CHAPTER IV

AQUATIC IMPACT

The generation of electricity is closely associated with rivers, lakes, and estuaries. These water bodies serve as sources of cooling water, receiving bodies for discharges, and sites for hydroelectric generation. Both steam and hydroelectric power plants can affect the aquatic environment.

A steam power plant using fossil fuel produces about 4,400 Btu of excess heat via its condenser for each kilowatt hour of electricity generated (a nuclear power plant produces about 6,600 Btu). Most Maryland steam power plants use once-through cooling systems to transport excess heat from the plant. In these systems, "new" water is continuously drawn into the plant from a source water body, heated 5 to 17`C as it passes the condenser, and discharged into a receiving water body. Approximately one million gallons of water per minute (or 63 m3/s) is required for each 1,000 MWe of generating capacity with once-through cooling. Closed-cycle cooling, which is used at some Maryland power plants, "recycles" condenser cooling water through a cooling tower and uses only 2 to 25 percent of the water volume required for once-through cooling. Facilities with closed-cycle cooling use source water as makeup for evaporative losses and to clean internal cooling tower structures.

A hydroelectric plant utilizes the potential energy of impounded water to generate electricity. The construction of dams, filling of impoundments, and discharge from impoundments necessary for hydroelectric generation modifies upstream and downstream habitats.

The Chesapeake Bay and its tributaries serve as the major source of cooling water for steam electric generation in Maryland, and some of Maryland's freshwater streams and rivers are used for hydroelectric sites. The Chesapeake Bay is one of the largest and most productive ecosystems in the world, supporting a complex aquatic food web that produces large quantities of renewable fish and shellfish resources (1,2). A major concern of the Power Plant Siting Program (PPSP) is to ensure that steam and hydroelectric facilities provide electricity at a reasonable cost, while not interfering with the maintenance of sustained yields of the Bay's natural resources and the stability of the system. To achieve this goal, the impact of steam and hydroelectric facilities on aquatic ecosystems as a whole must be evaluated, and measures to minimize these impacts should be examined for their benefits and costs. Another goal of the PPSP is to ensure that steam and hydroelectric facility operations do not interfere with uses of the Bay such as swimming, boating, recreational and commercial fishing, municipal water supplies, and transportation.

A. Sources and Nature of Impact

As water is drawn through a steam or hydroelectric power plant and returned to its source, aquatic biota may interact with intake structures, cooling or turbine system structures, intake and discharge velocity fields, heated effluents, chemicals used to prevent biofouling, and other alterations of the environment resulting from operations.[1] The locations and nature of these interactions and the ensuing stresses that are encountered by aquatic organisms are briefly described in Figures IV-1a and IV-1b). A fuller description of these interactions and stresses can be found in the previous CEIR (3). Individual groups of organisms may be more susceptible to damage by one type of interaction than by another as shown in Table IV-1.

Mortalities resulting from interactions between biota and steam or hydroelectric power plants can cause population declines if they are not offset by compensating mechanisms such as increases in growth, fecundity, and/or the survival of early life stages. In the case of phytoplankton or zooplankton, losses due to entrainment are generally recouped quickly because these biota are characterized by rapid growth and reproduction (generation times of hours to days). Higher trophic levels generally have much longer generation times. Fish, crabs, and many benthic organisms generally spawn once a year, and fish may not reproduce until several years of age. For species utilizing discrete or localized spawning or nursery areas adjacent to a steam electric generating plant, entrainment may result in the loss of a large proportion of early life stages unless cooling towers with controlled blowdown are used to reduce the volume of water and number of organisms entrained. The potential for entrainment losses to have an impact on adult populations is much less for ubiquitous species that spawn over and inhabit broad regions of rivers and estuaries. Although fish populations are more likely to be affected by the entrainment of their ichthyoplankton (a direct effect) they could also be affected indirectly by a change in the density or composition of their food. The dominant groups in the Bay that are important as forage for fish are phytoplankton, zooplankton, benthic organisms, and small fish species (e.g., bay anchovy and menhaden). Indirect effects resulting from food web changes may propagate through several trophic levels, although they are unlikely to be measurable beyond one link along the food chain. The construction of impoundments for hydroelectric power plants can have profound effects on foodweb dynamics of rivers and streams because the kinds and abundances of biota in the impounded area are frequently different from those existing prior to impoundment.

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[1]Radiological effects are discussed in Chapter V.

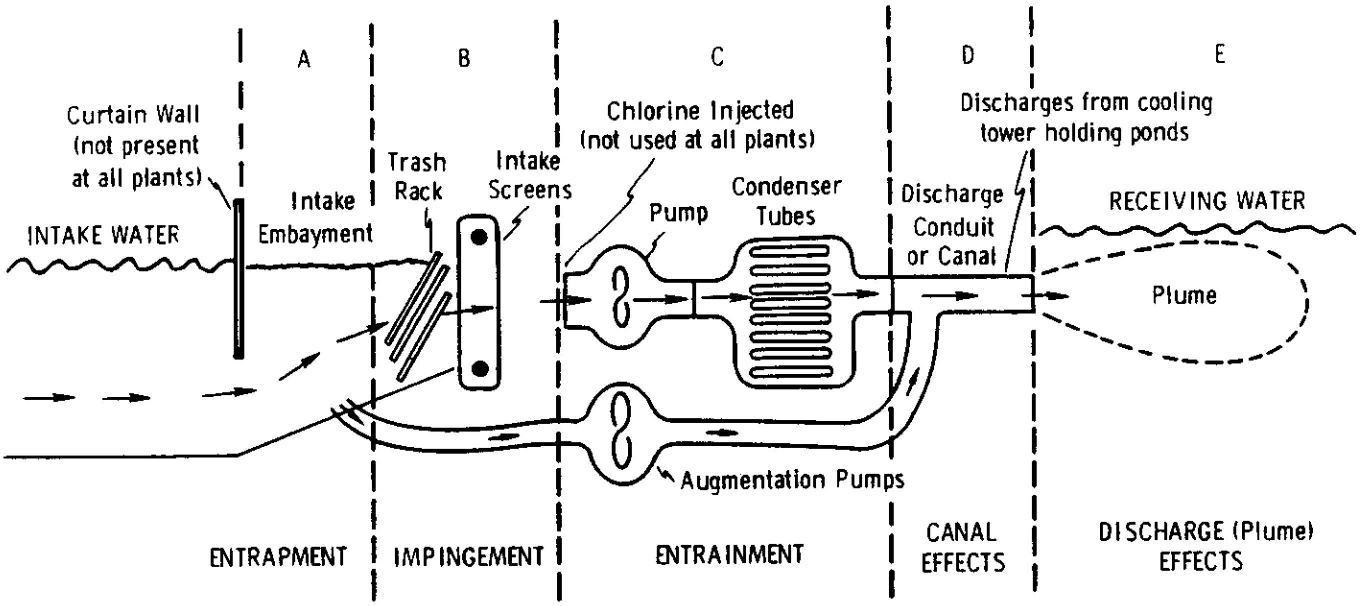

Figure IV-1a. Path of water flow through a power plant using once-through cooling and locations of plant-organism interactions.

A. Fish and crabs may accumulate and become entrapped in the intake embayment. During entrapment they may be exposed to water of low dissolved oxygen content that is sometimes drawn in with intake flows below a curtain wall (not present at all plants).

B. Organisms, mainly fish and crabs, too large to pass through intake screens may become trapped on them (i.e., are impinged). Intake screens are periodically rotated to wash off impinged organisms and return them to receiving water.

C. Organisms small enough to pass through intake screens (plankton) are drawn through the cooling system (i.e., are entrained). During entrainment, plankton experience a sudden temperature rise of from 5 to 17°C, shear and pressures forces, and may contact internal structures. At some plants entrained organisms are also exposed to lethal levels of chlorine and its residuals during warm months. Large organisms (fish and crabs) may also be entrained into unscreened augmentation pumps where they experience mechanical damage from contact with internal pump structures.

D. Organisms surviving entrainment and impingement are exposed to continued excess temperatures and possibly to chlorine residuals during transit down the discharge conduit or canal enroute back to the receiving body.

E. Organisms in the receiving water may be exposed to elevated temperatures and potentially stressful chemical substances in the discharge plume. Currents associated with the discharge plume may cause habitat modifications through bottom scouring and changes in circulation patterns.

NOTE: Although fewer organisms are entrained by closed-cycle cooling systems, mortality is essentially 100 percent because residence time in cooling towers is high. Cooling towers discharge a portion of their cooling water on a regular basis; this water is known as blowdown (4). Blowdown may contain high levels of metals such as copper (from the cooling system pipes) and chemicals used to prevent fouling and scaling of internal structures (5). Fortunately, many of these pollutants are retained in sediments that accumulate in the bottom of tower structures (6). Concentrations of pollutants in blowdown may be from 5 to 200 times higher than those in effluents from a once-through cooling power plant. Due to evaporative losses, blowdown at estuarine plants have a much higher salinity than ambient water. Discharge effects of blowdown release are similar to those from a once-through cooling system, but because only small water volumes are involved, the affected area is small.

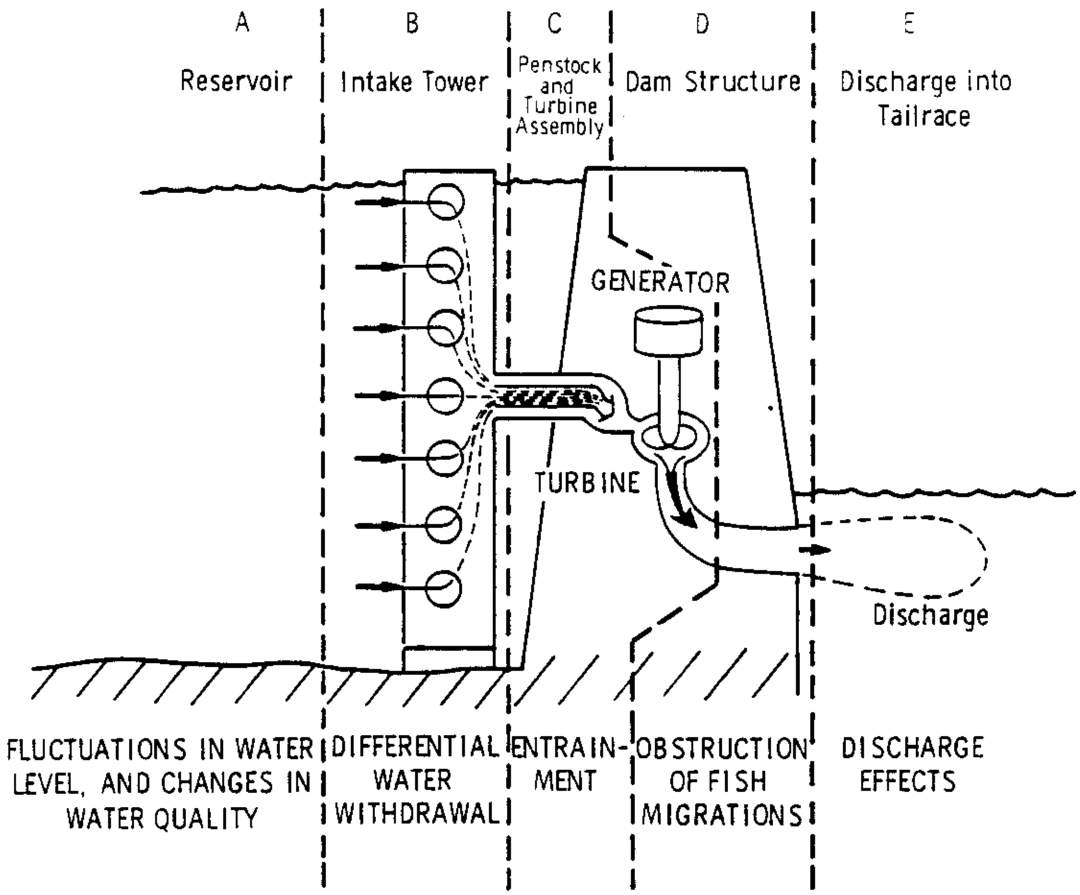

Figure IV-1b. Path of water flow through a hydroelectric power plant, and locations of plant-organism interactions.

A. Discontinuous (peaking) operation schedules cause fluctuations in water level and water quality within the reservoir.

B. The water quality (primarily dissolved oxygen levels and temperature) of both the reservoir and the water body downstream of the dam can be affected by differential water withdrawal through ports of a vertical intake tower (not present in all hydroelectric facilities).

C. Physical damage to biota may occur during entrainment. Downstream-migrating fish (both adults and juveniles) may be entrained through the penstock and turbine assembly.

D. The dam structure will block the upstream migration of anadromous fish if a fish passageway is not present.

E. A daily peaking-discharge schedule will cause fluctuations in water level, velocity, and water quality downstream of the dam. High-velocity releases may cause habitat modifications due to the scouring of sediments and erosion.

Table IV-1. Major Types of Aquatic Effects of Steam Electric and Hydroelectric Power Plant Operations

Sources of Effects	Primary Susceptible Organisms	Type of Stress: Low DO	Mechanical	Thermal	Chemical	Habitat Alteration
		STEAM ELECTRIC POWER PLANTS				
Entrapment	Adult and juvenile fish	x	-	-	-	-
Impingement	Juvenile fish and crabs Adult fish	-	x	-	-	-
Entrainment	Phytoplankton[(a)] Zooplankton[(b)] Ichthyoplankton[(c)] Adult and juvenile fish	-	x	x	x	-
Discharge	Benthos[(d)] Shellfish Adult and juvenile fish[(e)]	x	-	x	x	x
		HYDROELECTRIC FACILITIES				
Creation of Impoundment	All	x	-	-	-	x
Entrainment	Adult and juvenile fish	-	x	-	-	-
Discharge	Benthos Adult and juvenile fish[(e)] Ichthyoplankton[(e)]	x	-	-	-	x

(a) Minute plants present in the water.

(b) Weak swimming animals in the water.

(c) Eggs and larvae of fish.

(d) Organisms living in or on the bottom, including shellfish.

(e) Discharge effects are extremely difficult to detect for mobile taxa, such as fish, crabs, or plankton, whose behavior and resulting distributions may be strongly influenced by hydrodynamic conditions.

B. Aquatic Habitats

The central concept underlying the cumulative assessment of aquatic effects of steam and hydroelectric facilities presented here is that the Chesapeake Bay and its tributary waters are composed of distinct habitat types. Estuarine habitat types are defined by water salinity, which is the environmental variable most important in controlling distributions of organisms (2). In contrast, flow characteristics determine fresh-water habitat types (7). Each habitat can be identified with unique functions in producing or supporting important resource elements, although their biotic components overlap, and the extent of each habitat varies seasonally (with the exception of nontidal freshwaters). Cumulative impact will be assessed in terms of significant effects on the biota over the entire extent of each characteristic habitat type within Maryland, with the emphasis on whether its long-term integrity and characteristic functions are maintained. In order to accomplish this assessment, the habitat zones must be defined and the distribution of steam generating and hydroelectric power plants among the zones determined.

The salinity and flow characteristics designating the habitat types can be defined by a modification of the Venice system of classification (8) as:

Habitat	Salinity Ranges
Euhaline (Marine)	30.0 - 35.0 ppt (parts per thousand)
Polyhaline	18.0 - 30.0 ppt
Mesohaline	5.0 - 18.0 ppt
Oligohaline	0.5 - 5.0 ppt
Tidal fresh	0.0 - 0.5 ppt
Nontidal fresh (Rivers and Lakes)	0.0

The major ecological functions of each habitat are:

- Polyhaline and Marine

  These high-salinity waters are primary sites of the blue crab spawning and development; they also support hard clam populations. Several fish species (e.g., spot, croaker, weakfish, and Atlantic menhaden), whose young and adults seasonally feed in lower salinity zones, spawn and develop in marine waters. These salinity zones generally do not exist in the Maryland portion of the Chesapeake Bay.

- Mesohaline

  These medium salinity regions are the primary areas of production for shellfish (soft-shell clams and oysters), and benthic populations are frequently very productive here. Mesohaline habitats also support large crab populations and produce most of the estuarine forage fish biomass. These waters serve as important feeding areas for large predator fish (e.g., bluefish, striped bass).

- Oligohaline

  These brackish water environments support resident fish populations and serve as their spawning and nursery grounds. Although these fish populations serve primarily as forage for larger fish, they may also be exploited by man (e.g., white perch). Oligohaline areas also are feeding grounds for migratory species such as menhaden. Some spawning of anadromous fish occurs here.

- Tidal Fresh

  These segments of estuaries are under tidal influence but without significant salt intrusion. They provide spawning and nursery habitat for anadromous fish species and also support their larvae and juveniles during early development. The striped bass is a particularly important species using tidal fresh habitats as a spawning and nursery area. Some resident fish species spend their entire life cycles in this zone.

- Nontidal Fresh (Rivers and Lakes)

  Nontidal riverine habitats in Maryland serve as the major spawning and nursery areas for anadromous and semi-anadromous fish species (shad, river herrings, striped bass, and yellow perch). Rivers also support resident fish populations, many of which are actively pursued by sports fishermen (trout and smallmouth bass). All large lakes in the State are artificial reservoirs that have been constructed and are managed for particular purposes. Anticipated uses of reservoirs in the state include flood control, augmentation of low river flows, water supply, hydroelectric power, and cooling of thermal effluents. Such uses can conflict with the maintenance of aquatic habitat for fish species of recreational importance.

The locations of the estuarine zones change seasonally in response to rainfall and resulting changes in the amount of freshwater inflow (1, 2). Table IV-2a indicates the zones in which Maryland steam generating plants are located. Three operational plants (Crane, Possum Point, and Vienna) and one that is in the planning stages (Perryman) are located in the tidal fresh-oligohaline zone. A 500 MWe cooling tower unit is also licensed for a proposed expansion at Vienna. Six operational plants (Chalk Point, Gould Street, Morgantown, Riverside, Wagner, and Westport) and two scheduled to begin operations in 1984-1985 (Brandon Shores and BRESCO) are on oligohaline-mesohaline waters. One operational facility (Calvert Cliffs) is

Table IV-2a. Steam Electric Power Plant Locations in Estuarine Waters (by salinity regime and season).

Power Plant	Net Capacity (MWe)	Spring/Winter Tidal-fresh	Spring/Winter Oligo-haline	Spring/Winter Meso-haline	Summer/Fall Tidal-fresh	Summer/Fall Oligo-haline	Summer/Fall Meso-haline
Brandon Shores	1,240 (a)		x				x
BRESCO	50 (b)		x				x
Calvert Cliffs	1,650			x			x
Chalk Point	1,990		x				x
Crane	384	x				x	
Gould Street	103		x				x
Morgantown	1,112		x				x
Perryman	600-800 (c)	x				x	
Possum Point	478	x				x	
Riverside	321		x				x
Vienna	150 (d)	x				x	
Wagner	988		x				x
Westport	177		x				x
Total Capacity by Zone		1,612-1,812	5,981	1,650	0	1,612-1,812	7,631

(a) Brandon Shores is under construction.

(b) BRESCO (Baltimore Southwest Resource Recovery Facility) is under construction.

(c) Perryman is in the planning stages.

(d) Unit 9 at Vienna, a 500-MWe cooling tower unit, has been licensed and is scheduled to be operational by 1995.

located on a habitat that is mesohaline in all seasons. There are no operational or planned steam generating plants in polyhaline and marine habitats along the Atlantic shoreline of Maryland.

The characteristics and locations of steam and hydroelectric power plants in nontidal fresh waters are summarized in Table IV-2b. Water-use rates at peak power output, average river flows, and reservoir volumes permit comparisons of relative sizes and the possible magnitudes of impacts. The Conowingo plant on the Susquehanna River is the only large-scale hydroelectric facility in Maryland. Several small-scale hydroelectric facilities (i.e., less than 30 MWe capacity) are operational, and several more are presently in various stages of planning, licensing, and construction.

C. Regulatory Considerations

The intake, use, and discharge of water by power plants is regulated through Surface Water Appropriation Permits and National Pollutant Discharge Elimination System (NPDES) discharge permits. These permits reflect federal and State contraints on the amount of water and the type of intake used, as well as the chemical and physical characteristics of effluents.

The evaluation of existing once-through cooling systems on aquatic habitats is done in conjunction with the NPDES permit process and the Code of Maryland Regulations (COMAR) 10.50.01.13. Under these regulations, an initial evaluation of impact is made based on the size of the thermal plume with respect to specific mixing zone criteria and the importance of the area as a spawning and nursery site. If the plant fails to pass these screening criteria, a more detailed evaluation of biological impacts including field studies is required. Alternate effluent limitations may be requested by the utility based upon the findings of the detailed biological studies. Impingement and intake technologies that minimize impacts are also treated under the State regulation. The yearly impingement total and its value are estimated, and various methods of mitigating impingement losses are evaluated to determine which techniques are cost-effective. The status of the various Maryland plants that fall under this regulation is listed in Table IV-3.

Licensing of small scale hydroelectric facilities is a federal procedure. The State of Maryland does not require a State license for these facilities. However, State involvement in the licensing procedure is important. PPSP has been designated the lead agency within the Department of Natural Resources (DNR) for reviewing small-scale hydroelectric facility applications. Under provisions of the Fish and Wildlife Coordination Act, all comments and concerns of state and local resource agencies must be incorporated into federal licensing procedures. The federal licensing agency, the Federal Energy Regulatory

Table IV-2b. Electrical Generation Facility Locations in Nontidal Fresh Waters in Maryland

	Peak Capacity (MWe)	Location by River	Cooling Water Withdrawal or Hydroelectric Turbine Capacity (ft^3/sec) at nominal peak output	Average River Flow at plant (ft^3/sec)	Hydroelectric Reservoir Capacity (ft^3)
Hydroelectric Facilities					
Conowingo Dam (on line)	512.0	Susquehanna	75,800	44,000	1.35×10^{10}
Potomac Dam #4 (on line)	1.0 (planned increase to 1.9)	Potomac	940 (1800 planned)	5,900	3.18×10^{8}
Potomac Dam #5 (on line)	1.12	Potomac	940	5,100	2.57×10^{8}
Harpers Ferry Dam (on line)	0.6	Potomac	334	6,200	4.68×10^{7}
Deep Creek Lake (on line)	19.0	Deep Creek, Youghiogheny	N/A	65	4.05×10^{9}
Bloomington Dam (planned)	13.8	Potomac	900	498	5.70×10^{9}
Brighton (planned)	0.5	Patuxent	130	85	8.21×10^{8}
Gilpin Falls (under construction)	0.6	Northeast Creek	69	36	1.21×10^{5}
Duckett Dam (under construction)	0.1	Patuxent	16	16	1.07×10^{7}
Savage River (planned)	2.0	Savage	235	159	8.72×10^{8}
Union Dam (planned)	0.6	Patapsco	210	75	2.09×10^{6}
Parker Pond (operating without a license)	N/A	Beaver Dam Creek	N/A	9	–
Wilson Mill Dam (operating without a license)	.008	Deer Creek	N/A	N/A	–
Steam Electric Facilities					
R.P. Smith	127	Potomac	124	5,700	–
Dickerson	545	Potomac	530	9,100	–

Table IV-3. Status of Power Plants Under Maryland Thermal Discharge Regulations

Plant	Mixing Zone Criteria	Spawning and Nursery Area of Consequence	Alternate Effluent Limitations	Status
BRESCO	Fails	PPSP recommended passage	PPSP recommended passage	Final hearing not scheduled as of 7/83
Calvert Cliffs	Passes	PPSP recommended passage	N/A	Approved 12/81
Chalk Point	Fails[a)]	Presently being evaluated	Presently being evaluated	Impact Assessment Report submitted by PEPCO October 1983
Crane	Fails	PPSP recommended passage	PPSP recommended passage	PPSP recommendation of acceptable impact submitted 1/83, final hearing not scheduled as of 8/83
Dickerson	Fails (under some flow conditions)	PPSP recommended passage	PPSP recommended passage	Approved 2/82
Gould Street	Passes	Passes	N/A	Approved 7/82
Morgantown	Passes	PPSP recommended passage	PPSP recommended passage	Approved 8/81
Riverside	Passes	Passes	N/A	Approved 7/82
R.P. Smith	Fails (under some flow conditions)	PPSP recommended passage	PPSP recommended passage	Approved 5/82
Wagner	Fails	Presently being evaluated	Presently being evaluated	Detailed biological studies scheduled to begin in spring 1984
Westport	Passes	Passes	N/A	PPSP recommendation submitted

a) Presently being re-evaluated for applicability of criteria.

Commission (FERC), has recently adopted procedures for exempting certain projects (primarily small projects for which the applicant possesses property rights) from federal jurisdiction. In these cases, environmental concerns of State agencies are included in the license as conditions for exemptions and enforcement of these conditions is the responsibility of the State.

Although there are presently no State licenses or permits required for the operation of a hydroelectric power facility, Ch. 448 of COMAR requires that any person who owns or operates a dam on State waters must cooperate with DNR to assure sufficient water is released for maintenance of downstream water quality and aquatic habitat. Several State permits, such as the Surface Water Appropriation Permit and Waterway Construction Permit (both granted by the Water Resources Administration) are generally required. COMAR also calls for consultation with resource agencies such as the Wild and Scenic River Board, the Maryland Geological Survey, and the Maryland Historical Trust. For more details on the permits and consultations required for licensing and permitting of small-scale hydroelectric facilities, refer to Energy in Maryland (9).

The Conowingo hydroelectric facility is also licensed by FERC. FERC licenses are valid for 25 year periods, and Conowingo's license came up for renewal in 1976. At that time, a number of interested parties (U.S. Fish and Wildlife Service, Pennsylvania Fish Commission, Pennsylvania Department of Environmental Resources, Susquehanna River Basin Commission, Pennsylvania Federation of Sportsmen's Clubs, Upper Chesapeake Bay Watershed Association, and the State of Maryland) became involved in the licensing procedure as intervenors. These groups wanted the Philadelphia Electric Company, operator of the facility, to restore anadromous fish runs in the Susquehanna River watershed, and implement actions which would alleviate problems below the dam associated with variation in flow resulting from peaking operations. Problems below the dam included the presence of low dissolved oxygen concentrations during the summer and the reduction and degradation of aquatic habitats during periods of turbine shutdown. As part of the relicensing procedure, three regulatory proceedings before FERC are presently underway. The intervenors have requested a continuous minimum release of water to alleviate habitat modifications and low dissolved oxygen levels below the dam; such a release was ordered by FERC on an interim basis beginning in 1982. Hearings on a separate docket related to fish restoration took place over a two year period, concluding in final briefs submitted in early 1983, a decision is expected within 18 months. Finally, hearings are planned for late 1983 to resolve differences between the utility and intervenors on the technical design of field studies needed to develop management strategies to protect and enhance the fish resources below the dam.

D. Aquatic Impact Assessment

Many monitoring studies have been completed since the publication of the last CEIR (3). All data available through summer 1983 have been incorporated into the following assessment of the impacts of steam generating and hydroelectric power plants on aquatic habitats in Maryland.

Mesohaline

This medium salinity zone accounts for the greatest percentage of aquatic habitat in Maryland. Three of the plants located in this zone (Calvert Cliffs, Chalk Point, and Morgantown) are the largest in the State. The findings of the Calvert Cliffs monitoring studies, covering the preoperation period as well as the first five years of operations (1975-1980), are reported in References 10 through 23, and summarized in Reference 21 and the previous CEIR (3). The Morgantown findings are summarized in References 24 and 25 and were discussed in earlier CEIR's (3, 26, 27). Only major findings of Calvert Cliffs and Morgantown studies are summarized in this CEIR. The results of Chalk Point studies conducted in the 1960's are summarized in Reference 28. Results of recent studies for Chalk Point have been incorporated in the discussions that follow. These findings will be summarized in a final assessment report to be prepared in 1984.

Four plants (Gould Street, Riverside, Wagner, and Westport) are located in Baltimore Harbor where salinities tend to be in the oligohaline range in the spring and low mesohaline during the remainder of the year. Except for Wagner, these plants are all older than 20 years, and are used for peaking and cycling service. Because of their close proximity, they will frequently be discussed as a group in the material presented below. Brandon Shores and a resource recovery facility (BRESCO) which will burn municipal solid waste to produce electricity and steam for commercial sale, are presently being constructed in the Baltimore Harbor area. These facilities are scheduled to begin operations in 1984-1985; when appropriate, findings of siting studies conducted at these sites have been included.

- Entrainment

  Entrainment effects at Calvert Cliffs and Morgantown were summarized in previous CEIR's (3, 26, 27). Phytoplankton and zooplankton entrainment losses were generally variable, with greatest losses occurring in the summer, especially at Morgantown where chlorine is used as a biocide (24, 25). Entrainment losses did not result in nearfield depletions of phytoplankton or zooplankton at either facility.

Studies done in the 1960's indicated high mortalities in entrained organisms at Chalk Point. Both thermal and chlorine stresses were important causes (28, 29). Entrainment also caused near-field depletions of jellyfish, but no changes in river populations of zooplankton were found (28, 29).

Recent phytoplankton studies (1976-1979) for Chalk Point also report a decrease in phytoplankton cell number, biomass, productivity, and metabolism between the intake and discharge (30). Entrainment losses were greatest when chlorine was used and ambient water temperature was near maximum values. Additional decreases in photosynthetic activity occurred as water passed down the discharge canal, especially following chlorination. The discharge canal thus had the net effect of increasing exposure time and thereby increasing mortalities from high temperatures and chlorine. Near-field phytoplankton depletions from entrainment losses have not been observed consistently at Chalk Point, probably because phytoplankton populations recover rapidly in the warm effluents.

Chlorination severely depressed the activity of planktonic bacteria as long as water resided in the Chalk Point discharge canal (30). Otherwise, the activity of planktonic bacteria was stimulated by power plant operations. Entrainment effects on bacteria were quickly diluted in the nearfield area where natural gradients and seasonal fluctuations were the major sources of variation for bacterial activity. No nearfield effects were detected.

Entrainment was the largest source of mortality for zooplankton at Chalk Point (30). Losses were specific to species and life-stage and ranged from 20 to 78 percent. Entrainment effects on zooplankton were highest when summer discharge temperatures approached the upper lethal limits of dominant species and chlorine was used. Nearfield depletion of zooplankton was not observed consistently (30).

Entrainment effects on phytoplankton and zooplankton have not been directly studied at Baltimore Harbor facilities. However, no nearfield depletions that can be attributed to plant operations have been observed (31). Entrainment losses to phyto- and zooplankton from the BRESCO facility and Brandon Shores are not projected to have adverse impact upon plankton populations in the Harbor area (32, 33). Both of these facilities will use relatively small water volumes.

Some planktonic life stages of benthic organisms, including oysters and soft-shell clams, are entrained at Calvert Cliffs (21, 34). However, entrainment losses to these biota do not adversely affect local populations. Near-plant abundances of oysters and soft-shell clams, as well as most other benthic species, have increased relative to nearby reference areas since plant operations began (21, 34).

Salinities in the vicinity of Morgantown, Chalk Point, and Baltimore Harbor plants are marginal for the development and growth of planktonic life stages of oysters and soft-shell clams (24, 30, 32). Because these species seldom complete their development near these facilities, entrainment losses to their larval populations are not considered to be important sources of impact. Abundances of other benthic organisms with entrainable life stages have not declined in the discharge regions of Morgantown, Chalk Point, or Baltimore Harbor facilities (35, 36). However, the number of benthic species and the abundance of dominant species colonizing bottom sediments in the discharge canal at Chalk Point was retarded compared to colonization occurring at nearby reference areas (35).

Entrainment of ichthyoplankton was discussed for the Calvert Cliffs and Morgantown facilities in the previous CEIR (3). No nearfield depletions in ichthyoplankton populations that could be attributed to entrainment loss were detected near these facilities (21, 25).

Spawning activities of white perch, striped bass, yellow perch, and clupeids are concentrated upstream from Chalk Point (30, 37). Only during exceptionally wet springs are entrainable life stages of these resource species transported into regions of the Patuxent near the Chalk Point plant where they may be susceptible to entrainment. Spawning activities of forage species (anchovies, silversides, and naked gobies) occur near the Chalk Point site, and the potential for entrainment of these species is high. However, nearfield depletions have not been observed (30).

Entrainment rates of ichthyoplankton at the Gould Street plant were low, while those at the Riverside and Wagner plants were higher and similar to each other (38, 39, 40). Major species spawning in the Harbor are mostly forage species and included bay anchovy, Atlantic silverside, tidewater silversides, naked goby, rough silversides, and hogchoker (38, 39, 40). These results confirm that the Baltimore Harbor power plants are not located in a spawning area for exploited fish species, but suggest that spawning and nursery activities for forage species have increased in the Harbor area during recent years compared to that reported there during the early and mid-1970's (41).

Potential losses to regional fish populations from entrainment of ichthyoplankton were estimated at Calvert Cliffs (mid-Bay area) and Morgantown (tidal Potomac) to evaluate potential impacts of plant operations on Representative Important Species (RIS)(Tables IV-4 and IV-5). These estimates were made using information about system hydrodynamics, life history, and stock size, and assumed entrainment mortality was 100 percent. They suggest that regional ichthyoplankton populations of Atlantic croaker, bay anchovy, and possibly naked goby and winter flounder may be affected by entrainment losses at Calvert Cliffs (Table IV-4). Naked goby populations were potentially affected at Morgantown (42). The projected economic effect of entrainment losses at both facilities on regional fisheries was low because few harvested species are entrained (Table IV-5). The projected change in net system productivity resulting from the calculated entrainment losses was also low at both facilities (Table IV-5). Estimates of the potential consequences of entrainment losses for Baltimore Harbor facilities have not been made because information for ichthyoplankton in the Harbor area is inadequate. Estimates of the potential consequences of entrainment losses for Chalk Point are currently being made.

The entrained ichthyoplankton at all power plants in the mesohaline zone are mainly small forage species, such as bay anchovy, silversides, naked goby, and hogchoker. The mesohaline zone is not a spawning area for ichthyoplankton of commercial or recreational value. None of the mesohaline plants are located in areas that constitute discrete, major spawning area for the above-mentioned forage species. In general, these species spawn over much of the Maryland portion of the Chesapeake Bay (2). Thus, even large losses to local spawns are not likely to cause a significant change in Baywide populations.

A special form of entrainment occurs at Chalk Point where auxiliary pumps are used during warmer months to temper the magnitude of physical and chemical stresses in the discharge canal and receiving body by dilution (43). These pumps transport water directly from the intake region into the head of the discharge canal without passing through the plant cooling system, and they are not protected by intake screens. Large organisms such as fish and crabs, as well as planktonic forms may be drawn into these pumps. The number of adult and juvenile fish and crabs entrained through auxiliary pumps is equal to or larger than the number impinged on intake screens (43). About 42 percent of the crabs and 70 to 95 percent of the fish passing through auxiliary pumps die immediately. Delayed mortality has not been estimated but is expected to be high since organisms that survive passage through auxiliary pumps are exposed to high temperatures

Table IV-4. Potential Losses to Adult Fish Populations in the Regions Adjacent to Estuarine Power Plants Due to Entrainment Losses of Ichthyoplankton (Assuming 100% Mortality). Values in Percent of Total Population in Region.

Species	Calvert Cliffs[a] (mesohaline)	Morgantown[b] (mesohaline-oligohaline)	Crane[c] (oligohaline - tidal freshwater)	Possum Point[b] (oligohaline-tidal freshwater)
Striped bass	0	0.13	<0.10 (<0.01)[d]	6.30
White perch	0	0	2.10 (0.04)	5.10
Spot	0.27	0.07	1.10 (<0.01)	0
Atlantic croaker	6.39	0.22	<0.10 (<0.01)	0.02
Atlantic menhaden	1.04	0.89	1.10 (0.02)	0.62
River herrings	0	0.02	<0.10 (<0.01)	6.00
Winter flounder	4.68	0	0 (0)	0
Yellow perch	0	0	0.80 (0.01)	0
Bay anchovy	4.99	2.30	2.50 (0.07)	0.11
Naked goby	4.13	4.40	4.90 (0.07)	0
Silversides	0.26	2.10	2.00 (0.10)	1.20

(a) Region of evaluation was the head of the Bay to the mouth of the Patuxent (Ref. 21)
(b) Region of evaluation was the tidal Potomac (Ref. 42)
(c) Region of evaluation was the Gunpowder estuary (Ref. 59)
(d) Number in parenthesis is a similar evaluation using the entire upper Bay region as the region of evaluation.

Table IV-5. Percentage of Potential Economic and Ecological Effects Due to Entrainment Losses of Ichthyoplankton

Site	Economic Losses to The Regional Fishery ($)	Economic Losses to The Regional Fishery (%)	Loss of Ecological Productivity in the Regional Ecosystem (%)
Calvert Cliffs[a] (mesohaline)	200	0.12	0.73
Morgantown[b] (mesohaline oligohaline)	5,200	0.10	0.35
Crane[c] (oligohaline tidal freshwater)	202(100)[d]	0.33(0.004)[d]	0.95(0.0238)[d]
Possum Point[b] (tidal freshwater)	167,310	3.2	0.44

(a) Region of evaluation was the head of the Bay to the mouth of the Patuxent (Ref. 21).

(b) Region of evaluation was the tidal Potomac (Ref. 42).

(c) Region of evaluation was the Gunpowder estuary (Ref. 59).

(d) Number in parenthesis is a similar evaluation using the entire upper Bay region as the region of evaluation.

and chlorine residuals when they are released in the discharge canal. Auxiliary pump entrainment is much higher at night than during the day and is a function of the number of auxiliary pumps operating (43).

- Impingement

Impingement at mesohaline facilities was summarized and discussed in previous CEIR's (3, 26, 27). These data, along with additions, are summarized in Tables IV-6, IV-7, and IV-8.

At mesohaline facilities a few species (Atlantic menhaden, spot, bay anchovy, hogchoker, and blue crabs) generally dominate impingement counts (Tables IV-6 and IV-7). The Calvert Cliffs impingement data suggest that the species composition of impingement is relatively similar from year to year (Table IV-6). Year-to-year fluctuations in impingement catch generally reflected year-to-year fluctuations in fish and crab abundances in the intake area. Highest impingement generally occurred in late summer and fall, and lowest values occurred in winter and spring (21, 25, 30, 38, 39, 40). Juveniles dominated impingement catches, and the number of fish impinged usually was greatest at night. Mortality of impinged fish varies from species to species. About 90 percent of impinged spot and hogchoker survive, whereas only about 25 percent of impinged menhaden and other clupeids survive (21, 25, 30). Blue crabs had essentially no post-impingement mortality (21, 30, 44). Thus, losses of fish and crabs as a result of impingement are much less than the number impinged.

Mortality rates to impinged organisms generally were highest under intermittent screen rotation schedules (three times per day), rather than when screens were rotated frequently (once per hour) (21, 30, 45). However, more organisms were impinged by frequent rotation schedules, and as a result, overall losses to local populations were lower if infrequent screen rotation schedules were used.

Although rigorous estimates are not available for all species, post-impingement mortalities probably are highest at the Chalk Point and Morgantown facilities where impinged organisms are returned to the receiving body along with other plant discharges which include chlorine residuals (30, 44). A new screen wash discharge system that returns impinged organisms to the nearfield area is being installed at Morgantown. A barrier net has been installed across the intake canal at Chalk Point and

Table IV-6. Estimated Annual Impingement (Number of Individuals) at Calvert Cliffs Nuclear Power Plants 1975-1981. One Unit Was Operational in 1975 and 1976. A Second Unit Began Operating in 1977.

Species	1975[(a)]	1976[(b)]	1977[(c)]	1978[(d)]	1979[(e)]	1980[(f)]	1981[(g)]
Bay anchovy	774,442	78,369	382,254	362,254	258.636	731.719	731,393
Atlantic menhaden	342,614	454.253	136,963	177,675	63,496	217,273	53,700
Spot	337,254	1,279,947	141,741	159,797	56,511	256,453	222,774
Hogchoker	94,333	188.350	121,015	169,897	143,257	249,336	468,035
Misc. Finfish	501,103	233,138	291,173	233,169	344,775	150,973	134,464
Blue Crab	293,014	434,893	545.292	472,921	1,106,962	381,087	1,663,814
Total Fish	2,049.746	2,234,057	1,073,146	1,103,343	866,675	1,605.754	1,610,366
TOTAL IMPINGED ORGANISMS	2,342,760	2,668,950	1.618,438	1,576,264	1,973,637	1,986,841	3,274,180

(a) From Refs. 14 and 15

(b) From Refs. 16 and 17

(c) From Ref. 18

(d) From Ref. 19

(e) From Ref. 20

(f) From Ref. 22

(g) From Ref. 23

Table IV-7. Estimated Annual Impingement (Number of Individuals) at the Chalk Point, Morgantown, and Crane Power Plants

Species	Chalk Point[a] 1976-1977		Morgantown 1975[b]		Morgantown 1976-1977[c]		Crane 1978-1979[d]		Crane 1980[d]	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Atlantic menhaden	1,347,490	31	414,376	57	793,168	45	246,358	38	149,248	41
Spot	647,016	15	200,972	28	312,665	18	1[illegible],118	3	14,069	4
Hogchoker	191,926	5	2,510	0.3	38,095	2	9,205	1	6,281	2
White perch	41,910	1	60,648	8	91,525	5	148,941	23	76,428	21
Bay anchovy	Included with other fish		30,969	4	52,201	3	11,479	2	10,614	3
Other fish species	139,928	3	22,645	3	162,390	10	91,153	14	37,930	10
Total fish	2,368,324	55	732,081	100	1,450,044	82	526,249	81	294,580	81
Blue crabs	1,948,132	45	Not available		307,057	17	119,394	19	70,235	19
Total impinged organisms	4,316,456	100	Not available 1		1,757,101	100	645,643	100	364,815	100

(a) Data from Ref. 30

(b) Data from Ref. 25

(c) Data from Ref. 45

(d) Data from Ref. 58

Table IV-8. Estimated Annual Impingement (Number of Individuals) at Baltimore-Area Power Plants (1978-1979)

Species	Gould St.[a]	Riverside[b]	Wagner[c]	Total	Percent Total
Spot	745	176	554,151	555,072	38
Atlantic Menhaden	2,982	34,267	244.666	281,915	19
Atlantic Croaker	9,402	21,055	49,439	79,896	5
Gizzard Shad	3,786	6,758	20,966	31,510	2
Atlantic Silverside	223	414	21,230	21,867	2
White Perch	287	516	12,723	13,526	1
Other Fish Species	686	2,516	40.752	43,954	3
Total Fish	18,111	65,702	943,927	1,027,740	70
Blue Crab	6,348	9,241	430,045	445,634	30
Total Impinged Organisms	24,459	74,943	1,373,972	1,473,374	100

(a) Data from Ref. 40

(b) Data from Ref. 41

(c) Data from Ref. 42

is currently being tested to determine if it reduces impingement levels.[1]

High impingement episodes account for a large proportion of annual impingement estimates at mesohaline facilities (21, 30). As a result, impingement levels are not directly related to the volume of water pumped but are more a function of fish and crab abundance in the vicinity of intake screens. At Calvert Cliffs and Morgantown, high impingement episodes were related to low dissolved oxygen levels in the intake embayment (21). Removal of panels from curtain walls provided entrapped organisms with an escape route and reduced impingement levels. At Chalk Point, high impingement episodes are related to normal seasonal migration (30). Survival of most impinged species is high and mortalities are considerably less than actual impinged values. Impingement losses to dominant species are small compared to commercial landings and are only a small percentage of the forage required for major predator fish populations (21). Thus, impingement losses, including those projected for the BRESCO and Brandon Shores facilities, are not expected to impact upon commercial or recreational landings from mesohaline habitats.

• Discharge Effects and Habitat Modification

Thermal plume dimensions for power plants in the mesohaline zone were discussed in previous CEIR's (3, 26, 27). In all cases, the distribution and size of thermal plumes varied with season, tidal stage, wind velocity and direction, and plant operating level (21, 25, 30, 38, 39, 40).

Of the mesohaline power plants, the Chalk Point facility has the greatest potential for causing discharge effects.[2] This is because the Patuxent estuary at Chalk Point is shallow and plant water use exceeds freshwater flows during summer and fall. In addition, the plant discharge is located approximately 4-km upstream of the intake resulting in plant-related changes in salinity distributions. In the early 1960's, copper was eroded

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[1]A preliminary evaluation indicates that there has been 80 percent reduction in impingement of blue crab, spot, and menhaden. White perch impingement increased by about the same percentage. It is thought that this increase occurred because a large number of white perch was trapped behind the net at the time of the original deployment. These individuals could not escape and were eventually impinged. Since the net is now kept in place at all times there should be no repetition of this episode.

[2]It should be noted that oyster bars at Chalk Point do not support a fishery.

from condenser tubes and its subsequent uptake by oysters was observed (46). Although the conditions that caused the release of copper were corrected, even in recent times plant operations affect copper distributions in the discharge area, expecially during low flow periods (30, 47). Plant operations may have an effect on nutrient cycling in the discharge area but this effect, if it occurs at all, is small (48). Studies are being conducted to determine if entrainment mortality to phytoplankton affects carbon distributions in sediments.

Thermal plumes at all Baltimore Harbor power plants are strongly influenced by wind, and wind events often determine the length of time elevated temperatures persist at a given location (49). Tidal influence on the distribution of thermal discharges in the Harbor is small. Five to ten percent of the surface area is affected by the thermal discharges of power plants. Additional modifications to temperature distributions in the Harbor area from power plant operations at Brandon Shores and the BRESCO facility are not projected to be large (32, 33). The Brandon Shores facility uses closed-cycle cooling and will withdraw and discharge cooling water from the existing Wagner discharge area. The absolute temperature of Brandon Shores effluents is projected to be equivalent to or less than the present Wagner discharge temperatures. The BRESCO facility will discharge its thermal effluents using a jet diffuser. Thus, excess temperatures will be rapidly dispersed.

Details of discharge effects at the Calvert Cliffs and Morgantown facilities were covered by previous CEIR's (3, 26, 27). No consistent discharge effects to phytoplankton, zooplankton, or fish were detected at either plant. High-velocity discharge systems modified habitat characteristics at both sites, scouring away natural sands and mud in the immediate vicinity of discharges (21, 36). These modifications affected the abundance and makeup of benthic biota in the discharge area. Plant-related increases and decreases in benthic abundance, growth, and productivity have been observed away from scoured areas. Increases in benthic abundance, growth, and productivity far outweigh decreases and appear to be related to organic additions to bottom habitats resulting from entrainment mortality to plankton (21, 36). Copper levels in tissues of oysters have consistently been higher in the vicinity of Calvert Cliffs discharges, but densities of oysters in the discharge area are low and do not support a fishery (21, 22, 23). Copper uptake by oysters have also been reported in the Morgantown discharge canal but uptake of copper by biota in the nearfield has not been observed (24, 25). Oyster bars in the vicinity of the Morgantown facility also do not support a fishery (2).

During the 1960's, large concentrations of fish were reported in the discharge canal of the Chalk Point facility in fall and winter and the discharge region supported a sport fishery (50, 51). Recent studies indicate fish and crabs are attracted to and excluded from the discharge area depending upon season but no large winter attractions were observed (30, 52). Moreover, plant operations did not block migration routes, affect physiological condition, or interfere with spawning activities of fish (53, 54, 55, 56). Rather, whatever attractions of fish that occurred persisted only for short time-periods and varied in magnitude with season (30, 52).

Small worms, called oligochaetes, were the most abundant benthic organisms in the vicinity of the Chalk Point facility, being up to 10 times higher near the discharge site than they were at reference areas (30, 35). The high oligochaete abundances were not due to natural environmental conditions but were related to the location of the thermal discharge and plant-related organic inputs resulting from entrainment mortalities to plankton (35). Plant operations did not affect distributional patterns or abundance of other benthic biota, including the biomass of micro-organisms in sediments. No plant effects on growth or mortality of the most abundant clam, *Macoma balthica*, were observed (35). Blue crab growth, size, and sex ratios also were not affected by plant operations (30).

Discharge effects, if any exist, on benthic populations in the Patapsco River cannot be separated from the effects of sediment characteristics, most notably, sediment heavy metal concentrations (57). Zooplankton depletions were not observed in the discharge region of the Wagner plant (31). Although spot and white perch were attracted to the Wagner thermal plume, this phenomenon was not consistent (57).

- Conclusions

When the results of studies at all mesohaline plants are considered, a picture emerges that indicates a low probability of cumulative impact on mesohaline habitats. Although large phyto- and zoo-plankton entrainment losses have been occasionally reported, consistent depletions have not been observed in discharge waters. This is probably due to the rapid recovery of plankton. No important commercial or recreational species spawn in the mesohaline zone. Thus entrainment losses of ichthyoplankton have little economic significance. Forage fish species spawn in this zone and large numbers of their ichthyoplankton are entrained. However, no mesohaline facility is located in a discrete spawning area for forage species, and local entrainment losses do not have a deleterious impact on regional populations except possibly at Chalk Point. Large numbers of juvenile fish and blue crabs are impinged at mesohaline facilities. However, impingement losses have not had adverse impacts on nearfield populations of fish and crabs. This is probably because survival of most species is high following impingement and factors other than power plant operations are controlling abundance levels in the environment. Discharge effects in mesohaline habitats were generally localized within the thermally affected area and their magnitude was related to the amount of hot water discharged relative to the volume of ambient water available for dilution. Phytoplankton growth and productivity were stimulated in the immediate discharge area during colder seasons at some plants. Fish and crabs showed both attraction to and exclusion from plant discharges but these behavioral effects did not adversely affect migration, spawning activity, or physiological condition. Discharge effects were most detectable in benthic populations, probably because of their sessile life style. Because the effects on the benthos generally were to increase abundance and productivity, there was no adverse impact upon foodweb dynamics. The addition of the Brandon Shores and BRESCO facilities in the Harbor area is not likely to result in additional adverse impact on mesohaline habitats.

Tidal Fresh - Oligohaline

The tidal fresh-oligohaline habitat zone is where salt and fresh waters first mix and tidal circulation begins. Nutrient levels in the water usually are high and primary producers flourish. Sediments transported by river water are mostly deposited here. This habitat zone has significant value as the major spawning area of anadromous and semi-anadromous fish (2). Species of major importance that spawn here are striped bass, white perch, American shad, and river herrings, which as a group account for most of the monetary value of the harvested finfish in Maryland. Since spawning occurs in the spring, the plants of most concern are those in the tidal fresholigohaline zone at that time, particularly those sited near striped bass spawning areas. The tidal fresh-oligohaline zone also serves as a nursery area for many important RIS species year-around.

Seven plants use oligohaline waters for cooling purposes in the spring (Table IV-2a). At several of these plants (Chalk Point, Morgantown, and the Baltimore area plants), salinity is in the mesohaline range during most of the remainder of the year. Impacts associated with them were discussed in the preceeding section.

The remaining tidal fresh-oligohaline plants are Possum Point, Vienna, and Crane. Possum Point, on the Potomac, and Vienna, on the Nanticoke, are both in major striped bass spawning areas. Crane, though located on tidal fresh-oligohaline waters, does not impact on a striped bass spawning area. Delmarva Power and Light Company has been granted a license for a 500 MWe cooling tower expansion at Vienna. Baltimore Gas and Electric Company is planning the construction of a 600-800 MWe coal-fired plant in the tidal fresh-oligohaline zone of the Bush River (Perryman site). As yet, a Public Service Commission certificate has not been applied for and a specific design for the Perryman facility has not been proposed. It is, however, expected that the final design will use a cooling tower and draw make-up water from the Susquehanna River via an existing reservoir pipeline.

- Entrainment

Entrainment at Crane generally enhanced photosynthetic rates and efficiency when ambient temperatures were less than 25°C and the ΔT was less than 6°C. At higher ambient temperatures and ΔT's, phytoplankton productivity was inhibited and standing stock size was reduced (58, 59, 60, 61). Zooplankton entrainment generally did not result in nearfield depletions except during extreme summer conditions (58, 59, 62, 63).

Entrainment of zooplankton and phytoplankton at Vienna was estimated to be low (64). Entrainment studies have not been conducted at Possum Point. However, no depletions of phytoplankton or zooplankton have been observed in the nearfield area, suggesting entrainment losses are not large (65).

White perch and bay anchovy were the dominant ichthyoplankton entrained at Crane (59). Entrainment losses were moderate. The potential impact of these losses was placed into perspective by estimating the population, economic, and ecological consequences (Tables IV-4 and IV-5). This analysis indicated entrainment effects to some fish populations were potentially large in the immediate plant vicinity, but were small when placed into a regional perspective. The total economic value of entrainment losses to the regional fishery was estimated to be about $200 annually. Ecological losses in "un-utilized" energy flow was calculated to be 0.95 percent of the net production in Gunpowder/Middle River estuaries (59).

Possum Point is situated in the tidal fresh-oligohaline spawning grounds of the Potomac (42). In some years, striped bass spawning is concentrated in the vicinity of plant intakes. The estimated loss to spawning of RIS fish populations in the Potomac from entrainment at Possum Point is summarized in Table IV-4. Highest losses occurred for striped bass (6.3%), white perch (5.1%), and river herrings (6.0%). The monetary value of these losses was estimated to be $167,310 or about 3.2 percent of the annual value of the Potomac fishery. The change in net productivity of the Potomac ecosystem was calculated to be 0.44 percent (Table IV-5).

Vienna is located in the midst of the striped bass spawning area on the Nanticoke. Approximately 8 percent of the Nanticoke ichthyoplankton stocks were entrained annually from 1977 to 1979 (66). However, Units 5, 6, and 7 which used once-through cooling were operational when the above entrainment estimates were made. These units were retired in 1980 (3.6 m^3/s water use). Current water use at Vienna is only about 0.12 m^3/s most of which provides make-up water for Unit 8, which has a cooling tower. Delmarva Power and Light has proposed a 500-MWe cooling-tower expansion (Unit 9, 1995 completion date) which will withdraw 0.42 m^3/sec for condenser cooling and other plant purposes (67). The proposed intake for the new unit includes a fine mesh, wedge wire screen intake system which is designed to minimize entrainment of fish eggs and larvae. When Unit 9 begins operation, ichthyoplankton entrainment is predicted to average about 2 percent of the Nanticoke ichthyoplankton population (66). The proposed Perryman facility is not located in a major striped bass spawning region, and its addition is not likely to significantly increase power plant effects on striped bass populations.

• Impingement

Impingement at Chalk Point, Morgantown, and the Baltimore Harbor plants, where waters are oligohaline for only a few months in the spring, was discussed in the previous section on mesohaline plants. Impingement of juvenile and adult fish at Vienna is negligible (66). Impingement at Possum Point is suspected to be small since water use is not large.

Atlantic menhaden and white perch dominated impingement counts at Crane (Table IV-7). Blue crabs were also impinged in significant numbers (68). These are generally lower values in comparison to impingement levels from mesohaline plants. Increasing the intake screen wash cycle from once every 8 hours to once an hour increased the impingement rate (68). Despite higher survival rates associated with the 1-hour cycle, it was concluded that the currently-used 8-hour screen wash cycle minimized impingement losses. Although impingement rates at Crane were irregular and fluctuated considerably from one sampling date to another, the general trend was for highest rates to occur in summer and fall, and lowest rates to occur in late winter.

Post-impingement mortalities at Crane varied from species to species (69). Mortality rates were highest for menhaden and gizzard shad (70-100%). Spot, hogchoker,white perch, and yellow perch had post-impingement mortality rates of from 10 to 50 percent. Post-impingement mortality rates for most species were size-dependent, with largest mortalities generally occurring to smaller individuals (69). Essentially all impinged blue crabs survived.

The consequences of impingement at oligohaline plants are similar to those at mesohaline plants: many organisms survive impingement, and the major species impinged were ubiquitous and abundant throughout Maryland's tidal waters. Impingement losses appear too small to have a detectable effect on stock sizes.

- Discharge Effects and Habitat Modification

Thermal plumes at Vienna were sufficiently small so that discharge effects can be considered negligible (70).

Discharges from Possum Point are released into Quantico Creek which is in Virginia waters. No discharge effects have been observed in the Potomac from Possum Point probably because the thermally affected area in Quantico Creek is small (65). Natural fluctuations in zooplankton and benthic abundance in the thermally effected area of Quantico Creek were larger than any measurable plant effects. Some fish were attracted to thermal effluents at Possum Point during winter. Although thermally affected areas were avoided by fish during summer, this did not affect migration or spawning and nursery activities (65).

The thermal plume at Crane extended across the discharge creek system and affected about 40 percent of the total volume of the receiving water body (71). Crane effluents also resulted in slight increases in salinity in the receiving body but did not affect dissolved oxygen levels (72, 73, 74). No above-ambient levels of heavy metals were observed in sediments from the discharge area (75).

Thermal effluents from Crane enhanced phytoplankton productivity in the discharge region except during extreme summer conditions when phytoplankton growth was inhibited (59, 60, 72).

Greater densities and biomass of submerged aquatic vegetation (SAV) occurred in the intake area of the Crane facility than at four sample sites in the discharge area (76, 77). However, the area where the thermal plume was hottest did not consistently contain the lowest SAV density or biomass, suggesting that plant operations have only a limited effect on SAV. Spring SAV growth was initiated earlier at thermally affected sites, but thermal discharges did not delay the normal winter dieback (76, 77).

Depletions of the dominant zooplankton species were observed in the immediate discharge region at the Crane facility during summer of some years (61, 62, 63, 72). The makeup of the zooplankton community in the thermal plume region was also out of phase with zooplankton communities occurring in natural water bodies of the region. Cold water adapted forms were apparently at a competitive disadvantage in thermally affected areas during fall and spring. Transferring water of a higher salinity from the intake area to the discharge site produced a zooplankton community tolerant of more saline conditions than would have existed there had the plant not been operating (61, 62, 63). However, compared with normal seasonal trends in zooplankton community composition and abundance, plant effects were small (72).

The size of bottom area over which the benthic biota was influenced by plant operations at Crane varied seasonally as a function of freshwater flow. During high river flow periods (i.e., spring), the amount of bottom habitat and the extent that the benthic community was influenced was small and restricted to the immediate discharge area. During low flow periods (i.e., summer), the affected area was much larger and extended almost to the Gunpowder estuary. During summer, fewer benthic species occurred in the discharge area than at unaffected reference sites (72, 78, 79). During spring, the onset of growth and development of some numerically abundant benthic species occurred earlier in the discharge area than in adjacent unaffected sites (72, 78, 79, 80).

Summer fish predation on the dominant clam was higher in the discharge area than at reference areas (80). However, the higher-than-ambient temperatures characteristic of the discharge areas enhanced winter survival of this clam, which is susceptible to high winter mortalties in Chesapeake Bay. Thus, juvenile clams that survived the first summer in the discharge area had a higher probability of surviving extreme cold periods than did clams in reference areas (80). There was no evidence that plant operations affected the level of metals in clam tissues (75). Because the reproductive potential of most benthic species is large, any instability in their populations resulting from plant operations may affect short-term seasonal abundances but will not have long-term consequences.

The region around the Crane plant is not an important spawning area for anadromous fish (e.g., striped bass, shad). Spawning movements of semi-anadromous estuarine species such as white perch and yellow