Chapter D3: Evaluation of I&E Data

Although I&E data are available for the Big Bend facility, I&E data have not been collected at any other Tampa Bay CWIS. Thus, to estimate the potential cumulative impacts of all in-scope facilities of Tampa Bay, EPA extrapolated Big Bend's I&E rates to other Tampa Bay CWIS, as described in this chapter. Section D3-1 lists fish and shellfish species that are impinged and entrained at Big Bend, Section D3-2 summarizes the life histories of the species most often impinged and entrained, and Section D3-3 describes the methods used by Big Bend to estimate I&E. Section D3-4 presents results of EPA's analysis of annual impingement at Big Bend, and Section D3-5 presents annual entrainment results. Section D3-6 outlines the methods used by EPA to extrapolate Big Bend's I&E rates to other in-scope facilities in Tampa Bay. Section D3-7 presents impingement extrapolations, Section D3-8 presents entrainment extrapolations, and Section D3-9 summarizes the cumulative I&E impacts of all in-scope CWIS of Tampa Bay. The methods used by EPA to analyze I&E data are described in Chapter A5 of Part A of this document.

CHAPTER CONTENTS

D3-1 Tampa Bay Aquatic Species Vulnerable to I&E

EPA evaluated aquatic species impinged and entrained at Big Bend, including commercial, recreational, and forage species, based on information provided in facility I&E monitoring reports. Approximately 85 different species of aquatic organisms, including fish, crustaceans, and mollusks, were identified in I&E collections at Big Bend in 1976-1977 and 1979-1980 (Conservation Consultants Inc, 1977; U.S. EPA, 1981). Table D3-1 lists major species identified in Big Bend's I&E collections and their status as commercial, recreational, or forage species. EPA evaluated all species with commercial and recreational value and available site specific life history information. EPA did not evaluate species which did not meet these criteria and which had impingement numbers less than 5 percent of the facility total or entrainment numbers less than 7 percent of the facility total.

Table D3-1: Major Aquatic Species Vulnerable to I&E at the Big Bend Facility in Tampa Bay

Common Name	Scientific Name	Commercial	Recreational	Forage
Atlantic blue crab	*Callinectes sapidus*	X	X	
Atlantic bumper	*Chloroscombrus chrysurus*			X
Atlantic spadefish	*Chaetodipterus faber*			X
Bay anchovy	*Anchoa mitchilli*			X
Black drum	*Pogonias cromis*	X	X	
Blackcheek tonguefish	*Symphurus plagiusa*			X
Chain pipefish	*Syngnathus louisianae*			X
Clown goby	*Microgobius gulosus*			X
Code goby	*Gobiosoma robustum*			X
Dusky pipefish	*Syngnathus floridae*			X
Feather blenny	*Hypsoblennius hentzi*			X
Florida stone crab	*Menippe mercenaria*	X	X	
Gulf killifish	*Fundulus grandis grandis*			X
Gulf menhaden	*Brevoortia patronus*	X		
Hogchoker	*Trinectes maculatus*			X
Inland silverside	*Menidia beryllina*			X
Leatherjacket	*Oligoplites saurus*			X
Leopard searobin	*Prionotus scitulus*			X
Lined seahorse	*Hippocampus erectus*			X
Lined sole	*Achirus lineatus*			X
Northern kingfish	*Menticirrhus saxatilis*		X	
Pigfish	*Orthopristis chrysoptera*		X	X
Pinfish	*Lagodon rhomboides*	X	X	
Pink shrimp	*Penaeus duorarum duorarum*	X		
Puffer spp.	*Sphoeroides* spp.	X	X	
Redfin needlefish	*Strongylura notata notata*			X
Rough silverside	*Membras martinica*			X
Sand seatrout	*Cynoscion arenarius*		X	
Scaled sardine	*Harengula jaguana*			X
Sheepshead	*Archosargus probatocephalus*	X	X	
Silver perch	*Bairdiella chrysoura*		X	
Skilletfish	*Gobiesox strumosus*			X
Southern kingfish	*Menticirrhus americanus*		X	
Spotted seatrout	*Cynoscion nebulosus*		X	
Striped anchovy	*Anchoa hepsetus*			X
Tidewater silverside	*Menidia peninsulae*			X
Drum/croaker spp.	Family Sciaenidae	X	X	
Herring spp.	Family Clupeidae			X
Jack/pompano spp.	Family Carangidae			X
Other invertebrates[a]				X

[a] Other invertebrates include other species of shrimp (such as arrow, burrowing, combclaw, glass, grass, longeye, mantis, mud, night, sargassum, snapping, and true shrimp), other species of crab (such as commensal, fiddler, hermit, horseshoe, marsh, mud, mussel, pea, porcelain, spider, and true crab), barnacles, brief squid, isopods, shellfish, sea squirts, segmented worms, and tube worms.

Sources: Conservation Consultants Inc. 1977; U.S. EPA, 1981.

D3-2 LIFE HISTORIES OF PRIMARY SPECIES IMPINGED AND ENTRAINED

Bay anchovy (*Anchoa mitchilli*)

Bay anchovy is a member of the anchovy family, Engraulidae. It is one of the most common species in the Tampa Bay estuary (TBNEP, 1992b), as well as one of the most abundant species in estuaries along the mid-Atlantic region and throughout the Gulf of Mexico (Wang and Kernehan, 1979). Bay anchovy range from Maine to the coastal Gulf of Mexico, and young life stages can be found in every estuary in the Middle Atlantic Bight (Able and Fahay, 1998).

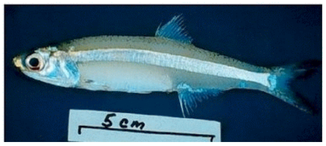
Bay anchovy are present in a wide range of habitats along the western Atlantic coast, from hypersaline ocean waters to tidal fresh waters. They are more commonly found in shallow tidal areas and vegetated areas such as eelgrass beds, feeding on copepods and other zooplankton (Castro and Cowen, 1991). Eggs and larvae may be more common in the higher salinity regions of the Tampa Bay estuary, where salinity is greater than 18 ppt (TBNEP., 1992b).

The spawning period of bay anchovy in Tampa Bay lasts from spring through fall, peaking between April and July (TBNEP, 1992b). A study conducted in Tampa Bay found that spawning began when water temperatures reached 20 ˚C (68 ˚F) and ended by November (TBNEP, 1992b). Spawning typically occurs in water less than 20 m deep (65.6 ft) (Robinette, 1983), and has been correlated with areas of high zooplankton abundance (Able and Fahay, 1998). Icthyoplankton collections conducted in and around Tampa Bay suggest that bay anchovy spawn within the Tampa Bay estuary (TBNEP, 1992b). Spawning generally occurs at night, and during peak spawning periods females may spawn nightly. Fecundity estimates for bay anchovy in mid-Chesapeake Bay were reported at 643 eggs per spawning episode in July 1986 and 731 eggs per spawning episode 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 water 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 (Leak and Houde, 1987).

Early juvenile stages of bay anchovy in Tampa Bay are approximately 15 mm (0.6 in.) (TBENP, 1992b). Individuals hatched early in the season may become sexually mature by their first summer (Robinette, 1983). The average size for adults is approximately 75 mm (2.95 in.) (Morton, 1989). Bay anchovy live for only 1 or 2 years (Zastrow et al., 1991).

There was an important bait fishery for bay anchovy in Tampa Bay until 1993, when the fishery was closed because of a declining population. Bay anchovy remains an important component of the food chain for recreational and commercial fish (Morton, 1989).



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: Fecundity per spawning event is about 700 eggs. During peak spawning periods, females may spawn nightly [c]

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

Prey for: Snook, spotted seatrout, white seatrout, gulf flounder, and lizard fish.[e]

Life stage information:

Eggs: *pelagic*
- Eggs are 0.8-1.3 mm (0.03 to 0.05 in.) in diameter.[a]

Larvae:
- Yolk-sac larvae are 1.8 to 2.0 mm (0.7 to 0.8 in.) on hatching.[a]
- Predation mortality ranges from 18 to 28% per day.[f]

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.[g]

Adults:
- The average adult is 75 mm (2.95 in.) long.[h]

[a] Able and Fahay, 1998.
[b] Castro and Cowen, 1991.
[c] Zastrow et al., 1991.
[d] Dorsey et al., 1996.
[e] TBENP, 1992b.
[f] Leak and Houde, 1987.
[g] Vouglitois et al., 1987.
[h] Morton, 1989.
Fish graphic from NOAA, 2001a.

Atlantic blue crab (*Callinectes sapidus*)

Blue crab belongs to the family Portunidae, also known as swimming crabs (Churchill, 1921). The Atlantic blue crab can be found in Atlantic coastal waters from Long Island to the Gulf of Mexico (Epifanio, 1995). Blue crabs are most abundant near bays and river mouths, but are found in brackish or fresh water (Churchill, 1921; Tagatz, 1968). In Tampa Bay, megalopal stage crabs are usually found at the base of estuaries or in seagrass beds, and as juveniles mature they migrate up the estuary (TBENP, 1992b). Blue crabs generally are found in shallower water in the summer and deeper water in the winter.

In areas of upper Tampa Bay, blue crab mating occurs from midwinter through spring and in September in low salinity waters of the upper estuary (TBENP, 1992b). Males can mate several times, but females are believed to mate only once (Tagatz, 1968). After mating, females store sperm in seminal receptacles, where sperm can remain viable for up to 1 year. Females then move into the high salinity waters of Tampa Bay or into the Gulf of Mexico to spawn (TBENP, 1992b). Females that mate in the fall usually wait until the following spring to spawn, when water temperatures are warmer (Tagatz, 1968). Spawning peaks in Tampa Bay occur in March or April with a second smaller peak in September (TBENP, 1992b). The eggs are carried externally by the female; during this stage females are referred to as “sponge or berried” (TBENP, 1992b). Although females mate only once, they may spawn more than once (Tagatz, 1968). The second or third spawning usually takes place later in the summer after the first spawning, or in the following spring (Tagatz, 1968; Pattillo et al., 1997). Females usually produce 1 to 2 million eggs per spawning (Tagatz, 1968). Eggs are approximately 0.025 mm (0.001 in.) in diameter (Churchill, 1921).

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 zoeal stage lasts 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).

The diet of the Atlantic blue crab varies with the crab's habitat, its life cycle stage, and the time of the year, and generally depends on what food sources are available (TBENP, 1992b). North of Tampa Bay, in the Apalachicola estuary of Florida, Laughlin (1982) found the primary food source for adult blue crabs to be bivalves. Smaller juveniles fed on plant matter, ostracods (small segmented crustaceans) and detritus, while larger juveniles consumed fishes, gastropods, plants and xanthid crabs. Large juveniles and adults also fed on fishes, xanthid crabs, and smaller blue crabs (Laughlin, 1982). Atlantic blue crab is also an important food source to upper level carnivores (e.g., spotted seatrout), and is a key species in the food web as a scavenger-predator species (TBENP, 1992b).

In Tampa Bay maturity is usually reached at 130-139 mm (5.1-5.5 in.) carapace width for females (TBENP, 1992b). Male crabs reach maturity after 1 year, when they are approximately 89 mm (3.5 in.) carapace width (TBENP, 1992b). The blue crab has a life span of 3 to 4 years (Tagatz, 1968). Causes of mortality include fungal infection, predation, CWIS, or excessively high or low water salinities or temperatures (TBENP, 1992b). Larval mortality is more often the result of water temperature and salinity extremes, whereas juvenile mortality is usually the result of exceeding the estuarine carrying capacity (TBENP, 1992b).

Total annual landings of commercial Atlantic blue crab along the west coast of Florida equaled 2.5 million kg (5.5 million lb) in 1991. Commercial landings of Atlantic blue crab from Tampa Bay contribute approximately 3.6 percent of Florida west coast landings annually (TBNEP, 1992b). In 1987, the proportion of Gulf of Mexico landings to U.S. national landings reached its peak at 38 percent; since 1990, it has declined to less than 30 percent (Pattillo et al., 1997). Landings in the Gulf of Mexico peaked in 1988 at approximately 35.8 million kg (79 million lb) and were approximately 28.1 million kg (62 million lb) in 1996 (NMFS, Fisheries Statistics and Economics Division, Silver Spring, Maryland, personal communication, May 2001).

ATLANTIC BLUE CRAB
(*Callinectes sapidus*)

Family: Portunidae (swimming crabs).

Common names: Blue crab.

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

Lifespan: Up to 4 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 Tampa 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] Adults are prey for fish such as spotted seatrout, red drum, sheepshead, and black drum, as well as raccoons and bird species.[b]

Life stage information:

Eggs:
- Eggs hatch near high tide.[a]

Larvae:
- Larvae are carried out to sea by the current, where they remain for seven molts before returning to estuaries.[a]
- Larvae are carried back into estuaries during the megalops stage

***Adults*:**
- Males prefer the lower salinity in upper parts of the bay, whereas females prefer the mouth of the bay.[a]
- Although mating occurs only once, females may spawn two to three times.[c]

[a] Epifanio, 1995.
[b] TBNEP, 1992b.
[c] Tagatz, 1968.
Graphic from U.S. FDA, 2001.

Spotted seatrout (*Cynoscion nebulosus*)

Spotted seatrout is a member of the drum and croaker family Sciaenidae (Froese and Pauly, 2001). It is commonly found throughout the Gulf of Mexico and ranges along the Atlantic coast from Cape Cod to Florida. As a top carnivore within its ecosystem and a popular sport fish, it is both ecologically and economically important in Tampa Bay (Lassuy, 1983).

Spotted seatrout complete their entire life cycle in inshore waters (Lassuy, 1983), and there is little interestuary movement (Pattillo et al., 1997). Larvae are found in central Tampa Bay, while juveniles and adults are more commonly found in nearshore, vegetated seagrass areas (TBENP, 1992b). Juveniles may also be found in marshes and unvegetated backwater areas (McMichael and Peters, 1989). Historical seagrass bed loss, particularly in Hillsborough Bay and the upper half of Old Tampa Bay, partly accounts for seatrout decline in Tampa Bay. This population may not fully recover until seagrass beds repopulate most of their historical range (TBNEP, 1992b).

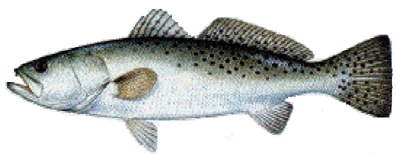
Spotted seatrout spawn in Tampa Bay from early April through October, with two major seasonal peaks in the spring and summer. Minor monthly peaks associated with the full moon also occur (McMichael and Peters, 1989). Based on the distribution of larvae within the Tampa Bay estuary, McMichael and Peters (1989) determined that spawning occurs in the middle and lower bay, and possibly in nearshore gulf waters.

Females may lay up to 0.75 million eggs per spawn, or up to 10 million eggs annually (Thomas, 2001). Eggs of the spotted seatrout are approximately 0.9 mm (0.036 in.) in diameter (Stone and Webster Engineering Corporation, 1980a). Hatching occurs after 40 hours at a water temperature of 25 ˚C (77 ˚F). Larvae hatch out at approximately 1.3 mm (0.05 in.) standard length and become demersal after 4 to 7 days (Lassuy, 1983). Transformation to the juvenile stage occurs at 10 to 12 mm (0.39 to 0.47 in.) (Pattillo et al., 1997).

Most females reach maturity by 220-240 mm (8.7-9.4 in.), while all males are fully mature by 200 mm (7.9 in.) (Pattillo et al., 1997). Estimated maximum ages for spotted seatrout are 6 to 8 years for females and 5 to 9 years for males (Pattillo et al., 1997).

The diet of juvenile spotted seatrout in Tampa Bay consists mainly of copepods. Once the fish reach approximately 15-30 mm (0.6-1.2 in.), they also eat fish and shrimp (McMichael and Peters, 1989). As adults, spotted seatrout are top carnivores, and feed on several fish species in the Tampa Bay estuary, including bay anchovy, silversides, code goby, clown goby, silver perch, and mojarras (McMichael and Peters, 1989; TBENP, 1992b).

Spotted seatrout are a major component of both commercial and recreational fisheries in the Gulf of Mexico. In 1992, 637.8 billion kg (703.1 million tons) of spotted seatrout were landed in the Gulf of Mexico, of which 233.3 billion kg (257.2 million tons) were caught in Florida waters (Pattillo et al., 1997). Landings in Tampa Bay have decreased from approximately 408,000 kg (900,000 lb) in the early 1950's to approximately 91,000 kg (200,000 lb) in the early 1980's, which may be partially attributable to the loss of seagrass habitat in the bay (TBENP, 1992b).



SPOTTED SEATROUT
(*Cynoscion nebulosus*)

Family: Sciaenidae (drum family).

Common names: Spotted seatrout.

Similar species: Weakfish**.**

Lifespan: Up to 8 years for females and 9 years for males.[a]

Geographic range: Atlantic coast from Cape Cod to Florida.[b]

Habitat: Primarily shallow, vegetated seagrass beds within estuaries.[c]

Fecundity: Up to 0.75 million eggs per spawn, or up to 10 million eggs per female annually.[d]

Food source: Copepods, shrimp, and fish, including bay anchovy, silversides, clown goby, silver perch, and mojarras.[c,e]

Prey for: Snook, tarpon, barracuda, Spanish mackerel, king mackerel, bluefish.[f]

Life stage information:

Eggs:
- Eggs are approximately 0.9 mm (0.036 in.) in diameter.[g]

Larvae:
- Larvae are found in the deeper central areas of Tampa Bay.[c]

Adults:
- Decline of spotted seatrout can be attributed to the loss of historical seagrass habitat.[c,f]

[a] Murphy and Taylor, 1994.
[b] Froese and Pauly, 2001.
[c] TBENP, 1992b.
[d] Thomas, 2001.
[e] McMichael and Peters, 1989.
[f] TBNEP, 1992b.
[g] Stone and Webster Engineering Corporation, 1980a.
Graphic from U.S. EPA, 2002b.

Pink shrimp *(Penaeus duorarum duorarum)*

Pink shrimp range from the lower portions of Chesapeake Bay to the Florida Keys and along the Gulf of Mexico (Pérez Farfante, 1969). Large populations are found off the southwestern coast of Florida and the southeast portion of the Gulf of Campeche. Pink shrimp are found in the highest densities at depths of 11 to 35 m (36 to 115 ft), but are abundant to 65 m (213 ft). Individuals have been found as deep as 330 m (1,082 ft) (Pérez Farfante, 1969).

Pink shrimp was separated into two subspecies by Pérez Farfante (Costello and Allen, 1970). *Penaeus duorarum duoarum* inhabits the northwestern Atlantic Ocean and the Gulf of Mexico, whereas *Penaeus duorarum notialis* is found in the Caribbean Sea, the Atlantic coast of South America, and the Atlantic coast of Africa.

Adult pink shrimp prefer firm or hard sandy or mixed substrate bottoms (Williams, 1958; Pérez Farfante, 1969). Juveniles and subadults are more commonly found in seagrass substrates (Ault et al., 1999). Adults can survive in waters ranging from 10 to 35.5 ˚C (50 to 96 ˚F) (Pattillo et al., 1997). Adults are primarily nocturnal, while postlarvae, juveniles, and subadults are active during the day (Pérez Farfante, 1969). Pink shrimp are bottom-feeders, ingesting algae, plants, crustaceans, and fish larvae as well as mud and sand (Pérez Farfante, 1969).

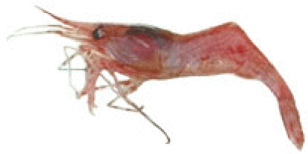
Females reach sexual maturity at approximately 69 to 89 mm (2.7 to 3.5 in.) total length, while males appear to be sexually mature at 65 mm (2.6 in.) total length (Pérez Farfante, 1969). Fecundity increases linearly with body weight, and fecundity for females weighing between 10.1 and 66.8 g (0.4 to 2.4 oz.) has been estimated at 44,000 to 534,000 eggs (Martosubroto, 1974). Pink shrimp move out of the estuary into deeper offshore waters to spawn, usually at depths of 3.5 to 50 m (11.5 to 164 ft) (Pérez Farfante, 1969). Spawning occurs throughout the year, although there is evidence that spawning is more intense during the spring and summer months (Cummings, 1961; Pérez Farfante, 1969). Eggs measure approximately 0.23 to 0.33 mm (0.009 to 0.013 in.) in diameter (Costello and Allen, 1970), and are opaque and yellow-brown.

Pink shrimp develop through several larval stages extending for 15 to 25 days in laboratory studies (Pérez Farfante, 1969). As larvae progress through their various life stages they range in size from nauplii, 0.35 to 0.61 mm (0.013 to 0.024 in.), to protozoeae, 0.86 to 2.7 mm (0.03 to 0.11 in.), to myses, 2.9 to 4.4 mm (0.11 to 0.17 in.) (Costello and Allen, 1970). Larvae are more sensitive to water temperature than adults, growing normally only between 21 and 26 ˚C (69.8 and 78.8 ˚F) (Pattillo et al., 1997).

Advanced larval pink shrimp enter estuaries when they are approximately 8 mm (0.31 in.) (Costello and Allen, 1970). They usually remain for 6-9 months before returning to open water as benthic juveniles, although some individuals may spend little or no time in an estuary (Costello and Allen, 1966; Beardsley, 1970; Allen et al., 1980). A study conducted in the Everglades National Park in Florida indicated that juvenile pink shrimp tend to rise into the surface waters during ebb tides to travel out of estuarine areas (Beardsley, 1970). Mark-recapture studies indicate that offshore adult populations are connected to specific nursery estuaries (Costello and Allen, 1966). Pink shrimp production is highly dependent on survival and growth in these nursery habitats (Sheridan, 1996). The average pink shrimp lives up to 83 weeks, but pink shrimp can potentially live for over 2 years (TBNEP, 1992b).

Pink shrimp are one of the most valuable species of commercial shrimp in the Gulf of Mexico (Pérez Farfante, 1969; Beardsley, 1970; Sheridan, 1996). Annual landings in the gulf through the 1990's averaged about 8,200 metric tons (9,039 tons) (NMFS, Fisheries Statistics and Economics Division, Silver Spring, Maryland, personal communication, May 2001). The pink shrimp fishery off Florida is concentrated in the winter and spring months (Pérez Farfante, 1969). The Tortugas Grounds, off the southwestern coast of Florida, produced an average of 4,525 metric tons (4,988 tons) of shrimp tails between 1960 and 1980 (Sheridan, 1996). However, landings in Tortugas declined for unknown reasons in the 1980's, reaching a low of 2,000 metric tons (2,204 tons). Catches rebounded to over 4,000 metric tons (4,409 tons) by 1994 (Sheridan, 1996).

Ecologically, pink shrimp is an important food source for important gamefish, including the spotted seatrout, snook, mangrove snapper (*Lutjanus griseus*), red grouper (*Epinephelus morio*), black grouper (*Mycteroperca bonaci*), and king mackerel (*Scomberomorus cavalla*). Bottlenose dolphins and many species of wading and diving birds also prey on this organism (TBNEP, 1992b).



PINK SHRIMP
(Penaeus duorarum duorarum)

Family: Palaemonidae.

Common names: Pink shrimp.

Similar species: Pink shrimp (*Penaeus duorarum notialis*).[a]

Lifespan: The average pink shrimp lives up to 83 weeks.[b]

Geographic range: From the lower portions of Chesapeake Bay to the Florida Keys and along the Gulf of Mexico.[a]

Habitat: Prefer firm or hard sandy or mixed substrate bottoms.[a,c]

Fecundity: Fecundity for females weighing between 10.1 and 66.8 g (0.4 to 2.4 oz.) has been estimated at 44,000 to 534,000 eggs.[d]

Food source: Algae, plants, crustaceans, and fish larvae as well as mud and sand.[a]

Prey for: Mangrove snapper, red grouper, black grouper, king mackerel, bottlenose dolphins, and many species of wading and diving birds.[b]

Life stage information:

Eggs:
- Eggs measure approximately 0.23 to 0.33 mm (0.009 to 0.013 in.) in diameter.[e]
- Eggs are opaque and yellow-brown.[e]

Larvae:
- Advanced larval pink shrimp enter estuaries as developmental nurseries when they are approximately 8 mm (0.31 in.).[e]

Adults:
- Pink shrimp are one of the most valuable species of commercial shrimp in the Gulf of Mexico.[a,f,g]

[a] Pérez Farfante, 1969.
[b] TBNEP, 1992b.
[c] Williams, 1958.
[d] Martosubroto, 1974.
[e] Costello and Allen, 1970.
[f] Beardsley, 1970.
[g] Sheridan, 1996.
Graphic from NOAA, 2002b.

Silver perch (*Bairdiella chrysoura*)

Silver perch is a member of the family Sciaenidae. It ranges along the Atlantic coast from New York to Florida, and throughout the Gulf of Mexico (Froese and Pauly, 2001). Of the 13 species of sciaenids in Tampa Bay, silver perch is one of the most abundant (TBENP, 1992b). Though silver perch are of little recreational and commercial value, they are an important component of the food chain as both a benthic predator and prey species of high abundance.

Silver perch spawn year-round in Tampa Bay and south Florida estuaries, with larval peaks occurring in April and May (TBENP, 1992b). Spawning seems to occur in deeper areas of bays and estuaries, although eggs have been found in offshore waters. A study of 11 females weighing between 55.3 and 123.8 g (1.95 and 4.37 oz.) found an average fecundity of 90,407 eggs (Pattillo et al.,1997).

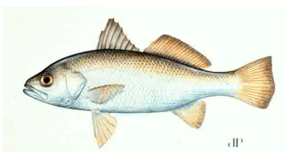
Eggs are buoyant and range from 0.59 to 0.82 mm (0.02 to 0.03 in.) in diameter (Pattillo et al.,1997). Incubation at a water temperature of 20 ˚C lasts approximately 40 to 50 hours, while incubation at 27 ˚C lasts approximately 18 hours (Pattillo et al.,1997). Yolk-sac larvae hatch out at 1.5 to 1.9 mm (0.06 to 0.07 in.). The newly-hatched larvae remain planktonic for several weeks and sink to the bottom after reaching 8 to 25 mm (0.3 to 1.0 in.). Larvae abundance peaks in April and May, but secondary peaks also occur in August, September, and January. Small juvenile silver perch less than 3.0 cm (1.2 in.) long are present during most months in Tampa Bay (TBNEP, 1992b). Silver perch reach the juvenile stage at 10 to 12 mm (0.39

to 0.47 in.). The growth rate for juveniles during May through November is approximately 15 mm (0.59 in.) per month (Pattillo et al., 1997).

Juveniles tend to prefer structural habitats such as seagrass beds, rocks, piers, jetties, and seawalls. They are often numerically dominant in seagrass beds throughout Tampa Bay (TBNEP, 1992b). In warmer months, shallow areas are preferred. During the colder months, large juveniles and adults move to deeper bay or offshore waters. Adult silver perch are most often found in shallow coastal areas outside Tampa Bay, where salinities exceed 30 ppt (TBNEP, 1992b).

Sexual maturity is reached within the first year in the southern parts of its range. Maturity occurs at approximately 95 mm (3.7 in.) for both males and females (Pattillo et al., 1997). Silver perch may live up to 6 years, and can reach approximately 240 mm (9.4 in.) (Pattillo et al., 1997).

The silver perch is a benthic carnivore. Smaller juveniles (7 to 20 mm, 0.3 to 0.8 in.) feed primarily on crustaceans such as copepods, mysids, amphipods, gammarids, shrimp, and crab larvae. Large juveniles and adults feed mainly on mysids, fish, and shrimp (TBNEP, 1992b). The silver perch is a known prey species for juvenile spotted seatrout in Tampa Bay (TBNEP, 1992b).



SILVER PERCH
(*Bairdiella chrysoura*)

Family: Sciaenidae.

Common names: Silver perch, silver croaker.

Similar species: Blue croaker.

Lifespan: May live up to 6 years.[a]

Geographic range: Along the Atlantic coast from New York to Florida, and throughout the Gulf of Mexico.[b]

Habitat: Prefer structural habitats such as seagrass beds, rocks, piers, jetties, and seawalls.[c]

Fecundity: A study of 11 females weighing between 55.3 and 123.8 g (1.95 to 4.37 oz.) found an average fecundity of 90,407 eggs.[a]

Food source: Juveniles feed primarily on crustaceans such as copepods, mysids, amphipods, gammarids, shrimp, and crab larvae. Large juveniles and adults feed mainly on mysids, fish, and shrimp.[c]

Prey for: Juvenile spotted seatrout.[c]

Life stage information:

Eggs:
- Eggs range from 0.59 to 0.82 mm (0.02 to 0.03 in.) in diameter.[a]

Larvae:
- Newly hatched larvae remain planktonic for several weeks and sink to the bottom after reaching 8 to 25 mm (0.3 to 1.0 in.).[c]

Juveniles:
- Small juvenile silver perch less than 3.0 cm (1.2 in.) long are present during most months in Tampa Bay.[c]

***Adults*:**
- Adults are most often found in shallow coastal areas outside Tampa Bay.[c]

[a] Pattillo et al.,1997.
[b] Froese and Pauly, 2001.
[c] TBNEP, 1992b.
Graphic from Florida Fish and Wildlife Conservation Commission, 2002a.

Black drum *(Pogonias cromis)*

Black drum is one of the largest members of the family Sciaenidae (Maryland Department of Natural Resources Fisheries Service, 2002). They are found from the Bay of Fundy south to Argentina (Fitzhugh et al., 1993). Black drum is a schooling species, with a maximum abundance in the northern Gulf of Mexico. Schools estimated at hundreds of tons of black drum have been observed in this area (Nieland and Wilson, 1993). Adults are found in offshore waters and enter estuarine habitats only to spawn (Maryland Department of Natural Resources Fisheries Service, 2002).

Female black drum reach maturity at approximately 628 to 699 mm (24.7 to 27.5 in.), corresponding to ages 5-6, and few individuals reach maturity before age 5 (Murphy and Taylor, 1989; Nieland and Wilson, 1993). Males mature when slightly smaller (450 to 499 mm, 17.7 to19.6 in.) and younger (2 years) than females (Murphy and Taylor, 1989)

Males and females are spatially segregated for much of the year. Fitzhugh et al. (1993) observed higher proportions of males in offshore waters and higher proportions of females in inshore waters between November and May, the period of reproductive development and spawning.

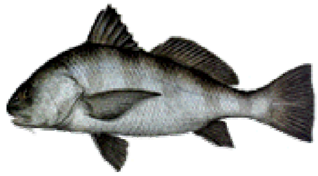
Mature adults enter estuaries to spawn (Wang and Kernehan, 1979). Spawning in Tampa Bay takes place primarily in the lower bay or nearshore waters, during the evening (Peters and McMichael, 1990; Saucier and Baltz, 1993). Females spawn approximately every 3-4 days from November to May (Fitzhugh et al., 1993), and spawning peaks in April or March (Murphy and Taylor, 1989). Nieland and Wilson (1993) estimated that annual fecundity per female ranged from 13 million eggs for a small (5 kg, 11 lb) age 11 female to 67 million eggs for a large (11.5 kg, 25.4 lb) age 19 female. Overall mean annual fecundity in 3 years of studies was 38 million ova per female.

Black drum eggs are buoyant and float on the surface (Saucier and Baltz, 1993). Eggs are approximately 0.8 to 1.0 mm (0.3 to 0.4 in.) in diameter (Wang and Kernehan, 1979). Eggs hatch after approximately 24 hours if waters are 20 ˚C (Pattillo et al., 1997).

Larval development occurs in estuarine environments. Larvae inhabit bottom waters during the day and rise to upper areas of the water column at night. In Tampa Bay, larvae are most abundant in late March. Larvae in Tampa Bay measure approximately 1.8 to 7.3 mm (0.07 to 0.29 in.). Juveniles range from 10 to 210 mm (0.39 to 8.27 in.). When they reach 100 mm (3.94 in.), juveniles disperse throughout Tampa Bay (Peters and McMichael, 1990). Adults can live up to 50 to 60 years (Murphy and Taylor, 1989).

The feeding habits of black drum change with maturity (Peters and McMichael, 1990). Larval black drum feed on copepods, while juveniles focus primarily on mollusks and amphipods. Adults mainly consume bivalves and gastropods. Black drum larger than 30 mm will also consume fish.

Black drum are harvested commercially and recreationally in the Gulf of Mexico (Leard et al., 1993). The popularity of the fishery increased through the late 1970's and 1980's, most likely because of increased regulation of other species such as red drum (*Sciaenops ocellatus*), expanding markets, and changes in preference. Annual landings in the Gulf of Mexico averaged about 3,000 metric tons (3,306 tons) between 1981 and 1990 (NMFS, Fisheries Statistics and Economics Division, Silver Spring, Maryland, personal communication, May 2001). Pressures on the black drum fishery may increase because of further catch restrictions on other gulf species (Beckman et al., 1990). However, evidence suggests that the species would not support intensive fishery because of slow growth associated with its longevity (Murphy and Taylor, 1989). Landings were somewhat lower in the 1990's than in the 1980's, averaging about 2,000 metric tons (2,204 tons; NMFS, Fisheries Statistics and Economics Division, Silver Spring, Maryland, personal communication, May 2001).



BLACK DRUM
(*Pogonias cromis*)

Family: Sciaenidae (drums and croakers).

Common names: Black drum, striped drum.

Similar species: Red drum**.**

Lifespan: Adults can live up to 50 to 60 years.[a]

Geographic range: From the Bay of Fundy south to Argentina.[b]

Habitat: Adults are found in offshore waters and enter estuarine habitats only to spawn.[c]

Fecundity: Can range from 13 million eggs for a small female to 67 million eggs for a large female.[d]

Food source: Larval black drum feed on copepods, while juveniles focus primarily on mollusks and amphipods. Adults mainly consume bivalves and gastropods. Black drum larger than 30 mm will also consume fish.[e]

Prey for: Larger carnivorous fish species.

Life stage information:

Eggs:
- Eggs are buoyant and float on the surface.[f]

Larvae:
- In Tampa Bay, larvae are most abundant in late March.[e]

***Adults*:**
- One of the largest members of the family Sciaenidae.[c]

[a] Murphy and Taylor, 1989.
[b] Fitzhugh et al., 1993.
[c] Maryland Department of Natural Resources Fisheries Service, 2002.
[d] Nieland and Wilson, 1993.
[e] Peters and McMichael, 1990.
[f] Saucier and Baltz, 1993.
Graphic from U.S. EPA, 2002b.

Florida stone crab *(Menippe mercenaria)*

Stone crabs are members of the Xanthadae crab family. The Florida stone crab *(Menippe mercenaria*) and the Gulf stone crab (*M. adina*) are found in the Gulf of Mexico. The Florida stone crab, found in Tampa Bay (Nelson, 1992), ranges from North Carolina, around the peninsula of Florida as far west as the Big Bend region, and as far south as Belize. The Gulf stone crab ranges from the Florida Big Bend region west and south to northern Mexico. The two species are very similar, and they hybridize in overlapping habitats.

Stone crabs are found in coastal marine to estuarine environments. They require substrate suitable for refuge, using available cover such as pilings, seagrass beds, and rocky areas (Bert and Stevely, 1989). Stone crabs will also dig burrows as deep as 1 m (3.3 ft) or more, primarily enlarging existing structures (Beck, 1995a). Juveniles are often found on oyster clumps (Wilber and Herrnkind, 1986). Lack of habitat complexity adversely affects stone crab growth and fecundity (Beck, 1995a).

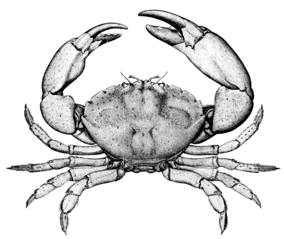
Stone crabs are nocturnal, and feed on gastropods, bivalves, and small crustaceans (Wilber and Herrnkind, 1986). They migrate from intertidal areas in the fall to overwinter in deeper subtidal waters, most likely to avoid cooler temperatures associated with shallow waters in winter.

Mating pairs of stone crabs are found in the spring and fall, and the highest densities of gravid females occur in August (Bert and Stevely, 1989). In southwestern Florida, Sullivan (1979) reported that spawning peaked in May and September, and spawning activity increased when water temperature rose above 20 ˚C (68 ˚F). Ovarian development is also correlated with local water temperature, with optimal development at 28 ˚C (82.4 ˚F) (Cheung, 1969). Females carry egg masses of up to 500,000 eggs, dependent on body size (Beck, 1995a). After hatching one egg mass, a female may deposit another within a week (Lindberg and Marshall, 1984). Spawning may occur up to six successive times without another mating. The sticky eggs are attached to the female until larvae are hatched in approximately 9 to 14 days (Lindberg and Marshall, 1984).

Stone crab larvae are free-swimming and planktonic (Bert et al., 1978). Larvae pass through five zoeal stages, reaching the first crab stage in approximately 27 to 30 days (Lindberg and Marshall, 1984). Larvae have very low survival rates due primarily to predation from fish and other zooplankton (Bert et al., 1978). A water temperature of 30 ˚C (86 ˚F) and salinities of 30 to 35 ppt are optimal for growth and survival. Juveniles molt every 40 days for approximately 320 days until the adult form is achieved at a carapace width of about 35 mm (1.4 in.). Predators of juvenile stone crabs include the mud crab (*Neopanope taxana*), species of grouper, and black seabass (*Centropristis striata*) (Bert et al., 1978).

Adult males and females can grow to a carapace width of 130 and 145 mm (5.1 and 5.7 in.) for females and males, respectively (Lindberg and Marshall, 1984), and may live up to 8 years or more (Restrepo, 1989). Predators of adult stone crabs include species of octopi, the Florida horse conch (*Pleuroploca gigantea*), and sea turtles (Bert et al., 1978).

Stone crabs are a highly valuable commercial species. During the 1981-1982 season, annual landings in Florida were at a high of 1.2 million kg (2.6 million lb) of claws (Williams and Felder, 1986). Florida landings in 1990 were valued at over $15 million (Restrepo, 1992). The fishery is unique in that the large claws are removed and the crabs are released, meaning that they do not necessarily die from harvesting (Restrepo, 1992). Males have larger claws and thus are most likely to be harvested (Restrepo, 1989). Males are generally 2.25 years old at entry to the fishery. Claw regeneration to the legal size of 70 mm propodus length may take more than a year (Restrepo, 1992).



FLORIDA STONE CRAB
(*Menippe mercenaria*)

Family: Xanthadae.

Common names: Florida stone crab.

Similar species: Gulf stone crab (*Menippe adina).*

Lifespan: May live up to 8 years or more.[a]

Geographic range: From North Carolina, around the peninsula of Florida as far west as the Big Bend region, and as far south as Belize.[b]

Habitat: Pilings, seagrass beds, and rocky areas.[c]

Fecundity: Females carry egg masses of up to 500,000 eggs, dependent on body size.[d]

Food source: Feed on gastropods, bivalves, and small crustaceans.[e]

Prey for: Juveniles are prey for mud crab, grouper, and black sea bass. Adults are prey for species of octopi, the Florida horse conch, and sea turtles.[f]

Life stage information:

Eggs:
- The sticky eggs are attached to the female until larvae are hatched in approximately 9 to 14 days.[g]

Larvae:
- Larvae are free-swimming and planktonic.
- Larvae pass through five zoeal stages reaching the first crab stage in approximately 27 to 30 days.[g]

***Adults*:**
- The large claws of adults are harvested and the adults are thrown back to regenerate new claws. Claw regeneration to the legal size of 70 mm propodus length may take more than a year.[h]

[a] Restrepo, 1989.
[b] Nelson, 1992.
[c] Bert and Stevely, 1989.
[d] Beck, 1995a.
[e] Wilber and Herrnkind, 1986.
[f] Bert et al., 1978.
[g] Lindberg and Marshall, 1984.
[h] Restrepo, 1992.
Graphic from NOAA, 2002d.

D3-3 Big Bend Impingement and Entrainment Monitoring Methods

I&E data are available for the Big Bend facility for 1976-77 and 1979-80. During this time, only three units were in operation. In 1985, a fourth unit was completed. It was operated with the same flow rate as each of the other three units. As necessary to estimate the current impact of Big Bend with all 4 units operating, EPA extrapolated impingement and entrainment data for units 1-3 to unit 4 based on flow.

Big Bend impingement monitoring

Big Bend conducted impingement sampling for dominant species at 2 week intervals from January 1976 to March 1977 (Conservation Consultants Inc., 1977). Only one of Big Bend's three units was sampled. Every 6 hours during each 24-hour sampling period, the screens were washed and the screenwash was filtered into a 9.7 mm (0.38 in.) mesh basket.

To estimate annual impingement for the facility using the 1976-77 sampling data, EPA first multiplied the single unit rates by 3 and divided the results by the number of sampling days (31). Annual impingement rates for the three existing units were then calculated by multiplying this daily rate by 365. Finally, EPA multiplied these annual rates by 1.33 to represent the annual impingement of the three existing units and a fourth unit of equal flow.

Impingement sampling was also conducted from March 14, 1979, to February 12, 1980 (Stone and Webster Engineering Corporation, 1980a; U.S. EPA, 1981) using methods similar to those used in 1976. Collections were made approximately every 2 weeks over this period of time. The facility estimated annual impingement for the three existing units using a trapezoidal integration, which used the mean impingement of two consecutive sampling periods as the estimated value for all dates that fall between them. Annual estimates for the three existing units were then made assuming that the facility operated at 100 percent load. EPA multiplied these annual rates by 1.33 to represent the annual impingement of the three existing units and a fourth unit of equal flow.

Big Bend entrainment monitoring

Big Bend conducted entrainment sampling at 2 week intervals from January 1976 to March 1977 (Conservation Consultants Inc., 1977). Entrainment at units 1-3 was estimated from samples collected at the plant discharge within the discharge flume. Samples were collected with a metered plankton net with a 363 μm (0.014 in.) mesh and 1 m (3.3 ft) mouth diameter towed at 2 knots. All larvae were sorted and placed in vials, and later reexamined to confirm sorting (except for bay anchovy because they were too plentiful). Three random 10 mL aliquots were withdrawn from each sample and sorted for eggs. If there were 100 or more eggs of a species in an aliquot, the number of eggs was used to extrapolate the number of eggs in the entire sample on a volume basis. For species with less than 100 eggs in the first aliquot, the entire sample was sorted. Identification was made to the lowest taxon possible. A constant flow rate of 15.21 m^3/sec was assumed for each of the three units.

The facility estimated entrainment by normalizing the number of individuals per cubic meter by the number of sampling trips and multiplying by the total flow of the plant for the number of days the plant operated during a period of time (Conservation Consultants Inc., 1977). A period was defined as including half the days since the previous sampling trip and half the days until the next sampling trip. Then daily rates were calculated and used to estimate monthly totals for the existing 3 units. To estimate annual entrainment from these data, EPA calculated the sum of all monthly totals from January 1976 to December 1976. EPA then multiplied these annual estimates by 1.33 to represent the annual entrainment of the three existing units and a fourth unit of equal flow.

Entrainment was also sampled every 2 weeks from February 1979 to February 1980 (Stone and Webster Engineering Corporation, 1980a; U.S. EPA, 1981). The facility used density data from the intake canal to calculate entrainment because samples in the discharge were not considered representative due to low sampling water volumes. Samples were collected with two nets with 1 m (3.3 ft) mouth diameter and 505 μm (0.020 in.) mesh, equipped with a flowmeter. Tows were oblique, from bottom to top. Subsamples were taken from the samples and sorted for selected species only. In their final calculations, U.S. EPA (1981) Region 4 estimated annual entrainment for the three existing units and a fourth proposed unit at 100 percent load.

D3-4 Annual Impingement at Big Bend

EPA evaluated annual impingement at Big Bend Units 1-4 using the methods described in Chapter A5 of Part A of this document. The species-specific life history values used by EPA for its analyses are presented in Appendix D1. Table D3-2 displays estimates of annual impingement (numbers of organisms) at Big Bend for the years of monitoring (1976-1977 and 1979-1980). Table D3-3 displays those numbers expressed as age 1 equivalents, Table D3-4 displays annual impingement of fishery species expressed as yield lost to fisheries, and Table D3-5 displays annual impingement expressed as production foregone.

The available data indicate that in the late 1970's mean annual impingement at Big Bend amounted to about 419,286 age 1 equivalents, 11,113 pounds of lost fishery yield, and 5,858 pounds of production foregone each year. Impingement losses were dominated by silver perch, pink shrimp, and bay anchovy.

D3-5 Annual Entrainment at Big Bend

EPA evaluated annual entrainment at Big Bend Units 1-4 using the methods in Chapter A5 of Part A of this document. The species-specific life history values used by EPA for its analyses are presented in Appendix D1. Table D3-6 displays estimates of annual entrainment (numbers of organisms) at Big Bend for the years of monitoring (1976-1977 and 1979-1980). Table D3-7 displays those numbers expressed as age 1 equivalents, Table D3-8 displays annual entrainment of fishery species expressed as yield lost to fisheries, and Table D3-9 displays annual entrainment expressed as production foregone.

Results indicate that in the late 1970's, entrainment at Big Bend was substantial, and far exceeded impingement rates. Mean annual entrainment amounted to over 7.71 billion age 1 equivalents, 22.8 million pounds of lost fishery yield, and nearly 47.9 million pounds of production foregone. The forage species bay anchovy accounted for most entrainment losses. Entrainment of fishery species was dominated by black drum (99% of the total lost fishery yield).

D3-6 EPA's Methods for Extrapolating Big Bend's I&E Rates to Other In-Scope Facilities of Tampa Bay

EPA used the results from its detailed analysis of I&E at Big Bend as a basis for estimating I&E at other in-scope CWIS of Tampa Bay (Hooker's Point, PL Bartow, FJ Gannon). Extrapolation was necessary because there are no empirical data describing actual I&E at these other facilities. Because intake characteristics, the fish community, and hydrodynamic conditions associated with the CWIS of Tampa Bay are similar, EPA assumed that I&E at Big Bend is representative of I&E at other Tampa Bay CWIS and that I&E is strictly proportional to intake flow. EPA extrapolated I&E separately using each of the three I&E metrics discussed previously (age 1 equivalents, fishery yield, and production foregone). The results are presented in Sections D3-7 and D3-8, and cumulative impacts of all Tampa Bay CWIS are summarized in Section D3-9. Economic valuation of these baseline losses is discussed in Chapter D4 of this report. A RUM analysis of I&E losses is presented in Chapter D5. Benefits of reducing estimated current I&E at Big Bend and other in-scope facilities are discussed in Chapter D6.

D3-7 EPA's Estimates of Big Bend's Impingement Extrapolated to Other In-Scope Facilities of Tampa Bay

EPA's estimates of Big Bend impingement extrapolated to other in-scope facilities of Tampa Bay are presented in Table D3-10 as age 1 equivalents, in Table D3-11 as foregone fishery yield, and in Table D3-12 as production foregone.

D3-8 EPA's Estimates of Big Bend's Entrainment Extrapolated to Other In-Scope Facilities of Tampa Bay

EPA's estimates of Big Bend entrainment extrapolated to other in-scope facilities of Tampa Bay are presented in Table D3-13 as age 1 equivalents, in Table D3-14 as foregone fishery yield, and in Table D3-15 as production foregone.

D3-9 Cumulative Impacts: Summary of Total I&E of Tampa Bay In-Scope Facilities

Tables D3-16 and D3-17 summarize the cumulative I&E impacts of all Tampa Bay in-scope facilities in terms of numbers of age 1 equivalents, yield lost to fisheries (in pounds), and production foregone (in pounds).

Table D3-2: Annual Impingement (numbers of organisms) at Big Bend, 1976-1977 and 1979-1980

Year	Atlantic Bumper	Bay Anchovy	Black Drum	Blue Crab	Florida Stone Crab	Leopard Searobin	Pinfish	Pink Shrimp	Scaled Sardine	Silver Perch	Spotted Seatrout	Unidentified Fish	Other Invertebrates
1976-1977	11,886	51,066	0	30,912	0	8,409	13,389	142,816	0	130,508	12,309	54,778	171,098
1979-1980	NA	10,972	56	16,958	798	NA	NA	97,755	219	28,928	283	NA	NA
Mean	11,886	31,019	28	23,935	399	8,409	13,389	120,286	110	79,718	6,296	54,778	171,098
Minimum	11,886	10,972	0	16,958	0	8,409	13,389	97,755	0	28,928	283	54,778	171,098
Maximum	11,886	51,066	56	30,912	798	8,409	13,389	142,816	219	130,508	12,309	54,778	171,098
SD	NA	28,351	39	9,867	564	NA	NA	31,863	155	71,828	8,503	NA	NA
Total	11,886	62,039	56	47,870	798	8,409	13,389	240,571	219	159,435	12,592	54,778	171,098

NA=Not sampled.
0=Sampled, but none collected.
Fri Feb 08 10:18:12 MST 2002 Raw.losses. IMPINGEMENT; Plant:bigbend.unit.1.4;
PATHNAME:P:/Intake/Tampa_Bay/Tampa_Science/scode/tables.output.unit.1.4/raw.losses.imp.bigbend.unit.1.4.csv

Table D3-3: Annual Impingement at Big Bend Expressed as Number of Age 1 Equivalents, 1976-1977 and 1979-1980

Year	Bay Anchovy	Black Drum	Blue Crab	Florida Stone Crab	Leopard Searobin	Pinfish	Pink Shrimp	Scaled Sardine	Silver Perch	Spotted Seatrout
1976-1977	85,319	0	49,396	0	10,150	16,641	162,681	0	255,523	16,643
1979-1980	18,332	63	27,097	1,239	NA	NA	111,352	323	56,638	383
Mean	51,826	31	38,247	620	10,150	16,641	137,016	161	156,081	8,513
Minimum	18,332	0	27,097	0	10,150	16,641	111,352	0	56,638	383
Maximum	85,319	63	49,396	1,239	10,150	16,641	162,681	323	255,523	16,643
SD	47,367	44	15,768	876	NA	NA	36,295	228	140,633	11,497
Total	103,652	63	76,493	1,239	10,150	16,641	274,033	323	312,161	17,026

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 A2, 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.
0=Sampled, but none collected.
Mon Feb 04 15:28:19 MST 2002 ;Results; I Plant: bigbend.unit.1.4 ; Units: equivalent.sums Pathname:
P:/Intake/Tampa_Bay/Tampa_Science/scode/tables.output.unit.1.4/I.equivalent.sums.bigbend.unit.1.4.csv

Table D3-4: Annual Impingement of Fishery Species at Big Bend Expressed as Yield Lost to Fisheries (in pounds), 1976-1977 and 1979-1980

Year	Black Drum	Blue Crab	Florida Stone Crab	Pinfish	Pink Shrimp	Silver Perch	Spotted Seatrout
1976-1977	0	4,306	0	438	1,156	28	11,300
1979-1980	271	2,362	869	NA	791	6	260
Mean	135	3,334	435	438	974	17	5,780
Minimum	0	2,362	0	438	791	6	260
Maximum	271	4,306	869	438	1,156	28	11,300
SD	191	1,375	615	NA	258	15	7,807
Total	271	6,669	869	438	1,948	34	11,561

NA=Not sampled.
0=Sampled, but none collected.
Mon Feb 04 15:28:26 MST 2002 ;Results; I Plant: bigbend.unit.1.4 ; Units: yield Pathname:
P:/Intake/Tampa_Bay/Tampa_Science/scode/tables.output.unit.1.4/I.yield.bigbend.unit.1.4.csv

Table D3-5: Annual Impingement at Big Bend Expressed as Production Foregone (in pounds), 1976-1977 and 1979-1980

Year	Bay Anchovy	Black Drum	Blue Crab	Florida Stone Crab	Leopard Searobin	Pinfish	Pink Shrimp	Silver Perch	Spotted Seatrout
1976-1977	14	0	1,614	0	286	1,065	1,069	178	3,891
1979-1980	3	30	885	468	NA	NA	732	39	90
Mean	8	15	1,250	234	286	1,065	901	108	1,991
Minimum	3	0	885	0	286	1,065	732	39	90
Maximum	14	30	1,614	468	286	1,065	1,069	178	3,891
SD	8	21	515	331	NA	NA	239	98	2,688
Total	17	30	2,499	468	286	1,065	1,801	217	3,981

NA=Not sampled.
0=Sampled, but none collected.
Mon Feb 04 15:28:23 MST 2002 ;Results; I Plant: bigbend.unit.1.4 ; Units: annual.prod.forg Pathname:
P:/Intake/Tampa_Bay/Tampa_Science/scode/tables.output.unit.1.4/I.annual.prod.forg.bigbend.unit.1.4.csv

Table D3-6: Estimates of Annual Entrainment (numbers of organisms) at Big Bend, 1976-1977 and 1979-1980

Year	Atlantic Bumper	Atlantic Spadefish	Bay Anchovy	Black Drum	Blenny Spp.	Chain Pipefish	Feather Blenny	Florida Stone Crab	Goby Spp.	Hog-choker	Kingcroaker Spp.
1976-1977	238,515,550	22,862,700	68,938,975,227	3,559,816,953	14,423,584	1,898,240	109,490,521	6,680,261,357	1,759,538,582	8,714,160	559,003,921
1979-1980	NA	NA	107,209,466,196	82,433,155,962	NA	NA	NA	2,416,375,102	NA	NA	NA
Mean	238,515,550	22,862,700	88,074,220,711	42,996,486,457	14,423,584	1,898,240	109,490,521	4,548,318,230	1,759,538,582	8,714,160	559,003,921
Minimum	238,515,550	22,862,700	68,938,975,227	3,559,816,953	14,423,584	1,898,240	109,490,521	2,416,375,102	1,759,538,582	8,714,160	559,003,921
Maximum	238,515,550	22,862,700	107,209,466,196	82,433,155,962	14,423,584	1,898,240	109,490,521	6,680,261,357	1,759,538,582	8,714,160	559,003,921
SD	NA	NA	27,061,323,684	55,771,872,868	NA	NA	NA	3,015,022,885	NA	NA	NA
Total	238,515,550	22,862,700	176,148,441,423	85,992,972,915	14,423,584	1,898,240	109,490,521	9,096,636,459	1,759,538,582	8,714,160	559,003,921

NA=Not sampled.
Fri Feb 08 10:18:16 MST 2002 Raw.losses. ENTRAINMENT; Plant:bigbend.unit.1.4;
PATHNAME:P:/Intake/Tampa_Bay/Tampa_Science/scode/tables.output.unit.1.4/raw.losses.ent.bigbend.unit.1.4.csv

Table D3-6: Estimates of Annual Entrainment (numbers of organisms) at Big Bend, 1976-1977 and 1979-1980 (cont.)

Year	Leather-jacket	Leopard Searobin	Lined Seahorse	Lined Sole	Menhaden Spp.	Northern Kingfish	Pigfish	Pink Shrimp	Puffer Spp.	Pupfish Spp.	Scaled Sardine	Sheepshead
1976-1977	470,369,263	61,443,340	370,272	168,699,847	1,110,949	257,998,720	591,314,422	9,287,656	2,016,945	2,688,196	831,359,060	341,829,950
1979-1980	NA	NA	NA	NA	NA	NA	NA	18,580,432	NA	NA	1,813,389,165	NA
Mean	470,369,263	61,443,340	370,272	168,699,847	1,110,949	257,998,720	591,314,422	13,934,044	2,016,945	2,688,196	1,322,374,112	341,829,950
Minimum	470,369,263	61,443,340	370,272	168,699,847	1,110,949	257,998,720	591,314,422	9,287,656	2,016,945	2,688,196	831,359,060	341,829,950
Maximum	470,369,263	61,443,340	370,272	168,699,847	1,110,949	257,998,720	591,314,422	18,580,432	2,016,945	2,688,196	1,813,389,165	341,829,950
SD	NA	NA	NA	NA	NA	NA	NA	6,570,985	NA	NA	694,400,147	NA
Total	470,369,263	61,443,340	370,272	168,699,847	1,110,949	257,998,720	591,314,422	27,868,088	2,016,945	2,688,196	2,644,748,225	341,829,950

NA=Not sampled.
Fri Feb 08 10:18:16 MST 2002 Raw.losses. ENTRAINMENT; Plant:bigbend.unit.1.4;
PATHNAME:P:/Intake/Tampa_Bay/Tampa_Science/scode/tables.output.unit.1.4/raw.losses.ent.bigbend.unit.1.4.csv

Table D3-6: Estimates of Annual Entrainment (numbers of organisms) at Big Bend, 1976-1977 and 1979-1980 (cont.)

Year	Silver Perch	Southern Kingfish	Spotted Seatrout	Tidewater Silverside	Unidentified Fish	Other Invertebrate
1976-1977	70,320,444,165	447,944	234,835,174	29,080,849	80,179,183	713,062,016,671
1979-1980	8,854,830,343	NA	35,612,546	1,597,396	NA	NA
Mean	39,587,637,254	447,944	135,223,860	15,339,123	80,179,183	713,062,016,671
Minimum	8,854,830,343	447,944	35,612,546	1,597,396	80,179,183	713,062,016,671
Maximum	70,320,444,165	447,944	234,835,174	29,080,849	80,179,183	713,062,016,671
SD	43,462,752,344	NA	140,871,672	19,433,736	NA	NA
Total	79,175,274,508	447,944	270,447,720	30,678,246	80,179,183	713,062,016,671

NA=Not sampled.
Fri Feb 08 10:18:16 MST 2002 Raw.losses. ENTRAINMENT; Plant:bigbend.unit.1.4;
PATHNAME:P:/Intake/Tampa_Bay/Tampa_Science/scode/tables.output.unit.1.4/raw.losses.ent.bigbend.unit.1.4.csv

Table D3-7: Annual Entrainment at Big Bend Expressed as Number of Age 1 Equivalents, 1976-1977 and 1979-1980

Year	Bay Anchovy	Black Drum	Chain Pipefish	Florida Stone Crab	Goby Spp.	Hog-choker	Leather-jacket	Leopard Searobin	Men-haden Spp.	Pink Shrimp	Scaled Sardine	Sheeps-head	Silver Perch	Spotted Seatrout	Tidewater Silverside
1976-1977	8,499,842,984	442,998	133,515	607,581	5,767,205	20,777	25,299	660,704	424	396,154	177,723	62,117	7,605,227	47,532	121,680
1979-1980	6,893,306,648	10,009,916	NA	28,489	NA	NA	NA	NA	NA	792,526	2,498,337	NA	944,277	7,420	142,824
Mean	7,696,574,816	5,226,457	133,515	318,035	5,767,205	20,777	25,299	660,704	424	594,340	1,338,030	62,117	4,274,752	27,476	132,252
Minimum	6,893,306,648	442,998	133,515	28,489	5,767,205	20,777	25,299	660,704	424	396,154	177,723	62,117	944,277	7,420	121,680
Maximum	8,499,842,984	10,009,916	133,515	607,581	5,767,205	20,777	25,299	660,704	424	792,526	2,498,337	62,117	7,605,227	47,532	142,824
SD	1,135,992,738	6,764,832	NA	409,480	NA	NA	NA	NA	NA	280,278	1,640,921	NA	4,710,003	28,363	14,951
Total	15,393,149,632	10,452,914	133,515	636,069	5,767,205	20,777	25,299	660,704	424	1,188,680	2,676,060	62,117	8,549,504	54,952	264,504

NA=Not sampled.
Mon Feb 04 15:28:16 MST 2002 ;Results; E Plant: bigbend.unit.1.4 ; Units: equivalent.sums Pathname:
P:/Intake/Tampa_Bay/Tampa_Science/scode/tables.output.unit.1.4/E.equivalent.sums.bigbend.unit.1.4.csv

Table D3-8: Annual Entrainment of Fishery Species at Big Bend Expressed as Yield Lost to Fisheries (in pounds), 1976-1977 and 1979-1980

Year	Black Drum	Florida Stone Crab	Menhaden Spp.	Pink Shrimp	Sheepshead	Silver Perch	Spotted Seatrout
1976-1977	1,910,681	426,047	52	2,816	208	834	32,274
1979-1980	43,173,453	19,977	NA	5,633	NA	104	5,038
Mean	22,542,067	223,012	52	4,224	208	469	18,656
Minimum	1,910,681	19,977	52	2,816	208	104	5,038
Maximum	43,173,453	426,047	52	5,633	208	834	32,274
SD	29,177,186	287,135	NA	1,992	NA	517	19,258
Total	45,084,134	446,024	52	8,448	208	938	37,312

NA=Not sampled.
Mon Feb 04 15:28:24 MST 2002 ;Results; E Plant: bigbend.unit.1.4 ; Units: yield Pathname:
P:/Intake/Tampa_Bay/Tampa_Science/scode/tables.output.unit.1.4/E.yield.bigbend.unit.1.4.csv

Table D3-9: Annual Entrainment at Big Bend Expressed as Production Foregone (in pounds), 1976-1977 and 1979-1980

Year	Bay Anchovy	Black Drum	Chain Pipefish	Florida Stone Crab	Goby Spp.	Hog-choker	Leather-jacket	Leopard Searobin	Pink Shrimp	Scaled Sardine	Sheeps-head	Silver Perch	Spotted Seatrout	Tidewater Silverside
1976-1977	21,619,895	14	180	739	3,014	10	5,843,346	59,619	87,927	17,931	13	4,870,516	20,034,368	2
1979-1980	18,402,298	16,492,342	NA	557,737	NA	NA	NA	NA	37,997	1,236,410	NA	604,955	21,299	2,879
Mean	20,011,097	8,246,178	180	279,238	3,014	10	5,843,346	59,619	62,962	627,170	13	2,737,735	10,027,833	1,441
Minimum	18,402,298	14	180	739	3,014	10	5,843,346	59,619	37,997	17,931	13	604,955	21,299	2
Maximum	21,619,895	16,492,342	180	557,737	3,014	10	5,843,346	59,619	87,927	1,236,410	13	4,870,516	20,034,368	2,879
SD	2,275,185	11,661,837	NA	393,857	NA	NA	NA	NA	35,305	861,595	NA	3,016,207	14,151,377	2,034
Total	40,022,193	16,492,356	180	558,475	3,014	10	5,843,346	59,619	125,924	1,254,340	13	5,475,471	20,055,667	2,882

NA=Not sampled.
Mon Feb 04 15:28:21 MST 2002 ;Results; E Plant: bigbend.unit.1.4 ; Units: annual.prod.forg Pathname:
P:/Intake/Tampa_Bay/Tampa_Science/scode/tables.output.unit.1.4/E.annual.prod.forg.bigbend.unit.1.4.csv

Table D3-10: EPA's Estimate of Mean Annual Impingement at Big Bend Expressed as Numbers of Age 1 Equivalents Extrapolated to Other In-scope Facilities of Tampa Bay

Facility	Bay Anchovy	Black Drum	Blue Crab	Florida Stone Crab	Leopard Searobin	Pinfish	Pink Shrimp	Scaled Sardine	Silver Perch	Spotted Seatrout	Totals
Big Bend	51,826	31	38,247	620	10,150	16,641	137,016	161	156,081	8,513	419,286
FJ Gannon	49,549	30	36,566	593	9,704	15,910	130,995	154	149,222	8,139	400,862
Hookers Point	3,327	2	2,455	40	652	1,068	8,796	10	10,020	547	26,917
PL Bartow	22,886	14	16,889	274	4,482	7,348	60,505	71	68,924	3,759	185,152
Total	127,588	76	94,158	1,526	24,988	40,968	337,312	396	384,247	20,958	1,032,217

\\alexandria\project\INTAKE\Tampa_Bay\Tampa_Science\scode\extrapolation.to.other.facilities\Chapter.B3\I.equivalent.xls
1/29/02

Table D3-11: EPA's Estimate of Mean Annual Impingement of Fishery Species at Big Bend Expressed as Yield Lost to Fisheries (in pounds) Extrapolated to Other In-scope Facilities of Tampa Bay

Facility	Black Drum	Blue Crab	Florida Stone Crab	Pinfish	Pink Shrimp	Silver Perch	Spotted Seatrout	Totals
Big Bend	135	3,334	435	438	974	17	5,780	11,113
FJ Gannon	129	3,187	416	419	931	16	5,526	10,625
Hookers Point	9	214	28	28	63	1	371	713
PL Bartow	60	1,472	192	193	430	8	2,552	4,907
Total	332	8,208	1,071	1,078	2,398	42	14,229	27,358

\\alexandria\project\INTAKE\Tampa_Bay\Tampa_Science\scode\extrapolation.to.other.facilities\Chapter.B3\I.yield.xls
1/29/02

Table D3-12: EPA's Estimate of Mean Annual Impingement at Big Bend Expressed Production Foregone (in pounds) Extrapolated to Other In-scope Facilities of Tampa Bay

Facility	Bay Anchovy	Black Drum	Blue Crab	Florida Stone Crab	Leopard Searobin	Pinfish	Pink Shrimp	Silver Perch	Spotted Seatrout	Totals
Big Bend	8	15	1,250	234	286	1,065	901	108	1,991	5,858
FJ Gannon	8	14	1,195	224	273	1,018	861	103	1,904	5,601
Hookers Point	1	1	80	15	18	68	58	7	128	376
PL Bartow	4	7	552	103	126	470	398	48	879	2,587
Total	20	37	3,077	576	704	2,622	2,218	266	4,902	14,421

\\alexandria\project\INTAKE\Tampa_Bay\Tampa_Science\scode\extrapolation.to.other.facilities\Chapter.B3\I.annual.prod.forg.xls
1/29/02

Table D3-13: EPA's Estimate of Mean Annual Entrainment at Big Bend Expressed as Numbers of Age 1 Equivalents Extrapolated to Other In-scope Facilities of Tampa Bay

Facility	Bay Anchovy	Black Drum	Chain Pipefish	Florida Stone Crab	Goby Spp.	Hogchoker	Leatherjacket	Leopard Searobin	Menhaden Spp.
Big Bend	7,696,574,816	5,226,457	133,515	318,035	5,767,205	20,777	25,299	660,704	424
FJ Gannon	7,358,368,906	4,996,794	127,648	304,060	5,513,780	19,864	24,187	631,671	405
Hookers Point	494,100,408	335,525	8,571	20,417	370,240	1,334	1,624	42,416	27
PL Bartow	3,398,725,350	2,307,948	58,959	140,441	2,546,736	9,175	11,172	291,760	187
Total	18,947,769,480	12,866,724	328,693	782,953	14,197,961	51,150	62,282	1,626,550	1,044

\\alexandria\project\INTAKE\Tampa_Bay\Tampa_Science\scode\extrapolation.to.other.facilities\Chapter.B3\E.equivalent.xls
1/29/02

Table D3-13: EPA's Estimate of Mean Annual Entrainment at Big Bend Expressed as Numbers of Age 1 Equivalents Extrapolated to Other In-scope Facilities of Tampa Bay (cont.)

Facility	Pink Shrimp	Scaled Sardine	Sheepshead	Silver Perch	Spotted Seatrout	Tidewater Silverside	Totals
Big Bend	594,340	1,338,030	62,117	4,274,752	27,476	132,252	7,715,156,199
FJ Gannon	568,223	1,279,234	59,387	4,086,909	26,269	126,441	7,376,133,779
Hookers Point	38,155	85,898	3,988	274,428	1,764	8,490	495,293,285
PL Bartow	262,454	590,860	27,430	1,887,685	12,133	58,401	3,406,930,691
Total	1,463,173	3,294,022	152,922	10,523,774	67,642	325,584	18,993,513,953

\\alexandria\project\INTAKE\Tampa_Bay\Tampa_Science\scode\extrapolation.to.other.facilities\Chapter.B3\E.equivalent.xls
1/29/02

Table D3-14: EPA's Estimate of Mean Annual Entrainment of Fishery Species at Big Bend Expressed as Yield Lost to Fisheries (in pounds) Extrapolated to Other In-scope Facilities of Tampa Bay

Facility	Black Drum	Florida Stone Crab	Menhaden Spp.	Pink Shrimp	Sheepshead	Silver Perch	Spotted Seatrout	Totals
Big Bend	22,542,067	223,012	52	4,224	208	469	18,656	22,788,688
FJ Gannon	21,551,515	213,212	50	4,038	199	448	17,836	21,787,299
Hookers Point	1,447,143	14,317	3	271	13	30	1,198	1,462,975
PL Bartow	9,954,336	98,480	23	1,865	92	207	8,238	10,063,242
Total	55,495,061	549,021	128	10,399	512	1,155	45,928	56,102,204

\\alexandria\project\INTAKE\Tampa_Bay\Tampa_Science\scode\extrapolation.to.other.facilities\Chapter.B3\E.yield.xls
1/29/02

Table D3-15: EPA's Estimate of Mean Annual Entrainment at Big Bend Expressed as Production Foregone (in pounds) Extrapolated to Other In-scope Facilities of Tampa Bay

Facility	Bay Anchovy	Black Drum	Chain Pipefish	Florida Stone Crab	Goby Spp.	Hog-choker	Leather-jacket	Leopard Searobin	Pink Shrimp	Scaled Sardine	Sheeps-head	Silver Perch	Spotted Seatrout	Tidewater Silverside	Totals
Big Bend	20,011,097	8,246,178	180	279,238	3,014	10	5,843,346	59,619	62,962	627,170	13	2,737,735	10,027,833	1,441	47,899,836
FJ Gannon	19,131,762	7,883,821	172	266,968	2,882	10	5,586,575	56,999	60,195	599,611	12	2,617,432	9,587,186	1,378	45,795,003
Hookers Point	1,284,661	529,384	12	17,926	193	1	375,128	3,827	4,042	40,263	1	175,756	643,761	93	3,075,047
PL Bartow	8,836,687	3,641,424	79	123,309	1,331	4	2,580,359	26,327	27,803	276,952	6	1,208,955	4,428,184	636	21,152,057
Total	49,264,207	20,300,807	443	687,441	7,420	25	14,385,409	146,773	155,003	1,543,995	32	6,739,878	24,686,964	3,548	117,921,942

\\alexandria\project\INTAKE\Tampa_Bay\Tampa_Science\scode\extrapolation.to.other.facilities\Chapter.B3\E.annual.prod.forg.xls
1/29/02

Table D3-16: Summary of Cumulative Impingement Impacts of In-scope Facilities of Tampa Bay

Facility	# of Age 1 Equivalents	Lb of Fishery Yield	Lb of Production Foregone
Big Bend	419,286	11,113	5,858
FJ Gannon	400,862	10,625	5,601
Hookers Point	26,917	713	376
PL Bartow	185,152	4,907	2,587
Total	1,032,217	27,358	14,421

\\alexandria\project\INTAKE\Tampa_Bay\Tampa_Science\scode\extrapolation.to.other.facilities\Chapter.B3\summary.cum.I.impact.xls
1/29/02

Table D3-17: Summary of Cumulative Entrainment Impacts of In-scope Facilities of Tampa Bay

Facility	# of Age 1 Equivalents	Lb of Fishery Yield	Lb of Production Foregone
Big Bend	7,715,156,199	22,788,688	47,899,836
FJ Gannon	7,376,133,779	21,787,299	45,795,003
Hookers Point	495,293,285	1,462,975	3,075,047
PL Bartow	3,406,930,691	10,063,242	21,152,057
Total	18,993,513,953	56,102,204	117,921,942

\\alexandria\project\INTAKE\Tampa_Bay\Tampa_Science\scode\extrapolation.to.other.facilities\Chapter.B3\summary.cum.E.impact.xls
37285

EPA estimates that total annual impingement in Tampa Bay is about 1,032,217 age 1 equivalents, 27,358 pounds of lost fishery yield, and 14,421 pounds of production foregone. Impingement losses are dominated by species for which viable fisheries no longer exist, including pink shrimp and bay anchovy.

Entrainment in Tampa Bay is substantially greater than impingement, estimated at 18.9 billion age 1 equivalents, 56.1 million pounds of lost fishery yield, and 117.9 million pounds of production foregone each year. Bay anchovy and black drum dominate entrainment collections and may be particularly vulnerable to Tampa Bay CWIS because of their schooling behavior and the bay's shallow waters.

The economic value of estimated I&E losses in Tampa Bay is discussed in Chapters D4 (benefits transfer) and D5 (RUM analysis), and the potential benefits of reducing these losses with the proposed rule are discussed in Chapter D6.

D3-10 Evaluation of Recent Larval Abundance Records as Indicators of Current Entrainment Losses at Tampa Bay CWIS

Entrainment sampling at Big Bend was conducted in 1976-1977 and 1979-1980, and therefore may not be an accurate representation of current entrainment rates. EPA has identified no records of impingement or entrainment monitoring that are more recent. Therefore, to gain some insight about entrainment rates in recent years, EPA analyzed records of larval abundance in Tampa Bay in 1988-1989 and 1998-2001 (unpublished data provided by Dr. Ernst Peebles, University South Florida).

An analysis of larval density records to estimate entrainment rests on the premise that entrainment is largely determined by the ambient density of organisms in the source water body and intake flow. The majority of organisms subject to entrainment, including fish larvae, are weak swimmers or planktonic. As a result, it is reasonable to assume that the density of organisms in the intake flow is equal to the ambient density of organisms in the source water body near the intake structure. Environmental sampling programs that quantify the abundance of fish larvae typically use small mesh plankton nets that are efficient at capturing roughly the same types of organisms that comprise the entrained species group; therefore, sampling conducted close to CWIS provides a good surrogate for entrainment monitoring conducted within the actual cooling water stream within a facility.

Larval abundance in Tampa Bay and its tributaries from 1988 to 2001 was investigated by Dr. Ernst Peebles (unpublished data, University South Florida). The majority of the samples were collected in 1988 and 1989, and no sampling was conducted from 1990 to 1997. Sample stations considered in this case study were located in Tampa Bay, Hillsborough Bay, and in the lower reaches of Hillsborough River, Alafia River and Little Manatee River. Sample stations located in the rivers were $\leq$ 3.5 km from the mouth of the river. These sample stations were selected because of their relative proximity to Big Bend and because the fish assemblages found at the stations were expected to be typical of the fish assemblage likely to be found at Big Bend (E. Peebles, pers. comm.). Original catch records were expressed in terms of density (fish/m^3).

The data recording procedures used in the ambient density monitoring by Peebles differed from the procedures used in Big Bend entrainment monitoring. Therefore, EPA conducted various data manipulations to enhance the utility of the ambient density records as indicators of potential entrainment and to facilitate comparisons with the recording methods used in the Big Bend entrainment studies. The conversion process included the following:

- Records of larval fishes that were distinguished into four distinct larval stages in the Peebles ambient density study were expressed simply as larvae.
- The ambient density of juvenile fishes was multiplied by 0.5 to account for the likelihood that juvenile fishes have a greater ability to avoid entrainment than to avoid capture in towed nets
- The ambient density of eggs was multiplied by 137 to account for low egg capture efficiency of the nets. The scalar value of 137 is the ratio of egg densities in the survey to egg density in Tampa Bay as determined in an independent study (Peebles et al., 1996).
- Adjusted density estimates (organisms/m^3) were multiplied by the annual total operational flow rate at Big Bend (1.489 billion m^3/year) to yield a final estimate of annual entrainment.

The result of these procedures was an estimate of annual entrainment rates at Big Bend that may have occurred during the late 1980's and through the 1990's. The estimates of annual entrainment were expressed as losses of age 1 equivalent fish using the same model that EPA applied to the actual records of entrainment at Big Bend during 1976 and 1979 (see Chapter A5 of Part A). The loss metric of age 1 equivalent fish was selected for comparison rather than total losses because it is insensitive to differences in the distribution of entrained life stages. Original losses include losses at multiple life stages, which complicates comparisons between years because the age distributions are likely to vary among years. Original losses are normalized to age 1 equivalent losses through consideration of stage-specific survival rates, which allows for comparisons across years with a common basis.

For most species, estimates of mean annual entrainment in the late 1970's appear to be roughly equivalent to more recent entrainment rates (Table D3-18). Differences were less than 26 million age 1 equivalents per year except for bay anchovy. The bay anchovy data indicate that 6.3 billion fewer age 1 equivalent bay anchovy are entrained per year in the recent period. This may reflect, in part, the decline in bay anchovy since the late 1970's, which prompted a ban on purse seining for bay anchovy in 1993.

Numerous confounding factors may invalidate comparisons of entrainment estimated by these two methods. An important assumption underlying the comparison is that the sampling methods employed for the ambient larval density estimates are efficient at capturing the same fish species that are vulnerable to entrainment. This assumption cannot be rigorously tested with the available data. Despite the possible shortcomings of the comparative analysis, the objective of the comparisons is not a detailed assessment of the estimated differences, but rather a comparison of the general magnitude of entrainment rates in the two periods.

EPA's analysis indicates that the magnitude of entrainment is similar for the two time periods. This observation suggests that the density of larval fishes (among the species considered in the case study) near Big Bend are not radically different than they were in 1976-1977 and 1979-1980 when actual entrainment sampling was conducted. This observation supports the use of entrainment estimates from 1976-1977 and 1979-1980 as a basis for projecting the benefits that may result from future changes in regulations. To a lesser extent, the concurrence between the two sets of results also supports the use of records from Big Bend as a basis for extrapolation of entrainment rates to other facilities in Tampa Bay, and the use of larval densities to estimate potential entrainment at facilities that have not conducted monitoring studies, including new facilities.

Table D3-18: Mean Annual Fish Losses Due to Entrainment at Big Bend Expressed as Age 1 Equivalents (millions)

Species	Facility Monitoring 1977-1979	Larval Densities 1988-2001	Difference
Bay anchovy	7,696.6	1,420.7	-6,275.9
Black drum	5.2	0.2	-5.1
Chain pipefish	0.1	22.0	+21.9
Goby spp.	5.8	39.4	+33.6
Hogchoker	0.0	0.1	+0.1
Menhaden spp.	0.0	0.0	0.0
Pinfish	0.0	9.8	+9.8
Pink shrimp	0.6	0.0	-0.6
Scaled sardine	1.3	0.1	-1.2
Searobin	0.7	1.3	+0.6
Sheepshead	0.1	0.0	-0.1
Silver perch	4.3	8.5	+4.2
Spotted seatrout	0.0	26.3	+26.3
Stone crab	0.3	0.0	-0.3
Tidewater silverside	0.1	0.7	+0.6
Total	7,715.1	1,189.2	-6,185.1

Note: Estimates for 1977-1979 are based on actual entrainment monitoring and estimates for 1988-2001 are based on estimates of ambient fish density in the general vicinity of Big Bend.
age01 equiv Fri Feb 08 14:23:00 MST 2002 P:/INTAKE/Tampa_Bay/Tampa_Science/tampa virtcomp xls