CHAPTER IV

AQUATIC IMPACT

For each kilowatt hour of electricity generated, a steam power plant burning fossil fuel must dispose of about 4,400 Btu of heat via its condenser, and a nuclear power plant must dispose of about 6,600 Btu. Most Maryland power plants use once-through cooling systems to transport this waste heat from the plant. In these systems, water is drawn into the plant, heated 10 to 17°F in the condenser, and discharged into a receiving body of water. Approximately one million gallons of water per minute (or 63 m^3/s) is required for each 1,000 MW of generating capacity. Closed-cycle cooling can be used to reduce water withdrawal. Use of this technology will allow consideration of such options as more power generation per site, or sites in more sensitive areas.

The Chesapeake Bay and its tributaries serve as the major source of cooling water in Maryland. At the same time, this ecological system supports complex aquatic food webs that produce renewable resources of fish and shellfish. A major concern of the Power Plant Siting Program is to ensure that power plants provide electricity at a reasonable cost, while not interfering with the maintenance of sustained yields of these resources and the stability of the system, which depends on all components of the food web. Thus, the impact of power plants on the aquatic ecosystem as a whole must be evaluated, and measures to mitigate this impact should be examined for their potential benefits and costs.

A. Sources and Nature of Impact

As water is drawn through a power plant and returned to its source, aquatic organisms interact with cooling system structures, intake and discharge velocity fields, the heated effluent, antifoulants, and other alterations of the environment caused by plant operations, as explained below.[1] The locations and nature of the interactions and ensuing stresses which are encountered by aquatic organisms are briefly described below: (See also Figure IV-1)

- Entrapment

  Two of the largest Maryland power plants (Calvert Cliffs and Morgantown) have intake embayments partially shut off from the main bay or river by a curtain wall, i.e., a wall reaching from above the surface of the water to some depth below the surface. The function of the curtain wall is to permit the plant to draw its cooling water from the deeper portions of the water column, where temperatures tend to be lower than at the surface during summer months. During the summer, large numbers of fish congregate in the intake embayments and may be entrapped there. During the summer months, dissolved oxygen (DO) concentrations in the water often drop to levels below that needed to sustain adult and

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[1]Radiological effects are discussed in Chapter V.

juvenile fish. The drop is pronounced in the deeper water entering the embayment under the curtain wall. Fish kills may result. The killed (or weakened) fish may then impinge in large numbers on the protective intake screens. In the following discussions entrapment will not be treated as a separate effect.

- Impingement

  The circulating pumps for the cooling water are protected by intake screens (usually 3/8-inch mesh). Organisms too large to pass through these screens may be impinged, i.e., pinned against them by the pressure of the passing water, a prospect that is markedly increased when the organisms (fish or crabs) are weakened by stresses such as low DO conditions. The screens are rotated periodically and the impinged matter is washed off. At several plants the organisms are flushed back into the cooling stream discharge. Some species survive this treatment, but others suffer a high rate of mortality.

- Entrainment

  Organisms small enough to go through the intake screens pass through the entire cooling system, where they are stressed by mechanical forces due to physical contact with pumps and pipes, and pressure and shear forces generated by complex flow patterns and turbulence.

  While passing through the condenser, the entrained biota will be subjected to a sudden temperature rise. The biological response to this heating depends on the magnitude of the temperature rise, the length of exposure to the elevated temperature, and the initial ambient temperature. In Maryland plants, the temperature rise varies from 10° to $32^{\circ}F$ and the exposure time from a few minutes to almost two hours (including retention time in effluent canals). Thus, " thermal stress dose," i.e., a product of temperature and time, is quite variable.

  Entrained biota experience additional stress at plants where biocide (usually chlorine) is added to the cooling water to prevent clogging of the cooling system by biomass build-up.

- Discharge Effects

  The alteration of local habitat produced by the discharge of cooling water can manifest itself in several ways. Aquatic organisms can be "entrained" into the discharge plume, where they will be exposed to higher-than-ambient temperatures and biocide residuals. Other toxic substances released with the cooling water (e.g., copper) may affect the stationary benthic communities near the plume. Finally, a fast-moving discharge flow may alter the characteristics of bottom sediment in its way and may also directly influence the behavior of some organisms in the discharge zone.

Plants using cooling towers rather than once through cooling systems exert similar stresses on organisms interacting with them. However, the degree of stress,in most cases, differs markedly between the two types of

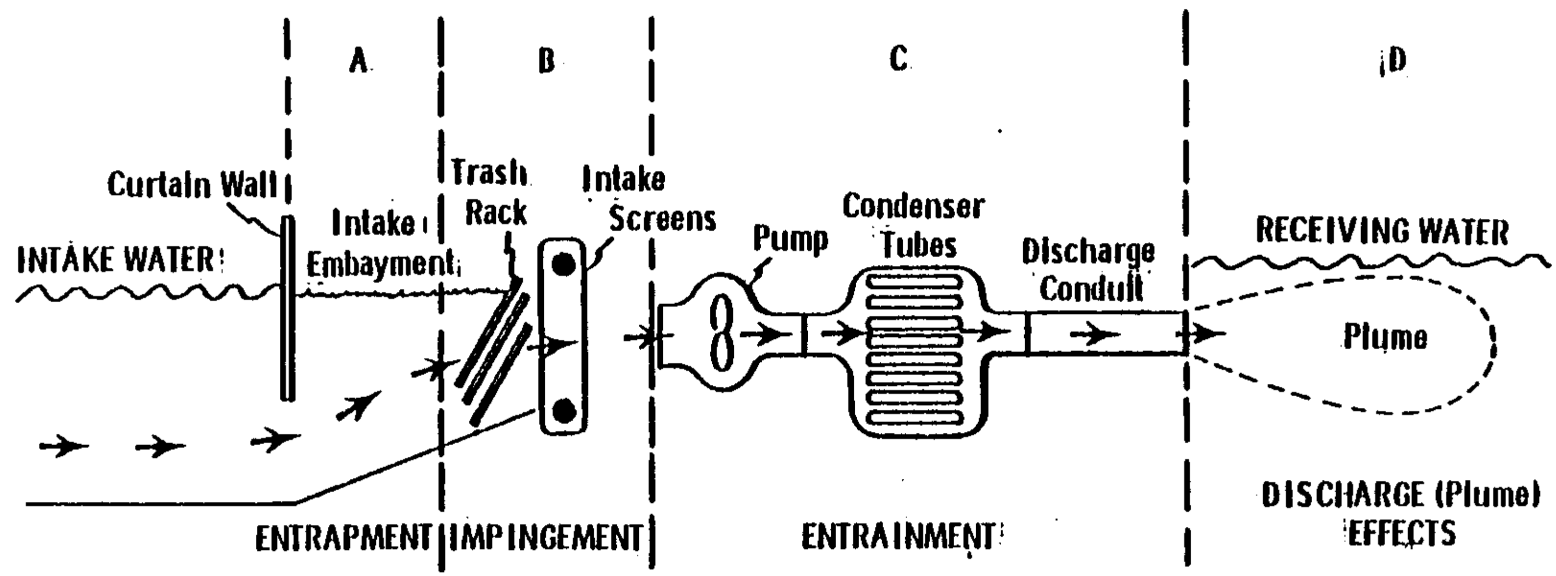

Figure IV-1. Path of water flow through a power plant using once-through cooling and locations of plant-organism interactions.

A. Fish may be entrapped in the intake embayment and may suffer prolonged exposure to water of low dissolved oxygen content drawn from below the curtain wall.

B. Organisms may be trapped on intake screens; the screens are rotated to wash fish and crabs from the screens back into the receiving water.

C. Small organisms in the water column (plankton) pass through the cooling system; they experience a temperature rise and also shear and pressure forces during their transit through the cooling system.

D. Organisms in the receiving water may encounter temperature rises in the plume (plume entrainment) and may be affected by the discharge.

cooling system. The volume of water withdrawn for use in cooling towers is small and intake velocities are low; the result is that entrapment and impingement tend to occur at low rates. The numbers of organisms entrained are low, but mortality is essentially 100 percent because residence time of water in cooling towers is very high. Cooling towers discharge a portion of their cooling water on a regular basis; this water is known as blowdown. Blowdown often contains high levels of metals such as copper (eroded from the cooling system pipes) and biocides, used to prevent fouling of the system. In saline waters, blowdown may also have a high salinity, due to evaporation. Discharge effects due to blowdown release will be similar to that from a once-through cooling system, but because of the small water volumes involved, the area experiencing discharge effects would be very small. For cooling towers the consumptive use of water can often be a concern, requiring augmentation reservoirs to make up for evaporative losses during low-flow conditions in the source waters.

The organisms interacting with the power plant can be grouped as follows:

- Phytoplankton
- Zooplankton
- Benthos
- Ichthyoplankton
- Juvenile and adult fish and crabs.

Individual groups may be more susceptible to damage by one type of power plant interaction than by another (Table IV-1). Entrapment most often stresses juvenile fish. Impingement stresses adult and juvenile fish and crabs. Entrainment stresses planktonic organisms (which serve as food for many resource species), as well as the planktonic larval stages of many resource and forage species. All aquatic biota may experience discharge effects, but benthic species, because of their predominantly immobile life style, would be most stressed.

Mortalities resulting from plant/organism interactions can cause a decline in a population if they are not offset by biological compensation mechanisms such as increases in growth rate, fecundity, recruitment and/or early survival. In the case of phytoplankton or zooplankton, losses due to entrainment are generally recouped quickly as a result of inherent rapid reproduction rates (generation times of hours to days). Other organisms have much longer generation times. Most fish spawn only once a year and may not reproduce until several years of age. For species utilizing a very localized spawning or nursery area adjacent to a power plant, high entrainment losses can occur unless cooling towers with carefully controlled blowdown are used to reduce the amount of organisms entrained. The potential for such losses having an impact is much less for ubiquitous species which spawn in or inhabit wide areas of the Bay.

Table IV-1. Major Types of Aquatic Effects of Power Plant Operations.

Sources of Effects	Primary Susceptible Organisms	Type of Stress				
		Low DO[a]	Mechanical	Thermal	Chemical	Habitat Alteration
Entrapment	Adult and juvenile fish	x	-	-	-	-
Impingement	Juvenile fish, crabs	-	x	-	-	-
Entrainment	Ichthyoplankton[b] Zooplankton[c] Phytoplankton[d]	-	x	x	x	-
Discharge	Adult and juvenile fish, benthos[e], shellfish	-	-	x	x	x

[a] Low dissolved oxygen concentrations -- oxygen deficiency

[b] Eggs and larvae of fish

[c] Weak swimming animals present in the water

[d] Minute plants present in the water

[e] Organisms living in or on the bottom.

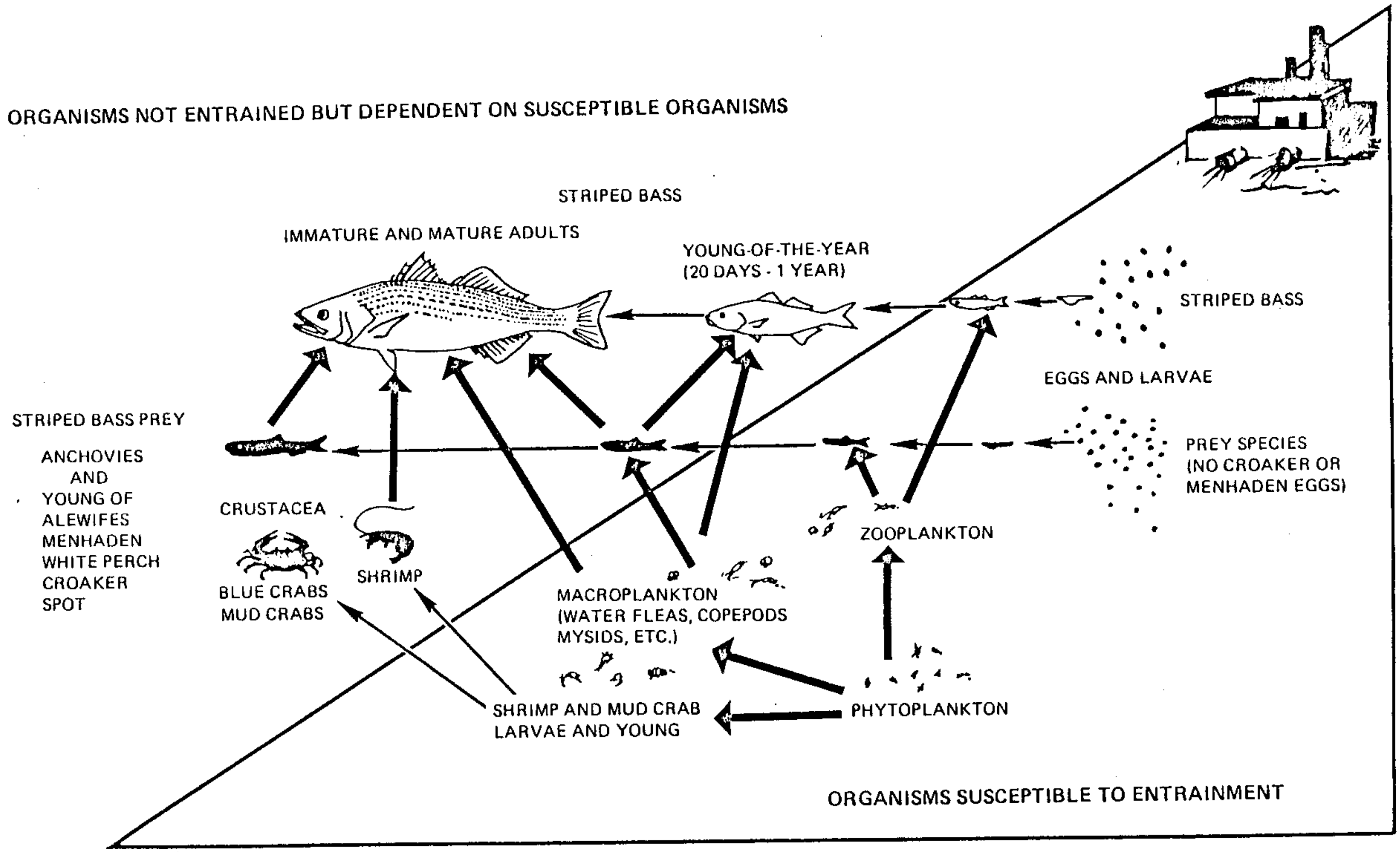

Fig. IV-2. Areas of potential power plant entrainment impact on striped bass and associated food items.

Plant operations can indirectly cause a decline of a population by decreasing the abundance of its food supply. (See Figure IV-2) The dominant groups in the Bay which are important as forage are phytoplankton, zooplankton, benthic organisms, and small fish species (e.g., bay anchovy and menhaden). Although fish populations are more likely to be affected by the entrainment of their ichthyoplankton, they could also be affected by a change in the density of their food. These indirect effects may propagate through several trophic levels, although they are unlikely to be measurable beyond one link along the food chain.

Plant operations also affect particular species through modification of the physical/chemical environment. Biocide residuals may accumulate in areas around the plant, and temperatures are elevated by varying amounts in the discharge vicinity. Discharge jets may also scour the bottom sediments, creating locally uninhabitable zones for benthic organisms. If such habitat modifications make an area unsuitable for use by some species, a subsequent decline in their abundance can occur locally.

B. Aquatic Habitats

The central concept underlying the cumulative aquatic assessment presented here is that the Chesapeake Bay and its tributary estuarine waters are composed of distinct habitat types. These habitat types are defined by water salinity, which is the environmental variable most important in controlling distributions of organisms in estuaries. Each of these habitats can be identified with unique functions in producing or supporting important resource elements, although their biotic components overlap, and their extent varies seasonally. 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 the long-term integrity of each estuarine habitat and its characteristic functions are maintained. In order to accomplish this assessment the salinity zones must be defined and the distribution of the power plants among the zones determined.

The salinity zones designating the habitat types can be defined by the Venice system of classification (1) as:

Habitat	Salinity Ranges
Euhaline (Marine)	30.0 ppt - 35.0 parts per thousand (ppt)
Polyhaline	18.0 ppt - 30.0 ppt
Mesohaline	5.0 ppt - 18.0 ppt
Oligohaline	0.5 ppt - 5.0 ppt
Tidal fresh	0 ppt - 0.5 ppt
Riverine	0 ppt

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 clams. Several fish species, (e.g., spot, croaker, and Atlantic menhaden) whose young and adults seasonally feed in upper estuarine zones, spawn and develop in these regions. These 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 those shellfish (clams, oysters) whose early life stages are planktonic. Mesohaline waters also support the adult crab populations and produce most of the estuarine forage fish biomass. Therefore these waters serve as feeding areas for large predator fish (e.g., bluefish, striped bass).

- Oligohaline

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

- Tidal Fresh

  These segments of estuaries are within tidal influence but without a significant salt intrusion. They provide spawning and nursery areas for anadromous fish species and also support their larvae and juveniles during the spring and summer months. In addition, resident fish species, some adapted to both this and riverine environments, spend their entire life cycles in this zone. The striped bass is a particularly important example of a species using this environment as a spawning and nursery area.

- Riverine

  These freshwater habitats beyond the head of the estuary have resident fish populations and supporting bottom (benthic) communities adapted to constant freshwater conditions.

The locations of these zones change seasonally as a result of changes in the amount of freshwater inflow (2). Table IV-2 indicates the zones in which Maryland power plants are located and designates their zone according to season. The majority of plants in Maryland are situated in oligohaline-mesohaline regions. Data collected since publication of the last Cumulative Environmental Impact Report (CEIR) (3) show that four plants previously considered to be in tidal fresh-oligohaline areas (Wagner, Westport, Gould Street, Riverside) are actually on oligohaline-mesohaline waters. The largest of the power plants in the state (Calvert Cliffs, Chalk Point, and Morgantown) are sited in mesohaline regions (at least in the fall) and new plants (e.g., Elms) will also be in the mesohaline habitat. There are no power plants in the polyhaline and marine habitats along the Atlantic shoreline in Maryland.

Table IV-2. Power Plant Location by Salinity Regime.

Power Plant	Net Capacity (MW)	Spring				Fall			
		Riverine	Tidal-fresh	Oligo-haline	Meso-Haline	Riverine	Tidal-fresh	Oligo-haline	Meso-haline
Brandon Shores	1,250			x					x
Calvert Cliffs	1,620				x				x
Chalk Point	1,265			x					x
Conowingo (hydro)	512	x							
C.P. Crane	384		x					x	
Dickerson	545	x				x			
Gould Street	103			x					x
Morgantown	1,163			x					x
Possum Point	478		x					x	
R.P. Smith	129	x				x			
Riverside	321			x					x
Vienna	241			x				x	
Wagner	988			x					x
Westport	177			x					x
Total Capacity by Zone		1,186	2,112	4,258	1,620	1,186	0	2,353	5,637

C. Regulatory Considerations

The intake, use, and discharge of waters for power plant use are regulated through the issuance of surface water appropriation permits and Natural Pollutant Discharge Elimination Systems (NPDES) discharge permits. These permits reflect Federal and State constraints on the amount of water used, the type of intake employed, and the chemical and physical characteristics of the effluent.

The evaluation of existing once-through cooling systems to determine if cooling towers are required to protect the "balanced, indigenous population" is done in conjunction with the NPDES permit process and the Code of Maryland Regulations (COMAR) 08.05.04.13. Under the State regulations, an initial evaluation of impact is made based on the size of the thermal plume with respect to mixing zone criteria and the importance of the area as a spawning and nursery area. If the plant fails to pass these screening criteria, a more detailed evaluation is required. Impingement (and intake technology used to minimize it) is also treated under the State regulation. Yearly impingement total are estimated (as discussed later in this chapter) and various methods of mitigation are evaluated to determine which techniques are cost-effective. The status of the various Maryland plants which fall under this regulation is listed in Appendix B.

The Dickerson Power Plant wastewater treatment system was under a compliance order during 1978-79. Testing of the new system was completed in August, 1979 with the plant passing a compliance test in February, 1980.

D. Aquatic Impact Assessment

Many additional monitoring studies have been completed since the publication of the last CEIR (3) including several carried out at sites where data had previously not been available. All additional data available through November 1980 has been incorporated into the following assessment of power plant impacts on each of the salinity zones in Maryland.

Mesohaline

This medium salinity zone accounts for the greatest percentage of aquatic habitat in the Maryland portion of the Chesapeake Bay. It serves as the primary area of shellfish and forage fish production and as nursery and feeding ground for most commerically and recreationally valuable fish species and blue crabs. Three of the plants located in this zone (Calvert Cliffs, Chalk Point, and Morgantown [summer-fall]) are the largest and newest in the State. All three of these plants have been or are being intensively studied. The findings of the Calvert Cliffs monitoring studies covering the preplant period as well as the first five years of operation (1975-1980) have been reported in References 4 through 14. The results of these studies are summarized in Reference 15. The Morgantown monitoring findings are summarized in References 16 and 17. The results of the Chalk Point Studies in the 1960's are summarized in Reference 18. This plant is currently being intensively studied.

Four additional plants (Gould Street, Riverside, H. A. Wagner, and Westport) are located on the Patapsco River and its tributaries in the Baltimore area. Salinities at these plants tend to be in the oligohaline range in the spring and low mesohaline during the remainder of the year. In the past, environmental degradation which was not related to these plants had elminated the area as an important anadromous spawning ground (19). However, as will be discussed below, numerous species of aquatic biota are currently using the area. Except for Wagner, these plants are all older than 20 years, are used for peaking and cycling service, and have seen decreased service since Calvert Cliffs came on-line. Because of the close proximity of these four plants, they will be discussed as a group in the material presented below.

- Entrainment

In-plant losses of about 30-70 percent of entrained zooplankton have been observed at Calvert Cliffs, but the percentage loss was very variable and often species-specific. Losses of entrained phytoplankton biomass and productivity (on the order of 30% for each) have also been observed, primarily in late summer and fall. No significant nearfield depletion of zoo- or phytoplankton has been observed. Regional reduction in zooplankton density and phytoplankton assimilation was noted in 1975, but the widespread nature of the changes suggests the plant was not the causative agent. Similar reductions were not observedin the nearfield in later years. A review of these studies is contained in Reference 15.

High zooplankton mortalities (50 %) have been measured as a result of entrainment at Morgantown only under the most severe thermal and chlorine stress conditions. Phytoplankton productivity was also reduced during those periods (16) . However, no changes in zooplankton and phytoplankton populations in the river were detected (16). It was estimated that 2 percent of the plankton transported past the plant would be destroyed by entrainment (16, 17). No adverse impact would result from losses of this magnitude to the rapidly reproducing plankton populations.

Large mortality of entrained organisms was reported at Chalk Point in studies done in the 1960's, with both thermal and biocide stresses appearing to be important causes (20). Near-field depletions of jellyfish were also noted, but no changes in river populations of copepods were found (18). More recent phytoplankton studies (21) also suggest a reduction in photosynthetic activity and chlorophyll concentrations between intake and discharge that is more marked during periods of chlorination. Similarly, recent zooplankton studies indicate entrainment losses of 21 and 52 percent without and with chlorination, respectively, during summer, but no apparent losses during winter sampling (22) (no chlorination is used in winter). Some plant effects on near-field phytoplankton biomass and productivity have also been observed in recent studies (24), with enhancement occurring in winter and depresssion in summer. However, these effects were inconsistent (21, 25). A lower density of zooplankton in the plant vicinity was observed during one study (22), but not during others (22, 26).

No zooplankton or phytoplankton entrainment studies have been done at Baltimore harbor plants. For phyto- and zooplankton entrainment we conclude that the findings at Morgantown and Calvert Cliffs are similar. Entrainment losses of phytoplankton and zooplankton do occur, but high reproduction rates of the affected populations compensate for the plant effects. Based on these findings, cumulative effects would not be expected.

At Chalk Point, the receiving water body has relatively low flushing rates, and near-field effects are detected. However, the effects are not consistently present. Further evaluations are currently underway to assess impacts at the plant. The assessment is complicated by the existence of other stresses on this ecosystem, such as sewage treatment plant discharge and non-point source pollution.

Eggs and larvae of bay anchovy, naked goby, and hogchoker (all forage species) are found in the Calvert Cliffs vicinity and are entrained. Densities near the plant have not differed significantly from those observed beyond the area of plant influence, and, in some cases, densities near the plant were highest (15). No conclusive evidence of ichthyoplankton depletion in the plant vicinity exists (15).

The same species of larvae are found at Morgantown, as at Calvert Cliffs. Nearfield ichthyoplankton depletions were not detectable at Morgantown (16).

Data from recent ichthyoplankton studies at Chalk Point (27, 28) have not yet been analysed to determine if depletions occur in the vicinity of the plant. Anchovy, naked goby, silversides, and hogchoker are the dominant ichthyoplankton species in the plant area. The data thus far suggest that striped bass and white perch larvae in the Patuxent are concentrated upstream and away from the plant, but that some larvae could be entrained under certain conditions of river flow (29).

Ichthyoplankton entrainment studies carried out at the Baltimore harbor plants in 1979 and 1980 indicate that entrainment rates at Gould Street are low, while those at Riverside and Wagner are higher and similar to each other (30, 31, 32). Major species spawning in the Harbor include bay anchovy, Atlantic silverside, tidewater silverside, naked goby, rough silverside, and hogchoker (30, 31, 33, 34). Entrainment at Gould street is dominated by naked goby (77%), juvenile eels (5%), and bay anchovy larvae (5%) (31). At Riverside,bay anchovy larvae dominated (43%), together with naked goby (24%), and tidewater silversides (11%) (32). Species entrained at Wagner included gobies (30%) bay anchovy (29%) and menhaden (19%) (30). These results confirm that the Baltimore area plants are not located in spawning areas of important exploited fish species.

In general it is found that the entrained ichthyoplankton at all the mesohaline plants belong to small forage species, mainly bay anchovy, silversides, naked goby, and hogchoker. These species spawn throughout the Maryland portion of the Chesapeake Bay and are ubiquitously distributed there. Thus localized losses at the plants under discussion are insufficient to cause decrease in Bay-wide stocks. When the negligible near-field effects observed to data are also considered, no cumulative Bay-wide impacts of ichthyoplankton entrainment at all the power plants are likely.

Chalk Point has an additional entrainment effect due to the lack of screens in front of the augmentation pumps used during the summer months. Without these screens, fish and crabs that would normally be impinged may be entrained into the pumps. Studies to quantify the magnitude of these losses have been complicated by difficulties in deploying sampling gear near the pumps. The studies have suggested that fish and crabs do pass through the pumps, however, an estimate of the number entrained could not be made (35).

- Impingement

Fish and crab impingement data from Calvert Cliffs, Morgantown, and Chalk Point, collected during the period 1976 through 1979, are presented in Table IV-3 along with data taken from the last CEIR (3) covering the period 1975 to 1977. Although the values presented represent an estimated total annual impingement, the years are not the same for each plant. However, they do permit an assessment of the consistency of impingement over a period of about 5 years. In some respects, data from the two time periods are very similar: the same six species account for 93 and 78 percent of the total fish impinged in the two time periods, respectively; the number of blue crabs impinged is nearly the same for the two time periods. The data differ in two respects: the total number of fish impinged decreased substantially from the earlier to the more recent time period, and numbers of impinged individuals of several species included in the "other" category (e.g., winter flounder, gizzard shad, and blueback herring) increased substantially.

Impingement data from Baltimore harbor plants are presented in Table IV-4. The same two species dominate impingement here: menhaden and spot. However, other species differences are evident; no substantial numbers of hogchoker are taken at Baltimore plants, while gizzard shad do not appear insignificant numbers at the other three plants. These differences may reflect the fact that the Baltimore plants are located on mesohaline waters of lower salinity than at the other three plants.

Table IV-5 presents the results of impingement mortality studies done at Calvert Cliffs in 1979 (14). These data suggest that nearly all crabs and hogchokers, and substantial percentages of other major species, are not directly killed by impingement. Similar mortality data are not available for other meoshaline plants, where screens are operated differently from those at Calvert Cliffs. However, the Calvert Cliffs data do suggest that impingement totals at all mesohaline plants do not necessarily represent numbers of fish lost to the ecosystem.

The implications of impingement losses to the Chesapeake Bay ecosystem and its fisheries were discussed in detail in the last CEIR (3). Because the nature of impingement at these mesohaline power plants has remained similar to that reported and discussed in the last CEIR, the significance of impingement as presented there remains the same: the

Table IV-3. Estimated Annual Total Impingement by Species at Three Power Plants in Mesohaline Waters (Calvert Cliffs, Chalk Point, Morgantown).

Species	1976[a]		1976 - 1979[b]	
	Number	Percent of Total	Number	Percent of Total
Atlantic Menhaden[c]	1,766,671	39	896,557	32
Spot[c]	1,821,367	40	424,632	15
Hogchoker	275,427	6	350,518	13
Bay Anchovy	135,543	3	316,629	11
Atlantic Croaker[c]	111,901	3	44,252	2
White Perch	106,110	2	140,705	5
Others	318,632	7	608,743	22
TOTAL FISH	4,535,651	100	2,782,036	100
Crabs	1,820,977		2,036,427	

(a) Data reproduced from the 1978 CEIR and are primarily from 1976.

(b) Excludes data used under (a); Calvert Cliffs data from 1979, all months (14); Chalk Point data from 1978, no data from January, February, and October (23,35); Morgantown data from May 1976 to May 1977 (17).

(c) Predominantly juveniles.

Table IV-4. Estimated Annual Impingement at Baltimore-Area Power Plants (1978-1979); Number of Individuals.

Species	Gould St.[a]	Riverside[b]	Wagner[c]	Total	Percent
Spot	745	176	554,151	555,072	54
Atlantic Menhaden	2,982	34,267	244,666	281,915	27
Atlantic Croaker	9,402	21,055	49,439	79,896	8
Gizzard Shad	3,786	6,758	20,966	31,510	3
Atlantic Silverside	223	414	21,230	21,867	2
White Perch	287	516	12,723	13,526	1
Other	686	2,516	40,752	43,954	5
					100
Blue Crab	6,348	9,241	430,045		

(a) Data from Ref. 31

(b) Data from Ref. 32

(c) Data from Ref. 30

species comprising most of the impingement total are ubiquitous and abundant in the mesohaline zone; juveniles of all species dominate in the impingement totals; and no changes in fish density or community composition in the vicinity of these plants have been observed. Thus, impingement losses appear to be too small to alter significantly the size of Bay populations of affected species.

Table IV-5
Percent Survival and Percent Loss of Equilibrium (LOE) of Major Fish Species Impinged at Calvert Cliffs in 1979

Species	Percent Survival	Percent LOE
Atlantic Menhaden	49.27	1.41
Spot	87.34	0.14
Hogchoker	>99.00	0.0
Bay Anchovy	66.82	2.66
Atlantic Croaker	3.81	1.04
White Perch	73.08	11.54
Blue Crab	>99.00	0.0

Data from Reference 14.

- Discharge Effects and Habitat Modification

The maximum radial extent of the 2°C excess temperature isotherm at Calvert Cliffs, with Units 1 and 2 both operating, was 2.3 km, and the areas enclosed by the isotherm did not exceed 50 x 10^4 m^2 on 14 of the 17 occasions when surveys were made[1] (20). Some depletion of zooplankton was noted near the plant, but it appeared to be attributable to in-plant entrainment rather than to thermal plume effects (15). No near-field effects on phytoplankton were observed during 2-unit operation (15). Although discharge effects on benthos as a result of bottom scouring have continued to be observed, in many instances the induced changes have resulted in increases in population biomass (15). Some benthic species near the plant have increased in abundance, possibly due to organic enrichment of the sediments caused by mortality of entrained plankton. Occasionally, higher copper content was observed in oysters in the immediate vicinity of the discharge during 2-unit operations, but densities of oysters here are relatively low and the area is not regularly fished (15). No plant effects on the feeding behavior of fish in the discharge area have been observed. No plant effects on distribution, abundance, or condition of fish in the discharge vicinity have been discerned (15).

At Morgantown the thermal plume as defined by the 2°C isotherm was generally about 0.1 x 10^4 to 0.6 x 10^4 m^2 in size, and occasionally was as great as 32 x 10^4 m^2. Morgantown findings are consistent with

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1 1x10^4 m^2 = 2.5 acres.

Calvert Cliffs results. No significant influence of the thermal discharge has been found (17).

Of the three largest mesohaline power plants, Chalk Point has the greatest potential for causing discharge effects, because the Patuxent estuary on which it is sited is shallow and has relatively low flows. The 24-hour average radial extent of the 2°C excess temperature isotherm was 1.98 km, but lower excess temperatures could be detected over a broad portion of the estuary (36, 37, 38, 39). The area of bottom covered by the 1°C excess temperature isotherm extends as far as 6 km upstream and downstream of the plant (40). Studies conducted in the 1960's revealed some plant discharge effects. Both erosion of copper from condenser tubes and uptake by oysters of copper discharged from the plant was found. The conditions that caused the release of copper were later corrected by changing the condenser material (41). Large concentrations of fish have appeared in fall and winter in the discharge canal and now supports an intensive sport fishery there. Large kills of fish and crabs in the discharge canal, attributed to accidental excessive discharge of chlorine were reported in the 1960's (18, 42). Similar kills have not been reported in recent years.

The recent studies on phytoplankton and zooplankton (already discussed in the Entrainment section), revealed some inconsistently ocurring near-field plant effects on these trophic groups. The effects are probably attributable more to entrainment losses than to habitat modifications caused by plant discharges.

In a 1979 study (40), the geographic distribution of species of benthic organisms showed no deleterious plant effects. Rather, densities of organisms in the plant vicinity often were 4 to 10 times higher than at upstream and downstream reference stations, possibly due to organic enrichment resulting from settling of planktonic organisms killed by entrainment. Fish studies have shown that distributions and feeding behavior of some species are influenced by plant operations (43). The significance of these non-lethal effects on fish stocks has not yet been determined, but they are likely to be inconsequential.

Baltimore harbor plants are situated on relatively small water bodies and exert substantial effects on the thermal regimes of these water bodies. The maximum radial extent of the 2°C isotherm averages 0.2 km at Gould Street (31), 0.3 km at Riverside (32) and 2.1 km at Wagner (30). Average areas enclosed are 26 x 10^4 m^2 and 110 x 10^4 m^2 for Riverside and Wagner, respectively (30, 31). Plumes at all three plants are strongly influenced by wind, and wind events often determine the length of time during which elevated temperatures will exist in a given location. Five to ten percent of the surface of Baltimore harbor appears to be affected by the thermal plumes of these three plants.

Near-field studies at Baltimore harbor plants are currently being conducted under funding from PPSP and BG&E. No data from those studies are yet available.

When the results of studies at all mesohaline plants are considered, a picture emerges that indicates a low probability of cumulative impact on the mesohaline environment. Although plankton entrainment losses have been measured from time to time at several of the power plants, there is no consistent occurence of measurable plankton depletion in the waters around the plant. This lack of consistent effects is probably due to the high reproduction rate of the plankton, and suggests that there is no cumulative influence due to plankton entrainment. Since no important commercial or recreational species spawn in this habitat, entrainment losses of ichthyoplankton have little economic significance. Localized effects on benthic organisms, including shellfish, are sometimes evident. These effects have no significance beyond the immediate discharge areas. A comparison of recent studies with the studies described in the previous CEIR published 2 years ago show no first-time or increased effects on any trophic level.

Current studies at Chalk Point and the Baltimore harbor plants will permit a more definitive assessment of impact at those sites.

Tidal Fresh - Oligohaline

These habitat zones have significant value as the major spawning area of anadromous fish, which as a group have accounted, on the average, for about 65% of the total monetary value of commercially harvested finfish from 1972 to 1976 in Maryland. Since anadromous spawning occurs in the spring, the plants of most concern are those in the tidal fresh-oligohaline zone at that time, particularly those sited near striped bass spawning areas. However, the zone also serves as a nursery area for many important fish species year around.

Seven plants use oligohaline waters for cooling purposes in the spring (Table IV-2). At six of these seven plants, salinity is in the mesohaline range during most of the remainder of the year. Impacts associated with those plants (Chalk Point, Morgantown and the Baltimore area plants) was discussed in the preceeding mesohaline section. Of these plants only Morgantown is situated near waters of sufficiently low salinity to be of interest as far as striped bass impact is concerned.

The remaining plants to be discussed here are Possum Point, Vienna and Crane. Possum Point, on the Potomac, and Vienna, on the Nanticoke, are both in the vicinity of major striped bass spawning areas. Crane, though located on tidal fresh-oligohaline waters, does not impact on a striped bass spawning area.

- Entrainment

  A detailed, in-plant phytoplankton entrainment study at Crane is currently being conducted under BG&E funding. Samples taken at intake and discharge locations during nearfield studies (33, 44, 45, 46) showed no discernable loss of either zooplankton or phytoplankton, and suggest an enhancement of phytoplankton productivity. Entrained zooplankton from Seneca Creek may be enhancing zooplankton populations in the discharge area (47). Entrainment of zooplankton and phytoplankton of the Vienna plant will be 0.20 - 0.25 percent of the organisms moving past the plants when Unit 9 comes on line (see below) (53). Such losses will have negligible effects.

Results of studies conducted in 1979 indicate that relatively low numbers of ichthyoplankton species and individuals are entrained at the Crane Station. Entrainment was highest in summer, when bay anchovy and naked goby were the dominant species. Other commonly entrained species were white perch and tidewater silversides (48). Highest densities entrained were 6 larvae/100m^3 of cooling water.

Possum Point is sited on the striped bass spawning grounds in the Potomac estuary. Recent work indicates that the plant entrains a maximum of about 2 percent of the striped bass larvae produced annually in the Potomac. Morgantown is located 20 km downstream of the center of the striped bass spawning area in the Potomac. Few eggs or larvae (less than 0.01% of Potomac production) are entrained (49, 50, 51). Consequently, the operation of this plant has no significant impact on the striped bass population. Vienna is in the midst of the spawning area in the Nanticoke. With the retirement of units 5, 6 and 7 (68 MW total) using once-through cooling (withdrawal 3.6 m^3/sec) only unit 8 (162 MW) using a cooling tower (withdrawal 0.12 m^3/sec from the discharge of units 5, 6, and 7) remains. Delmarva Power and Light has proposed a 500-MW expansion (Unit 9, 1988 completion date) which will withdraw 0.42 m^3/sec for cooling and plant purposes. The proposed intake of this unit includes a fine mesh, wedge wire screen which is designed to minimize entrainment of fish eggs and larvae (52). The estimated amounts oof striped bass eggs and larvae entrained by the previously existing units have been about 8 percent (of the Nanticoke Stock) annually from 1977 to 1979. When Unit 9 begins operation ichthyoplankton entrainment is predicted to average 2 percent (52).

The potential impact of entrainment by a power plant on the overall striped bass stock can be estimated by examining the contribution of the impacted area to total spawning in the Maryland part of the Chesapeake Bay and its tributaries. This contribution can be estimated from the commercial catch records for the months (March and April) just prior to spawning. This catch is assumed to be proportional to the presence of spawning adults and hence to the spawn. These data are summarized in Table IV-6 which shows, for example, the Potomac River spawning constitutes about one fourth of the total striped bass spawning in Maryland. Therefore, under our assumption, a 1 percent loss of striped bass larave in the Potomac would translate to a 0.25 percent loss of the Maryland fisheries, and the 2 percent loss at Possum Point translates into a 0.5 percent loss to the Maryland fisheries. The consequences of the 2 percent loss of ichthyoplankton at Vienna is compounded over generations (because of local effects) and could increase the estimated local loss of adults to 4 percent (52) since Table IV-6 shows that the Nanticoke-Wicomico region accounts for 12 percent of the commercial catch on the average this loss of adults is equivalent to a loss of almost 0.5 percent of the Maryland Bay Stock. The total potential loss to the Maryland striped bass population from the operation of these power plants will thus be 1 percent. The reported commercial catch in Maryland averaged 4.6 million lbs. annually from 1960 to 1975 (52), and the average annual sports catch is estimated to roughly equal the commercial catch (54). Consequently the 1 percent loss of striped bass ichtyoplankton through entrainment is equivalent to an annual loss of about 92,000 lbs. of striped bass based on the 1960 to 1975 average. In recent years the Maryland striped bass catch has declined substantially compared to the 1960-1975 average. Therefore, the calculated loss of striped bass in pounds will be correspondingly less.

For the tidal fresh-oligohaline plants the conclusion is that cumulative impacts due to zooplankton and phytoplankton entrainment at oligohaline plants have not been detected. Impact is unlikely because of the high reproduction rates of these groups of organisms. Cumulative impact of all plants in Maryland on striped bass due to entrainment of eggs and larvae would be about 1.0 percent of annual landings.

- Impingement

Impingement at Chalk Point, Morgantown, and the Baltimore area 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 (53).

Impingement data from Crane have only recently become available. The Crane data from 1978-1979 presented in Table IV-7 can be contrasted to that for mesohaline plants present in Tables IV-3 and 4. Atlantic menhaden and spot are dominant at both sets of mesohaline plants, while white perch replace spot as a dominant species at Crane. It is interesting to note that the majority of white perch recorded as impinged at mesohaline plants (Table IV-3) was taken at Morgantown in the spring, when waters at that site were actually oligohaline (16). Thus, white perch are demonstrated to be primarily an oligohaline species. Other species differences are evident between impingement at the two groups of mesohaline plants: gizzard shad and silversides are major components of impingement at the Baltimore plants whereas they are not prominent at the other mesohaline plants. This result may reflect the fact that the Baltimore plants are located on lower salinity mesohaline water. The data discussed here suggest that consequences of impingement at oligohaline plants are similar to those of impingement at mesohaline plants: the major species impinged are ubiquitous and abundant throughout Maryland tidal waters; impingement losses appear too small to have a detectable effect on stock sizes of affected species. For example, white perch are impinged in substantial numbers and have important commercial and recreational value. This species is, however, abundant throughout Maryland (2), and annual impingement losses are very small relative to the total commercial and recreational harvest. Thus, stocks are not likely to be affected.

Table IV-6. Commercial Catch of Striped Bass in March and April by Region in the Maryland Portion of the Chesapeake Bay, by Percent.

Year	Upper Bay above Sassafras River	Bay Bridge to Sassafras River	Chester River	Cove Point to Bay Bridge	Choptank River	Virginia to Cove Point	Patuxent River	Nanticoke River Wicomico River	Potomac River (including Virginia side)
1972	8.67	30.76	4.61	5.76	10.02	2.37	2.22	15.87	19.67
1971	10.13	27.24	2.39	5.66	10.58	0.85	4.07	13.15	25.87
1970	9.37	34.86	5.18	4.90	10.84	0.99	2.65	8.81	22.14
1969	17.17	33.66	1.63	4.18	9.24	0.86	3.27	8.27	21.67
1968	12.04	24.20	1.76	3.69	6.40	1.25	2.09	11.61	36.74
1967	9.54	29.58	1.36	3.31	7.00	0.82	2.18	11.45	34.75
1966	6.03	22.91	2.73	2.84	10.37	1.65	1.07	19.34	33.03
Averages	10.73	29.50	2.80	4.30	9.10	1.25	2.49	12.28	27.46

From Ref. 3

Table IV-7
Estimated Annual Impingement at Crane Located in Tidal-Fresh Oligohaline Waters (1978-1979)

Species	Number	Percent
Atlantic Menhaden	246,353	50
White Perch	148,941	30
Spot	19,118	4
Gizzard Shad	14,255	3
Atlantic Silverside	1,022	<1
Atlantic Croaker	78	<1
Other	67,124	13

Data from Reference 48.

- Discharge Effects and Habitat Modification

Thermal plumes at Vienna were sufficiently small that discharge effects can be considered negligible (55). Studies at Crane in 1979 and 1980 have documented the extent of influence of the plant's thermal discharge (56). The 24-hr. averge radial extent of the $2^{o}C$ excess temperature isotherm at that plant is 1.8 km, and an average area of 90×10^4 m^2 of river bottom is enclosed by that isotherm. Because of the relatively small dimension of the water body into which the discharge enters, (Saltpeter and Dundee Creeks), much of the creek system is thermally influenced. Thus, potential for thermal discharge effects is higher than in the case of the mesohaline plants.

At Crane, studies demonstrated that under extreme summer temperature conditions, the temperature in the immediate discharge area exceeded lethal limits for some zooplankton and inhibited photosynthesis by phytoplankton (44). Decreases in phytoplankton productivity and alternations in zooplankton community structure in late summer were observed in the discharge area (44, 46). However, during other periods phytoplankton productivity in the thermally affected area was enhanced and no effects on zooplankton abundances were evident (33, 45, 46). No major deleterious effects on submerged aquatic vegetation in the discharge area were noted (57, 58, 59). Vegatation growth appeared to be enhanced during some periods.

Benthic studies suggest that the brackish-water clam may be protected during cold winter periods by the thermal discharge, resulting in population enhancement (60, 61, 62). A summertime decrease of about 30 percent in density of an amphipod Leptocheirus in the discharge area was observed in 1979 (44). Several species in the discharge area also showed greater population build-ups in Spring 1980, suggesting accelerated growth or development (62).

Finfish studies in summer showed that white perch and, to some extent, spot were attracted to the plume (63).In Spring white perch avoided the plume region, whereas pumpkinseed were attracted to it. In a follow-up extended summer study (64) white perch did not show preference for the discharge region. The same study also found that low numbers of spot occurred in shallow creeks as well as in the discharge area, suggesting a generalized creek effect.

One effect which might be construed as cumulative, though not necessarily as deleterious, is a change in the zooplankton and benthic communities in the Crane discharge area. As the plant takes higher salinity water from the intake area and discharges it into lower salinity receiving waters, it also transports an oligohaline fauna into a location which, without the plant, would probably harbor a freshwater fauna (47, 62). This higher salinity water also provides a habitat more suited to oligohaline benthic and planktonic species during certain times of the year.

Riverine

The only Maryland steam electric stations located on riverine waters are R.P. Smith and Dickerson, both on the Potomac River. Each uses, at times, a substantial portion of average river flow for cooling purposes. The plants are relatively old, of low to medium generating capacity, and located in areas inhabited by typical warm water "riverine" biological communities (65). Conowingo Dam on the Susquehanna River is the only large hydroelectric generating station in Maryland. Significant stocks of fish, both comerically and recreationally important, inhabit the Susquehanna River below the dam.

- Entrainment

Limited entrainment data at the R.P. Smith plant are available from studies conducted in 1978 (66). Organisms primarily entrained were sucker and carp larvae, midges, and gammarid amphipods. Numbers entrained during the 3-month study period were very low, but the studies were not done during periods when high ichthyoplankton abundances were expected.

Entrainment at Dickerson during a 12-month study was an estimated 48 million fish eggs and larvae and one million juveniles which represents approximately 10 percent of the organisms drifting past the plant (67). Species entrained were primarily carp, spottail shiner, and spotfin shiner. Since most of these entrained species are nest builders or have demersal eggs, drifting eggs susceptible to entrainment represent only a small percentage of the total spawn. Maximum local population loss of 4.1 and 2.3 percent are predicted for spottail shiner and redbreast sunfish, respectively (68). Thus, localized entrainment effects will not alter river populations of these forage and rough species.

Very few eggs and larvae of sport fish were entrained at either plant; thus, direct entrainment effects on sport fish populations would be negligible. The species entrained are ubiquitous in the Potomac and spawn over the entire freshwater reach of the river in Maryland.

- Impingement

Very few fish (a total of about 300) were impinged at R. P. Smith during studies in 1978 (66). Golden redhorse and shiners dominated, and 72 percent of the annual total was taken in June. Impingement at this level is negligible in terms of effects on fish populations.

Other 1978 studies showed an estimated annual total of about 256,000 fish impinged at Dickerson (67). Primary species were spottail shiner, channel catfish, sunfish (several species), spotfin shiner, and smallmouth bass. Impingement was highest in winter and spring. The shiners are important forage species; the rest are important sportfish. With no data available from periods prior to plant operation, an assessment of whether the plant has had a deleterious impact on these fish stocks is difficult to make. Detection of effects on populations near the plant is made more difficult by the fact that fish are seasonally attracted and repelled by the plant's thermal plume (67).

- Discharge Effects and Habitat Modification

Data from thermal plume surveys at both Dickerson and R. P. Smith have become available since publication of the 1978 CEIR (3). At Dickerson, the 2°C excess temperature isotherm extended downstream more than 20 km and entended across the river approximately two thirds of its width during summer, low-flow conditions (67). The thermally influenced area is largest during summer and fall.

Discharge effects on insects were noted in the immediate plant vicinity in studies conducted in 1977. Decreases in abundance, numbers of species, and growth rates were found (67). Effects on fish were difficult to assess because of the seasonal change in response of many species to the thermal plume; avoidance during summer and fall, and attraction in winter and spring. Although literature data suggest that thermal conditions in summer are often deleterious for growth and reproduction of several species, no clear evidence of cumulative, adverse impact of river-wide stocks of any species is apparent in the data collected. Discharge effects apparently are localized (about 2.5 km in extent), and the area of greatest impact is not particularly critical for any of the fish species present.

The size of the thermal plume at R. P. Smith depends on river flow and meteorological conditions and is highly variable (66). The maximum downstream extent of the 2°C excess temperature isotherm is about 7 km and the same isotherm seldom extends further than 30 m across the river about one third of the width from the Maryland shore. Discharge effects on periphyton and benthic organisms (primarily insects) have been observed to be inconsistant and tend to be small (69, 70, 71). The riverine habitat is very heterogeneous in the vicinity of the plant, and communities at different unaffected stations often differ from each other. This situation complicates the evaluation of discharge effecs. However, the data do not suggest the existence of a well-defined area of depleted or modified biota in the discharge vicinity. This, in turn, suggests the absence of significant cumulative impact on periphyton and benthos. Fish distribution is influenced by the thermal plume. Golden redhorse, the dominant species in the area, is concentrated in the plume in winter. Summer avoidance was not evident for any species when plant discharge temperature was low (70). During one summer period with high plant discharge temperature resulting in near-field temperatures of 40°C, no live finfish were taken in the discharge plume. If localized distribution effects are discounted, fish data show no major differences between the fish community inhabiting the general region of the river near the plant and communities inhabiting unaffected areas upstream and across-stream. Those data suggest the absence of significant cumulative impact on fish.

Conowingo Dam - Hydroelectric Facility

The manner in which this hydroelectric facility can impact an aquatic ecosystem is entirely different from that in which nuclear or fossil fuel plants create effects. Although entrainment of organisms through the turbines of the facility may occur, the more important modes of effect relate to the facility's modification of flow regimes, water oxygen content, and habitat area.

The Conowingo Dam is operated as a peaking power generating unit, with fullest operation scheduled for weekday afternoons. Generation is reduced or stopped at night, and frequently also on weekends, to allow the reservoir level to rise. The generating station has seven 36-MW turbines and four 56-MW turbines. The addition of the four larger turbines in 1967 increased the maximum water use from 45,000 cfs to 85,000 cfs. By comparison, median monthly-average flows of the Susquehanna River range from 7,000 cfs (August) to 65,000 cfs (March).

Several water flow, water quality, and fisheries problems in the Susquehanna are thought to be related to Conowingo's operating patterns. Fluctuations in water levels below the dam caused by the mode of operation of the turbines periodically expose large aras of river bottom to the air. Benthic biomass may be reduced in these dewatered areas thus decreasing food availability for some resident fish species. Additionally, demersal fish eggs may become stranded and exposed to air as the water level falls after a flow reduction.

Water temperature, and, to some extent, dissolved oxygen (DO) concentrations in the river below the dam seem to reflect conditions near the bottom of Conowingo Pond. Although classical thermal stratification has never been observed in the pond, DO concentrations decrease with depth from saturation values at the surface to less than 2 ppm near the bottom (23 m below surface). Intake structures for the turbines draw water from 20 m below the surface, thus releasing this low DO water into the river.

Oxygen problems also have occurred in the river below the dam during periods when no water is being released. Biota in isolated pools consume available oxygen and can create low DO conditions. The danger of fish kills or other biological impacts are most severe in summer when river flow is near its annual minimum and prolonged shutdowns are required to refill the reservoir. At the same time, water temperature is high (approaching 30°C), resulting in a reduction in its DO capacity. These problems are exacerbated during periods when large numbers of fish are present below the dam, such as during anadromous spawning runs. The high fish densities accelerate the rate of oxygen depletion. Such events led to the repeated occurrence of resident and anadromous fish kills below Conowingo Dam in the 1960's.

These problems and the recent dramatic declines in upper Chesapeake Bay landings of American shad and other anadromous species (72), prompted the Maryland Department of Natural Resources to initiate studies through the Power Plant Siting Program to obtain data needed to assess these problems and develop solutions. The information will also be submitted during the Conowingo relicensing proceedings under the Federal Energy Regulatory Commission (FERC).

Some preliminary findings of these studies are:

- At high discharge volumes, the DO concentration of the river below the dam depends on that of the bottom layer of the reservoir (which is discharged through the dam turbines). At low flows, downstream DO distribution is patchy and is heavily influenced by local metabolic processes, including the unpredictable aggregations of fish which might cause localized anoxic conditions.

- In 1980, the population size of shad in the Upper Bay is below 10,000 adults, blueback herring is below 200,000 adults, and alewife and hickory shad populations are too small to estimate.

- Benthic invertebrate populations are extremely sparse on substrates which periodically dewater as a result of the present discharge pattern.

- In the Upper Bay, analyses of historical fisheries data have identified a weak relationship of shad landings to the general operating pattern of the dam (73).

Because of the absence of detailed historical biological data in the Susquehanna below Conowingo, a complete quantitative evaluation of the cumulative effects of Conowingo operations on the Susquehanna River ecosystem is not presently possible. Results of the on-going studies will provide data to further address this question.

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