, Wicomico River, Maryland. Prepared by Versar, Inc., Columbia, MD for the Maryland Department of Natural Resources, Power Plant and Envrionmental Review Division, Annapolis, MD.

Cada, G.F., K.D. Kumar, J.A. Solomon, and S.G. Hildebrand. 1982. Analysis of environmental issues related to small-scale hydroelectric development VI: Dissolved oxygen concentration below operating dams. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN. Publication No. 1828.

Cadman, L.R. 1988. Evaluation of collection efficiency for entrainment sampling at Chalk Point steam electric station. Prepared by Versar, Inc., ESM Operations, Columbia, MD, for Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPER-CP-88-1.

Cairns, J.C., A.L. Buikema, R.G. Heath and B.C. Parker. 1978. Effects of temperature on aquatic organism sensitivity to selected chemicals. Virginia Water Resources Research Center, Blacksburg, VA. Bulletin 106.

Cannon, J.B., G.F. Cada, K.K. Campbell, D.W. Lee and A.T. Szluha. 1979. Fish protection at steam-electric power plants: Alternative screening devices.

Prepared by Oak Ridge National Laboratory, Oak Ridge, TN, for the U.S. Nuclear Regulatory Commission and U.S. Environmental Protection Agency.

Chesapeake Executive Council. 1988. Strategy for removing impediments to migratory fishes in the Chesapeake Watershed. Chesapeake Bay Program, Agreement Commitment Report. (NTIS PB89-206999)

Clark, J.C., and W. Brownwell. 1973. Electric power plants in the coastal zone: Environmental issues. American Littoral Society, Highland, NJ. Special Publication 7.

Cochran, R.C. 1987. Effects of coal leachates on fish spermatogenesis. Can. J. Fish. Aquat. Sci. 44:134-139.

Corps of Engineers. 1984. Chesapeake Bay low freshwater inflow study. Department of the Army, Baltimore District, Corps of Engineers, Baltimore, MD.

Davis, J.C. 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: A review. Journal of Fisheries Research Board of Canada 32:2295-2332.

Diaz-Tous, I.A., and M.J. Miller. 1983. Condenser macrofouling control -- the state-of-the-art. In: Symposium on Condenser Macrofouling Control Technologies -- the State-of-the-Art. I.A. Diaz-Tous, M.J. Miller and Y.G. Mussalli, eds. Electric Power Research Institute, Palo Alto, CA.

DP&L (Delmarva Power and Light Company). 1982. Vienna power station-prediction of aquatic impacts of proposed cooling water intake. A Section 316(b) demonstration.

Dwyer, R.L., and M.A. Turner. 1982. A simulation model of river flow and DO dynamics downstream of Conowingo Dam. Prepared by the Martin Marietta Environmental Center, Baltimore, MD, for the Maryland Department of Natural Resources, Power Plant Siting Program, Annapolis, MD. UBLS-82-3.

Dwyer, R.L., and M.A. Turner. 1986. Simulations of the effects of minimum discharge schedules on the oxygen concentrations of the discharge of the Conowingo Dam. Prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. UBLS-86-1.

EA (Ecological Analysts, Inc.). 1979a. Possum Point power station aquatic monitoring studies. Prepared by Ecological Analyses, Inc., Melville, NY, for the Virginia Electric Power Company.

EA. 1981a. Impingement abundance and viability studies. Prepared by Ecological Analyses, Inc., Melville, NY, for the Baltimore Gas and Electric Company, Baltimore, MD.

EA. 1981b. A .13 demonstration in support of the application for alternate effluent limitations for the Baltimore Gas and Electric Company, C.P. Crane Power Plant. Prepared by Ecological Analyses, Inc., Melville, NY, for Baltimore Gas and Electric Company, Baltimore MD.

Edinger, J.E., and E.M. Buchak. 1983. Estimates of bay anchovy entrainment by Chalk Point power plant using 1982 fish surveys. Prepared by J.E. Edinger Associates, Inc., Philadelphia, PA, for the Potomac Electric Power Company, Washington, D.C.

Eaton, A., and C. Chamberlin. 1982. Copper cycling in the Patuxent River estuary and condenser microfouling studies. Prepared by The Johns Hopkins University, Baltimore, MD, for Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD.

EEM (Energy and Environmental Management, Inc.). 1983. Energy and environmental management: An assessment of turbine-related fish mortality at Dam Number 4 on the Potomac River. Prepared for the Potomac Edison Company, Washington, D.C.

EEM. 1986. Dam No. 4 Hydro Station Installation of Unit No. 3 1985 and 1986 Field Studies Summary Report. Prepared for the Potomac Edison Company and the Allegheny Power Service Corp.

Eisler, R. 1987. Mercury hazards to fish, wildlife, and invertebraes: a synoptic review. U.S. Fish and Wildlife Service, Biol. Rep. 85 (1:10).

EPA (U.S. Environmental Protection Agency). 1983. Chesapeake Bay: A framework for action. U.S. Environmental Protection Agency, Chesapeake Bay Program, Annapolis, MD.

EPA. 1990. Decision document for listings under section 304(l). EPA Region III, Philadelphia, PA.

Fendinger, N.J., J.C. Radway, J.H. Tuttle, and J.C. Means. 1989. Characterization of organic material leached from coal by simulated rainfall. Environ. Sci. Technol. 23:170-177.

Gitlitz, M.H. 1981. Recent developments in marine antifouling coatings. Journal of Coatings Technology 53:46-52.

Hall, L.W., Jr., D.T. Burton, W.C. Graves and S.T. Margrey. 1981. The effects of dechlorinated industrial effluent on striped bass *(Morone saxatilis)* ichthyoplankton. Prepared by the Academy of Natural Sciences of Philadelphia, Philadelphia, PA, for the Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSP-MP-33.

Hall, C.H., R.L. Martin and R.E. Hillman. 1983. Antifouling coatings: Potential for controlling macrofouling in operational power plants. In: Symposium on Condenser Macrofouling Control Technologies -- the State-of-the-Art. I.A. Diaz-Tous, M.J. Miller and T.G. Mussalli, eds. Electric Power Research Institute, Palo Alto, CA.

Hanson, B.N., W.H. Bason, B.E. Beitz and K.E. Charles. 1977. A practical intake screen which substantially reduced the entrainment of early life stages of fish. In: Fourth National Workshop on Entrainment and Impingement, pp. 392-407. L.D. Jensen, ed. Melville, NY: Ecological Analysts, Inc.

Hardy, J.T., C.W. Apts, E.A. Crecelius, and N.S. Bloom. 1985. Sea-surface microlayer metals enrichments in an urban and rural bay. Estuarine Coastal Shelf Sci. 20:299-312.

Haymes, G.T., and D.H. Patrick. 1984. Alternative fish protective techniques: Pneumatic guns and rope nets. Prepared by Ontario Hydro Biological Research Section, Chemical Research Department, Toronto, Ontario.

Heck, K., R. Horowitz, M. Hirshfield and J. Hixson. 1981. Benthic and fish studies to assess thermal impacts of the H.A. Wagner steam electric station, Patapsco River, Maryland, 1980-1981. Prepared by the Academy of Natural Sciences of Philadelphia, Philadelphia, PA, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. W-81-1.

Helz, G.R. 1981. The non-oxidative decay products of chlorine. Technical memorandum prepared by the University of Maryland Chemistry Department, College Park, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD.

Helz, G.R., J.H. Dai, P.J. Kijak, N.J. Fendinger, and J.C. Radway. 1987. Processes controlling the composition of acid sulfate solutions evolved from coal. Appl. Geochem. 2: 427-436.

Hildebrand, S.G., R.R. Turner, D. Wright, A.T. Szluka, B. Tschante and S. Tam. 1980. Analysis of environmental issues related to small-scale hydroelectric development. III. Water level fluctuations. Oak Ridge National Laboratory, Environmental Sciences Division, Oak Ridge, TN. Pub. No. 1597.

Holland, A.F., N.K. Mountford, M.H. Hiegel, D. Cargo and J.A. Mihursky. 1979. Results of benthic studies at Calvert Cliffs. Prepared by the Martin Marietta Environmental Center, Baltimore, MD, and the University of Maryland, Center for Environmental and Estuarine Studies, Chesapeake Biological Laboratory, Solomons, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSP-MP-28.

Holland, A.F., and M.H. Hiegel. 1981. Results of benthic studies at Chalk Point. Prepared by the Martin Marietta Environmental Center, Baltimore, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CP-81-1.

Holland, A.F., M.H. Hiegel, A.T. Shaughnessy, C.F. Stroup and E.A. Ross. 1985a. Long-term benthic monitoring programs near the Morgantown and Calvert Cliffs power plants: Third annual report. Prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CC-85-1.

Holland, A.F., A.T. Shaughnessy, M.H. Hiegel and C.F. Stroup. 1985b. Long-term benthic monitoring near the Morgantown and Calvert Cliffs power plant: Fourth annual report. Prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CC-85-1.

Holland, A.F., A.T. Shaughnessy, M.H. Hiegel and L.C. Scott. 1986. Long-term benthic monitoring for the Maryland portion of the Chesapeake Bay: July 1984-June 1986. Technical memorandum prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, and Department of Health and Mental Hygiene, Office of Environmental Programs.

Holland, A.F., A.T. Shaughnessy and M.H. Hiegel. 1988a. Long-term variation in mesohaline Chesapeake Bay macrobenthos: Spatial and temporal patterns. Estuaries 10(3):185-203.

Holland, A.F., A.T. Shaughnessy, L.C. Scott, V.A. Dickens, J. Gerritsen, and A. Ranasinghe. 1989. Long-term benthic monitoring and assessment program for the Maryland portion of the Chesapeake Bay: Interpretive Report. Prepared for Maryland Deparment of Natural Resources, Power Plant and Environmental Review Division, Annapolis, MD by Versar, Inc., ESM Operations, Columbia, Maryland. Report No. CBRM-LTB/EST-2.

Hynes, H.B.N. 1970. The Ecology of Running Water. University of Toronto Press, Toronto, Canada. 555 p.

Jensen, L.D., ed. 1977. Fourth national workshop on entrainment and impingement. Melville, NY: E.A. Communications.

Klauda, R.J. 1986. Acute and chronic effects of waterborne arsenic and selenium on the early life stages of striped bass (*Morone saxatilis*). Prepared by Johns Hopkins University, Applied Physics Laboratory, Shady Side, MD, for the Maryland Power Plant Research Program, Annapolis, PPRP-98.

Klose, P.N. 1984. Summary of environmental impact assessment studies at the Vienna Fly Ash Disposal Site. Prepared by Environmental Resources Management, Inc., West Chester, PA for the Maryland Department of Natural Resources, Power Plant Siting Program, Annapolis, MD. PPSP-MP-57.

Liden, L.H., D.T. Burton, L.H. Bongers and A.F. Holland. 1980. The effects of chlorobrominated and chlorinated cooling waters on estuarine organisms. Journal of Water Pollution Control Federation 52:173-182.

Lippson, A.J., Ed. 1973. The Chesapeake Bay in Maryland - an atlas of natural resources, Baltimore, MD: The Johns Hopkins University Press.

Lippson, A.J., M.S. Haire, A.F. Holland, F. Jacobs, J. Jensen, R.L. Moran-Johnson, T.T. Polgar and W.R. Richkus. 1979. Environmental atlas of the Potomac estuary. Prepared by the Martin Marietta Environmental Center, Baltimore, MD, for the Maryland Department of Natural Resources, Power Plant Siting Program, Annapolis, MD. Baltimore: The Johns Hopkins Research University Press.

Loar, J.M. and M.J. Sale. 1981. Analysis of environmental issues related to small-scale hydroelectric development. V. Instream flow needs for fishery resources. Oak Ridge National Laboratory, Environmental Sciences Division, Oak Ridge, TN. Pub. No. 1829.

Loos, J.J., and E.S. Perry. 1989. Evaluation of forage fish entrainment at Chalk Point Station. Appendix A. Prepared by Environmental Affairs Group, Water and Land Use Department Potomac Electric Power Company, Washington, D.C.

Lowe, T.P., T.W. May, W.G. Brumbaugh, and D.A. Kane. 1985. National Contaminant Biomonitoring Program: concentrations of seven elements in freshwater fish, 1978-1981. Arch. Environ. Contam. Toxicol. 14:363-388.

Majumdar, S.K., F.J. Brenner, and E.W. Miller (Eds.). 1987. Environmental Consequences of Energy Production: Problems and Prospects. Easton, PA: The Pennsylvania Academy of Science.

Mangum, D.C., and W.F. McIlhenny. 1974. Control of marine fouling in intake systems: A comparison of ozone and chlorine. In: Aquatic Applications of Ozone, 138-153. Proceedings of International Ozone Institute Workship Series.

Mansueti, R., and H. Kolb. 1953. A historical review of the shad fisheries of North America. Prepared by the University of Maryland, Chesapeake Biological Laboratory, Solomons, MD, for the Maryland Department of Research and Education. Publication No. 97.

Mattice, J.S. 1983. Freshwater macrofouling and control with emphasis on *Corbulica*. In: Symposium on Condenser Macrofouling Control Technologies -- the State-of-the-Art. I.A. Diaz-Tous, M.J. Miller and Y.G. Mussalli, eds. Electric Power Research Institute, Palo Alto, CA.

MDE (Maryland Department of the Environment). 1988. Preliminary Clean Water Act Section 304(l) lists. Data base prepared by Maryland Department of the Environment, Baltimore, MD.

MDE. 1989a. Industrial discharge program biomonitoring data base. Maryland Department of the Environment, Baltimore, MD. September 5, 1989.

MDE. 1989b. 304(1) lists submitted to the U.S. Environmental Protection Agency. Maryland Department of the Environment, Baltimore, MD.

MMEC (Martin Marietta Environmental Center). 1980. Summary of findings: Calvert Cliffs nuclear power plant Aquatic monitoring program. Prepared by Martin Marietta Environmental Center, Baltimore, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSP-CC-80-2.

MMES (Martin Marietta Environmental Systems). 1985a. Impact assessment report: Chalk Point steam electric station aquatic monitoring program. Prepared by Martin Marietta Environmental Systems, Inc., Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CPC-85-1.

MMES. 1985b. Assessment of compliance for the Chalk Point steam electric generating station with mixing zone criteria in COMAR 10.50.01.13E(1). Prepared by Martin Marietta Environmental Systems, Inc., Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CPC-85-2.

Morgan, R.P., III. 1968. Steam electric station effects upon primary productivity in the Patuxent River estuary. Prepared by the University of Maryland, Chesapeake Biological Laboratory, Solomons, MD. NRI Ref. No. 69-27.

Murphy, D.L. 1988. Potomac River fish tissue data from the Maryland Fish Tissue Network (1977-85). Computer printout. Maryland Department of the Environment, Baltimore, MD.

Officer, C.B., R.G. Biggs, J.L. Taft, L.E. Cronin, M.A. Tyler and W.R. Boynton. 1984. Chesapeake Bay anoxia: origin, development and significance. Science 223:22-27.

Otto, R.G., T.I. Hiebert and V.R. Kranz. 1981. The effectiveness of a remote profile-wire screen intake module in reducing the entrainment of fish eggs and larvae. In: Advanced Intake Technology for Power Plant Cooling Water Systems, 47-56. Proceedings of the Workshop of Advanced Intake Technology. P.B. Dorn and J.T. Johnson, eds. San Diego, CA.

Pavol, K.W., and R.M. Davis. 1982. Life history and arrangement of the smallmouth bass in the Susquehanna River below Conowingo Dam. State of Maryland Wildlife Administration, Report F-29-R.

PECO (Philadelphia Electric Company). 1989a. Licensees' procedures to ensure that Maryland's dissolved oxygen standard is met in releases from Conowingo

Hydroelectric Station, Project No. 405. Philadelphia Electric Co., 2301 Market St., Philadelphia, PA. July 1989.

PECO (Potomac Electric Power Company). 1989b. Evaluation of turbine aeration tests at Conowingo Hydroelectric Station, Project No. 405. Philadelphia Electric Co., 2301 Market St., Philadelphia, PA 19101. January 1989.

PEPCO. 1985. Long-term aquatic monitoring in the vicinity of the Chalk Point generating station. Prepared by the Environmental Affairs Group, Water and Land Use Department, Potomac Electric Power Company, Washington, D.C.

PEPCO. 1987. Chalk Point station biofouling control program: 1986 Annual Report. Prepared by the Environmental Affairs Group, Water and Land Use Department, Potomac Electric Power Company, Washington, D.C.

PEPCO. 1989. Executive summary mitigation alternatives for entrainment losses at the Potomac Electric Power Company Chalk Point Station. Prepared by Potomac Electric Power Company, Washington, D.C.

Phelps, H. 1979. Copper and zinc concentrations in oysters from selected locations on the Chesapeake Bay, Summary Report 1979-1977. Prepared by the University of the District of Columbia for NASA. Grant NGR 0-050-019.

Phillip, K.R., and P.N. Klose. 1981. Lower Susquehanna River oxygen dynamics study. Prepared by Environmental Resources Management, Inc., West Chester, PA, for the Maryland Department of Natural Resources, Power Plant Siting Program, Annapolis, MD. PPSP-UBLS-81-4.

RGH (Rogers, Golden & Halpern). 1989. Environmental evaluation of sites for a coal-fired ACFBC power plant. Prepared for Delmarva Power and Light by Rogers, Golden & Halpern, Philadelphia, PA.

PPSP (Maryland Power Plant Siting Program). 1975. Power plant cumulative environmental impact report. Prepared by Maryland Department of Natural Resources, Power Plant Siting Program, Annapolis, MD. PPSP-CEIR-1.

PPSP. 1978. Power plant cumulative environmental impact report. Prepared by Maryland Department of Natural Resources, Power Plant Siting Program, Annapolis, MD. PPSP-CEIR-2.

PPSP. 1982. Power plant cumulative environmental impact report. Prepared by Maryland Department of Natural Resources, Power Plant Siting Program, Annapolis, MD. PPSP-CEIR-3.

PPSP. 1984. Power plant cumulative environmental impact report. Prepared by Maryland Department of Natural Resources, Power Plant Siting Program, Annapolis, MD. PPSP-CEIR-4.

PPSP. 1986. Power plant cumulative environmental impact report. Prepared by Maryland Department of Natural Resources, Power Plant Siting Program, Annapolis, MD. PPSP-CEIR-5.

PPRP (Maryland Department of Natural Resources, Power Plant Research Program). 1988. Power plant cumulative environmental impact report. Prepared by Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD PPRP-CEIR-6.

Roberts, M.H., Jr., R.J. Diaz, M.E. Bender and R.J. Huggett. 1975. Acute toxicity of chlorine to selected estuarine species. Journal Fisheries Research Board of Canada 32:2525-2528.

Roosenburg, W.H. 1969. Greening and copper accumulation in the American oyster, *Cassostrea virginica*, in the vicinity of steam electric generating stations, Chesapeake Science 10:241-252.

Rose, K.A., R.L. Dwyer and M.A. Turner. 1986. Prediction of the effects of nutrient loadings from a power plant at Perryman on the water quality of the Bush River estuary. Prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSE-2-8.

Seliger, H.H., J.A. Boggs and W.H. Biggs. 1985. Catastrophic anoxia in the Chesapeake Bay in 1984. Science 228:70-73.

Shanks, A.L. 1983. Surface slicks associated with tidally forced internal waves may transport pelagic larvae of benthic invertebrates and fishes shoreward. Mar. Ecol. Prog. Ser. 13: 311-315.

Shaughnessy, A.T and A.F. Holland. 1989. Long-term benthic monitoring studies in the freshwater portion of the Potomac River: 1983 to 1985, cumulative report. Prepared by Versar, Inc., ESM Operations, Columbia, MD, for Chesapeake Bay Research and Monitoring Division, Tidewater Administration, Department of Natural Resources, Annapolis, MD. CBRM-MP-60.

Shaughnessy, A.T, A.F. Holland and W. Richkus. 1990. Review of environmental data relevant to H.A. Wagner SES operations and preliminary evaluation of issues fro alternate effluent limitations and 1991 NPDES permit. Prepared by Versar, Inc., ESM Operations, Columbia, MD for Power Plant and Environmental Review Division, Maryland Department of Natural Resources.

Solley, W.B., C.F. Merk, and R.R. Pierce. 1988. Estimated use of water in the United States in 1985. U.S. Geological Survey, Denver, CO. USGS Circular 1004.

SRAFRC (Susquehanna River Anadromous Fish Restoration Committee). 1990. Restoration of American Shad to the Susquehanna River. Annual Progress Report.

SRBC (Susquehanna River Basin Commission). 1989. Letter from Susquehanna River Basin Commission, Basin Commission, Harrisburg, PA, to Versar, Inc., Columbia, MD, dated December 18, 1989. Cites Pennsylvania Water Use Study, Major Water-Related Electric Generating Facilities, 1987-2001. June 1987.

Sugam, R., and G.R. Helz. 1977. The chemistry of chlorine on estuarine waters. Prepared by the University of Maryland, Chemistry Department, College Park, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPRP-26.

Summers, J.K. 1984. Conowingo reservoir ecosystem simulation model. Prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. UBLS-82-5.

Tablada, H. 1990. Personal communication from H. Tablada, Maryland Department of the Environment, Baltimore, MD, to F. Pinkney, Versar, Inc. Columbia, MD. June 1990.

Taft, J.L., W.R. Taylor, E.O. Hartwig and R. Loftus. 1980. Seasonal oxygen depletion in Chesapeake Bay. Estuaries 3:242-247.

Tatham, T.R., D.L. Thomas and G.J. Miller. 1977. Survival of fishes and macroinvertebrates impinged at Oyster Creek generating stations. In: Fourth National Workshop on Entrainment and Impingement, pp. 235-244. L.D. Jensen, ed. Mellvile, NY: E.A. Communications.

TI (Texas Instruments). 1981. Evaluation of C.P. Crane generating station thermal discharge effects on the finfish community, Summer 1980. Prepared for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CPC-81-1.

Turbak, S.C., D.R. Reichle and C.R. Shriver. 1981. Analysis of environmental issues related to small-scale hydroelectric development IV: Fish mortality resulting from turbine passage. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN. Publication No. 1597.

Turner, M. and D. Heimbuch. 1986. Application of the empirical transport model to Patuxent River anchovy data to estimate entrainment impact from PEPCO's Chalk Point steam electric station. Technical memorandum prepared by Martin Marietta Environmental Systems, Columbia, MD, for Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD.

Tuttle, J.H., G.R. Helz, J.C. Radway, N.J. Fendinger, and J.C. Means. 1989. Chemical and microbiological factors influencing the leaching of trace metals and trace organics from coal. Prepared by Chesapeake Biological Laboratory, Solomons, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPRP-101.

UE&C (United Engineers and Constructors, Inc.). 1989. Alternative intake design and operational strategies for reducing entrainment at Chalk Point Units 1 and 2 Potomac Electric Power Company. Prepared by United Engineers and Constructors, Inc. Philadelphia, PA, for Potomac Electric Power Company, Washington, D.C.

Vannote, R.L., and B.N. Sweeney. 1985. Long-term benthic monitoring studies in the freshwater portion of the Potomac River. Prepared by Stroud Water Research Center of the Academy of Natural Sciences of Philadelphia, Philadelphia, PA, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSP-MP-58.

Versar, Inc. 1989a. Review and evaluation of PEPCO's 1989 fractional entrainment loss estimates for the Chalk Point SES. Prepared by Versar, Inc., ESM Operations, Columbia, MD. Prepared for Maryland Department of Natural Resources, Power Plant and Environmental Review Division, Annapolis, MD. TR89-20.

Versar, Inc. 1989b. Benthic macroinvertebrate monitoring below Conowingo Dam during the winter period 1988-1989. Prepared by Versar, Inc., ESM Operations for Maryland Department of Natural Resources, Power Plant and Environmental Review Division, Annapolis, MD. TR89-20.

Viessman, W., Jr., and C. DeMoncada. 1980. State and National Water use Trends to the Year 2000. Congressional Research Service, the Library of Congress, Washington, D.C. Serial No. 96-12.

Walburg, C.H., and R.P. Nichols. 1967. Biology and management of the American shad and status of the fisheries, Atlantic Coast of the United States, 1960-1967. Prepared by U.S. Fish and Wildlife Service, Atlanta, GA. Special Scientific Report Fish No. 550.

Waldock, M.J. and J.E. Thain. 1983. Shell thickening in Crassostrea gigas: Organotin antifouling or sediment induced. Marine Pollution Bulletin 14:411-415.

Weisberg, S.B., W.H. Burton, E.A. Ross and F. Jacobs. 1984a. The effects of screen slot size, screen diameter, and through-slot velocity on entrainment of estuarine ichthyoplankton through wedge-wire screens. Prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CP-84-1.

Weisberg, S.B., C.F. Stroup, A.F. Holland and E.A. Ross. 1984b. Biofouling potential on fine mesh-wire screens and a test of some mechanisms of biofouling control. Prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CP-84-3.

Weisberg, S.B., and A.J. Janicki. 1985. The effects of an interim minimum flow from the Conowingo Dam on fish feeding and benthos in the Susquehanna River. Prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. UBLS-85-4.

Weisberg, S.B., K.A. Rose, B.S. Clevenger and J.O. Smith. 1985. Inventory of Maryland dams and assessment of hydropower resources. Prepared by Martin Marietta Environmental Systems, Columbia, MD, and Dam Safety Division of the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSP-85-02.

Weisberg, S.B., W.H. Burton and H.T. Wilson. 1989. Effects of instituting a minimum flow from Conowingo Dam on downstream fish populations. Prepared by Versar, Inc., ESM Operations for Maryland Department of Natural Resources, Power Plant and Environmental Review Division, Annapolis, MD. TR89-26.

Wendling, L.C. 1989. Evaluation of dissolved oxygen monitoring locations and flow patterns below Conowingo Dam. Prepared by Versar, Inc., ESM Operations for Maryland Department of Natural Resources, Power Plant Environmental Review Division, Annapolis, MD. PPER-UBLS-89-1.

Wendling, L.C., and A.F. Holland. 1989. Evaluation of auxiliary tempering pump effectiveness at Chalk Point steam electric station. Prepared by Versar, Inc., ESM Operations, Columbia, MD, for Maryland Department of Natural Resources, Power Plant Environmental Review Division, Annapolis, MD. PPER-CP-89-1.

Weitz, D.H. 1982. Problems associated with the installation of fish barrier nets at the Morgantown generating station. Prepared by Potomac Electric Power Company, Washington, D.C.

M. Glossary

Anadromous. A type of fish that ascends rivers from the sea to spawn. Examples in the Chesapeake Bay include shad and alewife; striped bass are considered semianadromous.

Anoxic. Water devoid of oxygen.

Benthic. Of or pertaining to the bottom of a water body.

Benthos. Those organisms living on or in the bottom of a water body.

Biota. The plant and animal life of a region.

Bryozoans. The moss-animals, colonial invertebrates that often grow attached to rocks, pilings, intake barriers, and other fixed objects in the water.

Chlorophyll. A plant pigment responsible for photosynthesis; often used as a measure of phytoplankton biomass.

Detritus. The non-dissolved products of disintegration or decay; organic detritus is the food source of the estuarine food web.

Entrainment. Transport of smaller organisms such as plankton through a power plant and/or auxiliary pumps. Such transport may cause physical damage or death.

Entrapment. Accumulation of fish, crabs, and other organisms brought in with cooling water flows in the intake region of a power plant. Such accumulation may weaken or kill organisms due to exposure to low DO, or lead to impingement.

Estuarine. Of or pertaining to an estuary -- a partially enclosed body of water, with a connection to the ocean, in which fresh water from rivers is mixed with saline water moving in from the ocean; also that portion of a stream or river influenced by the body of water into which it flows.

Fecundity. Rate at which an individual produces offspring, usually only calculated for females.

Food web. A representation of the various paths of material and energy flow through populations in a biological community.

Forage fish. Fish comprising the prey items of predator fish.

Hydroids. Small, often colonial invertebrates that often grow attached to rocks, pilings, intake barriers, and other fixed objects in the water.

Hypoxic. Water low in oxygen.

Ichthyoplankton. Planktonic forms consisting of fish larvae.

Impingement. Trapping of larger organisms brought in with water flows on barriers protecting internal plant structures. Such trapping may cause physical damage or death.

Impoundment. Lake or reservoir created by a man-made dam.

Marine. Aquatic habitat type with salinities ranging between 30-35 ppt; the ocean, seas, and mouths of estuaries.

Mesohaline. Aquatic habitats with salinities between 5 and 18 ppt.

Nekton. Actively swimming aquatic animals such as fish.

Nontidal fresh. Aquatic habitats such as lakes and rivers not under tidal influence.

Oligohaline. Aquatic habitats with salinities between 0.5 and 5 ppt.

Phytoplankton. The plant forms of plankton such as small algae and diatoms.

Plankton. The passively drifting or weakly swimming organisms in marine or fresh water.

Polyhaline. Aquatic habitats with salinities between 18 and 30 ppt.

Salinity. A measure of the dissolved solids content of water; the weight in grams of the total salts dissolved in 1 kg of water. Seawater is about 35 parts per thousand salinity by weight, drinking water standards allow about 0.25 ppt salinity.

Semianadromous. A type of fish from the sea that ascends estuaries to spawn in lower salinity regions; e.g., striped bass.

Stratification. The process of creation of two or more layers of water with different densities; density differences may be due to temperature and/or salinity.

Tidal fresh. Aquatic habitats under tidal influence but with salinities less than 0.5 ppt.

Traveling screens. A type of physical barrier designed to prevent withdrawal of organisms into a power plant cooling system, thereby reducing entrainment.

Zooplankton. The animal forms of plankton, including certain types of protozoans, crustaceans, jellyfishes, etc., and the eggs and larvae of many benthic and nektonic animals.