Chapter B3: Evaluation of I&E Data

Although 20 years of I&E data are available for the Salem facility, I&E data for other CWIS of the transition zone are limited. Thus, to evaluate the potential cumulative impacts of all transition zone CWIS, EPA extrapolated Salem's I&E rates to other transition zone facilities, as described in this chapter. Section B3-1 lists fish and shellfish species that are impinged and entrained by CWIS of the transition zone, Section B3-2 summarizes the life histories of the primary species impinged and entrained, Section B3-3 describes the methods PSEG used to estimate I&E at Salem, Section B3-4 presents estimates of annual impingement at Salem, and Section B3-5 presents estimates of annual entrainment at Salem. Section B3-6 outlines the methods used by EPA to extrapolate Salem's I&E rates to other transition zone CWIS, Section B3-7 presents impingement extrapolations, Section B3-8 presents entrainment extrapolations, and Section B3-9 summarizes the cumulative I&E impacts of CWIS of the transition zone.

Chapter Contents

B3-1 Transition Zone Species Vulnerable to I&E B3-1
B3-2 Life Histories of Primary Species Impinged and Entrained B3-4
B3-3 Salem I&E Monitoring and PSEG's Methods for Calculating Annual I&E B3-21
B3-3.1 Impingement Monitoring B3-21
B3-3.2 Entrainment Monitoring B3-23
B3-3.3 Potential Biases and Uncertainties in PSEG's I&E Estimates B3-25
B3-3.4 Overview of EPA's Evaluation of Salem's I&E Data B3-27
B3-4 Salem's Annual Impingement B3-27
B3-5 Salem's Annual Entrainment B3-33
B3-6 Extrapolation of Salem's I&E Rates to Other Transition Zone Facilities B3-40
B3-6.1 Impingement Extrapolation B3-40
B3-6.2 Impingement Extrapolation B3-40
B3-7 Salem's Current I&E B3-40
B3-8 Cumulative Impacts: Summary of Estimated Total I&E at All Transition Zone CWIS B3-41

B3-1 Transition Zone Species Vulnerable to I&E

EPA evaluated all fishery species known to be impinged or entrained by the Salem facility and other CWIS of the transition zone, including commercial, recreational, and forage species. Table B3-1 lists these species and the categories used by the Salem facility in their assessment of these species for their 1999 Permit Renewal Application (see F-4 Table 1 of Appendix F). Species names in bold indicate those fishery species considered by Salem to be "representative important species" (RIS) for assessment purposes. All other species were classified by Salem as non-RIS species.

Several federally listed T&E species are occasionally impinged at these facilities, including shortnose sturgeon (*Acipenser brevirostrum*), green sea turtle (*Chelonia mydas*), Kemp's ridley turtle (*Lepidochelys kempii*), and loggerhead sea turtle (*Caretta caretta*). However, biological assessments conducted by the U.S. Nuclear Regulatory Commission and the National Marine Fisheries Service indicated that populations of these T&E species are not being jeopardized, and therefore potential losses of these species were not considered by PSEG in Salem's 1999 Application (PSEG, 1999c). Because of the lack of I&E data on these species, EPA was unable to evaluate potential CWIS impacts on them.

Table B3-1: Aquatic Species Vulnerable to I&E by CWIS in the Transition Zone. Names in Bold Are Species Designated as RIS by the Salem Facility (see F-4 Table 1 of Appendix F of the 1999 Salem Permit Renewal Application).

Common Name	Scientific Name	Commercial	Recreational	Forage
Alewife	***Alosa pseudoharengus***	X		
American eel	*Anguilla rostrata*	X	X	
American shad	***Alosa sapidissima***	X	X	
Atlantic cod	*Gadus morhua*		X	

Table B3-1: Aquatic Species Vulnerable to I&E by CWIS in the Transition Zone (cont.). Names in Bold Are Species Designated as RIS by the Salem Facility (see F-4 Table 1 of Appendix F of the 1999 Salem Permit Renewal Application).

Common Name	Scientific Name	Commercial	Recreational	Forage
Atlantic croaker	***Micropogonias undulatus***	X	X	
Atlantic herring	*Clupea harengus*		X	
Atlantic menhaden	*Brevoortia tyrannus*	X		
Atlantic silverside	*Menidia menidia*	X		
Atlantic sturgeon	*Acipenser oxyrinchus oxyrinchus*			X
Banded killifish	*Fundulus diaphanus diaphanus*			X
Bay anchovy	***Anchoa mitchilli***			X
Black crappie	*Pomoxis nigromaculatus*			X
Black drum	*Pogonias cromis*	X	X	
Black sea bass	*Centropristis striata*	X	X	
Blackcheek tonguefish	*Symphurus plagiusa*			X
Blue crab	***Callinectes sapidus***	X	X	
Blue runner	*Caranx crysos*			X
Blueback herring	***Alosa aestivalis***		X[a]	X
Bluefish	*Pomatomus saltator*	X	X	
Bluegill	*Lepomis macrochirus*			X
Bluespotted sunfish	*Enneacanthus gloriosus*			X
Brown bullhead	*Ameiurus nebulosus*		X	
Butterfish	*Peprilus triacanthus*	X		
Channel catfish	*Ictalurus punctatus*		X[a]	
Common carp	*Cyprinus carpio carpio*	X		
Conger eel	*Conger oceanicus*		X	
Crevalle jack	*Caranx hippos*			X
Cusk-eel	*Lepophidium spp.*			X
Eastern silvery minnow	*Hybognathus regius*			X
Feather blenny	*Hypsoblennius hentzi*			X
Florida pompano	*Trachinotus carolinus*		X	
Fourspine stickleback	*Apeltes quadracus*			X
Fringed flounder	*Etropus crossotus*			X
Gizzard shad	*Dorosoma cepedianum*	X		
Goosefish	*Lophius americanus*	X		
Hake	*Urophycis spp.*	X	X	
Harvestfish	*Peprilus alepidotus*			X
Herring	*Alosa spp.*		X	
Hogchoker	*Trinectes maculatus*			X
Inland silverside	*Menidia beryllina*			X
Jack	*Caranx hippos*		X	
King mackerel	*Scomberomorus cavalla*		X	
Largemouth bass	*Micropterus salmoides*			X
Lined seahorse	*Hippocampus erectus*			X
Minnows	*Fundulus spp.*			X
Mud sunfish	*Acantharchus pomotis*			X

Table B3-1: Aquatic Species Vulnerable to I&E by CWIS in the Transition Zone (cont.). Names in Bold Are Species Designated as RIS by the Salem Facility (see F-4 Table 1 of Appendix F of the 1999 Salem Permit Renewal Application).

Common Name	Scientific Name	Commercial	Recreational	Forage
Mummichog	*Fundulus heteroclitus heteroclitus*			X
Naked goby	*Gobiosoma bosci*			X
Northern kingfish	*Menticirrhus saxatilis*		X	
Northern pipefish	*Syngnathus fuscus*			X
Northern puffer	*Sphoeroides maculatus*		X	
Northern searobin	*Prionotus carolinus*		X	
Orange filefish	*Aluterus schoepfii*		X	
Oyster toadfish	*Opsanus tau*	X	X	
Permit	*Trachinotus falcatus*			X
Pigfish	*Orthopristis chrysoptera*		X	
Pipefish	*Syngnathus spp.*			X
Planehead	*Stephanolepis hispidu*			X
Pollock	*Pollachius pollachius*		X	
Pumpkinseed	*Lepomis gibbosus*			X
Rainbow smelt	*Osmerus mordax mordax*			X
Red hake	*Urophycis chuss*	X	X	
Redfin pickerel	*Esox americanus americanus*			X
Rough silverside	*Membras martinica*			X
Sandbar shark	*Carcharhinus plumbeus*		X[a]	X
Scup	*Stenotomus chrysops*		X	
Sea lamprey	*Petromyzon marinus*			X
Searobins	*Triglidae*		X	
Sheepshead minnow	*Cyprinodon variegatus varieg*		X	
Shrimp	*Gammarus spp.*			X
Shrimp	*Neomysis spp.*			X
Silver perch	*Bairdiella chrysoura*		X	
Silversides	*Membras/Menidia spp.*	X		
Skilletfish	*Gobiesox strumosus*			X
Smallmouth bass	*Micropterus dolomieui*			X
Smooth dogfish	*Mustelus canis*			X
Spanish mackerel	*Scomberomorus maculatus*		X	
Spot	***Leiostomus xanthurus***	X	X	
Spotted hake	*Urophycis regia*		X	
Spotted seatrout	*Cynoscion nebulosus*		X	
Striped anchovy	*Anchoa hepsetus*			X
Striped bass	***Morone saxatilis***	X	X	
Striped cusk-eel	*Ophidion marginatum*			X
Striped killifish	*Fundulus majalis*			X
Striped mullet	*Mugil cephalus*		X	
Striped searobin	*Prionotus evolans*		X	
Summer flounder	*Paralichthys dentatus*	X	X	
Tautog	*Tautoga onitis*	X	X	

Table B3-1: Aquatic Species Vulnerable to I&E by CWIS in the Transition Zone (cont.). Names in Bold Are Species Designated as RIS by the Salem Facility (see F-4 Table 1 of Appendix F of the 1999 Salem Permit Renewal Application).

Common Name	Scientific Name	Commercial	Recreational	Forage
Tessellated darter	*Etheostoma olmstedi*			X
Threespine stickleback	*Gasterosteus aculeatus aculeatus*			X
Warmouth	*Lepomis gulosus*			X
Weakfish	***Cynoscion regalis***	X	X	
White catfish	*Ictalurus catus*		X[a]	
White crappie	*Pomoxis annularis*			X
White mullet	*Mugil curema*			X
White perch	***Morone americana***	X	X	
White sucker	*Catostomus commersoni*			X
Windowpane	*Scophthalmus aquosus*	X	X[a]	
Winter flounder	*Pleuronectes americanus*		X	
Yellow bullhead	*Ictalurus natalis*		X	
Yellow perch	*Perca flavescens*			X

[a] Designated as being in the recreational fishery at family level only.
Sources: PSEG, 1999c, Attachment 4, Table 1, NMFS, 2001a, NMFS, 2001b.

B3-2 Life Histories of Primary Species Impinged and Entrained

Life history characteristics of the primary species impinged or entrained at the Salem facility are summarized in the following sections. The species described are those with the highest I&E rates at Salem (presented below in Sections 3.4 and 3.5).

Alewife *(Alosa pseudoharengus)*

Alewife is a member of the herring family, Clupeidae, and ranges along the Atlantic coast from Newfoundland to North Carolina (Scott and Crossman, 1998). Alewife tend to be more abundant in the mid-Atlantic and along the northeastern coast. They are anadromous, migrating inland from coastal waters in the spring to spawn. Adult alewife overwinter along the northern continental shelf, settling at the bottom in depths of 56 to 110 m (184 ft to 361 ft) (Able and Fahay, 1998). Adults feed on a wide variety of food items, while juveniles feed mainly on plankton (Waterfield, 1995).

Alewife has been introduced to a number of lakes to provide forage for sport fish (Jude et al., 1987b). Ecologically, alewife is an important prey item for many fish, and commercial landings of river herring along the Atlantic coast have ranged from a high of 33,974 metric tons (74.9 million pounds) in 1958 to a low of less than 2,268 metric tons (5 million pounds) in recent years (Atlantic States Marine Fisheries Commission, 2000b).

Spawning is temperature-driven, beginning in the spring as water temperatures reach 13 to 15 ˚C, and ending when they exceed 27 ˚C (Able and Fahay, 1998). Spawning takes place in the upper reaches of coastal rivers, in slow-flowing sections of slightly brackish or freshwater.

Females lay demersal eggs in shallow water less than 2 m (6.6 ft) deep (Wang and Kernehan, 1979). They may lay from 60,000 to 300,000 eggs at a time (Kocik, 2000). The demersal eggs are 0.8 to 1.27 mm (0.03 to 0.05 in) in diameter. Larvae hatch at a size of approximately 2.5 to 5.0 mm (0.1 to 0.2 in) total length (Able and Fahay, 1998). Larvae remain in the upstream spawning area for some time before drifting downstream to natal estuarine waters. Juveniles exhibit a diurnal vertical migration in the water column, remaining near the bottom during the day and rising to the surface at night (Fay et al., 1983c). In the fall, juveniles move offshore to nursery areas (Able and Fahay, 1998).

Maturity is reached at an age of 3 to 4 years for males, and 4 to 5 years for females (Able and Fahay, 1998). The average size at maturity is 265 to 278 mm (10.4 to 10.9 in) for males and 284 to 308 mm (11.2 to 12.1 in) for females (Able and Fahay, 1998). Alewife can live up to 8 years, but the average age of the spawning population tends to be 4 to 5 years (Waterfield, 1995; PSEG, 1999c).

ALEWIFE
(Alosa pseudoharengus)

Family: Clupeidae (herrings).

Common names: River herring, sawbelly, kyak, branch herring, freshwater herring, bigeye herring, gray herring, grayback, white herring.

Similar species: Blueback herring.

Geographic range: Along the western Atlantic coast from Newfoundland to North Carolina.[a]

Habitat: Wide-ranging, tolerates fresh to saline waters, travels in schools.

Lifespan: May live up to 8 years.[b,c]

Fecundity: Females may lay from 60,000 to 300,000 eggs at a time.[d]

Food source: Small fish, zooplankton, fish eggs, amphipods, mysids.[c]

Prey for: Striped bass, weakfish, rainbow trout.

Life stage information:

Eggs: *demersal*
- Found in waters less than 2 m (6.6 ft) deep.[d]
- Are 0.8 to 1.27 mm (0.03 to 0.05 in) in diameter.[f]

Larvae:
- Approximately 2.5 to 5.0 mm (0.1 to 0.2 in) at hatching.[f]
- Remain in upstream spawning area for some time before drifting downstream to natal estuarine waters.

Juveniles:
- Stay on the bottom during the day and rise to the surface at night.[g]
- Emigrate to ocean in summer and fall.[f]

Adults: *anadromous*
- Reach maturity at 3-4 years for males and 4-5 years for females.[f]
- Average size at maturity is 265-278 mm (10.4-10.9 in) for males and 284-308 mm (11.2-12.1 in) for females.[f]
- Overwinter along the northern continental shelf.[f]

Location:
- Range along the western Atlantic coast from Newfoundland to North Carolina.
- Some landlocked populations exist in the Great Lakes and smaller lakes.

[a] Scott and Crossman, 1998.
[b] PSEG, 1999c.
[c] Waterfield, 1995.
[d] Kocik, 2000.
[e] Wang and Kernehan, 1979.
[f] Able and Fahay, 1998.
[g] Fay et al., 1983c.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

American shad (*Alosa sapidissima*)

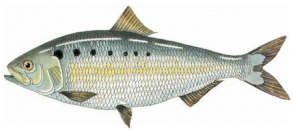
American shad is a member of the herring family, Clupeidae. American shad ranges from the Gulf of St. Lawrence, Canada, south to Florida, and are most abundant from Connecticut to North Carolina (Able and Fahay, 1998). An anadromous species, American shad migrate inland to spawn in natal rivers. Suitable American shad spawning habitat has declined over the years because of degradation in water quality and the construction of dams blocking natal spawning grounds (Atlantic States Marine Fisheries Commission, 2000b). Though still commercially and recreationally an important species, the economic importance of American shad has declined in the last century with its decreased abundance (Wang and Kernehan, 1979).

Spawning generally takes place from mid-April through early June, when water temperatures reach 12 ˚C (Able and Fahay, 1998). The slightly demersal eggs may hatch in 12 to 15 days at 12 ˚C (54 ˚F) and in 6 to 8 days at 17 ˚C (63 ˚F) (Wang and Kernehan, 1979; Able and Fahay, 1998). Larvae hatch at 5 to 10 mm (0.2 to 0.4 in) , and are pelagic for 2 to 3 weeks. At 25 to 28 mm, shad become juveniles (Able and Fahay, 1998), and will remain in riverine habitats through the first summer, gradually dispersing downstream (Able and Fahay, 1998). Emigration from estuarine habitats to marine waters occurs in the fall, and is triggered by decreasing water temperatures. Young-of-year are approximately 75 to 125 mm (3.0 to 4.9 in) at this point (Able and Fahay, 1998).

At 1 year, juveniles reach approximately 120 mm (4.7 in). Males tend to mature at 3 to 5 years, while females mature at 4 to 6 years (Able and Fahay, 1998). Mortality rates vary according to spawning grounds. Over half of the American shad that

spawn in the Hudson River survive spawning migration and return to spawn again the following year (Wang and Kernehan, 1979), compared to less than 5 percent in the Delaware River (Wang and Kernehan, 1979).

American shad have a potential lifespan of up to 11 years (Carlander, 1969), but generally do not live longer than 8 years (PSEG, 1999c).



AMERICAN SHAD
(Alosa sapidissima)

Family: Clupeidae (herrings).

Common names: Shad, Atlantic shad, white shad.

Similar species: Atlantic herring, alewife, blueback herring, Atlantic menhaden.

Geographic range: Atlantic coast from the St. Lawrence River to Florida.[a] May migrate more than 12,000 miles during their average lifespan.

Habitat: Marine waters, returning to inland tributaries and streams to spawn.

Lifespan: Generally up to 8 years.[b]

Fecundity: Females can lay over 600,000 eggs, as several hovering males fertilize them.[c]

Food source: Primarily plankton feeders, while at sea they feed on plankton, small crustaceans, and small fishes.

Prey for: Sea lamprey, striped bass, bluefish.

Life stage information:

Eggs: *slightly demersal*
- Shad move far enough upstream for the eggs to drift downstream and hatch before reaching saltwater.
- The eggs mature rapidly and transform into young fish in 3 to 4 weeks.

Larvae: *pelagic*
- Larvae hatch out at 5 to 10 mm (0.2 to 0.4 in) and are pelagic for 2 to 3 weeks.[d]

Juveniles:
- The young-of-year remain in fresh to brackish water until early fall before entering the sea. Some juveniles do not enter the sea and instead overwinter in deep holes near the mouth of the bay.

Adults: *anadromous*
- American shad are anadromous and do not feed during their return migration.

Location:
- Inshore and offshore. Atlantic coast from the St. Lawrence River to Florida. Spends most of its life at sea in large schools. It only enters the freshwater river in which it was born to spawn.
- American shad may migrate more than 1,000 miles during their average life span of five years at sea. They enter the bay from January to June between the ages of 4 and 6 to spawn in the freshwater and low-salinity tributaries.

[a] Able and Fahay, 1998.
[b] PSEG, 1999c.
[c] Walburg, 1960.
[d] Able and Fahay, 1998.
Fish graphic from State of Maine Department of Marine Resources, 2001a.

Atlantic croaker (*Micropogonias undulatus*)

The Atlantic croaker is a member of the drum family Sciaenidae. Its distribution ranges from Massachusetts to the Gulf of Mexico along the Atlantic coast, with the greatest abundance from Chesapeake Bay to Florida (Able and Fahay, 1998; Desfosse et al., 1999). Populations of Atlantic croaker fluctuated over the last century, showing high levels in the 1940's, then declining sharply in the 1950's and 1960's (Joseph, 1972). Numbers remained low until the mid-1970's and steadily increased since then (Wang and Kernehan, 1979). Commercial landings in Delaware were reported as low as 0.1 metric tons (220 lb) in 1988, increasing to 6.7 metric tons (14,770 lb) in 1999 (Personal Communication, National Marine Fisheries Service, Fisheries Statistics and Economics Division, Silver Spring, Maryland, March 26, 2001).

As a bottom-feeding fish, the Atlantic croaker feeds mainly on worms, crustaceans, and fish (Atlantic States Marine Fisheries Commission, 2000a). It can tolerate a wide range of salinities ranging from freshwater to 70 ppt (Able and Fahay, 1998). Spawning occurs offshore from September through December along the continental shelf between Delaware Bay and Cape Hatteras (Morse, 1980a; Able and Fahay, 1998).

Female fecundity along the mid-Atlantic coast ranges from 100,800 to 1,742,000 eggs in females from 196 to 390 mm (7.7 to 15.4 in) in total length (Morse, 1980a). Atlantic croaker larvae enter Delaware Bay in fall and spend the winter over the continental shelf. Young croaker use the estuary as a nursery area in late winter, spring, and summer. Larvae are most abundant in September-October and juveniles are most abundant in October-January. Young-of-year leave the offshore shelf waters for inshore estuaries beginning in October, at lengths of 8 to 20 mm (0.3 to 0.8 in) (Able and Fahay, 1998). Young-of-year are often found over soft mud bottoms at water temperatures between 9.5 and 23.2 °C (49.1 and 73.8 °F), and tend to overwinter in deeper areas of the same habitats (Cowan and Birdsong, 1995). By age 1, individuals in the Delaware Bay have reached lengths of 135 to 140 mm (Able and Fahay, 1998). In the fall, age 1 individuals leave their overwintering estuaries to migrate offshore and south for their second winter (Able and Fahay, 1998).

Maturity begins at lengths of 140 to 170 mm (5.5 to 6.7 in), as Atlantic croaker approach 2 years (White and Chittenden, 1977). Atlantic croaker is a relatively short-lived species, living to a maximum age of 2 to 4 years in the Mid-Atlantic Bight (White and Chittenden, 1977). Adults tend to be less than 200 mm (7.9 in) long south of Cape Hatteras (North Carolina), although they can reach more than 350 mm (13.8 in). Individuals north of Cape Hatteras are generally larger (White and Chittenden, 1977).

ATLANTIC CROAKER
(Micropogonias undulatus)

Family: Sciaenidae (drums).

Common names: Corvina, hardhead, king billy, roncadina, and grumbler.

Similar species: Red drum, weakfish, spotted seatrout, spot.

Geographic range: From Massachusetts to the Gulf of Mexico along the western Atlantic coast, with the greatest abundance from Chesapeake Bay to Florida.[a,b]

Habitat: Usually found over mud and sandy mud bottoms in coastal waters and estuaries.[b]

Lifespan: Croaker generally live for 2-4 years.[c]

Fecundity: Females may lay between 100,800 to 1.74 million eggs.[d]

Food source: Croaker are opportunistic bottom-feeders that consume a variety of invertebrates (mysid shrimp, copepods, marine worms) and occasionally fish.

Prey for: Striped bass, flounder, shark, spotted seatrout, other croaker, bluefish, and weakfish.

Life stage information:

Eggs: *weakly demersal*
- Develop offshore.

Larvae:
- Larvae are most abundant in September-October.[e]

Juveniles:
- Young-of-year migrate to inshore estuaries in the fall, and tend to overwinter in relatively deep areas with soft mud bottoms.
- Juvenile croaker leave estuaries in the fall to spend their second winter offshore.

Adults:
- Maturity begins at approximately 140-170 mm (5.5 to 6.7 in).[c]
- May reach over 350 mm (13.8 in).[c]

Location:
- New Jersey to the Gulf of Mexico and the Western Atlantic Coast. Most abundant between the Chesapeake Bay and Florida.
- Adult croaker generally spend the spring and summer in estuaries and move offshore and south along the Atlantic coast in the fall.
- Prefer muddy bottoms and depths less than 120 m.
- Euryhaline species — able to tolerate a wide range of salinities.

[a] Desfosse et al., 1999.
[b] Froese and Pauly, 2001.
[c] White and Chittenden, 1977.
[d] Morse, 1980a.
[e] Able and Fahay, 1998.
Fish graphic from South Carolina Department of Natural Resources, 2001.

Atlantic menhaden (*Brevoortia tyrannus*)

The Atlantic menhaden, a member of the Clupeidae (herring) family, is a euryhaline species, occupying coastal and estuarine habitats. It is found along the Atlantic coast of North America, from Maine to northern Florida (Hall, 1995). Adults congregate in large schools in coastal areas; these schools are especially abundant in and near major estuaries and bays. They consume plankton, primarily diatoms and dinoflagellates, which they filter from the water through elaborate gill rakers. In turn, menhaden are consumed by almost all commercially and recreationally important piscivorous fish, as well as by dolphins and birds (Hall, 1995).

The menhaden fishery, one of the most important and productive fisheries on the Atlantic coast, is a multimillion-dollar enterprise (Hall, 1995). Menhaden are considered an "industrial fish" and are used to produce products such as paints, cosmetics, margarine (in Europe and Canada), and feed, as well as bait for other fisheries. Landings in New England declined to their lowest level of approximately 2.7 metric tons (5,952 lb) in the 1960s because of overfishing. Since then, landings have varied, ranging from approximately 240 metric tons (529,100 lb) in 1989 to 1,069 metric tons in 1998 (Personal Communication, National Marine Fisheries Service, Fisheries Statistics and Economics Division, Silver Spring, Maryland, March 19, 2001).

Atlantic menhaden spawn year round at sea and in larger bays (Scott and Scott, 1988). Spawning peaks during the southward fall migration and continues throughout the winter off the North Carolina coast. There is limited spawning during the northward migration and during summer months (Hall, 1995). The majority of spawning occurs over the inner continental shelf, with less activity in bays and estuaries (Able and Fahay, 1998).

Females mature just before age 3, and release buoyant, planktonic eggs during spawning (Hall, 1995). Atlantic menhaden annual egg production ranges from approximately 100,000 to 600,000 eggs for fish age 1 to age 5 (Dietrich, 1979). Eggs are spherical and between 1.3 to 1.9 mm (0.05 to 0.07 in) in diameter (Scott and Scott, 1988).

Larvae hatch after approximately 24 hours and remain in the plankton. Larvae hatched in offshore waters enter the Delaware Estuary 1 to 2 months later to mature (Hall, 1995). Juveniles then migrate south in the fall, joining adults off North Carolina in January (Hall, 1995). Water temperatures below 3 ˚C (37 ˚F) kill the larvae, and therefore larvae that fail to reach estuaries before the fall are more likely to die than those arriving in early spring (Able and Fahay, 1998). Larvae hatchout at 2.4 to 4.5 mm (0.09 to 0.18 in). The transition to the juvenile stage occurs between 30 and 38 mm (1.2 and 1.5 in) (Able and Fahay, 1998). The juvenile growth rate in some areas is estimated to be 1 mm (0.04 in) per day (Able and Fahay, 1998).

During the fall and early winter, most menhaden migrate south off of the North Carolina coast, where they remain until March and early April. They avoid waters below 3 ˚C, but can tolerate a wide range of salinities from less than 1 percent up to 33-37 percent (Hall, 1995). Sexual maturity begins at age 2, and all individuals are mature by age 3 (Scott and Scott, 1988).

Adult fish are commonly between 30 and 35 cm (11.8 and 13.8 in) in length. The maximum age of a menhaden is approximately 7 to 8 years (Hall, 1995), although individuals of 8-10 years have been recorded (Scott and Scott, 1988).

ATLANTIC MENHADEN
(*Brevoortia tyrannus*)

Family: Clupeidae (herrings).

Common names: menhaden, bunker, fatback, bugfish.

Similar species: Gulf menhaden, yellowfin menhaden.

Geographic range: From Maine to northern Florida along the Atlantic coast.[a]

Habitat: Open-sea, marine waters. Travels in schools.[b]

Lifespan:
- Approximately 7 to 8 years.[a]

Fecundity:
- Females may produce between 100,000 to 600,000 eggs.[c]

Food Source: Phytoplankton, zooplankton, annelid worms, detritus[b]

Prey for: Sharks, cod, pollock, hakes, bluefish, tuna, swordfish, seabirds, whales, porpoises.[b]

Life Stage Information

Eggs: *pelagic*
- Spawning takes place along the inner continental shelf, in open marine waters.[d]
- Eggs hatch after approximately 24 hours.

Larvae: *pelagic*
- Larvae hatch out at sea, and enter estuarine waters 1 to 2 months later.[a]
- Remain in estuaries through the summer, emigrating to ocean waters as juveniles in September or October.[d]

Adults
- Congregate in large schools in coastal areas.
- Spawn year round.[b]

[a] Hall, 1995.
[b] Scott and Scott, 1988.
[c] Dietrich, 1979.
[d] Able and Fahay, 1998.
Fish graphic from South Carolina Department of Natural Resources, 2001.

Atlantic silverside (*Menidia menidia*)

The Atlantic silverside is a member of the silverside family, Atherinidae. Its geographic range extends from coastal waters of New Brunswick to northern Florida (Fay et al., 1983c), but it is most abundant between Cape Cod and South Carolina (Able and Fahay, 1998). Atlantic silversides inhabit sandy seashores and the mouths of inlets (Froese and Pauly, 2001). Silversides are an important species of forage fish, eaten by valuable fishery species such as striped bass (*Morone saxatilis*), bluefish (*Pomatomus salatrix*), weakfish (*Cynoscion regalis*), and Atlantic mackerel (*Scomber scombrus*) (Fay et al., 1983c; McBride, 1995).

Atlantic silversides spawn in the upper intertidal zone during spring and summer. Spawning appears to be stimulated by new and full moons, in association with spring tides. On average, females produce 4,500 to 5,000 demersal eggs per spawning season, which may include four to five separate spawning bouts (Fay et al., 1983c). The eggs are 0.9 to 1.2 mm (0.04 to 0.05 in) in diameter. Larvae range in size from 5.5 to 15.0 mm (0.2 to 0.6 in) (Fay et al., 1983c). The sex of Atlantic silversides is determined during the larval stage, at approximately 32 to 46 days after hatching. Water temperatures between 11 and 19 ˚C (52 and 66 ˚F) produce significantly more females, whereas temperatures between 17 and 25 ˚C (63 and 77 ˚F) produce significantly more males (Fay et al., 1983c).

Juveniles occur in estuaries during the summer months, occupying intertidal creeks, marshes, and shore zones of bays and estuaries. Silversides typically migrate offshore in the winter (McBride, 1995). In studies of seasonal distribution in Massachusetts, all individuals left inshore waters during winter months (Able and Fahay, 1998).

The diet of juveniles and adults consists of copepods, mysids, amphipods, cladocerans, fish eggs, squid, worms, molluscs, insects, algae, and detritus (Fay et al., 1983c). Atlantic silversides feed in large schools, preferring gravel and sand bars, open beaches, tidal creeks, river mouths, and marshes (Fay et al., 1983c).

Silversides live for only 1 or 2 years, usually dying after completing their first spawning (Fay et al., 1983c). Adults can reach sizes of up to 15 cm (5.9 in) in total length (Froese and Pauly, 2001).

ATLANTIC SILVERSIDE
(*Menidia menidia*)

Family: Atherinidae (silversides).

Common names: Spearing, sperling, green smelt, sand smelt, white bait, capelin, shiner.[a]

Similar species: Inland silverside (*Menidia beryllina*).[a]

Geographic range: New Brunswick to northern Florida[a]

Habitat: Sandy seashores and the mouths of inlets.[b]

Lifespan: One or 2 years. Often die after their first spawning.[a]

Fecundity: Females produce an average of 4,500 to 5,000 eggs per spawning season.[a]

Food Source: Zooplankton, fish eggs, squid, worms, molluscs, insects, algae, and detritus.[a]

Prey for: Striped bass, bluefish, weakfish, and Atlantic mackerel.[a,c]

Life Stage Information

Eggs: *demersal*
- Found in shallow waters of estuarine intertidal zones.[a]
- Can be found adhering to submerged vegetation.[a]

Larvae:
- Range from 5.5 to 15.0 mm (0.2 to 0.6 in) in size.[a]
- Sex is determined during the larval stage by the temperature regime. Colder temperatures tend to produce more females, and warmer temperatures produce more males.[a]

Adults:
- Overwinter in offshore marine waters.[d]
- Can reach sizes of up to 15 cm (5.9 in) total length.[d]

[a] Fay et al., 1983c.
[b] Froese and Pauly, 2001.
[c] McBride, 1995.
[d] Able and Fahay, 1998.
Fish graphic from Government of Canada, 2001.

Bay anchovy *(Anchoa mitchilli)*

Bay anchovy is a member of the anchovy family, Engraulidae, and is one of the most abundant species in estuaries along the Atlantic and Gulf coasts of the United States (Vouglitois et al., 1987). In Delaware Bay, bay anchovy shares the status of most abundant species with the Atlantic silverside (de Sylva et al., 1962). Because of its widespread distribution and overall abundance, bay anchovy are an important component of the food chain for recreational and commercial fish, and as such have indirect economic importance (Morton, 1989).

Bay anchovy is commonly found in shallow tidal areas, feeding mainly on copepods and other zooplankton. It tends to appear in higher densities in vegetated areas such as eelgrass beds (Castro and Cowen, 1991).

The spawning period of bay anchovy is long, with records ranging from April to November (Vouglitois et al., 1987). In the Delaware Estuary, the spawning season usually occurs from early April through mid-June (Wang and Kernehan, 1979). Spawning within the Delaware Estuary primarily occurs in the western part of the C & D Canal, and in the Elk River (Wang and Kernehan, 1979) (see Figure B1-1), and has been correlated with areas of high zooplankton abundance (Dorsey et al., 1996). In Chesapeake Bay, a minimum of 50 spawning events per female was estimated, with spawning events occurring every 4 days in June and every 1.3 days in July. Spawning generally occurs nocturnally, and during peak spawning periods females may spawn nightly. Fecundity estimates for bay anchovy in mid-Chesapeake Bay were reported at 643 eggs in July 1986 and 731 eggs in July 1987 (Zastrow et al., 1991). The pelagic eggs are 0.8 to 1.3 mm (0.03 to 0.05 in) in diameter (Able and Fahay, 1998). Size of the eggs varies with increased water salinity.

Eggs hatch in approximately 24 hours at average summer temperatures (Monteleone, 1992). The yolk sac larvae are 1.8 to 2.0 mm (0.07 to 0.08 in) long, with nonfunctioning eyes and mouth parts (Able and Fahay, 1998). Mortality during these stages is high. In a study conducted in the Chesapeake Bay, 73 percent of the eggs died before hatching, and mortality for surviving larvae was 72 percent within the first 24 hours of hatching (Dorsey et al., 1996).

Growth estimates for larval bay anchovy have been estimated at 0.53 to 0.56 mm (0.021 to 0.022 in) per day in Great South Bay, New York (Castro and Cowen, 1991), and young-of-year growth rates averaged 0.47 mm (0.02 in) per day in Chesapeake Bay (Zastrow et al., 1991). Sexual maturity occurs at a length of 40 to 45 mm (1.6 to 1.8 in) in Chesapeake Bay

(Zastrow et al., 1991). Individuals hatched early in the season may become sexually mature by their first summer (Morton, 1989).

Most young-of-year migrate out of the estuaries at the end of the summer in schools, and can be found in large numbers on the inner continental shelf in the fall (Vouglitois et al., 1987). The average size for adults is 75 mm (2.95 in) (Morton, 1989). Bay anchovy live for only 1 or 2 years (Zastrow et al., 1991).

Near the Salem station, bay anchovy eggs are present from May to November and are most abundant from May to August. Larvae are present from May to October, with greatest abundance from June to August. Juveniles are present throughout the year but are most abundant from July to October. Adults are also present year-round and are most abundant from April to November.

BAY ANCHOVY
(Anchoa mitchilli)

Family: Engraulidae (anchovies).

Common names: Anchovy.

Similar species: Atlantic silverside.

Geographic range: From Maine, south to the Gulf of Mexico.[a]

Habitat: Commonly found in shallow tidal areas with muddy bottoms and brackish waters; often appears in higher densities in vegetated areas such as eelgrass beds.[b]

Lifespan: 1-2 years.[c]

Fecundity: Females spawn a minimum of 50 times over the spawning season in the Chesapeake Bay. Fecundity per spawning event is about 700 eggs.[c]

Food source: Primarily feed on copepods and other zooplankton, as well as small fishes and gastropods.[b]

Prey for: Striped bass, weakfish, jellyfish.

Life stage information:

Eggs: *pelagic*
- Eggs are 0.8-1.3 mm (0.03 to 0.05 in) in diameter.[a]
- Eggs experience an average mortality of 73 percent.[d]

Larvae:
- Yolk-sac larvae are 1.8 to 2.0 mm (0.7 to 0.8 in) on hatching.[a]
- Daily mortality for yolk-sac larvae is as high as 88 percent.[b]
- Daily mortality for 3-15 day old larvae is approximately 28 percent.[b]

Juveniles:
- Young-of-year migrate out of estuaries at the end of summer, and can be found in large numbers on the inner continental shelf in fall.[e]

Adults:
- Adults reach sexual maturity at 40 to 45 mm (1.6 to 1.8 in) in Chesapeake Bay.[c]
- The average adult is 75 mm (2.95 in) long.[f]

Location:
- Ranges from Cape Cod, Massachusetts, south to the Gulf of Mexico. Spawns in the Delaware Estuary in the Elk River and C&D Canal.[g]
- Most commonly found in shallow tidal areas with muddy bottoms and brackish waters, but can be found in a wide range of habitats.
- Tolerates a wide range of salinities.

[a] Able and Fahay, 1998.
[b] Castro and Cowen, 1991.
[c] Zastrow et al., 1991.
[d] Dorsey et al., 1996.
[e] Vouglitois et al., 1987.
[f] Morton, 1989.
[g] Wang and Kernehan, 1979.
Fish graphic from NOAA, 2001a.

Blue crab (*Callinectes sapidus*)

The Atlantic blue crab can be found in Atlantic coastal waters from Long Island to the Gulf of Mexico. Blue crab supports the most economically important inshore commercial fishery in the mid-Atlantic (Epifanio, 1995); Chesapeake Bay provides over 50 percent of the commercial landings of Atlantic blue crab nationwide (Epifanio, 1995).

Females typically mate only once within their lifetime. Spawning in the Delaware Bay peaks from late July to early August. After an elaborate courtship ritual, females lay two to three broods of eggs, each containing over 1 million eggs. Mating occurs in areas of low salinity. The eggs hatch near high tide and the larvae are carried out to sea by the current (Epifanio, 1995). This stage of the lifecycle is called the zoeal stage. The zoea go through seven molts before entering the next stage, the megalops stage, and are carried back to estuarine waters (Epifanio, 1995). The zoea stages last approximately 35 days, and the megalops stage may vary from several days to a few weeks (Epifanio, 1995).

While in the zoeal stage along the continental shelf, larvae are vulnerable to predators, starvation, and transport to unsuitable habitats. Larvae are especially vulnerable to predators while molting. Dispersal of young Atlantic blue crabs is primarily controlled by wind patterns, and they do not necessarily return to their parent estuaries (Epifanio, 1995). In the Delaware Estuary, maturity is reached at approximately 18 months (Epifanio, 1995).

Atlantic blue crabs inhabit all regions of the Delaware Estuary. Males prefer areas of low salinity, while females prefer the mouth of the estuary. In the warmer months, crabs occupy shallower areas in depths of less than 4.0 m (13 ft). They can tolerate water temperatures exceeding 35 ˚C (95 ˚F), but do not fare as well in cold water (Epifanio, 1995). In winter months, adults burrow into the bottom of deep channels and remain inactive (Epifanio, 1995). Extremely cold weather has resulted in high mortality of overwintering crabs (Epifanio, 1995).

Atlantic blue crabs are omnivorous, foraging on molluscs, mysid shrimp, small crabs, worms, and plant material (Epifanio, 1995). Adults prey heavily on juvenile Atlantic blue crab (Epifanio, 1995).

Atlantic blue crab can live up to 3 years (Epifanio, 1995).

Impingeable sizes of blue crab are present throughout the year near Salem, but are most abundant from April to November.

ATLANTIC BLUE CRAB
(*Callinectes sapidus*)

Family: Portunidae (swimming crabs).

Common names: Blue crab.

Similar species: Lesser blue crab (*Callinectes similis*).

Lifespan: Up to 3 years. Maturity is reached at 18 months.[a]

Geographic range: Atlantic coast from Long Island to the Gulf of Mexico.[a]

Habitat: Inhabit all areas of the Delaware Estuary. In warmer weather they occupy shallow areas less than 4 m (13 ft) deep. They burrow into the bottom of deep channels and remain inactive in winter.[a]

Fecundity: Typically mate once in their lifetime. Mating occurs in low salinity areas. Females lay two to three broods of 1 million eggs each.[a]

Food Source: Atlantic blue crabs are omnivores, foraging on molluscs, mysids, shrimp, small crabs, worms, and plant material.[a]

Prey for: Juveniles are preyed upon by a variety of fish (eels, striped bass, weakfish) and are heavily preyed upon by adult blue crabs.[a]

Life Stage Information

Eggs:
- Hatch near high tide.[a]

Larvae:
- Carried out to sea by the current, where they remain for seven molts before returning to estuaries.[a]

***Adults*:**
- Males prefer lower salinity while females prefer the mouth of the bay.[a]

[a] Epifanio, 1995.
Graphic from U.S. FDA, 2001.

Blueback herring (*Alosa aestivalis*)

Blueback herring is a member of the herring family, Clupeidae. It is closely related to the alewife; together they are commonly referred to as river herring. The range of blueback herring extends from Nova Scotia south to northern Florida, though they are more abundant in the southern portion of their range (Scott and Scott, 1988). Within the Delaware Estuary, blueback herring tend to be more abundant in the upper region of the estuary than do the closely related alewife (Waterfield, 1995). Economically, blueback herring are an important bait species for the blue crab industry of the Delaware and Chesapeake bays. They are also a significant prey item for many estuarine fish species.

Adults spawn from spring to early summer in upstream brackish or freshwater areas of rivers and tributaries. Spawning occurs at night in fast currents over a hard substrate (Loesch and Lund, 1977). Spawning groups have been observed diving to the bottom and releasing the semi-adhesive eggs over the substrate, but many eggs are dislodged by the current and enter the water column. Loesch and Lund (1977) reported fecundity estimates of 45,800 to 349,700 eggs per female, and noted that fecundity was positively correlated with total fish length up to approximately 300 mm. After spawning, adults move downstream and return to the ocean.

Eggs float near the bottom for 2 to 4 days until hatching, depending on temperature. At hatching, larvae are 3.1 to 5.0 mm (0.12 to 0.20 in) (Jones et al., 1978). Larvae become juveniles at approximately 20 mm (0.79 in), or at 25 to 35 days (Able and Fahay, 1998). Juveniles are distributed high in the water column and avoid bottom depths (Able and Fahay, 1998). In the early juvenile stages, fish are swept downstream by the tide. Some juveniles will move upstream until late summer before migrating downstream in late summer to early fall. Juveniles are sensitive to sudden water temperature changes, and emigrate downstream in response to a decline in temperature (Able and Fahay 1998). By late fall, most young-of-year emigrate to ocean waters to overwinter (Wang and Kernehan, 1979).

Male blueback herring mature at ages 3 to 4, and females mature at ages 4 to 5. Over half of the adults are repeat spawners, returning to natal spawning grounds every year (Scherer, 1972). Females tend to grow larger than males and dominate the older age groups. Blueback herring can live to 8 years (Froese and Pauly, 2001).

Near Salem, blueback herring juveniles are present from winter through late spring and again in fall.

BLUEBACK HERRING
(*Alosa aestivalis*)

Family: Clupeidae (herrings).

Common names: River herring, glut herring, summer herring, kyak, blackbelly.

Similar species: alewife, American shad, Atlantic menhaden.

Geographic range: From Nova Scotia south to northern Florida.[a]

Habitat: Euryhaline, marine. Adults form schools and overwinter near the bottom out from the coast.[b]

Lifespan: May live up to 8 years.[b]

Fecundity: Fecundity ranges from 45,800 to 349,700 eggs per female.[c] Over half of adults are repeat spawners and return to natal spawning grounds every year.[d]

Food source: Shrimp, zooplankton, finfish.

Prey for: Striped bass, weakfish, bluefish.

Life stage information:

Eggs: *pelagic*
- Eggs float near the bottom for 2-4 days.[e]

Larvae:
- Larvae are 3.1-5.0 mm at hatching.[e]
- The larval stage duration is 25-35 days.[f]

Juveniles:
- Blueback herring reach the juvenile stage at 20 mm (0.79 in), or at an age of 25-35 days.[f]
- Juveniles are distributed high in the water column and avoid bottom depths.
- Juveniles tend to move upstream until late summer before migrating downstream in late summer in response to a decline in temperature.

Adults:
- Males mature at ages 3-4, females at ages 4-5.
- Adults overwinter near the bottom and out from the coast, then return to shore in late spring to spawn.

Location:
- Range from Nova Scotia south to northern Florida.
- More common in upper region of Delaware estuary than the closely related alewife.

[a] Scott and Scott, 1988.
[b] Froese and Pauly, 2001.
[c] Loesch and Lund, 1977.
[d] Scherer, 1972.
[e] Jones et al., 1978.
[f] Able and Fahay, 1998.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

Spot (*Leiostomus xanthurus*)

Spot is a member of the drum family, Sciaenidae. Its range extends along the Atlantic coast from Massachusetts Bay to Campeche Bay, Mexico, and it is most abundant from Chesapeake Bay to South Carolina (Hildebrand and Schroeder, 1928; Mercer, 1987). Spot are occasionally harvested for food, but because of their small size, are typically used as bait and in pet food and fish meal (Hales and Van Den Avyle, 1989). Spot are often caught by anglers because they take the bait easily and are often found near piers and bridges (Hales and Van Den Avyle, 1989).

Ecologically they are an important species because of their high abundance and their status on the food chain as both predator and prey for many species. Because of their short lifespan, annual landings tend to consist of a single year class and fluctuate greatly from year to year, yet show no long-term trends (Atlantic States Marine Fisheries Commission, 2000c).

Spawning occurs in deeper waters along the continental shelf from late fall through early spring (Mercer, 1987). Females produce 30,000 to 60,000 eggs (Phillips et al., 1989), and eggs are 0.72-0.87 mm (0.028 to 0.034 in) in diameter (Able and Fahay, 1998). Larvae hatch out at 1.5 to 1.7 mm (0.06 to 0.07 in) in length and begin migrating to inshore estuaries, reaching the nursery estuarine waters in early to late spring. Young larvae show a preference for low salinity waters (Wang and Kernehan, 1979), and continue to migrate to the upper areas of estuaries to spend the summer. By the fall, young-of-year reach 10 to 11 cm (3.9 to 4.3 in) (Able and Fahay, 1998). First year growth rates for spot in Chesapeake Bay have been recorded from 10.5 mm (0.4 in) per month to 19.1 mm (0.8 in) per month (Hildebrand and Schroeder, 1928; McCambridge and Alden, 1984).

As water temperatures decrease in the fall, juveniles emigrate to the ocean in October and November. Larger individuals tend to leave the estuaries earliest. In the Chesapeake Bay, some young-of-year spot have remained in the estuaries throughout the first winter.

Spot are able to avoid heavy competition with Atlantic croaker by occupying different spatial and temporal niches. While Atlantic croaker spawn from October through February in the Delaware Estuary, spot spawn from December through March (Wang and Kernehan, 1979). They share a similar diet, consisting mostly of mysid shrimp, copepods, and marine worms, but spot feed more on burrowing worm species while Atlantic croaker show a preference for worms on the bottom surface (Chao and Musick, 1977).

Spot mature at 2 to 3 years (Atlantic States Marine Fisheries Commission, 2000c). The maximum recorded age for spot is 5 years (Mercer, 1987). The largest recorded spot was 35.6 cm (14.0 in) long, although most mature adults are 17.8 to 20.3 cm (7.0 to 8.0 in) (Atlantic States Marine Fisheries Commission, 2000c).

Spot may be particularly vulnerable to I&E in intake structures because of their slow swimming speeds and low endurance (Hales and Van Den Avyle, 1989). Young spot have significantly lower swimming speeds than most estuarine fishes and cannot maintain their orientation in currents exceeding 15 cm/s. Larger spot have increased swimming capabilities, but may also be vulnerable to I&E because they tend to drift with the currents (Hales and Van Den Avyle, 1989).

SPOT
(Leiostomus xanthurus)

Family: Sciaenidae (drums).

Common names: Spot croaker.

Similar species: Red drum, weakfish, spotted seatrout, Atlantic croaker.

Geographic range: Along the Atlantic coast from Massachusetts Bay to Campeche Bay, Mexico, and most abundant from Chesapeake Bay to South Carolina.[a,b]

Habitat: Often found near piers and bridges.[c] Occurs over sandy or muddy bottoms in coastal waters up to 60 m (197 ft) in depth.[d]

Lifespan: Up to 5 years.[b]

Fecundity: Females produce 30,000 to 60,000 eggs.[e]

Food source: Worms, mysid shrimp, copepods.[f]

Prey for: Striped bass, weakfish, bluefish, flounder, bonito, sandbar shark.

Life stage information:

Eggs: *pelagic*
- Eggs are 0.72-0.87 mm (0.028 to 0.034 in) in diameter.[f]

Larvae:
- Larvae are 1.5-1.7 mm (0.06 to 0.07 in) long at hatching.[e]
- Larvae migrate to inshore estuary waters, arriving in early to late spring.
- Young larvae prefer low salinity waters and are found in upper estuary waters.

Juveniles:
- As water temperature decreases in the fall, most young-of-year spot migrate out to the ocean.
- Larger individuals tend to leave the estuary earlier.

Adults:
- Spot mature at 2-3 years.[h]
- The largest recorded spot was 35.6 cm (14.0 in) long, although most mature adults are 17.8-20.3 cm (7.0 to 8.0 in).[h]

Location:
- Range along the western Atlantic coast from Massachusetts Bay to Campeche Bay, Mexico.
- Found over sandy or muddy bottoms in coastal waters to about 60 m depth.
- Found in nursery and feeding grounds in river estuaries in summer and fall.

[a] Hildebrand and Schroeder, 1928.
[b] Mercer, 1987.
[c] Hales and Van Den Avyle, 1989.
[d] Froese and Pauly, 2000.
[e] Phillips et al., 1989.
[f] Chao and Musick, 1977.
[g] Able and Fahay, 1998.
[h] Atlantic States Marine Fisheries Commission, 2000c.
Fish graphic from South Carolina Department of Natural Resources, 2001.

Striped bass (*Morone saxatilis*)

Striped bass is a member of the temperate bass family, Moronidae. Both migratory and nonmigratory populations span the Atlantic coast, from the St. Lawrence River, Canada, to the St. John's River in Florida (Scott and Scott, 1988). Striped bass has long been an important commercial and recreational species. The perceived decline in striped bass populations was the reason behind the creation of the Atlantic States Marine Fisheries Commission in 1942 (Miller, R.W., 1995). Spawning populations of striped bass were nearly eliminated from the Delaware River in the mid-1900's, because of poor water quality. Pollution in the lower portions of the Delaware River caused a decline in striped bass reproduction due to a decrease in dissolved oxygen for several years, but cleanup efforts in the 1980's and 1990's resulted in improved water quality and increased striped bass reproduction (Chittenden, 1971; Weisberg and Burton, 1993; Miller, R.W., 1995). A moratorium was declared on striped bass fishing in the state of Delaware from 1985 through 1989 (Miller, R.W., 1995). While populations of striped bass have rebounded, the fishery is still managed closely and tight restrictions on size limits and the length of the fishing season are kept to maintain the goals established under Amendment 5 of the Striped Bass Fishery Management Plan of 1995 (Atlantic States Marine Fisheries Commission, 2000g).

Striped bass are a popular catch among recreational anglers; however, consumption advisories are currently in place for striped bass from the Delaware River and Bay as a result of bioaccumulation of PCBs (PSEG, 1999c). These advisories recommend limiting the consumption of striped bass to less than five 267 g (8-oz.) meals per year. A 1997 landings report estimated the yearly catch by recreational and commercial fisheries to be 4.094 million striped bass (Atlantic States Marine Fisheries Commission, 2000d). Angling efforts are typically centered on the C&D canal, from Port Penn to Augustine Beach, Delaware, and in the mouths of tributaries south of the canal (PSEG, 1999c). In the Delaware Bay, there are currently no directed commercial fishing efforts for striped bass, although historically commercial harvesting of striped bass was an important resource (PSEG, 1999c).

Striped bass are common along mid-Atlantic coastal waters. They are an anadromous fish that spend most of the year in saltwater but use the upper fresh and brackish water reaches of estuaries as spawning and nursery areas in spring and summer (Setzler et al., 1980). The principal spawning areas for striped bass along the Atlantic coast are the major tributaries of Chesapeake Bay, and the Delaware and Hudson rivers (NOAA, 2001c). The timing of spawning may be triggered by an increase in water temperature, and generally occurs from April to June (Fay et al., 1983c). Spawning behavior consists of a female surrounded by up to 50 males at or near the surface (Setzler et al., 1980). Eggs are broadcast loosely in the water and fertilized by the males. Females may release an estimated 14,000 to 40.5 million eggs, depending on the size of the female (Jackson and Tiller, 1952). A 23 kg (50 pound) female may produce approximately 5 million eggs (Mansueti and Hollis, 1963).

Striped bass eggs are semibuoyant, and require minimum water velocities to remain buoyant. Eggs that settle to the bottom may become smothered by sediment (Hill et al., 1989). The duration of larval development is influenced by water temperature; temperatures ranging from 24 to 15 ˚C (75 to 59 ˚F) correspond to larval durations of 23 to 68 days, respectively (Rogers et al., 1977). Saila and Lorda (1977) reported a 6 percent probability of survival for egg and yolk-sac stages of development, and a 4 percent probability of survival for the post yolk-sac stage.

At 30 mm (1.2 in), most striped bass enter the juvenile stage. Juveniles begin schooling in larger groups after age 2 (Bigelow and Schroeder, 1953). Migratory patterns of juveniles vary with locality (Setzler et al., 1980). In both the Delaware and the Hudson rivers, young-of-year migrate downstream from their spawning grounds to the tidal portions of the rivers to spend their first summer (Able and Fahay, 1998). In the Delaware River, young-of-year may spend 2 or more years within the estuary before joining the offshore migratory population (Miller, R.W., 1995). Similar trends were found in the Hudson River, where individuals were found to stay up to 3 years in estuaries before migrating offshore (Able and Fahay, 1998). Results of tagging studies reported by the Delaware Department of Natural Resources and Environmental Control (DDNREC, 2000) and Public Service Electric and Gas Company (PSEG, 1999c) showed that striped bass tagged in the Delaware Estuary were recaptured from North Carolina to Maine. However, the majority of tagged fish were recovered between Maryland and Massachusetts.

Adult striped bass feed in intervals while schooling (Fay et al., 1983c). They primarily eat smaller fish species such as herring, silversides, and anchovies (Miller, R.W, 1995). Larvae feed primarily on copepods (Miller, R.W, 1995), and stomach contents of juveniles from the Delaware Estuary show mysid shrimp as a favored food item (Bason, 1971).

Adults may live up to 30 years (Atlantic States Marine Fisheries Commission, 2000d), and have been reported at sizes up to 200 cm (79 in) (Froese and Pauly, 2001).

STRIPED BASS
(Morone saxatilis)

Family: Moronidae (temperate basses).

Common names: Striper, rockfish, linesider, and sea bass.[g]

Similar species: White perch.

Geographic range: St. Lawrence River in Canada to the St. Johns River in Florida, and from the Suwannee River in western Florida to Lake Pontchartrain, Louisiana.[a]

Habitat: Juveniles prefer shallow rocky to sandy areas. Adults in inshore areas use a variety of substrates, including rock, boulder, gravel, sand, detritus, grass, moss, and mussel beds.[a]

Lifespan: Adults may reach 30 years.[b]

Fecundity: Females release 14,000 to 40.5 million eggs, depending on the size of the female.[c]

Food sources:
- Larvae feed primarily on mobile planktonic invertebrates (beetle larvae, copepodids *Daphnia* spp.).[a]
- Juveniles eat larger aquatic invertebrates and small fishes.[a]
- Adults are piscivorous. Clupeid fish are the dominant prey and adults prefer soft-rayed fishes.[a]

Prey for: Any sympatric piscivorous fish.[a]

Life stage information:

Eggs: *pelagic*
- Eggs and newly hatched larvae require sufficient turbulence to remain suspended in the water column; otherwise, they can settle to the bottom and be smothered.[d]

Larvae: *pelagic*
- Larvae range from 5 to 30 mm (0.2 to 1.2 in).[a]

Juveniles:
- Most striped bass enter the juvenile stage at 30 mm (1.2 in) total length.[d]
- Juveniles school in larger groups after 2 years of age.[d]
- Juveniles in the Delaware River generally remain in estuarine areas for 2 or more years before joining the offshore migratory population.[e]

***Adults*:** Anadromous

- Adults school offshore, but swim upstream to spawn.[f]
- May grow as large as 200 cm (79 in).[g]

Location:
- Estuaries are spawning grounds and nurseries and thus critically important to their life cycle.
- Mature striped bass are found in and around a variety of inshore habitats, including areas off sandy beaches and along rocky shorelines, in shallow water or deep trenches, and in rivers and the open bay.
- St. Lawrence River in Canada to the St. Johns River in Florida, and from the Suwannee River in western Florida to Lake Pontchartrain, Louisiana.
- Migratory behavior is more complex than that of most other anadromous fish. Seasonal movements depend on their age, sex, degree of maturity, and the river in which they were born.
- Mature striped bass move from the ocean into tidal freshwater to spawn in late winter and spring. Spawning generally occurs in April, May, and early June. Shortly after spawning, mature fish return to the coast. Most spend summer and early fall months in middle New England near-shore waters. In late fall and early winter they migrate south off the North Carolina and Virginia capes.

[a] Hill et al., 1989.
[b] Atlantic States Marine Fisheries Commission, 2000d.
[c] Jackson and Tiller, 1952.
[d] Bigelow and Schroeder, 1953.
[e] Miller, R.W, 1995.
[f] Setzler et al., 1980.
[g] Froese and Pauly, 2001.
Fish graphic from NOAA, 2001b.

Weakfish (*Cynoscion regalis*)

Weakfish is a member of the family Sciaenidae (drums), which is considered an important recreational and commercial resource along the Atlantic coast (Seagraves, 1995). Weakfish are found along the eastern seaboard, primarily from Massachusetts Bay to southern Florida (Seagraves, 1995). Adults travel in schools, following a seasonal migratory pattern from offshore wintering grounds in the spring to northern inland estuarine spawning grounds with warming of coastal waters in the spring (Seagraves, 1995). Weakfish spawn in the Delaware Estuary in spring and usually move north as far as Massachusetts for the summer (Shepherd and Grimes, 1984). These same fish over-winter as far south as Cape Hatteras, North Carolina. Weakfish favor shallow waters and sandy bottoms. They typically feed throughout the water column on fish, shrimp, and other small invertebrates (Seagraves, 1995).

Steady declines in weakfish landings since 1980 caused enough concern to prompt the Atlantic States Marine Fisheries Commission to develop a management plan for the species in 1985. In addition, the commission developed three amendments in an attempt to strengthen the management plan; the third amendment called for a 5-year restoration period to bring the weakfish population back to its historical age and size structure. Since 1993, annual landings have steadily increased (Atlantic States Marine Fisheries Commission, 2000f). Weakfish are very popular as a recreational fishing target in Delaware Bay and surrounding coastline. In a survey of Delaware anglers, weakfish was consistently one of the top three species targeted by anglers from 1982 to 1996 (PSEG, 1999c). Recreational catches of weakfish in Delaware and New Jersey comprised greater than 70 percent the coastal recreational weakfish catch since 1995 (PSEG, 1999c).

Spawning occurs shortly after the inshore migration, peaking from late April to June, with some geographic variation in timing. In the fall, an offshore and southerly migration of adults coincides with declining water temperatures (Atlantic States Marine Fisheries Commission, 2000f). Specific spawning time is correlated with the size of the individual; larger fish tend to spawn earlier (Shepherd and Grimes, 1984), often resulting in a bimodal distribution of size in larvae (Able and Fahay, 1998).

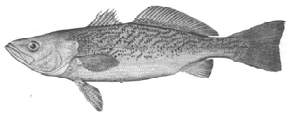
Fecundity of female weakfish varies with locality. A 50 cm (20 in) female weakfish from the New York Bight produced about 306,000 ova, while southern weakfish of the same size produced 2.05 million ova. Southern weakfish reproduce until approximately age 5, while northern weakfish can reproduce longer, meaning that lifetime fecundity would be similar (Shepherd and Grimes, 1984). Shepherd and Grimes (1984) found that females may not release all ova during spawning, and fertility may only be 60-75 percent of the estimated potential fecundity.

Weakfish eggs hatch approximately 50 hours after fertilization. The pelagic larvae hatch at 1.5 to 1.7 mm (0.6 to 0.7 in) in length, and move further upstream during the summer months. Though young-of-year are most abundant in estuarine waters, they have been found in coastal ocean waters and as far upstream as freshwater nurseries. Scales begin to form when larvae are approximately 14.3 mm (5.6 in) or 26 days old. Growth rates vary considerably depending on locality, salinity, and water temperature. Weakfish in the Delaware Bay exhibited growth rates from 0.29 mm (0.1 in) per day at 20 ˚C (68 ˚F) to 1.49 mm (0.6 in) per day at 28 ˚C (82 ˚F) (Able and Fahay, 1998).

In the fall, weakfish less than 4 years of age tend to stay inshore and move southward to inner shelf waters, while older weakfish move southward to offshore areas until the spring (Seagraves, 1995).

As with most fish, size upon maturity for weakfish varies with locality. In northern weakfish, females mature at 25.4 cm (10 in), and males at 22.9 cm (9 in); in southern weakfish, both sexes mature at 17.8 cm (7 in). By age 2, all individuals are fully mature (Atlantic States Marine Fisheries Commission, 2000f). Weakfish may obtain a maximum size and age of approximately 80 cm (31.5 in) and 11 years in the northern part of their range (Shepherd and Grimes, 1983).

Weakfish larvae are most abundant near Salem from June to August (PSEG, 1999c). Juveniles occur in summer and early fall. Eggs are present in some years, primarily in June and July.



WEAKFISH
(Cynoscion regalis)

Family: Sciaenidae (drums).

Common names: Gray/bastard/saltwater trout, silver seatrout, grey/bastard/common/silver weakfish, chickwick, gray/silver, silver seatrout.[a]

Similar species: Red drum, spot, spotted seatrout, Atlantic croaker.

Geographic Range: Along the Atlantic coast from Florida to Massachusetts, in shallow coastal and estuarine waters.[b] Estuaries provide feeding areas and spawning grounds for adult weakfish and are as important as nursery areas are for juveniles.[c]

Habitat: Occurs over sand and sandy mud bottoms in shallow coastal waters.[c]

Lifespan: Can live up to 11 years.[d]

Fecundity: Reach maturity at approximately 1 year. Fecundity for fish in the New York Bight is about 306,000. Females may not release all ova during spawning, meaning that fertility may be only 60-75 percent of total fecundity.[e]

Food source: Juveniles feed primarily on shrimp and other small invertebrates. Adults consume species such as butterfish, herrings, silversides, anchovies, young weakfish, Atlantic croaker, spot, scup, and killifishes.[f]

Prey for: Bluefish, striped bass, summer flounder, and larger weakfish.[f]

Life stage information:

Eggs:
- Hatch approximately 50 hours after fertilization.[c]

Larvae: *pelagic*
- Larvae are approximately 1.5-1.7 mm (0.6 to 0.7 in) long at hatching.[c]
- Larvae utilize tidal stream transport to move through the water column.[c]

Juveniles:
- Growth rates in the Delaware Bay range from 0.29 mm (0.1 in) per day at 20 ˚C (68 ˚F) to 1.49 mm (0.6 in) per day at 28 ˚C (82 ˚F).[c]
- Juveniles begin to migrate offshore and southward for overwintering in the fall.[c]

Adults:
- Travel in schools, and migrate seasonally from offshore wintering grounds to northern inland estuarine spawning grounds in the spring.[b]
- Adults can reach a maximum total length of 80 cm (31.5 in).[d]

Location:
- The young use the shore margins of the spawning area as nursery grounds.
- From spring through autumn, white perch are present on flats and in channels, retreating to deep channels in the winter.
- They move into waters with low salinity to freshwaters of large rivers in April through June.
- Located in estuaries and freshwater from Nova Scotia to South Carolina.
- Frequent areas with level bottoms of compact silt, mud, sand, or clay and show little preference for vegetation, structures, or other shelter.
- Able to live in salinities from zero to full strength seawater; they prefer waters < 18 percent salinity.

[a] Froese and Pauly, 2001.
[b] Seagraves, 1995.
[c] Able and Fahay, 1998.
[d] Shephard and Grimes, 1983.
[e] Shephard and Grimes, 1984.
[f] Seagraves, 1995.
Fish graphic from NOAA, 2001b.

White perch (*Morone americana*)

White perch is a member of the temperate bass family, Moronidae. Its geographic range extends from the upper St. Lawrence to South Carolina (Able and Fahay, 1998; Scott and Scott, 1988). Adults can be found in a wide range of habitats, but they prefer shallow water during warmer months (Stanley and Danie, 1983). In the winter months, adults can be found in deeper, saline waters (Beck, 1995b). At the larval stage, white perch feed mainly on plankton. Adults feed on a variety of prey, including shrimp, fish, and crab. Their diet composition changes with seasonal and spatial food availability (Beck, 1995b).

Unlike most other species, white perch has not suffered a drastic population decline in the past century. Because of their abundance, white perch are valuable for commercial fisheries and the recreational fishing industry. Their heartiness and abundance is due to their proliferation, early maturation, ability to utilize a large spawning and nursery ground, and tolerance of poor water quality (Beck, 1995b).

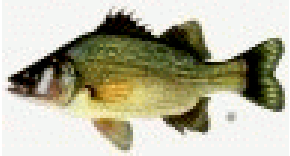
White perch are semi-anadromous, overwintering in deeper estuarine waters and migrating seasonally in the spring to spawn. Spawning occurs from April through early June in shallow waters of upstream brackish and freshwater tributaries. Fecundity estimates are higher for white perch than for other species of similar size, with estimates of 20,000 to 300,000 eggs per female (Stanley and Danie, 1983).

Depending on temperature, larvae hatch out between 2 to 6 days (Able and Fahay, 1998). Larvae are pelagic, remaining slightly below the surface of the water. They enter the juvenile stage in 6 weeks, at 20 to 30 mm (0.8 to 1.2 in) (Able and Fahay, 1998). Juveniles become increasingly demersal with size (Wang and Kernehan, 1979), and school in shallow, inshore waters through the summer. During the fall, juveniles tend to move offshore into more brackish, deeper waters to overwinter (Able and Fahay, 1998).

By age 1, white perch range from 72 to 93 mm (2.8 to 3.7 in). Rates of growth are positively correlated with water temperature during the first year (Able and Fahay, 1998). Most males and females reach maturity at age 2 to 3. Males were reported to mature at 72 mm (2.8 in) and females at 98 mm (3.9 in) (Stanley and Danie, 1983).

Average annual mortality rates for white perch in the Delaware River are 49 to 59 percent for males and 53 to 65 percent for females (Stanley and Danie, 1983). Mortality rates appear to be higher for females because females have higher growth rates and therefore reach a desirable harvest size earlier (Stanley and Danie, 1983). White perch up to 9 years of age have been caught in Delaware Bay (Wallace, 1971).

White perch larvae occur near Salem from April to July, with greatest abundance in April and May (PSEG, 1999c). Juveniles occur from October to May. Adults are present throughout the year.



WHITE PERCH
(Morone americana)

Family: Moronidae, temperate bass.

Common names: White perch.[a]

Similar species: Striped bass.

Geographic range: Estuaries and freshwater from the upper St. Lawrence to South Carolina.[b,c]

Habitat: Occurs in fresh, brackish, and coastal waters, but prefers brackish, quieter waters.[a]

Lifespan: To 17 years (to 9 years in Delaware Bay).

Fecundity: Semi-anadromous spawners. Spawning occurs from April to early June in shallow waters of upstream brackish and freshwater tributaries. Females produce 20,000 to 300,000 eggs.[d]

Food source: White perch feed on zooplankton as larvae and juveniles. Adults primarily consume aquatic insects, but also crustaceans and fish, including their own young.[d]

Prey for: Striped bass, bluefish, weakfish, walleye.[a]

Life stage information:

Eggs: *demersal, semipelagic*
- Hatch out between 2 and 6 days.[b]

Larvae: *pelagic*
- Larvae float slightly below the surface of the water.[b]

Juveniles:
- White perch enter the juvenile stage in 6 weeks, at 20 to 30 mm (0.8 to 1.2 in).[b]
- School in shallow, inshore waters through the summer.[b]
- Move offshore to brackish, deeper waters to overwinter.[b]
- Growth rates are positively correlated with temperature during the first year.[b]

Adults:
- Reach maturity at 2 to 3 years of age, and lengths of 72 mm (2.8 in) for most males and 98 mm (3.9 in) for most females.[d]

[a] Froese and Pauly, 2001.
[b] Able and Fahay, 1998.
[c] Scott and Scott, 1988.
[d] Stanley and Danie, 1983.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

B3-3 Salem I&E Monitoring and PSEG's Methods for Calculating Annual I&E

Salem is the only facility of the four in-scope facilities of the transition zone (Salem, Hope Creek, Deepwater, Edge Moor) that is required to collect I&E data on an on-going basis as part of their New Jersey Pollutant Discharge Elimination System (NJPDES) permit. Some I&E data are available for Hope Creek and Deepwater, but only for very limited time periods. Although Salem's data can be improved upon as discussed later in this chapter, it is one of the most comprehensive I&E data sets in the nation.

PSEG has sampled impinged and entrained organisms at Salem since station operation began in 1977. I&E data for the years 1978-1998 are available in PSEG's 1999 Permit Renewal Application for Salem (PSEG, 1999e). The application consists of 36 volumes of application material and 167 volumes of appendices and reference material. Some aspects of the sampling protocol have changed in response to changing sampling objectives, and details of these changes are outlined in Appendix F, Attachment 1 of the Application (PSEG, 1999c).

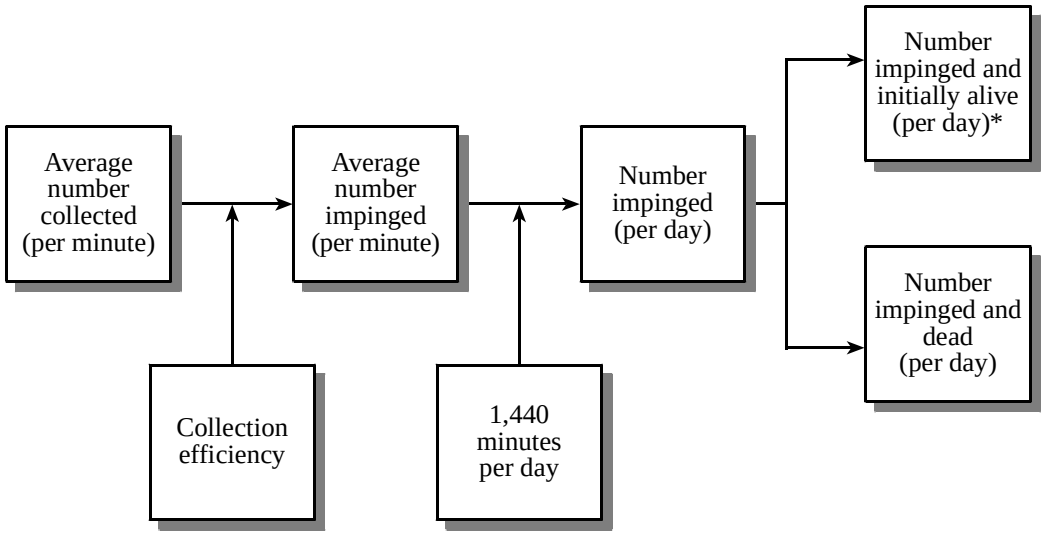
The following sections outline methods used by PSEG to estimate I&E losses based on information in Appendix F, Attachment 1 of the Application (PSEG, 1999c). The figures outlining monitoring steps and methods for calculating I&E are based on figures from a July 1999 presentation by PSEG to the New Jersey Department of Environmental Protection (NJDEP).

B3-3.1 Impingement Monitoring

PSEG collects impingement samples by diverting screen wash water from an estuary-bound sluice to an impingement sampling pool (PSEG, 1999c, Appendix F, Attachment 1, Section II.D). Fish collected in the sampling pool are sorted by species and counted, and the condition of each specimen (live, dead, or damaged) is noted. The length of each specimen of a sample of each representative important species (RIS) is measured as well as the total weight for all specimens of each species. Information on station operations, sampling details, and environmental conditions is also recorded.

PSEG processes the impingement sampling data in a series of steps to arrive at an estimate of the number of organisms impinged and initially alive, and the number impinged and dead, per day of sampling (PSEG, 1999c, Appendix F, Attachment 2, Section III.D). The steps for processing the impingement data to estimate the number impinged in the cooling water system (CWS) per day of sampling are outlined in Figure B3-1.

Figure B3-1: Estimation of Numbered Impinged (CWS) per Day of Sampling



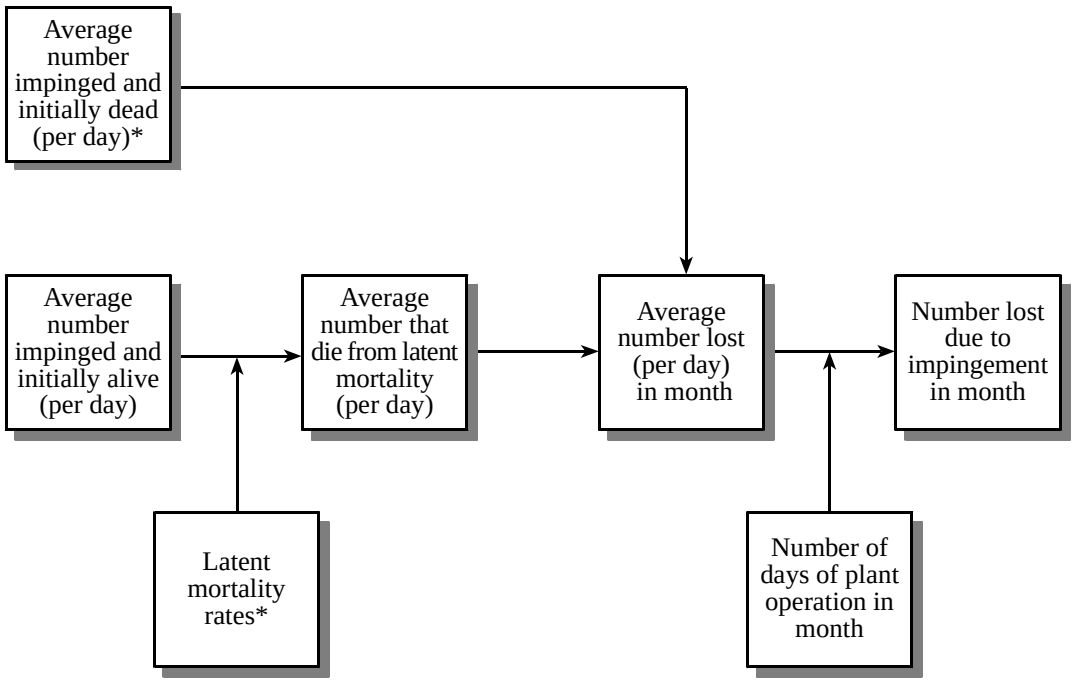
*Prior to 1996, initially alive fish were further classified as damaged or not damaged.

Since the duration of sampling varies from collection to collection, PSEG first standardizes impingement counts to fish counted per minute sampled. The number collected is adjusted by a species-specific collection efficiency factor to estimate the average number impinged per minute (PSEG, 1999c, Appendix F, Attachment 2, Section III.D.3). Factors are based on impingement collection efficiency studies conducted by PSEG from 1979 to 1982 and in 1998 (PSEG, 1999c, Appendix F, Section VI). PSEG's collection efficiency factors are duplicated in Appendix B1of this report.

For each day of impingement sampling, the daily average number of fish sampled per minute is calculated for each species, length interval, and condition (live, dead, damaged). PSEG uses the estimated number of impinged organisms in the CWS per day of sampling to calculate the number lost to impingement in the CWS and in the service water system (SWS) each month (PSEG, 1999c, Appendix F, Attachment 2, Section III.D).

Figure B3-2 outlines the steps involved in calculating the monthly impingement loss estimate for the CWS. To adjust impingement estimates for mortality that may occur after collection, PSEG multiplies the initial survival rate of live or damaged fish by a species-specific latent mortality rate determined from historical data (PSEG, 1999c, Appendix F, Attachment 2, Section III.D.5). Different latent mortality factors are used for impingement samples from old Ristroph screens (1977-1995) and new Ristroph screens (1996-1998). The latent screen mortality factors used by PSEG are duplicated in Appendix B1 of this report. For non-RIS commercial and recreational species, PSEG applied the highest impingement screen mortality observed for the other species, and bay anchovy parameters were applied to non-RIS forage species.

Figure B3-2: Estimation of Number Lost to Impingement (CWS) in Each Month

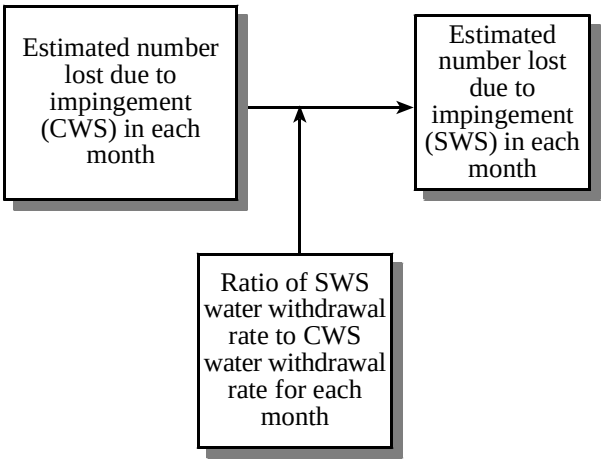


*Latent mortality represents 48 hr holding time, except for original screens (96 hr)

The average number that die from latent mortality per day is added to the average number impinged per day that are initially dead to derive the average number lost per day in each month. This number is then adjusted by the number of days of plant operation per month to determine the total number lost to impingement in the CWS per month. This number is adjusted by the ratio of SWS water withdrawal to CWS water withdrawal for each month to derive an estimate of the number lost to impingement in the SWS each month (Figure B3-3).

Total impingement loss is then calculated for actual flow conditions by species and life stage for each year (PSEG, 1999c, Appendix F, Attachment 2, Section III.D.6).

Figure B3-3: Estimation of Number Lost to Impingement (SWS) in Each Month

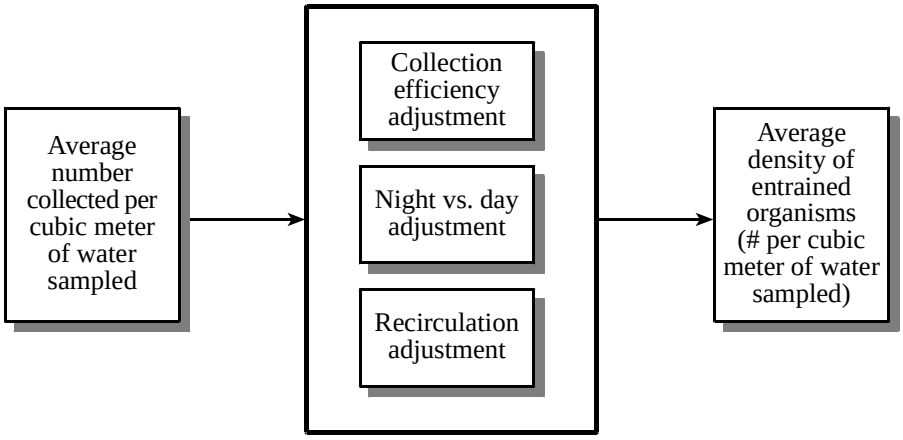


B3-3.2 Entrainment Monitoring

PSEG collects entrainment samples by pumping a volume of water ranging from 50 to 75 m^3 through an abundance net and chamber at 1.0-1.5 m^3/min (PSEG, 1999c, Appendix F, Attachment 1, Section II.C). The net is a 1 m plankton net with 0.5 mm mesh. After sampling, the net is washed and the contents are rinsed into a jar, preserved, and taken to a laboratory for identification and counting. All specimens collected are identified to the lowest practical taxon and life stage. For each sample, total length is measured to the nearest millimeter for a representative subsample of each target species and life stage.

To estimate the density of entrained organisms in the CWS for each day of sampling, PSEG adjusts the average number collected per cubic meter of water sampled by factors for collection efficiency (including net extrusion and net avoidance), time of day of sampling, and potential re-entrainment (Figure B3-4). PSEG's net extrusion and net avoidance factors are duplicated in Appendix B1 of this report. PSEG's uses the average entrainment density for days with sampling to interpolate the density of entrained organisms for days without sampling to arrive at a density for each day of the year.

Figure B3-4: Estimation of Density of Entrained Organisms for Each Day of Sampling (CWS)



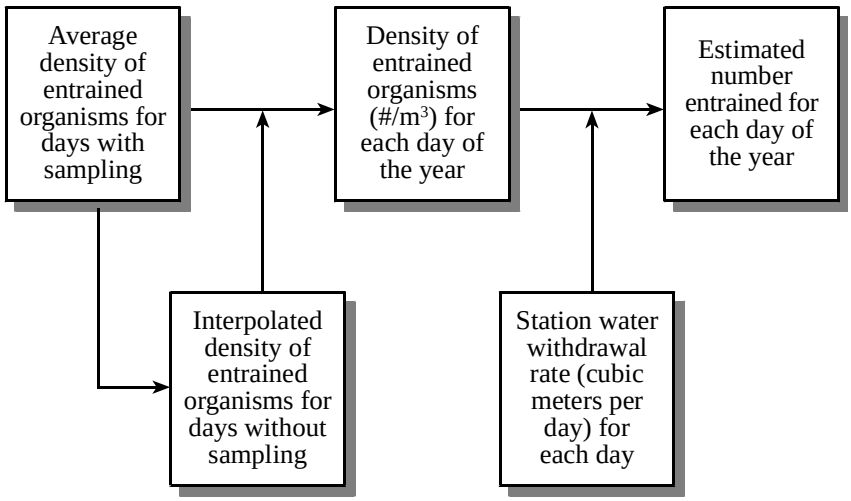
PSEG quantifies collection efficiency related to net extrusion for organisms less than 7 mm in total length by determining the relative probability of capture based on comparison of gear efficiency in the river with gear efficiency in the plant, under the assumption that densities of larvae in the river and plant are equal (PSEG, 1999c, Appendix F, Attachment 2, Section III.C.2.c.i). For organisms longer than 0.5 mm, collection bias associated with net avoidance and vertical stratification is quantified based on paired samples collected at the intake and discharge over a 2 week period in 1980 (PSEG, 1999c, Appendix F, Attachment 2, Section III.C.2.c.ii).

To correct for potential bias resulting from a lack of nighttime sampling from 1982 to 1994, PSEG analyzed sampling data to test for differences among samples taken at different times of day, and developed correction factors to adjust entrainment estimates for species and life stages that showed a statistically significant day/night effect (PSEG, 1999c, Appendix F, Attachment 2, Section III.C.2.b). Day/night correction factors used to estimate historical losses for bay anchovy juveniles, larvae of *Morone* spp., striped bass juveniles, weakfish eggs, and weakfish juveniles are presented in Appendix F, Attachment 2, Table 9 of PSEG (1999c).

Adjustment for potential recirculation of previously entrained organisms (re-entrainment) is based on results of a dye survey conducted in 1998 that indicated that 10 percent of organisms that survive through-plant transport are re-entrained (PSEG, 1999c, Appendix F, Attachment 2, Section III.C.3). PSEG's recirculation factors are duplicated in Appendix B1 of this report.

Once collection numbers are adjusted for collection efficiency, day/night sampling, and potential re-entrainment to derive estimates of daily entrainment, the daily densities are adjusted by the station water withdrawal rate for each day to estimate the total number entrained for each day of the year (Figure B3-5).

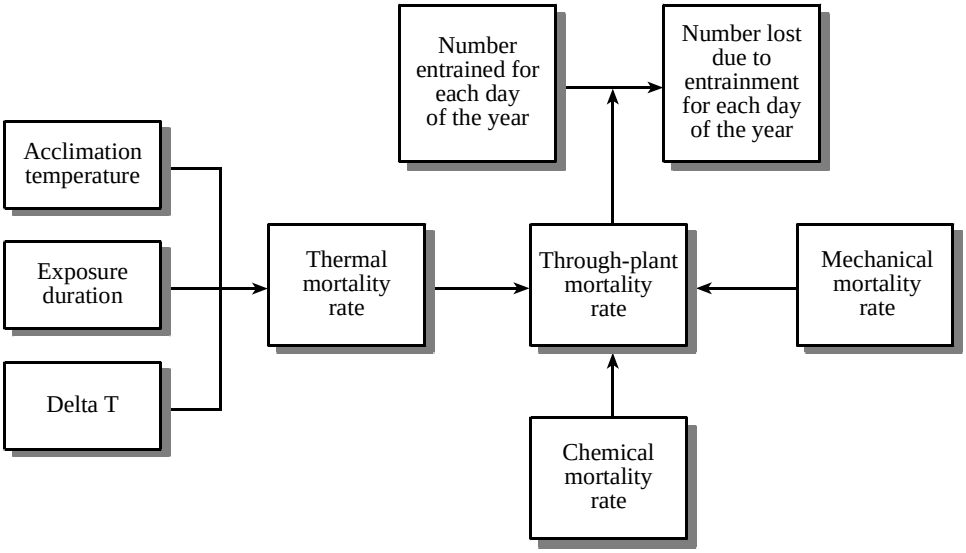
Figure B3-5: Estimation of Daily Number Entrained for Each Day of the Year (CWS)



To estimate the daily number of organisms that are actually killed by CWS entrainment, PSEG adjusts the number entrained for each day of the year by species- and life stage-specific through-plant survival rates estimated from on-site studies, model simulations, and published results of studies at other facilities (Figure B3-6) (PSEG, 1999c, Appendix F, Attachment 2, Section III.C.4).

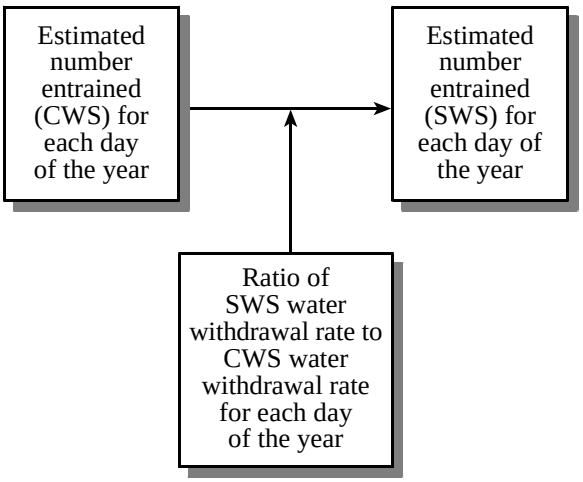
PSEG adjusts entrainment estimates for through-plant mortality resulting from thermal mortality, mechanical mortality, and chemical mortality. Because biocides are not used in the CWS, PSEG assumes that chemical mortality is zero for all species and life stages at Salem (PSEG, 1999c, Appendix F, Attachment 2, Section III.C.4.b). Thermal mortality was modeled as a function of exposure temperature, acclimation temperature, and exposure duration (PSEG, 1999c, Appendix F, Attachment 2, Section III.C.4.c.). Mechanical mortality was estimated based on studies conducted at the Indian Point Generating Station on the Hudson River in the 1980's (EA Engineering, Science, and Technology, 1989) and using data from the 1984 PSE&G 316(b) Demonstration (PSEG, 1999c, Appendix F, Attachment 2, Section III.C.4.a). PSEG's thermal and mechanical mortality factors are duplicated in Appendix B1 of this report. For non-RIS commercial/recreational species, PSEG assumed 100 percent through-plant mortality, and bay anchovy parameters were applied to non-RIS forage species.

Figure B3-6: Estimation of Daily Number Lost to Entrainment (CWS)



The number of organisms entrained in the CWS for each day of the year is adjusted by the ratio of SWS water withdrawal to CWS water withdrawal for each day to derive an estimate of the number lost to entrainment in the SWS each day of the year (Figure B3-7).

Figure B3-7: Estimation of Daily Number Entrained for Each Day of the Year



To obtain an annual entrainment loss estimate, PSEG sums all of the daily estimates over the year (PSEG, 1999c, Appendix F, Attachment 2, Section III.C.5).

B3-3.3 Potential Biases and Uncertainties in PSEG's I&E Estimates

Because of the extensive and complex biological information presented in Salem's 1999 Application, NJDEP contracted with several scientists from ESSA Technologies Ltd. to review and comment on the application (ESSA Technologies, 2000). ESSA Technologies commended PSEG for the thoroughness of the application, but expressed several concerns about potential biases and uncertainties in PSEG's estimates of I&E losses. Bias refers to a potential error in which the direction of the error is known (i.e., an under- or overestimate), whereas uncertainty refers to a potential error with no known directional bias.

ESSA Technologies (2000) identified several aspects of PSEG's sampling program that increased data uncertainties and introduced bias in PSEG's I&E estimates, and EPA shares these concerns. For example, ESSA Technologies noted that year-

to-year variations in the sampling protocol created a need for data interpolation and extrapolation to fill data gaps, increasing uncertainty about the true numbers of organisms impinged and entrained. They observed that the need for adjustment of the 1980-1994 entrainment data to account for a lack of nighttime sampling during this period is a particular concern because this is the only period of complete seasonal coverage and was therefore the basis for extrapolation to other years with incomplete seasonal coverage.

ESSA Technologies (2000) expressed concern that the sampling changes necessitated the use of numerous adjustment factors that may have biased I&E estimates. Many adjustments appeared to be biased low, which would result in an underestimate of losses. For example, ESSA Technologies argued that PSEG may have underestimated the latent screen mortality of impinged organisms because they did not consider the high velocity and turbulence of exit flume waters in their estimate. The high velocity of water in the fish return sluice and the extremely turbulent conditions in the sampling pool to which impinged fish are diverted expose fish to significant stress that could increase, or at least obscure, true impingement mortality. Impingement mortality may also have been underestimated because PSEG did not take into account impairment in the ability of impinged organisms that are returned to the estuary to locate prey and avoid predators (Boreman, 1993).

ESSA Technologies (2000) expressed concern about the magnitude of correction needed to adjust entrainment estimates for net extrusion. In addition, they argued that there may be species-specific errors in PSEG's entrainment estimates because differences in collection efficiency for different species were not taken into account.

ESSA Technologies (2000) also found that PSEG may have substantially underestimated entrainment mortality by assuming only moderate rates of mortality as organisms pass through the plant. PSEG based its estimates of thermal mortality on a probit model (regression equation) that estimates thermal mortality as a function of acclimation temperature, exposure duration, and exposure temperature (PSEG, 1999c, Appendix F, Attachment 1, Section II.C). Because the model was fit to laboratory data it may not reflect actual rates of thermal mortality experienced by organisms in the condenser water and does not consider deaths due to cold shock that occur when organisms in the heated condenser water are discharged back into the cooler receiving waters of the estuary (Boreman, 1993). Mechanical mortality rates were estimated by PSEG from studies in which larvae were held in jars or aquaria (PSEG, 1999c, Appendix F, Attachment 1, Section II.C). ESSA Technologies argued that this in vitro environment does not reflect the stresses faced by larvae on exiting the discharge, and therefore they concluded that mechanical mortality was probably also underestimated by PSEG. EPA shares these concerns.

ESSA Technologies (2000) also noted some potential sources of mortality not captured by the sampling program. One of these is mortality of eggs and larvae that are impinged on material clogging intake screens. This material is cleaned off the screens with high pressure sprays and then is carried away in the impingement discharge flow system. No attempt is made by PSEG to count any eggs and larvae that are impinged within this material. In addition, certain geographic features near Salem may have caused a large back eddy, which would cause different flow dynamics depending on tidal cycle, and result in episodic entrainment patterns that might not have been captured by the sampling program.

In addition to these concerns about the sampling program and estimates of I&E losses, ESSA Technologies (2000) argued that the natural mortality rates used by PSEG were too high for many species, which would lead to an underestimate of adult equivalent and yield-per-recruit losses. They argued that rates were biased high because the "life cycle balancing" method used by PSEG assumed that fish populations in the Delaware Estuary are at equilibrium. Most fish populations in the estuary are increasing due to significant water quality improvements and fishing restrictions in recent years, and ESSA Technologies noted that natural mortality rates of an expanding population are typically lower than for an equilibrium population. In a rebuttal to the ESSA Technologies review, PSEG (2001a,f) argued that this would influence their calculations only if higher than average early survival was responsible for the increased population growth. Instead, PSEG (2001a,f) contended that the increases are largely due to increases in adult survival rates resulting from reduced harvest, and therefore there is no need to adjust their estimates of early mortality.

PSEG (2001a,f) also noted that recent spawner-recruit data from National Marine Fishery Service regional stock assessments for weakfish and striped bass indicate that density-dependent compensation is occurring as stock size increases, resulting in a decrease in the number of recruits produced per spawner. PSEG (2001a,f) argued that this implies that early mortality rates of these species are increasing, not decreasing, suggesting that if PSEG's estimates are biased, they are biased low. Relative to published values, PSEG's adjusted rates are higher for 10 species, lower for 11 species, and within the range of measured values for 7 species (PSEG, 2001b,c).

B3-3.4 Overview of EPA's Evaluation of Salem's I&E Data

Based on the potential biases and uncertainties discussed in the previous section, NJDEP's draft permit requires that "the uncertainty of the estimated historic annual entrainment loss estimates should be characterized and presented as ranges with maximum and minimum levels" (NJDEP, 2000). These data requirements were implemented in a June 29, 2001 NJPDES permit action, but this information is not yet available for review. Therefore, EPA was unable to conduct a formal evaluation of potential biases and uncertainties in the Salem I&E data for the case study analyses reported here. However, because of EPA's concern that the uncertainties associated with PSEG's assumptions about I&E survival may significantly underestimate Salem's I&E rates, particularly for extrapolation purposes, EPA adjusted Salem's estimates to eliminate PSEG's survival factors for many of its analyses, as discussed in the following sections.

- **Salem's Historical Baseline:** Developed using Salem's impingement estimates for 1978-98 and Salem's impingement survival factors (Tables B3-2 through B3-5), and Salem's entrainment estimates for 1978-98 assuming no through-plant survival (Tables B3-7 through B3-10).

- **Extrapolation Baseline:** Developed using Salem's impingement estimates for 1978-95 and 1997-98 assuming no impingement survival (Table B3-11), and Salem's entrainment estimates for 1978-95 and 1997-98 assuming no entrainment survival (Table B3-7). 1996 was eliminated from the analysis because Salem was shut down much of the year and therefore I&E during this year is not considered representative. The average impingement and entrainment rates estimated on this basis were used to extrapolate Salem's I&E rates to other transition zone CWIS on the basis of intake flow.

- **Salem's Benefits Baseline:** The baseline used in Chapter B6 to estimate the benefits of the proposed regulation for the Salem facility was developed using EPA's estimate of Salem's current I&E rates. Current I&E rates were based on Salem's impingement estimates for 1995 and 1997-1998 assuming impingement survival (Tables B3-20 through B3-22), and Salem's entrainment estimates for 1978-95 and 1997-98 assuming no through plant survival (Table B3-7). 1996 was eliminated from the analysis because Salem was shut down much of the year and therefore I&E during this year is not considered representative.

- **Benefits Baseline for Other In-scope CWIS of the Transition Zone:** EPA's estimate of current I&E at transition zone CWIS was developed using Salem's impingement estimates for 1978-95 and 1997-98 assuming no impingement survival (Table B3-11), since these facilities do not have technologies for reducing impingement mortality, and Salem's entrainment estimates for 1978-95 and 1997-98 assuming no entrainment survival (Table B3-7). 1996 was eliminated from the analysis because Salem was shut down much of the year and therefore I&E during this year is not considered representative. This baseline was used to estimate benefits of the proposed regulation for Hope Creek, Deepwater, and Edge Moor (see Chapter B6).

Because PSEG's impingement survival factors reflect the estimated effectiveness of Salem's modified Ristroph screens in reducing impingement mortality, these factors were retained for EPA's analysis of Salem's historical impingement (Tables B3-2 through B3-5) and current impingement (Tables B3-20 through B3-22). However, PSEG's impingement survival factors were eliminated for extrapolation of Salem's impingement rates to facilities without Ristroph screens (see Section B3-7 and Table B3-11). Salem's entrainment survival factors were eliminated for all analyses (Tables B37 through B3-10) because EPA found insufficient justification in Salem's 1999 Application for their use.

The results of EPA's analyses are presented in the following sections. The data tables associated with these sections present annual I&E numbers from facility monitoring and EPA's estimates of these losses expressed as age 1 equivalents, lost fishery yield, and production foregone, as calculated by EPA according to the methods discussed in Chapter A5 of Part A of this document.

B3-4 Salem's Annual Impingement

Annual impingement losses (numbers of organisms) at Salem as calculated by PSEG are presented in Appendix L, Tab 9 of Salem's 1999 Permit Renewal Application (PSEG, 1999e) and duplicated here in Table B3-2. For its estimates, PSEG assumed that some proportion of impinged organisms survive. The species-specific initial and latent screen mortality factors used by PSEG in its calculations of impingement are presented in Appendix B1. Table B3-3 presents the results of EPA's calculations to express these losses as numbers of age 1 equivalents, Table B3-4 presents impingement losses as pounds of yield lost to commercial and recreational fisheries, and Table B3-5 presents the losses as pounds of production foregone.

PSEG's impingement estimates indicate that impingement losses at Salem vary substantially by species and by year. Over the period 1978-1998, PSEG's estimates of impingement losses ranged from a minimum of 193 individuals of striped bass and other *Morone* species in 1985 to a maximum of 11,264,933 bay anchovy in 1981. In most years, bay anchovy and weakfish dominate impingement collections, followed by spot and blueback herring. However, according to PSEG's estimates, losses of Atlantic croaker, blue crab, and white perch at Salem have also been high (over 1 million) in some years.

Of interest in recent years is PSEG's estimated high losses of Atlantic croaker in 1998, when the station was operating close to its expected future intake flow rate. This occurred despite the addition of modified Ristroph screens in 1995 to increase impingement survival. This may be related in part to the increasing trend in Atlantic croaker abundance in the estuary in recent years (see Appendix J in PSEG, 1999d).

Striped bass impingement has also been generally higher during the past decade, apparently related in part to increases in the striped bass population in the estuary. Some of this increase is attributed to movement into the estuary of Chesapeake Bay striped bass via the C&D canal (see Appendix J in PSEG, 1999d).

Although both weakfish and white perch populations have shown significant increases in the estuary in recent years (see Appendix J in PSEG, 1999d), impingement rates of both species have declined since the installation in 1995 of modified Ristroph screens designed to increase impingement survival. A study by PSEG indicated that weakfish impingement mortality declined by 51 percent after installation of the new technology (Ronafalvy et al., 2000).

By contrast, bay anchovy impingement has generally been lower in the past decade. However, a corresponding decreasing trend in the population of bay anchovy in the estuary has not been detected, and some of the apparent decline in impingement numbers appears to be related to an exceptionally high year class and related high impingement in 1980 (see Appendix J in PSEG, 1999d).

Blueback herring and spot impingement has declined in the past decade at the same time populations of these species have shown significant declines within the estuary (see Appendix J in PSEG, 1999d). However, in the case of spot the decline is in part because of an exceptionally strong year class in 1988, a year that also showed exceptionally high spot impingement.

Table B3-2: Annual Impingement (numbers of organisms), by Species, at the Salem Station as Estimated by PSEG Using Impingement Survival Factors (see the initial and latent mortality factors in Appendix B1 of Part B).

Year	Alewife + 21% *Alosa* spp.	American Shad	Atlantic Croaker	Bay Anchovy	Blueback Herring + 79% *Alosa* spp.	Blue Crab	Spot	Striped Bass + 58% *Morone* spp.	Weakfish	White Perch + 42% *Morone* spp.	Non-RIS Fishery Species	Non-RIS Forage Species
1978	17,057	4,549	125,822	2,623,694	438,248	111,627	84,519	3,213	6,391,256	254,688	—	—
1979	11,513	2,144	8,494	1,321,105	651,005	97,434	292,471	9,625	580,628	541,715	—	—
1980	11,301	6,382	93,232	11,046,658	460,638	501,000	146,794	4,350	1,821,462	403,453	—	—
1981	647,832	8,820	14,996	11,264,933	364,803	347,436	857,167	1,895	1,818,578	344,726	—	—
1982	46,951	9,406	2,975	3,846,612	418,130	122,032	979,961	542	967,867	261,912	—	—
1983	19,584	5,359	2,326	3,784,994	224,303	100,953	681,704	924	1,038,356	143,904	—	—
1984	128,002	3,266	853	2,444,847	1,335,665	87,890	316,579	430	357,125	300,333	—	—
1985	4,676	11,033	275,670	3,771,190	162,478	1,011,790	183,679	193	1,263,119	582,528	—	—
1986	20,788	11,007	233,915	2,011,567	467,361	1,228,076	52,445	2,875	756,956	1,033,048	—	—
1987	74,461	24,120	1,245,098	3,346,956	157,496	834,857	2,204	6,673	1,095,105	715,912	—	—
1988	31,082	35,182	4,046	4,657,784	357,896	1,247,649	1,917,236	10,450	427,218	646,825	—	—
1989	137,998	65,138	24,168	781,653	891,085	344,310	119,381	26,006	184,538	760,842	—	—
1990	50,074	15,393	5,787	1,373,446	168,555	178,511	120,833	28,003	170,778	768,431	—	—
1991	21,275	22,874	45,535	1,719,784	137,107	307,503	134,807	10,089	575,349	688,724	1,318,756	3,759,670
1992	23,847	64,807	55,267	1,286,667	120,649	370,591	2,999	20,966	841,319	1,158,199	1,082,303	4,187,464
1993	23,267	22,087	176,279	596,243	100,999	387,190	16,869	74,100	723,366	1,043,913	248,137	1,189,847
1994	22,946	6,315	31,538	178,764	31,835	491,199	247,677	23,612	2,130,349	1,266,489	300,779	2,068,499
1995	14,745	7,940	610,261	363,601	143,846	1,012,348	27,435	10,812	890,341	321,359	1,057,789	3,541,198
1996	1,321	829	21,010	18,802	5,548	83,457	7,281	9,191	130,459	75,006	456,756	876,044
1997	5,899	819	266,558	309,018	50,879	475,443	30,245	12,779	1,582,441	228,996	1,292,807	979,870
1998	8,037	2,214	2,370,135	1,104,126	57,267	280,741	2,654	10,660	1,572,811	124,351	452,514	678,595

Non-RIS species are listed in Table B3-1.
Source: PSEG, 1999e, Appendix L, Tab 9.

Table B3-3: Annual Impingement at the Salem Station, by Species, Expressed as Numbers of Age 1 Equivalents.

Year	Alewife +21% *Alosa* spp.	American Shad	Atlantic Croaker	Bay Anchovy	Blue Crab	Blueback Herring +79% *Alosa* spp.	Spot	Striped Bass +58% *Morone* spp.	Weakfish	White Perch +42% *Morone* spp.	Non-RIS Fishery Species	Non-RIS Forage Species
1978	2,636	400	26,237	3,207,895	106,937	45,217	47,840	2,207	237,865	205,508	NA	NA
1979	5,228	28	1,694	1,658,005	87,450	64,659	152,505	6,972	30,527	432,155	NA	NA
1980	7,399	789	18,705	12,307,910	430,887	74,240	76,140	3,979	73,243	384,326	NA	NA
1981	70,931	717	2,991	10,305,370	494,609	45,175	453,422	2,093	109,740	304,727	NA	NA
1982	24,093	435	593	4,492,784	151,012	79,830	506,074	452	54,048	232,375	NA	NA
1983	2,792	120	464	3,840,211	122,827	24,128	404,825	1,068	66,312	147,348	NA	NA
1984	20,129	4	170	3,240,737	90,517	138,154	168,227	183	23,718	248,481	NA	NA
1985	1,475	4,825	61,635	5,436,267	1,012,273	78,420	135,544	103	125,274	459,338	NA	NA
1986	2,811	13	46,652	3,111,302	1,103,054	62,359	27,780	1,621	43,753	736,078	NA	NA
1987	25,409	645	248,827	4,954,486	691,684	30,682	3,100	3,711	128,477	540,814	NA	NA
1988	7,234	1,262	807	7,457,023	1,098,308	40,597	993,151	8,014	19,004	678,298	NA	NA
1989	13,510	80	5,454	1,147,108	316,747	99,184	65,855	15,325	33,553	752,529	NA	NA
1990	4,296	1,884	3,961	1,923,258	201,566	2,053	62,524	18,440	15,173	690,946	NA	NA
1991	2,340	166	12,514	2,632,605	294,155	30,708	89,166	11,106	51,978	686,910	401,457	3,200,087
1992	2,899	419	15,441	1,998,807	477,614	15,064	3,357	13,967	65,868	1,035,386	205,300	3,032,060
1993	3,058	381	44,324	725,913	387,967	11,683	8,692	18,883	30,845	793,814	74,659	1,438,503
1994	4,323	8	6,549	199,838	439,444	12,944	127,624	17,955	86,759	872,029	101,808	1,472,900
1995	2,054	10	151,250	400,287	837,514	18,864	38,554	6,713	35,243	247,600	256,295	2,728,877
1996	136	11	7,656	19,780	65,818	755	3,797	1,844	5,125	50,414	121,929	725,920
1997	941	1	58,241	299,061	286,356	7,480	15,640	6,312	66,917	161,697	302,775	964,074
1998	3,412	1,142	485,999	876,041	282,114	12,061	2,673	4,890	65,409	93,927	88,394	747,858
Mean	9,862	635	57,151	3,344,509	427,564	42,584	161,262	6,945	65,182	464,510	194,077	1,788,785
Min	136	1	170	19,780	65,818	755	2,673	103	5,125	50,414	74,659	725,920
Max	70,931	4,825	485,999	12,307,910	1,103,054	138,154	993,151	18,883	237,865	1,035,386	401,457	3,200,087
SD	15,873	1,084	115,178	3,302,811	335,346	36,221	242,791	6,432	52,417	287,940	118,302	1,037,657
Total	207,106	13,339	1,200,163	70,234,680	8,978,851	894,257	3,386,492	145,837	1,368,830	9,754,701	1,552,617	14,310,280

Note: Impingement losses expressed as age 1 equivalents are larger than raw losses (the actual number of organisms impinged). This is because the ages of impinged individuals are assumed to be distributed across the interval between the start of year 1 and the start of year 2, and then the losses are normalized back to the start of year 1 by accounting for mortality during this interval (for details, see description of S*j in Chapter A5, Equation 4 and Equation 5). This type of adjustment is applied to all raw loss records, but the effect is not readily apparent among entrainment losses because the majority of entrained fish are younger than age 1.
NA = Not sampled
Non-RIS species are listed in Table B3-1.
Tue Feb 12 18:03:39 MST 2002; Results; I Plant: salemhistoric; Units: equivalent.sums Pathname:
P:/Intake/Delaware/Del-Science/scodes/tables.output.historic.damages/I.equivalent.sums.salem.historic.csv

Table B3-4: Annual Impingement of Fishery Species at the Salem Station Expressed as Yield Lost to Fisheries (in pounds).

Year	Alewife +21% *Alosa* spp.	American Shad	Atlantic Croaker	Blue Crab	Spot	Striped Bass +58% *Morone* spp.	Weakfish	White Perch +42% *Morone* spp.	Non-RIS Fishery Species
1978	24	98	5,341	3,412	5,358	3,064	187,007	90	NA
1979	47	7	345	2,791	17,080	9,676	24,000	190	NA
1980	66	193	3,808	13,750	8,528	5,522	57,583	169	NA
1981	633	175	609	15,783	50,783	2,904	86,276	134	NA
1982	215	106	121	4,819	56,680	628	42,492	102	NA
1983	25	29	94	3,919	45,340	1,482	52,134	65	NA
1984	180	1	35	2,888	18,841	254	18,647	109	NA
1985	13	1,181	12,548	32,302	15,181	144	98,489	202	NA
1986	25	3	9,498	35,198	3,111	2,250	34,398	324	NA
1987	227	158	50,658	22,072	347	5,150	101,007	238	NA
1988	65	309	164	35,047	111,232	11,123	14,941	298	NA
1989	121	20	1,110	10,107	7,376	21,270	26,379	331	NA
1990	38	461	806	6,432	7,003	25,593	11,929	304	NA
1991	21	41	2,548	9,386	9,987	15,414	40,864	302	35,864
1992	26	103	3,144	15,241	376	19,386	51,784	456	18,340
1993	27	93	9,024	12,380	974	26,210	24,250	349	6,670
1994	39	2	1,333	14,023	14,294	24,921	68,209	384	9,095
1995	18	2	30,793	26,725	4,318	9,318	27,708	109	22,896
1996	1	3	1,559	2,100	425	2,559	4,029	22	10,892
1997	8	0	11,857	9,138	1,752	8,761	52,609	71	27,048
1998	30	280	98,943	9,002	299	6,787	51,423	41	7,897
Mean	88	155	11,635	13,644	18,061	9,639	51,246	204	17,338
Min	1	0	35	2,100	299	144	4,029	22	6,670
Max	633	1,181	98,943	35,198	111,232	26,210	187,007	456	35,864
SD	142	265	23,449	10,701	27,192	8,927	41,210	127	10,568
Total	1,849	3,265	244,338	286,514	379,285	202,417	1,076,157	4,292	138,702

NA = Not sampled
0 = Sampled, but none collected.
Non-RIS species are listed in Table B3-1.
Tue Feb 12 18:03:58 MST 2002; Results; I Plant: salem.historic; Units: yield Pathname: P:/Intake/Delaware/Del-Science/scodes/tables.output.historic.damages/I.yield.salem.historic.csv

Table B3-5: Annual Impingement at the Salem Station, by Species, Expressed as Production Foregone (in pounds).

Year	Alewife +21% *Alosa* spp.	American Shad	Atlantic Croaker	Bay Anchovy	Blue Crab	Blueback Herring +79% *Alosa* spp.	Spot	Striped Bass +58% *Morone* spp.	Weakfish	White Perch +42% Morone spp.	Non-RIS Fishery Species	Non-RIS Forage Species
1978	1,208	2,402	14,499	1,642	19,881	12,839	18,309	6,087	521,227	6,616	NA	NA
1979	3,026	210	820	998	17,206	17,694	43,316	26,048	58,940	13,888	NA	NA
1980	4,419	4,675	9,231	5,943	72,343	25,299	21,120	17,014	161,901	11,135	NA	NA
1981	26,788	4,315	1,448	8,021	71,992	13,044	136,883	8,059	203,167	10,451	NA	NA
1982	14,447	2,714	287	2,431	23,411	27,741	137,584	1,580	105,301	6,568	NA	NA
1983	1,170	815	225	2,435	17,183	6,700	176,815	6,228	121,846	4,710	NA	NA
1984	9,356	100	82	1,218	16,131	39,240	51,728	267	42,141	7,459	NA	NA
1985	725	27,915	40,302	2,260	185,850	25,011	88,315	147	204,726	13,629	NA	NA
1986	1,242	336	22,589	1,030	211,790	18,789	8,433	2,967	88,536	21,899	NA	NA
1987	14,314	4,262	121,273	1,546	127,351	10,436	3,325	8,304	254,259	15,727	NA	NA
1988	3,681	8,060	391	1,540	224,946	11,238	273,860	26,605	43,273	23,888	NA	NA
1989	4,840	1,986	3,637	372	62,499	29,470	23,220	38,789	74,671	23,953	NA	NA
1990	1,356	11,160	6,329	928	35,630	837	17,153	65,835	24,548	23,832	NA	NA
1991	916	1,487	11,454	922	41,847	3,585	48,968	37,896	85,143	22,367	102,927	2,273
1992	1,209	3,924	14,420	770	73,970	4,937	3,199	48,234	116,550	36,357	92,095	3,183
1993	1,331	2,700	35,867	525	67,273	2,726	2,339	52,471	64,785	25,648	18,627	586
1994	2,176	193	3,578	120	87,416	5,918	34,340	71,550	182,867	25,383	21,907	1,460
1995	920	242	119,652	284	165,441	5,795	41,326	20,774	77,204	8,423	91,452	2,745
1996	50	84	9,152	14	14,070	256	1,079	4,591	11,010	1,586	33,969	526
1997	447	25	36,180	242	58,276	2,602	4,280	18,167	139,981	5,094	102,541	741
1998	1,965	6,600	256,217	975	53,341	4,411	2,375	12,814	148,532	3,148	38,158	377
Mean	4,552	4,010	33,697	1,629	78,469	12,789	54,189	22,592	130,029	14,846	62,709	1,486
Min	50	25	82	14	14,070	256	1,079	147	11,010	1,586	18,627	377
Max	26,788	27,915	256,217	8,021	224,946	39,240	273,860	71,550	521,227	36,357	102,927	3,183
SD	6,595	6,230	61,783	1,945	66,142	11,023	71,288	21,909	110,443	9,542	37,665	1,108
Total	95,584	84,204	707,632	34,215	1,647,847	268,567	1,137,968	474,427	2,730,609	311,761	501,675	11,892

NA = Not sampled.
Non-RIS species are listed in Table B3-1.
Tue Feb 12 18:03:49 MST 2002; Results; I Plant: salem.historic; Units: annual.prod.forg Pathname:
P:/Intake/Delaware/Del-Science/scodes/tables.output.historic.damages/I.annual.prod.forg.salem.historic.csv

B3-5 Salem's Annual Entrainment

Annual entrainment losses (numbers of organisms) at Salem as calculated by PSEG are presented in Appendix L, Tab 8 of Salem's 1999 Permit Renewal Application (PSEG, 1999e) and duplicated below in Table B3-6. For its estimates, PSEG assumed that some proportion of entrained organisms survive. The through-plant survival factors used by PSEG to calculate entrainment losses are presented in Tab 10 of Appendix L of the Salem Application and presented in Appendix B1 of Part B.

As discussed in Section B3-3.3, an independent review of Salem's 1999 Application by scientists with ESSA Technologies, Ltd. (2000) concluded that Salem's entrainment rates were most likely underestimated by PSEG because their entrainment calculations assumed substantial through-plant survival of entrained organisms. EPA concurs with ESSA that Salem's 1999 Application provides inadequate justification for PSEG's assumptions about through-plant survival, and therefore, EPA recalculated Salem's entrainment without the thermal and mechanical mortality factors used by PSEG for its calculations (see Appendix B1 for the species-specific thermal and mechanical mortality factors used by PSEG). Table B3-7 presents the results of EPA's calculations of Salem's annual entrainment rates assuming 100 percent through-plant mortality of entrained organisms. EPA's entrainment estimates (Table B3-7) are higher than PSEG's (Table B3-6) for all species except Atlantic menhaden, bay anchovy, and silversides. EPA's entrainment estimate of Atlantic croaker is three times higher than PSEG's and EPA's estimate for spot is five times higher.

EPA used its estimates of entrainment assuming 100 percent through-plant mortality to express entrainment at Salem in terms of numbers of age 1 equivalents, fishery yield, and production foregone. Table B3-8 presents numbers of age 1 equivalents entrained, Table B3-9 presents entrainment as pounds of yield lost to commercial and recreational fisheries, and Table B3-10 presents entrainment as pounds of production foregone.

As with impingement, entrainment at Salem varies substantially by species and by year. For the period 1978-1998, EPA's estimates of mean annual entrainment at Salem entrainment range from 55,575 for American shad to nearly 12.5 billion for bay anchovy. Maximum entrainment during this period was over 45 billion bay anchovy in 1986. Bay anchovy typically dominate entrainment collections, but several hundred million Atlantic croaker, weakfish, striped bass, and white perch have also been entrained in many years in the period.

In 1998, exceptionally high numbers of alewife were entrained, over 16 million, compared to a mean of about 1.2 million fo the period. In 1995 and 1998, unusually high entrainment of Atlantic menhaden occurred, reaching about 180 million compared to a mean of 20.8 million. Similarly, in 1998 blueback herring entrainment was over 66 million compared to a mean of about 5.2 million, striped bass entrainment was about 537 million compared to a mean of 39.7 million, and white perch entrainment was nearly 416 million compared to a mean of 42.6 million. Of note is that Salem's intake flow in 1998 was substantially higher than other years and close to the level of use projected by the facility over the next permit cycle.

In contrast to these recent increases in entrainment rates, spot entrainment was substantially lower than average from 1995 on. All species showed lower entrainment in 1996, but this was due to a plant shut down during that year (PSEG, 1999e).

Table B3-6: Annual Entrainment (number of organisms), by Species, at the Salem Station as Estimated by PSEG Assuming Through-Plant Survival.

Year	Alewife +21% *Alosa* spp.	American Shad	Atlantic Croaker	Atlantic Menhaden	Bay Anchovy	Blueback Herring +79% *Alosa* spp.	Silversides	Spot	Striped Bass +58% *Morone* spp.	Weakfish	White Perch +42% *Morone* spp.	Non-RIS Fishery Species[a]	Non-RIS Forage Species[a]
1978	7,632	3,975	784,064	0	7,962,051,278	775,494	79,935,119	5,095,551	25,601	399,818,310	0	NA	NA
1979	49,684	0	14,514,986	72,137	3,535,124,407	19,274	18,082,977	1,095,197	20,304	23,192,970	625,399	NA	NA
1980	859,887	15,132	755,706	4,276,613	15,155,926,538	2,812,879	145,109,137	10,295,704	0	256,708,366	27,513,718	NA	NA
1981	2,002,234	0	8,156,747	9,206,968	11,714,057,177	11,852,670	113,240,053	5,417,848	0	45,764,940	969,236	NA	NA
1982	0	0	0	4,156,955	3,712,919,795	16,656	22,200,895	29,963,409	0	74,456,905	18,857,094	NA	NA
1983	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1985	163,133	126,276	933,196	0	29,463,744,796	1,151,370	0	183,598	0	63,615,990	447,265	NA	NA
1986	348,352	59,250	492,348	0	45,248,806,030	1,593,617	0	858,283	0	110,396,880	653,875	NA	NA
1987	0	62,364	0	0	40,172,399,532	82,394	0	54,551	0	61,266,916	628,439	NA	NA
1988	748,616	0	1,709,851	0	22,331,488,597	2,987,578	0	73,501,509	0	57,063,491	8,968,240	NA	NA
1989	540,788	0	56,341,150	0	10,163,461,645	2,395,307	0	1,026,809	47,946,144	3,026,428	192,130,782	NA	NA
1990	101,432	0	123,374,873	0	7,678,380,444	260,035	0	4,395,303	1,312,530	6,685,346	2,606,258	NA	NA
1991	0	0	131,798,465	0	19,506,554,577	0	0	1,095,693	777,984	72,477,718	1,108,499	NA	NA
1992	319,124	0	71,351,661	0	1,570,462,617	864,490	0	0	1,728,235	10,374,786	3,392,824	NA	NA
1993	675,884	0	75,030,114	0	11,774,247,388	2,339,735	0	584,884	108,064,811	122,672,393	37,634,808	NA	NA
1994	697,126	0	24,782,692	0	1,120,303,600	2,622,523	0	46,858,797	7,490,424	88,781,352	66,926,677	NA	NA
1995	477,453	14,474	31,454,237	177,220,933	1,404,485,840	81,566	31,018,748	71,245	579,481	335,082,605	2,039,275	153,969,300	967,814,700
1996	82,548	27,559	4,384,613	3,039,455	70,642,422	425,090	1,226,981	25,366	7,288,639	14,257,625	16,799,904	153,969,300	967,814,700
1997	52,865	746,895	71,819,490	16,667,564	1,811,782,029	318,483	6,919,466	7,482	6,504,598	12,600,665	7,865,126	153,969,300	967,814,700
1998	14,480,142	0	132,129,651	180,557,345	2,003,681,602	59,282,494	51,528,345	20,054	448,563,394	76,343,394	412,839,168	153,969,300	967,814,700

[a] Annual entrainment losses of non-RIS fishery and forage species were not reported in Salem's 1999 Permit Renewal Application. Instead, the facility presented an annual average for the years 1995-1998. For these years, entrainment of non-RIS fishery species was 153,969,330 organisms per year and entrainment of non-RIS forage species was 967,814,720 organisms per year (PSEG, 1999e, Appendix L, Tab 8).

NA = Not sampled.

0 = Sampled, but none collected.

Non-RIS species are listed in Table B3-1.

Source: PSEG, 1999e, Appendix L, Tab 8.

Table B3-7: Annual Entrainment (number of organisms) at the Salem Station, by Species, as Estimated by EPA Assuming 100 Percent Through-Plant Mortality.

Year	Alewife +21% *Alosa* spp.	American Shad	Atlantic Croaker	Atlantic Menhaden	Bay Anchovy	Blueback Herring +79% *Alosa* spp.	Silversides	Spot	Striped Bass +58% *Morone* spp.	Weakfish	White Perch +42% *Morone* spp.
1978	8,544	3,975	2,177,952	0	7,962,051,277	868,182	79,935,118	24,990,602	25,601	428,114,400	0
1979	55,622	0	40,319,346	72,137	3,535,124,407	21,578	18,082,978	5,371,280	20,304	24,617,925	646,711
1980	962,662	15,132	2,099,180	4,276,613	15,155,926,538	3,149,079	145,109,137	50,494,214	0	271,959,260	27,519,051
1981	2,241,544	0	22,657,594	9,206,968	11,714,057,178	13,269,320	113,240,054	26,571,274	0	48,426,552	1,002,628
1982	0	0	0	4,156,955	3,712,919,793	18,647	22,200,895	146,952,435	0	78,517,574	18,881,133
1983	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1985	182,631	126,276	2,592,205	0	29,463,744,795	1,288,984	0	900,437	0	10,075,085	462,674
1986	389,988	59,250	1,367,631	0	45,248,806,032	1,784,089	0	4,209,360	0	118,057,915	664,022
1987	0	62,364	0	0	40,172,399,531	92,242	0	267,540	0	62,702,941	650,090
1988	838,092	0	4,749,579	0	22,331,488,597	3,344,658	0	360,480,535	0	60,536,736	9,277,212
1989	605,424	0	156,502,967	0	10,163,461,644	2,681,597	0	5,035,878	57,430,456	3,254,760	194,817,233
1990	113,555	0	342,707,477	0	7,678,380,445	291,115	0	21,556,308	1,572,164	7,145,540	2,696,047
1991	0	0	366,106,309	0	19,506,554,576	0	0	5,373,713	931,878	77,073,686	1,146,689
1992	357,266	0	198,198,767	0	1,570,462,619	967,815	0	0	2,070,100	11,216,240	3,509,712
1993	756,667	0	208,416,677	0	11,774,247,387	2,619,384	0	2,868,503	129,441,302	130,205,448	38,205,582
1994	780,448	0	68,840,707	0	1,120,303,600	2,935,971	0	229,814,115	8,899,097	95,852,608	67,542,554
1995	534,519	14,474	87,372,752	177,220,933	1,404,485,841	91,315	31,018,749	349,414	694,109	356,747,253	2,109,532
1996	92,414	27,559	12,179,463	3,039,455	70,642,420	475,899	1,226,981	124,405	8,730,418	15,394,030	16,959,115
1997	59,184	746,894	199,498,293	16,667,564	1,811,782,028	356,549	6,919,466	36,695	7,786,536	13,582,304	7,936,108
1998	16,210,831	0	367,026,271	180,557,344	2,003,681,603	66,368,030	51,528,345	98,353	536,955,425	80,823,960	415,734,553
Mean	1,273,126	55,575	109,621,746	20,799,893	12,442,132,648	5,296,024	24,697,985	46,605,003	39,713,547	99,700,222	42,618,981
Min	0	0	0	0	70,642,420	0	0	0	0	3,254,760	0
Max	16,210,831	746,894	367,026,271	180,557,344	45,248,806,032	66,368,030	145,109,137	360,480,535	536,955,425	428,114,400	415,734,553
SD	3,657,744	170,575	133,246,350	55,874,625	13,411,735,891	15,089,818	42,925,237	96,477,467	124,417,960	121,478,051	101,071,419
Total	24,189,391	1,055,924	2,082,813,171	395,197,969	236,400,520,311	100,624,451	469,261,723	885,495,061	754,557,389	1,894,304,218	809,760,647

Table B3-7: Annual Entrainment (number of organisms) at the Salem Station, by Species, as Estimated by EPA Assuming 100 Percent Through-Plant Mortality (cont.)

Year	Non-RIS Fishery Species[a]	Non-RIS Forage Species[a]
1978	NA	NA
1979	NA	NA
1980	NA	NA
1981	NA	NA
1982	NA	NA
1983	NA	NA
1984	NA	NA
1985	NA	NA
1986	NA	NA
1987	NA	NA
1988	NA	NA
1989	NA	NA
1990	NA	NA
1991	NA	NA
1992	NA	NA
1993	NA	NA
1994	NA	NA
1995	153,969,300	967,814,700
1996	153,969,300	967,814,700
1997	153,969,300	967,814,700
1998	153,969,300	967,814,700
Mean	153,969,300	967,814,700
Min	153,969,300	967,814,700
Max	153,969,300	967,814,700
SD	0	0
Total	615,877,300	3,871,259,000

[a] Annual entrainment losses of non-RIS fishery and forage species were not reported in Salem's 1999 Permit Renewal Application. Instead, the facility presented an annual average for the years 1995-1998 data. Averaged for these years, entrainment of non-RIS fishery species was 153,969,330 organisms per year and entrainment of non-RIS forage species was 967,814,720 organisms per year (PSEG, 1999e, Appendix L, Tab 8).

NA = Not sampled.

0 = Sampled, but none collected.

Non-RIS species are listed in Table B3-1.

Tue Feb 12 18:23:34 MST 2002 Raw.losses. ENTRAINMENT; Plant:salem.historic; PATHNAME:P:/Intake/Delaware/Del-Science/scodes/tables.output.historic.damages/raw.losses.ent.salem.historic.csv

Table B3-8: EPA's Estimates of Annual Entrainment at the Salem Station, by Species, Expressed as Numbers of Age 1 Equivalents.

Year	Alewife +21% *Alosa* spp.	American Shad	Atlantic Croaker	Atlantic Menhaden	Bay Anchovy	Blueback Herring +79% *Alosa* spp.	Silver-sides	Spot	Striped Bass +58% *Morone* spp.	Weakfish	White Perch +42% *Morone* spp.	Non-RIS Fishery Species[a]	Non-RIS Forage Species[a]
1978	33	0	187,667	0	901,202,064	3,177	7,196	12,849,708	0	7,572,325	0	NA	NA
1979	214	0	7,349,321	7,856	36,089,496	79	294,761	2,767,731	0	119,038	407,951	NA	NA
1980	3,701	19	392,787	465,750	469,989,469	11,525	363,415	25,929,445	0	486,109	143,074	NA	NA
1981	8,619	0	1,106,959	1,002,696	317,219,041	48,561	1,251,766	13,691,736	0	227,950	639,195	NA	NA
1982	0	0	0	452,718	108,544,490	68	17,713	61,012,334	0	429,948	487,447	NA	NA
1983	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1985	702	155	109,948	0	19,766,087	4,717	0	463,980	0	474,167	294,964	NA	NA
1986	1,500	73	685	0	240,228,921	6,529	0	931,631	0	1,949,102	194,770	NA	NA
1987	0	76	0	0	276,775,535	338	0	137,859	0	299,142	414,445	NA	NA
1988	3,223	0	387,145	0	779,119,078	12,240	0	183,257,758	0	480,213	3,937,433	NA	NA
1989	369	0	23,972,452	0	162,851,234	1,631	0	2,594,904	2,479,335	79,595	3,123,551	NA	NA
1990	11	0	51,609,459	0	142,100,458	167	0	10,828,831	99,360	105,794	1,393,936	NA	NA
1991	0	0	66,409,497	0	1,353,741,468	0	0	2,062,486	169	826,872	731,037	NA	NA
1992	218	0	35,296,188	0	99,601,622	554	0	0	105,432	365,908	848,321	NA	NA
1993	461	0	36,627,606	0	114,994,298	1,499	0	1,478,092	4,100,226	532,087	1,371,627	NA	NA
1994	475	0	8,292,818	0	50,694,237	1,680	0	111,206,379	35,850	2,926,134	2,816,509	NA	NA
1995	1,977	18	15,049,904	19,137,281	33,360,491	52	1,743	41,596	30,092	3,214,782	1,170,460	13,879,730	6,423,701
1996	56	3	1,072,040	331,015	3,293,313	688	0	285	177,046	471,205	674,948	13,879,730	6,423,701
1997	228	913	21,801,029	1,774,949	32,344,695	1,305	0	84	48,394	381,118	137,540	13,879,730	6,423,701
1998	6,469	0	27,581,872	19,389,774	88,750,958	27,295	5,014	11,708	652,225	1,409,028	3,696,144	13,879,730	6,423,701
Mean	1,487	66	15,644,598	2,240,107	275,298,261	6,427	102,190	22,592,976	406,744	1,176,343	1,183,334	13,879,730	6,423,701
Min	0	0	0	0	3,293,313	0	0	0	0	79,595	0	13,879,730	6,423,701
Max	8,619	913	66,409,497	19,389,774	1,353,741,468	48,561	1,251,766	183,257,758	4,100,226	7,572,325	3,937,433	13,879,730	6,423,701
SD	2,422	209	19,963,265	6,016,379	362,368,419	12,217	297,009	47,806,599	1,061,913	1,798,880	1,253,917	0	0
Total	28,255	1,256	297,247,365	42,562,039	5,230,666,954	122,105	1,941,607	429,266,547	7,728,129	22,350,520	22,483,350	55,518,900	25,694,800

[a] Annual entrainment losses of non-RIS fishery and forage species were not reported in Salem's 1999 Permit Renewal Application. Instead, the facility presented an annual average for the years 1995-1998 (see Table B3-6). The age 1 equivalents presented here are derived from this annual average.

NA = Not sampled.

0 = Sampled, but none collected.

Non-RIS species are listed in Table B3-1.

Tue Feb 12 18:03:37 MST 2002; Results; E Plant: salem.historic; Units: equivalent.sums Pathname: P:/Intake/Delaware/Del-Science/scodes/tables.output.historic.damages/E.equivalent.sums.salem.historic.csv

Table B3-9: Annual Entrainment of Fishery Species at the Salem Station Expressed as Yield Lost to Fisheries (in pounds).

Year	Alewife +21% *Alosa* spp.	American Shad	Atlantic Croaker	Atlantic Menhaden	Silversides	Spot	Striped Bass +58% *Morone* spp.	Weakfish	White Perch +42% *Morone* spp.	Non-RIS Fishery Species[a]
1978	0	0	38,207	0	3	1,439,161	0	5,953,264	0	NA
1979	2	0	1,496,229	3,943	119	309,985	0	93,586	180	NA
1980	33	5	79,967	233,739	146	2,904,085	0	382,173	63	NA
1981	77	0	225,363	503,208	504	1,533,468	0	179,211	281	NA
1982	0	0	0	227,199	7	6,833,350	0	338,020	214	NA
1983	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1985	6	38	22,384	0	0	51,966	0	372,784	130	NA
1986	13	18	139	0	0	104,342	0	1,532,359	86	NA
1987	0	19	0	0	0	15,440	0	235,182	182	NA
1988	29	0	78,818	0	0	20,524,780	0	377,537	1,733	NA
1989	3	0	4,880,487	0	0	290,628	3,441,225	62,576	1,374	NA
1990	0	0	10,507,030	0	0	1,212,824	137,909	83,174	613	NA
1991	0	0	13,520,130	0	0	230,997	234	650,076	322	NA
1992	2	0	7,185,856	0	0	0	146,335	287,672	373	NA
1993	4	0	7,456,916	0	0	165,546	5,690,961	418,320	604	NA
1994	4	0	1,688,313	0	0	12,455,060	49,759	2,300,488	1,239	NA
1995	18	4	3,063,970	9,604,144	1	4,659	41,767	2,527,420	515	1,239,935
1996	1	1	218,254	166,122	0	32	245,733	370,455	297	1,239,935
1997	2	224	4,438,413	890,767	0	9	67,169	299,630	61	1,239,935
1998	58	0	5,615,319	9,730,859	2	1,311	905,264	1,107,759	1,626	1,239,935
Mean	13	16	3,185,042	1,124,209	41	2,530,402	564,545	924,826	521	1,239,935
Min	0	0	0	0	0	0	0	62,576	0	1,239,935
Max	77	224	13,520,130	9,730,859	504	20,524,780	5,690,961	5,953,264	1,733	1,239,935
SD	22	51	4,064,268	3,019,351	120	5,354,315	1,473,895	1,414,256	552	0
Total	252	307	60,515,790	21,359,980	781	48,077,640	10,726,360	17,571,690	9,893	4,959,740

[a] Annual entrainment losses of non-RIS fishery species were not reported in Salem's 1999 Permits Renewal Application. Instead, the facility presented an annual average for the years 1995-1998 (see Table B3-6). The fishery yields for non-RIS fishery species presented here are derived from this annual average.
NA = Not sampled.
0 = Sampled, but none collected.
Non-RIS species are listed in Table B3-1.
Tue Feb 12 18:03:55 MST 2002; Results; E Plant: salem.historic; Units: yield Pathname: P:/Intake/Delaware/Del-Science/scodes/tables.output.historic.damages/E.yield.salem.historic.csv

Table B3-10: Annual Entrainment at the Salem Station, by Species, Expressed as Production Foregone (in pounds).

Year	Alewife +21% *Alosa* spp.	American Shad	Atlantic Croaker	Atlantic Menhaden	Bay Anchovy	Blueback Herring +79% *Alosa* spp.	Silver-sides	Spot	Striped Bass +58% *Morone* spp.	Weakfish	White Perch +42% *Morone* spp.	Non-RIS Fishery Species[a]	Non-RIS Forage Species[a]
1978	39	162	127,801	0	5,044,739	2,267	1	3,457,903	1,560	19,665,920	0	NA	NA
1979	253	0	3,738,114	550	1,867,947	56	34	744,715	1,237	513,003	11,178	NA	NA
1980	4,375	461	196,901	32,587	8,296,371	8,221	42	6,976,999	0	5,734,506	191,150	NA	NA
1981	10,187	0	1,373,572	70,156	6,301,636	34,642	144	3,684,043	0	1,035,307	17,488	NA	NA
1982	0	0	0	31,675	2,030,206	49	2	16,441,100	0	1,723,094	137,914	NA	NA
1983	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1985	830	3,851	141,791	0	15,433,644	3,365	0	124,843	0	937,860	8,070	NA	NA
1986	1,772	1,807	22,087	0	23,596,774	4,658	0	265,483	0	5,003,485	7,794	NA	NA
1987	0	1,902	0	0	21,003,339	241	0	37,094	0	1,707,528	11,339	NA	NA
1988	3,809	0	332,854	0	12,097,167	8,732	0	49,313,420	0	1,711,452	152,913	NA	NA
1989	3,234	0	13,438,260	0	5,663,320	7,607	0	698,212	7,217,789	182,919	1,320,113	NA	NA
1990	592	0	29,334,516	0	4,176,184	1,606	0	2,914,184	241,566	263,136	44,881	NA	NA
1991	0	0	33,870,021	0	10,590,381	0	0	556,130	51,186	2,071,668	20,001	NA	NA
1992	1,909	0	18,016,150	0	945,053	2,748	0	0	269,665	814,321	34,974	NA	NA
1993	4,042	0	18,864,867	0	6,296,170	7,438	0	397,711	13,401,050	2,146,684	287,486	NA	NA
1994	4,169	0	5,416,038	0	630,580	8,337	0	29,959,930	627,015	6,555,749	488,538	NA	NA
1995	2,448	441	7,903,765	1,618,054	754,828	259	0	11,423	80,395	9,693,254	33,500	16,152,790	418,599
1996	494	1,126	783,827	23,160	30,794	1,321	0	1,063	773,058	1,055,400	135,192	16,152,790	418,599
1997	269	22,794	15,095,100	193,029	942,041	931	0	313	536,200	887,983	53,961	16,152,790	418,599
1998	85,638	0	20,482,086	1,750,015	1,121,473	185,336	1	3,215	33,984,300	3,718,167	2,842,755	16,152,790	418,599
Mean	6,529	1,713	8,901,987	195,749	6,674,876	14,622	12	6,083,567	3,009,738	3,443,233	305,224	16,152,790	418,599
Min	0	0	0	0	30,794	0	0	0	0	182,919	0	16,152,790	418,599
Max	85,638	22,794	33,870,021	1,750,015	23,596,774	185,336	144	49,313,420	33,984,300	19,665,920	2,842,755	16,152,790	418,599
SD	19,321	5,203	10,849,792	526,909	7,003,493	42,075	34	12,868,640	8,218,962	4,671,217	686,407	0	0
Total	124,059	32,544	169,137,748	3,719,226	126,822,647	277,813	224	115,587,800	57,185,030	65,421,430	5,799,247	64,611,140	1,674,398

[a] Annual entrainment losses of non-RIS fishery species were not reported in Salem's 1999 Permit Renewal Application. Instead, the facility presented an annual average for the years 1995-1998 (see Table B3-6). The production foregone estimates presented here for these species are derived from this annual average.
NA = Not sampled.
0 = Sampled, but none collected.
Non-RIS species are listed in Table B3-1.
Tue Feb 12 18:03:47 MST 2002; Results; E Plant: salem.historic; Units: annual.prod.forg Pathname:
P:/Intake/Delaware/Del-Science/scodes/tables.output.historic.damages/E.annual.prod.forg.salem.historic.csv

B3-6 Extrapolation of Salem's I&E Rates to Other Transition Zone Facilities

EPA used the results from its detailed analysis of I&E at Salem as a basis for estimating I&E at other CWIS in the transition zone of the Delaware Estuary. For extrapolation purposes, EPA used Salem's impingement estimates for the years 1978-95 and 1997-98, assuming no impingement survival (see Table B3-11), and Salem's entrainment estimates 1978-95, 1997-98, assuming no entrainment survival (see Table B3-7). 1996 was eliminated from the analysis because Salem was shut down much of the year and therefore I&E during this year is not considered representative. The average impingement and entrainment rates estimated on this basis were used to extrapolate Salem's I&E rates to other transition zone CWIS on the basis of intake flow

Extrapolation was necessary because empirical data describing actual I&E at these facilities are extremely limited or absent. Because intake characteristics, the fish community, and hydrodynamic conditions associated with transition zone CWIS are similar, EPA assumed that I&E at Salem is representative of I&E at other transition zone CWIS and that I&E is strictly proportional to intake flow. The following sections discuss in more detail how EPA used Salem I&E data to develop a model for extrapolation.

B3-6.1 Impingement Extrapolation

Except for Salem, impingement controls at transition zone CWIS are non-existent or minimal.[1] Therefore, to extrapolate Salem's impingement rates to CWIS without screens, EPA re-calculated Salem's impingement rates without the screen survival factors used by PSEG for its calculations (see Appendix B1 for the species-specific initial and latent mortality factors used by PSEG to calculate annual impingement). EPA averaged Salem's species-specific mortality rates by month of highest impingement to obtain annual initial and latent mortality rates (see shaded areas in Appendix B1) and then calculated impingement without these factors. Table B3-11 presents the results of EPA's calculations of Salem's annual impingement assuming 100 percent mortality of impinged organisms. EPA used these estimates to estimate impingement at other transition zone CWIS expressed as age 1 equivalents, fishery yield, and production foregone. These results are presented in Tables B3-12, B3-13, and B3-14, respectively. Chapter A5 of Part A of this document discusses the methods used to calculate these metrics. Note that in these tables, the data for Salem are for Salem as an extrapolation model.

B3-6.2 Entrainment Extrapolation

As outlined in Section B3-3.2, PSEG adjusted their entrainment estimates using the thermal and mechanical survival factors presented in Appendix B1. As discussed previously, EPA believes that PSEG provided insufficient justification for the use of these through-plant survival factors. Thus, for extrapolation purposes, EPA used the entrainment rates it calculated assuming no through-plant survival (presented in Table B3-7). Extrapolation results are expressed as age 1 equivalents in Table B3-15, as foregone fishery yield in Table B3-16, and as production foregone in Table B3-17. Chapter A5 of Part A of this document discusses the methods used to calculate these metrics. Note that in these tables, the data for Salem are for Salem as an extrapolation model.

B3-7 Salem's Current I&E

EPA estimated Salem's current entrainment rates using the data discussed in Section B3-5 and presented in Tables B3-7 through B3-10. Current impingement at Salem was estimated by considering only the years since 1995, when Salem's Ristroph screens were modified with improved fish handling systems that increase the survival of impinged organisms. The results of these impingement calculations are presented in Tables B3-18, B3-19, and B3-20 as age 1 equivalents, foregone fishery yield and production foregone, respectively.

[1] EPA understands that Logan has some impingement control but technical details are lacking. Therefore, for the purposes of the analysis presented here, EPA assumed none of the transition zone CWIS have impingement controls.

B3-8 Cumulative Impacts: Summary of Estimated Total I&E at All Transition Zone CWIS

Tables B3-21 and B3-22 summarize the cumulative I&E impacts of all transition zone CWIS (both in-scope and out of scope) in terms of numbers of age 1 equivalents, yield lost to fisheries (in pounds), and production foregone (in pounds). The rates for Salem in these tables are EPA's estimates of Salem's current annual I&E rates, as described above in Section B3-7. EPA estimates that total fish impingement in the transition zone is 9,648,808 age 1 equivalents, 332,767 pounds of fishery yield, and 794,381 pounds of production foregone. Total entrainment is substantially greater, estimated as 615,900,092 age 1 equivalents, 16,867,112 pounds of fishery yield, and 72,000,391 pounds of production foregone. Economic valuation of these losses is discussed in Chapters B4 and B5 of this report. EPA evaluated the data for in-scope facilities only (Salem Hope Creek, Deepwater, Edge Moor) to estimate the potential economic benefits of various regulatory options, as discussed in Chapter B6.

Table B3-11: Annual Impingement (number of organisms), by Species, at the Salem Station as Estimated by EPA Assuming No Impingement Survival.

Year	Alewife +21% *Alosa* spp.	American Shad	Atlantic Croaker	Atlantic Menhaden	Bay Anchovy	Blue Crab	Blueback Herring +79% *Alosa* spp.	Spot	Striped Bass +58% *Morone* spp.	Weakfish	White Perch +42% *Morone* spp.	Non-RIS Fishery Species	Non-RIS Forage Species
1978	17,873	7,412	259,849	NA	2,803,345	336,611	464,023	114,685	11,459	9,260,270	514,214	NA	NA
1979	12,063	3,493	17,542	NA	1,411,564	293,812	689,293	396,853	34,314	841,270	1,093,725	NA	NA
1980	11,841	10,397	192,542	NA	11,803,050	1,510,762	487,729	199,184	15,513	2,639,110	814,573	NA	NA
1981	678,796	14,368	30,970	NA	12,036,270	1,047,688	386,261	1,163,085	6,760	2,634,932	696,003	NA	NA
1982	49,196	15,323	6,144	NA	4,110,000	367,990	442,722	1,329,707	1,936	1,402,339	528,803	NA	NA
1983	20,521	8,732	4,804	NA	4,044,164	304,423	237,494	925,002	3,298	1,504,471	290,543	NA	NA
1984	134,120	5,321	1,762	NA	2,612,252	265,032	1,414,221	429,566	1,533	517,437	606,374	NA	NA
1985	4,899	17,974	569,312	NA	4,029,411	3,051,046	172,033	249,233	688	1,830,128	1,176,126	NA	NA
1986	21,782	17,931	483,080	NA	2,149,305	3,703,258	494,850	71,162	10,251	1,096,751	2,085,730	NA	NA
1987	78,019	39,293	2,571,368	NA	3,576,131	2,517,506	166,760	2,991	23,788	1,586,694	1,445,431	NA	NA
1988	32,568	57,314	8,356	NA	4,976,715	3,762,281	378,943	2,601,491	37,262	618,996	1,305,942	NA	NA
1989	144,594	106,115	49,912	NA	835,175	1,038,268	943,494	161,989	92,719	267,377	1,536,145	NA	NA
1990	52,467	25,075	11,951	NA	1,467,489	538,302	1,892	163,959	99,842	247,441	1,551,465	NA	NA
1991	22,292	37,265	94,039	NA	1,837,543	927,273	321,747	182,919	35,972	833,621	1,390,537	1,318,756	3,759,669
1992	24,988	105,574	114,135	NA	1,374,769	1,117,518	127,746	4,069	74,753	1,218,984	2,338,407	1,082,304	4,187,465
1993	24,379	35,982	364,050	NA	637,069	1,167,566	106,938	22,889	264,201	1,048,084	2,107,665	248,137	1,189,847
1994	24,043	10,288	65,134	NA	191,004	1,481,211	33,707	336,072	84,187	3,086,656	2,557,047	300,779	2,068,499
1995	15,450	12,935	1,260,307	NA	388,498	3,052,729	152,306	37,226	38,549	1,290,012	648,825	1,057,790	3,541,200
1997	22,289	1,530	945,130	NA	448,347	7,552,705	210,344	239,578	108,717	3,091,169	2,521,240	1,292,807	979,870
1998	30,369	4,137	8,403,714	NA	1,601,949	4,459,744	236,758	21,024	90,681	3,072,358	1,369,101	452,514	678,595
Mean	71,127	26,823	772,705	NA	3,116,702	1,924,786	373,463	432,634	51,821	1,904,405	1,328,895	821,870	2,343,592
Min	4,899	1,530	1,762	NA	191,004	265,032	1,892	2,991	688	247,441	290,543	248,137	678,595
Max	678,796	106,115	8,403,714	NA	12,036,270	7,552,705	1,414,221	2,601,491	264,201	9,260,270	2,557,047	1,318,756	4,187,465
SD	148,018	30,622	1,900,129	NA	3,322,331	1,871,996	335,012	637,518	62,336	1,965,251	701,530	470,689	1,465,046
Total	1,422,549	536,460	15,454,100	NA	62,334,050	38,495,720	7,469,263	8,652,686	1,036,423	38,088,100	26,577,900	5,753,087	16,405,150

NA = Not sampled.
Non-RIS species are listed in Table B3-1.
Fri Feb 08 14:51:44 MST 2002 Raw.losses. IMPINGEMENT; Plant:salem100.extrapolation
PATHNAME:P:/Intake/Delaware/Del-Science/scodes/tables.output.extrapolation.baseline/raw.losses.imp.salem100.extrapolation.csv

Table B3-12: EPA's Estimate of Mean Annual Impingement at Salem Expressed as Numbers of Age 1 Equivalents Extrapolated to Other Transition Zone Facilities.

Facility	Operational Flow (MGD)[b]	Alewife	American Shad	Atlantic Croaker	Bay Anchovy	Blue Crab	Blueback herring	Spot	Striped Bass	Weak-fish	White Perch	Non-RIS Fishery Species	Non-RIS Forage Species	Total
Salem as extrapolation model[a]	1,722	11,438	1,099	163,425	3,773,602	1,709,674	50,307	235,509	28,438	102,131	1,094,565	204,384	1,940,623	7,920,942
Hope Creek	CBI	412	40	5,884	135,867	61,556	1,811	8,479	1,024	3,677	39,409	7,359	69,871	285,191
DuPont	7	46	4	664	15,340	6,950	205	957	116	415	4,449	831	7,889	32,199
Edge Moor	782	5,194	499	74,215	1,713,680	776,402	22,846	106,950	12,914	46,380	497,067	92,815	881,282	3,597,083
Delaware City Refinery	CBI	2,418	232	34,545	797,672	361,394	10,634	49,782	6,011	21,589	231,372	43,203	410,213	1,674,345
Deepwater	105	695	67	9,927	229,221	103,851	3,056	14,306	1,727	6,204	66,488	12,415	117,880	481,144
Chambers Cogen	37	246	24	3,511	81,082	36,735	1,081	5,060	611	2,194	23,519	4,392	41,697	170,194
General Chemical Corp.	34	225	22	3,217	74,289	33,657	990	4,636	560	2,011	21,548	4,024	38,204	155,935
SPI Polyols	5	33	3	475	10,957	4,964	146	684	83	297	3,178	593	5,635	22,999
Sun Refining	6	40	4	569	13,148	5,957	175	821	99	356	3,814	712	6,762	27,599
Logan Generating Co.	2	13	1	190	4,383	1,986	58	274	33	119	1,271	237	2,254	9,200
Hay Road	2	11	1	152	3,506	1,589	47	219	26	95	1,017	190	1,803	7,360
Totals	--	20,770	1,996	296,774	6,852,748	3,104,716	91,357	427,678	51,643	185,468	1,987,698	371,155	3,524,113	14,384,191

Note: Impingement losses expressed as age 1 equivalents are larger than raw losses (the actual number of organisms impinged). This is because the ages of impinged individuals are assumed to be distributed across the interval between the start of year 1 and the start of year 2, and then the losses are normalized back to the start of year 1 by accounting for mortality during this interval (for details, see description of S*j in Chapter A5, Equation 4 and Equation 5). This type of adjustment is applied to all raw loss records, but the effect is not readily apparent among entrainment losses because the majority of entrained fish are younger than age 1.

[a] Based on EPA's estimate of Salem's average impingement assuming no impingement survival (see Table B3-11). Salem's data for 1996 was not included because the facility was shut down much of the year.

[b] Current operational flows from results of EPA's survey of the industry were used for all facilities except for Hay Road, Chambers Cogen, SPI Polyols, Sun Refining, and Salem. For Hay Road, Chamberts Cogen, SPI Polyols, Sun Refining, and Salem the average intake flow was used based on the EIA data presented in Chapter B1. For Salem, EPA used the average operational flow for 1978-1998 (excluding 1996, when the facility was shut down).

CBI = Confidential Business Information.

Non-RIS species are listed in Table B3-1.

Wed Feb 06 13:09:42 MST 2002; extrapolation salem.extrapolation; endpoint age.1.equiv.imp P:/INTAKE/Delaware/Del-Science/scodes/extrapolation.baseline.facilities/extrapolation.age.1.equiv.imp.csv

Table B3-13: EPA's Estimate of Mean Annual Impingement of Fishery Species at Salem Expressed as Yield Lost to Fisheries (in pounds) Extrapolated to Other Transition Zone Facilities.

Facility	Operational Flow (MGD)[b]	Alewife	American Shad	Atlantic Croaker	Blue Crab	Spot	Striped Bass	Weakfish	White Perch	Non-RIS Fishery Species	Total
Salem as extrapolation model[a]	1,722	102	269	33,271	54,556	26,377	39,471	80,294	482	18,258	241,212
Hope Creek	CBI	4	10	1,198	1,964	950	1,421	2,891	17	657	8,685
DuPont	7	0	1	135	222	107	160	326	2	74	981
Edge Moor	782	46	122	15,109	24,775	11,978	17,925	36,464	219	8,292	109,540
Delaware City Refinery	CBI	22	57	7,033	11,532	5,576	8,343	16,973	102	3,860	50,988
Deepwater	105	6	16	2,021	3,314	1,602	2,398	4,877	29	1,109	14,652
Chambers Cogen	37	2	6	715	1,172	567	848	1,725	10	392	5,183
General Chemical Corp.	34	2	5	655	1,074	519	777	1,581	9	359	4,749
SPI Polyols	5	0	1	97	158	77	115	233	1	53	700
Sun Refining	6	0	1	116	190	92	138	280	2	64	840
Logan Generating Co.	2	0	0	39	63	31	46	93	1	21	280
Hay Road	2	0	0	31	51	25	37	75	0	17	224
Totals	--	185	489	60,419	99,071	47,899	71,678	145,812	875	33,157	438,034

[a] Based on EPA's estimate of Salem's average impingement assuming no impingement survival (see Table B3-11). Salem's data for 1996 was not included because the facility was shut down much of the year.

[b] Current operational flows from results of EPA's survey of the industry were used for all facilities except for Hay Road, Chambers Cogen, SPI Polyols, Sun Refining, and Salem. For Hay Road, Chamberts Cogen, SPI Polyols, Sun Refining, and Salem the average intake flow was used based on the EIA data presented in Chapter B1. For Salem, EPA used the average operational flow for 1978-1998 (excluding 1996, when the facility was shut down).

0 = Sampled, but none collected.

CBI = Confidential Business Information.

Non-RIS species are listed in Table B3-1.

Wed Feb 06 13:09:35 MST 2002; extrapolation salem100.extrapolation; endpoint yield.lbs.imp P:/INTAKE/Delaware/Del-Science/scodes/extrapolation.baseline.facilities/extrapolation.yield.lbs.imp.csv

Table B3-14: EPA's Estimate of Mean Annual Impingement at Salem Expressed as Production Foregone (in pounds) Extrapolated to Other Transition Zone Facilities.

Facility	Operational Flow (MGD)[b]	Alewife	American Shad	Atlantic Croaker	Bay Anchovy	Blue Crab	Blueback herring	Spot	Striped Bass	Weak-fish	White Perch	Non-RIS Fishery Species	Non-RIS Forage Species	Total
Salem as extrapolation model[a]	1,722	5,334	6,931	93,769	1,850	318,159	15,283	79,316	91,414	204,299	35,017	66,815	1,624	875,327
Hope Creek	CBI	192	250	3,376	67	11,455	550	2,856	3,291	7,356	1,261	2,406	58	31,516
DuPont	7	22	28	381	8	1,293	62	322	372	830	142	272	7	3,558
Edge Moor	782	2,422	3,148	42,583	840	144,483	6,940	36,019	41,513	92,777	15,902	30,342	737	397,506
Delaware City Refinery	CBI	1,128	1,465	19,821	391	67,253	3,231	16,766	19,323	43,185	7,402	14,124	343	185,028
Deepwater	105	324	421	5,696	112	19,326	928	4,818	5,553	12,410	2,127	4,059	99	53,170
Chambers Cogen	37	115	149	2,015	40	6,836	328	1,704	1,964	4,390	752	1,436	35	18,808
General Chemical Corp.	34	105	136	1,846	36	6,263	301	1,561	1,800	4,022	689	1,315	32	17,232
SPI Polyols	5	15	20	272	5	924	44	230	265	593	102	194	5	2,542
Sun Refining	6	19	24	327	6	1,109	53	276	319	712	122	233	6	3,050
Logan Generating Co.	2	6	8	109	2	370	18	92	106	237	41	78	2	1,017
Hay Road	2	5	6	87	2	296	14	74	85	190	33	62	2	813
Totals	--	9,687	12,587	170,282	3,360	577,767	27,753	144,036	166,004	371,001	63,591	121,334	2,948	1,589,567

[a] Based on EPA's estimate of Salem's average impingement assuming no impingement survival (see Table B3-11). Salem's data for 1996 was not included because the facility was shut down much of the year.

[b] Current operational flows from results of EPA's survey of the industry were used for all facilities except for Hay Road, Chambers Cogen, SPI Polyols, Sun Refining, and Salem. For Hay Road, Chamberts Cogen, SPI Polyols, Sun Refining, and Salem the average intake flow was used based on the EIA data presented in Chapter B1. For Salem, EPA used the average operational flow for 1978-1998 (excluding 1996, when the facility was shut down).

CBI = Confidential Business Information.

Non-RIS species are listed in Table B3-1.

Wed Feb 06 13:09:38 MST 2002 extrapolation salem100.extrapolation; endpoint pf.lbs.imp P:/INTAKE/Delaware/Del-Science/scodes/extrapolation.baseline.facilities/extrapolation.pf.lbs.imp.csv

Table B3-15: EPA's Estimate of Mean Annual Entrainment at Salem Expressed as Numbers of Age 1 Equivalents Extrapolated to Other Transition Zone Facilities.

Facility	Operational Flow (MGD)[b]	Ale-wife	American Shad	Atlantic Croaker	Atlantic Men-haden	Bay Anchovy	Blue-back herring	Silver-sides	Spot	Striped Bass	Weakfish	White Perch	Non-RIS Fishery Species	Non-RIS Forage Species	Total
Salem as extrapolation model[a]	1,722	1,567	70	16,454,185	2,346,168	290,409,647	6,745	107,867	23,848,126	419,505	1,215,517	1,211,578	13,879,726	6,423,701	339,404,878
Hope Creek	CBI	56	3	592,427	84,473	10,456,096	243	3,884	858,643	15,104	43,764	43,622	499,735	231,283	12,220,152
DuPont	7	6	0	66,887	9,537	1,180,527	27	438	96,944	1,705	4,941	4,925	56,422	26,113	1,379,695
Edge Moor	782	711	32	7,472,226	1,065,449	131,881,733	3,063	48,985	10,829,985	190,507	551,994	550,206	6,303,104	2,917,151	154,131,600
Delaware City Refinery	CBI	331	15	3,478,120	495,938	61,387,405	1,426	22,801	5,041,067	88,676	256,939	256,106	2,933,926	1,357,856	71,744,121
Deepwater	105	95	4	999,482	142,514	17,640,447	410	6,552	1,448,614	25,482	73,835	73,595	843,101	390,197	20,616,580
Chambers Cogen	37	34	1	353,545	50,411	6,239,929	145	2,318	512,416	9,014	26,117	26,033	298,229	138,024	7,292,672
General Chemical Corp.	34	31	1	323,924	46,188	5,717,124	133	2,124	469,484	8,259	23,929	23,852	273,242	126,460	6,681,664
SPI Polyols	5	5	0	47,776	6,812	843,234	20	313	69,245	1,218	3,529	3,518	40,301	18,652	985,496
Sun Refining	6	5	0	57,332	8,175	1,011,880	24	376	83,095	1,462	4,235	4,222	48,361	22,382	1,182,595
Logan Generating Co.	2	2	0	19,111	2,725	337,293	8	125	27,698	487	1,412	1,407	16,120	7,461	394,198
Hay Road	2	1	0	15,288	2,180	269,835	6	100	22,159	390	1,129	1,126	12,896	5,969	315,359
Totals	--	2,845	126	29,880,303	4,260,570	527,375,149	12,249	195,883	43,307,476	761,808	2,207,343	2,200,189	25,205,163	11,665,247	616,349,010

[a] Based on EPA's estimate of Salem's average entrainment assuming no entrainment survival (see Table B3-7). Salem's data for 1996 was not included because the facility was shut down much of the year.

[b] Current operational flows from results of EPA's survey of the industry were used for all facilities except for Hay Road, Chambers Cogen, SPI Polyols, Sun Refining, and Salem. For Hay Road, Chamberts Cogen, SPI Polyols, Sun Refining, and Salem the average intake flow was used based on the EIA data presented in Chapter B1. For Salem, EPA used the average operational flow for 1978-1998 (excluding 1996, when the facility was shut down).

0 = Sampled, but none collected.

CBI = Confidential Business Information.

Non-RIS species are listed in Table B3-1.

Wed Feb 06 13:09:43 MST 2002 extrapolation salem100.extrapolation; endpoint age.1.equiv.ent P:/INTAKE/Delaware/Del-Science/scodes/extrapolation.baseline.facilities/extrapolation.age.1.equiv.ent.csv

Table B3-16: EPA's Estimate of Mean Annual Entrainment of Fishery Species at Salem Expressed as Yield Lost to Fisheries (in pounds) Extrapolated to Other Transition Zone Facilities.

Facility	Operational Flow (MGD)[b]	Alewife	American Shad	Atlantic Croaker	Atlantic Menhaden	Silversides	Spot	Striped Bass	Weakfish	White Perch	Non-RIS Fishery Species	Total
Salem as extrapolation model[a]	1,722	14	17	3,349,863	1,177,437	43	2,670,978	582,257	955,624	533	1,239,935	8,943,422
Hope Creek	CBI	1	1	120,611	42,393	2	96,168	20,964	34,407	19	44,643	322,005
DuPont	7	0	0	13,617	4,786	0	10,858	2,367	3,885	2	5,040	36,355
Edge Moor	782	6	8	1,521,250	534,701	20	1,212,953	264,416	433,971	242	563,083	4,061,415
Delaware City Refinery	CBI	3	4	708,101	248,889	9	564,597	123,079	202,002	113	262,100	1,890,479
Deepwater	105	1	1	203,482	71,521	3	162,244	35,368	58,048	32	75,318	543,253
Chambers Cogen	37	0	0	71,977	25,299	1	57,390	12,511	20,533	11	26,642	192,164
General Chemical Corp.	34	0	0	65,947	23,180	1	52,582	11,463	18,813	10	24,410	176,064
SPI Polyols	5	0	0	9,727	3,419	0	7,755	1,691	2,775	2	3,600	25,968
Sun Refining	6	0	0	11,672	4,103	0	9,307	2,029	3,330	2	4,320	31,162
Logan Generating Co.	2	0	0	3,891	1,368	0	3,102	676	1,110	1	1,440	10,387
Hay Road	2	0	0	3,113	1,094	0	2,482	541	888	0	1,152	8,310
Totals	--	25	31	6,083,251	2,138,189	79	4,850,415	1,057,361	1,735,384	968	2,251,685	16,240,984

[a] Based on EPA's estimate of Salem's average entrainment assuming no entrainment survival (see Table B3-7). Salem's data for 1996 was not included because the facility was shut down much of the year.

[b] Current operational flows from results of EPA's survey of the industry were used for all facilities except for Hay Road, Chambers Cogen, SPI Polyols, Sun Refining, and Salem. For Hay Road, Chamberts Cogen, SPI Polyols, Sun Refining, and Salem the average intake flow was used based on the EIA data presented in Chapter B1. For Salem, EPA used the average operational flow for 1978-1998 (excluding 1996, when the facility was shut down).

0 = Sampled, but none collected.

CBI = Confidential Business Information.

Non-RIS species are listed in Table B3-1.

Wed Feb 06 13:09:36 MST 2002 extrapolation salem100.extrapolation; endpoint yield.lbs.ent P:/INTAKE/Delaware/Del-Science/scodes/extrapolation.baseline.facilities/extrapolation.yield.lbs.ent.csv

Table B3-17: EPA's Estimate of Mean Annual Entrainment at Salem Expressed as Production Foregone (in pounds) Extrapolated to Other Transition Zone Facilities.

Facility	Operational Flow (MGD)[b]	Alewife	American Shad	Atlantic Croaker	Atlantic Menhaden	Bay Anchovy	Blueback herring	Silver-sides	Spot	Striped Bass	Weakfish	White Perch	Non-RIS Fishery Species	Non-RIS Forage Species	Total
Salem as extrapolation model[a]	1,722	6,865	1,745	9,352,996	205,337	7,043,992	15,361	12	6,421,484	3,133,998	3,575,891	314,670	16,152,785	418,599	32,834,248
Hope Creek	CBI	247	63	336,751	7,393	253,616	553	0	231,203	112,839	128,749	11,330	581,575	15,072	1,182,185
DuPont	7	28	7	38,020	835	28,634	62	0	26,104	12,740	14,536	1,279	65,662	1,702	133,473
Edge Moor	782	3,117	793	4,247,411	93,248	3,198,839	6,976	6	2,916,144	1,423,221	1,623,895	142,899	7,335,353	190,096	14,910,791
Delaware City Refinery	CBI	1,451	369	1,977,056	43,405	1,488,974	3,247	3	1,357,387	662,471	755,879	66,516	3,414,410	88,484	6,940,573
Deepwater	105	417	106	568,132	12,473	427,875	933	1	390,062	190,369	217,211	19,114	981,174	25,427	1,994,461
Chambers Cogen	37	148	38	200,964	4,412	151,352	330	0	137,976	67,339	76,834	6,761	347,069	8,994	705,498
General Chemical Corp.	34	135	34	184,127	4,042	138,671	302	0	126,416	61,697	70,396	6,195	317,990	8,241	646,389
SPI Polyols	5	20	5	27,157	596	20,453	45	0	18,645	9,100	10,383	914	46,901	1,215	95,338
Sun Refining	6	24	6	32,589	715	24,544	54	0	22,375	10,920	12,460	1,096	56,281	1,459	114,405
Logan Generating Co.	2	8	2	10,863	238	8,181	18	0	7,458	3,640	4,153	365	18,760	486	38,135
Hay Road	2	6	2	8,690	191	6,545	14	0	5,967	2,912	3,323	292	15,008	389	30,508
Totals	--	12,466	3,170	16,984,758	372,886	12,791,676	27,895	23	11,661,222	5,691,246	6,493,709	571,431	29,332,970	760,164	59,626,003

[a] Based on EPA's estimate of Salem's average entrainment assuming no entrainment survival (see Table B3-7). Salem's data for 1996 was not included because the facility was shut down much of the year.

[b] Current operational flows from results of EPA's survey of the industry were used for all facilities except for Hay Road, Chambers Cogen, SPI Polyols, Sun Refining, and Salem. For Hay Road, Chamberts Cogen, SPI Polyols, Sun Refining, and Salem the average intake flow was used based on the EIA data presented in Chapter B1. For Salem, EPA used the average operational flow for 1978-1998 (excluding 1996, when the facility was shut down).

0 = Sampled, but none collected.

CBI = Confidential Business Information.

Non-RIS species are listed in Table B3-1.

Wed Feb 06 13:09:40 MST 2002 extrapolation salem100.extrapolation; endpoint pf.lbs.ent P:/INTAKE/Delaware/Del-Science/scodes/extrapolation.baseline.facilities/extrapolation.pf.lbs.ent.csv

Table B3-18: Salem's Current Impingement Rate Expressed as Numbers of Age 1 Equivalents.

Year	Alewife +21% *Alosa* spp.	American Shad	Atlantic Croaker	Bay Anchovy	Blue Crab	Blueback Herring +79% *Alosa* spp.	Spot	Striped Bass +58% *Morone* spp.	Weakfish	White Perch +42% *Morone* spp.	Non-RIS Fishery Species	Non-RIS Forage Species
1995	2,054	10	151,250	400,287	837,514	18,864	38,554	6,713	35,243	247,600	256,295	2,728,877
1997	941	1	58,241	299,061	286,356	7,480	15,640	6,312	66,917	161,697	302,775	964,074
1998	3,412	1,142	485,999	876,041	282,114	12,061	2,673	4,890	65,409	93,927	88,394	747,858
Mean	2,136	384	231,830	525,130	468,661	12,802	18,956	5,972	55,856	167,741	215,821	1,480,270
Min	941	1	58,241	299,061	282,114	7,480	2,673	4,890	35,243	93,927	88,394	747,858
Max	3,412	1,142	485,999	876,041	837,514	18,864	38,554	6,713	66,917	247,600	302,775	2,728,877
SD	1,238	656	224,976	308,084	319,442	5,728	18,168	958	17,867	77,014	112,776	1,086,716
Total	6,407	1,153	695,490	1,575,389	1,405,984	38,405	56,867	17,916	167,568	503,224	647,464	4,440,810

Note: Impingement losses expressed as age 1 equivalents are larger than raw losses (the actual number of organisms impinged). This is because the ages of impinged individuals are assumed to be distributed across the interval between the start of year 1 and the start of year 2, and then the losses are normalized back to the start of year 1 by accounting for mortality during this interval (for details, see description of S*j in Chapter A5, Equation 4 and Equation 5). This type of adjustment is applied to all raw loss records, but the effect is not readily apparent among entrainment losses because the majority of entrained fish are younger than age 1.
Non-RIS species are listed in Table B3-1.
Fri Feb 01 16:43:32 MST 2002; Results; I Plant: salem100.benefits; Units: equivalent.sums Pathname:
P:/Intake/Delaware/Del-Science/scodes/tables.output.benefits.baseline/I.equivalent.sums.salem100.benefits.csv

Table B3-19: Salem's Current Impingement of Fishery Species Expressed as Yield Lost to Fisheries (in pounds).

Year	Alewife +21% *Alosa* spp.	American Shad	Atlantic Croaker	Blue Crab	Spot	Striped Bass +58% *Morone* spp.	Weakfish	White Perch +42% *Morone* spp.	Non-RIS Fishery Species
1995	18	2	30,793	26,725	4,318	9,318	27,708	109	22,896
1997	8	0	11,857	9,138	1,752	8,761	52,609	71	27,048
1998	30	280	98,943	9,002	299	6,787	51,423	41	7,897
Mean	19	94	47,198	14,955	2,123	8,289	43,913	74	19,280
Min	8	0	11,857	9,002	299	6,787	27,708	41	7,897
Max	30	280	98,943	26,725	4,318	9,318	52,609	109	27,048
SD	11	161	45,802	10,193	2,035	1,330	14,047	34	10,075
Total	57	282	141,593	44,865	6,369	24,866	131,740	221	57,841

0 = Sampled, but none collected.
Non-RIS species are listed in Table B3-1.
Fri Feb 01 16:43:53 MST 2002; Results; I Plant: salem100.benefits; Units: yield Pathname:
P:/Intake/Delaware/Del-Science/scodes/tables.output.benefits.baseline/I.yield.salem100.benefits.csv

Table B3-20: Salem's Current Impingement Rate Expressed as Production Foregone (in pounds).

Year	Alewife +21% *Alosa* spp.	Americans Shad	Atlantic Croaker	Bay Anchovy	Blue Crab	Blueback Herring +79% *Alosa* spp.	Spot	Striped Bass +58% *Morone* spp.	Weakfish	White Perch +42% *Morone* spp.	Non-RIS Fishery Species	Non-RIS Forage Species
1995	920	242	119,652	284	165,441	5,795	41,326	20,774	77,204	8,423	91,452	2,745
1997	447	25	36,180	242	58,276	2,602	4,280	18,167	139,981	5,094	102,541	741
1998	1,965	6,600	256,217	975	53,341	4,411	2,375	12,814	148,532	3,148	38,158	377
Mean	1,111	2,289	137,350	500	92,353	4,269	15,993	17,252	121,906	5,555	77,383	1,288
Min	447	25	36,180	242	53,341	2,602	2,375	12,814	77,204	3,148	38,158	377
Max	1,965	6,600	256,217	975	165,441	5,795	41,326	20,774	148,532	8,423	102,541	2,745
SD	777	3,735	111,081	412	63,344	1,601	21,959	4,058	38,948	2,667	34,420	1,275
Total	3,332	6,867	412,050	1,501	277,058	12,807	47,980	51,755	365,717	16,665	232,150	3,863

Non-RIS species are listed in Table B3-1.
Fri Feb 01 16:43:43 MST 2002; Results; I Plant: salem100.benefits; Units: annual.prod.forg Pathname: P:/Intake/Delaware/Del-Science/scodes/tables.output.benefits.baseline/I.annual.prod.forg.salem100.benefits.csv

Table B3-21: Summary of Cumulative Impingement Impacts of Delaware Estuary Transition Zone CWIS (sum of annual means of all species evaluated).

Facility	Raw Losses	# of Age 1 Equivalents	Lb of Fishery Yield	Lb of Production Foregone
Salem[a]	6,633,845	3,185,559	135,945	477,249
Hope Creek	—	285,191	8,685	31,516
DuPont	—	32,199	981	3,558
Edge Moor	—	3,597,083	109,540	397.506
Delaware City Refinery	—	1,674,345	50,988	185,028
Deepwater	—	481,144	14,652	53,170
Chambers Cogen	—	170,194	5,183	18,808
General Chemical Corp.	—	155,935	4,749	17,232
SPI Polyols	—	22,999	700	2,542
Sun Refining	—	27,599	840	3,050
Logan Generating Co.	—	9,200	280	1,017
Hay Road	—	7,360	224	813
TOTALS	—	**9,648,808**	**332,767**	**794,381**

[a] Based on EPA's estimate of Salem's current impingement (see Section B3-7).

Table B3-22: Summary of Cumulative Entrainment Impacts of Delaware Estuary Transition Zone CWIS (sum of annual means of all species evaluated).

Facility	Raw Losses	# of Age 1 Equivalents	Lb of Fishery Yield	Lb of Production Foregone
Salem[a]	14,660,055,610	338,955,960	9,569,550	45,208,635
Hope Creek	—	12,220,152	322,005	1,182,185
DuPont	—	1,379,695	36,355	133,473
Edge Moor	—	154,131,600	4,061,415	14,910,791
Delaware City Refinery	—	71,744,121	1,890,479	6,940,573
Deepwater	—	20,616,580	543,253	1,994,461
Chambers Cogen	—	7,292,672	192,164	705,498
General Chemical Corp.	—	6,681,664	176,064	646,389
SPI Polyols	—	985,496	25,968	95,338
Sun Refining	—	1,182,595	31,162	114,405
Logan Generating Co.	—	394,198	10,387	38,135
Hay Road	—	315,359	8,310	30,508
TOTALS	—	**615,900,092**	**16,867,112**	**72,000,391**

[a] Based on EPA's estimate of Salem's current entrainment (see Section B3-7).