

Chapter F2: Evaluation of Impingement and Entrainment in the Gulf of Mexico

BACKGROUND: GULF OF MEXICO MARINE FISHERIES

Important marine fisheries of the Gulf of Mexico include both migratory pelagic species and reef fishes. Coastal pelagic fishes include king mackerel, Spanish mackerel, cero, dolphinfish, and cobia. These species range from the northeastern U.S. through the Gulf of Mexico and Caribbean Sea, and as far south as Brazil (NMFS, 1999b). They are managed under the Coastal Migratory Pelagic Resources Fishery Management Plan and regulations of the South Atlantic and Gulf of Mexico Fishery Management Councils, which are

implemented by the National Marine Fisheries Service. King and Spanish mackerel make up nearly 95 percent of harvested coastal pelagic species, and are managed as two separate groups, the Gulf group and the Atlantic group (NMFS, 1999b). Most of the commercial catch of Spanish mackerel is landed in Florida. Up to 40 percent of the Gulf stock is also recreationally fished. Dolphinfish and cobia are also important recreational species, but the status of these stocks is uncertain (NMFS, 1999b).

Reef fishes include over 100 species ranging from North Carolina through the Gulf of Mexico and the Caribbean Sea that are important for commercial and recreational anglers. (NMFS, 1999b). Many reef fisheries are closely associated with other managed reef animals, including spiny lobster and stone crab. In the Gulf of Mexico, reef fisheries include snapper and grouper species as well as grunts, amberjacks, and seabasses. Although landings of individual species aren't large, collectively reef fisheries have significant landings and value (NMFS, 1999b). However, stock status of many of these species remains unknown. Red snapper, the most important Gulf reef fish, is considered overutilized, in part because it is caught incidentally by the shrimp fishery (NMFS, 1999b).

F2-1 FISHERY SPECIES IMPINGED AND ENTRAINED

Table F2-1 shows the status of managed stocks in the Gulf region, indicating in bold the stocks subject to impingement and entrainment (I&E). Overfishing occurs when fishing mortality is above a management threshold, jeopardizing the long term capacity of the stock to produce the potential maximum sustainable yield on a continuing basis. A stock is considered overfished when biomass falls below a given threshold. In some cases, heavy fishing in the past may have reduced a stock to low abundance, so that it is now considered overfished even though the stock is not currently subject to overfishing.

As indicated in Table F2-1, 4 of the 16 managed stocks are classified as overfished, including red snapper, red grouper, gag, and red drum. Gag and red drum are species subject to I&E.

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Table F2-1: Summary of Stock Status for Harvested Species of the Gulf Region Included in Federal Fishery Management Plans

| Stock (species in bold are subject to I&E) | Overfishing? (fishing mortality above threshold) | Overfished? (biomass below threshold) | Approaching Overfished Condition? |
|-----------------------------------------------|--------------------------------------------------------|---------------------------------------------|-----------------------------------------|
| Stone crab | No | No | No |
| Brown shrimp | No | No | No |
| Pink shrimp | No | No | No |
| White shrimp | No | No | No |
| Royal red shrimp | No | Undefined | Unknown |
| Spiny lobster | No | No | No |
| King mackerel | No | Yes | N/A |
| Spanish mackerel | No | No | No |
| Dolphin | No | No | No |
| Red snapper | Yes | Yes | N/A |
| Red grouper | Yes | Yes | N/A |
| Nassau grouper | No | Yes | N/A |
| Goliath grouper (Jewfish) | No | Yes | N/A |
| Greater amberjack | No | Yes | Unknown |
| Gag | Yes | No | Yes |
| Red drum | Yes | Yes | N/A |

F2-2 I&E SPECIES AND SPECIES GROUPS EVALUATED

Table F2-2 provides a list of species and associated species groups that were evaluated in EPA's analysis of I&E in the Gulf region.

| Table F2-2: Species Groups Evaluated by EPA | | | | |
|---------------------------------------------|------------------|--------------|------------|--------|
| Species Group | Species | Recreational | Commercial | Forage |
| Atlantic croaker | Atlantic croaker | X | X | |
| Bay anchovy | Bay anchovy | | | X |
| | Striped anchovy | | | X |
| Black drum | Black drum | X | | |
| | Red drum | X | X | |
| Blue crab | Blue crab | | X | |
| Chain pipefish | Chain pipefish | | | X |
| | Dusky pipefish | | | X |
| | Gulf pipefish | | | X |
| Goby species | Clown goby | | | X |
| | Code goby | | | X |
| | Frillfin goby | | | X |
| | Green goby | | | X |

| Species Group | Species | Recreational | Commercial | Forage |
|----------------------|-------------------------|----------------------|-------------------|---------------|
| | Naked goby | | | X |
| | Sharptail goby | | | X |
| | Skilletfish | | | X |
| | Violet goby | | | X |
| Gulf killifish | Bayou killifish | | | X |
| | Gulf killifish | | | X |
| | Longnose killifish | | | X |
| Hogchoker | Hogchoker | | | X |
| | Lined sole | | | X |
| Leatherjacket | Atlantic bumper | | X | |
| | Atlantic moonfish | | | X |
| | Bluntnose jack | | X | |
| | Carangidae | | X | |
| | Crevalle jack | | | X |
| | Leatherjacket | | X | |
| | Lookdown | | | X |
| Mackerels | Spanish mackerel | X | X | |
| | Alabama shad | | X | |
| Menhaden species | Atlantic thread herring | | X | |
| | Finescale menhaden | | X | |
| | Gizzard shad | | X | |
| | Gulf menhaden | | X | |
| | Skipjack herring | | X | |
| | Yellowfin menhaden | | X | |
| | Other (commercial) | Atlantic cutlassfish | | X |
| Black bullhead | | | X | |
| Cobia | | | X | |
| Grey snapper | | | X | |
| Gulf butterfish | | | X | |
| Ladyfish | | | X | |
| Largehead hairtail | | | X | |
| Silver jenny | | | X | |
| Spotfin mojarra | | | X | |
| Tripletail | | | X | |
| Yellow bullhead | | | X | |
| Other (forage) | Atlantic midshipman | | | X |
| | Atlantic needlefish | | | X |
| | Atlantic spadefish | | | X |
| | Atlantic threadfin | | | X |

| Species Group | Species | Recreational | Commercial | Forage |
|----------------------|-----------------------------------|---------------------|-------------------|---------------|
| | Barbfish | | | X |
| | Bay whiff | | | X |
| | Blackcheek tonguefish | | | X |
| | Blackwing flyingfish | | | X |
| | Bluegill | | | X |
| | Bridle cardinalfish | | | X |
| | Carp | | | X |
| | Common halfbeak | | | X |
| | Diamond lizardfish | | | X |
| | Dwarf seahorse | | | X |
| | Fat sleeper | | | X |
| | Feather blenny | | | X |
| | Florida blenny | | | X |
| | Freckled blenny | | | X |
| | Fringed filefish | | | X |
| | Fringed flounder | | | X |
| | Golden shiner | | | X |
| | Green sunfish | | | X |
| | Gulf flounder | | | X |
| | Gulf of Mexico ocellated flounder | | | X |
| | Halfbeak | | | X |
| | Harvestfish | | | X |
| | Inshore lizardfish | | | X |
| | Jawfish | | | X |
| | Lined seahorse | | | X |
| | Live sharksucker | | | X |
| | Longear sunfish | | | X |
| | Mottled jawfish | | | X |
| | Needlefish | | | X |
| | Orange filefish | | | X |
| | Planehead filefish | | | X |
| | Polka-dot batfish | | | X |
| | Redfin needlefish | | | X |
| | Roughback batfish | | | X |
| | Sailfin molly | | | X |
| | Scrawled cowfish | | | X |
| | Sheepshead minnow | | | X |
| | Snakefish | | | X |
| | Southern codling | | | X |
| | Southern hake | | | X |

| Species Group | Species | Recreational | Commercial | Forage |
|----------------------|--------------------------|---------------------|-------------------|---------------|
| | Southern stargazer | | | X |
| | Spotted whiff | | | X |
| | Striped blenny | | | X |
| | Striped burrfish | | | X |
| | Warmouth | | | X |
| | Yellowhead jawfish | | | X |
| Other (recreational) | Atlantic sharpnose shark | X | | |
| | Atlantic stingray | X | | |
| | Bandtail puffer | X | | |
| | Belted sandfish | X | | |
| | Blackear bass | X | | |
| | Bluefish | X | | |
| | Bonnethead | X | | |
| | Channel catfish | X | | |
| | Dwarf sandperch | X | | |
| | Gafftopsail catfish | X | | |
| | Gag grouper | X | | |
| | Gulf toadfish | X | | |
| | Hardhead sea catfish | X | | |
| | Least puffer | X | | |
| | Pigfish | X | | |
| | Puffer | X | | |
| | Rock sea bass | X | | |
| | Sand perch | X | | |
| | Sea catfish | X | | |
| | Smooth butterfly ray | X | | |
| | Smooth puffer | X | | |
| Southern flounder | X | | | |
| Southern puffer | X | | | |
| Tomtate | X | | | |
| Pinfish | Spottail pinfish | X | | |
| Pink shrimp | Pink shrimp | | X | |
| | White shrimp | | X | |
| Scaled sardine | Brazilian sardinella | | | X |
| | Scaled sardine | | | X |
| | Threadfin shad | | | X |
| Sea basses | Black sea bass | X | | |
| Searobin | Bighead searobin | X | | |
| Searobin | Leopard searobin | X | | |
| Sheepshead | Sheepshead | X | X | |

| Species Group | Species | Recreational | Commercial | Forage |
|----------------------|----------------------|--------------|------------|--------|
| Silver perch | Banded drum | X | | |
| | Northern kingfish | X | | |
| | Silver perch | X | | |
| | Silver seatrout | X | | |
| | Southern kingfish | X | | |
| | Star drum | X | | |
| Spot | Spot | | X | |
| Spotted seatrout | Kingcroaker species | X | | |
| | Sand seatrout | X | | |
| | Sand weakfish | X | | |
| | Spotted seatrout | X | | |
| Stone crab | Stone crab | | X | |
| Striped mullet | Striped mullet | X | | |
| | White mullet | X | | |
| Tidewater silverside | California grunion | | | X |
| | Inland silverside | | | X |
| | Rough silverside | | | X |
| | Tidewater silverside | | | X |

Life histories of the species with the highest losses are summarized in the following section. The life history data used in EPA's analysis and associated data sources are provided in Appendix F1 of this report.

F2-3 LIFE HISTORIES OF PRIMARY SPECIES IMPINGED AND ENTRAINED IN THE GULF REGION

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.

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, 1992), 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, 1992).

The spawning period of bay anchovy in Tampa Bay lasts from spring through fall, peaking between April and July (TBNEP, 1992). A study conducted in Tampa Bay found that spawning began when water temperatures reached 20 °C (68 °F) and ended by November (TBNEP, 1992). 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). Ichthyoplankton collections conducted in and around Tampa Bay suggest that bay anchovy spawn within the Tampa Bay estuary (TBNEP, 1992). 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.) (TBNEP, 1992). 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.^c

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 percent 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 TBNEP, 1992.

^f Leak and Houde, 1987.

^g Vouglitois et al., 1987.

^h Morton, 1989.

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.

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 protozoae, 0.86 to 2.7 mm (0.03 to 0.11 in.), to mysids, 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, 1992).

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) (personal communication, NMFS, Fisheries Statistics and Economics Division, Silver Spring, Maryland, 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, 1992).



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, 1992.

^c Williams, 1958.

^d Martosubroto, 1974.

^e Costello and Allen, 1970.

^f Beardsley, 1970.

^g Sheridan, 1996.

Graphic from NOAA, 2002.

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 (TBNEP, 1992). 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, 1992).

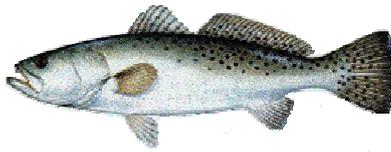
Spotted seatrout spawn in Tampa Bay from early April through October, with two major seasonal peaks in the spring and summer. Minor monthly peaks associated with the full moon also occur (McMichael and Peters, 1989). Based on the distribution of larvae within the Tampa Bay estuary, McMichael and Peters (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 & Webster Engineering Corporation, 1980). 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; TBNEP, 1992).

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 (TBNEP, 1992).



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.^e

Prey for: Snook, tarpon, barracuda, Spanish mackerel, king mackerel, bluefish.^c

Life stage information:

Eggs:

- ▶ Eggs are approximately 0.9 mm (0.036 in.) in diameter.^f

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

^a Murphy and Taylor, 1994.

^b Froese and Pauly, 2001.

^c TBNEP, 1992.

^d Thomas, 2001.

^e McMichael and Peters, 1989.

^f Stone & Webster Engineering Corporation, 1980.

Graphic from U.S. EPA, 2002c.

F2-4 DATA EVALUATED

Table F2-3 lists Gulf facilities in scope of the Phase II rule and the facility I&E data evaluated by EPA to estimate current I&E rates for the region.

| Table F2-3: California Facilities In Scope of the Section 316(b) Phase II Rule and Facility I&E Data Evaluated | | |
|---------------------------------------------------------------------------------------------------------------------------|----------------------|----------------------|
| In Scope Facilities | I&E Data? | Years of Data |
| A B Paterson (LA) | No - extrapolated | |
| Anclote (FL) | No - extrapolated | |
| Barney M Davis (TX) | No - extrapolated | |
| Big Bend (FL) | Yes | 1976, 1979 |
| Crist (FL) | No - extrapolated | |
| Crystal River (FL) | Yes | 1984 |
| Cutler (FL) | No - extrapolated | |
| Deepwater (TX) | No - extrapolated | |
| E S Joslin (TX) | No - extrapolated | |
| F J Gannon (FL) | No - extrapolated | |
| Fort Myers (FL) | No - extrapolated | |
| Hookers Point (FL) | No - extrapolated | |
| Jack Watson (MS) | No - extrapolated | |
| Lansing Smith (FL) | No - extrapolated | |
| Michoud (LA) | No - extrapolated | |
| Nueces Bay (TX) | No - extrapolated | |
| P H Robinson (TX) | No - extrapolated | |
| P L Bartow (FL) | Yes | 1978 |
| S O Purdom (FL) | No - extrapolated | |
| Sabine (TX) | No - extrapolated | |
| Sam Bertron (TX) | No - extrapolated | |
| South Texas Nuclear (TX) | No - extrapolated | |
| Teche (LA) | No - extrapolated | |
| Webster (TX) | Yes | 1978 |

F2-5 EPA'S ESTIMATE OF CURRENT I&E IN THE GULF REGION EXPRESSED AS AGE 1 EQUIVALENTS, FOREGONE YIELD, AND PRODUCTION FOREGONE

Table F2-4 provides EPA's estimate of the annual age 1 equivalents, foregone fishery yield, and production foregone resulting from the impingement of aquatic species at facilities located in the Gulf region. Table F2-5 displays this information for entrainment.

| Species Group | Age 1 Equivalents (#s) | Yield (lbs) | Production Foregone |
|----------------------------|-------------------------------|--------------------|----------------------------|
| Atlantic croaker | 3,809,400 | 775,545 | 257,421 |
| Bay anchovy | 7,288,096 | 0 | 787 |
| Black drum | 30,369 | 136,743 | 21,157 |
| Blue crab | 11,718,239 | 118,321 | 47,092 |
| Chain pipefish | 148,425 | 0 | 892 |
| Gobies | 54,758 | 0 | 11 |
| Gulf killifish | 86,514 | 0 | 533 |
| Hogchoker | 204,318 | 0 | 2,751 |
| Leatherjacket | 1,610,418 | 186,919 | 230,106 |
| Mackerels | 19,702 | 2,724 | 1,802 |
| Menhadens | 12,142,537 | 2,360,839 | 1,557,447 |
| Other (commercial) | 2,652,948 | 515,805 | 340,277 |
| Other (forage) | 4,290,717 | 0 | 463 |
| Other (recreational) | 985,538 | 191,615 | 126,409 |
| Pinfish | 67,031 | 1,764 | 4,290 |
| Red drum | 190,347 | 857,064 | 132,604 |
| Scaled sardine | 324,907 | 0 | 732 |
| Sea basses (com. and rec.) | 1,743 | 363 | 41 |
| Searobin | 2,212,666 | 88,968 | 122,541 |
| Sheepshead | 1,023 | 3 | 14 |
| Shrimp (commercial) | 51,222,033 | 364,041 | 336,693 |
| Silver perch | 676,308 | 74 | 470 |
| Spot | 906,538 | 101,532 | 51,256 |
| Spotted seatrout | 2,931,573 | 2,593,981 | 820,677 |
| Stone crab | 397,026 | 278,402 | 149,872 |
| Striped mullet | 860,443 | 364,724 | 93,431 |
| Tidewater silverside | 523,985 | 0 | 253 |

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Table F2-5: Current Annual Entrainment in the Gulf Region Expressed as Age 1 Equivalents, Foregone Fishery Yield, and Production Foregone

| Species Group | Age 1 Equivalents (#s) | Yield (lbs) | Production Foregone |
|----------------------|------------------------|-------------|---------------------|
| Atlantic croaker | 1,587 | 323 | 3,207 |
| Bay anchovy | 16,434,395 | 0 | 300,911 |
| Black drum | 5,545,684 | 24,970,270 | 14,168,078 |
| Blue crab | 17,999,496 | 181,744 | 243,944 |
| Chain pipefish | 67,188 | 0 | 3,068 |
| Gobies | 5,283,066 | 0 | 87,762 |
| Hogchoker | 50,267 | 0 | 27,224 |
| Leatherjacket | 31,851 | 3,697 | 21,620 |
| Menhadens | 48,462 | 9,422 | 111,301 |
| Other (commercial) | 32,410 | 6,301 | 21,765,577 |
| Other (forage) | 17,447,761 | 0 | 122,746 |
| Other (recreational) | 117,234 | 22,794 | 269,261 |
| Pinfish | 1,013,606 | 26,669 | 222,241 |
| Red drum | 13,685 | 61,619 | 34,828 |
| Scaled sardine | 567,076 | 0 | 37,370 |
| Searobin | 345,217 | 13,881 | 48,542 |
| Sheepshead | 32,908 | 110 | 14,268 |
| Shrimp (commercial) | 12,233,458 | 86,945 | 1,288,687 |
| Silver perch | 4,838,028 | 531 | 3,115,945 |
| Spot | 84,591 | 9,474 | 16,011 |
| Spotted seatrout | 138,776 | 122,795 | 352,834 |
| Stone crab | 392,534 | 275,252 | 1,073,087 |
| Striped mullet | 2,476,134 | 1,049,583 | 494,958 |
| Tidewater silverside | 675,206 | 0 | 939 |

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F2-6 ASSUMPTIONS USED IN CALCULATING RECREATIONAL AND COMMERCIAL LOSSES

The lost yield estimates presented in Tables F2-4 and F2-5 are expressed as total pounds and include losses to both commercial and recreational catch. To estimate the economic value of these losses, total yield was partitioned between commercial and recreational fisheries based on the landings in each fishery. Table F2-6 presents the percentage impacts assumed for each species, as well as the value per pound for commercially harvested species. Commercial and recreational fishing benefits are presented in Chapters F3 and F4.

Table F2-6: Percentage of Total Impacts Occurring to the Commercial and Recreational Fisheries and Commercial Value per Pound for Species Impinged and Entrained at Gulf of Mexico Facilities

| Species Group | Percent Impact to Recreational Fishery ^{a,b} | Percent Impact to Commercial Fishery ^{a,b} | Commercial Value per Pound ^c |
|-----------------------------|-------------------------------------------------------|-----------------------------------------------------|-----------------------------------------|
| Atlantic croaker | 88.2% | 11.8% | \$0.24 |
| Black drum | 93.0% | 7.0% | \$0.67 |
| Blue crab | 0.0% | 100.0% | \$0.66 |
| Leatherjacket | 0.0% | 100.0% | \$1.08 |
| Mackerels | 73.5% | 26.5% | \$0.46 |
| Menhaden | 0.0% | 100.0% | \$0.05 |
| Other (commercial) | 0.0% | 100.0% | \$0.57 |
| Other (recreational) | 100.0% | 0.0% | na |
| Pinfish | 100.0% | 0.0% | \$2.09 |
| Pink shrimp | 0.0% | 100.0% | \$2.37 |
| Red drum | 100.0% | 0.0% | na |
| Sea basses | 86.0% | 14.0% | \$0.54 |
| Searobin | 100.0% | 0.0% | na |
| Sheepshead | 67.0% | 33.0% | \$0.32 |
| Silver perch | 100.0% | 0.0% | na |
| Spot | 23.9% | 76.1% | \$0.27 |
| Spotted seatrout | 100.0% | 0.0% | na |
| Stone crab | 0.0% | 100.0% | \$1.47 |
| Striped mullet | 10.1% | 89.9% | \$0.68 |
| Other (forage) ^d | 50.0% | 50.0% | \$0.46 |

^a Based on landings from 1993-2001 in Alabama, Florida (west coast), Louisiana, and Mississippi. Recreational landings data for Texas are not collected by NMFS.

^b Calculated using recreational landings data from NMFS (2003b, <http://www.st.nmfs.gov/recreational/queries/catch/snapshot.html>) and commercial landings data from NMFS (2003a, http://www.st.nmfs.gov/commercial/landings/annual_landings.html).

^c Calculated using commercial landings data from NMFS (2003a).

^d Assumed equally likely to be caught by recreational or commercial fishermen. Commercial value calculated as overall average for region based on data from NMFS (2003a).

Age-1 equivalent fish that are spared from I&E are not necessarily old enough or large enough to be attractive to anglers. It may take one or more years for these fish to reach a harvestable age. For this reason, EPA discounts commercial and recreational benefits so that the cost and benefits estimates will be comparable. Tables F2-7 and F2-8 present the multiplicative discounting factors used in discounting benefits assuming a 3 percent real discount rate and a 7 percent real discount rate. For details on how these factors are developed, see Chapter A14.

| Species Group | Discount Factors for Entrainment | | Discount Factors for Impingement | |
|----------------------|----------------------------------|------------------|----------------------------------|------------------|
| | 3% Discount Rate | 7% Discount Rate | 3% Discount Rate | 7% Discount Rate |
| Atlantic croaker | 0.934 | 0.858 | 0.962 | 0.918 |
| Black drum | 0.884 | 0.764 | 0.910 | 0.818 |
| Mackerels | na | na | 0.928 | 0.845 |
| Other (recreational) | 0.922 | 0.831 | 0.950 | 0.889 |
| Pinfish | 0.960 | 0.911 | 0.989 | 0.975 |
| Red drum | 0.884 | 0.764 | 0.910 | 0.818 |
| Sea basses | na | na | 0.850 | 0.691 |
| Searobin | 0.912 | 0.813 | 0.940 | 0.870 |
| Sheepshead | 0.909 | 0.804 | 0.936 | 0.861 |
| Silver perch | 0.943 | 0.873 | 0.971 | 0.935 |
| Spot | 0.949 | 0.888 | 0.977 | 0.950 |
| Spotted seatrout | 0.936 | 0.863 | 0.965 | 0.923 |
| Striped mullet | 0.930 | 0.848 | 0.957 | 0.907 |
| Other (forage) | 0.919 | 0.829 | 0.919 | 0.829 |

| Species Group | Discount Factors for Entrainment | | Discount Factors for Impingement | |
|--------------------|----------------------------------|------------------|----------------------------------|------------------|
| | 3% Discount Rate | 7% Discount Rate | 3% Discount Rate | 7% Discount Rate |
| Atlantic croaker | 0.899 | 0.788 | 0.926 | 0.843 |
| Black drum | 0.788 | 0.592 | 0.811 | 0.633 |
| Blue crab | 0.949 | 0.888 | 0.978 | 0.950 |
| Leatherjacket | 0.933 | 0.854 | 0.961 | 0.914 |
| Mackerels | na | na | 0.918 | 0.826 |
| Menhaden | 0.913 | 0.813 | 0.940 | 0.870 |
| Other (commercial) | 0.913 | 0.813 | 0.940 | 0.870 |
| Pink shrimp | 0.971 | 0.935 | 0.898 | 0.788 |
| Sea basses | na | na | 0.836 | 0.666 |
| Sheepshead | 0.907 | 0.800 | 0.934 | 0.856 |
| Spot | 0.921 | 0.831 | 0.949 | 0.889 |
| Stone crab | 0.944 | 0.877 | 0.972 | 0.938 |
| Striped mullet | 0.890 | 0.768 | 0.916 | 0.821 |
| Other (forage) | 0.901 | 0.793 | 0.901 | 0.793 |