United States
Environmental Protection
Agency

Case Study Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule

Part H - I

May 2002

U.S. Environmental Protection Agency
Office of Water (4303T)
1200 Pennsylvania Avenue, NW
Washington, DC 20460

EPA-821-R-02-002

Part H: J.R. Whiting Facility Case Study

Chapter H1: Background

This case study presents the results of an analysis performed by EPA to assess the potential benefits of reducing the cumulative impacts of I&E at CWIS at the J.R. Whiting plant, a Great Lakes facility located on Lake Erie. Section H1-1 of this background chapter provides a brief description of the facility, Section H1-2 describes the environmental setting, and Section H1-3 presents information on the area's socioeconomic characteristics.

CHAPTER CONTENTS

H1-1 Overview of J.R. Whiting Facility H1-1
H1-2 Environmental Setting H1-3
H1-2.1 Lake Erie H1-3
H1-2.2 Aquatic Habitat and Biota H1-3
H1-2.3 Major Environmental Stressors H1-4
H1-3 Socioeconomic Characteristics H1-5
H1-3.1 Major Industrial Activities H1-6
H1-3.2 Commercial Fisheries H1-6
H1-3.3 Recreational Fisheries H1-6

H1-1 Overview of J.R. Whiting Facility

The J.R. Whiting power plant is a 346 MW power plant located on Lake Erie. It began commercial service in 1952 and currently operates three coal-fired steam-electric units and one oil-fired gas turbine. J.R. Whiting had 134 employees in 1999 and generated 2.1 million MWh of electricity. Estimated baseline revenues in 1999 were $141 million, based on the plant's 1999 estimated electricity sales of 2.0 million MWh and the 199 company-level electricity revenues of $71.14 per MWh. J.R. Whiting's 1999 production expenses totaled $44 million, or 2.060 cents per kWh, for an operating income of $97 million.

The facility is located at Luna Pier, Michigan, on the Woodtick Peninsula, 10 miles north of Toledo, Ohio, and 35 miles south of Detroit, Michigan (Figure H1-1).

❖ *Ownership Information*
J.R. Whiting is a regulated utility plant owned by Consumers Energy Co., a subsidiary of CMS Energy Corporation. CMS Energy Corporation is an energy holding company with over 11,600 employees. The firm owns or controls almost 8.1 million megawatts of electric generating capability. In 2000, CMS posted sales of $9.0 billion and sold 41.0 million MWh of electricity (Hoover's Online, 2001c; CMS, 2001).

Table H1-1 below summarizes the plant characteristics of the J.R. Whiting plant.

Table H1-1: Summary of J.R. Whiting Plant Characteristics (1999).

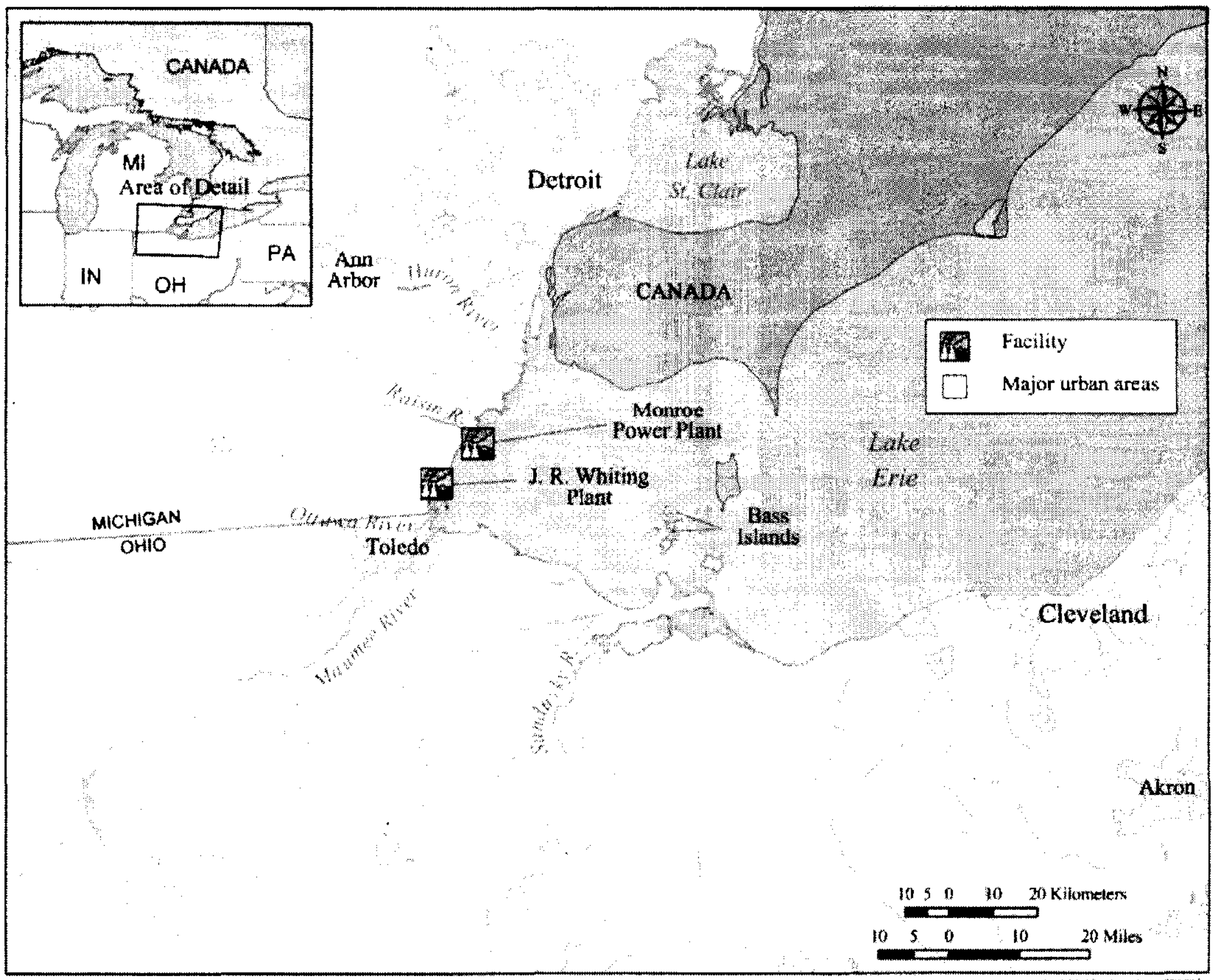
	J.R. Whiting
Plant EIA Code	1723
NERC Region	ECAR
Total Capacity (MW)	346
Primary Fuel	Coal
Number of Employees	134
Net Generation (million MWh)	2.1
Estimated Revenues (million dollars)	141
Total Production Expense (million dollars)	44
Production Expense (¢/kWh)	2.060
Estimated Operating Income (million dollars)	97

Notes: NERC = North American Electric Reliability Council
ECAR = East Central Area Reliability Coordination Agreement
Dollars are in $2001.
Source: Form EIA-860A (NERC Region, Total Capacity, Primary Fuel); FERC Form-1 (Number of Employees, Total Production Expense); Form EIA-906 (Net Generation).

The Monroe power plant (evaluated in Part I) is located just to the north, where the Raisin River enters Lake Erie, as indicated in Figure H1-1.

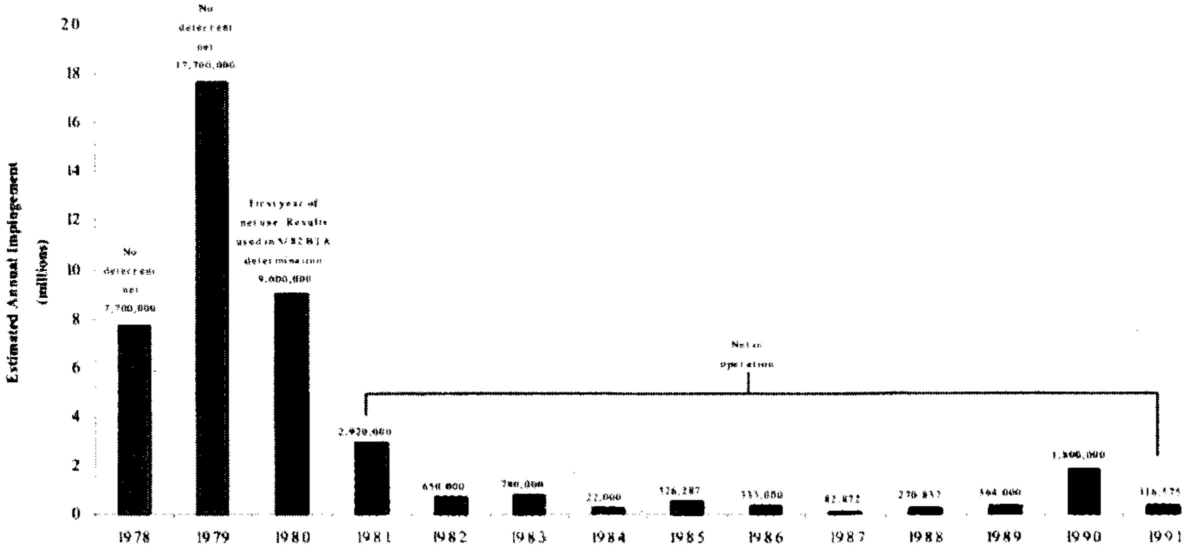
Consumer Power's J.R. Whiting facility has one cooling water intake structure serving one once-through cooling system. The facility withdraws cooling water from North Maumee Bay (located in western Lake Erie) via a recessed shoreline intake at the lake surface. The intake has a fish deterrent net located across the recessed portion of the shoreline and a dual entry/single exit traveling screen. The design intake capacity of the intake is 308 MGD.

Figure H1-1: Locations of the J.R. Whiting and Monroe Facilities Within the Great Lakes Region



In 1980, a deterrent net was installed to reduce high impingement of gizzard shad *(Dorosoma cepedianum)*, emerald shiner (*Notropis atherinoides)*, spottail shiner (*Notropis hudsonius*), yellow perch *(Perca flavescens*), and several other lake fishes (Consumers Power Company, 1984). Studies indicate that the net has dramatically reduced impingement rates (Consumers Power Company, 1984, 1994; Figure H1-2).

Figure H1-2: Estimated Annual Fish Impingement of All Species at Consumers Powers Company's J.R. Whiting Plant, 1978-1991



Source: Consumers Power Company, 1984; 1994.

H1-2 Environmental Setting

H1-2.1 Lake Erie

Lake Erie has 1,402 km (871.2 miles) of coastline and a surface area of 25,657 km^2 (9,906.2 mi^2) (U.S. EPA, 2001a). With an average depth of only 19 m (62 ft), Lake Erie is by far the shallowest of the Great Lakes (University of Wisconsin Sea Grant, 2001), and therefore the most susceptible to storms, wind tides, and seiches (U.S. EPA, 2000). Its shallowness results in considerable temperature variations throughout the year. Lake Erie warms quickly in the spring and summer and cools rapidly in the fall (U.S. EPA, 2000). During particularly long, cold winters a large part (or sometimes all) of the lake may freeze over.

Lake Erie has undergone drastic biological changes during the past 20 years (U.S. EPA, 2000). Although the water was once severely polluted, water clarity has improved dramatically as a result of stricter water pollution controls as well as filtering by expanding populations of the introduced zebra mussel (U.S. EPA, 2000).

H1-2.2 Aquatic Habitat and Biota

Lake Erie consists of three relatively distinct aquatic regions: the western, central, and eastern basins (U.S. EPA, 2000). The central and eastern basins are deep, with depths reaching approximately 29 and 53 m (95 and 175 ft) respectively. They have low flushing rates and exhibit noticeable thermal stratification. The western basin, from which J.R. Whiting withdraws its water, is the shallowest of the three basins. With an average depth of only 7.4 m (24 ft) and a maximum depth of 19 m (82 ft) (U.S. EPA, 2000), the western basin is so shallow that its entire depth is stirred by wind action. The cycling motion of the water resuspends bottom sediments in the water column and makes stratification very rare and brief. The shallow depth of the basin also results in warmer water and relatively high biological productivity in the area surrounding the J.R. Whiting facility.

Historically, benthic organisms, animals that live on or in association with the bottom of the lake, have been dominant in the western basin. These organisms find an abundance of food in the organic load deposited by the Detroit and Maumee rivers directly into the basin. Though it receives a high sediment loading, most sediment eventually moves to the central and eastern basins. The west basin's shallow sandbanks also provide ideal spawning habitat for fish from all three basins (U.S. EPA, 2000). Typical fish found in Lake Erie include bowfin, brown trout, carp, chinook salmon, coho salmon, freshwater drum, lake herring, lake sturgeon, lake trout, lake whitefish, longnose sucker, rainbow smelt, pumpkinseed, and rock, white, and smallmouth bass (University of Wisconsin Sea Grant, 2001).

The Lake Erie shore is composed of silty-clay soils and is predominantly steep with very little beach area (Dodge and Kavetsky, 1995). Shoreline erosion, caused by the stirring of the lake, results in milky-colored inshore waters. In contrast, offshore waters are much more transparent. Wind in the central basin causes strong along-shore currents and undertows that build peninsulas by pulling sediments from the shores. The peninsulas shelter significant remaining wetlands and create bays that provide spawning and nursery habitat for several fish species.

On the U.S. side, Lake Erie once had significant wetlands, including the 4,000 km^2 (1544 mi^2) Black Swamp at the Maumee River (Dodge and Kavetsky, 1995). However, the Black Swamp has been reduced to 100 km^2 (39 mi^2) by agricultural activities, including conversion. An especially severe problem for Lake Erie's wetland habitats is agricultural nutrients and sediments, which cause a high level of turbidity. Suspended sediments in the water prevent the establishment of submergent vegetation and adversely affect the aquatic ecosystem.

Compared to the other Great Lakes, Lake Erie has few areas of rocky substrate for fish spawning. Virtually all such habitat is encrusted with zebra and quagga mussels, except for areas where waterfowl or fish predation and ice scour limit mussels to the sheltered sides of rocks. In addition, the rocky substrates of Lake Erie have also been degraded by algal growth and sedimentation, further limiting fish spawning habitats. In the Detroit River, contaminated sediments are thought to be affecting fish eggs. On the Grand River, dams have limited the upstream migration of walleye (Dodge and Kavetsky, 1995).

H1-2.3 Major Environmental Stressors

The large human population surrounding Lake Erie has led to a number of major stresses on the aquatic environment (U.S. EPA, 2000). Nonpoint source pollution combined with the productive waters of the western basin have at times (particularly 1950-1970) resulted in accelerated eutrophication, large algal blooms, and anoxic waters. Overfishing and the introduction of non-native species have hurt some fish populations, though control efforts for both overfishing and invasive species have helped populations to rebound in recent years (U.S. EPA, 2000).

a. Habitat alteration

The western area of Lake Erie once had an extensive coastal marsh and swamp system stretching from the Detroit River to Maumee Bay, but most marshes were cleared and drained throughout the 1900's (Dodge and Kavetsky, 1995). About 5300 ha (13,100 acres) of wetlands remain in Ohio, but Michigan's Lake Erie shoreline wetlands have been reduced to only 100 ha (247 acres). Remaining wetlands have been severely degraded.

The Woodtick Peninsula, where J.R. Whiting is located, serves as a barrier beach protecting the wetlands behind it from wave erosion (U.S. EPA, 2001a). However, the peninsula itself is now being eroded as the sediment drift that once replenished it has been diminished by structures built to protect shoreline properties. As the Peninsula erodes, so too do the wetlands.

b. Introduction of nonnative species

The introduced zebra mussel became established in large numbers in Lake Erie the late 1980's and early 1990's (U.S. EPA, 2000). As in the other Great Lakes, zebra mussels have altered habitat, the food web dynamic, energy transfer, and how nutrients are cycled in the lakes. However, filtering by zebra mussels has apparently contributed to a dramatic increase in Lake Erie's water clarity. A preferred course of action on how to deal with the zebra mussels has not been established by the Lake Erie Lakewide Management Plan Committee (U.S. EPA, 2000).

c. Overfishing

Lake Erie has historically encountered problems of overfishing, particularly in the late 1800s (Egerton, 1985). In this century, the exact impact of overfishing has been debated because decreases in stocks may also be attributed to pollution, invasive species, and habitat degradation (Egerton, 1985). Ultimately, the governments of the Great Lakes states and provinces came together to form the Great Lakes Fishery Commission in 1955, and since then the Commission has studied the issues and set commercial and recreational fishing quotas to help maintain important fish species (U.S. EPA, 2000).

d. Pollution

Discharges to Lake Erie of persistent toxic chemicals were banned in the 1970s, but effects of these historic discharges continue to linger (U.S. EPA, 2000). Two sites near the J.R. Whiting facility have been designated as Areas of Concern (AOC): the Maumee AOC, which resulted from high concentrations of PCBs in the Maumee River drainage area, and the River Raisin AOC, caused by historical discharges of oils and grease, heavy metals, and PCBs into the River Raisin (U.S. EPA, 2000).

The presence of PCBs has resulted in fish consumption advisories being issued for Lake Erie, the Ottawa River and the Raisin River (see Table H1-2). The Ottawa River, in the Maumee drainage area, has the highest fish contaminant concentrations and the most restrictive fish consumption advisories. The River Raisin and the Lake Erie FCAs are milder (MDCH, 2001).

Table H1-2: State of Michigan Fish Consumption Advisories for Lake Erie, Ottawa River, and River Raisin, 2001[a]

	Fish Length (in.)								
	6-8	**8-10**	**10-12**	**12-14**	**14-18**	**18-22**	**22-26**	**26-30**	**30+**
Lake Erie									
Carp	◆	◆	◆	◆	◆	◆	◆	◆	◆
Catfish	◆	◆	◆	◆	◆	◆	◆	◆	◆
Chinook salmon			▲/■	▲/■	▲/■	▲/■	▲/■	▲/■	▲/■
Coho salmon			▲/■	▲/■	▲/■	▲/■	▲/■	▲/■	▲/■
Freshwater drum	▲/▼	▲/▼	▲/▼	▲/▼	▲/▼	▲/▼	▲/▼	▲/▼	▲/▼
Lake trout			▲/✣	▲/✣	▲/✣	▲/✣	▲/✣	▲/✣	▲/✣
Rainbow trout			▲/■	▲/■	▲/■	▲/■	▲/■	▲/■	▲/■
Smallmouth bass					▲/■	▲/■	▲/■	▲/■	
Walleye				▲/▼	▲/▼	▲/▼	▲/■	▲/■	▲/■
White bass	▲/■	▲/■	▲/■	▲/■	▲/■	▲/■			
Whitefish	▼/◆	▼/◆	▼/◆	▼/◆	▼/◆	▼/◆	◆	◆	◆
White perch	▲/■	▲/■	▲/■	▲/■					
Yellow Perch	▲/▼	▲/▼	▲/▼	▲/▼	▲/▼	▲/▼			
Ottawa River									
All species	◆	◆	◆	◆	◆	◆	◆	◆	◆
River Raisin (below Monroe Dam)									
Carp	◆	◆	◆	◆	◆	◆	◆	◆	◆
Freshwater drum	▲/■	▲/■	▲/■	▲/■	▲/■	▲/■	▲/■	▲/■	▲/■
Smallmouth bass					▼/✣	▼/✣	▼/✣	▼/✣	
White bass	▲/✣	▲/✣	▼/✣	◆	◆	◆			

◆ = No consumption.
✣ = Limit consumption to 6 meals (½ pound) per year.
■ = Limit consumption to 1 meal (½ pound) per month.
▼ = Limit consumption to 1 meal (½ pound) per week.
▲ = Unlimited consumption

[a] If there is only one symbol it is the advice for the whole population. When two symbols are shown, the first is the advice for the "general population" and the second is the advice for "children age 15 and under and women who are pregnant, nursing, or expect to bear children."

Source: MCDH, 2001.

H1-3 Socioeconomic Characteristics

The J.R. Whiting plant is located in Monroe County, Michigan, a rural county bordered to the east by Lake Erie and to the north and south by more urban counties (Wayne County, Michigan and Lucas County, Ohio). In 2000, Monroe had a population of 145,945, a high rate of home ownership, and a higher median income than surrounding counties (U.S. Census Bureau, 2001). The socioeconomic characteristics of Monroe and neighboring counties are summarized in Table H1-3.

Table H1-3: Socioeconomic Characteristics of Monroe and Neighboring Counties.

	Monroe County, MI	Wayne County, MI	Lucas County, OH
Population in 2000	145,945	2,061,162	455,054
Land area in 2000, km² (mi²)	1,427 (551)	1,590 (614)	881 (340)
Persons per square mile, 2000	265	3,357	1,338
Metropolitan Area	Detroit, MI	Detroit, MI	Toledo, OH
Median household money income, 1997 model-based estimate	$48,607	$35,357	$37,064
Persons below poverty, percent, 1997 model-based estimate	7.60%	18.00%	13.60%
Housing units in 2000	56,471	826,145	196,259
Homeownership rate in 2000	81.00%	66.60%	65.40%
Households in 2000	53,772	768,440	182,847
Persons per household in 2000	2.69	2.64	2.44
Households with persons under 18 years in 2000	39.10%	37.70%	34.10%
High school graduates, 25 and older in 1990	60,968	926,603	221,052
College graduates, 25 and older in 1990	8,655	180,822	49,393

Source: U.S. Census Bureau, 2001.

H1-3.1 Major Industrial Activities

Monroe County produces agricultural products such as soybeans, grains, corn, sugar beets, potatoes and alfalfa, and industrial processes such as auto-parts manufacturing, metal fabrication, cement, packaging and glass production (InfoMI, 2001). Luna Pier, where J.R. Whiting is located, is primarily a resort town with a sandy beach and a half mile crescent shaped pier stretching out into Lake Erie (InfoMI, 2001).

H1-3.2 Commercial Fisheries

Commercial fishing on Lake Erie has generated between $2 million and $3 million of revenue per year for the last decade (USGS, 2001c). A small share of this catch comes from the Michigan waters. Tables H1-4 and H1-5 show the pounds harvested and the revenue generated for the Michigan Lake Erie commercial fishery from 1985 to 1999. Despite fish consumption advisories, carp is the most important commercial species, comprising 72 percent of the catch and 51 percent of revenues over this 15-year period. Channel catfish, quillback, and bigmouth buffalo make up most of the remaining harvest and revenue (USGS, 2001c).

H1-3.3 Recreational Fisheries

Lake Erie fish species also help support several charter boat companies. In 1997, Lake Erie charter boats reported 1,727 excursions with 8,284 anglers (Rakoczy and Wesander-Russell, 1998). Ninety percent of these anglers were local residents. About half of the 74,000 fish caught on charter boats that year were walleye and about half were yellow perch (Rakoczy and Wesander-Russell, 1998).

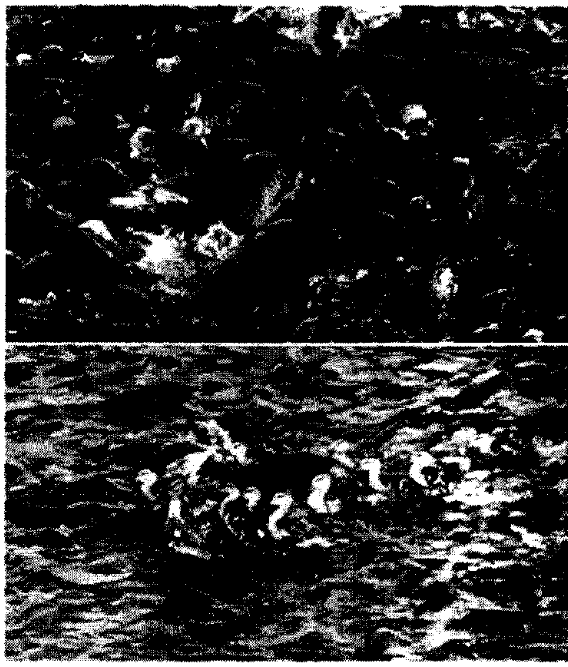
Recreational anglers spent about 175,000 noncharter days fishing the Michigan waters of Lake Erie in 1994 (Rakoczy and Svoboda, 1997). Their most commonly caught species were yellow perch and walleye (44 percent and 35 percent of the total harvest, respectively). White bass, channel catfish, freshwater drum, and white perch made up most of the remaining catch.

Total recreational hours (including charter) spent fishing Michigan's Lake Erie dropped in the early 1990s (see Table H1-6), but the reasons for this are unclear. Some of the reduction in fishing days may be related to declines in species such as yellow perch. However, Thomas and Haas (2000) note that the apparent declines in yellow perch and other species may reflect lower catchability resulting from an improved ability to avoid fishing gear because of improved water clarity rather than actual population reductions.

❖ *The Linesville, PA Spillway at Pymatuning State Park: "Where Ducks Walk on Fishes' Backs"*

Carp swarm above and below the spillway. They compete with ducks and Canada geese for slices of bread tossed to them by visitors. The ducks clamor over the seemingly endless school of carp to get their share. The ducks actually walk on the back of the carp.

The Spillway is a popular recreational site where visitors bring old bread or buy it at a nearby concession stand. Birds and fish compete for the bread. The spillway is the outflow of a secondary impoundment at the 2500 acre Pymatuning reservoir / sanctuary that serves as fish propagation waters for the Linesville Fish Culture Station.



Source: http://www.sideroads.com/outdoors/spillway.html
Photos: © Lynne G. Tudor

Table H1-4: Pounds of Commercial Landings in the Michigan Waters of Lake Erie

Species	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Gizzard shad	878,000							2,845	395	2,103	23	36,996	24,494	4,988	6,200
Brown bullhead	7,340	7,687	4,462	5,421	3,572	488	704	444	844	659	827	828	744	2,139	7,050
Channel catfish	9,253	11,183	39,603	15,208	11,481	2,025	1,941	2,929	9,152	5,760	16,168	24,969	17,936	16,573	7,561
White perch							8	10			64	45	4		
White bass	4,764	1,397	4,142	1,049	991		19	357	1,180	1,819	1,850	2,923	7,306	1,326	23
Freshwater drum	905	2,032	1,825	1,180				290	4,206	111	39,673	48,218	8,823	24,507	265
Gars									441	68		27	90	279	
Suckers	1,378	123	88								436	4,286	72	6,180	1,945
Goldfish			551	188	2,951	877	8,416	1,025	501	111	517	7,138	10,497	6,862	
Carp	738,857	367,310	685,395	417,365	194,320	158,151	198,294	251,365	238,805	94,662	329,262	387,671	325,433	620,015	211,055
Quillback	87,326	2,217	1,062	1,380	568		6,894	30,204	28,175	8,930	66,013	73,662	33,937	22,990	
Bigmouth buffalo	577	14,732	17,814	9,471	19,549	40,064						104	91,877	15,721	25,894
Totals	1,728,400	406,681	754,942	451,262	233,432	201,605	216,276	289,469	283,699	114,223	454,833	586,867	521,213	721,580	259,993

Source: USGS, 2001c.

Table H1-5: Revenue from Commercial Landings in the Michigan Waters of Lake Erie

Species	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Gizzard shad	$241,450							$342	$40	$274	$1	$4,809	$1,714	$350	$744
Brown bullhead	$1,834	$1,888	$1,076	$1,355	$895	$123	$171	$122	$213	$185	$189	$209	$253	$599	$1,904
Channel catfish	$5,364	$6,453	$23,201	$9,114	$6,898	$1,215	$1,138	$1,569	$5,580	$3,628	$10,189	$14,236	$9,684	$9,281	$4,461
White perch							$4	$5			$42	$28	$2		
White bass	$1,219	$1,073	$3,209	$629	$488		$18	$374	$1,191	$1,474	$1,702	$2,661	$6,213	$1,074	$18
Freshwater drum	$89	$185	$187	$472				$28	$462	$22	$7,538	$7,714	$1,411	$4,168	$48
Gars										$17		$11	$45	$112	
Suckers	$155	$7	$6								$26	$256	$5	$371	$253
Goldfish			$827	$47	$495	$201	$1,689	$308	$126		$130	$2,929	$3,466	$2,745	
Carp	$85,409	$38,937	$79,199	$63,611	$26,000	$19,590	$23,794	$30,612	$31,044	$12,306	$36,222	$46,521	$45,562	$80,601	$27,438
Quillback	$5,086	$170	$106	$139	$227		$2,661	$12,856	$10,144	$3,130	$22,446	$26,516	$6,449	$4,598	
Bigmouth buffalo	$292	$6,060	$7,148	$3,975	$8,332	$16,358						$47	$40,425	$8,018	$11,913
Totals	$340,898	$54,773	$114,959	$79,342	$43,335	$37,487	$29,475	$46,216	$48,800	$21,036	$78,485	$105,937	$115,229	$111,917	$46,779

Source: USGS, 2001c.

Table H1-6: Michigan Lake Erie Boat Fishery Angler Effort and Primary Species Catch April Through October, 1986 to 1998

	Angler Hours	Number of Yellow Perch Harvested	Number of Walleye Harvested
1986[a]	2,068,779	834,310	605,666
1987	2,455,903	619,112	902,378
1988[b]	4,362,452	318,786	1,996,824
1989	3,799,067	1,466,442	1,092,289
1990	2,482,242	770,507	780,508
1991[a]	805,294	378,716	132,322
1992	836,216	255,747	249,713
1993	935,249	473,580	270,376
1994	1,012,595	246,327	216,040
1995	na	343,240	107,909
1996	na	635,233	174,607
1997	na	529,435	112,400
1998	na	586,277	114,607

[a] May through October.
[b] May through September.
na = not available.
Sources: Rakoczy and Svoboda, 1997; Thomas and Haas, 2000.

Chapter H2: Technical and Economic Descriptions of the J.R. Whiting Facility

CHAPTER CONTENTS

H2-1 Baseline Operational Characteristics ... H2-1
H2-2 CWIS Configuration and Water Withdrawal ... H2-2

H2-1 Baseline Operational Characteristics

The J.R. Whiting power plant operates four units. Three are coal-fired steam electric units that use cooling water withdrawn from Lake Erie (Units 1-3) while the fourth unit (Unit 4) is an oil-fired gas turbine that does not require cooling water. The units began operation between July 1952 and May 1968.

J.R. Whiting's total net generation in 1999 was 2.1 million MWh. The three steam turbine units (Units 1-3) had capacity utilization rates between 71.4 and 77.3 percent. Table H2-1 presents details for J.R. Whiting's four units.

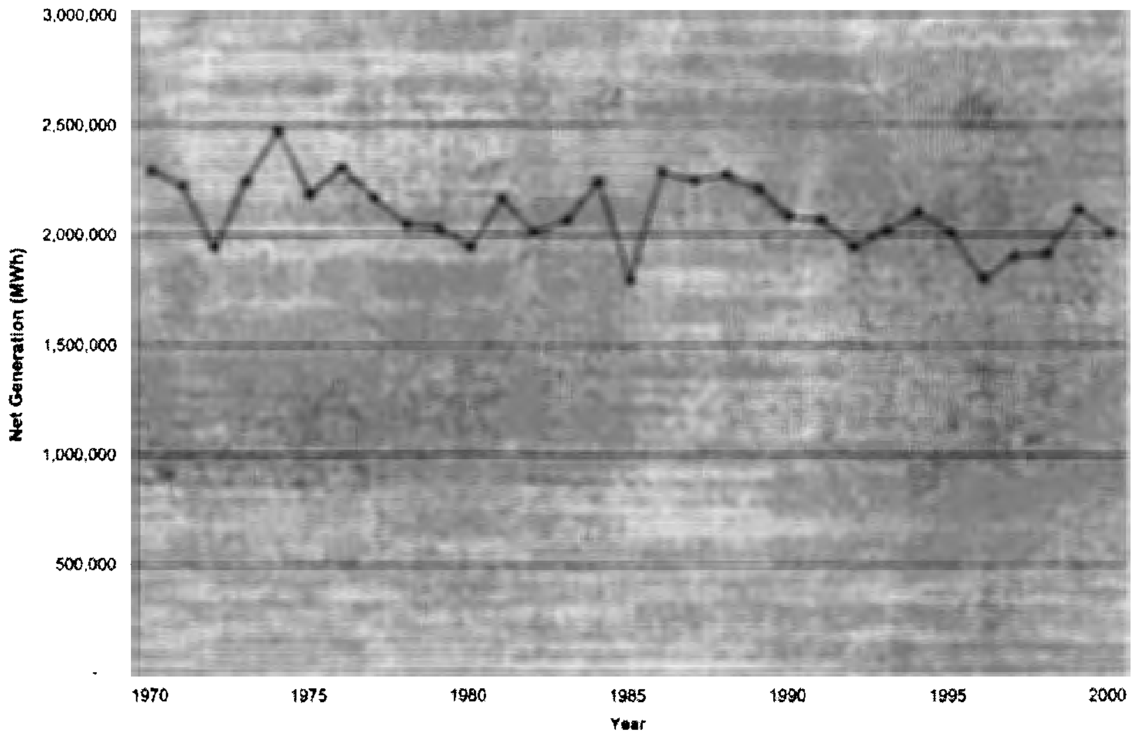
Table H2-1: Generator Detail of the J.R. Whiting Plant (1999)

Generator ID	Capacity (MW)	Prime Mover[a]	Energy Source[b]	In-Service Date	Operating Status	Net Generation (MWh)	Capacity Utilization[c]	ID of Associated CWIS
1	100	ST	BIT	Jul. 1952	Operating	625,383	71.4%	1
2	100	ST	BIT	Dec. 1952	Operating	677,547	77.3%	2
3	125	ST	BIT	Nov. 1953	Operating	807,688	73.8%	3
A	21	GT	FO2	May 1968	Operating	1,826	1.0%	Not applicable
Total	**346**					**2,112,444**	**69.8%**	

[a] Prime mover categories: ST = steam turbine; GT = gas turbine.
[b] Energy source categories: BIT = bituminous coal; FO2 = No. 2 fuel oil.
[c] Capacity utilization was calculated by dividing the unit's actual net generation by the potential generation if the unit ran at full capacity all the time (i.e., capacity * 24 hours * 365 days).
Source: U.S. Department of Energy, 2001a, 2001b, 2001d.

Figure H2-1 below presents J.R. Whiting's electricity generation history between 1970 and 2000.

Figure H2-1: J.R. Whiting Net Electricity Generation 1970 -2000 (in MWh)



Source: Form EIA-906.

H2-2 CWIS CONFIGURATION AND WATER WITHDRAWAL

The J.R. Whiting facility has one cooling water intake structure serving the entire facility. The facility withdraws cooling water from North Maumee Bay (located in western Lake Erie) via a recessed shoreline intake at the lake surface. The intake has a fish barrier net located across the recessed portion of the shoreline and a dual entry/single exit traveling screen, as well as trash racks located at the entrance to intake structure. In 1996, the facility withdrew an average of 298 MGD at an average intake velocity of 1.03 feet per second. The total design intake flow for J.R. Whiting is 308 MGD.

Chapter H3: Evaluation of I&E Data

EPA evaluated impacts to aquatic organisms resulting from the CWIS of the J.R. Whiting facility using the assessment methods described in Chapter A5 of Part A of this document. EPA's analysis focused on I&E rates at J.R. Whiting before and after installation of a deterrent net in 1980 to reduce impingement. The facility's I&E monitoring program was designed to evaluate the effectiveness of the net, and therefore included 2 years of sampling of baseline I&E losses before installation of the net and several years of impingement monitoring after (Wapora, 1979, 1980; Consumers Power Company, 1984, 1988, 1994). EPA evaluated these two sampling periods to estimate (1) I&E rates with no technology in place, and (2) the reduction in impingement resulting from the deterrent net. Section H3-1 of this chapter lists fish species that are impinged and entrained at J.R. Whiting. Section H3-2 presents life histories of the most abundant species in the facility's I&E collections, and Section H3-3 summarizes the facility's I&E collection methods. Section H3-4 presents annual I&E losses before installation of the deterrent net to reduce impingement, Section H3-5 presents impingement losses following net installation, and Section H3-6 summarizes these results.

CHAPTER CONTENTS

H3-1 Species Vulnerable to I&E H3-1
H3-2 Life Histories of Major Species Impinged and Entrained H3-2
H3-3 J.R. Whiting's Methods for Estimating I&E H3-11
H3-3.1 Impingement Monitoring H3-11
H3-3.2 Entrainment Monitoring H3-12
H3-4 J.R. Whiting's Annual I&E Without the Net H3-12
H3-4.1 Annual Impingement Without the Net ... H3-12
H3-4.2 Annual Entrainment Without the Net ... H3-15
H3-5 J.R. Whiting's Annual Impingement With the Net . H3-15
H3-6 Summary H3-25

H3-1 SPECIES VULNERABLE TO I&E

EPA evaluated all species known to be impinged and entrained by the J.R. Whiting facility based on information provided in facility I&E monitoring reports (Wapora, 1979, 1980; Consumers Power Company, 1984, 1988, 1994). Table H3-1 lists these species, and their classification as recreational, commercial, or forage species.

Table H3-1: Species Vulnerable to I&E by J.R. Whiting

Common Name	Scientific Name	Recreational	Commercial	Forage
Alewife	*Alosa pseudoharengus*			X
Bluegill	*Lepomis macrochirus*	X		
Bluntnose minnow	*Pimephales notatus*			X
Bullhead species	*Ameiurus* spp.		X	
Carp	*Cyprinus carpio carpio*		X	
Carpsucker or buffaloe	Catostomidae			X
Channel catfish	*Ictalurus punctatus*	X	X	
Crappie species	*Pomoxi* spp.	X		
Emerald shiner	*Notropis atherinoides*			X
Freshwater drum	*Aplodinotus grunniens*		X	
Gizzard shad	*Dorosoma cepedianum*		X	
Goldfish	*Carassius auratus auratus*		X	
Herring family	Clupeidae			X
Logperch	*Percina caprodes*			X
Minnow family	Cyprinidae			X
Orangespotted sunfish	*Lepomis humilis*	X		

Table H3-1: Species Vulnerable to I&E by J.R. Whiting (cont.)

Common Name	Scientific Name	Recreational	Commercial	Forage
Perch family	*Percidae*	X		
Pumpkinseed	*Lepomis gibbosus*	X		
Rainbow smelt	*Osmerus mordax mordax*			X
Shiner species	Cyprinidae			X
Smallmouth bass	*Micropterus dolomieui*	X		
Spottail shiner	*Notropis hudsonius*			X
Sucker species	Catostomidae		X	
Sunfish species	Centrarchidae	X		
Tadpole madtom	*Noturus gyrinus*			X
Troutperch	*Percopsis omiscomaycus*			X
Walleye	*Stizostedion vitreum*	X		
Warmouth	*Lepomis gulosus*	X		
White bass	*Morone chrysops*	X	X	
White perch	*Morone americana*	X		
Yellow perch	*Perca flavescens*	X		

Sources: Wapora, 1979, 1980.

H3-2 Life Histories of Major Species Impinged and Entrained

Alewife *(Alosa pseudoharengus)*

Alewife is a member of the herring family, Clupeidae, and ranges along the Atlantic coast from Newfoundland to North Carolina (Scott and Crossman, 1998). Alewives entered the Great Lakes region through the Welland Canal which connects Lake Erie and Lake Ontario, and by 1949, they were present in Lake Michigan (University of Wisconsin Sea Grant Institute, 2001). Because alewives are not a freshwater species, they are particularly susceptible to osmotic stress associated with freshwater. Freshwater fish have larger kidneys which they use to constantly pump water from their bodies. Since they lack this physiological adaptation, alewives are more susceptible to environmental disturbances.

In the Great Lakes, alewives spend most of their time in deeper water. During spawning season, they move towards shallower inshore waters to spawn. Although alewives generally do not die after spawning, the fluctuating temperatures that the adults are exposed to when they move to inshore waters often results in mortality due to osmotic stress. In certain years, temperature changes caused by upwelling may result in a massive die-off of spawning alewives (University of Wisconsin Sea Grant Institute, 2001).

Alewife has been introduced to a number of lakes to provide forage for sport fish (Jude et al., 1987b). Ecologically, alewife is an important prey item for many fish.

Spawning is temperature-driven, beginning in the spring as water temperatures reach 13 to 15 °C, and ending when they exceed 27 °C (Able and Fahay, 1998). In their native coastal habitats, alewives spawn in the upper reaches of coastal rivers, in slow-flowing sections of slightly brackish or freshwater. In the Great Lakes, alewives move inshore toward the outlets of rivers and streams to spawn (University of Wisconsin Sea Grant Institute, 2001).

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

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

ALEWIFE
(Alosa pseudoharengus)

Family: Clupeidae (herrings).

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

Similar species: Blueback herring.

Geographic range: Along the western Atlantic coast from Newfoundland to North Carolina.[a] Arrived in the Great Lakes via the Welland Canal.[b]

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

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

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

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

Prey for: Striped bass, weakfish, rainbow trout.

Life stage information:

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

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

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

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

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

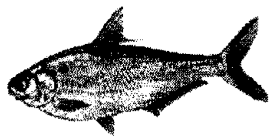
Gizzard shad (*Dorosoma cepedianum*)

Gizzard shad is a member of the family Clupeidae. Its distribution is widespread throughout the eastern United States and into southern Canada, with occurrences from the St. Lawrence River south to eastern Mexico (Miller, 1960; Scott and Crossman, 1973). Gizzard shad are found in a range of salinities from freshwater inland rivers to brackish estuaries and marine waters along the Atlantic Coast of the United States (Miller, 1960; Carlander, 1969). Gizzard shad often occur in schools (Miller, 1960). Young-of-year are considered an important forage fish (Miller, 1960), though their rapid growth rate limits the duration of their susceptibility to many predators (Bodola, 1966). In Lake Erie, gizzard shad are most populous in the shallow waters of western Lake Erie, around the Bass Islands, and in protected bays and mouths of tributaries (Bodola, 1966).

Spawning occurs from late winter or early spring to late summer, depending on temperature. Spawning has been observed in early June to July in Lake Erie (Bodola, 1966), and in May elsewhere in Ohio (Miller, 1960). The spawning period generally lasts 2 weeks (Miller, 1960). Males and females release sperm and eggs while swimming in schools near the surface of the water. Eggs sink slowly to the bottom or drift with the current, and adhere to any surface they encounter (Miller, 1960). Females release an average of 378,990 eggs annually (Bodola, 1966), which average 0.75 mm (0.03 in.) in diameter (Wallus et al., 1990).

Hatching time can be anywhere from 36 hours to 1 week, depending on water temperature (Bodola, 1966). Young shad may remain in upstream natal waters if conditions permit (Miller, 1960). By age 2 all gizzard shad are sexually mature, though some may mature as early as age 1 (Bodola, 1966). Unlike many other fish, fecundity in gizzard shad declines with age (Electric Power Research Institute, 1987).

Gizzard shad generally live up to 6 years in Lake Erie, but individuals up to 10 years have been reported in southern locations (Scott and Crossman, 1973). Mass mortalities have been documented in several locations during winter months, due to extreme temperature changes (Williamson and Nelson, 1985).



GIZZARD SHAD
(Dorosoma cepedianum)

Family: Clupeidae (herrings).

Common names: Gizzard shad.

Similar species: Threadfin shad.[a]

Geographic range: Eastern North America from the St. Lawrence River to Mexico.[b,c]

Habitat: Inhabits inland lakes, ponds, rivers, and reservoirs to brackish estuaries and ocean waters.[b,c]

Lifespan: Gizzard shad generally live 5 to 6 years, but have been reported up to 10 years.[b]

Fecundity: Maturity is reached by age 2; females produce average of 378,990 eggs.[b]

Food sources: Larvae consume protozoans, zooplankton, and small crustaceans.[c] Adults are mainly herbivorous, feeding on plants, phytoplankton, and algae. They are one of the few species able to feed solely on plant material.[b]

Prey for: Walleye, white bass, largemouth bass, crappie, among others (immature shad only).[b]

Life stage information:

Eggs: demersal
- During spawning, eggs are released near the surface and sink to the bottom, adhering to any surface they touch.

Larvae: pelagic
- Larvae serve as forage to many species.
- After hatching, larvae travel in schools for the first few months.

Adults
- May grow as large as 52.1 cm (20.5 in.).[a]
- May be considered a nuisance species because of sporadic mass winter die-offs.[3]

[a] Trautman, 1981.
[b] Miller, 1960.
[c] Scott and Crossman, 1973.
Fish graphic from Iowa Dept. of Natural Resources, 2001.

Emerald shiner (*Notropis atherinoides*)

Emerald shiner is a member of the family Cyprinidae. It is found in large open lakes and rivers from Canada south throughout the Mississippi Valley to the Gulf Coast in Alabama (Scott and Crossman, 1973). Emerald shiner prefer clear waters in the mid to upper sections of the water column, and are most often found in deep, slow moving rivers and in Lake Erie (Trautman, 1981). The emerald shiner is one of the most prevalent fishes in Lake Erie (Trautman, 1981). Because of their small size, they are an important forage fish for many species.

Spawning occurs from July to August in Lake Erie (Scott and Crossman, 1973). Females lay anywhere from 870 to 8,700 eggs (Campbell and MacCrimmon, 1970), which hatch within 24 hours (Scott and Crossman, 1973). Young-of-year remain in large schools in inshore waters until the fall, when they move into deeper waters to overwinter (Scott and Crossman, 1973). Young-of-year average 5.1 to 7.6 cm (2 to 3 in.) in length (Scott and Crossman, 1973).

Emerald shiner are sexually mature by age 2, though some larger individuals may mature at age 1 (Campbell and MacCrimmon, 1970). Most do not live beyond 3 years of age (Fuchs, 1967). Adults typically range from 6.4 to 8.4 cm (2.5 to 3.3 in.) (Trautman, 1981). Populations may fluctuate dramatically from year to year (Trautman, 1981).

EMERALD SHINER
(Notropis atherinoides)

Family: Cyprinidae (herrings).

Common names: Emerald shiner.

Similar species: Silver shiner, rosyface shiner.[a]

Geographic range: From Canada south throughout the Mississippi valley to the Gulf Coast in Alabama.[b,c]

Habitat: Large open lakes and rivers.[b]

Lifespan: Emerald shiner live to 3 years.[a,d]

Fecundity: Mature by age 2. Females can lay anywhere from approximately 870-8,700 eggs.[3]

Food source: Microcrustaceans, midge larvae, zooplankton, algae.[d]

Prey for: Gulls, terns, mergansers, cormorants, smallmouth bass, yellow perch, and others.[d]

Life stage information:

Eggs: *demersal*
- Eggs hatch in less than 24 hours.[d]

Larvae: *pelagic*
- Individuals from different year classes can have varying body proportions and fin length, as can individuals from different localities.[a]

Adults:
- Typically range in size from 6.4 to 8.4 cm (2.5 to 3.3 in.).[a]

[a] Trautman, 1981.
[b] Froese and Pauly, 2000.
[c] Campbell and MacCrimmon, 1970.
[d] Scott and Crossman, 1973.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

Carp (*Cyprinus carpio carpio*)

Carp is a member of the family of carps and minnows, Cyprinidae, and is abundant in Lake Erie. Carp were first introduced from Asia to the United States in the 1870's and 1880's, and by the 1890's were abundant in the Maumee River and in the west end of Lake Erie (Trautman, 1981). Carp are most abundant in low-gradient, warm streams and lakes with high levels or organic matter, but tolerate all types of bottom and clear to turbid waters (Trautman, 1981). Carp overwinter in deeper water and migrate to shallow water, preferably marshy environments with submerged aquatic vegetation in advance of the spawning season (McCrimmon, 1968). Adults feed on a wide variety of plants and animals, and juveniles feed primarily on plankton.

Carp are often considered a nuisance species because of their habit of uprooting vegetation and increase turbidity when feeding (McCrimmon, 1968; Scott and Crossman, 1973). Carp are not widely popular fishes for anglers, although carp fishing may be an important recreational activity in some parts of the United States (Scott and Crossman, 1973). They are occasionally harvested commercially and sold for food (Scott and Crossman, 1973).

Male carp reach sexual maturity between ages 3 and 4, and the females reach maturity between ages 4 and 5 (Swee and McCrimmon, 1966). Spawning can occur at temperatures between 16 and 28 °C (60.8 and 82.4 °F) with optimum activity between 19 and 23 °C (66.2 and 73.4 °F) (Swee and McCrimmon, 1966). Fecundity in carp can range from 36,000 eggs for a 39.4 cm (15.5 in.) fish to 2,208,000 in a 85.1 cm (33.5 in.) fish (Swee and McCrimmon, 1966) but individuals may spawn only about 500 eggs at a given time (Dames and Moore, 1977a). Eggs are demersal and stick to submerged vegetation.

Eggs hatch 3 to 6 days after spawning and larvae tend to lie in shallow water among vegetation (Swee and McCrimmon, 1966). The lifespan of a typical carp in North America is less than 20 years (McCrimmon, 1968). Adult carp can reach 102-122 cm (40-48 in.) long, and weigh 18-27 kg (40-60 lb) (Trautman, 1981).

CARP
(Cyprinus carpio carpio)

Family: Cyprinidae (minnows or carp).

Common names: Carp.

Similar species: Goldfish, buffalofishes, carpsuckers.[a]

Geographic range: Wide-ranging throughout the United States.

Habitat: Low-gradient, warm streams and lakes with high levels or organic carbon. Tolerates relatively wide range of turbidity. Often associated with submerged aquatic vegetation.[b]

Lifespan: Less than 20 years.[b]

Fecundity: 36,000 to 2,208,000 eggs per season.[c]

Food source: Omnivorous; diet includes invertebrates, small molluscs, ostracods, and crustaceans as well as roots, leaves, and shoots of water plants.[b]

Prey for: Juveniles provide limited forage for northern pike, smallmouth bass, striped bass, and longnosed gar, as well as green frogs, bullfrogs, turtles, snakes, mink.[b]

Life stage information:

Eggs: *demersal*
- During spawning, eggs are released in shallow, vegetated water. Eggs are demersal and stick to submerged vegetation.
- Eggs hatch in 3-6 days.[c]

Larvae:
- Larvae are found in shallow, weedy, and muddy habitats.[d]

Adults:
- May reach lengths of 102-122 cm (40-48 in.).[a]

[a] Trautman, 1981.
[b] McCrimmon, 1968.
[c] Swee and McCrimmon, 1966.
[d] Wang, 1986a.
Fish graphic from North Dakota Game and Fish Department (1986).

Yellow perch (*Perca flavescens*)

The yellow perch is a member of the Percidae family and is found in fresh waters in the northern and eastern United States and across eastern and central Canada. Yellow perch are also occasionally seen in brackish waters (Scott and Crossman, 1973). They are typically found in greatest numbers in clear waters with low gradients and abundant vegetation (Trautman, 1981). Perch feed during the day on immature insects, larger invertebrates, fishes, and fish eggs (Scott and Crossman, 1973).

Yellow perch are of major commercial and recreational value in Lake Erie, and the Great Lakes are a major source of yellow perch to the commercial fishing industry.

Sexual maturity is reached at age 1 for males and at ages 2 and 3 for females (Saila et al., 1987). Perch spawn in the spring in water temperatures ranging from 6.7 to 12.2 °C (44-54 °F) (Scott and Crossman, 1973). Adults move to shallower water to spawn, usually near rooted vegetation, fallen trees, or brush. Spawning takes place at night or in the early morning. Females lay all their eggs in a single transparent strand that is approximately 3 cm (1.2 in.) wide (Saila et al., 1987) and up to 2.1 m (7 ft) long (Scott and Crossman, 1973). These egg cases are semi-buoyant and attach to submerged vegetation or occasionally to the bottom and may contain 2,000-90,000 eggs (Scott and Crossman, 1973). In western Lake Erie, fecundities for yellow perch were reported to range from 8,618 to 78,741 eggs (Saila et al., 1987).

Yellow perch larvae hatch within about 8-10 days and are inactive for about 5 days until the yolk is absorbed (Scott and Crossman, 1973). Young perch are initially pelagic and found in schools, but become demersal after their first summer (Saila et al., 1987).

Adult perch are inactive at night and rest on the bottom (Scott and Crossman, 1973). Females generally grow faster than males and reach a greater final length (Scott and Crossman, 1973). In Lake Erie, perch may reach up to approximately 31 cm (12 in.) in total length and have been reported to live up to 11 years.

YELLOW PERCH
(Perca flavescens)

Family: Percidae (perches).

Common names: Yellow perch, perch, American perch, lake perch.[a]

Similar species: Dusky darter.[b]

Geographic range: Northern and eastern United States.[c]

Habitat: Lakes, ponds, creeks, rivers. Found in clear water near vegetation.[a,b]

Lifespan: Up to 11 years.[c]

Fecundity: 2,000-90,000 eggs.[c]

Food source: Immature insects, larger invertebrates, fishes, and fish eggs.[c]

Prey for: Almost all warm to cool water predatory fish including bass, sunfish, crappies, walleye, sauger, northernpike, muskellunge, and other perch, as well as a number of birds.[c]

Life stage information:

Eggs: *semi-buoyant*
- Eggs laid in long tubes containing 2,000-90,000 eggs.[c]
- Eggs usually hatch in 8-10 days.[c]

Larvae: *pelagic*
- Larvae are 4.1-5.5 mm (0.16-0.22 in.) upon hatching.[d]
- Found in schools with other species.[c]
- Become demersal during the first summer.[d]

Adults: *demersal*
- Reach up to 31 cm (12 in.) in Lake Erie.[c]
- Found in schools near the bottom.

[a] Froese and Pauly, 2001.
[b] Trautman, 1981.
[c] Scott and Crossman, 1973.
[d] Saila et al., 1987b.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

Channel catfish (*Ictalorus punctatus*)

Channel catfish is a member of the Ictaluridae (North American freshwater catfish) family. It is found from Manitoba to southern Quebec, and as far south as the Gulf of Mexico (Dames and Moore, 1977a). Channel catfish can be found in freshwater streams, lakes, and ponds. They prefer deep water with clean gravel or boulder substrates and low to moderate currents (Ohio Department of Natural Resources, 2001b).

Channel catfish reach sexual maturity at ages 5-8, and females will lay 4,000-35,000 eggs dependent on body weight (Scott and Crossman, 1998). Spawning begins when temperatures reach 24-29 °C (75-85 °F) in late spring or early summer. Spawning occurs in natural nests such as undercut banks, muskrat burrows, containers, or submerged logs. Eggs approximately 3.5 mm (0.1in) in diameter are deposited in a large, flat, gelatinous mass (Wang, 1986a). After spawning, the male guards the nest and fans it to keep it aerated. Eggs hatch in 7-10 days at 24-26 °C (75-79 °F) and the newly hatched larvae remain near the nest for several days (Wang, 1986a). Young fish prefer to inhabit riffles and turbulent areas. Channel catfish are very popular with anglers and are relatively prized as a sport fish (Dames and Moore, 1977a).

CHANNEL CATFISH
(Ictalarus punctatus)

Family: Ictaluridae (North American freshwater catfish).

Common names: Channel catfish, graceful catfish.[a]

Similar species: Blue and white catfishes.[b]

Geographic range: South-central Canada, central United States, and northern Mexico.[a]

Habitat: Freshwater streams, lakes, and ponds. Prefer deep water with clean gravel or boulder substrates.[c]

Lifespan: Maximum reported age: 16 years.[a]

Fecundity: 4,000 to 35,000 eggs depending on body weight.[e]

Food source: Small fish, crustaceans, clams, snails.[a]

Prey for: Chestnut lamprey.[a]

Life stage information:

Eggs: *demersal*
- 3-4 mm in diameter.[d]
- Hatch in 7-10 days.[d]

Larvae:
- Remain near nest for a few days then disperse to shallow water.[d]
- Approx. 6.4 mm (0.25 in.) upon hatching.[d]

Adults: *demersal*
- Average length: 30-36 cm (12-14 in.).[c]
- Maximum length: up to 104 cm (41 in.).[c]

[a] Froese and Pauly, 2001.
[b] Trautman, 1981.
[c] Ohio Department of Natural Resources, 2001b.
[d] Wang, 1986a.
[e] Scott and Crossman, 1998.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

Freshwater drum (*Aplodinotus grunniens*)

Freshwater drum is a member of the drum family, Sciaenidae. Possibly exhibiting the greatest latitudinal range of any North American freshwater species, its distribution ranges from Manitoba, Canada, to Guatemala, and throughout the Mississippi River drainage basin (Scott and Crossman, 1973). The freshwater drum is found in deeper pools of rivers and in Lake Erie at depths between 1.5 and 18 m (5 and 60 ft) (Trautman, 1981). Drum is not a favored food item of either humans or other fish (Edsall, 1967; Trautman, 1981; Bur, 1982).

Based on studies in Lake Erie, the spawning season peaks in July (Daiber, 1953), although spent females have been found as late as September (Scott and Crossman, 1973). Females in Lake Erie produce anywhere from 43,000 to 508,000 eggs (Daiber, 1953). The eggs are buoyant, floating at the surface of the water (Daiber, 1953; Scott and Crossman, 1973). This unique quality may be one explanation for the freshwater drum's exceptional distribution (Scott and Crossman, 1973). Yolk-sac larvae are buoyant as well, floating inverted at the surface of the water with the posterior end of the yolk sac and tail touching the surface (Swedberg and Walburg, 1970).

Larvae develop rapidly over the course of their first year. Maturity appears to be reached earlier among freshwater drum females from the Mississippi River than females from Lake Erie. Daiber (1953) found Lake Erie females begin maturing at age 5, and 46% reach maturity by age 6. Lake Erie males begin maturing at age 4, and by age 5, 79% had reached maturity.

The maximum age for fish in western Lake Erie is 14 years for females and 8 years for males (Edsall, 1967). Adults tend to be between 30 to 76 cm (12 to 30 in.) long.

FRESHWATER DRUM
(Aplodinotus grunniens)

Family: Sciaenidae.

Common names: freshwater drum, white perch, sheepshead.[a]

Similar species: white bass, carpsuckers.[a]

Geographic range: From Manitoba, Canada, to Guatemala. They can be found throughout the Mississippi River drainage basin.

Habitat: Bottoms of medium- to large-sized rivers and lakes.[b]

Lifespan: The maximum age for fish in western Lake Erie is 14 years for females and 8 years for males.[c]

Fecundity: Females in Lake Erie produce from 43,000 to 508,000 eggs.[c]

Food sources: Juveniles: Cladocerans (plankton), copepods, dipterans.[d]

Adults: Dipterans, cladocerans,[d] darters, emerald shiner.[e]

Prey for: Very few species.

Life stage information:

***Eggs:** pelagic*
- The buoyant eggs float at the surface of the water, possibly accounting for the species' high distribution.[e]

Larvae:
- Prolarvae float inverted at the surface of the water with the posterior end of the yolk sac and their tail touching the surface.[f]

Adults:
- The species owes its name to the audible "drumming" sound that it is often heard emitting during summer months.[e]
- Tend to be between 30 to 76 cm (12 to 30 in.) long.[a]

[a] Trautman, 1981
[b] Froese and Pauly, 2001.
[c] Edsall, 1967.
[d] Bur, 1982.
[e] Scott and Crossman, 1973.
[f] Swedberg and Walburg, 1970.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

White bass (*Morone chrysops*)

White bass is a member of the temperate bass family, Moronidae. It ranges from the St. Lawrence River south through the Mississippi valley to the Gulf of Mexico, though the species is most abundant in the Lake Erie drainage (Van Oosten, 1942).. White bass has both commercial and recreational fishing value.

Spawning take place in May in Lake Erie and may extend into June, depending on temperatures. Spawning bouts can last from 5 to 10 days (Scott and Crossman, 1973). Adults typically spawn near the surface, and eggs are fertilized as they sink to the bottom. Fecundity increases directly with size in females; the average female lays approximately 565,000 eggs. Eggs hatch within 46 hours at a water temperature of 15.6 °C (60 °F) (Scott and Crossman, 1973).

Larvae grow rapidly, and young white bass reach lengths of 13 to 16 cm (5.1 to 6.3 in.) by the fall (Scott and Crossman, 1973). They feed on microscopic crustaceans, insect larvae, and small fish. As adults, the diet switches to fish. Yellow perch are an especially important prey species for white bass (Scott and Crossman, 1973).

Most white bass mature at age 3 (Van Oosten, 1942). Upon reaching sexual maturation, adults tend to form unisexual schools, traveling up to 11.1 km (6.9 mi) a day. Adults occupy the upper portion of the water column, maintaining depths of 6 m or less (Scott and Crossman, 1973). On average, adults are between 25.4 to 35.6 cm (10 to 14 in.) long (Ohio Department of Natural Resources, 2001b). White bass rarely live beyond 7 years (Scott and Crossman, 1973).

WHITE BASS
(*Morone chrysops*)

Family: Moronidae.

Common names: White bass, silver bass.

Similar species: White perch, striped bass.[a]

Geographic range: St. Lawrence River south through the Mississippi valley to the Gulf of Mexico, highly abundant in the Lake Erie drainage.[b]

Habitat: Occurs in lakes, ponds, and rivers.[c]

Lifespan: White bass may live up to 7 years.[d]

Fecundity: The average female lays approximately 565,000 eggs.[b]

Food source: Juveniles consume microscopic crustaceans, insect larvae, and small fish.[b] Adults have been found to consume yellow perch, bluegill, white crappie,[b] and carp.[b,d]

Prey for: Other white bass.[a]

Life stage information:

***Eggs:** demersal*
- Eggs are approximately 0.8 mm (0.03 in.) in diameter.[b]

***Larvae:** pelagic*
- White bass experience their maximum growth in their first year.[b]

Adults:
- Travel in schools, traveling up to 11.1 km (6.9 mi) a day.[b]
- Most mature at age 3.[c]
- Adults prefer clear waters with firm bottoms.[e]

[a] Trautman, 1981.
[b] Scott and Crossman, 1973.
[c] Froese and Pauly, 2000.
[d] Carlander, 1997.
[e] Van Oosten, 1942.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

Walleye (*Stizostedion vitreum*)

Walleye is a member of the perch family, Percidae. It is found in freshwater from as far north as the Mackenzie River near the Arctic Coast to as far south as Georgia, and is common in the Great Lakes. Walleye are popular sport fish both in the summer and winter. They generally feed at night because their eyes are sensitive to bright daylight (Scott and Crossman, 1998).

Walleye spawn in spring or early summer, although the exact timing depends on latitude and water temperature. Spawning has been reported at temperatures of 5.6 to 11.1 °C (42 to 52 °F), in rocky areas in white water or shoals of lakes (Scott and Crossman, 1998). They do not fan nests like other similar species, but instead broadcast eggs over open ground, which reduces their ability to survive environmental stresses (Carlander, 1997). Females produce between 48,000 and 614,000 eggs in Lake Erie, and the eggs are 1.4 to 2.1 mm (0.06 to 0.08 in.) in diameter (Carlander, 1997). Eggs hatch in 12-18 days (Scott and Crossman, 1998). Larvae are approximately 6.0 to 8.6 mm (0.23 to 0.33 in.) at hatching (Carlander, 1997).

Walleye develop more slowly in the northern extent of their range; in Lake Erie they are 8.9 to 20.3 cm (3.5 to 8.0 in.) by the end of the first growing season. Males generally mature at 2-4 years and females at 3-6 years (Scott and Crossman, 1998), and females tend to grow faster than males (Carlander, 1997). Walleye may reach up to 78.7 cm (31 in.) long in Lake Erie (Scott and Crossman, 1998).

WALLEYE
(Stizostedion vitreum)

Family: Percidae (perch).

Common names: Blue pike, glass eye, gray pike, marble eye, yellow pike-perch.[a]

Similar species: Sauger.[b]

Geographic range: Canada to southern United States.[c]

Habitat: Large, shallow, turbid lakes; large streams or rivers.[c]

Lifespan: Maximum reported age: 12 years.[b]

Fecundity: 48,000 to 614,000 in Lake Erie.[b]

Food source: Insects, yellow perch, freshwater drum, crayfish, snails, frogs.[a]

Prey for: Sea lamprey, northern pike, muskellunge, sauger.[a]

Life stage information:

Eggs: *demersal*
- 1.4 - 2.1 mm (0.06 - 0.08 in.) in diameter.[b]
- Hatch in 12-18 days.[c]

Larvae: *pelagic*
- Approx. 6.2 - 7.3 mm (0.24 - 0.29 in.) upon hatching.[b]

Adults: *demersal*
- Maximum length: up to 78.7 cm (31 in.).[c]

[a] Froese and Pauly, 2001.
[b] Carlander, 1997.
[c] Scott and Crossman, 1998.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

H3-3 J.R. WHITING'S METHODS FOR ESTIMATING I&E

Sampling of impingement and entrainment was conducted from 1978 to 1991 at the J.R. Whiting facility. In 1980, a deterrent net was installed to reduce high impingement rates. Sampling methods are described in the following sections.

H3-3.1 Impingement Monitoring

The methods used by the J.R. Whiting facility to monitor impingement from April through December 1979 are described in Wapora (1980). There were 76 sampling events, with the most frequent sampling in the spring and fall, and comparatively less sampling in summer. Impingement monitoring involved backwashing intake traveling screens to remove debris and impinged organisms, and then collecting organisms for approximately 24 hours. During periods of high impingement rates, sampling periods were shortened. The collected organisms were then backwashed from the screens into a 9.5 mm (0.375 in.) mesh basket placed in the backwash trough adjacent to the traveling screen. Impingement sampling duration and intake and discharge water quality parameters were recorded. The total number of each species of fish was determined, and a representative subset of 25 fish per species were measured and weighed. Any remaining fish beyond the 25 selected for measurement were counted and weighed as a group.

Because the duration of sampling varied from collection to collection, impingement counts were first normalized to the total intake volume for the sampling period. Impingement densities were then scaled to estimate the total number of each species impinged using daily intake volumes for the monitoring period. The estimated impingement totals reported in Wapora (1980) were based on the assumption that sampling densities are representative of the overall rate of impingement.

Wapora (1980) does not contain an annual estimate based on the April-December 1979 impingement data. However, Consumers Power Company (1984) presents impingement estimates for 19 major species for March 1978 to March 1979, March 1979 to December 1979, February 1980 to December 1980, January 1981 to December 1981, January 1982 to December 1982, and January 1983 to December 1983. These annual rates were evaluated by EPA, as described in Sections H3-4 and H3-5.

H3-3.2 Entrainment Monitoring

Entrainment monitoring methods for the J.R. Whiting facility are reported in Wapora (1980). Sampling took place on 25 dates from April through October 1979, with most sampling in June and July. Entrained eggs and larvae were collected from the discharge canal using a 0.351 mm (0.01 in.) mesh plankton net fitted with a screw-on PVC collection bucket. On each sampling date, four samples were collected at various times during the day and night. Nets were placed in the canal perpendicular to the flow for a sampling period of at least 10 minutes.

The flow rate through the sampling net was monitored using a flowmeter centered in the mouth of the net. For each sample, the total collection time and flow rate were recorded and used to calculate the total volume of water filtered. Once sample collection was complete, the resulting collection of organisms was transferred to a 10% formalin solution to which Rose Bengal stain was added to facilitate sorting of ichthyoplankton.

Each entrainment sample was rinsed with tap water in a 0.125 mm (0.005 in.) sieve, and then washed into an enamel sorting tray. Eggs and larvae were removed from any debris. Samples containing greater than 100 larvae were subsampled with a plankton splitter, and no sample was split to less than 12.5% of the initial count.

All larvae were counted and the species and developmental stages were noted. In addition, up to 50 larvae of each species and developmental stage were measured to the nearest 0.1 millimeter. Eggs were counted and up to 50 per sample were measured to the nearest 0.1 millimeter.

Because the duration of entrainment sampling varied from collection to collection, entrainment counts were first normalized to the total volume of water filtered during sampling. Entrainment densities were then scaled to the daily intake volumes for the monitoring period to estimate the total number of each species entrained. The estimated entrainment totals were based on the assumption that sampling densities are representative of the overall rate of entrainment. Since no annual estimate was given, EPA used entrainment losses for October through August as an annual estimate for the calculations described in Sections H3-4 and H3-5.

H3-4 J.R. Whiting's Annual I&E Without the Net

H3-4.1 Annual Impingement Without the Net

Annual impingement before installation of the deterrent net to reduce impingement is presented in the following tables. Table H3-2 presents the annual number of impinged organisms without the net as estimated by J.R. Whiting, Table H3-3 presents these losses expressed as age 1 equivalents, Table H3-4 presents impingement losses of fishery species expressed as lost fishery yield, and Table H3-5 presents impingement losses expressed as production foregone. Details of these calculations are provided Chapter A5 of Part A of this document.

Table H3-2: J.R. Whiting Annual Impingement (numbers of organisms) Without Net, As Estimated by the Facility

Year	Alewife	Bullhead spp.	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Freshwater Drum	Gizzard Shad	Log-perch	Rainbow Smelt	Sucker spp.	Sunfish spp.	Walleye	White Bass	Yellow Perch
1978	3,051	1,239	2,310	79,825	771	691,515	36,200	6,722,765	6,822	5,181	1,420	1,010	7,204	37,771	120,031
1979	311	2,203	2,291	30,817	364	582,946	31,353	16,709,084	5,078	433	660	1,054	965	35,226	56,837
Mean	1,681	1,721	2,300	55,321	568	637,230	33,776	11,715,924	5,950	2,807	1,040	1,032	4,084	36,498	88,434
Minimum	311	1,239	2,291	30,817	364	582,946	31,353	6,722,765	5,078	433	660	1,010	965	35,226	56,837
Maximum	3,051	2,203	2,310	79,825	771	691,515	36,200	16,709,084	6,822	5,181	1,420	1,054	7,204	37,771	120,031
SD	1,937	682	13	34,654	288	76,770	3,427	7,061,394	1,233	3,357	537	31	4,412	1,800	44,685
Total	3,362	3,442	4,601	110,642	1,135	1,274,461	67,553	23,431,849	11,900	5,614	2,080	2,064	8,169	72,997	176,868

Thu Jan 10 14:21:33 MST 2002 Raw.losses. IMPINGEMENT; Plant:jr.whiting.78.79;
PATHNAME:P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/raw.losses.imp.jr.whiting.78.79.csv

Table H3-3: J.R. Whiting Annual Impingement Without Net, Expressed as Numbers of Age 1 Equivalents

Year	Alewife	Bullhead spp.	Channel Catfish	Common Carp	Crapple spp.	Emerald Shiner	Freshwater Drum	Gizzard Shad	Log-perch	Rainbow Smelt	Sucker spp.	Sunfish spp.	Wall-eye	White Bass	Yellow Perch	Total
1978	3,505	1,441	2,977	87,500	933	818,373	41,766	11,739,860	9,117	6,970	1,701	1,683	8,288	50,643	141,464	12,916,222
1979	357	2,562	2,953	33,780	441	689,887	36,174	29,178,814	6,786	582	791	1,757	1,110	47,230	66,986	30,070,211
Mean	1,931	2,001	2,965	60,640	687	754,130	38,970	20,459,337	7,951	3,776	1,246	1,720	4,699	48,937	104,225	21,493,216
Minimum	357	1,441	2,953	33,780	441	689,887	36,174	11,739,860	6,786	582	791	1,683	1,110	47,230	66,986	12,916,222
Maximum	3,505	2,562	2,977	87,500	933	818,373	41,766	29,178,814	9,117	6,970	1,701	1,757	8,288	50,643	141,464	30,070,211
SD	2,226	793	17	37,986	348	90,853	3,954	12,331,203	1,648	4,516	644	52	5,075	2,413	52,664	12,129,702
Total	3,863	4,002	5,930	121,280	1,374	1,508,260	77,941	40,918,675	15,903	7,552	2,491	3,440	9,398	97,873	208,450	42,986,432

Note: Impingement losses expressed as age 1 equivalents are larger than raw losses (the actual number of organisms impinged). This is because the ages of impinged individuals are assumed to be distributed across the interval between the start of year 1 and the start of year 2, and then the losses are normalized back to the start of year 1 by accounting for mortality during this interval (for details, see description of S*j in Chapter A5, Equation 4 and Equation 5). This type of adjustment is applied to all raw loss records, but the effect is not readily apparent among entrainment losses because the majority of entrained fish are younger than age 1.
Thu Jan 10 14:29:33 MST 2002 ;Results; I Plant: jr.whiting.78.79 ; Units: equivalent.sums Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/I.equivalent.sums.jr.whiting.78.79.csv

Table H3-4: Annual Impingement of Fishery Species at J.R. Whiting, Without Net Expressed as Yield Lost to Fisheries (in pounds)

Year	Bullhead spp.	Channel Catfish	Common Carp	Crappie spp.	Freshwater Drum	Gizzard Shad	Sucker spp.	Sunfish spp.	Walleye	White Bass	Yellow Perch	Total
1978	22	93	42,282	8	2,219	463,399	21	1	1,455	4,280	334	514,113
1979	39	92	16,323	4	1,922	1,151,753	10	1	195	3,992	158	1,174,488
Mean	30	93	29,303	6	2,070	807,576	15	1	825	4,136	246	844,300
Minimum	22	92	16,323	4	1,922	463,399	10	1	195	3,992	158	514,113
Maximum	39	93	42,282	8	2,219	1,151,753	21	1	1,455	4,280	334	1,174,488
SD	12	1	18,356	3	210	486,740	8	0	891	204	124	466,956
Total	60	185	58,606	11	4,140	1,615,152	31	1	1,650	8,272	492	1,688,601

0 = Sampled, but none collected.
Thu Jan 10 14:29:40 MST 2002 ;Results; I Plant: jr.whiting.78.79 ; Units: yield Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/I.yield.jr.whiting.78.79.csv

Table H3-5: J.R. Whiting Annual Impingement Without Net, Expressed as Production Foregone (in pounds)

Year	Alewife	Bullhead spp.	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Freshwater Drum	Gizzard Shad	Log-perch	Rainbow Smelt	Sucker spp.	Sunfish spp.	Wall-eye	White Bass	Yellow Perch	Total
1978	206	38	155	27,277	32	10,056	3,972	209,925	45	50	181	3	2,980	3,086	1,544	259,550
1979	21	67	154	10,530	15	8,477	3,440	521,757	34	4	84	3	399	2,878	731	548,596
Mean	114	52	155	18,904	23	9,267	3,706	365,841	40	27	133	3	1,689	2,982	1,138	404,073
Minimum	21	38	154	10,530	15	8,477	3,440	209,925	34	4	84	3	399	2,878	731	259,550
Maximum	206	67	155	27,277	32	10,056	3,972	521,757	45	50	181	3	2,980	3,086	1,544	548,596
SD	131	21	1	11,842	12	1,116	376	220,499	8	32	69	0	1,825	147	575	204,386
Total	227	105	309	37,807	47	18,533	7,412	731,682	79	54	266	6	3,379	5,964	2,276	808,146

0 = Sampled, but none collected.
Thu Jan 10 14:29:37 MST 2002 ;Results; I Plant: jr.whiting.78.79 ; Units: annual.prod.forg Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/I.annual.prod.forg.jr.whiting.78.79.csv

H3-4.2 Annual Entrainment Without the Net

Annual entrainment before net installation is presented in the following tables. Table H3-6 presents the annual number of entrained organisms without the net as estimated by J.R. Whiting, Table H3-7 presents these losses expressed as age 1 equivalents, Table H3-8 presents entrainment losses expressed as lost commercial and recreational fishery yields, and Table H3-9 presents entrainment losses expressed as production foregone. Details of these calculations are provided in Chapter A5 of Part A of this document.

H3-5 J.R. Whiting's Annual Impingement With the Net

Results of impingement monitoring after installation of the net indicate 92% reduction in impingement averaged over the years 1981-1991. The tables in this section present annual impingement rates after net installation. Table H3-10 presents annual impingement (numbers of organisms) with the net as estimated by J.R. Whiting, Table H3-11 presents these losses expressed as age 1 equivalents, Table H3-12 presents impingement losses with the net expressed as lost commercial and recreational fishery yields, and Table H3-13 presents losses with the net expressed as production foregone. Details of these calculations are provided in Chapter A5 of Part A of this document. No entrainment monitoring was conducted after net installation.

H3-6 Summary

Table H3-14 summarizes total I&E at J.R. Whiting before net installation in terms of raw losses, age 1 equivalents, fishery yield, and production foregone. Table H3-15 displays this information for impingement at J.R. Whiting after installation of the deterrent net. EPA estimates that without the net, baseline impingement damages at J.R. Whiting amount to 21,493,415 age 1 equivalent fish per year, representing 844,301 pounds of foregone fishery yield each year. With the net, lost fishery yield is reduced to 62,730 pounds per year. The following chapters discuss the estimated economic value of baseline I&E damages at J.R. Whiting without the net, the economic benefits of the deterrent net in reducing baseline impingement, and the potential economic benefits of various §316(b) regulatory options.

Table H3-6: J.R. Whiting Annual Entrainment (numbers of organisms) Without Net, As Estimated by the Facility

Year	Bluntnose Minnow	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Freshwater Drum	Gizzard Shad	Logperch
1979	1,623,716	28,918	7,372,177	132,964	7,584,514	32,762,696	569,558,422	191,471

Thu Jan 10 14:21:34 MST 2002 Raw.losses. ENTRAINMENT; Plant:jr.whiting.78.79;
PATHNAME:P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/raw.losses.ent.jr.whiting.78.79.csv

Table H3-6: J.R. Whiting Annual Entrainment (numbers of organisms) Without Net, As Estimated by the Facility (cont.)

Year	Others	Rainbow Smelt	Sucker spp.	Sunfish spp.	White Bass	Yellow Perch
1979	553,800,944	155,897	268,228	1,040,904	5,679,922	2,788,745

Thu Jan 10 14:21:34 MST 2002 Raw.losses. ENTRAINMENT; Plant:jr.whiting.78.79;
PATHNAME:P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/raw.losses.ent.jr.whiting.78.79.csv

Table H3-7: J.R. Whiting Annual Entrainment Without Net, Expressed as Numbers of Age 1 Equivalents

Year	Bluntnose Minnow	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Freshwater Drum	Gizzard Shad	Log-perch	Rainbow Smelt	Sucker spp.	Sunfish spp.	White Bass	Yellow Perch	Total
1979	46,669	143	36,496	5,391	69,046	29,768	1,221,061	7,405	20,575	3,853	350,828	28,118	12,360	1,831,715

Thu Jan 10 14:29:31 MST 2002 ;Results; E Plant: jr.whiting.78.79 ; Units: equivalent.sums Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/E.equivalent.sums.jr.whiting.78.79.csv

Table H3-8: Annual Entrainment of Fishery Species at J.R. Whiting Without Net Expressed as Yield Lost to Fisheries (in pounds)

Year	Channel Catfish	Common Carp	Crappie spp.	Freshwater Drum	Gizzard Shad	Sucker spp.	Sunfish spp.	White Bass	Yellow Perch	Total
1979	4	17,636	45	1,581	48,198	48	127	2,377	29	70,045

Thu Jan 10 14:29:38 MST 2002 ;Results; E Plant: jr.whiting.78.79 ; Units: yield Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/E.yield.jr.whiting.78.79.csv

Table H3-9: J.R. Whiting Annual Entrainment Without Net, Expressed as Production Foregone (in pounds)

Year	Bluntnose Minnow	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Freshwater Drum	Gizzard Shad	Log-perch	Rainbow Smelt	Sucker spp.	Sunfish spp.	White Bass	Yellow Perch
1979	198	47	53,476	4,726	20,775	21,050	135,481	570	714	4,125	1,856	39,474	7,723

Thu Jan 10 14:29:35 MST 2002 ;Results; E Plant: jr.whiting.78.79 ; Units: annual.prod.forg Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/E.annual.prod.forg.jr.whiting.78.79.csv

Table H3-10: J.R. Whiting Annual Impingement (numbers of organisms) With Net, As Estimated by the Facility

Year	Alewife	Bull-head spp.	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Fresh-water Drum	Gizzard Shad	Log-perch	Others	Rainbow Smelt	Sucker spp.	Sun-fish spp.	Wall-eye	White Bass	White Perch	Yellow Perch
1981	605	138	1,903	10,507	917	201,851	37,610	2,605,856	2,494	NA	723	154	2,090	441	19,421	0	34,044
1982	0	107	1,832	1,567	501	14,050	8,309	610,812	640	NA	8	38	646	283	5,612	0	4,864
1983	0	64	1,097	1,174	655	11,217	2,297	752,149	1,298	NA	22	29	1,025	83	2,815	0	3,431
1984	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1985	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1986	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1987	0	67	250	122	181	5,604	886	72,428	0	177	0	0	290	9	269	1,697	892
1988	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1989	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1990	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1991	0	21	578	405	58	354	4,254	300,253	0	356	0	0	395	2	686	8,698	515
Mean	121	79	1,132	2,755	462	46,615	10,671	868,300	886	266	151	44	889	164	5,761	2,079	8,749
Minimum	0	21	250	122	58	354	886	72,428	0	177	0	0	290	2	269	0	515
Maximum	605	138	1,903	10,507	917	201,851	37,610	2,605,856	2,494	356	723	154	2,090	441	19,421	8,698	34,044
SD	271	45	737	4,372	349	86,939	15,316	1,006,849	1,047	127	320	64	728	192	7,925	3,772	14,254
Total	605	397	5,660	13,775	2,312	233,076	53,356	4,341,498	4,432	533	753	221	4,446	818	28,803	10,395	43,746

NA = Not sampled.
0 = Sampled, but none collected.
Thu Jan 10 14:52:24 MST 2002 Raw.losses. IMPINGEMENT; Plant:jr.whiting.81.plus;
PATHNAME:P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting tables.output.81.plus raw.losses.imp.jr.whiting.81.plus.csv

Table H3-11: J.R. Whiting Annual Impingement With Net, Expressed as Numbers of Age 1 Equivalents

Year	Alewife	Bull-head spp.	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Fresh-water Drum	Gizzard Shad	Log-perch	Rain-bow Smelt	Sucker spp.	Sun-fish spp.	Wall-eye	White Bass	White Perch	Yellow Perch
1981	695	160	2,453	11,517	1,110	238,880	43,393	4,550,566	3,333	973	184	3,483	507	26,039	0	40,123
1982	0	124	2,361	1,718	606	16,627	9,587	1,066,652	855	11	46	1,077	326	7,524	0	5,733
1983	0	74	1,414	1,287	793	13,275	2,650	1,313,466	1,735	30	35	1,708	95	3,774	0	4,044
184	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1985	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1986	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1987	0	78	322	134	219	6,632	1,022	126,480	0	0	0	483	10	361	2,263	1,051
1988	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1989	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1990	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1991	0	24	745	444	70	419	4,908	524,327	0	0	0	658	2	920	11,597	607
Mean	139	92	1,459	3,020	560	55,167	12,312	1,516,298	1,185	203	53	1,482	188	7,724	2,772	10,312
Minimum	0	24	322	134	70	419	1,022	126,480	0	0	0	483	2	361	0	607
Maximum	695	160	2,453	11,517	1,110	238,880	43,393	4,550,566	3,333	973	184	3,483	507	26,039	11,597	40,123
SD	311	52	949	4,792	423	102,888	17,671	1,758,245	1,399	431	76	1,214	221	10,626	5,030	16,800
Total	695	462	7,295	15,099	2,799	275,834	61,561	7,581,491	5,923	1,013	265	7,410	941	38,619	13,860	51,558

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

NA = Not sampled.

0 = Sampled, but none collected.

Thu Jan 10 15:33:14 MST 2002 ;Results; I Plant: jr.whiting.81.plus ; Units: equivalent.sums Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.81.plus/I.equivalent.sums.jr.whiting.81.plus.csv

Table H3-12: Annual Impingement of Fishery Species at J.R. Whiting With Net Expressed as Yield Lost to Fisheries (in pounds)

Year	Bullhead spp.	Channel Catfish	Common Carp	Crappie spp.	Freshwater Drum	Gizzard Shad	Sucker spp.	Sunfish spp	Walleye	White Bass	White Perch	Yellow Perch
1981	2	77	5,565	9	2,305	179,621	2	1	89	2,201	0	95
1982	2	74	830	5	509	42,103	1	0	57	636	0	14
1983	1	44	622	7	141	51,845	0	1	17	319	0	10
1984	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1985	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1986	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1987	1	10	65	2	54	4,992	0	0	2	30	1	2
1988	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1989	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1990	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1991	0	23	215	1	261	20,696	0	0	0	78	5	1
Mean	1	46	1,459	5	654	59,852	1	1	33	653	1	24
Minimum	0	10	65	1	54	4,992	0	0	0	30	0	1
Maximum	2	77	5,565	9	2,305	179,621	2	1	89	2,201	5	95
SD	1	30	2,316	4	939	69,402	1	0	39	898	2	40
Total	7	228	7,296	23	3,270	299,258	3	3	165	3,264	6	122

NA = Not sampled.
0 = Sampled, but none collected.
Thu Jan 10 15:33:21 MST 2002 ;Results; I Plant: jr.whiting.81.plus ; Units: yield Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.81.plus/I.yield.jr.whiting.81.plus.csv

Table H3-13: J.R. Whiting Annual Impingement With Net, Expressed as Production Foregone (in pounds)

Year	Alewife	Bullhead spp.	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Freshwater Drum	Gizzard Shad	Log-perch	Rainbow Smelt	Sucker spp.	Sunfish spp.	Wall-eye	White Bass	White Perch	Yellow Perch
1981	41	4	128	3,590	38	2,935	4,127	81,370	17	7	20	6	182	1,587	0	438
1982	0	3	123	535	21	204	912	19,073	4	0	5	2	117	459	0	63
1983	0	2	74	401	27	163	252	23,487	9	0	4	3	34	230	0	44
1984	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1985	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1986	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1987	0	2	17	42	7	81	97	2,262	0	0	0	1	4	22	8	11
1988	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1989	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1990	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1991	0	1	39	138	2	5	467	9,376	0	0	0	1	1	56	39	7
Mean	8	2	76	941	19	678	1,171	27,113	6	1	6	3	68	471	9	113
Minimum	0	1	17	42	2	5	97	2,262	0	0	0	1	1	22	0	7
Maximum	41	4	128	3,590	38	2,935	4,127	81,370	17	7	20	6	182	1,587	39	438
SD	18	1	50	1,494	14	1,264	1,681	31,440	7	3	8	2	79	648	17	183
Total	41	12	380	4,707	95	3,389	5,855	135,567	30	7	28	13	338	2,353	47	563

NA = Not sampled.
0 = Sampled, but none collected.
Thu Jan 10 15:33:17 MST 2002 ;Results; I Plant: jr.whiting.81.plus ; Units: annual.prod.forg Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.81.plus/I.annual.prod.forg.jr.whiting.81.plus.csv

Table H3-14: Average Annual Impingement and Entrainment at J.R. Whiting Before Net Installation
(sum of annual means of all species evaluated)

	Impingement	Entrainment
Raw losses (# of organisms)	12,588,366	1,182,989,518
Age 1 equivalents (# of fish)	21,493,215	1,831,713
Fishery yield (lbs of fish)	844,301	70,045
Production foregone (lbs of fish)	404,074	290,215

Table H3-15: Average Annual Impingement at J.R. Whiting Following Net Installation
(sum of annual means of all species evaluated)

	Impingement
Raw losses (# of organisms)	949,124
Age 1 equivalents (# of fish)	1,612,966
Fishery yield (lbs of fish)	62,730
Production foregone (lbs of fish)	30,685

Note: Entrainment was not sampled after installation of the impingement deterrent net.

Chapter H4: Economic Value of I&E Losses Based on Benefits Transfer Techniques

This chapter presents an analysis using benefits transfer techniques of the economic losses associated with I&E at the J.R. Whiting facility without the currently installed impingement deterrent net using I&E data for 1978 and 1979 only (baseline). Section H4-1 provides an overview of the valuation approach, Section H4-2 discusses the value of recreational fishery losses, Section H4-3 discusses commercial fishery values, Section H4-4 discusses the value of forage species losses, Section H4-5 discusses nonuse values, and Section H4-6 summarizes the benefits transfer results. Chapter H5 discusses the results of an alternative valuation approach (the Habitat-based Replacement Cost methodology) and Chapter H6 discusses potential benefits of reductions in I&E.

CHAPTER CONTENTS

H4-1 Overview of Valuation Approach H4-1
H4-2 Value of Baseline Recreational Fishery Losses at J.R. Whiting Facility H4-3
H4-2.1 Economic Values for Recreational Losses Based on Literature H4-3
H4-2.2 Baseline Economic Losses from Recreational Fishing H4-4
H4-3 Baseline Economic Losses from Commercial Fishing H4-5
H4-4 Indirect Use: Forage Fish H4-6
H4-5 Nonuse Values H4-8
H4-6 Summary of Annual Value of Baseline Economic Losses at J.R. Whiting H4-10

H4-1 Overview of Valuation Approach

Fish losses from I&E at J.R. Whiting affect commercial and recreational fisheries, as well as forage species that contribute to the biomass of commercial and recreational species. EPA evaluated all of these species groups to capture the total economic impact of I&E at J.R. Whiting.

Commercial fishery impacts are based on commodity prices for the individual species. Recreational fishery impacts are based on benefits transfer methods, applying the results from nonmarket valuation studies. The economic impact of forage species losses is determined by estimating the replacement cost of these fish if they were to be restocked with hatchery fish (ignoring several costs and issues associated with restocking), and by considering the foregone biomass production of forage fish resulting from I&E losses and the consequential foregone production of commercial and recreational species that prey on the forage species. All of these methods are explained in further detail in the Chapter A9 in Part A of this document.

Many of the I&E-impacted fish species at J.R. Whiting are harvested both recreationally and commercially. Table H4-1 presents the percentage impacts of the I&E losses occurring to the commercial and recreational fisheries. To avoid double-counting the economic impacts of I&E occurring to species that are both commercially and recreationally fished but for which locally and applicable catch data were not available, EPA assumed that 50 percent of the estimated catch of I&E-impacted fish are assigned to a loss in commercial landings, and the remaining 50 percent of the estimated total number of losses due to I&E are assigned to the recreational landings.

Table H4-1: Percentages of Total I&E Impacts at J.R. Whiting Occurring to Commercial and Recreational Fisheries

Fish Species	Percent Impacts to Recreational Fishery	Percent Impacts to Commercial Fishery
Bullhead spp.	0	100
Channel catfish	50	50
Common carp	0	100
Crappie spp.	100	0
Gizzard shad	0	100
Sucker spp.	0	100
Sunfish spp.	100	0
Walleye	100	0
White bass	50	50
White perch	100	0
Yellow perch	100	0

Wed Jan 09 14:09:50 MST 2002 ; Table A: Percentages of total impacts occurring to the commercial and recreational fisheries of selected species; Plant: jr.whiting.78.79 ; Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/TableA.Perc.of total.impacts.jr.whiting.78.79.csv

As discussed in Chapters A5 and A9 of Part A of this document, the yield estimates presented in Chapter H3 are expressed as total pounds for both the commercial and recreational catch combined. For the economic valuation discussed in this chapter, total yield was partitioned between commercial and recreational fisheries based on the landings in each fishery (presented in Table H4-1). Because the economic evaluation of recreational yield is based on numbers of fish rather than pounds, foregone recreational yield was converted to numbers of fish. This conversion was based on the average weight of harvestable fish of each species. Table H4-2 shows these conversions for the impingement data presented in Section H3-4.1 of Chapter H3 and Table H4-3 displays these data for the entrainment estimates given in Section H3-4.2. Note that the numbers of foregone recreational fish harvested are typically lower than the numbers of age 1 equivalent losses, since the age of harvest of most fish is greater than age 1.

Table H4-2: Summary of Mean Annual Impingement of Fishery Species at J.R. Whiting (without impingement deterrent net)

Species	Impingement Count (#)	Age 1 Equivalents (#)	Total Catch (#)	Total Yield (lb)	Commercial Catch (#)	Commercial Yield (lb)	Recreational Catch (#)	Recreational Yield (lb)
Bullhead spp.	1,721	2,001	96	30	96	30	0	0
Channel catfish	2,300	2,965	112	93	56	46	56	46
Common carp	55,321	60,640	4,482	29,303	4,482	29,303	0	0
Crappie spp.	568	687	10	6	0	0	10	6
Freshwater drum	33,776	38,970	2,265	2,070	2,265	2,070	0	0
Gizzard shad	11,715,924	20,459,337	2,608,142	807,576	2,608,142	807,576	0	0
Sucker spp.	1,040	1,246	31	15	31	15	0	0
Sunfish spp.	1,032	1,720	10	1	0	0	10	1
Walleye	4,084	4,699	381	825	0	0	381	825
White bass	36,498	48,937	5,872	4,136	2,936	2,068	2,936	2,068
White perch	0	0	0	0	0	0	0	0
Yellow perch	88,434	104,225	1,953	246	0	0	1,953	246
Total	11,940,698	20,725,427	2,623,353	844,300	2,618,007	841,109	5,346	3,191

\\alexandria\project\INTAKE\Great_Lakes\GL_Science\scodes\jr.whiting\tables.output.78.79\flowchart.Imp.New.xls

Table H4-3: Summary of Mean Annual Entrainment of Fishery Species at J.R. Whiting (without impingement deterrent net)

Species	Entrainment Count (#)	Age 1 Equivalents (#)	Total Catch (#)	Total Yield (lb)	Commercial Catch (#)	Commercial Yield (lb)	Recreational Catch (#)	Recreational Yield (lb)
Channel catfish	28,918	143	5	4	3	2	3	1
Common carp	7,372,177	36,496	2,697	17,636	2,697	17,636	0	0
Crappie spp	132,964	5,391	79	45	0	0	79	23
Freshwater drum	32,762,696	29,768	1,731	1,581	1,731	1,581	0	0
Gizzard shad	569,558,422	1,221,061	155,660	48,198	155,660	48,198	0	0
Sucker spp	268,228	3,853	95	48	95	48	0	0
Sunfish spp	1,040,904	350,828	2,053	127	0	0	2,053	64
Walleye	0	0	0	0	0	0	0	1
White bass	5,679,922	28,118	3,374	2,377	1,687	1,188	1,687	594
White perch	0	0	0	0	0	0	0	1
Yellow perch	2,788,745	12,360	232	29	0	0	232	15
Total	619,632,976	1,688,020	165,927	70,045	161,873	68,654	4,054	699

\\alexandria\project\INTAKE\Great_Lakes\GL_Science\scodes\jr.whiting\tables.output.78.79\flowchart.ENT.New.xls

H4-2 Value of Baseline Recreational Fishery Losses at J.R. Whiting Facility

H4-2.1 Economic Values for Recreational Losses Based on Literature

There is a large literature that provides willingness-to-pay values for increases in recreational catch rates. These increases in value are benefits to the anglers, and are often referred to by economists as a "consumer surplus" per additional fish caught.

When using values from the existing literature as proxies for the value of a trip or fish at a site not studied, it is important to select values for similar areas and species. Table H4-4 gives a summary of several studies that are closest to the Great Lakes fishery in geographic area and relevant species.

Table H4-4: Selected Valuation Studies for Estimating Changes in Catch Rates

Authors	Study Location and Year	Item Valued	Value Estimate ($2000)	
Boyle et al. (1998)	National, by state, 1996	Catch rate increase of 1 fish per trip	Bass (low/high)	$1.58 - $5.32
Sorg et al. (1985)	Idaho, 1982	Catch rate increase of 1 fish per trip	Warmwater fish	$5.02
Milliman et al. (1992)	Green Bay	Catch rate increase of 1 fish per trip	Yellow perch	$0.31
Charbonneau and Hay (1978)	National, 1975	Catch rate increase of 1 fish per trip	Walleye Catfish Panfish	$7.92 $2.64 $1.00

[a] Value was reported as "two month value per angler for a half fish catch increase per trip." From 1996 National Survey of Fishing, Hunting and Wildlife-Associated Recreation (U.S. DOI, 1997), the average saltwater angler takes 1.5 trips in a 2 month period. Therefore, to convert to a "1 fish per trip" value EPA divided the 2 month value by 1.5 trips and then multiplied it by 2, assuming the value of a fish was linear.

Boyle et al. (1998) used the 1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation to estimate the marginal economic value of an additional bass, trout, and walleye per trip.

Sorg et al. (1985) used travel cost and contingent valuation methods to estimated the value of recreational fishing at 51 sites in Idaho. Several of the species valued in Sorg et al. are also found in the Great Lakes fishery.

Milliman et al. (1992) used a logit model and the responses, creel data, and the responses to a contingent valuation dichotomous choice survey question the study estimated the value of recreational fishing for Yellow Perch in Green Bay, Michigan.

Charbonneau and Hay (1978) used travel cost and contingent valuation methods to estimate the consumer surplus for a season of the respondent's favorite wildlife-related activity. These consumer surplus values were then converted to a one fish increase per trip.

EPA estimated the economic value of I&E impacts to recreational fisheries using the I&E estimates presented in Tables H4-2 and H4-3 and the economic values in Table H4-4. Since none of the studies discussed in the previous section consider the Great Lakes fishery directly, EPA used these estimates to create a range of possible consumer surplus values for the recreational fish landings gained by reducing impingement and entrainment at J.R. Whiting. To estimate a unit value for recreational landings, EPA established a lower and upper value for the recreational species, based on values reported in studies in Table H4-4.

H4-2.2 Baseline Economic Losses from Recreational Fishing

EPA applied a 50/50 recreational and commercial split to obtain the losses to the recreational fishery where a fish is both commercially or recreationally harvested. If not commercially harvested, recreational losses were assumed to be 100 percent of losses due to I&E, and vice versa. Results are displayed in Tables H4-5 and H4-6, for impingement and entrainment, respectively. The total losses to the recreational fisheries are estimated to range from $7,300 to $20,900 for impingement per year, and from $3,500 to $11,700 annually for entrainment.

Table H4-5: Baseline Annual Recreational Impingement Losses at the J.R. Whiting Facility and Associated Economic Values

Species	Loss to Recreational Catch from Impingement (# of fish)	Recreational Value/Fish		Loss in Recreational Value from Impingement	
		Low	High	Low	High
Channel catfish	56	$2.64	$5.02	$147	$280
Crappie spp.	10	$1.00	$5.02	$10	$51
Sunfish spp.	10	$0.31	$1.00	$3	$10
Walleye	381	$5.02	$7.92	$1,912	$3,016
White bass	2,936	$1.58	$5.32	$4,639	$15,619
White perch	0	$0.31	$1.00	$0	$0
Yellow perch	1,953	$0.31	$1.00	$606	$1,953
Total	5,346			$7,316	$20,929

Tues Feb 05 MST 2002 ; Table B: recreational losses and value for selected species; Plant: jr.whiting.78.79; type: I
Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/TableB.rec.losses.jr.whiting.78.79.I.csv

Table H4-6: Baseline Annual Recreational Entrainment Losses at the J.R. Whiting Facility and Associated Economic Values

Species	Loss to Recreational Catch from Entrainment (# of fish)	Recreational Value/Fish		Loss in Recreational Value from Entrainment	
		Low	High	Low	High
Channel catfish	3	$2.64	$5.02	$7	$14
Crappie spp.	79	$1.00	$5.02	$79	$399
Sunfish spp.	2,053	$0.31	$1.00	$637	$2,053
Walleye	0	$5.02	$7.92	$0	$0
White bass	1,687	$1.58	$5.32	$2,665	$8,975
Yellow perch	232	$0.31	$1.00	$72	$232
Total	4,054			$3,460	$11,672

Tue Feb 05 MST 2002 ; TableB: recreational losses and value for selected species; Plant: jr.whiting.78.79; type: E
Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/TableB.rec.losses.jr.whiting.78.79.E.csv

H4-3 Baseline Economic Losses from Commercial Fishing

I&E losses to commercial catch (pounds) are presented in Tables H4-2 (for impingement) and H4-3 (for entrainment) based on the recreational and commercial splits in Table H4-1. EPA estimates of the economic value of these losses are displayed in Tables H4-7 and H4-8. Values for commercial fishing are relatively straightforward because commercially caught fish are a commodity with a market price. The market value of foregone landings to commercial fisheries is $128,300 for impingement per year, and $11,600 annually for entrainment.

Tables H4-7 and H4-8 express commercial impacts based on dockside market prices only. However, to determine the total economic impact from changes to the commercial fishery, EPA also determined the losses experienced by producers wholesalers, retailers and consumers. The total social benefits (economic surplus) are greater than the increase in dockside landings, because the increased landings by commercial fishermen contribute to economic surplus in each of a multi-tiered set of markets for commercial fish. The total economic surplus impact thus is valued by examining the multi-tiered markets through which the landed fish are sold, according to the methods and data detailed in Chapter A9.

The first step of the analysis involves a fishery-based assessment of I&E-related changes in commercial landings (pounds of commercial species as sold dockside by commercial harvesters). The results of this dockside landings value step are described above. The next steps then entail tracking the anticipated additional economic surplus generated as the landed fish pass from dockside transactions to other wholesalers, retailers and, ultimately, consumers. The resulting total economic surplus measures include producer surplus to the watermen who harvest the fish, as well as the rents and consumer surplus that accrue to buyers and sellers in the sequence of market transactions that apply in the commercial fishery context.

To estimate producer surplus from the landings values, EPA relied on empirical results from various researchers that can be used to infer producer surplus for watermen based on gross revenues (landings times wholesale price). The economic literature (Huppert, 1990; Rettig and McCarl, 1985) suggests that producer surplus values for commercial fishing ranges from 50 to 90 percent of the market value. In assessments of Great Lakes fisheries, an estimate of approximately 40% has been derived as the relationship between gross revenues and the surplus of commercial fishermen (Cleland and Bishop, 1984, Bishop, personal communication, 2002). For the purposes of this study, EPA believes producer surplus to watermen is probably in the range of 40% to 70% of dockside landings values.

Producer surplus is one portion of the total economic surplus impacted by increased commercial stocks — the total benefits are comprised of the economic surplus to producers, wholesalers, processors, retailers, and consumers. Primary empirical research deriving "multi-market" welfare measures for commercial fisheries have estimated that surplus accruing to commercial anglers amount to approximately 22% of the total surplus accruing to watermen, retailers and consumers combined (Norton et al., 1983; Holt and Bishop, 2002). Thus, total economic surplus across the relevant commercial fisheries multi-tiered markets can be estimated as approximately 4.5 times greater than producer surplus alone (given that producer surplus is roughly 22% of the total surplus generated). This relationship is applied in the case studies to estimate total surplus from the projected changes in commercial landings.

Table H4-7: Baseline Mean Annual Commercial Impingement Losses at J.R. Whiting Facility and Associated Economic Values

Species	Loss to Commercial Catch from Impingement (lb of fish)	Commercial Value/Fish	Loss in Commercial Value from Impingement
Bullhead spp.	30	$0.33	$10
Channel catfish	46	$0.76	$35
Common carp	29,303	$0.16	$4,688
Freshwater drum	2,070	$0.21	$435
Gizzard shad	807,576	$0.15	$121,136
Sucker spp.	15	$0.09	$1
White bass	2,068	$0.98	$2,027
Total	841,109		$128,333

Tue Feb 05 MST 2002 ; Table C: commercial losses and value for selected species; Plant: jr.whiting.78.79 ; type: I
Pathname:
P:/Intakc/Great_Lakes/GL_Scicnce/scodes/jr.whiting/tablcs.output.78.79/TablcC.comm.losses.jr.whiting.78.79.I.csv

Table H4-8: Baseline Mean Annual Commercial Entrainment Losses at J.R. Whiting Facility and Associated Economic Values

Species	Loss to Commercial Catch from Entrainment (lb of fish)	Commercial Value/Fish	Loss in Commercial Value from Entrainment
Channel catfish	2	$0.76	$2
Common carp	17,636	$0.16	$2,822
Freshwater drum	1,581	$0.21	$332
Gizzard shad	48,198	$0.15	$7,230
Sucker spp.	48	$0.09	$4
White bass	1,188	$0.98	$1,165
Total	68,654		$11,554

Tue Feb 09 MST 2002 ; Table C: commercial losses and value for selected species; Plant: jr.whiting.78.79; type: E
Pathname:
P:/Intakc/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/TablcC.comm.losscs.jr.whiting.78.79.E.csv

Accordingly, EPA estimates that the total baseline economic loss to commercial fisheries ranges from $233,000 to $408,000 for impingement per year, and from $21,000 to $37,000 annually for entrainment at the J.R. Whiting facility (before installation of the impingement deterrent net).

H4-4 Indirect Use: Forage Fish

Many species affected by I&E are not commercially or recreationally fished. For the purposes of this study, EPA refers to these species as forage fish. Forage fish are species that are prey for other species, and are important components of aquatic food webs. Table H4-9 summarizes impingement losses of forage species at J.R. Whiting before net installation and Table H4-10 summarizes entrainment losses. The following sections discuss the economic valuation of these losses using two alternative valuation methods.

Table H4-9: Summary of Mean Annual Impingement of Forage Fish at J.R. Whiting (without impingement deterrent net)

Species	Impingement Count (#)	Age 1 Equivalents (#)	Production Foregone (lb)
Alewife	1,681	1,931	114
Bluntnose minnow	0	0	0
Emerald shiner	637,230	754,130	9,267
Logperch	5,950	7,951	40
Rainbow smelt	2,807	3,776	27
Forage species total	647,668	767,789	9,447

\\alexandria\project\INTAKE\Great_Lakes\GL_Science\scodes\jr.whiting\tables.output.78.79 \flowchart.Imp.New.xls

Table H4-10: Summary of Mean Annual Entrainment of Forage Fish at J.R. Whiting (without impingement deterrent net)

Species	Entrainment Count (#)	Age 1 Equivalents (#)	Production Foregone (lb)
Alewife	0	0	0
Bluntnose minnow	1,623,716	46,669	199
Emerald shiner	7,584,514	69,046	20,775
Logperch	191,471	7,405	570
Rainbow smelt	155,897	20,575	714
Total	9,555,598	143,695	22,257

\\alexandria\project\INTAKE\Great_Lakes\GL_Science\scodes\jr.whiting\tables.output.78.79 \flowchart.ENT.New.xls

Replacement value of fish

The replacement value of fish can be used in several cases. First, if a fish kill of a fishery species is mitigated by stocking of hatchery fish, then losses to the commercial and recreational fisheries would be reduced, but fish replacement costs would still be incurred and should be accounted for. Second, if the fish are not caught in the commercial or recreational fishery, but are important as forage or bait, the replacement value can be used as a lower bound estimate of their value (it is a lower bound because it would not consider how reduction in their stock may affect other species' stocks). Third, where there are not enough data to value losses to the recreational and commercial fisheries, replacement cost can be used as a proxy for lost fishery values. Typically the consumer or producer surplus is greater than fish replacement costs, and replacement costs typically omit problems associated with restocking programs (e.g., limiting genetic diversity).

The cost of replacing forage fish lost to I&E has two main components. The first component is the cost of raising the replacement fish. Table H4-11 displays the replacement costs of forage species at J.R. Whiting. The annual costs of replacing annual forage losses are $18,000 for impingement and $2,500 for entrainment. The per pound costs listed in Table H4-11 are average costs to fish hatcheries across North America to produce different species of fish for stocking (AFS. 1993).

Table H4-11: Replacement Cost of Forage Losses at J.R. Whiting (2000$)

Species	Hatchery Costs[a] ($/lb)	Annual Cost of Replacing Forage Losses ($2000)	
		Impingement	Entrainment
Alewife	$0.52	$30	$0
Bluntnose minnow	$2.21	$0	$603
Emerald shiner	$0.91	$17,862	$1,635
Logperch	$1.05	$107	$99
Rainbow smelt	$0.34	$25	$136
Total		$18,025	$2,474

[a] These values were inflated to 2000$ from 1989$, but this could be imprecise for current fish rearing and stocking costs.
Source: Sourcebook for Investigation and Valuation of Fish Kill, AFS 1993.
Tue Feb 05 MST 2002 ; Table D: loss in selected forage species; Plant: jr.whiting.78.79 ; type: I Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/TableD.forage.eco.ter.repl.jr.whiting.78.79.I.csv

The second component of replacement cost is the transportation cost, which includes costs associated with vehicles, personnel, fuel, water, chemicals, containers, and nets. The AFS (1993) estimates these costs at approximately $1.13 per mile, but does not indicate how many fish (or how many pounds of fish) are transported for this price. Lacking relevant data, EPA did not include the transportation costs in this valuation approach.

Production foregone value of forage fish

This approach considers the foregone biomass production of commercial and recreational fishery species resulting from I&E of forage species based on estimates of trophic transfer efficiency, as discussed in Chapter A5 of Part A of this document. The economic valuation of forage losses is based on the dollar value of the foregone fishery yield resulting from the loss of forage.

Summary of values of baseline forage fish losses

Tables H4-12 and H4-13 display the values for baseline losses of forage fish based on the production foregone of fishery yield for I&E, respectively. Baseline losses range from $200 to $400 for impingement and from $40 to $100 for entrainment.

H4-5 Nonuse Values

Recreational consumer surplus and commercial impacts are only part of the total losses that the public realizes from I&E impacts on fisheries. Nonuse or passive use impacts arise when individuals value environmental changes apart from any past, present or anticipated future use of the resource in question. Such passive use values have been categorized in several ways in the economic literature, typically embracing the concepts of existence (stewardship) and bequest (intergenerational equity) motives. Using a "rule of thumb" that nonuse impacts are at least equivalent to 50 percent of the recreational use impact (see Chapter H6 for further discussion), nonuse values for baseline losses at J.R. Whiting are estimated to range from $3,700 to $10,500 for impingement and from $1,700 to $5,800 for entrainment.

Table H4-12: Mean Annual Economic Value of Production Foregone of Selected Fishery Species Resulting from Impingement of Forage Species at J.R. Whiting.

Species	Loss in Production Foregone from Impingement	
	Low	High
Bullhead spp.	$7	$12
Channel catfish	$27	$50
Common carp	$9	$16
Crappie spp.	$9	$43
Freshwater drum	$4	$7
Gizzard shad	$12	$21
Sucker spp.	$0	$1
Sunfish spp.	$21	$69
Walleye	$22	$35
White bass	$55	$147
Yellow perch	$11	$34
Total	$178	$435

Tue Feb 05 10:47:18 MST 2002 ; TableD: loss in selected forage species; Plant: jr.whiting.78.79 ; type: I Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables. output.78.79/TableD.forage.eco.ter.repl.jr.whiting.78.79.I.csv

Table H4-13: Mean Annual Value of Production Foregone of Selected Fishery Species Resulting from Entrainment of Forage Species at J.R. Whiting.

Species	Loss in Production Foregone from Entrainment	
	Low	High
Channel catfish	$10	$19
Common carp	$4	$8
Crappie spp.	$1	$4
Freshwater drum	$1	$2
Gizzard shad	$5	$8
Sunfish spp.	$16	$52
White bass	$6	$15
Yellow perch	$0	$1
Total	$43	$109

Tue Feb 05 10:47:24 MST 2002 ; TableD: loss in selected forage species; Plant: jr.whiting.78.79 ; type: E Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79 /TableD.forage.eco.ter.repl.jr.whiting.78.79.E.csv

H4-6 Summary of Annual Value of Baseline Economic Losses at J.R. Whiting

Table H4-14 summarizes the total economic value of annual baseline I&E at the J.R. Whiting facility. Total impacts range from $244,000 to $458,000 per year from impingement and from $26,000 to $57,000 per year from entrainment. These reflect losses before installation of the deterrent net that reduced impingement significantly (see Chapter H6).

Table H4-14: Summary of Values of Baseline Annual I&E Losses at J.R. Whiting Facility

		Impingement	Entrainment	Total
Commercial: Total surplus (direct use, market)	Low	$233,333	$21,007	$254,340
	High	$408,332	$36,763	$445,095
Recreational (direct use, nonmarket)	Low	$7,316	$3,460	$10,777
	High	$20,929	$11,672	$32,601
Forage (indirect use, nonmarket)				
Production Foregone	Low	$178	$43	$221
	High	$435	$109	$544
Replacement		$18,025	$2,474	$20,499
Nonuse (passive use, nonmarket)	Low	$3,658	$1,730	$5,388
	High	$10,465	$5,836	$16,301
Total (Com + Rec + Forage + Nonuse)[a]	Low	$244,485	$26,241	$270,726
	High	$457,750	$56,745	$514,496

[a] In calculating the total low values, the lower of the two forage valuation methods (production foregone and replacement) was used and to calculate the total high values, the higher of two forage valuation methods was used.
Tue Feb 05 MST 2002 ; TableE.summary; Plant: jr.whiting.78.79 ; Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/TableE.summary.jr.whiting.78.79.csv

Chapter H5: Streamlined HRC Valuation of I&E Losses at the J.R. Whiting Facility

This chapter presents the results of EPA's streamlined habitat-based replacement cost (HRC) valuation of I&E losses at the J.R. Whiting facility in Monroe, Michigan, for the following scenarios:

- the cost of offsetting all I&E losses without the currently installed impingement deterrent net using I&E data for 1978 and 1979 only (baseline losses);
- the cost of offsetting 95 percent of baseline losses, assumed to be equivalent to installation of a cooling tower;
- the cost of offsetting losses equivalent to installation of the net using the difference in average annual impingement for 1978-1979 compared to 1981-1991.

CHAPTER CONTENTS

H5-1 Quantify I&E Losses by Species (Step 1) H5-2
H5-2 Identify Species Habitat Requirements (Step 2), Identify Habitat Restoration Alternatives (Step 3), and Prioritize Restoration Alternatives (Step 4) H5-3
H5-3 Quantify the Benefits for the Prioritized Habitat Restoration Alternatives (Step 5) H5-4
H5-4 Scale the Habitat Restoration Alternatives to Offset I&E Losses (Step 6) H5-5
H5-5 Estimate "Unit Costs" for the Habitat Restoration Alternatives (Step 7) H5-7
H5-6 Develop Total Cost Estimates for I&E Losses (Step 8) H5-8
H5-7 Strengths and Weaknesses of the Streamlined HRC Analysis H5-9

A description of the HRC method and the process for undertaking a complete HRC valuation of I&E losses is provided in Chapter A11 of Part A of this document. To summarize, a complete HRC valuation of I&E losses reflects the combined costs for implementing habitat restoration actions, administering the programs, and monitoring the increased production after the restoration actions. In a complete HRC valuation, these costs are developed by first identifying the preferred habitat restoration alternative for each species with I&E losses and then scaling the level of habitat restoration until the losses across all the species for that restoration alternative have been exactly offset by the expected increases in production of each species. The total value of the I&E losses at the facility is then calculated as the sum of the costs across the set of preferred habitat restoration alternatives that were identified.

The HRC method is thus a supply-side approach for valuing I&E losses in contrast to the more typically used demand-side valuation approaches (e.g., commercial and recreational fishing impacts valuations). An advantage of the HRC method is that the HRC values address losses for species lacking a recreational or commercial fishery (e.g., forage species). Further, the HRC explicitly recognizes and captures the fundamental ecological relationships between species with I&E losses at a facility and their surrounding environment by determining the value of I&E losses through the cost of the actions required to provide an offsetting increase in the existing populations of those species in their natural environment.

Streamlining was necessary to meet the schedule of the 316(b) existing sources rule and entailed combining Step 2 (identification of species habitat requirements), Step 3 (identification of habitat time and budget constraints typically faced by NPDES permit t restoration alternatives), and Step 4 (consolidation and prioritization of habitat restoration alternatives), restricting the analysis to readily available information, and eliminating site visits, in-depth discussions with local experts, and development of primary data (see Chapter A11 of Part A of this document), which would be required before doing an actual restoration. Despite these restrictions, the streamlined HRC provided a more comprehensive, ecological-based valuation of the I&E losses than valuation by traditional commercial and recreational impacts methods. In addition, the streamlined HRC valued direct, indirect, and passive uses not included in more traditional economic valuation techniques used in Chapter H4 and H6.

The annualized costs, in 2000 dollars, of restoring sufficient fish production habitat to offset the I&E losses in perpetuity for each scenario at the J.R. Whiting facility are as follows:

- Baseline losses: $0.2 - $3.5 million
- Losses equivalent to those avoided by a cooling tower: $0.2 - $3.3 million
- Losses equivalent to those avoided by the barrier net in place at J.R. Whiting: $0.1 - $1.0 million.

The following subsections describe the streamlined HRC valuation applied to the J.R. Whiting facility and the advantages and disadvantages of streamlining the HRC method.

H5-1 Quantify I&E Losses by Species (Step 1)

The streamlined HRC method relies on the same estimates of annual age 1 equivalent species losses that are developed in Chapter H3 and incorporated in the commercial and recreational fishing impacts valuation presented in Chapters H4 (baseline) and H6 (cooling tower and barrier net). EPA developed these estimates using I&E data reported directly by the facility (Wapora, 1979, 1980; Consumers Power Company, 1984, 1988, 1992). Total I&E losses at the facility may be underestimated, particularly if certain species were not targeted by monitoring efforts or if short duration population spikes occurred outside of monitoring events. The HRC method inherently reduces the former problem by targeting restoration activities that might benefit species lost but not monitored, but like all other measures of I&E losses, it relies on representative monitoring.

Various life stages of organisms were lost to I&E at J.R. Whiting. As with other facilities, primarily early stages such as eggs and larvae are entrained, and primarily juveniles and adults are impinged. However, EPA estimated total losses for each species by converting all losses to a common equivalent life stage by applying average mortality rates between life stages for each species. These mortality rates were derived from the literature and best professional judgment. Conversion between life stages did not change the overall scale of required restoration in the streamlined HRC method because many eggs are equivalent to few adults on both the I&E loss and increased production sides of the HRC equation. For example, if on average one adult survives from 10 eggs via a 90 percent cumulative mortality rate and 1 acre of habitat produces 10 eggs, then restoration of 1 acre is needed to produce either one adult or 10 eggs.

Age 1 equivalent I&E losses of 17 species of fish were calculated using the available I&E monitoring data available from the J.R. Whiting facility from 1978 through 1991. These data are presented in Chapter H3 of this document. A summary of average annual age 1 equivalent losses in the different scenarios under consideration is presented in Table H5-1.

Several species impinged or entrained at J.R. Whiting are important to commercial or recreational fishing, including walleye, yellow perch, catfish, and crappie. Many others, including alewife, rainbow smelt, bluntnose minnows, emerald shiners, and herrings, indirectly affect commerce and recreation because they are prey for commercially or recreationally important aquatic and terrestrial wildlife species such as salmon and northern pike, bald eagles, and mink. Furthermore, all of the species provide numerous, complex, ecological services as sources of carbon and energy transfer through the food web, as well as continuous interactive exploitation of niches available in the Great Lakes ecosystem (a system already under tremendous stress from exotic species introductions, hazardous substance contamination, nonpoint source runoff, heat contamination, habitat loss, overfishing, and I&E) from multiple sources.

For example, freshwater drum feed on a variety of small fish. When food supplies are short, freshwater drum often out-compete other species and thereby may increase mortality rates or decrease growth rates for those species (Edsall, 1967). In addition, several species of Centrarchids, including the crappie, are sensitive to the size of their predators' population. When predators such as walleye are absent, species such as crappie can overcrowd their habitats and exhaust their own food supplies, resulting in stunted growth (Wang, 1986a; Steiner, 2000). Finally, some species are already subject to wide fluctuations in population size from year to year, and may not be able to tolerate I&E losses, particularly at certain times of the year. For example, the gizzard shad is often subject to high mortality in the winter (Miller, 1960).

Table H5-1: Average Annual I&E Losses of Age 1 Equivalent Fish at the J.R. Whiting Facility

Species	Baseline Scenario: (1978 and 1979)			Reductions in I&E	
	Impinged	Entrained	Total	Cooling Tower Scenario: 95% of Baseline Losses	Barrier Net Scenario: 1978-1979 vs. 1981-1991[a]
Gizzard shad	20,459,337	1,221,061	21,680,398	20,596,378	18,943,039
Emerald shiner	754,130	69,046	823,176	782,017	698,963
Sunfish spp.	1,720	350,828	352,548	334,921	238
Yellow perch	104,225	12,360	116,585	110,756	93,913
Common carp	60,640	36,496	97,136	92,279	57,620
White bass	48,937	28,118	77,055	73,202	41,213
Freshwater drum	38,970	29,768	68,738	65,301	26,658
Bluntnose minnow	N/A[b]	46,669	46,669	44,336	N/A[b]
Rainbow smelt	3,776	20,575	24,351	23,133	3,573
Logperch	7,951	7,405	15,356	14,588	6,766
Crappie spp.	687	5,391	6,078	5,774	127
Sucker spp.	1,246	3,853	5,099	4,844	1,193
Walleye	4,699	N/A[b]	4,699	4,464	4,511
Channel catfish	2,965	143	3,108	2,953	1,506
Bullhead spp.	2,001	N/A[b]	2,001	1,901	1,909
Alewife	1,931	N/A[b]	1,931	1,834	1,792
White perch[c]	N/A[b]	N/A[b]	N/A[b]	N/A[b]	N/A[b]
Total	**21,493,215**	**1,831,713**	**23,324,928**	**22,158,681**	**19,883,021**

[a] Indirect evidence suggests the barrier net only reduces impingement, so only the difference in pre- and post-barrier net impingement estimates of age 1 equivalents were estimated.
[b] N/A for a species reflects no data reported as opposed to a reported value of 0. N/A for the barrier net always corresponds to N/A for baseline impingement.
[c] Impingement losses of white perch prior to the installation of the barrier net were not reported. Quantified impingement losses are reported for subsequent years, making white perch a species with recorded quantified I&E impacts at the J.R. Whiting facility.

H5-2 Identify Species Habitat Requirements (Step 2), Identify Habitat Restoration Alternatives (Step 3), and Prioritize Restoration Alternatives (Step 4)

EPA combined steps 2, 3, and 4 of the HRC method by seeking a single habitat restoration program capable of increasing production for most of the species with quantified I&E losses at J.R. Whiting. Addressing each of these steps separately for each of the I&E species would improve the analysis but would require more time than was available for the analysis for the proposed rule.

J.R. Whiting's CWISs are located in the shallow and enclosed end of Maumee Bay (western Lake Erie) and are surrounded by marsh and wetlands, including the Woodtick Peninsula and the lands of the Erie Shooting Club (R. Micka, Lake Erie Clean Up Committee Inc., personal communication, 2001). Further, species affected by I&E clearly use these habitats, as demonstrated by their I&E at the facility. In addition, wetland restoration and preservation programs are active in many Great Lakes states, providing a good source of readily available information on restoration costs. Finally, readily available information describes fish species use of Great Lakes' coastal wetlands that can be used as a proxy for increased production benefit estimates. Therefore, coastal wetland restoration is the preferred restoration alternative for offsetting the I&E losses at the J.R. Whiting facility in this streamlined HRC valuation.

H5-3 QUANTIFY THE BENEFITS FOR THE PRIORITIZED HABITAT RESTORATION ALTERNATIVES (STEP 5)

A literature search revealed a study (Brazner, 1997) that provides fish capture data by species from sampling efforts conducted at a series of Green Bay (Lake Michigan) coastal wetland and sand beach sites. No other studies provide more direct measures of increased fish species production following Great Lakes coastal wetland restoration, or fish capture data in wetlands closer to the J.R. Whiting facility. However, the Brazner study sampled wetlands in the warmer, shallower, more eutrophic waters of southern Green Bay, which are similar to the waters of western Lake Erie. After examining the data from the Brazner study and discussing them with the author, EPA dropped less similar sites from northern Green Bay. For each of the species lost at J.R. Whiting, a match was found with a species, or combination of species, among those captured at the southern sites in the Brazner study. Table H5-2 shows the species caught in the Brazner study that were paired with the species being lost at the J.R. Whiting facility (this represents only a fraction of the species caught in these southern locations in the Brazner study).

Table H5-2: Species with I&E Loss Estimates at J.R. Whiting and the Corresponding Species Captured in Green Bay Wetland Sampling

Species with I&E Loss Estimates at J.R. Whiting	Corresponding Species Caught in Sampling of Green Bay Coastal Wetlands (Brazner, 1997)
Alewife	Yes
Bluntnose minnow	Yes
Bullhead spp.	Yes (as black, brown, and yellow bullhead)
Channel catfish	Yes
Common carp	Yes
Crappie spp.	Yes (as black crappie)
Emerald shiner	Yes
Freshwater drum	Yes
Gizzard shad	Yes
Logperch	Yes
Rainbow smelt	Yes
Sucker spp.	Yes (as white sucker)
Sunfish spp.	Yes (as green sunfish)
Walleye	Yes
White bass	Yes
White perch	Yes
Yellow perch	Yes

Because of the close match between the physical habitats of southern Green Bay and western Lake Erie and the confirmation of similar species between the sites, EPA estimated densities for each southern Green Bay species and used them as a proxy for direct measurements of potential increased production following wetland restoration. This approach assumed that additional wetland habitat restored near J.R. Whiting would provide similar densities of each species as the wetland habitats sampled in Green Bay. Direct measurements of densities of each species before and after actual wetland habitat restorations in western lake Erie could test this assumption and improve the reliability of the HRC valuation for J.R. Whiting.

EPA developed the density estimates for each species for each site using aggregate sampling results provided by the author (J. Brazner, U.S. EPA, Duluth Lab, personal communication, 2001). Table H5-3 provides a summary of the Green Bay capture data (J. Brazner, U.S. EPA, Duluth Lab, personal communication, 2001) for each species that has quantified I&E losses at J.R. Whiting. Data for each of four Green Bay sites are presented, as are the average and maximum of all four sites.

Table H5-3: Green Bay Wetland Abundance Data

Species Name for HRC Analysis	Number Captured: Lower Green Bay Wetland Locations[a]				Summary Statistics	
	Long Tail Point Wetland	Little Tail Point Wetland	Atkinson Marsh	Sensiba Wildlife Refuge	Average	Maximum
Yellow perch	3,525	942	333	1,108	1,477	3,525
Gizzard shad	384	264	160	137	236	384
Bluntnose minnow	285	116	15	259	169	285
Alewife	265	142	92	124	156	265
Emerald shiner	113	31	251	224	155	251
White bass	52	226	106	9	98	226
Sucker spp.[b]	14	10	1	103	32	103
Carp	19	10	3	1	8	19
Green sunfish	3	5	22	2	8	22
Bullhead spp.[c]	9	4	0	2	4	9
Freshwater drum	4	4	7	1	4	7
White perch	0	0	0	7	2	7
Crappie spp.[d]	1	2	1	1	1	2
Channel catfish	0	0	3	0	1	3
Logperch	0	0	0	1	0	1
Rainbow smelt	0	1	0	0	0	1
Walleye	1	0	0	0	0	1

[a] Number captured in samples of 100 meters linear coastal wetland frontage. Reflects age 1 fish (not eggs and larvae).
[b] Sucker spp. values are those reported for white sucker.
[c] Bullhead spp. values are the sum of the black, brown, and yellow bullhead values at each location.
[d] Crappie spp. values are those reported for black crappie.

The raw capture data were converted to density estimates for each species by assuming that each sampling event of 100 m of linear coastal wetland frontage corresponded to an average of 100 m of perpendicular width of connected coastal wetlands (i.e., each sampling event included fish from an assumed 100 m x 100 m area of wetlands). This assumption is based on discussions with the author about the likely perpendicular width of the sampled wetlands that was being used as habitat by the sampled species (J. Brazner, U.S. EPA, personal communication, 2001). A further adjustment was then made to the raw capture data to recognize the fact that shoreline sampling would capture only a portion of the fish actually using the 100 m x 100 m wetland habitat. After discussions with the author, the capture data were increased by a factor of 100 (1/0.01), based on the assumption that only 1 percent of the fish present or relying on the wetland habitat were captured in the sampling event.

The resulting per acre average density estimates for each species was used in the HRC equation as the measure of increased production that would most likely be provided by wetland habitat restoration near J.R. Whiting. The maximum per acre density estimate for each species was used as an upper bound estimate of fish density that would result from wetland restoration near the J.R. Whiting facility.

Brazner (1997) captured young-of-year (younger than age 1), age 1 fish, and adult fish (older than age 1) in the Green Bay wetlands. In this evaluation, the capture data were treated as if it represented age 1 fish, which eliminated the need to apply mortality rates to adjust for survival between life stages for each species, as was done for I&E losses. Since Brazner (1997) reports a high percentage of young-of-year fish captured at all Green Bay sites, this assumption most likely results in a slight overestimation of age 1 fish densities, and therefore potentially underestimates the scale of restoration required to offset the average annual I&E loss for each species (i.e., it underestimates baseline losses from I&E).

H5-4 Scale the Habitat Restoration Alternatives to Offset I&E Losses (Step 6)

EPA calculated the amount of Great Lakes coastal wetland restoration required to offset I&E losses for each species at the J.R. Whiting facility by dividing the average annual I&E loss for each species in each scenario by its per-acre estimate of increased production of age 1 equivalents. The results of this scaling for the baseline scenario are presented in Table H5-4.

Table H5-4: Wetland Restoration Required to Offset I&E Losses at the J.R. Whiting CWIS (baseline scenarios, i.e., without net)

Species	Average Annual Age 1 Equivalents Lost to I&E	Per-Unit Production Benefit (age 1 fish per restored coastal wetland acre)		Required Acres of Wetland Restoration to Offset I&E Loss	
		Average Value	Maximum Value Across Sites	Based on Average Production Value	Based on Maximum Production Value
Rainbow smelt	24,351	10	40	2,407	602
Gizzard shad	21,680,398	9,561	15,540	2,268	1,395
Logperch	15,356	10	40	1,518	379
Sunfish spp.	352,548	324	890	1,089	396
Walleye	4,699	10	40	464	116
Freshwater drum	68,738	162	283	425	243
Common carp	97,136	334	769	291	126
Emerald shiner	823,176	6,263	10,158	131	81
Crappie spp.	6,078	51	81	120	75
Channel catfish	3,108	30	121	102	26
White bass	77,055	3,976	9,146	19	8
Bullhead spp.	2,001	152	364	13	5
Bluntnose minnow	46,669	6,829	11,534	7	4
Sucker spp.	5,099	1,295	4,168	4	1
Yellow perch	116,585	59,774	142,657	2	1
Alewife	1,931	6,303	10,725	0.3	0.2
White perch	N/A	71	283	N/A	N/A

Whether using average or maximum production values, over half of the species listed in Table H5-4 would require that hundreds or thousands of acres of wetland habitat be restored to fully offset the I&E losses caused by the J.R. Whiting CWIS. If Great Lakes coastal wetland restoration is the best natural restoration alternative for offsetting losses for each of these species, then approximately 2,400 acres of coastal wetland restoration is required to fully offset all I&E losses under the baseline scenario using the average adjusted per acre density estimates (because restoring either rainbow smelt or gizzard shad would require that much wetland restoration, and all other species would be fully restored as well). However, without further discussions with local experts, and perhaps additional investigation of the relationship between feasible restoration activities and per-acre production benefits (particularly for the species driving the highest acreage needs), these assumptions may not be valid. On the other hand, the benefit of any given restoration program should always vary among species, and species with relatively high productivity or low I&E losses cannot drive the HRC results without sacrificing necessary offsets for other species with lower productivity or higher I&E losses. As seen in the results in Table H5-4, a large restoration requirement can reflect either low productivity of the restored habitat for the species (e.g., rainbow smelt) or very large I&E losses (e.g., gizzard shad).

Table H5-4 also shows that both the scale and distribution of the estimates of required wetland restoration change when maximum species density estimates are substituted for the averages. EPA used average species density estimates as the primary source of information because they are more representative of wetland productivity in the Brazner study, and more accurately reflect the difficulties of achieving full function in restored versus native habitats.[1]

Since a rigorous investigation of the relationship between feasible restoration alternatives and per-unit production estimates was not completed under the streamlined approach, using the highest restoration requirement (for rainbow smelt) may not be justified. Therefore, the restoration requirements were ordered for all of the species so that percentiles could be calculated. Using the 100th percentile (rainbow smelt) would offset losses for all of the species, as appropriate under a complete HRC

[1] The maximum species-density-based estimates are included only as a sensitivity analysis and reflect a minimal scale of restoration that would be required if Lake Erie wetland restorations were much more highly successful then EPA anticipates. Detailed, repeated monitoring of I&E species in areas where restoration has occurred will increase the accuracy of future analyses.

analysis. However, the 90th and 50th percentiles (corresponding to gizzard shad and emerald shiner, respectively) were used to bound the estimate of the required scale of restoration. Using a lower percentile than the 100th recognizes that further analyses (or monitoring) might identify restoration programs more efficient and less costly than wetland restoration for species with the highest wetland restoration needs, or might produce better and higher wetland restoration productivity estimates (lower cost) for those same species. Nevertheless, using lower percentiles risks underestimating the costs of needed restoration because most species benefit from wetland restoration, and wetland restoration could easily prove to be the best alternative for those species with the greatest wetland restoration needs. Further, improved analysis and monitoring are as likely to lower productivity estimates as they are to raise them. Therefore, percentiles less than the 50th were rejected as unreasonable.[2]

Table H5-5 presents the 90th and 50th percentile results from the distribution of required Great Lakes coastal wetland restoration calculated using the average species density estimates as a proxy for increased species production for each of the I&E scenarios under consideration and combined average annual I&E losses of age 1 equivalent fish. Table H5-5 also presents the results using the maximum species density estimates as a sensitivity analysis.

Table H5-5: Acres of Coastal Wetland Restoration Required under Different I&E Scenarios with Alternative Increased Production Benefits Assumptions

I&E Scenario	Acres of Required Wetland Restoration with Average Species-Specific Density Estimates (preferred alternative)		Acres of Required Wetland Restoration with Maximum Species-Specific Density Estimates (sensitivity test)	
	90th Percentile Result	50th Percentile Result	90th Percentile Result	50th Percentile Result
Baseline	2,268	131	602	81
In lieu of cooling tower	2,154	125	572	77
In lieu of barrier net	669	50	167	12

H5-5 Estimate "Unit Costs" for the Habitat Restoration Alternatives (Step 7)

EPA calculated annualized per-acre costs for restoring coastal wetlands in a Great Lakes ecosystem from the information in the Restoration and Compensation Determination Plan (RCDP) produced for the Lower Fox River/Green Bay Natural Resource Damage Assessment (U.S. Fish and Wildlife Service and Stratus Consulting, 2000), which incorporated a similar program as a restoration alternative. The RCDP's per-acre cost included expenses for the restoration implementation (fieldwork), project administration, maintenance, and monitoring.

The RCDP's wetland restoration program focused on acquiring lands around Green Bay that are currently in agricultural use and that are located on hydric soils (an indicator of a wetland area). These former wetlands were generally brought into agricultural production through the draining or tiling of the land. Therefore, most of the expense (63 percent) in the RCDP's per-acre cost estimates was for land acquisition and restoration actions necessary to re-establish functioning wetlands. Maintenance costs (9 percent) consisted of expenses for periodic mowing and burning to maintain the dominance of wetland vegetation. The remaining expenditures (28 percent) covered anticipated administrative expenses for the program. The per-acre cost estimates for the various components of the wetland restoration program as presented in the Lower Fox River/Green Bay RCDP are provided in Table H5-6 along with the equivalent annualized per-acre cost that is used to value the required scale of wetland restoration in this streamlined HRC (the development of this annualized value is discussed in the following paragraph).

[2] For instance, using the 25th percentile restoration requirement from Table H5-4 (7 acres for bluntnose minnow) would be valid only if further analysis produced superior (cheaper or more productive) restoration alternatives, or superior wetland productivity estimates that were higher for most of the species, including rainbow smelt, gizzard shad, sunfish spp., logperch, walleye, freshwater drum, common carp, emerald shiner, crappie spp., channel catfish, white bass, and bullhead spp. Even the 50th percentile value that we use as a lower bound estimate assumes that eight of these species could each be produced more effectively with different restoration alternatives, or that wetland productivity is actually higher for all eight species.

Table H5-6: Wetland Restoration Costs (2000 dollars)

Restoration Program Component	$/Acre	Cost Method
Land acquisition	3,000	Survey of land prices
Land transaction costs	600	20 percent of land price, reflects agency (U.S. FWS) experience
Restoration action	2,600	Project experience (See Table Source)
Contingency on restoration action	260	10 percent of restoration actions, consistent with standard practice
Project maintenance	590	Project experience (See Table Source)
Monitoring	340	5 percent of total of land acquisition, land transaction, restoration action, and maintenance
Agency (landowner) overhead (project administration)	2,900	38.84 percent of sum of all other cost, reflects agency (U.S. FWS) experience
Total Cost	10,300	
Total Annualized Cost	**1,540**	

Source: U.S. Fish and Wildlife Service and Stratus Consulting, 2000.

In annualizing the RCDP's unit costs for this streamlined HRC, EPA made a distinction between expected initial one-time program outlays (expenditures for land, transaction costs, restoration actions, contingency, and agency overhead) and anticipated recurring annual expenses (project maintenance and monitoring). Those costs that were viewed as initial program outlays were treated as a capital cost and annualized over a 20-year period at a 7 percent interest rate providing an annualized value of $882 from their initial combined value of $9,360. EPA then estimated the present value (PV), using a 7 percent interest rate, of the recurring annual expenses for 10 years as this is the length of time incorporated for monitoring in the complete HRC valuations conducted for the Brayton Point and Pilgrim facility case studies. This PV for the recurring annual expenses was then annualized over a 20 year period, again using a 7 percent interest rate resulting in an annualized expense of $658. This process effectively treats the monitoring expenses associated with the wetland restoration consistently with the annual operating and maintenance costs presented in the costing, economic impact, and cost-benefit analysis chapters. The annualized recurring expenses were then added to the annualized initial program outlays resulting in a total annualized cost for the wetlands restoration alternative of $1,540 per acre.

However, these unit costs probably understate the cost of monitoring that would be sufficient to measure per-unit production benefits in restored wetlands, which could then improve future HRC calculations. In the RCDP's wetland restoration monitoring program, the emphasis was on evaluating whether the hydrology of the former wetlands and the associated vegetation were returning over time, activities that could be achieved with relatively minimal effort. In contrast, a monitoring program capable of addressing whether anticipated increases in the production of certain species were being achieved in the restored wetland areas would require a far more significant commitment of time and resources, resulting in commensurately larger expenditures.

H5-6 Develop Total Cost Estimates for I&E Losses (Step 8)

EPA estimated the total annualized cost to offset the average annual I&E losses at the J.R. Whiting facility by multiplying the 50th percentile and 90th percentile results of the required acreage of wetland restoration (see Table H5-5) by the annualized per-acre wetlands restoration costs from the RCDP (see Table H5-6). These results are presented in Table H5-7.

Table H5-7: Total Annualized Costs for a Wetland Restoration Program to Offset I&E Losses (millions of 2000 dollars)

I&E Scenario	Cost of Required Wetland Restoration with Average Species-Specific Density Estimates (preferred results)		Cost of Required Wetland Restoration with Maximum Species-Specific Density Estimates (sensitivity test)	
	90th Percentile Result	50th Percentile Result	90th Percentile Result	50th Percentile Result
Baseline	$3.5	$0.2	$0.9	$0.1
In lieu of cooling tower	$3.3	$0.2	$0.9	$0.1
In lieu of barrier net	$1.0	$0.1	$0.3	$0.0[a]

[a] Exact value of $19,103 is converted to $0.0 when rounded for presentation in millions.

The results of the streamlined HRC provide an annualized present value estimate of roughly $3.5 million for a program of Great Lakes coastal wetland restoration that would offset the average annual age 1 equivalent losses from the baseline period in perpetuity using the 90th percentile results and average species density estimates. Using the same 90th percentile selection rule and the average species density results, the preferred results provide a value for installing a cooling tower that would eliminate 95 percent of the baseline I&E losses in perpetuity of $3.3 million, while the reduced impingement from the barrier net is valued at $1.0 million assuming the estimated average annual reduction in lost age 1 equivalents continues in perpetuity. Incorporating the maximum observed species density from any of the sampled wetlands in Green Bay reduces the value of the 90th percentile scenario results to roughly one-fourth the average species density results.

Table H5-8 shows the results of the streamlined HRC analysis for impingement losses, entrainment losses, and total I&E losses separately.

Table H5-8: Present Value and Annualized Results for the Monetization of I&E Losses at J.R. Whiting Incorporating Average Species-Specific Density Estimates (millions of 2000 dollars)

I&E Scenario	Component of I&E Loss	Annualized Value	
		90th Percentile	50th Percentile
Baseline	Impingement	$1.2	$0.2
	Entrainment	$1.7	$0.2
	I&E total[a]	$3.5	$0.2
Cooling tower	I&E total	$3.3	$0.2
Barrier net[b]	Impingement (Total)	$1.0	$0.1

[a] The total is not equal to the sum of the results from the I&E components because of different numbers of species in these components as well as different rankings of the species based on the extent of required restoration in these components.
[b] For the barrier net analysis, the impingement results also serve as the total results because no entrainment monitoring was done in the post-net period.

H5-7 Strengths and Weaknesses of the Streamlined HRC Analysis

The fundamental appeal of the HRC is its ability to incorporate and value environmental losses that are either undervalued or ignored by traditional valuation approaches, such as recreational and commercial fishing valuation (see Chapter A11 in Part A of this document for additional discussion). The primary advantage of the streamlined HRC is the limited effort and time required to provide regulators with an initial assessment of whether a complete HRC is justified. For facilities like J.R. Whiting with relatively large I&E impacts and I&E impacts to many species not targeted by anglers, a complete HRC is likely to be worthwhile, even given budgetary and time constraints associated with permit re-issuance cycles. In addition, the streamlined HRC provides regulators with a framework to evaluate mitigation proposals put forth by industry to address residual I&E losses associated with the permitted BTA.

The primary weakness of the streamlined HRC is the uncertainty resulting from limited opportunities to access local resource experts and unpublished primary data in the selection of a preferred restoration alternative, the development of per-unit production benefits for each species, and the estimation of restoration unit costs.

For these reasons, streamlining an HRC may be most appropriate when:

- a limited number of species experience I&E losses or the majority of I&E losses are realized by a small number of species
- the regulator is familiar with, or can quickly determine, the preferred restoration alternative for these critical species
- benefits information from evaluations of local habitats is available, and extrapolations do not lead to extreme variability
- published sources of information allow estimation of all important aspects of the restoration costs.

If these conditions are absent, a complete HRC analysis will provide a more comprehensive estimate of the losses associated with I&E than provided by traditional valuations.

In conclusion, the streamlined HRC method provides regulators, industry, and the public with an important method to quickly estimate the likely value of I&E losses at 316b-regulated facilities. Further, because regulators and local experts can often quickly assess whether appropriate and necessary information exists for the valuation of I&E resources, streamlining may offer many opportunities to broaden the evaluation of I&E to include ecological and related public services, even when facing significant time and budgetary constraints.

Chapter H6: Benefits Analysis for the J.R. Whiting Facility

CHAPTER CONTENTS

H6-1	Summary of Figures of Baseline Losses	H6-1
H6-2	Baseline Economic Losses	H6-1
H6-3	Economic Benefits of Installing a Barrier Net	H6-5
H6-4	Potential Economic Benefits due to Regulation	H6-5
H6-5	Summary of Omissions, Biases, and Uncertainties	H6-6

This chapter presents the results of EPA's evaluation of the economic benefits associated with reductions in estimated I&E at the J.R. Whiting facility. The economic benefits that are reported here are based on the values presented in Chapters H4 and H5, and EPA's estimates of I&E at the facility with and without an impingement deterrent net in place (see Chapter H3). Section H6-1 summarizes the estimates of baseline economic loss developed in Chapters H4 and H5. Section H6-2 summarizes the economic benefits attributable to the impingement deterrent net installed at the J.R. Whiting facility to reduce impingement. Section H6-3 discusses anticipated reductions in current I&E under the proposed regulation. Section H6-4 presents the estimated total economic benefit attributable to the regulation. Section H6-5 discusses the uncertainties in the analysis.

H6-1 Summary Figures of Baseline Losses

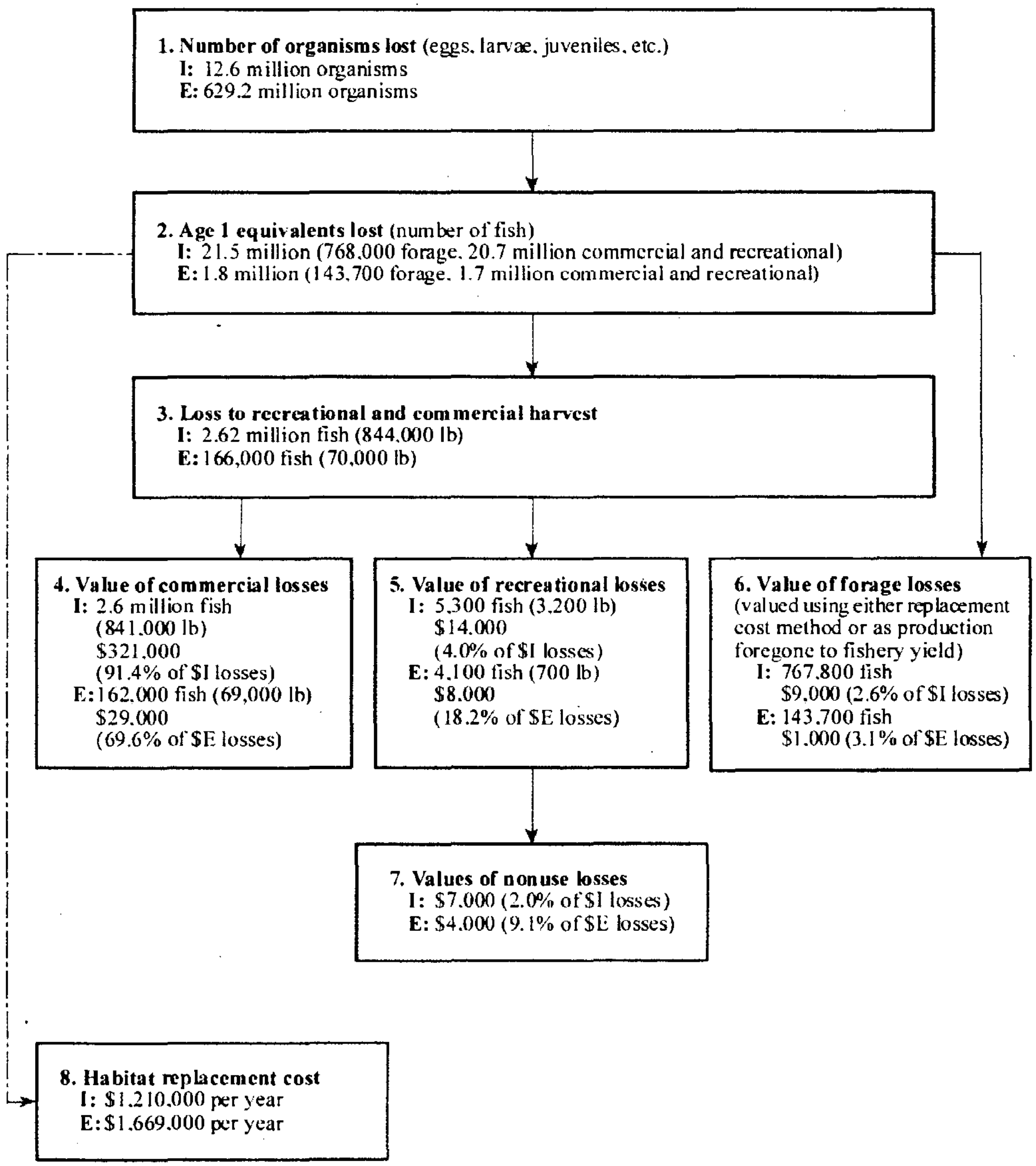
The flowchart in Figure H6-1 summarizes how the economic estimates for J.R. Whiting were derived from I&E estimates presented in Chapter H3. Figures H6-2 and H6-3 indicate the distribution of I&E losses by species category and associated economic values. These diagrams reflect the baseline losses without the net. All dollar values (and loss percents) reflect midpoints of the ranges for the categories of commercial, recreational, nonuse, and forage.

H6-2 Baseline Economic Losses

Baseline economic losses due to I&E at the J.R. Whiting facility were calculated in Chapters H4 and H5. In Chapter H4, total economic loss was estimated using a benefits transfer approach to estimate the commercial, recreational, forage, and nonuse values of fish lost to I&E. This is a demand-driven approach, i.e., it focuses on the values that people place on fish. In Chapter H5, total economic loss was estimated by calculating the cost to increase fish populations using habitat restoration techniques (HRC approach). This is a supply-driven approach, i.e., it focuses on the costs associated with producing fish in natural habitats.

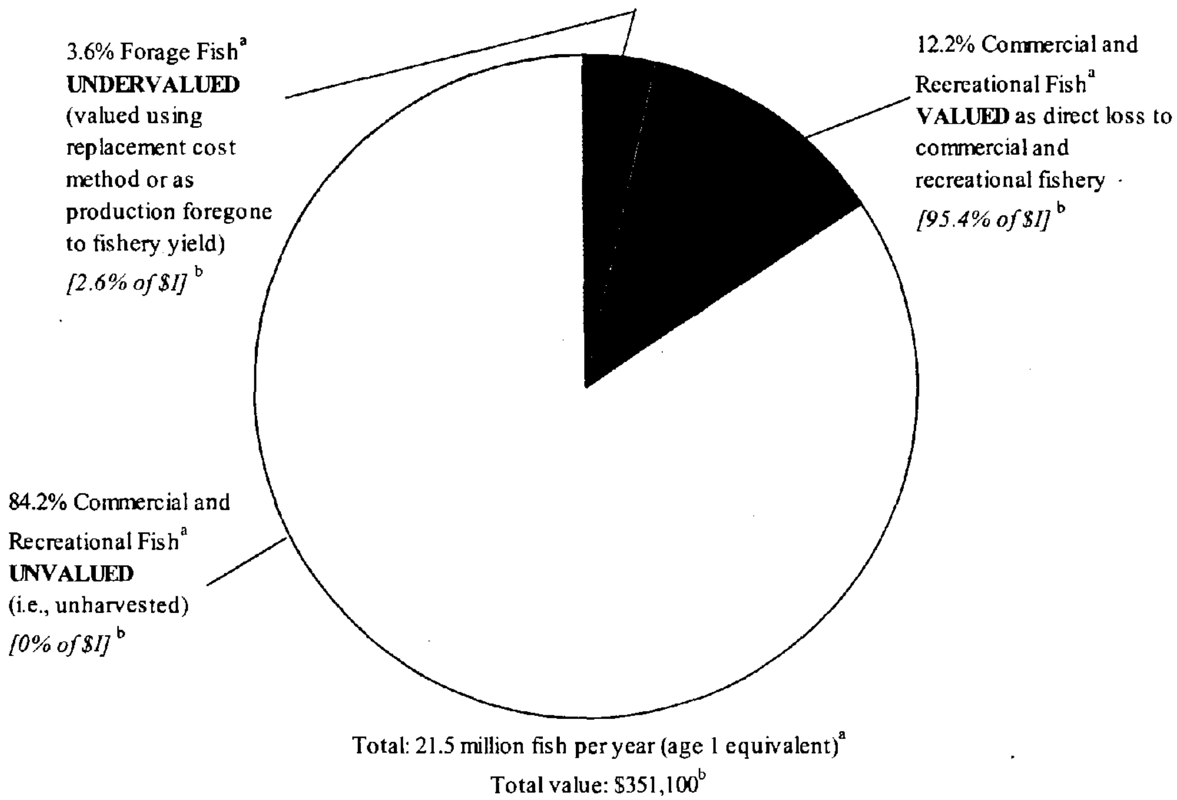
The total annual economic losses associated with each method are summarized in Table H6-1. These values range from \$351,000 to \$1,210,000 for impingement, and from \$41,000 to \$1,669,000 for entrainment. The range of economic loss is developed by taking the midpoint of the benefits transfer results and thc 90th percentile species results from the HRC approach.

Figure H6-1: Overview and Summary of Average Annual I&E at J.R. Whiting Before Installation of the Impingement Deterrent Net and Associated Economic Values (all results are annualized)[a,b]



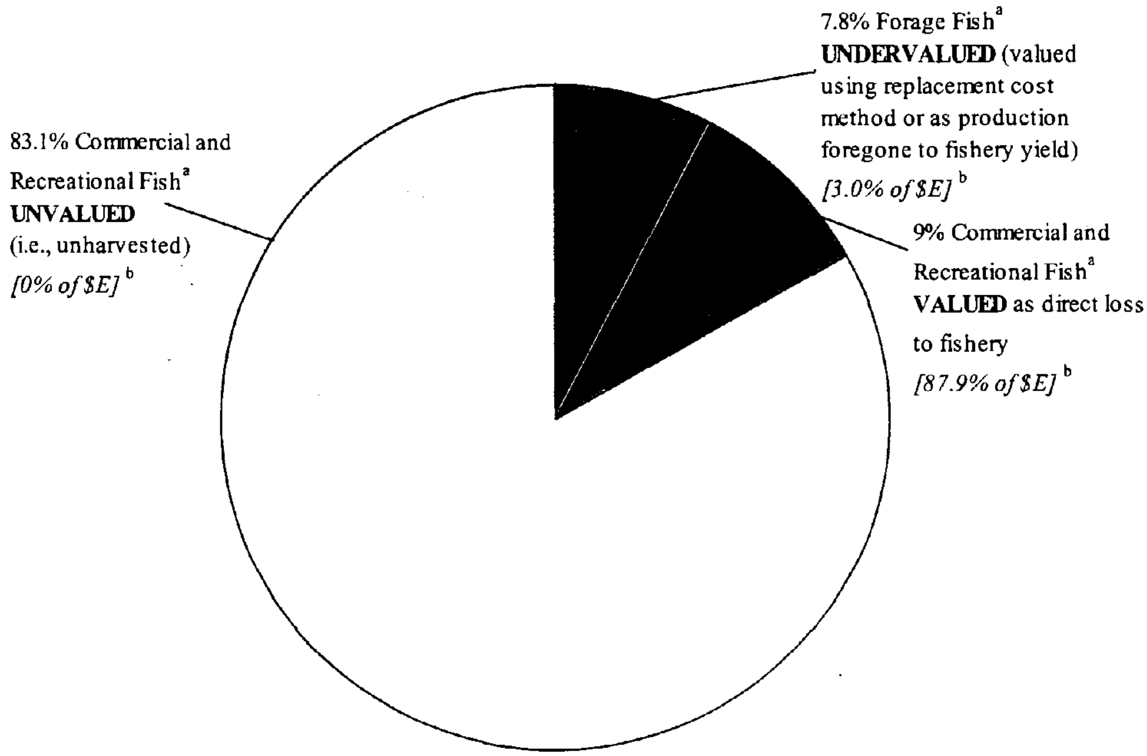
[a] All dollar values are the midpoint of the range estimates.
[b] I&E loss estimates are from Tables H4-2, H4-3, H4-9, and H4-10 in Chapter H4.
Note: Species with I&E <1% of the total I&E were not valued.

Figure H6-2: J.R. Whiting: Distribution of Impingement Losses by Species Category and Associated Economic Values



[a] Impacts shown are to age 1 equivalents, except that impacts to the commercially and recreationally harvested fish include impacts to fish 2 or more years of age, depending on the age of entry into the fishery.
[b] Midpoint of estimated range. Nonuse values are 2.0% of total estimated $I loss.

Figure H6-3: J.R. Whiting: Distribution of Entrainment Losses by Species Category and Associated Economic Values



Total: 1.8 million fish per year (age 1 equivalent)[a]
Total value: $41,500[b]

[a] Impacts shown are to age 1 equivalents, except that impacts to the commercially and recreationally harvested fish include impacts to fish 2 or more years of age, depending on the age of entry into the fishery.
[b] Midpoint of estimated range. Nonuse values are 9.1% of total estimated $E loss.

Table H6-1: Total Baseline Economic Loss from I&E (2000$, annually)

	Impingement	Entrainment
Benefits transfer approach (demand driven approach from Chapter H4)[a]	$351,000	$41,000
Habitat replacement cost approach (supply driven approach from Chapter H5)[b]	$1,210,000	$1,669,000
Range	$351,000 to $1.2 million	$41,000 to $1.7 million

[a] Midpoint of Range from Chapter H4.
[b] Based on cost to restore 90th percentile species impacted. Note that the lower bound estimates from the HRC approach reflect restoration of only half the impacted fish species (i.e., the 50th percentile). As such, the low end values for HRC were not considered in establishing the range of losses.

H6-3 Economic Benefit of Installing a Barrier Net

In 1980, J.R. Whiting installed a deterrent net to reduce impingement at the facility. This dramatically reduced the number of fish impinged (from an average of 21.5 million age 1 equivalents per year to an average of 1.6 million per year). The total economic loss from impingement with the net installed is just 8 percent of the baseline value, or from $28,000 to $97,000 per year.

As summarized in Table H6-2, the total economic benefit of the J.R. Whiting net can be calculated by subtracting the total economic loss from impingement with the net installed from the baseline economic loss from impingement without the net. Thus, the economic benefits attributable to the net are $323,000 to $1.1 million per year.

The net does not appear to significantly affect entrainment at the site, so there are no entrainment benefits attributable to the net.

Table H6-2: Economic Benefits of J.R. Whiting Barrier Net

	Impingement Reduction (2000$ annually)
Baseline economic loss	$351,000 to $1.2 million
Economic loss with net installed	$28,000 to $97,000
Total economic benefit of net	$323,000 to $1.1 million

H6-4 Potential Economic Benefits due to Regulation

The impingement deterrent net installed at the J.R. Whiting facility meets the requirements set forth in the proposed regulation for impingement reduction. Therefore, there are no anticipated reductions in impingement attributable to the regulation at this site. However, under the proposed regulation, J.R. Whiting would be required to take additional measures to reduce entrainment. Such measures could include the installation of fine mesh screens or using passive intake of cooling water. Table H6-3 summarizes the total annual benefits from entrainment reductions, under scenarios ranging from 10 percent to 90 percent reductions in entrainment. Table H6-4 considers the benefits of two options with varying percent reductions of I&E. Table H6-4 indicates that the benefits are expected to range from $21,000 to $835,000 for a 50 percent reduction in entrainment.

Table H6-3: Summary of Current Economic Losses and Benefits of a Range of Potential Entrainment Reductions at J.R. Whiting Facility ($2000)

		Entrainment
Baseline losses	low	$41,000
	high	$1,670,000
Benefits of 10% reductions	low	$4,000
	high	$167,000
Benefits of 20% reductions	low	$8,000
	high	$334,000
Benefits of 30% reductions	low	$12,000
	high	$501,000
Benefits of 40% reductions	low	$16,000
	high	$668,000
Benefits of 50% reductions	low	$21,000
	high	$835,000
Benefits of 60% reductions	low	$25,000
	high	$1,002,000
Benefits of 70% reductions	low	$29,000
	high	$1,169,000
Benefits of 80% reductions	low	$33,000
	high	$1,336,000
Benefits of 90% reductions	low	$37,000
	high	$1,503,000

Table H6-4: Summary of Benefits of Potential Entrainment Reductions at J.R. Whiting Facility ($2000)

		Entrainment
50% entrainment reduction	low	$21,000
	high	$835,000

H6-5 Summary of Omissions, Biases, and Uncertainties in the Benefits Analysis

Table H6-5 presents an overview of omissions, biases, and uncertainties in the benefits estimates. Factors with a negative impact on the benefits estimate bias the analysis downward, and therefore would raise the final estimate if they were properly accounted for.

Table H6-5: Omissions, Biases, and Uncertainties in the Benefits and HRC Estimates

Issue	Impact on Benefits Estimate	Comments
Long-term fish stock effects not considered	Understates benefits[a]	EPA assumed that the effects on stocks are the same each year, and that the higher fish kills would not have cumulatively greater impact.
Effect of interaction with other environmental stressors	Understates benefits[a]	EPA did not analyze how the yearly reductions in fish may make the stock more vulnerable to other environmental stressors. In addition, as water quality improves over time due to other watershed activities, the number of fish impacted by I&E may increase.
Recreation participation is held constant[a]	Understates benefits[a]	Recreational benefits only reflect anticipated increase in value per activity outing; increased levels of participation are omitted.
Boating, bird-watching, and other in-stream or near-water activities are omitted[a]	Understates benefits[a]	The only impact to recreation considered is fishing.
HRC monitoring program costs for wetland restoration not consistent with evaluating fish production/abundance	Understates benefits[a]	A monitoring program to determine wetland production/abundance of fish would be more labor intensive than current monitoring program
HRC based on capture data assumed to represent age 1 fish	Understates benefits[a]	High percent of less than age 1 fish observed in capture data, thereby leading to potential underestimate of scale of restoration required.
Effect of change in stocks on number of landings	Uncertain	EPA assumed a linear stock to harvest relationship (e.g., that a 13 percent change in stock would have a 13 percent change in landings); this may be low or high, depending on the condition of the stocks.
Nonuse benefits	Uncertain	EPA assumed that nonuse benefits are 50 percent of recreational angling benefits.
Recreation values for various geographic areas	Uncertain	Some recreational values used are from various regions beyond the Great Lakes.

[a] Benefits would be greater than estimated if this factor were considered.

Chapter H7: Conclusions

EPA examined economic value of impingement and entrainment at J.R. Whiting before net installation (1978-1979) to estimate the losses at the plant without the deterrent net and potential I&E damages at other Great Lakes facilities that do not employ impingement or entrainment reduction technologies. Average annual impingement before net installation was about 21.5 million age 1 equivalents and average annual entrainment was about 1.8 million age 1 equivalents (see Table H3-14). As indicated in Chapter H6, average impingement without the net is valued at between $351,000 and $1.2 million per year, and average entrainment is valued at between $41,000 and $1.7 million per year (all in $2000).

The results of EPA's evaluation of I&E rates at J.R. Whiting also indicate that a deterrent net can be very effective at reducing impingement. Facility monitoring data indicate that annual impingement at J.R. Whiting declined an average of 92% over the period 1981-1991 (see impingement data presented in Chapter H3). EPA estimated that the economic benefits of reducing impingement with the net can be substantial, ranging from $323,000 to $1.1 million per year (all in $2000).

EPA also estimated the potential economic benefits of additional technologies that might currently be applied to reduce CWIS impacts at J.R. Whiting (Chapter H6). EPA assumed that no further impingement technology would be required at J.R. Whiting, since the deterrent net appears to minimize impingement to the extent possible. However, EPA estimated that the benefits of 60% entrainment reductions (which may result from installation of fine mesh nets or using passive intake of cooling water) would range from $25,000 to $1.0 million per year (all in $2000).

The upper ends of the valuation of losses and benefits at J.R. Whiting include results of the HRC method for valuing impingement and entrainment losses. HRC-based estimates of the economic value of impingement and entrainment losses at J.R. Whiting were included with the transfer-based estimates to provide a better estimate of loss values, particularly for forage species for which valuation techniques are limited The HRC technique is designed to provide a more comprehensive, ecological-based valuation of impingement and entrainment losses than valuation by traditional commercial and recreational impacts methods. Losses are valued on the basis of the combined costs for implementing habitat restoration actions, administering the programs, and monitoring the increased production after the restoration actions.

For a variety of reasons, EPA believes that the estimates developed here underestimate the total economic benefits of reducing I&E at Great Lakes facilities (Chapter H6). EPA assumed that the effects of I&E on fish populations are constant over time (i.e., that fish kills do not have cumulatively greater impacts on diminished fish populations). EPA also did not analyze whether the number of fish affected by I&E would increase as populations increase in response to improved water quality or other improvements in environmental conditions. In the economic analyses, EPA also assumed that fishing is the only recreational activity affected and that fishing effort does not increase in response to increases in recreational catch.

Appendix H1: Life History Parameter Values Used to Evaluate I&E

The tables in this appendix present the life history parameter values used by EPA to calculate age 1 equivalents, fishery yields, and production foregone from I&E data for the J.R. Whiting facility.

Table H1-1: Alewife Species Parameters

Stage Name	Natural Mortality (per stage)[a]	Fishing Mortality (per stage)[b]	Fraction Vulnerable to Fishery[b]	Weight (lb)
Eggs	0.554	0	0	0.000022[c]
Yolksac larvae	1.81	0	0	0.00606[d]
Post-yolksac larvae	1.72	0	0	0.0121[d]
Juvenile 1	3.11	0	0	0.0181[d]
Juvenile 2	3.11	0	0	0.0242[d]
Age 1+	0.3	0	0	0.0303[a]
Age 2+	0.3	0	0	0.125[a]
Age 3+	0.3	0	0	0.254[a]
Age 4+	0.9	0	0	0.379[a]
Age 5+	1.5	0	0	0.485[a]
Age 6+	1.5	0	0	0.565[a]
Age 7+	1.5	0	0	0.625[a]
Age 8+	1.5	0	0	0.666[a]

[a] Based on Delaware Estuary alewife from PSEG, 1999c.
[b] Not a commercial or recreational species, thus no fishing mortality.
[c] Assumed.
[d] Assumed based on Delaware Estuary alewife from PSEG, 1999c.
Wed Jan 09 14:10:50 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.alewife.csv

Table H1-2: Bluntnose Minnow Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[d]	Fraction Vulnerable to Fishery[d]	Weight (lb)[e]
Eggs	2.3[a]	0	0	0.000000985[f]
Larvae	2.06[b]	0	0	0.000375[g]
Age 0	2.06[b]	0	0	0.00208[g]
Age 1+	1[c]	0	0	0.00585[g]
Age 2+	1[c]	0	0	0.0121[g]
Age 3+	1[c]	0	0	0.0143[f]

[a] Calculated from assumed survival using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Calculated from estimated survival (Froese and Pauly, 2001) using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[c] Froese and Pauly, 2001.
[d] Not a commercial or recreational species, thus no fishing mortality.
[e] Weight calculated from length using the formula: $(4.466\text{x}10^{-4})$*Length(mm)$^{2.34}$ = weight(g) (Froese and Pauly, 2001).
[f] Length assumed based on Carlander, 1969.
[g] Length from Carlander, 1969.
Wed Jan 09 14:10:57 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.bluntnose.minnow.csv

Table H1-3: Bullhead Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[d]	Fraction Vulnerable to Fishery[d]	Weight (lb)[f]
Eggs	2.3[a]	0	0	0.000000559[g]
Larvae	4.61[b]	0	0	0.000186[h]
Age 0	1.39[b]	0	0	0.00132[i]
Age 1+	0.223[c]	0.223[e]	0.5	0.0362[i]
Age 2+	0.223[c]	0.223[e]	1	0.0797[i]
Age 3+	0.223[c]	0.223[e]	1	0.137[i]
Age 4+	0.223[c]	0.223[e]	1	0.233[i]
Age 5+	0.223[c]	0.223[e]	1	0.402[i]
Age 6+	0.223[c]	0.223[e]	1	0.679[h]

[a] Calculated from assumed survival using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Calculated from estimated survival for channel catfish (Geo-Marine Inc., 1978) using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[c] Calculated from survival for brown bullhead (Carlander, 1969) assuming that half of mortality was natural and half was fishing, using the equation: (natural mortality) = -LN((survival)^{½}).
[d] Commercial species; vulnerable to fishing at age 1.
[e] Calculated based on survival for brown bullhead (Carlander, 1969) assuming that half of mortality was natural and half was fishing, using the equation: (fishing mortality) = -LN((survival)^{½}).
[f] Weight calculated from length using the formula: $(8.80\text{x}10^{-6})$*Length(mm)$^{3.06}$ = weight(g) (Froese and Pauly, 2001).
[g] Length from Wang, 1986a.
[h] Length assumed based on Carlander, 1969.
[i] Length from Carlander, 1969.
Wed Jan 09 14:11:02 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.bullhead.spp.csv

Table H1-4: Channel Catfish Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery[d]	Weight (lb)[f]
Eggs	2.3[a]	0[d]	0	0.000000408[g]
Larvae	4.61[b]	0[d]	0	0.0000191[g]
Age 0	1.39[b]	0[d]	0	0.00987[h]
Age 1+	0.41[c]	0.41[c]	0.5	0.0554[h]
Age 2+	0.41[c]	0.41[c]	1	0.189[h]
Age 3+	0.41[c]	0.41[c]	1	0.436[h]
Age 4+	0.41[c]	0.41[c]	1	0.71[h]
Age 5+	0.41[c]	0.41[c]	1	1.22[h]
Age 6+	0.41[c]	0.41[c]	1	1.55[h]
Age 7+	0.41[c]	0.41[c]	1	2.27[h]
Age 8+	0.41[c]	0.41[e]	1	2.66[h]
Age 9+	0.41[c]	0.41[c]	1	3.41[h]
Age 10+	0.41[c]	0.41[e]	1	5.59[h]
Age 11+	0.41[c]	0.41[e]	1	5.81[i]
Age 12+	0.41[c]	0.41[e]	1	5.92[h]

[a] Calculated from assumed survival using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Calculated based on survival from (Geo-Marine Inc., 1978) using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[c] Calculated based on survival from (Miller, 1966) assuming that half of mortality was natural and half was fishing, using the equation: (natural mortality) = -LN((survival)$^{1/2}$).
[d] Recreational and commercial species; vulnerable to fishing at age 1. Based on hake (Saila et al., 1997).
[e] Calculated based on survival from (Miller, 1966) assuming that half of mortality was natural and half was fishing, using the equation: (fishing mortality) = -LN((survival)$^{1/2}$).
[f] Weight calculated from length using the formula: (2.94×10^{-6})*Length(mm)$^{3.13}$ = weight(g) (Froese and Pauly, 2001).
[g] Length from Wang, 1986a.
[h] Length from Carlander, 1969.
[i] Length assumed based on Carlander, 1969.
Wed Jan 09 14:11:07 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.channel.catfish.csv

Table H1-5: Common Carp Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)	Fraction Vulnerable to Fishery[d]	Weight (lb)[e]
Eggs	2.3[a]	0[d]	0	0.000000143[f]
Larvae	4.61[b]	0[d]	0	0.0000118[f]
Age 0	1.39[b]	0[d]	0	0.0225[g]
Age 1+	0.13[c]	0.13[c]	0.5	0.79[g]
Age 2+	0.13[c]	0.13[c]	1	1.21[g]
Age 3+	0.13[c]	0.13[c]	1	1.81[g]
Age 4+	0.13[c]	0.13[c]	1	5.13[g]
Age 5+	0.13[c]	0.13[c]	1	5.52[h]
Age 6+	0.13[c]	0.13[c]	1	5.82[h]
Age 7+	0.13[c]	0.13[c]	1	6.76[g]
Age 8+	0.13[c]	0.13[c]	1	8.17[g]
Age 9+	0.13[c]	0.13[c]	1	8.55[h]
Age 10+	0.13[c]	0.13[c]	1	8.94[h]
Age 11+	0.13[c]	0.13[c]	1	9.76[h]
Age 12+	0.13[c]	0.13[c]	1	10.2[h]
Age 13+	0.13[c]	0.13[c]	1	10.6[h]
Age 14+	0.13[c]	0.13[c]	1	11.1[h]
Age 15+	0.13[c]	0.13[c]	1	11.5[h]
Age 16+	0.13[c]	0.13[c]	1	12[h]
Age 17+	0.13[c]	0.13[c]	1	12.5[h]

[a] Calculated from assumed survival using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Calculated from survival (Geo-Marine Inc., 1978) using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[c] Froese and Pauly, 2001, assuming half of mortality was natural and half was fishing.
[d] Commercial species; vulnerable to fishing at age 1.
[e] Weight calculated from length using the formula: (1.1×10^{-5})*Length(mm)$^{3.025}$ = weight(g) (Froese and Pauly, 2001).
[f] Length from Wang, 1986a.
[g] Length from Carlander, 1969.
[h] Length assumed based on Carlander, 1969.
Wed Jan 09 14:11:12 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.common.carp.csv

Table H1-6: Crappie Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[c]	Fraction Vulnerable to Fishery[c]	Weight (lb)[d]
Eggs	1.8[a]	0	0	0.0000000179[e]
Larvae	0.498[a]	0	0	0.00000857[e]
Age 0	2.93[a]	0	0	0.012[f]
Age 1+	0.292[b]	0.292[b]	0.5	0.128[f]
Age 2+	0.292[b]	0.292[b]	1	0.193[f]
Age 3+	0.292[b]	0.292[b]	1	0.427[f]
Age 4+	0.292[b]	0.292[b]	1	0.651[f]
Age 5+	0.292[b]	0.292[b]	1	0.888[f]
Age 6+	0.292[b]	0.292[b]	1	0.925[f]
Age 7+	0.292[b]	0.292[b]	1	0.972[g]
Age 8+	0.292[b]	0.292[b]	1	1.08[f]
Age 9+	0.292[b]	0.292[b]	1	1.26[f]

[a] Bartell and Campbell, 2000. Black crappie.
[b] Bartell and Campbell, 2000 assuming half of mortality was natural and half was fishing. Black crappie.
[c] Recreational species, vulnerable to fishing at age 1.
[d] Weight calculated from length using the formula: $(1.014 \times 10^{-5}) * \text{Length(mm)}^{3.066} = \text{weight(g)}$ (Froese and Pauly, 2001).
[e] Length from Wang, 1986a.
[f] Length from Carlander, 1977.
[g] Length assumed based on Carlander, 1977.
Wed Jan 09 14:11:17 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.crappie.spp.csv

Table H1-7: Emerald Shiner Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[d]	Fraction Vulnerable to Fishery[d]	Weight (lb)[e]
Eggs	2.3[a]	0	0	0.000000252[f]
Larvae	4.61[b]	0	0	0.0016[f]
Age 0	0.776[b]	0	0	0.0135[g]
Age 1+	0.371[b]	0	0	0.026[g]
Age 2+	4.61[b]	0	0	0.0478[g]
Age 3+	4.61[c]	0	0	0.106[g]

[a] Calculated from assumed survival using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Wapora, 1979.
[c] Assumed based on Wapora, 1979.
[d] Not a commercial or recreational species, thus no fishing mortality.
[e] Weight calculated from length using the formula: $(1.114 \times 10^{-4}) * \text{Length(mm)}^{2.922} = \text{weight(g)}$ (Fuchs, 1967).
[f] Length assumed based on Trautman, 1981.
[g] Length from Trautman, 1981.
Wed Jan 09 14:11:22 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.emerald.shiner.csv

Table H1-8: Freshwater Drum Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[d]	Fraction Vulnerable to Fishery[d]	Weight (lb)
Eggs	2.27[a]	0[d]	0	0.0000011[e]
Larvae	6.13[a]	0[d]	0	0.00000295[f]
Age 0	1.15[b]	1.15[b]	0.5	0.0166[f]
Age 1+	0.155[c]	0.155[c]	1	0.05[g]
Age 2+	0.155[c]	0.155[c]	1	0.206[g]
Age 3+	0.155[c]	0.155[c]	1	0.438[g]
Age 4+	0.155[c]	0.155[c]	1	0.638[g]
Age 5+	0.155[c]	0.155[c]	1	0.794[g]
Age 6+	0.155[c]	0.155[c]	1	0.95[g]
Age 7+	0.155[c]	0.155[c]	1	1.09[g]
Age 8+	0.155[c]	0.155[c]	1	1.26[g]
Age 9+	0.155[c]	0.155[c]	1	1.44[g]
Age 10+	0.155[c]	0.155[c]	1	1.6[g]
Age 11+	0.155[c]	0.155[c]	1	1.78[g]
Age 12+	0.155[c]	0.155[c]	1	2[g]

[a] Bartell and Campbell, 2000.
[b] Bartell and Campbell, 2000 assuming half of mortality was natural and half was fishing.
[c] Froese and Pauly, 2001, assuming half of mortality was natural and half was fishing.
[d] Commercial species; vulnerable to fishing at age 0.
[e] Assumed based on Bartell and Campbell, 2000.
[f] Bartell and Campbell, 2000.
[g] Scott and Crossman, 1973.
Wed Jan 09 14:11:27 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.freshwater.drum.csv

Table H1-9: Gizzard Shad Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[d]	Fraction Vulnerable to Fishery[d]	Weight (lb)
Eggs	2.3[a]	0	0	0.0000022[e]
Larvae	6.33[b]	0	0	0.00000663[b]
Age 0	0.511[b]	0	0	0.0107[b]
Age 1+	1.45[c]	1.45[c]	0.5	0.141[b]
Age 2+	1.27[c]	1.27[c]	1	0.477[b]
Age 3+	0.966[c]	0.966[c]	1	0.64[b]
Age 4+	0.873[c]	0.873[c]	1	0.885[b]
Age 5+	0.303[c]	0.303[c]	1	1.17[b]
Age 6+	0.303[c]	0.303[c]	1	1.54[b]

[a] Calculated from assumed survival using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Wapora, 1979.
[c] Wapora, 1979, assuming half of mortality was natural and half was fishing.
[d] Commercial species; vulnerable to fishing at age 1.
[e] Assumed based on Wapora, 1979.
Wed Jan 09 14:11:32 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.gizzard.shad.csv

Table H1-10: Logperch Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[d]	Fraction Vulnerable to Fishery[d]	Weight (lb)[e]
Eggs	2.3[a]	0	0	0.00000000309[f]
Larvae	1.9[b]	0	0	0.000276[g]
Age 0	1.9[b]	0	0	0.00345[f]
Age 1+	0.7[c]	0	0	0.0128[f]
Age 2+	0.7[c]	0	0	0.0274[f]
Age 3+	0.7[c]	0	0	0.0443[f]

[a] Calculated from assumed survival using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Calculated from estimated survival based on (Froese and Pauly, 2001) using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[c] Froese and Pauly, 2001.
[d] Not a commercial or recreational species, thus no fishing mortality.
[e] Weight calculated from length using the formula: $(5.240 \times 10^{-7}) * \text{Length(mm)}^{3.641} = \text{weight(g)}$ (Carlander, 1997).
[f] Length from Carlander, 1997.
[g] Length assumed based on Carlander, 1997.
Wed Jan 09 14:11:36 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.logperch.csv

Table H1-11: Rainbow Smelt Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[c]	Fraction Vulnerable to Fishery[c]	Weight (lb)[d]
Eggs	3.32[a]	0	0	0.0000000115[e]
Larvae	2.65[a]	0	0	0.00000233[e]
Age 1+	0.72[b]	0	0	0.0195[f]
Age 2+	0.72[b]	0	0	0.041[g]
Age 3+	0.72[b]	0	0	0.177[g]
Age 4+	0.72[b]	0	0	0.338[f]
Age 5+	0.72[b]	0	0	0.537[f]
Age 6+	0.72[b]	0	0	0.597[f]

[a] Calculated from survival from (Stone and Webster Engineering Corporation, 1977) using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Froese and Pauly, 2001.
[c] Not a commercial or recreational species, thus no fishing mortality.
[d] Weight calculated from length using the formula: $(5.23 \times 10^{-6})*\text{Length(mm)}^{3.114}$ = weight(g) (Froese and Pauly, 2001).
[e] Length from Able and Fahay, 1998.
[f] Length assumed based on Able and Fahay, 1998 and Scott and Scott, 1988.
[g] Length from Scott and Scott, 1988.
Wed Jan 09 14:11:41 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.rainbow.smelt.csv

Table H1-12: Sucker Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[c]	Fraction Vulnerable to Fishery[c]	Weight (lb)[d]
Eggs	2.05[a]	0	0	0.0000000135[e]
Larvae	2.56[a]	0	0	0.00000198[e]
Age 0+	2.3[a]	0	0	0.000145[f]
Age 1+	0.274[b]	0.274[b]	0.5	0.0447[f]
Age 2+	0.274[b]	0.274[b]	1	0.249[f]
Age 3+	0.274[b]	0.274[b]	1	0.305[f]
Age 4+	0.274[b]	0.274[b]	1	0.609[f]
Age 5+	0.274[b]	0.274[b]	1	0.823[f]
Age 6+	0.274[b]	0.274[b]	1	0.929[f]

[a] Bartell and Campbell, 2000.
[b] Bartell and Campbell, 2000 assuming half of mortality is natural and half is fishing.
[c] Commercial species; vulnerable to fishing at age 1.
[d] Weight calculated from length based on river carpsucker using the formula: $(6.13 \times 10^{-6})*\text{Length(mm)}^{3.099}$ = weight(g) (Froese and Pauly, 2001).
[e] Length assumed based on Carlander, 1969.
[f] Length from Carlander, 1969.
Wed Jan 09 14:11:45 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.sucker.spp.csv

Table H1-13: Sunfish Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[c]	Fraction Vulnerable to Fishery[c]	Weight (lb)[e]
Eggs	1.71[a]	0	0	0.00000000736[f]
Larvae	0.687[a]	0	0	0.000000994[f]
Age 0+	0.687[a]	0	0	0.000878[g]
Age 1+	1.61[a]	0	0	0.00666[g]
Age 2+	1.61[a]	0	0	0.0271[g]
Age 3+	1.5[b]	1.5[d]	0.5	0.0593[g]
Age 4+	1.5[b]	1.5[d]	1	0.0754[g]
Age 5+	1.5[b]	1.5[d]	1	0.142[g]
Age 6+	1.5[b]	1.5[d]	1	0.18[g]
Age 7+	1.5[b]	1.5[d]	1	0.214[g]
Age 8+	1.5[b]	1.5[d]	1	0.232[g]

[a] Calculated from survival for pumpkinseed from (Carlander, 1977) using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Calculated from survival for pumpkinseed from (Carlander, 1977) using the equation: (natural mortality) = -LN((survival)^{½}).
[c] Recreational species; vulnerable to fishing at age 3.
[d] Calculated from survival for pumpkinseed from (Carlander, 1977) using the equation: (fishing mortality) = -LN((survival)^{½}).
[e] Weight calculated from length based on pumpkinseed using the formula: (6.13×10^{-6})*Length(mm)$^{3.262}$ = weight(g) (Froese and Pauly, 2001).
[f] Length for Pumpkinseed from Wang, 1986a.
[g] Length for Pumpkinseed from Carlander, 1977.
Wed Jan 09 14:11:50 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.sunfish.spp.csv

Table H1-14: Walleye Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[c]	Fraction Vulnerable to Fishery[c]	Weight (lb)[e]
Eggs	1.05[a]	0	0	0.00000000506[f]
Larvae	3.55[b]	0	0	0.0000768[g]
Age 0+	1.93[b]	0	0	0.03[g]
Age 1+	0.0474[b]	0.6[d]	0.5	0.328[g]
Age 2+	0.0474[b]	0.6[d]	1	0.907[g]
Age 3+	0.0474[b]	0.6[d]	1	1.77[g]
Age 4+	0.0474[b]	0.6[d]	1	2.35[g]
Age 5+	0.0474[b]	0.6[d]	1	3.37[g]
Age 6+	0.0474[b]	0.6[d]	1	3.97[g]
Age 7+	0.0474[b]	0.6[d]	1	4.66[f]
Age 8+	0.0474[b]	0.6[d]	1	5.58[g]

[a] Calculated from survival from (Carlander, 1997) using the equation: (natural mortality) = -LN(survival) -(fishing mortality).
[b] Bartell and Campbell, 2000.
[c] Recreational species; vulnerable to fishing at age 1.
[d] McDermot and Rose, 2000.
[e] Weight calculated from length using the formula: (2.296×10^{-6})*Length(mm)$^{3.23}$ = weight(g) (Froese and Pauly, 2001).
[f] Length assumed based on Carlander, 1997.
[g] Length from Carlander, 1997.
Wed Jan 09 14:11:55 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.walleye.csv

Table H1-15: White Bass Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[d]	Fraction Vulnerable to Fishery[e]	Weight (lb)
Eggs	2.3[a]	0	0	0.0000000266[f]
Larvae	4.61[b]	0	0	0.00000174[g]
Age 0+	1.39[b]	0	0	0.174[h]
Age 1+	0.42[c]	0	0	0.467[h]
Age 2+	0.42[c]	0.7	0.5	0.644[h]
Age 3+	0.42[c]	0.7	1	1.02[h]
Age 4+	0.42[c]	0.7	1	1.16[h]
Age 5+	0.42[c]	0.7	1	1.26[h]
Age 6+	0.42[c]	0.7	1	1.66[h]
Age 7+	0.42[c]	0.7	1	1.68[i]

[a] Calculated from assumed survival using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Calculated from survival from (Geo-Marine Inc., 1978) using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[c] Froese and Pauly, 2001.
[d] McDermot and Rose, 2000.
[e] Assumed based on fishing mortality.
[f] Weight calculated from assumed length of 1mm using the formula: (1.206×10^{-5})*Length(mm)$^{3.132}$ = weight(g) (Van Oosten, 1942).
[g] Weight calculated from length of 3.8mm (Carlander, 1997) using the formula: (1.206×10^{-5}) * Length(mm)$^{3.132}$ = weight(g) (Van Oosten, 1942).
[h] Carlander, 1997.
[i] Assumed based on Carlander, 1997.
Wed Jan 09 14:12:00 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.white.bass.csv

Table H1-16: White Perch Species Parameters

Stage Name	Natural Mortality (per stage)[a]	Fishing Mortality (per stage)[a]	Fraction Vulnerable to Fishery[a]	Weight (lb)
Eggs	2.75	0	0	0.000022[b]
Yolksac larvae	2.1	0	0	0.00946[c]
Post-yolksac larvae	3.27	0	0	0.0189[c]
Juvenile 1	0.947	0	0	0.0283[c]
Juvenile 2	0.759	0	0	0.0378[c]
Age 1+	0.693	0	0	0.0472[a]
Age 2+	0.693	0	0	0.0567[a]
Age 3+	0.693	0.15	0.0008	0.103[a]
Age 4+	0.689	0.15	0.0266	0.15[a]
Age 5+	1.58	0.15	0.212	0.214[a]
Age 6+	1.54	0.15	0.48	0.265[a]
Age 7+	1.48	0.15	0.838	0.356[a]
Age 8+	1.46	0.15	1	0.387[a]
Age 9+	1.46	0.15	1	0.516[a]
Age 10+	1.46	0.15	1	0.619[a]

[a] Based on Delaware Estuary white perch from PSEG, 1999c.
[b] Assumed based on PSEG, 1999c.
Wed Jan 09 14:12:05 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.white.perch.csv

Table H1-17: Yellow Perch Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[d]	Fraction Vulnerable to Fishery[e]	Weight (lbs)
Eggs	2.75[a]	0	0	0.0000022[f]
Larvae	3.56[b]	0	0	0.00000384[b]
Age 0+	2.53[b]	0	0	0.0232[b]
Age 1+	0.361[b]	0	0	0.0245[b]
Age 2+	0.248[b]	0	0	0.0435[b]
Age 3+	0.504[b]	0.7	0.5	0.0987[b]
Age 4+	0.504[b]	0.7	1	0.132[b]
Age 5+	0.504[b]	0.7	1	0.166[b]
Age 6+	0.504[c]	0.7	1	0.214[b]

[a] Based on Delaware Estuary yellow perch from PSEG, 1999c.
[b] Wapora, 1979.
[c] Assumed based on Wapora, 1979.
[d] McDermot and Rose, 2000.
[e] Recreational species; vulnerable to fishing at age 3.
[f] Assumed based on Wapora, 1979.
Wed Jan 09 14:12:10 MST 2002 Results: Life history Plant: jr.whiting.78.79 Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/lifehistory.yellow.perch.csv

Part I: Monroe Facility Case Study

Chapter I1: Background

This case study presents the results of an analysis performed by EPA to assess the potential benefits of reducing impingement and entrainment (I&E) at cooling water intake structures (CWIS) at the Detroit Edison Monroe Power plant, located at the mouth of the River Raisin on the western shore of Lake Erie (Figure I1-1). Section I1-1 of this background chapter provides a brief description of the facility, Section I1-2 describes the environmental setting, and Section I1-3 presents information on the area's socioeconomic characteristics.

CHAPTER CONTENTS

I1-1 Overview of Monroe Facility I1-1
I1-2 Environmental Setting I1-3
I1-2.1 The River Raisin I1-3
I1-2.2 Aquatic Habitat and Biota I1-4
I1-2.3 Major Environmental Stressors I1-4
I1-3 Socioeconomic Characteristics I1-6
I1-3.1 Major Industrial Activities I1-6
I1-3.2 Commercial Fisheries I1-6
I1-3.3 Recreational Fisheries I1-8
I1-3.4 Other Water-Based Recreation I1-8

I1-1 OVERVIEW OF MONROE FACILITY

The Detroit Edison Monroe Power Plant is a four-unit, 3,293 MW fossil fuel, steam electric power plant (Cole, 1978; Goodyear, 1978; Jude et al., 1983). The facility is located where the River Raisin enters Lake Erie, just north of the J.R. Whiting facility, evaluated in Part H of this case study document (Figure I1-1). The first unit went online in 1971, and all four generating units were completed by 1974. Each unit has four circulating water pumps, each of which is capable of a flow of 7.3 m^3/sec (116,000 gpm). Monroe is one of the largest fossil fuel burning power plants in the United States (Detroit Edison, 2002).

Monroe operates a once-through cooling system (Goodyear, 1978). The cooling water intake draws a maximum flow of 85 m^3/sec (3,000 cfs) (Cole, 1978). The 100 m (328 ft) long cooling water intake channel is located about 650 m (2,133 ft) upstream from the mouth of the River Raisin (Goodyear, 1978). The intake has two screenhouses and 12 circulating water pumps (Jude et al., 1983). Each pump is equipped with trash racks with vertical bars spaced 7.6 cm (3in.) apart, and a traveling screen with 1 cm (0.4in.) openings (Goodyear, 1978). The traveling screens normally rotate once each 8 hours, but will rotate at a higher speed when debris restricts flow (Jude, et al., 1983). The cooling water discharge canal, which is 1.8 km (1.1 mi) long and 171 m (561 ft) wide, empties into Plum Creek just upstream of its confluence with Lake Erie approximately 2.5 km (1.6 mi) south-southwest of the mouth of the River Raisin (Goodyear, 1978).

Monroe uses a fish return system to divert fish from the intake channel (Jude et al., 1983; Dodge, 1998), reducing impingement by an estimated 60 percent (Dodge, 1998). Fish and debris are diverted by the traveling screens to a pump, and transported into a series of pipes that discharge into Lake Erie east of the plant.

The cooling water design flow of the Monroe plant of 1,975 MGD is 4 times greater than the River Raisin's average flow (Dodge, 1998). During most of the year, the entire flow of the river is withdrawn, and Lake Erie water is drawn upstream to the plant to provide the additional water required, reversing the flow of the river at its mouth (Goodyear, 1978; Cole, 1978).

> ❖ *Ownership Information*
> Monroe is a regulated utility plant owned by Detroit Edison, a subsidiary of DTE Energy Company. DTE Energy is an energy holding company with over 9,100 employees. The firm owns or controls over 11 million megawatts of electric generating capability. In 2001, DTE Energy posted sales of $7.8 billion. 2000 electricity sales were 55 million MWh (Hoover's Online, 2002; DTE Energy, 2002).

It began commercial service in 1969 and currently operates four coal-fired steam-electric units and five oil-fired internal combustion turbines. Monroe had 345 employees in 1999 and generated 18.3 million megawatt hours (MWh) of electricity. Estimated baseline revenues in 1999 were $1.4 billion, based on the plant's 1999 estimated electricity sales of 17.2 million MWh and the 1999 company-level electricity revenues of $81.59 per MWh. Monroe's 1999 production expenses totaled $284 million, or 1.553 cents per KWh, for an operating income of $1.1 billion.

Figure II-1: Location of Monroe Power Plant on the River Raisin and Lake Erie. J.R. Whiting Power Plant is just south of Monroe Power Plant

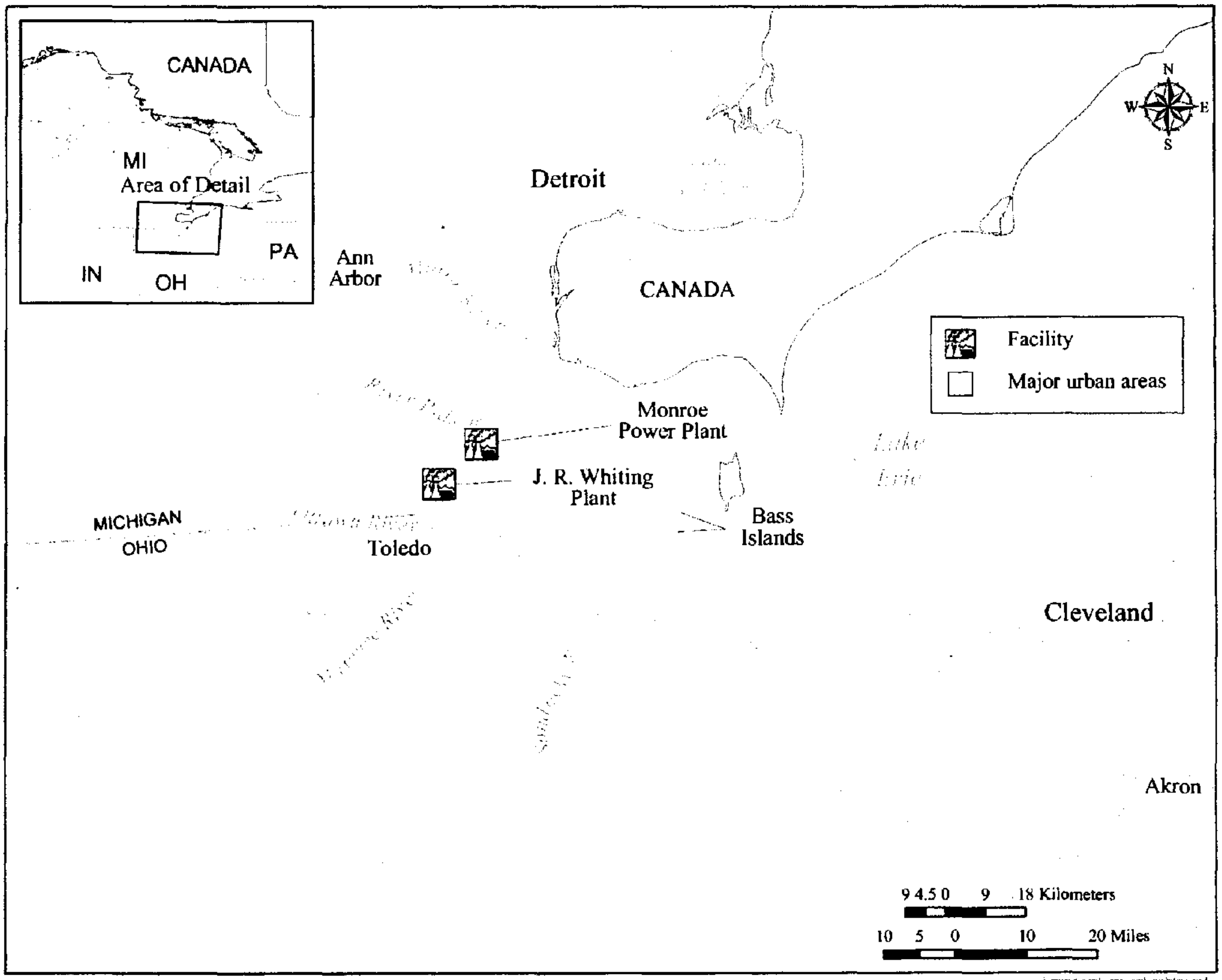


Table I1-1 below summarizes the plant characteristics of the Monroe plant.

Table I1-1: Summary of Monroe Plant Characteristics (1999)

	Monroe
Plant EIA Code	1733
NERC Region	ECAR
Total Capacity (MW)	3,293
Primary Fuel	Coal
Number of Employees	345
Net Generation (million MWh)	18.3
Estimated Revenues (billion)	$1.4
Total Production Expense (million)	$284
Production Expense (¢/KWh)	1.553¢
Estimated Operating Income (billion)	$1.1

Notes: NERC = North American Electric Reliability Council
ECAR = East Central Area Reliability Coordination Agreement
Dollars are in $2001.
Source: Form EIA-860A (NERC Region, Total Capacity, Primary Fuel); FERC Form-1 (Number of Employees, Net Generation, Total Production Expense).

I1-2 Environmental Setting

The Monroe plant withdraws water from both the River Raisin and Lake Erie. The following section focuses on the River Raisin to avoid repetition of information in Part H, the case study of J.R. Whiting. Readers seeking more information on Lake Erie are referred to Chapter H1 of Part H of this document.

I1-2.1 The River Raisin

The River Raisin drains approximately 2,770 km^2 (1,070 mi^2) in Michigan and northwestern Ohio (Dodge, 1998; USGS, 2001b). The mainstem of the river is about 240 km (150 mi) long, and the drop in elevation is about 146 m (480 ft) from the headwaters to the mouth (Dodge, 1998). The average discharge measured at a station approximately 19 km (12 mi) upstream from the mouth is 21 m^3/sec (741 cfs). The annual flow pattern is representative of a snowmelt-fed river, with high flows in March and April and low flows in July through October. It is believed that the river was named "Raisin" by French explorers who discovered plentiful grapevines growing along its banks.

The River Raisin has been affected by many factors over time (Dodge, 1998). Agricultural activity has contributed to flow instability and erosion, which in turn have altered the channel structure. In addition, agricultural land use contributes to sedimentation problems, altered temperature regimes, and nutrient loading. Point source pollution from industrial and municipal sources was a problem for many years, but has been dramatically reduced since the 1970's. Despite the potential for recreational use, public perception of the river as polluted, with limited access and poor fishery management mean that it is not heavily used.

The lower portion of the River Raisin was identified by the International Joint Commission as one of Michigan's 14 Areas of Concern (AOCs) because of polychlorinated biphenyl (PCB) and metal contamination of fish and sediments (Dodge, 1998). The River Raisin AOC is defined as the lower portion of the river from the Winchester Bridge Dam in Monroe, extending 0.8 km (0.5 mi) out into Lake Erie, and 1.6 km (1 mi) north and south along the nearshore zone of the lake (Dodge, 1998; U.S. EPA, 2001b).

I1-2.2 Aquatic Habitat and Biota

The lower River Raisin has an average gradient of 0.91 m per km (3.0 ft per mi), and a firm stream bed composed of cobble, rock, sand and limestone bedrock (Dodge, 1998). Because of the bedrock substrate, much of the river is usually shallow and wide. Overall, the river has a diversity of benthic macroinvertebrate and fish species. The northern clearwater crayfish (*Orconectes propinquus*) is found throughout the river. The lower River Raisin once supported 20 species of mussels, but a recent survey found only four species.

A survey conducted by the Michigan Department of Natural Resources in 1985 identified 36 fish species in the lower reach of the river (Dodge, 1998). Smallmouth bass were abundant, although they are not found in the middle reaches because of the shallow gradient there. Lake Erie fish are not typically found in the River Raisin, because access is restricted by a series of dams.

Many of the fish identified in I&E studies at the Monroe Plant (see Table I3-1) are common to the River Raisin (Dodge, 1998). These species include spotfin shiner (*Cyprinella spiloptera*), emerald shiner (*Notropis atherinoides*), common carp (*Cyprinus carpio*), bluntnose minnow (*Pimephales notatus*), white sucker (*Catostomus commersoni*), northern hog sucker (*Hypentelium nigricans*), bullheads (*Ameiurus* spp.), northern pike (*Esox lucius*), muskellunge (*Esox masquinongy*), rainbow trout (*Oncorhynchus mykiss*), pumpkinseed (*Lepomis gibbosus*), largemouth bass (*Micropterus salmoides*), crappies (*Pomoxis* spp.), yellow perch (*Perca flavescens*), logperch (*Percina caprodes*), and walleye (*Stizostedion vitreum*).

Other species, particularly those impinged and entrained most frequently at the plant, are most likely drawn from Lake Erie (Dodge, 1998). These species include gizzard shad (*Dorosoma cepedianum*), alewife (*Alosa pseudoharengus*), rainbow smelt (*Osmerus mordax*), burbot (*Lota lota*), freshwater drum (*Aplodinotus grunniens*), and white bass (*Morone chrysops*).

Species of special concern identified by the Michigan Natural Features Inventory (MNFI) found in the River Raisin include the black redhorse (*Moxostoma duquesnei*), brindled madtom (*Noturus miurus*), and pugnose shiner (*Notropis anogenus*). Threatened species identified by MNFI are creek chubsucker (*Erimyzon oblongus*), eastern sand darter (*Ammocrypta pellucida*), silver shiner (*Notropis photogenis*), and southern redbelly dace (*Phoxinus erythrogaster*).

I1-2.3 Major Environmental Stressors

Human activity in the River Raisin basin has led to a number of major stresses on the aquatic environment (Dodge, 1998). Dam construction and habitat alteration have affected habitat quality on the river. Prior to the 1970's, extensive point source pollution from municipal and industrial sources, particularly paper mills, resulted in PCB and metal contamination of the sediments and biota in the river. Fish communities have also been affected by stocking of species such as common carp and rainbow trout, as well as accidental introductions of invasive species.

a. Habitat alteration

The River Raisin has experienced extensive modification over time (Dodge, 1998). There are 22 dams on the river mainstem, 38 dams on tributaries, and numerous small dams on smaller streams. The construction of dams has altered the flow regime of the river and eliminated much of the highest gradient habitat in the mainstem. Approximately 94 percent of the River Raisin basin is devoted to agricultural use. Activities associated with the extensive agricultural development in the basin such as deforestation, channelization and wetland drainage have reduced the quality and diversity of aquatic habitat. Although urban land use is minimal (estimates range from 2 to 3 percent), development is increasing and affects the flow regime of the river.

River Raisin habitat for fish (fish that migrate from lakes up rivers, like salmon, walleye, and white bass) has been eliminated by the combination of the large water withdrawals by the Monroe power plant and the series of dams in the lower river (Dodge, 1998). While spring spawning runs of walleye and white bass have increased dramatically in other western Lake Erie tributaries, they are absent in the River Raisin.

b. Introduction of nonnative species

The introduced zebra mussel became established in large numbers in Lake Erie and its tributaries in the late 1980's and early 1990's (U.S. EPA, 2000). Zebra mussels have altered habitat, food web dynamics, energy transfer, and nutrient cycles in the lakes. However, filtering by zebra mussels has apparently contributed to a dramatic increase in Lake Erie's water clarity. A preferred course of action on how to deal with the zebra mussels has not yet been established by the Lake Erie Lakewide

Management Plan Committee (U.S. EPA, 2000). Zebra mussels have been found in headwater lakes of the River Raisin (Dodge, 1998).

Another invasive species of concern in the River Raisin is the rusty crayfish (*Oronectes rusticus*), an aggressive species that outcompetes native crayfish and is a predator of fish eggs. Although sea lamprey (*Petromyzon marinus*) is an invasive species of concern in Lake Erie, it has not been found in the River Raisin (Dodge, 1998).

c. Overfishing

Overfishing is not a significant stressor on the River Raisin (Dodge, 1998). While major sport fish like largemouth bass are present and other species like smallmouth bass, muskellunge, rainbow trout, and walleye are stocked, fishing pressure on the lower River Raisin is only light to moderate. This may be because river fishing is more difficult than nearby lake fishing, because there are competing uses, and because of the number of dams along the river, which impede passage of boats.

d. Pollution

Discharges to Lake Erie and its tributaries of persistent toxic chemicals were banned in the 1970's, but effects of these historical discharges continue to linger (U.S. EPA, 2000). Water quality in the River Raisin was historically affected by both industrial point source pollution and agricultural nonpoint source pollution. Today, sediments, water, and biota are contaminated with PCBs and metals such as zinc, chromium, and copper (Dodge, 1998; U.S. EPA, 2001b).

The presence of PCBs has resulted in fish consumption advisories being issued for the River Raisin and Lake Erie (see Table I1-2; MDCH, 2001).

Table I1-2: State of Michigan Fish Consumption Advisories for the River Raisin and Lake Erie, 2001[a]

	Fish Length (in.)								
	6-8	8-10	10-12	12-14	14-18	18-22	22-26	26-30	30+
River Raisin (below Monroe Dam)									
Carp	◆	◆	◆	◆	◆	◆	◆	◆	◆
Freshwater drum	/■	/■	/■	/■	▲■	/■	/■	/■	/■
Smallmouth bass					▼/⁘	▼/⁘	▼/⁘	▼/⁘	
White bass	/⁘	/⁘	▼/⁘	◆	◆	◆			
Lake Erie									
Carp	◆	◆	◆	◆	◆	◆	◆	◆	◆
Catfish	◆	◆	◆	◆	◆	◆	◆	◆	◆
Chinook salmon			/■	/■	/■	/■	/■	/■	/■
Coho salmon			/■	/■	/■	/■	/■	/■	/■
Freshwater drum	/▼	/▼	/▼	/▼	/▼	/▼	/▼	/▼	/▼
Lake trout			/⁘	/⁘	/⁘	/⁘	/⁘	/⁘	/⁘
Rainbow trout			/■	/■	/■	/■	/■	/■	/■
Smallmouth bass					/■	/■	/■	/■	
Walleye				/▼	/▼	/▼	/■	/■	/■
White bass	/■	/■	/■	/■	/■	/■			
Whitefish	▼/◆	▼/◆	▼/◆	▼/◆	▼/◆	▼/◆	◆	◆	◆
White perch	/■	/■	/■	/■					
Yellow Perch	/▼	/▼	/▼	/▼	/▼	/▼			

◆ = No consumption.
⁘ = Limit consumption to 6 meals (½ pound) per year.
■ = Limit consumption to 1 meal (½ pound) per month.
▼ = Limit consumption to 1 meal (½ pound) per week.
= Unlimited consumption

[a] If there is only one symbol it is the advice for the whole population. When two symbols are shown, the first is the advice for the "general population" and the second is the advice for "children age 15 and under and women who are pregnant, nursing, or expect to bear children."

Source: MDCH, 2001.

e. Surface water withdrawals by CWIS

Steam electric power generation accounts for 68 percent of all surface water withdrawals from Lake Erie and its surrounding watersheds in the United States (USGS, 1995). The watersheds draining into the western Lake Erie hydrologic subregion are more heavily used by cooling water intake structures, which represent 92 percent of all surface water withdrawals.

I1-3 Socioeconomic Characteristics

The Monroe plant is located in Monroe County, Michigan, a rural county bordered to the east by Lake Erie and to the north and south by more urban counties (Wayne County, Michigan, and Lucas County, Ohio). In 2000, Monroe had a population of 145,945, a high rate of home ownership, and a higher median income than surrounding counties (U.S. Census Bureau, 2001). The socioeconomic characteristics of Monroe and neighboring counties are summarized in Table I1-3.

Table I1-3: Socioeconomic Characteristics of Monroe and Neighboring Counties

	Monroe County, MI	Wayne County, MI	Lucas County, OH
Population in 2000	145,945	2,061,162	455,054
Land area in 2000, km^2 (mi^2)	1,427 (551)	1,590 (614)	881 (340)
Persons per square mile, 2000	265	3,357	1,338
Metropolitan Area	Detroit, MI	Detroit, MI	Toledo, OH
Median household money income, 1997 model-based estimate	$48,607	$35,357	$37,064
Persons below poverty, percent, 1997 model-based estimate	7.60%	18.00%	13.60%
Housing units in 2000	56,471	826,145	196,259
Homeownership rate in 2000	81.00%	66.60%	65.40%
Households in 2000	53,772	768,440	182,847
Persons per household in 2000	2.69	2.64	2.44
Households with persons under 18 years in 2000	39.10%	37.70%	34.10%
High school graduates, 25 and older in 1990	60,968	926,603	221,052
College graduates, 25 and older in 1990	8,655	180,822	49,393

Source: U.S. Census Bureau, 2001.

I1-3.1 Major Industrial Activities

Monroe County produces agricultural products such as soybeans, grains, corn, sugar beets, potatoes, and alfalfa, and industrial processes such as auto parts manufacturing, metal fabrication, cement, packaging, and glass production (InfoMI, 2001). The city of Monroe is the county seat and the largest city in the county. Industrial activity in the city is dominated by steel production, paper products, furniture, electrical power and auto parts.

I1-3.2 Commercial Fisheries

There is no commercial fishing on the River Raisin. In Lake Erie, commercial fishing generated between $2 million and $3 million of revenue per year over the last decade (USGS, 2001c). A small share of this catch comes from Michigan waters. Tables I1-4 and I1-5 show the pounds harvested and the revenue generated for the Michigan Lake Erie commercial fishery from 1985 to 1999. Despite fish consumption advisories, carp is the most important commercial species, comprising 72 percent of the catch and 51 percent of revenues over this 15-year period. Channel catfish, quillback, and bigmouth buffalo make up most of the remaining harvest and revenue (USGS, 2001c).

Table I1-4: Pounds of Commercial Landings in the Michigan Waters of Lake Erie, 1985-1999

Species	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Gizzard shad	878,000							2,845	395	2,103	23	36,996	24,494	4,988	6,200
Brown bullhead	7,340	7,687	4,462	5,421	3,572	488	704	444	844	659	827	828	744	2,139	7,050
Channel catfish	9,253	11,183	39,603	15,208	11,481	2,025	1,941	2,929	9,152	5,760	16,168	24,969	17,936	16,573	7,561
White perch							8	10			64	45	4		
White bass	4,764	1,397	4,142	1,049	991		19	357	1,180	1,819	1,850	2,923	7,306	1,326	23
Freshwater drum	905	2,032	1,825	1,180				290	4,206	111	39,673	48,218	8,823	24,507	265
Gars									441	68		27	90	279	
Suckers	1,378	123	88								436	4,286	72	6,180	1,945
Goldfish			551	188	2,951	877	8,416	1,025	501	111	517	7,138	10,497	6,862	
Carp	738,857	367,310	685,395	417,365	194,320	158,151	198,294	251,365	238,805	94,662	329,262	387,671	325,433	620,015	211,055
Quillback	87,326	2,217	1,062	1,380	568		6,894	30,204	28,175	8,930	66,013	73,662	33,937	22,990	
Bigmouth buffalo	577	14,732	17,814	9,471	19,549	40,064						104	91,877	15,721	25,894
Totals	1,728,400	406,681	754,942	451,262	233,432	201,605	216,276	289,469	283,699	114,223	454,833	586,867	521,213	721,580	259,993

Source: USGS, 2001c.

Table I1-5: Revenue from Commercial Landings in the Michigan Waters of Lake Erie, 1985-1999

Species	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Gizzard shad	$241,450							$342	$40	$274	$1	$4,809	$1,714	$350	$744
Brown bullhead	$1,834	$1,888	$1,076	$1,355	$895	$123	$171	$122	$213	$185	$189	$209	$253	$599	$1,904
Channel catfish	$5,364	$6,453	$23,201	$9,114	$6,898	$1,215	$1,138	$1,569	$5,580	$3,628	$10,189	$14,236	$9,684	$9,281	$4,461
White perch							$4	$5			$42	$28	$2		
White bass	$1,219	$1,073	$3,209	$629	$488		$18	$374	$1,191	$1,474	$1,702	$2,661	$6,213	$1,074	$18
Freshwater drum	$89	$185	$187	$472				$28	$462	$22	$7,538	$7,714	$1,411	$4,168	$48
Gars										$17		$11	$45	$112	
Suckers	$155	$7	$6								$26	$256	$5	$371	$253
Goldfish			$827	$47	$495	$201	$1,689	$308	$126		$130	$2,929	$3,466	$2,745	
Carp	$85,409	$38,937	$79,199	$63,611	$26,000	$19,590	$23,794	$30,612	$31,044	$12,306	$36,222	$46,521	$45,562	$80,601	$27,438
Quillback	$5,086	$170	$106	$139	$227		$2,661	$12,856	$10,144	$3,130	$22,446	$26,516	$6,449	$4,598	
Bigmouth buffalo	$292	$6,060	$7,148	$3,975	$8,332	$16,358						$47	$40,425	$8,018	$11,913
Totals	$340,898	$54,773	$114,959	$79,342	$43,335	$37,487	$29,475	$46,216	$48,800	$21,036	$78,485	$105,937	$115,229	$111,917	$46,779

Source: USGS, 2001c.

I1-3.3 Recreational Fisheries

Recreational fishing is minimal in the lower portion of the River Raisin, and most fishing is concentrated in the lakes of the upper basin (Dodge, 1998). A combination of factors such as limited access and a public perception of the river as polluted contributes to the lack of recreational fishing in the river. The lower River Raisin does have good smallmouth bass habitat and experiences light to moderate fishing pressure. Because of logjams and other obstacles, bank and wading fishing tends to be more popular than boat fishing.

Recreational fishing in Lake Erie is more predominant. Recreational anglers spent about 175,000 noncharter days fishing the Michigan waters of Lake Erie in 1994 (Rakoczy and Svoboda, 1997). Their most commonly caught species were yellow perch and walleye (44 percent and 35 percent of the total harvest, respectively; Table I1-6). White bass, channel catfish, freshwater drum, and white perch made up most of the remaining catch. Total recreational hours averaged approximately 2 million between 1986 and 1994 (Table I1-6).

Table I1-6: Michigan Lake Erie Boat Fishery Angler Effort and Primary Species Catch April Through October, 1986 to 1998

	Angler Hours	Number of Yellow Perch Harvested	Number of Walleye Harvested
1986[a]	2,068,779	834,310	605,666
1987	2,455,903	619,112	902,378
1988[b]	4,362,452	318,786	1,996,824
1989	3,799,067	1,466,442	1,092,289
1990	2,482,242	770,507	780,508
1991[a]	805,294	378,716	132,322
1992	836,216	255,747	249,713
1993	935,249	473,580	270,376
1994	1,012,595	246,327	216,040
1995	na	343,240	107,909
1996	na	635,233	174,607
1997	na	529,435	112,400
1998	na	586,277	114,607

[a] May through October.
[b] May through September.
na = not available.
Sources: Rakoczy and Svoboda, 1997; Thomas and Haas, 2000.

I1-3.4 Other Water-Based Recreation

The River Raisin is used for other recreational activities such as canoeing, power boating, and hunting (Dodge, 1998). Although passage is complicated by six low-head dams in Monroe, canoeing activity occurs just upstream of Monroe. The current is gentle for easy nonpower boating, although flow may be too low at some times of the year. The town of Blissfield sponsors a canoe race each September. Motor boating is concentrated in the lakes of the upper portion of the River Raisin watershed and at the mouth of the River Raisin. Many private marinas are located downstream of the last dam on the river, and boaters access Lake Erie from the river.

Although limited, some hunting occurs along the River Raisin. The Sharonville State Game Area, located in Jackson and Washtenaw Counties, is managed for deer, small mammal, and fowl hunting. Waterfowl hunting includes wood duck and Canada goose. Other game areas managed for similar hunting opportunities are the Onsted State Game Area, the Somerset State Game Area, and the Lake Hudson State Recreation Area. In Monroe County, The Michigan Department of Natural Resources manages the Petersburg State Game area for deer and small game hunting.

❖ *The Linesville, PA Spillway at Pymatuning State Park:---"Where Ducks Walk on Fishes' Backs"*

Carp swarm above and below the spillway. They compete with ducks and Canada geese for slices of bread tossed to them by visitors. The ducks clamor over the seemingly endless school of carp to get their share. The ducks actually walk on the back of the carp.

The Spillway is a popular recreational site where visitors bring old bread or buy it at a nearby concession stand. Birds and fish compete for the bread. The spillway is the outflow of a secondary impoundment at the 2500 acre Pymatuning reservoir / sanctuary that serves as fish propagation waters for the Linesville Fish Culture Station.

Source: http://www.sideroads.com/outdoors/spillway.html
Photos: © Lynne G. Tudor

Chapter I2: Technical Description of Monroe

This chapter presents technical information related to the case study facility. Section I2-1 presents detailed Energy Information Administration (EIA) data on the generating units addressed by this case study and in scope of the Phase II rulemaking. Section I2-2 describes the configuration of the facility's intake structures.

CHAPTER CONTENTS

I2-1 Operational Profiles I2-1
I2-2 CWIS Configuration and Water Withdrawal I2-2

I2-1 OPERATIONAL PROFILES

Baseline operational characteristics

The Monroe power plant operates nine units. Four are coal-fired steam electric units (Units 1-4) that use cooling water withdrawn from the River Raisin while five units (Units IC1-IC5) are oil-fired internal combustion turbines that do not require cooling water. The internal combustion turbines began operation in 1969 while the four coal units began operation between June 1971 and May 1974.

Monroe's total net generation in 1999 was 18.3 million MWh. The four steam turbine units (Units 1-4) had capacity utilization rates between 50.4 and 73.3 percent. Table I2-1 presents details for Monroe's nine units.

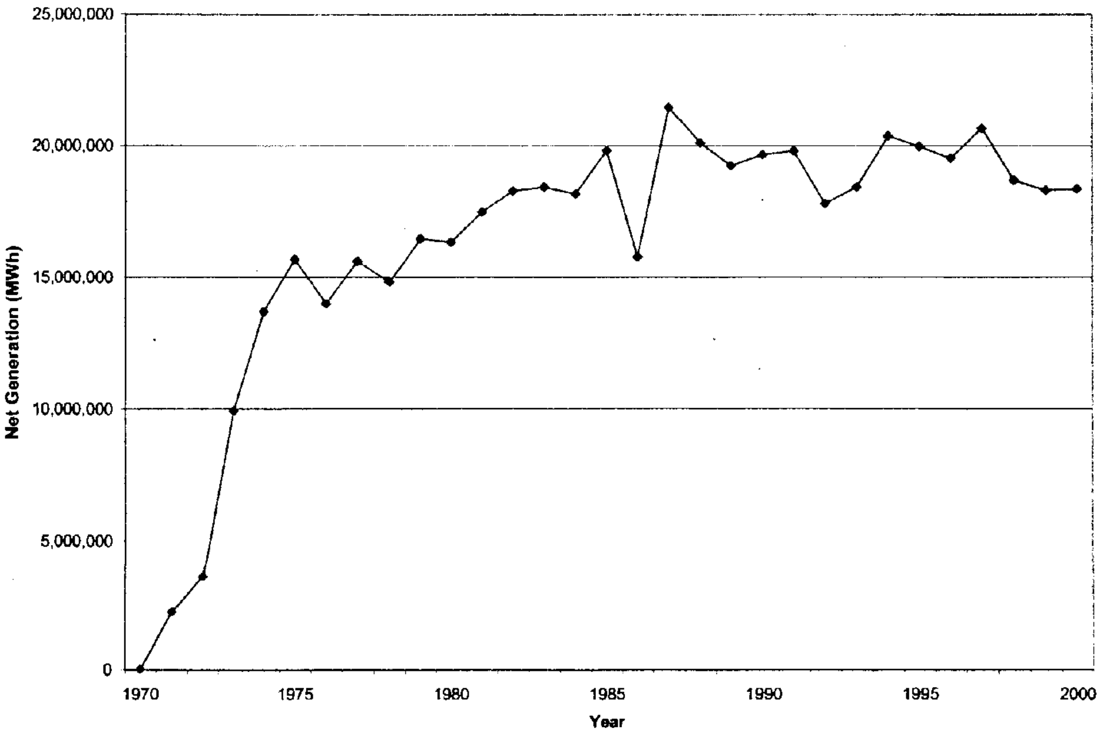
Table I2-1: Generator Detail of the Monroe Plant (1999)

Generator ID	Capacity (MW)	Prime Mover[a]	Energy Source[b]	In-Service Date	Operating Status	Net Generation (MWh)	Capacity Utilization[c]	ID of Associated CWIS
1	817	ST	BIT	June 1971	Operating	4,667,517	65.2%	1
2	823	ST	BIT	March 1973	Operating	3,633,349	50.4%	2
3	823	ST	BIT	May 1973	Operating	4,755,872	66.0%	3
4	817	ST	BIT	May 1974	Operating	5,249,776	73.3%	4
IC1	2.8	IC	FO2	Nov. 1969	Operating	1,916	1.6%	Not Applicable
IC2	2.8	IC	FO2	Dec. 1969	Operating			
IC3	2.8	IC	FO2	Nov. 1969	Operating			
IC4	2.8	IC	FO2	Dec. 1969	Operating			
IC5	2.8	IC	FO2	Nov. 1969	Operating			
Total	**3,293**					**18,308,430**	**63.5%**	

[a] Prime mover categories: ST = steam turbine; IC = internal combustion turbine.
[b] Energy source categories: BIT = bituminous coal; FO2 = No. 2 fuel oil.
[c] Capacity utilization was calculated by dividing the unit's actual net generation by the potential generation if the unit ran at full capacity all the time (i.e., capacity * 24 hours * 365 days).
Source: U.S. Department of Energy, 2001a, 2001b, 2001d.

Figure I2-1 below presents Monroe's electricity generation history between 1970 and 2000.

Figure I2-1: Monroe Net Electricity Generation 1970 -2000 (in MWh)



Source: Form EIA-906.

I2-2 CWIS Configuration and Water Withdrawal

The Monroe Power Station is located at the mouth of the River Raisin, approximately 2000 ft upstream from the open water of western Lake Erie. Monroe currently employs two intake structures that supply cooling water to the facility's once-through cooling system. Water from the River Raisin is diverted down a man-made intake canal to the intake structures. The first intake structure is 330 feet from the canal opening, while the second structure is 880 feet from the opening. Both structures share the same design and technology configuration.

Intake water drawn into one of the two structures passes through trash racks consisting of vertical bars spaced 7.6 cm apart and under a skimmer wall to one of the eight intake bays. Each intake bay contains fish collecting pans and guide screens that divert most impingeable organisms to a fish pump. Fish pumped out of the intake canal are deposited in a fish return pipe 20 cm in diameter. The return pipe expands to 66 cm in diameter downstream from the diversion point. Diverted fish are returned to Lake Erie at the end of a rocky jetty. Intake water not diverted with pumped fish passes through a vertical traveling screen to the circulating pumps and through the condenser. Traveling screens are rotated every eight hours, except during periods of high impingement. Heated water returns to the River Raisin via a discharge canal located to the west of the main powerhouse.

At maximum capacity, the Monroe Power Plant can withdraw 1,975 MGD through its two cooling water intake structures, representing 4 times the mean annual flow of the source water, the River Raisin. Because of the proximity of the intake canal to Lake Erie (~2000 ft.) and the large volume of water required for cooling operations at the facility, Monroe often draws water from Lake Erie up the mainstem of the river to the intake canal. Seasonal variations (spring flood) prevent this from occurring on a daily basis.

During the 1970s, Detroit Edison evaluated a fish pump and return system at its Monroe facility for its ability to reduce the impingement of aquatic organisms. Data from a 1977 316(b) demonstration study indicate a diversion rate associated with the fish pumps of 95 percent, meaning 95 percent of the fish passing through the trash racks into the main portion of the intake structure were successfully diverted through the return system to Lake Erie. The survival rate of diverted fish is unclear. Given the nature of the diversion (mechanical pumps), the distance of the return pipe (~2000 ft.), and the differences between the original and terminal environments (River Raisin vs. Lake Erie), it is reasonable to assume that some number of diverted fish do not survive for an extended period of time after the return to Lake Erie. However, there have been no studies of long-term survival.

No technologies are currently in place to reduce entrainment mortality.

Chapter I3: Evaluation of I&E Data

EPA evaluated impacts to aquatic organisms resulting from the CWIS of the Monroe facility using the assessment methods described in Chapter A5 of this document. EPA focused its evaluation on data collected when the facility was operated as it is currently configured. Section I3-1 lists fish species that are impinged and entrained at Monroe, Section I3-2 presents life histories of the most abundant species in the facility's I&E collections, and Section I3-3 summarizes the facility's I&E collection methods. Section I3-4 presents annual I&E data, and Section I3-5 summarizes the results of EPA's evaluation of Monroe's I&E data.

CHAPTER CONTENTS

I3-1 Species Impinged and Entrained at Monroe I3-1
I3-2 Life Histories of Major Species Impinged and Entrained I3-2
I3-3 Methods for Estimating I&E at Monroe I3-12
I3-3.1 Impingement Monitoring I3-12
I3-3.2 Entrainment Monitoring I3-13
I3-4 Annual Impingement and Entrainment I3-14
I3-5 Summary I3-14

I3-1 SPECIES IMPINGED AND ENTRAINED AT MONROE

Table I3-1 lists species known to be impinged and entrained at Monroe, and their classification as recreational, commercial, or forage species. In general, EPA evaluated only those species with impingement and entrainment numbers greater than 1 percent of the total at the facility. However, species that were uncommon in I&E collections were still included if they had commercial or recreational value and there was available site specific life history information.

Table I3-1: Species Vulnerable to I&E by Monroe

Common Name	Scientific Name	Recreational	Commercial	Forage
Alewife	*Alosa pseudoharengus*			X
Black bass	*Micropterus dolomieui*	X		
Black bullhead	*Ameiurus melas*		X	
Black crappie	*Pomoxis nigromaculatus*	X		
Bluegill	*Lepomis macrochirus*	X		
Bluntnose minnow	*Pimephales notatus*			X
Bowfin	*Amia calva*	X		
Brown bullhead	*Ameiurus nebulosus*		X	
Burbot	*Lota lota*	X	X	
Carp	*Cyprinus carpio carpio*		X	
Central mudminnow	*Umbra limi*			X
Channel catfish	*Ictalurus punctatus*	X	X	
Chinook salmon	*Oncorhynchus tshawytscha*	X	X	
Coho salmon	*Oncorhynchus kisutch*	X	X	
Emerald shiner	*Notropis atherinoides*			X
Fathead minnow	*Pimephales promelas*			X
Flathead catfish	*Pylodictis olivaris*	X		
Freshwater drum	*Aplodinotus grunniens*		X	

Table I3-1: Species Vulnerable to I&E by Monroe (cont.)

Common Name	Scientific Name	Recreational	Commercial	Forage
Gizzard shad	*Dorosoma cepedianum*		X	
Golden redhorse	*Moxostoma erythrurum*			X
Goldfish	*Carassius auratus auratus*		X	
Green sunfish	*Lepomis cyanellus*	X		
Hornyhead chub	*Nocomis biguttatus*		X	
Largemouth bass	*Micropterus salmoides*	X		
Logperch	*Percina caprodes*			X
Longnose gar	*Lepisosteus osseus*			X
Mottled sculpin	*Cottus bairdii*			X
Muskellunge	*Esox masquinongy*	X		
Northern hog sucker	*Hypentelium nigricans*		X	
Northern pike	*Esox lucius*	X		
Pumpkinseed	*Lepomis gibbosus*	X		
Quillback	*Carpiodes cyprinus*		X	
Rainbow smelt	*Osmerus mordax mordax*	X	X	
Rainbow trout	*Oncorhynchus mykiss*	X	X	
Rock bass	*Ambloplites rupestris*	X		
Silver lamprey	*Icthyomyzon unicuspis*			X
Smallmouth bass	*Micropterus dolomieui*	X		
Spotfin shiner	*Cyprinella spiloptera*			X
Spottail shiner	*Notropis hudsonius*			X
Sunfish species	Centrarchidae	X		
Tadpole madtom	*Noturus gyrinus*			X
Troutperch	*Percopsis omiscomaycus*			X
Walleye	*Stizostedion vitreum*	X		
White bass	*Morone chrysops*	X	X	
White crappie	*Pomoxis annularis*	X		
White perch	*Morone americana*	X		
White sucker	*Catostomus commersoni*		X	
Whitefish species	Coregoninae	X	X	
Yellow bullhead	*Ameiurus natalis*		X	
Yellow perch	*Perca flavescens*	X		

Sources: (Andrew Nuhfer, Michigan Department of Natural Resources, Fisheries Division, personal communication, 2/13/02; Jude et al., 1983; Cole, 1978; Goodyear, 1978)

I3-2 Life Histories of Major Species Impinged and Entrained

Alewife *(Alosa pseudoharengus)*

Alewife is a member of the herring family, Clupeidae, and ranges along the Atlantic coast from Newfoundland to North Carolina (Scott and Crossman, 1998). Alewives entered the Great Lakes region through the Welland Canal, which connects Lake Erie and Lake Ontario; by 1949, they were present in Lake Michigan (University of Wisconsin Sea Grant Institute, 2001). Because alewives are not a freshwater species, they are particularly susceptible to osmotic stress associated with freshwater. Freshwater fish have larger kidneys, which they use to constantly pump water from their bodies. Since alewives lack this physiological adaptation, they are more susceptible to environmental disturbances.

In the Great Lakes, alewives spend most of their time in deeper water. During spawning season, they move to shallower inshore waters to spawn. Although alewives generally do not die after spawning, the fluctuating temperatures that the adults are exposed to when they move to inshore waters often results in mortality due to osmotic stress. In some years, temperature changes caused by upwelling may result in a massive die-off of spawning alewives (University of Wisconsin Sea Grant Institute, 2001).

Alewife has been introduced to a number of lakes to provide forage for sport fish (Jude et al., 1987b). Ecologically, alewife is an important prey item for many fish.

Spawning is driven by water temperature, beginning in the spring as water temperatures reach 13 to 15 °C (55.4 to 59.0 °F), and ending when they exceed 27 °C (80.6 °F) (Able and Fahay, 1998). In their native coastal habitats, alewives spawn in the upper reaches of coastal rivers, in slow-flowing sections of slightly brackish or freshwater. In the Great Lakes, alewives move inshore to the outlets of rivers and streams to spawn (University of Wisconsin Sea Grant Institute, 2001).

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

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

ALEWIFE
(Alosa pseudoharengus)

Family: Clupeidae (herrings).

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

Similar species: Blueback herring.

Geographic range: Along the western Atlantic coast from Newfoundland to North Carolina.[a] Arrived in the Great Lakes via the Welland Canal.[b]

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

Lifespan: Generally 4-5 years but may live up to 8 years.[c,d]

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

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

Prey for: Striped bass, weakfish, rainbow trout.

Life stage information:

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

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

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

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

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

Carp (*Cyprinus carpio carpio*)

Carp is a member of the family of carps and minnows, Cyprinidae, and is abundant in Lake Erie. Carp were first introduced from Asia to the United States in the 1870's and 1880's, and by the 1890's were abundant in the Maumee River and in the west end of Lake Erie (Trautman, 1981). Carp are most abundant in low-gradient, warm streams and lakes with high levels or organic matter, but tolerate all types of bottom and clear to turbid waters (Trautman, 1981). Carp overwinter in deeper water and migrate to shallow water, preferably marshy environments with submerged aquatic vegetation in advance of the spawning season (McCrimmon, 1968). Adults feed on a wide variety of plants and animals, and juveniles feed primarily on plankton.

Carp are often considered a nuisance species because of their habit of uprooting vegetation and increasing turbidity when feeding (McCrimmon, 1968; Scott and Crossman, 1973). Carp are not widely popular fishes for anglers, although carp fishing may be an important recreational activity in some parts of the United States (Scott and Crossman, 1973). They are occasionally harvested commercially and sold for food (Scott and Crossman, 1973).

Male carp reach sexual maturity between ages 3 and 4, and the females reach maturity between ages 4 and 5 (Swee and McCrimmon, 1966). Spawning can occur at water temperatures between 16 and 28 °C (60.8 and 82.4 °F) with optimum activity between 19 and 23 °C (66.2 and 73.4 °F) (Swee and McCrimmon, 1966). Fecundity in carp can range from 36,000 eggs for a 39.4 cm (15.5 in.) fish to 2,208,000 in a 85.1 cm (33.5 in.) fish (Swee and McCrimmon, 1966), but individuals may spawn only about 500 eggs at a given time (Dames and Moore, 1977a). Eggs are demersal and stick to submerged vegetation.

Eggs hatch 3 to 6 days after spawning and larvae tend to lie in shallow water among vegetation (Swee and McCrimmon, 1966). The lifespan of a typical carp in North America is less than 20 years (McCrimmon, 1968). Adult carp can reach 102-122 cm (40-48 in.) long, and weigh 18-27 kg (40-60 lb) (Trautman, 1981).

CARP
(*Cyprinus carpio carpio*)

Family: Cyprinidae (minnows or carp).

Common names: Carp.

Similar species: Goldfish, buffalofishes, carpsuckers.[a]

Geographic range: Wide-ranging throughout the United States.

Habitat: Low-gradient, warm streams and lakes with high levels or organic carbon. Tolerates relatively wide range of turbidity. Often associated with submerged aquatic vegetation.[b]

Lifespan: Less than 20 years.[b]

Fecundity: 36,000 to 2,208,000 eggs per season.[c]

Food source: Omnivorous; diet includes invertebrates, small molluscs, ostracods, and crustaceans as well as roots, leaves, and shoots of water plants.[b]

Prey for: Juveniles provide limited forage for northern pike, smallmouth bass, striped bass, and longnosed gar, as well as green frogs, bullfrogs, turtles, snakes, mink.[b]

Life stage information:

Eggs: demersal
- During spawning, eggs are released in shallow, vegetated water. Eggs are demersal and stick to submerged vegetation.
- Eggs hatch in 3-6 days.[c]

Larvae:
- Larvae are found in shallow, weedy, and muddy habitats.[d]

Adults:
- May reach lengths of 102-122 cm (40-48 in.).[a]

[a] Trautman, 1981.
[b] McCrimmon, 1968.
[c] Swee and McCrimmon, 1966.
[d] Wang, 1986a.
Fish graphic from North Dakota Game and Fish Department, 2002.

Channel catfish (*Ictalarus punctatus*)

Channel catfish is a member of the Ictaluridae (North American freshwater catfish) family. It is found from Manitoba to southern Quebec, and as far south as the Gulf of Mexico (Dames and Moore, 1977a). Channel catfish can be found in freshwater streams, lakes, and ponds. They prefer deep water with clean gravel or boulder substrates and low to moderate currents (Ohio Department of Natural Resources, 2001b).

Channel catfish reach sexual maturity at ages 5-8, and females will lay 4,000-35,000 eggs dependent on body weight (Scott and Crossman, 1998). Spawning begins when water temperatures reach 24-29 °C (75-85 °F) in late spring or early summer. Spawning occurs in natural nests such as undercut banks, muskrat burrows, containers, or submerged logs. Eggs approximately 3.5 mm (0.1 in) in diameter are deposited in a large, flat, gelatinous mass (Wang, 1986a). After spawning, the male guards the nest and fans it to keep it aerated. Eggs hatch in 7-10 days at 24-26 °C (75-79 °F), and the newly hatched larvae remain near the nest for several days (Wang, 1986a). Young fish prefer to inhabit riffles and turbulent areas. Channel catfish are very popular with anglers and are relatively prized as a sport fish (Dames and Moore, 1977a).

CHANNEL CATFISH
(Ictalarus punctatus)

Family: Ictaluridae (North American freshwater catfish).

Common names: Channel catfish, graceful catfish.[a]

Similar species: Blue and white catfishes.[b]

Geographic range: South-central Canada, central United States, and northern Mexico.[a]

Habitat: Freshwater streams, lakes, and ponds. Prefer deep water with clean gravel or boulder substrates.[c]

Lifespan: Maximum reported age: 16 years.[a]

Fecundity: 4,000 to 35,000 eggs depending on body weight.[e]

Food source: Small fish, crustaceans, clams, snails.[a]

Prey for: Chestnut lamprey.[a]

Life stage information:

***Eggs:** demersal*
- 3-4 mm (0.12-0.16 in.) in diameter.[d]
- Hatch in 7-10 days.[d]

Larvae:
- Remain near nest for a few days then disperse to shallow water.[d]
- Approx. 6.4 mm (0.25 in.) upon hatching.[d]

***Adults:** demersal*
- Average length: 30-36 cm (12-14 in.).[c]
- Maximum length: up to 104 cm (41 in.).[c]

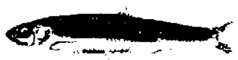
[a] Froese and Pauly, 2001.
[b] Trautman, 1981.
[c] Ohio Department of Natural Resources, 2001b.
[d] Wang, 1986a.
[e] Scott and Crossman, 1998.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

Emerald shiner (*Notropis atherinoides*)

Emerald shiner is a member of the family Cyprinidae. It is found in large open lakes and rivers from Canada south throughout the Mississippi Valley to the Gulf Coast in Alabama (Scott and Crossman, 1973). Emerald shiner prefer clear waters in the mid- to upper sections of the water column, and are most often found in deep, slow moving rivers and in Lake Erie (Trautman, 1981). The emerald shiner is one of the most prevalent fishes in Lake Erie, although populations may fluctuate dramatically from year to year (Trautman, 1981). Because of its small size, it is an important forage fish for many species.

Spawning occurs from July to August in Lake Erie (Scott and Crossman, 1973). Females lay anywhere from 870 to 8,700 eggs (Campbell and MacCrimmon, 1970), which hatch within 24 hours (Scott and Crossman, 1973). Young-of-year remain in large schools in inshore waters until the fall, when they move into deeper waters to overwinter (Scott and Crossman, 1973). Young-of-year average 5.1 to 7.6 cm (2 to 3 in.) in length (Scott and Crossman, 1973).

Emerald shiner are sexually mature by age 2, though some larger individuals may mature at age 1 (Campbell and MacCrimmon, 1970). Most do not live beyond 3 years (Fuchs, 1967). Adults typically range from 6.4 to 8.4 cm (2.5 to 3.3 in.) (Trautman, 1981).



EMERALD SHINER
(Notropis atherinoides)

Family: Cyprinidae (herrings).

Common names: Emerald shiner.

Similar species: Silver shiner, rosyface shiner.[a]

Geographic range: From Canada south throughout the Mississippi valley to the Gulf Coast in Alabama.[b,c]

Habitat: Large open lakes and rivers.[b]

Lifespan: Emerald shiner live to 3 years.[a,d]

Fecundity: Mature by age 2. Females can lay anywhere from approximately 870 to 8,700 eggs.[3]

Food source: Microcrustaceans, midge larvae, zooplankton, algae.[d]

Prey for: Gulls, terns, mergansers, cormorants, smallmouth bass, yellow perch, and others.[d]

Life stage information:

Eggs: demersal
- Eggs hatch in less than 24 hours.[d]

Larvae: pelagic
- Individuals from different year classes can have varying body proportions and fin length, as can individuals from different localities.[a]

Adults:
- Typically range in size from 6.4 to 8.4 cm (2.5 to 3.3 in.).[a]

[a] Trautman, 1981.
[b] Froese and Pauly, 2000.
[c] Campbell and MacCrimmon, 1970.
[d] Scott and Crossman, 1973.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

Freshwater drum (*Aplodinotus grunniens*)

Freshwater drum is a member of the drum family, Sciaenidae. Possibly exhibiting the greatest latitudinal range of any North American freshwater species, its distribution ranges from Manitoba, Canada, to Guatemala, and throughout the Mississippi River drainage basin (Scott and Crossman, 1973). The freshwater drum is found in deep pools of rivers and in Lake Erie at depths between 1.5 and 18 m (5 and 60 ft) (Trautman, 1981). Drum is not a favored food item of either humans or other fish; however, it supports a minor commercial fishery (Edsall, 1967; Trautman, 1981; Bur, 1982).

Based on studies in Lake Erie, the spawning season peaks in July (Daiber, 1953), although spent females have been found as late as September (Scott and Crossman, 1973). Females in Lake Erie produce anywhere from 43,000 to 508,000 eggs (Daiber, 1953). The eggs are buoyant, floating at the surface of the water (Daiber, 1953; Scott and Crossman, 1973). This unique quality may be one explanation for the freshwater drum's exceptional distribution (Scott and Crossman, 1973). Yolk-sac larvae are buoyant as well, floating inverted at the surface of the water with the posterior end of the yolk sac and tail touching the surface (Swedberg and Walburg, 1970).

Larvae develop rapidly over their first year. Maturity appears to be reached earlier in freshwater drum females from the Mississippi River than in females from Lake Erie. Daiber (1953) found Lake Erie females begin maturing at age 5, and 46 percent reach maturity by age 6. Lake Erie males begin maturing at age 4, and by age 5, 79 percent had reached maturity.

The maximum age for fish in western Lake Erie is 14 years for females and 8 years for males (Edsall, 1967). Adults tend to be between 30 to 76 cm (12 to 30 in.) long.

FRESHWATER DRUM
(*Aplodinotus grunniens*)

Family: Sciaenidae.

Common names: freshwater drum, white perch, sheepshead.[a]

Similar species: white bass, carpsuckers.[a]

Geographic range: From Manitoba, Canada, to Guatemala. They can be found throughout the Mississippi River drainage basin.

Habitat: Bottoms of medium to large sized rivers and lakes.[b]

Lifespan: The maximum age for fish in western Lake Erie is 14 years for females and 8 years for males.[c]

Fecundity: Females in Lake Erie produce from 43,000 to 508,000 eggs.[c]

Food sources: Juveniles: Cladocerans (plankton), copepods, dipterans.[d] Adults: Dipterans, cladocerans,[d] darters, emerald shiner.[c]

Prey for: Very few species.

Life stage information:

***Eggs:** pelagic*
- The buoyant eggs float at the surface of the water, possibly accounting for the species' high distribution.[c]

Larvae:
- Prolarvae float inverted at the surface of the water with the posterior end of the yolk sac and their tail touching the surface.[f]

Adults:
- The species owes its name to the audible "drumming" sound that it is often heard emitting during summer months.[c]
- Tend to be between 30 to 76 cm (12 to 30 in.) long.[a]

[a] Trautman, 1981
[b] Froese and Pauly, 2001.
[c] Edsall, 1967.
[d] Bur, 1982.
[e] Scott and Crossman, 1973.
[f] Swedberg and Walburg, 1970.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

Gizzard shad (*Dorosoma cepedianum*)

Gizzard shad is a member of the family Clupeidae. Its distribution is widespread throughout the eastern United States and into southern Canada, with occurrences from the St. Lawrence River south to eastern Mexico (Miller, 1960; Scott and Crossman, 1973). Gizzard shad are found in a range of salinities from freshwater inland rivers to brackish estuaries and marine waters along the Atlantic Coast of the United States (Miller, 1960; Carlander, 1969). Gizzard shad often occur in schools (Miller, 1960). Young-of-year are considered an important forage fish (Miller, 1960), though their rapid growth rate limits the duration of their susceptibility to many predators (Bodola, 1966). In Lake Erie, gizzard shad are most populous in the shallow waters of western Lake Erie, around the Bass Islands, and in protected bays and mouths of tributaries (Bodola, 1966).

Spawning occurs from late winter or early spring to late summer, depending on temperature. Spawning has been observed in early June to July in Lake Erie (Bodola, 1966), and in May elsewhere in Ohio waters (Miller, 1960). The spawning period generally lasts 2 weeks (Miller, 1960). Males and females release sperm and eggs while swimming in schools near the surface of the water. Eggs sink slowly to the bottom or drift with the current, and adhere to any surface they encounter (Miller, 1960). Females have been reported to release an average of 378,990 eggs annually (Bodola, 1966), which average 0.75 mm (0.03 in.) in diameter (Wallus et al., 1990).

Hatching time can be anywhere from 36 hours to 1 week, depending on water temperature (Bodola, 1966). Young shad may remain in upstream natal waters if conditions permit (Miller, 1960). By age 2 all gizzard shad are sexually mature, though some may mature as early as age 1 (Bodola, 1966). Unlike many other fish, fecundity in gizzard shad declines with age (Electric Power Research Institute, 1987).

Gizzard shad generally live up to 6 years in Lake Erie, but individuals up to 10 years have been reported in southern locations (Scott and Crossman, 1973). Mass mortalities have been documented in several locations during winter months, due to extreme temperature changes (Williamson and Nelson, 1985).

GIZZARD SHAD
(Dorosoma cepedianum)

Family: Clupeidae (herrings).

Common names: Gizzard shad.

Similar species: Threadfin shad.[a]

Geographic range: Eastern North America from the St. Lawrence River to Mexico.[b,c]

Habitat: Inhabits inland lakes, ponds, rivers, and reservoirs to brackish estuaries and ocean waters.[b,c]

Lifespan: Gizzard shad generally live 5 to 6 years, but have been reported up to 10 years.[b]

Fecundity: Maturity is reached by age 2; females produce average of 378,990 eggs.[b]

Food sources: Larvae consume protozoans, zooplankton, and small crustaceans.[c] Adults are mainly herbivorous, feeding on plants, phytoplankton, and algae. They are one of the few species able to feed solely on plant material.[b]

Prey for: Walleye, white bass, largemouth bass, crappie, among others (immature shad only).[b]

Life stage information:

Eggs: demersal
- During spawning, eggs are released near the surface and sink to the bottom, adhering to any surface they touch.

Larvae: pelagic
- Larvae serve as forage to many species.
- After hatching, larvae travel in schools for the first few months.

Adults:
- May grow as large as 52.1 cm (20.5 in.).[a]
- May be considered by some to be a nuisance species because of sporadic mass winter die-offs.[3]

[a] Trautman, 1981.
[b] Miller, 1960.
[c] Scott and Crossman, 1973.
Fish graphic from Iowa Dept. of Natural Resources, 2001.

Lake whitefish (*Coregonus clupeaformis*)

Lake whitefish are a member of the whitefish family, Salmonidae (Coregoninae subfamily). They are distributed widely in fresh water from Alaska, through Canada and south into the Great Lakes and northern New England (Scott and Crossman, 1998). They are a valuable commercial and recreational fish and are prized for their fine tasting meat as well as their eggs, which are prepared and marketed as caviar. Their liver is also used for paté.

Lake whitefish spawn in the autumn, usually in November and December, in the Great Lakes (Scott and Crossman, 1998). They deposit demersal eggs in shallow water of less than 7.6 m (25 ft) over rocky, hard, or sandy substrate. Fecundity is estimated at 16,100 eggs per pound of fish. The eggs are initially about 2.3 mm (0.09 in.) in diameter, but increase to up to 3.2 mm (0.13 in.) after 24 hours in the water. Eggs do not hatch right away, but overwinter and hatch in April or May when water temperatures rise (approximately 140 days; Froese and Pauly, 2001). The optimal temperature range for development is 0.6-6.1 °C (33-43 °F; Scott and Crossman, 1998).

Young whitefish develop rapidly, and reach the commercial size of 0.9 kg (2 lb) at age 3 in Lake Erie (Scott and Crossman, 1998). They may reach a length of 676 mm (26.6 in.) in Lake Erie. Males generally mature and die earlier than females.

LAKE WHITEFISH
(Coregonus clupeaformis)

Family: Salmonidae, subfamily Coregoninae (whitefish).[a]

Common names: Whitefish, Great Lakes whitefish, humpback whitefish.[b]

Geographic range: Alaska and Canada to Great Lakes and New England.[a]

Habitat: Lakes and large rivers.[b]

Lifespan: Maximum reported age: 28 years. In Lake Erie, live to approximately 16 years.[a]

Fecundity: 16,100 eggs per pound in Lake Erie.[a]

Food source: Young consume copepods, cladocerans, and insect larvae. Adults consume eggs and small fish such as darter, alewife, minnow, and stickleback.[a]

Prey for: Lake trout, northern pike, burbot, yellow walleye, whitefish. Parasitized by sea lamprey.[a]

Life stage information:

***Eggs:** demersal*
- 2.3-3.2 mm (0.09-0.13 in.) in diameter.[a]
- Hatch in 140 days.[b]

Larvae:
- Approx. 12 mm (0.47 in.) at 1 week.[a]
- Concentrate in shallow water of about 30 cm (12 in.).[c]

***Adults:** demersal*
- Maximum length in Lake Erie: up to 67.6 cm (26.6 in.).[a]

[a] Scott and Crossman, 1998.
[b] Froese and Pauly, 2001.
[c] University of Saskatchewan, 2002.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

Walleye (*Stizostedion vitreum*)

Walleye is a member of the perch family, Percidae. It is found in freshwater from as far north as the Mackenzie River near the Arctic Coast to as far south as Georgia, and is common in the Great Lakes. Walleye are popular sport fish both in the summer and winter.

Walleye spawn in spring or early summer, although the exact timing depends on latitude and water temperature. Spawning has been reported at water temperatures of 5.6 to 11.1 °C (42 to 52 °F), in rocky areas in white water or shoals of lakes (Scott and Crossman, 1998). They do not fan nests like other similar species, but instead broadcast eggs over open ground, which reduces their ability to survive environmental stresses (Carlander, 1997). Females typically produce between 48,000 and 614,000 eggs in Lake Erie, and the eggs are 1.4 to 2.1 mm (0.06 to 0.08 in.) in diameter (Carlander, 1997). Eggs hatch in 12-18 days (Scott and Crossman, 1998). Larvae are approximately 6.0 to 8.6 mm (0.23 to 0.33 in.) at hatching (Carlander, 1997).

Walleye develop more slowly in the northern extent of their range; in Lake Erie they typically are 8.9 to 20.3 cm (3.5 to 8.0 in.) by the end of the first growing season. Males generally mature at 2-4 years and females at 3-6 years (Scott and Crossman, 1998), and females tend to grow faster than males (Carlander, 1997). Walleye may reach up to 78.7 cm (31 in.) long in Lake Erie (Scott and Crossman, 1998).

WALLEYE
(Stizostedion vitreum)

Family: Percidae (perch).

Common names: Blue pike, glass eye, gray pike, marble eye, yellow pike-perch.[a]

Similar species: Sauger.[b]

Geographic range: Canada to southern United States.[c]

Habitat: Large, shallow, turbid lakes; large streams or rivers.[c]

Lifespan: Maximum reported age: 12 years.[b]

Fecundity: Broadcast spawners; in Lake Erie, 48,000 to 614,000 eggs per spawn.[b]

Food source: Insects, yellow perch, freshwater drum, crayfish, snails, frogs.[a]

Prey for: Sea lamprey, northern pike, muskellunge, sauger.[a]

Life stage information:

Eggs: demersal
- 1.4-2.1 mm (0.06-0.08 in.) in diameter.[b]
- Hatch in 12-18 days.[c]

Larvae: pelagic
- Approx. 6.2-7.3 mm (0.24-0.29 in.) upon hatching.[b]

Adults: demersal
- Maximum length: up to 78.7 cm (31 in.).[c]

[a] Froese and Pauly, 2001.
[b] Carlander, 1997.
[c] Scott and Crossman, 1998.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

White bass (*Morone chrysops*)

White bass is a member of the temperate bass family, Moronidae. It ranges from the St. Lawrence River south through the Mississippi valley to the Gulf of Mexico, though the species is most abundant in the Lake Erie drainage (Van Oosten, 1942). White bass has both commercial and recreational fishing value.

Spawning take place in May in Lake Erie and may extend into June, depending on water temperatures. Spawning bouts can last from 5 to 10 days (Scott and Crossman, 1973). Adults typically spawn near the surface, and eggs are fertilized as they sink to the bottom. Fecundity increases directly with size in females; the average female lays approximately 565,000 eggs. Eggs hatch within 46 hours at a water temperature of 15.6 °C (60 °F) (Scott and Crossman, 1973).

Larvae grow rapidly, and young white bass reach lengths of 13 to 16 cm (5.1 to 6.3 in.) by the fall (Scott and Crossman, 1973). They feed on microscopic crustaceans, insect larvae, and small fish. As adults, the diet switches to fish. Yellow perch are an especially important prey species for white bass (Scott and Crossman, 1973).

Most white bass mature at age 3 (Van Oosten, 1942). Upon reaching sexual maturation, adults tend to form unisexual schools, traveling up to 11.1 km (6.9 mi) a day. Adults occupy the upper portion of the water column, maintaining depths of 6 m (19.7 ft) or less (Scott and Crossman, 1973). On average, adults are between 25.4 to 35.6 cm (10 to 14 in.) long (Ohio Department of Natural Resources, 2001b). White bass rarely live beyond 7 years (Scott and Crossman, 1973).

WHITE BASS
(Morone chrysops)

Family: Moronidae.

Common names: White bass, silver bass.

Similar species: White perch, striped bass.[a]

Geographic range: St. Lawrence River south through the Mississippi valley to the Gulf of Mexico, highly abundant in the Lake Erie drainage.[b]

Habitat: Occurs in lakes, ponds, and rivers.[c]

Lifespan: White bass may live up to 7 years.[d]

Fecundity: The average female lays approximately 565,000 eggs.[b]

Food source: Juveniles consume microscopic crustaceans, insect larvae, and small fish.[b] Adults have been found to consume yellow perch, bluegill, white crappie,[b] and carp.[b,d]

Prey for: Other white bass.[a]

Life stage information:

Eggs: *demersal*
- Eggs are approximately 0.8 mm (0.03 in.) in diameter.[b]

Larvae: *pelagic*
- White bass experience their maximum growth in their first year.[b]

Adults:
- Travel in schools, traveling up to 11.1 km (6.9 mi) a day.[b]
- Most mature at age 3.[e]
- Adults prefer clear waters with firm bottoms.[a]

[a] Trautman, 1981.
[b] Scott and Crossman, 1973.
[c] Froese and Pauly, 2000.
[d] Carlander, 1997.
[e] Van Oosten, 1942.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

Yellow perch (*Perca flavescens*)

The yellow perch is a member of the Percidae family and is found in fresh waters in the northern and eastern United States and across eastern and central Canada. Yellow perch are also occasionally seen in brackish waters (Scott and Crossman, 1973). They are typically found in greatest numbers in clear waters with low gradients and abundant vegetation (Trautman, 1981). The Great Lakes are a major source of yellow perch for the commercial fishing industry. Perch feed during the day on immature insects, larger invertebrates, fishes, and fish eggs (Scott and Crossman, 1973).

Sexual maturity is reached at age 1 for males and at ages 2 and 3 for females (Saila et al., 1987). Perch spawn in the spring in water temperatures ranging from 6.7 to 12.2 °C (44 to 54 °F) (Scott and Crossman, 1973). Adults move to shallower water to spawn, usually near rooted vegetation, fallen trees, or brush. Spawning takes place at night or in the early morning. Females lay all their eggs in a single transparent strand that is approximately 3 cm (1.2 in.) wide (Saila et al., 1987) and up to 2.1 m (7 ft) long (Scott and Crossman, 1973). These egg cases are semi-buoyant and attach to submerged vegetation or occasionally to the bottom and may contain 2,000-90,000 eggs (Scott and Crossman, 1973). In western Lake Erie, fecundities for yellow perch were reported to range from 8,618 to 78,741 eggs (Saila et al., 1987).

Yellow perch larvae hatch within about 8-10 days and are inactive for about 5 days until the yolk is absorbed (Scott and Crossman, 1973). Young perch are initially pelagic and found in schools, but become demersal after their first summer (Saila et al., 1987).

Adult perch are inactive at night and rest on the bottom (Scott and Crossman, 1973). Females generally grow faster than males and reach a greater final length (Scott and Crossman, 1973). In Lake Erie, perch may reach up to approximately 31 cm (12 in.) in total length and have been reported to live up to 11 years.

YELLOW PERCH
(Perca flavescens)

Family: Percidae (perches).

Common names: Yellow perch, perch, American perch, lake perch.[a]

Similar species: Dusky darter.[b]

Geographic range: Northern and eastern United States.[c]

Habitat: Lakes, ponds, creeks, rivers. Found in clear water near vegetation.[a,b]

Lifespan: Up to 11 years.[c]

Fecundity: 8,618 to 78,741 eggs.[c]

Food source: Immature insects, larger invertebrates, fishes, and fish eggs.[c]

Prey for: Almost all warm to cool water predatory fish, including bass, sunfish, crappies, walleye, sauger, northern pike, muskellunge, and other perch, as well as a number of birds.[c]

Life stage information:

Eggs: semi-buoyant
- Eggs laid in long tubes containing 2,000-90,000 eggs.[c]
- Eggs usually hatch in 8-10 days.[c]

Larvae: pelagic
- Larvae are 4.1-5.5 mm (0.16-0.22 in.) upon hatching.[d]
- Found in schools with other species.[c]
- Become demersal during the first summer.[d]

Adults: demersal
- Reach up to 31 cm (12 in.) in Lake Erie.[c]
- Found in schools near the bottom.

[a] Froese and Pauly, 2001.
[b] Trautman, 1981.
[c] Scott and Crossman, 1973.
[d] Saila et al., 1987.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

I3-3 Methods for Estimating I&E at Monroe

EPA examined I&E data from a variety of facility and agency monitoring reports. Impingement data were collected in 1972, 1973, and 1975 by the U.S. Fish and Wildlife Service (Goodyear, 1978), in 1982-83 by the University of Michigan Great Lakes Research Division (Jude et al., 1983), and in 1985-86 by the Michigan Department of Natural Resources (Andrew Nuhfer, Michigan Department of Natural Resources, Fisheries Division, personal communication, 2/13/02). Entrainment data were collected in 1973, 1974, and 1975 by the U.S. EPA (Cole, 1978) and in 1982-83 by the University of Michigan Great Lakes Research Division (Jude et al., 1983). For this benefits case study, EPA determined that only the data for the 1980's are relevant for an evaluation of the facility as it is currently operated and configured. The methods used to collect these data are summarized below.

I3-3.1 Impingement Monitoring

University of Michigan, Great Lakes Research Division, 1982-1983

Impingement was sampled by scientists from the University of Michigan, Great Lakes Research Division once per week from February 18, 1982, to February 7, 1983 (Jude et al., 1983). Samples were collected once a week for the 52 week sampling period, and one additional sample was collected on February 25, 1982, to sample a large gizzard shad impingement event. Sampling lasted for 24 hours and was conducted on Monday to Tuesday, or Tuesday to Wednesday (if Monday was a holiday).

Samples were collected from the two screenhouses via a conveyor belt, which delivered impinged fish from the traveling screens to a dump truck. Trucks were checked to ensure that they were not switched during the sampling period. After the 24 hour sampling period, either all of the fish were counted or, if the collection was too large to count, a subsample was collected. Subsampling was done by leveling the collected fish in the truck bed, visually dividing the bed into square sections, assigning a number to each section, and randomly selecting a subset of sections (usually two). The remaining fish were spread evenly again, and the length, width, and depth of the pile were measured. The volume of unsampled fish was converted to an estimated weight using a conversion factor of 0.758 g/cm^3, which was derived from 10 replicates of 20 kg (44.09 lb) samples of alewives. This conversion was checked on several dates by comparing the volume of the fish sampled to the volume of the unsampled fish. When the resulting relationship from the volume comparison was consistently different from that calculated by the conversion factor because of variations in fish size and percentage of nonfish debris, the volume comparison was used to determine the percentage of fish subsampled. Estimates of the total number of fish impinged in a sampling period were made from subsampled counts by scaling up to the total amount for a sampling period.

During the large gizzard shad impingement event on February 25, 1982, the sampling method had to be altered because the fish were filling up trucks too quickly to be subsampled according to the usual protocol. A subsample of gizzard shad was collected from each truck, with an attempt made to collect a representative size distribution. Fish other than gizzard shad that were seen were also collected. The time to fill each truck and the volume of fish in the truck were recorded. A subset of the trucks was measured and the information applied to other truckloads collected that day.

The University of Michigan calculated average daily impingement rates by dividing the sum of impingement during all sampling days in the month by the number of sampling days. They then calculated monthly impingement by multiplying the average daily impingement by the number of days in the month. Annual impingement was the sum of all 12 months in the study.

Michigan Department of Natural Resources, 1985-1986

Impingement was also sampled by the Michigan Department of Natural Resources (DNR) from May 16, 1985, to May 6, 1986.

Samples were collected on 3 days in May and June 1985, 5 days per month in July and August 1985, and 4 days per month from September 1985 through April 1986, so that a total of 49 samples were collected. The day of sampling was randomly selected from weekdays (Monday through Friday). The duration of sampling was approximately 24 hours, although shorter periods were sampled when impingement was high and longer periods were sampled when there were few fish.

Samples were collected from the two screenhouses via a conveyor belt, which delivered impinged fish from the traveling screens to a dump truck. When the number of fish collected could be processed in less than 5 hours, the entire sample was counted. When this was not the case, the collection was subsampled. Subsampling was done by leveling the collected fish in the truck bed, visually dividing the bed into square sections, assigning a number to each section, and randomly selecting a subset of sections (approximately 40 percent). Equal numbers of buckets of debris and fish were collected from each selected section to draw a subsample. The subsamples and the remaining fish were weighed to determine what percentage of the total of the subsamples represented. On days when subsamples were taken, they represented an average of 26 percent by weight of the total collection. Subsamples were extrapolated to the total amount by multiplying by an expansion factor (calculated by dividing the weight of the total collection by the weight of the subsample).

The Michigan DNR calculated daily impingement values for each species by standardizing the collection rate to a 24 hour period. Periodic estimates were derived by multiplying the daily estimate by the number of days in a period of time represented by that sampling event (approximately 7). They then calculated monthly totals by summing the periodic rates for a given month. Final annual estimates are representative of both screenhouses combined.

I3-3.2 Entrainment Monitoring

University of Michigan, Great Lakes Research Division, 1982-1983

Entrainment sampling was also conducted from February 1982 to February 1983 (Jude et al., 1983). Samples were taken weekly from March through August; twice a month in January, February, September, and October; and once per month in November and December.

Lake and river water in the intake canal was often stratified because of temperature differences. Thus, samples used to estimate entrainment were collected in the discharge canal, because the water was well mixed. Larvae were collected using a 0.5 m (1.6 ft), 363 μm (0.0014 in) mesh net. A flowmeter was used to measure the volume of water per sample, usually between 20 and 55 m^3 (706 and 1,942 ft^3). Four replicate samples were collected in each of four daily periods on each sampling date.

In their calculations, the Michigan DNR first multiplied the mean density in each of the four daily periods by the total weekly volume of water that passed through the plant during the corresponding daily period. Then these estimates for each daily time period were summed to estimate a weekly total across all time periods. Annual estimates were calculated by Michigan DNR by summing all of the weekly estimates.

I3-4 Annual Impingement and Entrainment

EPA evaluated annual I&E at Monroe using the methods presented 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 I1. Table I3-2 displays estimates of annual impingement (numbers of organisms) at Monroe for the years of monitoring (1982 and 1985). Table I3-3 presents these numbers expressed as age 1 equivalents, Table I3-4 displays annual impingement of fishery species as pounds of lost fishery yield, and Table I3-5 displays annual impingement expressed as production foregone. Tables I3-6 through I3-9 display the same information for entrainment at Monroe for 1982.

The results of EPA's analysis indicate that both impingement and entrainment collections at Monroe are dominated by gizzard shad, followed by white bass, yellow perch, and freshwater drum. Impingement rates are about 4.5 times entrainment rates. However, more commercial and recreational species are entrained than impinged. About 34.3 million gizzard shad, 0.7 million white bass, 0.3 million yellow perch, and 0.15 million freshwater drum age 1 equivalents are impinged per year. Annual age 1 equivalents entrained average about 8.7 million gizzard shad, 0.8 million white bass, 0.6 million yellow perch, and 0.15 million freshwater drum. Impingement and entrainment of all species combined results in over 2 million pounds of lost fishery yield per year.

I3-5 Summary

Table I3-10 summarizes EPA's estimates of annual I&E at Monroe. Results indicate that, on average, nearly 21 million organisms are impinged at Monroe each year. This represents 35.8 million age 1 equivalents, 1.4 million pounds of lost fishery yield, and 0.7 million pounds of production foregone. Over 4.6 billion organisms are entrained per year, representing about 11.6 million age 1 equivalents, 0.6 million pounds of lost fishery yield, and 3.5 million pounds of production foregone. The economic value of these losses is discussed in Chapter I4, and the potential benefits of reducing these losses with the proposed rule are discussed in Chapter I5.

Table I3-2: Estimates of Annual Impingement (numbers of organisms) at Monroe, 1982 and 1985

Year	Alewife	Blue-gill	Bluntnose Minnow	Bullhead spp.	Carp	Central Mudminnow	Channel Catfish	Coho Salmon	Crappie	Fathead Minnow	Freshwater Drum	Gizzard Shad	Golden Redhorse	Hornyhead Chub	Log-perch
1982	250	750	6	1,732	7,100	12	1,333	18	1,310	170	160,000	30,000,000	12	210	96,800
1985	0	0	0	0	0	0	0	0	0	0	96,847	9,310,023	0	0	137,854
Mean	125	375	3	866	3,550	6	666	9	655	85	128,424	19,655,012	6	105	117,327
Minimum	0	0	0	0	0	0	0	0	0	0	96,847	9,310,023	0	0	96,800
Maximum	250	750	6	1,732	7,100	12	1,333	18	1,310	170	160,000	30,000,000	12	210	137,854
SD	177	530	4	1,225	5,020	8	943	13	926	120	44,656	14,630,023	8	148	29,030
Total	250	750	6	1,732	7,100	12	1,333	18	1,310	170	256,847	39,310,023	12	210	234,654

0=Sampled, but none collected.
Fri Feb 15 13:29:27 MST 2002 Raw.losses. IMPINGEMENT; Plant:monroe; PATHNAME:P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/raw.losses.imp.monroe.csv

Table I3-2: Estimates of Annual Impingement (numbers of organisms) at Monroe, 1982 and 1985 (cont.)

Year	Longnose Gar	Mottled Sculpin	Muskel-lunge	Northern Pike	Rainbow Trout	Shiner spp.	Silver Lamprey	Smallmouth Bass	Smelt	Suckers	Sunfish	Tadpole Madtom	Walleye	White Bass	Yellow Perch	Other
1982	140	60	7	86	68	320,012	270	194	2,300	8,278	7,412	580	26,000	530,000	370,000	0
1985	0	0	0	0	0	40,491	0	0	6,221	0	0	0	7,374	567,550	78,246	24,817
Mean	70	30	4	43	34	180,252	135	97	4,260	4,139	3,706	290	16,687	548,775	224,123	12,408
Minimum	0	0	0	0	0	40,491	0	0	2,300	0	0	0	7,374	530,000	78,246	0
Maximum	140	60	7	86	68	320,012	270	194	6,221	8,278	7,412	580	26,000	567,550	370,000	24,817
SD	99	42	5	61	48	197,651	191	137	2,773	5,853	5,241	410	13,171	26,552	206,301	17,548
Total	140	60	7	86	68	360,503	270	194	8,521	8,278	7,412	580	33,374	1,097,550	448,246	24,817

0=Sampled, but none collected.
Fri Feb 15 13:29:27 MST 2002 Raw.losses. IMPINGEMENT; Plant:monroe; PATHNAME:P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/raw.losses.imp.monroe.csv

Table I3-3: Annual Impingement at Monroe Expressed as Numbers of Age 1 Equivalents, 1982 and 1985

Year	Alewife	Blue-gill	Bull-head spp.	Carp	Channel Catfish	Crappie	Fresh-water Drum	Gizzard Shad	Log-perch	Muskel-lunge	Shiner spp.	Small-mouth Bass	Smelt	Suckers	Sun-fish	Wall-eye	White Bass	Yellow Perch
1982	311	894	2,014	7,783	1,718	1,586	184,603	52,388,535	129,361	8	378,718	281	2,770	9,916	12,353	35,303	639,692	436,069
1985	0	0	0	0	0	0	111,739	16,257,949	184,225	0	47,919	0	7,493	0	0	10,013	685,014	92,218
Mean	156	447	1,007	3,891	859	793	148,171	34,323,242	156,793	4	213,319	141	5,132	4,958	6,177	22,658	662,353	264,144
Minimum	0	0	0	0	0	0	111,739	16,257,949	129,361	0	47,919	0	2,770	0	0	10,013	639,692	92,218
Maximum	311	894	2,014	7,783	1,718	1,586	184,603	52,388,535	184,225	8	378,718	281	7,493	9,916	12,353	35,303	685,014	436,069
SD	220	632	1,424	5,503	1,215	1,121	51,523	25,548,182	38,794	5	233,910	199	3,340	7,011	8,735	17,883	32,047	243,139
Total	311	894	2,014	7,783	1,718	1,586	296,342	68,646,484	313,586	8	426,637	281	10,264	9,916	12,353	45,316	1,324,706	528,287

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

0=Sampled, but none collected.

Fri Feb 15 13:35:00 MST 2002 ;Results; I Plant: monroe ; Units: equivalent.sums Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/I.equivalent.sums.monroe.csv

Table I3-4: Annual Impingement of Fishery Species at Monroe Expressed as Yield Lost to Fisheries (in pounds), 1982 and 1985

Year	Bullhead spp.	Carp	Channel Catfish	Crappie	Freshwater Drum	Gizzard Shad	Smallmouth Bass	Smelt	Suckers	Sunfish	Walleye	White Bass	Yellow Perch
1982	44	3,761	54	13	9,806	2,067,893	11	24	123	4	520	48,743	465
1985	0	0	0	0	5,936	641,738	0	64	0	0	148	52,196	98
Mean	22	1,880	27	7	7,871	1,354,816	6	44	62	2	334	50,469	282
Minimum	0	0	0	0	5,936	641,738	0	24	0	0	148	48,743	98
Maximum	44	3,761	54	13	9,806	2,067,893	11	64	123	4	520	52,196	465
SD	31	2,659	38	9	2,737	1,008,444	8	29	87	3	263	2,442	259
Total	44	3,761	54	13	15,742	2,709,631	11	88	123	4	668	100,939	563

0=Sampled, but none collected.

Fri Feb 15 13:35:17 MST 2002 ;Results; I Plant: monroe ; Units: yield Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/I.yield.monroe.csv

Table I3-5: Annual Impingement at Monroe Expressed as Production Foregone (in pounds), 1982 and 1985

Year	Alewife	Blue-gill	Bull-head spp.	Carp	Channel Catfish	Crappie	Fresh-water Drum	Gizzard Shad	Log-perch	Muskel-lunge	Shiner spp.	Small-mouth Bass	Smelt	Suckers	Sun-fish	Wall-eye	White Bass	Yellow Perch
1982	5	11	53	2,426	90	54	17,556	936,779	645	4	4,654	20	31	1,057	21	6,388	59,868	4,761
1985	0	0	0	0	0	0	10,627	290,714	918	0	589	0	85	0	0	1,812	64,109	1,007
Mean	2	5	26	1,213	45	27	14,091	613,747	781	2	2,621	10	58	529	10	4,100	61,988	2,884
Minimum	0	0	0	0	0	0	10,627	290,714	645	0	589	0	31	0	0	1,812	59,868	1,007
Maximum	5	11	53	2,426	90	54	17,556	936,779	918	4	4,654	20	85	1,057	21	6,388	64,109	4,761
SD	3	8	37	1,716	63	38	4,900	456,837	193	3	2,874	14	38	747	15	3,236	2,999	2,655
Total	5	11	53	2,426	90	54	28,183	1,227,494	1,563	4	5,243	20	116	1,057	21	8,199	123,977	5,768

0–Sampled, but none collected.
Fri Feb 15 13:35:09 MST 2002 ;Results; I Plant: monroe ; Units: annual.prod.forg Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/I.annual.prod.forg.monroe.csv

Table I3-6: Estimates of Annual Entrainment (numbers of organisms) at Monroe, 1982

Year	Burbot	Carp	Channel Catfish	Crappie	Freshwater Drum	Gizzard Shad	Logperch	Shiner spp.
1982	2,770,000	79,700,000	4,160,000	580,000	158,000,000	4,080,000,000	2,983,000	30,420,000

Fri Feb 15 13:29:29 MST 2002 Raw.losses. ENTRAINMENT; Plant:monroe;
PATHNAME:P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/raw.losses.ent.monroe.csv

Table I3-6: Estimates of Annual Entrainment (numbers of organisms) at Monroe, 1982 (cont.)

Year	Smallmouth Bass	Smelt	Suckers	Sunfish	Walleye	White Bass	Whitefish	Yellow Perch	Unknown
1982	599,000	11,000,000	6,204,000	923,000	2,080,000	156,000,000	190,000	128,000,000	38,300,000

Fri Feb 15 13:29:29 MST 2002 Raw.losses. ENTRAINMENT; Plant:monroe;
PATHNAME:P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/raw.losses.ent.monroe.csv

Table I3-7: Annual Entrainment at Monroe Expressed as Numbers of Age 1 Equivalents, 1982

Year	Burbot	Carp	Channel Catfish	Crappie	Fresh-water Drum	Gizzard Shad	Log-perch	Shiner spp.	Small-mouth Bass	Smelt	Suckers	Sunfish	Walleye	White Bass	White-fish	Yellow Perch
1982	1,765	394,554	20,594	23,517	143,558	8,747,005	115,373	276,928	48,283	89,543	89,117	311,090	16,749	772,277	81	567,330

Fri Feb 15 13:34:58 MST 2002 ;Results; E Plant: monroe ; Units: equivalent.sums Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/E.equivalent.sums.monroe.csv

Table I3-8: Annual Entrainment of Fishery Species at Monroe Expressed as Yield Lost to Fisheries (in pounds), 1982

Year	Burbot	Carp	Channel Catfish	Crappie	Freshwater Drum	Gizzard Shad	Smallmouth Bass	Smelt	Suckers	Sunfish	Walleye	White Bass	Whitefish	Yellow Perch
1982	206	190,659	643	195	7,626	345,264	1,972	766	1,108	113	247	58,845	73	605

Fri Feb 15 13:35:15 MST 2002 ;Results; E Plant: monroe ; Units: yield Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/E.yield.monroe.csv

Table I3-9: Annual Entrainment at Monroe Expressed as Production Foregone (in pounds), 1982

Year	Burbot	Carp	Channel Catfish	Crappie	Freshwater Drum	Gizzard Shad	Logperch	Shiner spp.	Smallmouth Bass	Smelt	Suckers	Sunfish	Walleye	White Bass	Yellow Perch
1982	<1	578,130	6,789	20,614	101,515	970,508	8,873	83,324	7,469	5,350	95,408	1,645	28,802	1,185,004	354,467

Fri Feb 15 13:35:07 MST 2002 ;Results; E Plant: monroe ; Units: annual.prod.forg Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/E.annual.prod.forg.monroe.csv

Table I3-10: Average Annual Impingement and Entrainment at Monroe (sum of annual means of all species evaluated)

	Impingement	Entrainment
Raw losses (# of organisms)	20,889,043	4,663,609,000
Age 1 equivalents (# of fish)	35,814,243	11,617,765
Fishery yield (lb of fish)	1,415,820	608,321
Production foregone (lb of fish)	702,141	3,447,899

mixed.rollup.chap3.ent Fri Feb 15 14:09:44 MST 2002
P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/flowchart.chap3.ENT.csv
mixed.rollup.chap3.imp Fri Feb 15 14:09:42 MST 2002
P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/flowchart.chap3.IMP.csv

Chapter I4: Economic Value of I&E Losses Based on Benefits Transfer Techniques

CHAPTER CONTENTS

I4-1 Overview of Valuation Approach I4-1
I4-2 Value of Baseline Recreational Fishery Losses at the Monroe Facility I4-3
I4-2.1 Economic Values for Recreational Losses Based on Literature I4-3
I4-2.2 Baseline Losses in Recreational Yield at Monroe and Value of Losses I4-4
I4-3 Value of Baseline Commercial Fishery Losses at the Monroe Facility I4-5
I4-3.1 Baseline Losses in Commercial Yield at Monroe and Value of Losses I4-5
I4-4 Value of Forage Fish Losses at the Monroe Facility I4-7
I4-5 Nonuse Values for Baseline Losses at the Monroe Facility I4-9
I4-6 Summary of Mean Annual Values of Baseline Economic Losses at the Monroe Facility I4-9

This chapter presents the results of EPA's evaluation of the economic losses associated with I&E at the Detroit Edison Monroe Power Plant using benefits transfer techniques. Section I4-1 provides an overview of the valuation approach, Section I4-2 discusses the value of recreational fishery losses, Section I4-3 discusses commercial fishery values, Section I4-4 discusses the value of forage species losses, Section I4-5 discusses nonuse values, and Section I4-6 summarizes the benefits transfer results.

I4-1 OVERVIEW OF VALUATION APPROACH

Fish losses from I&E at Monroe affect recreational and commercial fisheries as well as forage species that contribute to the biomass of recreational and commercial species. EPA evaluated all of these species groups to capture the total economic impact of I&E at Monroe.

Recreational fishery impacts are based on benefits transfer methods, applying the results from nonmarket valuation studies. Commercial fishery impacts are based on commodity prices for the individual species. The economic value of forage species losses is determined by estimating the replacement cost of these fish if they were to be restocked with hatchery fish, and by considering the foregone biomass production of forage fish resulting from I&E losses and the consequential foregone production of commercial and recreational species that use the forage species as a prey base. All of these methods are explained in further detail in the Chapter A9 of Part A of this document.

Many of the fish species impacted by I&E at Monroe are harvested both recreationally and commercially. To avoid double-counting the economic impacts of I&E on these species, EPA determined the proportion of total species landings attributable to recreational and commercial fishing, and applied this proportion to the impacted fishery catch. For example, if 30 percent of the landed numbers of one species are harvested commercially at a site, then 30 percent of the estimated catch of I&E-impacted fish are assigned to the increase in commercial landings. The remaining 70 percent of the estimated total landed number of I&E-impacted adult equivalents are assigned to the recreational landings.

The National Marine Fisheries Service (NMFS) provides both recreational and commercial fishery landings data by state. To determine what proportions of total landings per state occur in the recreational or commercial fishery, EPA summed the landings data for the recreational and commercial fishery, and then divided by each category to get the corresponding percentage. The percentages applied in this analysis are presented in Table I4-1.

As discussed in Chapters A5 and A9 of Part A of this document, the yield estimates presented in Chapter I3 are expressed as total pounds for both the commercial and recreational catch combined. For the economic valuation discussed in this chapter, total yield was partitioned between commercial and recreational fisheries based on the landings in each fishery (presented in Table I4-1). Because the economic evaluation of recreational yield is based on numbers of fish rather than pounds, foregone recreational yield was converted to numbers of fish, based on the average weight of harvestable fish of each species. Table

I4-2 shows these conversions for impingement and Table I4-3 displays these data for entrainment using the data presented in Section I3-4 of Chapter I3. Note that the numbers of foregone recreational fish harvested are typically lower than the numbers of age 1 equivalent losses, since the age of harvest of most fish is greater than age 1.

Table I4-1: Percentages of Total I&E Impacts at Monroe Occurring to Recreational and Commercial Fisheries[a]

Fish Species	Percent Impacts to Recreational Fishery	Percent Impacts to Commercial Fishery
Bluegill	100	0
Bullhead spp.	0	100
Burbot	50	50
Carp	0	100
Channel catfish	50	50
Crappie	100	0
Freshwater drum	0	100
Gizzard shad	0	100
Muskellunge	100	0
Smallmouth bass	100	0
Smelt	50	50
Suckers	0	100
Sunfish	100	0
Walleye	100	0
White bass	50	50
Whitefish	50	50
Yellow perch	100	0

[a] Accurate recreational landings data for Lake Erie have not yet been located, and thus EPA applied a 50/50 split for species that are both commercially and recreationally harvested.
Fri Feb 15 13:45:13 MST 2002 ; TableA:Percentages of total impacts occurring to the commercial and recreational fisheries of selected species; Plant: monroe ; Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/TableA.Perc.of total.impacts.monroe.csv

Table I4-2: Summary of Mean Annual Impingement of Fishery Species at Monroe

Species	Impingement Count (#)	Age 1 Equivalents (#)	Total Catch (#)	Total Yield (lb)	Commercial Catch (#)	Commercial Yield (lb)	Recreational Catch (#)	Recreational Yield (lb)
Bluegill	375	447	1	0	0	0	1	0
Bullhead spp.	866	1,007	50	22	50	22	0	0
Carp	3,550	3,891	288	1,880	288	1,880	0	0
Channel catfish	666	859	32	27	16	13	16	13
Crappie	655	793	12	7	0	0	12	7
Freshwater drum	128,424	148,171	8,614	7,871	8,614	7,871	0	0
Gizzard shad	19,655,012	34,323,242	4,375,502	1,354,816	4,375,502	1,354,816	0	0
Muskellunge	4	4	0	0	0	0	0	0
Smallmouth bass	97	141	10	6	0	0	10	6
Smelt	4,260	5,132	117	44	58	22	58	22
Suckers	4,139	4,958	122	62	122	62	0	0
Sunfish	3,706	6,177	36	2	0	0	36	2
Walleye	16,687	22,658	178	334	0	0	178	334
White bass	548,775	662,353	54,381	50,469	27,190	25,235	27,190	25,235
Yellow perch	224,123	264,144	2,237	282	0	0	2,237	282
Commercial and Recreational Species Total	20,591,339	35,443,976	4,441,580	1,415,820	4,411,841	1,389,920	29,739	25,900

Table I4-3: Summary of Mean Annual Entrainment Results of Fishery Species at Monroe

Species	Entrainment Count (#)	Age 1 Equivalents (#)	Total Catch (#)	Total Yield (lb)	Commercial Catch (#)	Commercial Yield (lb)	Recreational Catch (#)	Recreational Yield (lb)
Burbot	2,770,000	1,765	132	206	66	103	66	52
Carp	79,700,000	394,554	29,161	190,659	29,161	190,659	0	0
Channel catfish	4,160,000	20,594	775	643	387	322	387	161
Crappie	580,000	23,517	347	195	0	0	347	98
Freshwater drum	158,000,000	143,558	8,346	7,626	8,346	7,626	0	0
Gizzard shad	4,080,000,000	8,747,005	1,115,062	345,264	1,115,062	345,264	0	0
Smallmouth bass	599,000	48,283	3,399	1,972	0	0	3,399	986
Smelt	11,000,000	89,543	2,038	766	1,019	383	1,019	192
Suckers	6,204,000	89,117	2,198	1,108	2,198	1,108	0	0
Sunfish	923,000	311,090	1,821	113	0	0	1,821	57
Walleye	2,080,000	16,749	132	247	0	0	132	124
White bass	156,000,000	772,277	63,406	58,845	31,703	29,423	31,703	14,712
Whitefish	190,000	81	50	73	25	36	25	18
Yellow perch	128,000,000	567,330	4,805	605	0	0	4,805	303
Commercial and Recreational Species Total	4,630,206,000	11,225,463	1,231,670	608,321	1,187,966	574,923	43,704	16,704

I4-2 Value of Baseline Recreational Fishery Losses at the Monroe Facility

I4-2.1 Economic Values for Recreational Losses Based on Literature

There is a large literature that provides willingness-to-pay values for increases in recreational catch rates. These increases in value are benefits to the anglers, and are often referred to by economists as a "consumer surplus" per additional fish caught.

When using values from the existing literature as proxies for the value of a trip or fish at a site not studied, it is important to select values for similar areas and species. Table I4-4 gives a summary of several studies that are closest to the Great Lakes fishery in geographic area and relevant species.

McConnell and Strand (1994) estimated fishery values using data from the National Marine Fisheries Statistical Survey. They created a random utility model of fishing behavior for nine Atlantic states, the northernmost being New York. In this model they specified four categories of fish: small gamefish (e.g., striped bass), flatfish (e.g., flounder), bottomfish (e.g., weakfish, spot, Atlantic croaker, perch), and big gamefish (e.g., shark). For each fish category, they estimated per angler values for access to marine waters and for an increase in catch rates.

Boyle et al. (1998) used the 1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation to estimate the marginal economic value of an additional bass, trout, and walleye per trip.

Sorg et al. (1985) used travel cost and contingent valuation methods to estimated the value of recreational fishing at 51 sites in Idaho. Several of the species valued in Sorg et al. are also found in the Great Lakes fishery.

Milliman et al. (1992) used a logit model, creel data, and the responses to a contingent valuation dichotomous choice survey question the study estimated the value of recreational fishing for yellow perch in Green Bay, Michigan.

Table I4-4: Selected Valuation Studies for Estimating Changes in Catch Rates

Authors	Study Location and Year	Item Valued	Value Estimate ($2000)	
McConnell and Strand (1994)	Mid- and south Atlantic coast, anglers targeting specific species, 1988	Catch rate increase of 1 fish per trip[a]	Small gamefish	$10.06
Hicks et al. (1999)	Mid-Atlantic coast, 1994	Catch rate increase of 1 fish per trip	Small gamefish Bottomfish	$2.95 $2.38
Boyle et al. (1998)	National, by state, 1996	Catch rate increase of 1 fish per trip	Bass (low/high)	$1.58 - $5.32
Sorg et al. (1985)	Idaho, 1982	Catch rate increase of 1 fish per trip	Warmwater fish	$5.02
Milliman et al. (1992)	Green Bay	Catch rate increase of 1 fish per trip	Yellow perch	$0.31
Charbonneau and Hay (1978)	National, 1975	Catch rate increase of 1 fish per trip	Walleye Catfish Panfish	$7.92 $2.64 $1.00

[a] Value was reported as "two month value per angler for a half fish catch increase per trip." From 1996 National Survey of Fishing, Hunting and Wildlife-Associated Recreation (U.S. DOI, 1997), the average saltwater angler takes 1.5 trips in a 2 month period. Therefore, to convert to a "1 fish per trip" value, EPA divided the 2 month value by 1.5 trips and then multiplied it by 2, assuming the value of a fish was linear.

Charbonneau and Hay (1978) used travel cost and contingent valuation methods to estimate the consumer surplus for a season of the respondent's favorite wildlife-related activity. These consumer surplus values were then converted to a one fish increase per trip.

I4-2.2 Baseline Losses in Recreational Yield at Monroe and Value of Losses

Since most of these studies discussed in the previous section do not consider the Great Lakes fishery directly, EPA used these estimates to create a range of possible consumer surplus values for the recreational fish landings gained by reducing impingement and entrainment at the Monroe facility. To estimate a unit value for recreational landings, EPA established a lower and upper value for the recreational species, based on values reported in studies in Table I4-4. EPA estimated the economic value of I&E impacts to recreational fisheries using the I&E estimates presented in Tables I4-2 and I4-3 and the economic values in Table I4-5.

EPA used the percentages listed in Table I4-1 to obtain losses to recreational fisheries. Results are displayed in Tables I4-5 and I4-6, for impingement and entrainment, respectively, and are expressed as average annual I&E and corresponding values. The estimated total loss to recreational fisheries ranges from $44,800 to $149,100 for impingement per year, and from $62,800 to $209,100 annually for entrainment.

Table I4-5: Baseline Mean Annual Recreational Impingement Losses at the Monroe Facility and Associated Economic Values

Species	Loss to Recreational Catch from Impingement (number of fish)	Recreational Value/Fish		Loss in Recreational Value from Impingement	
		Low	High	Low	High
Bluegill	1	$0.31	$1.00	$0	$1
Channel catfish	16	$2.64	$5.02	$43	$81
Crappie	12	$1.00	$5.02	$12	$59
Smallmouth bass	10	$1.58	$5.32	$16	$53
Smelt	58	$2.95	$10.06	$172	$588
Sunfish	36	$0.31	$1.00	$11	$36
Walleye	178	$5.02	$7.92	$896	$1,413
White bass	27,190	$1.58	$5.32	$42,961	$144,653
Yellow perch	2,237	$0.31	$1.00	$694	$2,237
Total	29,739			$44,804	$149,121

Fri Feb 15 13:45:23 MST 2002 ; TableB: recreational losses and value for selected species; Plant: monroe ; type: I Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/TableB.rec.losses.monroe.I.csv

Table I4-6: Baseline Mean Annual Recreational Entrainment Losses at the Monroe Facility and Associated Economic Values

Species	Loss to Recreational Catch from Entrainment (number of fish)	Recreational Value/Fish ($2000)		Annual Loss in Recreational Value from Entrainment ($2000)	
		Low	High	Low	High
Burbot	66	$2.95	$10.06	$194	$662
Channel catfish	387	$2.64	$5.02	$1,023	$1,945
Crappie	347	$1.00	$5.02	$347	$1,740
Smallmouth bass	3,399	$1.58	$5.32	$5,370	$18,082
Smelt	1,019	$2.95	$10.06	$3,006	$10,251
Sunfish	1,821	$0.31	$1.00	$564	$1,821
Walleye	132	$5.02	$7.92	$662	$1,045
White bass	31,703	$1.58	$5.32	$50,091	$168,660
Whitefish	25	$1.50	$2.38	$37	$59
Yellow perch	4,805	$0.31	$1.00	$1,490	$4,805
Total	43,704			$62,784	$209,070

Fri Feb 15 13:45:28 MST 2002 ; TableB: recreational losses and value for selected species; Plant: monroe ; type: E Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/TableB.rec.losses.monroe.E.csv

I4-3 Value of Baseline Commercial Fishery Losses at the Monroe Facility

I4-3.1 Baseline Losses in Commercial Yield at Monroe and Value of Losses

I&E losses to commercial catch (pounds) are presented in Tables I4-2 (for impingement) and I4-3 (for entrainment) based on the commercial and recreational splits listed in Table I4-1. Values for commercial fishing are relatively straightforward because commercially caught fish are a commodity with a market price. EPA estimates of the economic value of these losses are displayed in Tables I4-7 and I4-8. Market values per pound are listed as well as the total market losses experienced by the commercial fishery. The estimates of market loss to the commercial fisheries are $229,900 for impingement per year, and $113,400 annually for entrainment.

Table I4-7: Baseline Mean Annual Commercial Impingement Losses at the Monroe Facility and Associated Economic Values

Species	Loss to Commercial Catch from Impingement (lb of fish)	Commercial Value ($/lb of fish)	Annual Loss in Commercial Value from Impingement ($2000)
Bullhead spp.	22	$0.33	$7
Burbot	0	$0.35	$0
Carp	1,880	$0.16	$301
Channel catfish	13	$0.76	$10
Freshwater drum	7,871	$0.21	$1,653
Gizzard shad	1,354,816	$0.15	$203,222
Smelt	22	$0.35	$8
Suckers	62	$0.17	$10
White bass	25,235	$0.98	$24,730
Whitefish	0	$0.82	$0
Total	1,389,920		$229,942

Fri Feb 15 13:45:23 MST 2002 ; TableC: commercial losses and value for selected species; Plant: monroe ; type: I Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/TableC.comm.losses.monroe.I.csv

Table I4-8: Baseline Mean Annual Commercial Entrainment Losses at the Monroe Facility and Associated Economic Values

Species	Loss to Commercial Catch from Entrainment (lb of fish)	Commercial Value ($/lb of fish)	Annual Loss in Commercial Value from Entrainment ($2000)
Burbot	103	$0.35	$36
Carp	190,659	$0.16	$30,505
Channel catfish	322	$0.76	$245
Freshwater drum	7,626	$0.21	$1,601
Gizzard shad	345,264	$0.15	$51,790
Smelt	383	$0.35	$134
Suckers	1,108	$0.17	$188
White bass	29,423	$0.98	$28,834
Whitefish	36	$0.82	$30
Total	574,923		$113,363

Fri Feb 15 13:45:29 MST 2002 ; TableC: commercial losses and value for selected species; Plant: monroe ; type: E Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/TableC.comm.losses.monroe.E.csv

Tables I4-7 and I4-8 express commercial impacts based on changes from dockside market landings only. However, to determine the total economic impact from changes to the commercial fishery, EPA also determined the losses experienced by producers wholesalers, retailers, and consumers.

The total social benefits (economic surplus) are greater than the increase in dockside landings, because the increased landings by commercial fishermen contribute to economic surplus in each of a multi-tiered set of markets for commercial fish. The total economic surplus impact thus is valued by examining the multi-tiered markets through which the landed fish are sold, according to the methods and data detailed in Chapter A9.

The first step of the analysis involves a fishery-based assessment of I&E-related changes in commercial landings (pounds of commercial species as sold dockside by commercial harvesters). The results of this dockside landings value step are described above. The next steps then entail tracking the anticipated additional economic surplus generated as the landed fish pass from dockside transactions to other wholesalers, retailers and, ultimately, consumers. The resulting total economic surplus measures include producer surplus to the watermen who harvest the fish, as well as the rents and consumer surplus that accrue to buyers and sellers in the sequence of market transactions that apply in the commercial fishery context.

To estimate producer surplus from the landings values, EPA relied on empirical results from various researchers that can be used to infer producer surplus for watermen based on gross revenues (landings times wholesale price). The economic literature (Huppert, 1990; Rettig and McCarl, 1985) suggests that producer surplus values for commercial fishing ranges from 50 to 90 percent of the market value. In assessments of Great Lakes fisheries, an estimate of approximately 40% has been derived as the relationship between gross revenues and the surplus of commercial fishermen (Cleland and Bishop, 1984, Bishop, personal communication, 2002). For the purposes of this study, EPA believes producer surplus to watermen is probably in the range of 40% to 70% of dockside landings values.

Producer surplus is one portion of the total economic surplus impacted by increased commercial stocks — the total benefits are comprised of the economic surplus to producers, wholesalers, processors, retailers, and consumers. Primary empirical research deriving "multi-market" welfare measures for commercial fisheries have estimated that surplus accruing to commercial anglers amount to approximately 22% of the total surplus accruing to watermen, retailers and consumers combined (Norton et al., 1983; Holt and Bishop, 2002). Thus, total economic surplus across the relevant commercial fisheries multi-tiered markets can be estimated as approximately 4.5 times greater than producer surplus alone (given that producer surplus is roughly 22% of the total surplus generated). This relationship is applied in the case studies to estimate total surplus from the projected changes in commercial landings.

Applying this method, EPA estimates that baseline economic loss to commercial fisheries ranges from $418,000 to $732,000 per year for impingement, and from $206,000 to $361,000 per year for entrainment at the Monroe facility.

I4-4 Value of Forage Fish Losses at the Monroe Facility

Many species affected by I&E are not commercially or recreationally fished. For the purposes of this study, EPA refers to these species as forage fish. Forage fish are species that are prey for other species, and are important components of aquatic food webs. Table I4-9 summarizes impingement losses of forage species at Monroe and Table I4-10 summarizes entrainment losses. The following sections discuss the economic valuation of these losses using two alternative valuation methods.

Table I4-9: Summary of Mean Annual Impingement of Forage Fish at Monroe

Species	Impingement Count (#)	Age 1 Equivalents (#)	Production Foregone (lb)
Alewife	125	156	2
Logperch	117,327	156,793	781
Shiner spp	180,252	213,319	2,621
Forage species total	297,704	370,267	3,405

Table I4-10: Summary of Mean Annual Entrainment of Forage Fish at Monroe

Species	Entrainment Count (#)	Age 1 Equivalents (#)	Production Foregone (lb)
Alewife	0	0	0
Logperch	2,983,000	115,373	8,873
Shiner spp.	30,420,000	276,928	83,324
Forage species total	33,403,000	392,301	92,197

Replacement cost of fish

The replacement value of fish can be used in several instances. First, if a fish kill of a fishing species is mitigated by stocking of hatchery fish, then losses to the commercial and recreational fisheries would be reduced, but fish replacement costs would still be incurred and should be accounted for. Second, if the fish are not caught in the commercial or recreational fishery, but are important as forage or bait, the replacement value can be used as a lower bound estimate of their value (it is a lower bound because it would not consider how reduction in their stock may affect other species' stocks). Third, where there are not enough data to value losses to the recreational and commercial fisheries, replacement cost can be used as a proxy for lost fishery values. Typically the consumer or producer surplus is greater than fish replacement costs, and replacement costs typically omit problems associated with restocking programs (e.g., limiting genetic diversity).

The cost of replacing forage fish lost to I&E has two main components. The first component is the cost of raising the replacement fish. Table I4-11 displays the replacement costs of two of the forage fish species known to be impinged or entrained at Monroe. The costs are average costs to fish hatcheries (in dollars per pound) across North America to produce different species of fish for stocking. The second component of replacement cost is the transportation cost, which includes costs associated with vehicles, personnel, fuel, water, chemicals, containers, and nets. The AFS (1993) estimates these costs at approximately $1.13 per mile, but does not indicate how many fish (or how many pounds of fish) are transported for this price. Lacking relevant data, EPA does not include the transportation costs in this valuation approach.

Table I4-11 presents the computed values of the annual average forage replacement costs. The value of the losses of forage species using the replacement cost method is $7,000 per year for impingement and $8,000 per year for entrainment.

Table I4-11: Replacement Cost of Various Forage Fish Species at the Monroe Facility[a]

Species	Hatchery Costs ($/lb)	Annual Cost of Replacing Forage Losses ($2000)	
		Impingement	Entrainment
Alewife	$0.52	$1	$0
Logperch	$1.05	$2,104	$1,548
Shiner spp.	$0.91	$5,053	$6,559
Total		$7,158	$8,108

[a] Values are from AFS (1993).
Fri Feb 15 13:45:24 MST 2002 ; TableD: loss in selected forage species; Plant: monroe ; type: I Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/TableD.forage.eco.ter.repl.monroe.I.csv

Production foregone value of forage fish

This approach considers the foregone biomass production of commercial and recreational fishery species fish resulting from I&E losses of forage species based on estimates of trophic transfer efficiency as discussed in Chapter A5 of Part A of this document. The economic valuation of forage losses is based on the dollar value of the foregone fishery yield resulting from the loss of forage.

Table I4-12 displays the results of this method of valuing forage species lost from entrainment. Impingement results were insignificant (as estimated by this method) and thus are not discussed. The values listed are obtained by converting the forage species into species that may be commercially or recreationally valued. The values of entrainment losses range from $822,000 to $1.6 million per year.

Table I4-12: Mean Annual Economic Value of Production Foregone of Selected Fishery Species Resulting from Entrainment of Forage Species at Monroe

Species	Annual Loss in Production Foregone Value from Entrainment of Forage Species ($2000)	
	Low	High
Burbot	$148,564	$444,405
Carp	$13	$23
Channel catfish	$30	$55
Crappie	$2	$12
Freshwater drum	$4	$7
Gizzard shad	$13	$23
Smallmouth bass	$98	$331
Smelt	$83	$273
Suckers	$0	$1
Sunfish	$47	$151
Walleye	$3	$5
White bass	$12	$30
Whitefish	$673,405	$1,133,734
Yellow perch	$1	$2
Total	$822,275	$1,579,051

Fri Feb 15 13:45:29 MST 2002 ; TableD: loss in selected forage species; Plant: monroe ; type: E Pathname: P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/TableD.forage.eco.ter.repl.monroe.E.csv

I4-5 Nonuse Values for Baseline Losses at the Monroe Facility

Recreational consumer surplus and commercial impacts are only part of the total losses that the public realizes from I&E impacts on fisheries. Nonuse or passive use impacts arise when individuals value environmental changes apart from any past, present, or anticipated future use of the resource in question. Such passive use values have been categorized in several ways in the economic literature, typically embracing the concepts of existence (stewardship) and bequest (intergenerational equity) motives. Using a "rule of thumb" that nonuse impacts are at least equivalent to 50 percent of the recreational use impact (see Chapter A9 of Part A of this document for further discussion), EPA estimated nonuse values for baseline losses at Monroe to range from $22,000 to $75,000 per year for impingement and from $31,000 to $105,000 per year for entrainment.

I4-6 Summary of Mean Annual Values of Baseline Economic Losses at the Monroe Facility

Table I4-13 summarizes the estimated annual baseline losses from I&E at the Monroe facility. Total impacts range from $492,400 to $962,500 per year for impingement and from $308,400 to $2,253,400 per year for entrainment.

Table I4-13: Summary of Valuation of Baseline Mean Annual I&E at Monroe Facility ($2000)

		Impingement	Entrainment	Total
Commercial: Total Surplus (Direct Use, Market)	Low	$418,076	$206,115	$624,191
	High	$731,632	$360,702	$1,092,334
Recreational (Direct Use, Nonmarket)	Low	$44,804	$62,784	$107,588
	High	$149,121	$209,070	$358,191
Nonuse (Passive Use, Nonmarket)	Low	$22,402	$31,392	$53,794
	High	$74,560	$104,535	$179,095
Forage (Indirect Use, Nonmarket)				
Production Foregone	Low	NA	$822,275	$822,275
	High	NA	$1,579,051	$1,579,051
Replacement		$7,158	$8,108	$15,266
Total (Com + Rec + Nonuse + Forage)[a]	Low	$492,440	$308,399	$800,839
	High	$962,471	$2,253,358	$3,215,829

NA = Results were not significant and thus are not reported.
[a] In calculating the total low values for entrainment, the lower of the two forage valuation methods (production foregone and replacement) was used and to calculate the total high values, the higher of the two forage valuation methods was used. For impingement, only the replacement value results are used.
Fri Feb 15 13:45:31 MST 2002 ; TableE.summary; Plant: monroe ; Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/monroe/tables.output/TableE.summary.monroe.csv

Chapter I5: Streamlined HRC Valuation of I&E Losses at the Monroe Facility

This chapter presents the results of EPA's streamlined habitat-based replacement cost (HRC) valuation of I&E losses at the Monroe facility in Monroe, Michigan, for a baseline scenario based on I&E data for the years 1982 and 1985.

CHAPTER CONTENTS

I5-1 Quantify I&E Losses by Species (Step 1) I5-2
I5-2 Identify Species Habitat Requirements (Step 2), Identify Habitat Restoration Alternatives (Step 3), and Prioritize Restoration Alternatives I5-3
I5-3 Quantify the Benefits for the Prioritized Habitat Restoration Alternatives (Step 5) I5-3
I5-4 Scale the Habitat Restoration Alternatives to Offset I&E Losses (Step 6) I5-5
I5-5 Estimate "Unit Costs" for the Habitat Restoration Alternatives (Step 7) I5-7
I5-6 Develop Total Cost Estimates for I&E Losses (Step 8) I5-8
I5-7 Strengths and Weaknesses of the Streamlined HRC Analysis I5-9

A description of the HRC method and the process for undertaking a complete HRC valuation of I&E losses is provided in Chapter A11 of Part A of this document. To summarize, a complete HRC valuation of I&E losses reflects the combined costs for implementing habitat restoration actions, administering the programs, and monitoring the increased production after the restoration actions. In a complete HRC valuation, these costs are developed by first identifying the preferred habitat restoration alternative for each species with I&E losses and then scaling the level of habitat restoration until the losses across all the species for that restoration alternative have been exactly offset by the expected increases in production of each species. The total value of the I&E losses at the facility is then calculated as the sum of the costs across the set of preferred habitat restoration alternatives that were identified.

The HRC method is thus a supply-side approach for valuing I&E losses in contrast to the more typically used demand-side valuation approaches (e.g., commercial and recreational fishing impacts valuations). An advantage of the HRC method is that the HRC values address losses for species lacking a recreational or commercial fishery (e.g., forage species). Further, the HRC explicitly recognizes and captures the fundamental ecological relationships between species with I&E losses at a facility and their surrounding environment by determining the value of I&E losses through the cost of the actions required to provide an offsetting increase in the existing populations of those species in their natural environment.

Streamlining was necessary to meet the schedule of the 316(b) existing sources rule and entailed combining Step 2 (identification of species habitat requirements), Step 3 (identification of habitat restoration alternatives), and Step 4 (consolidation and prioritization of habitat restoration alternatives), restricting the analysis to readily available information, and eliminating site visits, in-depth discussions with local experts, and development of primary data (see Chapter A11 of Part A of this document), which would be required before doing an actual restoration. Despite these restrictions, the streamlined HRC provided a more comprehensive, ecological-based valuation of the I&E losses than valuation by traditional commercial and recreational impacts methods. In addition, the streamlined HRC valued direct, indirect, and passive uses not included in more traditional economic valuation techniques used in Chapters I4 and I6.

The calculated range in annualized costs, expressed in 2000 dollars, of restoring sufficient fish production habitat to offset the I&E losses in perpetuity at the Monroe facility for the baseline scenario is $1.1 - $14.4 million.

The following subsections describe the streamlined HRC valuation applied to the Monroe facility and the advantages and disadvantages of streamlining the HRC method.

I5-1 Quantify I&E Losses by Species (Step 1)

The streamlined HRC method relies on the same estimates of annual age 1 equivalent species losses that are developed in Chapter I3 from data reported directly by the facility and incorporated in the commercial and recreational fishing impacts valuation presented in Chapter I4. Total I&E losses at the facility may be underestimated, particularly if certain species were not targeted by monitoring efforts or if short duration population spikes occurred outside of monitoring events. The HRC method inherently reduces the former problem by targeting restoration activities that might benefit species lost but not monitored, but like all other measures of I&E losses, it relies on representative monitoring.

Various life stages of organisms were lost to I&E at the Monroe facility. As with other facilities, primarily early stages such as eggs and larvae are entrained, and primarily juveniles and adults are impinged. However, EPA estimated total losses for each species by converting all losses to a common equivalent life stage by applying average mortality rates between life stages for each species. These mortality rates were derived from the literature and best professional judgment. Conversion between life stages did not change the overall scale of required restoration in the streamlined HRC method because many eggs are equivalent to few adults on both the I&E loss and increased production sides of the HRC equation. For example, if on average one adult survives from 10 eggs via a 90% cumulative mortality rate and 1 acre of habitat produces 10 eggs, then restoration of 1 acre is needed to produce either one adult or 10 eggs.

Age 1 equivalent I&E losses of 20 species of fish were calculated using the available I&E monitoring data available from the Monroe facility. A summary of average annual age 1 equivalent losses from the available data is presented in Table I5-1.

Table I5-1: Average Annual I&E Losses of Age 1 Equivalent Fish at the Monroe Facility

Species	Baseline Scenario: (1982 and 1985)		
	Impinged	**Entrained**	**Total**
Gizzard shad	34,323,242	8,747,005	43,070,247
White bass	662,353	772,277	1,434,630
Yellow perch	264,144	567,330	831,474
Shiner spp.	213,319	276,928	490,247
Carp	3,891	394,554	398,445
Sunfish spp.	6,177	311,090	317,267
Freshwater drum	148,171	143,558	291,729
Logperch	156,793	115,373	272,166
Smelt	5,132	89,543	94,675
Suckers	4,958	89,117	94,075
Smallmouth bass	141	48,283	48,424
Walleye	22,658	16,749	39,407
Crappie spp.	793	23,517	24,310
Channel catfish	859	20,594	21,453
Burbot	0	1,765	1,765
Bullhead spp.	1,007	0	1,007
Bluegill	447	0	447
Alewife	156	0	156
Whitefish	0	81	81
Muskellunge	4	0	4
Total	**35,814,245**	**11,617,764**	**47,432,009**

Several species impinged or entrained at the Monroe facility are important to commercial or recreational fishing, including walleye, yellow perch, catfish, and crappie. Many others, including alewife, smelt, and shiners, indirectly affect commerce and recreation because they are prey for commercially or recreationally important aquatic and terrestrial wildlife species such as salmon and northern pike, bald eagles, and mink. Furthermore, all of the species provide numerous, complex, ecological services as sources of carbon and energy transfer through the food web, as well as continuous interactive exploitation of niches available in the Great Lakes ecosystem (a system already under tremendous stress from exotic species introductions, hazardous substance contamination, nonpoint source runoff, heat contamination, habitat loss, overfishing, and I&E) from multiple sources.

For example, freshwater drum feed on a variety of small fish. When food supplies are short, freshwater drum often out-compete other species and thereby may increase mortality rates or decrease growth rates for those species (Edsall, 1967). In addition, several species of Centrarchids, including the crappie, are sensitive to the size of their predators' population. When predators such as walleye are absent, species such as crappie can overcrowd their habitats and exhaust their own food supplies, resulting in stunted growth (Wang, 1986a; Steiner, 2000). Finally, some species are already subject to wide fluctuations in population size from year to year, and may not be able to tolerate I&E losses, particularly at certain times of the year. For example, the gizzard shad is often subject to high mortality in the winter (Miller, 1960).

I5-2 Identify Species Habitat Requirements (Step 2), Identify Habitat Restoration Alternatives (Step 3), and Prioritize Restoration Alternatives (Step 4)

EPA combined steps 2, 3, and 4 of the HRC method by seeking a single habitat restoration program capable of increasing production for most of the species with quantified I&E losses at the Monroe facility. Addressing each of these steps separately for each of the I&E species would improve the analysis but would require more time than was available for the analysis for the proposed rule.

The selection of coastal wetland restoration as the preferred restoration alternative for offsetting the I&E losses at the Monroe facility builds of the work conducted in the streamlined HRC valuation of the I&E losses at the nearby J.R. Whiting facility. This decision is viewed as appropriate recognizing the relative proximity of the Monroe and J.R. Whiting facilities, the existence of coastal wetland preservation and restoration programs in many Great Lakes states, and the prior knowledge that many of the fish species with quantified age 1 equivalent I&E losses at the Monroe facility have readily available information describing their abundance in Great Lakes' coastal wetlands which can be used as a proxy for increased production benefit estimates.

I5-3 Quantify the Benefits for the Prioritized Habitat Restoration Alternatives (Step 5)

A literature search revealed a study (Brazner, 1997) that provides fish capture data by species from sampling efforts conducted at a series of Green Bay (Lake Michigan) coastal wetland and sand beach sites. No other studies provide more direct measures of increased fish species production following Great Lakes coastal wetland restoration, or fish capture data in wetlands closer to the Monroe facility. However, the Brazner study sampled wetlands in the warmer, shallower, more eutrophic waters of southern Green Bay, which are similar to the waters of western Lake Erie. After examining the data from the Brazner study and discussing them with the author, EPA dropped less similar sites from northern Green Bay. For almost all of the species with quantified I&E losses at the Monroe facility, a match was found with a species, or combination of species, among those captured at the southern sites in the Brazner study. Table I5-2 shows the species caught in the Brazner study that were paired with the species being lost at the Monroe facility (this represents only a fraction of the species caught in these southern locations in the Brazner study).

Because of the similarity between the physical habitats of southern Green Bay and western Lake Erie and the confirmed presence of similar species in both locations, EPA estimated densities for each southern Green Bay species and used them as a proxy for direct measurements of potential increased production following wetland restoration. This approach assumed that additional wetland habitat restored near the Monroe facility would provide similar densities of each species as the wetland habitats sampled in Green Bay. Direct measurements of densities of each species before and after actual wetland habitat restorations in western lake Erie could test this assumption and improve the reliability of the HRC valuation for the Monroe facility.

Table I5-2: Species with I&E Loss Estimates at the Monroe Facility and the Corresponding Species Captured in Green Bay Wetland Sampling

Species with I&E Loss Estimates at the Monroe Facility	Corresponding Species Caught in Sampling of Green Bay Coastal Wetlands (Brazner, 1997)
Alewife	Yes
Bluegill	Yes
Bullhead spp.	Yes (as sum of black, brown, and yellow bullhead)
Burbot	No
Carp	Yes
Channel catfish	Yes
Crappie spp.	Yes (as black crappie)
Freshwater drum	Yes
Gizzard shad	Yes
Logperch	Yes
Muskellunge	Yes
Shiner spp.	Yes (as sum of common, emerald, golden, spotfin, and spottail shiner)
Smallmouth bass	Yes
Smelt	Yes (as rainbow smelt)
Suckers spp.	Yes (as white sucker)
Sunfish	Yes (as green sunfish)
Walleye	Yes
White bass	Yes
Whitefish	No
Yellow perch	Yes

EPA developed the density estimates for each species for each site using aggregate sampling results provided by the author (J. Brazner, U.S. EPA, Duluth Lab, personal communication, 2001). Table I5-3 provides a summary of the Green Bay capture data (J. Brazner, U.S. EPA, Duluth Lab, personal communication, 2001) for each species that has quantified I&E losses at the Monroe facility for which a matching species or groups of species was available. Data for each of four Green Bay sites are presented, as are the average and maximum of all four sites.

The raw capture data were converted to density estimates for each species by assuming that each sampling event of 100 m of linear coastal wetland frontage corresponded to an average of 100 m of perpendicular width of connected coastal wetlands (i.e., each sampling event included fish from an assumed 100 m x 100 m area of wetlands). This assumption is based on discussions with the author about the likely perpendicular width of the sampled wetlands that was being used as habitat by the sampled species (J. Brazner, U.S. EPA, personal communication, 2001). A further adjustment was then made to the raw capture data to recognize the fact that shoreline sampling would capture only a portion of the fish actually using the 100 m x 100 m wetland habitat. After discussions with the author, the capture data were increased by a factor of 100 (1/0.01), based on the assumption that only 1% of the fish present or relying on the wetland habitat were captured in the sampling event.

The resulting per acre average density estimates for each species was used in the HRC equation as the measure of increased production that would most likely be provided by wetland habitat restoration near the Monroe facility. The maximum per acre density estimate for each species was used as an upper bound estimate of fish density that would result from wetland restoration near the Monroe facility.

Brazner (1997) captured young-of-year (younger than age 1), age 1 fish, and adult fish (older than age 1) in the Green Bay wetlands. In this evaluation, the capture data were treated as if it represented age 1 fish, which eliminated the need to apply mortality rates to adjust for survival between life stages for each species, as was done for I&E losses. Since Brazner (1997) reports a high percentage of young-of-year fish captured at all Green Bay sites, this assumption most likely results in a slight overestimation of age 1 fish densities, and therefore potentially underestimates the scale of restoration required to offset the average annual I&E loss for each species (i.e., it underestimates baseline losses from I&E).

Table I5-3: Green Bay Wetland Abundance Data

Species Name for HRC Analysis	Number Captured: Lower Green Bay Wetland Locations[a]				Summary Statistics	
	Long Tail Point Wetland	Little Tail Point Wetland	Atkinson Marsh	Sensiba Wildlife Refuge	Average	Maximum
Yellow perch	3,525	942	333	1,108	1,477	3,525
Shiner spp.[b]	1,202	499	526	769	749	1,202
Gizzard shad	384	264	160	137	236	384
Alewife	265	142	92	124	156	265
White bass	52	226	106	9	98	226
Sucker spp.[c]	14	10	1	103	32	103
Carp	19	10	3	1	8	19
Sunfish[d]	3	5	22	2	8	22
Bluegill	18	3	0	6	7	18
Freshwater drum	4	4	7	1	4	7
Bullhead spp.[e]	9	4	0	2	4	9
Crappie spp.[f]	1	2	1	1	1	2
Channel catfish	0	0	3	0	1	3
Muskellunge	2	0	0	0	1	2
Smallmouth bass	0	0	0	2	1	2
Logperch	0	0	0	1	0	1
Smelt.[g]	0	1	0	0	0	1
Walleye	1	0	0	0	0	1
Burbot	not captured in Green Bay wetlands				n/a	n/a
Whitefish	not captured in Green Bay wetlands				n/a	n/a

[a] Number captured in samples of 100 meters linear coastal wetland frontage. Reflects age 1 fish (not eggs and larvae).
[b] Shiner spp. values are the sum of the common, emerald, golden, spotfin, and spottail shiner values at each location.
[c] Sucker spp. values are those reported for white sucker.
[d] Sunfish values are those reported for green sunfish.
[e] Bullhead spp. values are the sum of the black, brown, and yellow bullhead values at each location.
[f] Crappie spp. values are those reported for black crappie.
[g] Smelt values are those reported for rainbow smelt.

I5-4 Scale the Habitat Restoration Alternatives to Offset I&E Losses (Step 6)

EPA calculated the amount of Great Lakes coastal wetland restoration required to offset I&E losses for each species at the Monroe facility by dividing the combined average annual I&E loss for each species in the baseline scenario by its per-acre estimate of increased production of age 1 equivalents. The results of this scaling are presented in Table I5-4.

Whether using average or maximum production values, over half of the species listed in Table I5-4 would require that hundreds or thousands of acres of wetland habitat be restored to fully offset the I&E losses caused by the Monroe facility's CWIS. If Great Lakes coastal wetland restoration is the best natural restoration alternative for offsetting losses for each of these species, then approximately 26,900 acres of coastal wetland restoration is required to fully offset all I&E losses under the baseline scenario using the average adjusted per acre density estimates (because restoring logperch would require that much wetland restoration, and all other species would be fully restored as well). However, without further discussions with local experts, and perhaps additional investigation of the relationship between feasible restoration activities and per-acre production benefits (particularly for the species driving the highest acreage needs), these assumptions may not be valid. On the other hand, the benefit of any given restoration program should always vary among species, and species with relatively high productivity or low I&E losses cannot drive the HRC results without sacrificing necessary offsets for other species with lower productivity or higher I&E losses. As seen in the results in Table I5-4, a large restoration requirement can reflect either low productivity of the restored habitat for the species (e.g., logperch and smelt) or very large I&E losses (e.g., gizzard shad).

Table I5-4: Wetland Restoration Required to Offset Combined I&E Losses at the Monroe CWIS

Species	Average Annual Age 1 Equivalents Lost to I&E	Per-Unit Production Benefit (age 1 fish per restored coastal wetland acre)		Required Acres of Wetland Restoration to Offset I&E Loss (rounded to nearest acre)	
		Average Value	Maximum Value Across Sites	Based on Average Production Value	Based on Maximum Production Value
Logperch	272,166	10	40	26,901	6,725
Smelt	94,675	10	40	9,358	2,339
Gizzard shad	43,070,247	9,561	15,540	4,505	2,771
Walleye	39,407	10	40	3,895	974
Smallmouth bass	48,424	20	81	2,393	598
Freshwater drum	291,729	162	283	1,802	1,030
Carp	398,445	334	769	1,193	518
Sunfish	317,267	324	890	980	356
Channel catfish	21,453	30	121	707	177
Crappie spp.	24,310	51	81	481	300
White bass	1,434,630	3,976	9,146	361	157
Suckers spp.	94,075	1,295	4,168	73	23
Shiner spp.	490,247	30,312	48,645	16	10
Yellow perch	831,474	59,774	142,657	14	6
Bullhead spp.	1,007	152	364	7	3
Bluegill	447	273	728	2	1
Muskellunge[a]	4	20	81	0	0
Alewife[b]	156	6,303	10,725	0	0
Burbot	1,765	n/a			
Whitefish	81	n/a			

[a] The exact requirement for restored wetland acreage for muskellunge is 0.20 acres under the average production value estimate and 0.05 acres under the maximum production value estimate. Both values are rounded to 0 acres for presentation.
[a] The exact requirement for restored wetland acreage for alewife is 0.02 acres under the average production value estimate and 0.01 acres under the maximum production value estimate. Both values are rounded to 0 acres for presentation.

Table I5-4 also shows that both the scale and distribution of the estimates of required wetland restoration change when maximum species density estimates are substituted for the averages. EPA used average species density estimates as the primary source of information because they are more representative of wetland productivity in the Brazner study, and more accurately reflect the difficulties of achieving full function in restored versus native habitats.[1]

Since a rigorous investigation of the relationship between feasible restoration alternatives and per-unit production estimates was not completed under the streamlined approach, using the highest restoration requirement (for logperch) may not be justified. Therefore, the restoration requirements were ordered for all of the species so that percentiles could be calculated. Using the 100th percentile (logperch) would offset losses for all of the species, as appropriate under a complete HRC analysis. However, the 90th and 50th percentiles (corresponding to smelt and channel catfish, respectively) were used to bound the estimate of the required scale of restoration. Using a lower percentile than the 100th recognizes that further analyses (or monitoring) might identify restoration programs more efficient and less costly than wetland restoration for species with the highest wetland restoration needs, or might produce better and higher wetland restoration productivity estimates (lower cost) for those same species. Nevertheless, using lower percentiles risks underestimating the costs of needed restoration because most species benefit from wetland restoration, and wetland restoration could easily prove to be the best alternative for those species with the greatest wetland restoration needs. Further, improved analysis and monitoring are as

[1] The maximum species-density-based estimates are included only as a sensitivity analysis and reflect a minimal scale of restoration that would be required if Lake Erie wetland restorations were much more highly successful then EPA anticipates. Detailed, repeated monitoring of I&E species in areas where restoration has occurred will increase the accuracy of future analyses.

likely to lower productivity estimates as they are to raise them. Therefore, percentiles less than the 50th were rejected as unreasonable.[2]

Table I5-5 presents the 90th and 50th percentile results from the distribution of required Great Lakes coastal wetland restoration calculated using the average species density estimates as a proxy for increased species production for the baseline scenario and combined average annual I&E losses of age 1 equivalent fish. Table I5-5 also presents the results using the maximum species density estimates as a sensitivity analysis.

Table I5-5: Acres of Coastal Wetland Restoration Required under Different I&E Scenarios with Alternative Increased Production Benefits Assumptions

I&E Scenario	Acres of Required Wetland Restoration with Average Species-Specific Density Estimates (preferred alternative)		Acres of Required Wetland Restoration with Maximum Species-Specific Density Estimates (sensitivity test)	
	90th Percentile Result	50th Percentile Result	90th Percentile Result	50th Percentile Result
Baseline	9,358	707	2,771	300

I5-5 Estimate "Unit Costs" for the Habitat Restoration Alternatives (Step 7)

EPA calculated annualized per-acre costs for restoring coastal wetlands in a Great Lakes ecosystem from the information in the Restoration and Compensation Determination Plan (RCDP) produced for the Lower Fox River/Green Bay Natural Resource Damage Assessment (U.S. Fish and Wildlife Service and Stratus Consulting, 2000), which incorporated a similar program of Great Lakes wetland restoration as a restoration alternative. The RCDP's per-acre cost included expenses for the restoration implementation (fieldwork), project administration, maintenance, and monitoring.

The RCDP's wetland restoration program focused on acquiring lands around Green Bay that are currently in agricultural use and that are located on hydric soils (an indicator of a wetland area). These former wetlands were generally brought into agricultural production through the draining or tiling of the land. Therefore, most of the expense (63%) in the RCDP's per-acre cost estimates was for land acquisition and restoration actions necessary to re-establish functioning wetlands. Maintenance costs (9%) consisted of expenses for periodic mowing and burning to maintain the dominance of wetland vegetation. The remaining expenditures (28%) covered anticipated administrative expenses for the program. The per-acre cost estimates for the various components of the wetland restoration program as presented in the Lower Fox River/Green Bay RCDP are provided in Table I5-6 along with the equivalent annualized per-acre cost that is used to value the required scale of wetland restoration in this streamlined HRC (the development of this annualized value is discussed in the following paragraph).

In annualizing the RCDP's unit costs for this streamlined HRC, EPA made a distinction between expected initial one-time program outlays (expenditures for land, transaction costs, restoration actions, contingency, and agency overhead) and anticipated recurring annual expenses (project maintenance and monitoring). Those costs that were viewed as initial program outlays were treated as a capital cost and annualized over a 20-year period at a 7% interest rate providing an annualized value of $882 from their initial combined value of $9,360. EPA then estimated the present value (PV), using a 7% interest rate, of the recurring annual expenses for 10 years as this is the length of time incorporated for monitoring in the complete HRC valuations conducted for the Brayton Point and Pilgrim facility case studies. This PV for the recurring annual expenses was then annualized over a 20 year period, again using a 7% interest rate resulting in an annualized expense of $658. This process effectively treats the monitoring expenses associated with the wetland restoration consistently with the annual operating and maintenance costs presented in the costing, economic impact, and cost-benefit analysis chapters. The annualized recurring expenses were then added to the annualized initial program outlays resulting in a total annualized cost for the wetlands restoration alternative of $1,540 per acre.

[2] For instance, using the 25th percentile restoration requirement from Table I5-4 (14 acres for yellow perch) would be valid only if further analysis produced superior (cheaper or more productive) restoration alternatives, or superior wetland productivity estimates that were higher for most of the species, including logperch, smelt, gizzard shad, walleye, smallmouth bass, freshwater drum, carp, sunfish, channel catfish, crappie, white bass, suckers, and shiner spp. Even the 50th percentile value that we use as a lower bound estimate assumes that eight of these species could each be produced more effectively with different restoration alternatives, or that wetland productivity is actually higher for all eight species.

Table I5-6: Wetland Restoration Costs (2000 dollars)

Restoration Program Component	$/Acre	Cost Method
Land acquisition	3,000	Survey of land prices
Land transaction costs	600	20% of land price, reflects agency (U.S. FWS) experience
Restoration action	2,600	Project experience (See Table Source)
Contingency on restoration action	260	10% of restoration actions, consistent with standard practice
Project maintenance	590	Project experience (See Table Source)
Monitoring	340	5% of total of land acquisition, land transaction, restoration action, and maintenance
Agency (landowner) overhead (project administration)	2,900	38.84% of sum of all other cost, reflects agency (U.S. FWS) experience
Total Cost	10,300	
Total Annualized Cost	**1,540**	

Source: U.S. Fish and Wildlife Service and Stratus Consulting, 2000.

However, these unit costs probably understate the cost of monitoring that would be sufficient to measure per-unit production benefits in restored wetlands, which could then improve future HRC calculations. In the RCDP's wetland restoration monitoring program, the emphasis was on evaluating whether the hydrology of the former wetlands and the associated vegetation were returning over time, activities that could be achieved with relatively minimal effort. In contrast, a monitoring program capable of addressing whether anticipated increases in the production of certain species were being achieved in the restored wetland areas would require a far more significant commitment of time and resources, resulting in commensurately larger expenditures.

I5-6 Develop Total Cost Estimates for I&E Losses (Step 8)

EPA estimated the total annualized cost to offset the average annual I&E losses at the Monroe facility by multiplying the 50th percentile and 90th percentile results of the required acreage of wetland restoration (see Table I5-5) by the annualized per-acre wetlands restoration costs from the RCDP (see Table I5-6). These results are presented in Table I5-7.

Table I5-7: Total Annualized Costs for a Wetland Restoration Program to Offset I&E Losses (millions of 2000 dollars)

I&E Scenario	Cost of Required Wetland Restoration with Average Species-Specific Density Estimates (preferred results)		Cost of Required Wetland Restoration with Maximum Species-Specific Density Estimates (sensitivity test)	
	90th Percentile Result	50th Percentile Result	90th Percentile Result	50th Percentile Result
Baseline	$14.4	$1.1	$4.3	$0.5

The results of the streamlined HRC provide an annualized present value estimate of roughly $14.4 million for a program of Great Lakes coastal wetland restoration that would offset the average annual age 1 equivalent losses from the baseline period in perpetuity using the 90th percentile results and average species density estimates. Incorporating the maximum observed species density from any of the sampled wetlands in Green Bay reduces the value of the 90th percentile scenario results to between one-third and one-fourth the average species density results.

Table I5-8 shows the results of the streamlined HRC analysis for impingement losses, entrainment losses, and total I&E losses separately.

Table I5-8: Annualized Results for the Monetization of I&E Losses at the Monroe Facility Incorporating Average Species-Specific Density Estimates (millions of 2000 dollars)

I&E Scenario	Component of I&E Loss	Annualized Value	
		90th Percentile	50th Percentile
Baseline	Impingement	$5.5	$0.0[a]
	Entrainment	$13.6	$1.4
	I&E total[b]	$14.4	$1.1

[a] The exact value of $24,141 is rounded to $0.0 when rounded to millions of dollars for presentation.
[b] The total is not equal to the sum of the results from the I&E components because of different numbers of species in these components as well as different rankings of the species based on the extent of required restoration in these components.

I5-7 Strengths and Weaknesses of the Streamlined HRC Analysis

The fundamental appeal of the HRC is its ability to incorporate and value environmental losses that are either undervalued or ignored by traditional valuation approaches, such as recreational and commercial fishing valuation (see Chapter A11 in Part A of this document for additional discussion). The primary advantage of the streamlined HRC is the limited effort and time required to provide regulators with an initial assessment of whether a complete HRC is justified. For facilities like Monroe with relatively large I&E impacts and I&E impacts to many species not targeted by anglers, a complete HRC is likely to be worthwhile, even given budgetary and time constraints associated with permit re-issuance cycles. In addition, the streamlined HRC provides regulators with a framework to evaluate mitigation proposals put forth by industry to address residual I&E losses associated with the permitted BTA.

The primary weakness of the streamlined HRC is the uncertainty resulting from limited opportunities to access local resource experts and unpublished primary data in the selection of a preferred restoration alternative, the development of per-unit production benefits for each species, and the estimation of restoration unit costs.

For these reasons, streamlining an HRC may be most appropriate when:

- a limited number of species experience I&E losses or the majority of I&E losses are realized by a small number of species
- the regulator is familiar with, or can quickly determine, the preferred restoration alternative for these critical species
- benefits information from evaluations of local habitats is available, and extrapolations do not lead to extreme variability
- published sources of information allow estimation of all important aspects of the restoration costs.

If these conditions are absent, a complete HRC analysis will provide a more comprehensive estimate of the losses associated with I&E than provided by traditional valuations.

In conclusion, the streamlined HRC method provides regulators, industry, and the public with an important method to quickly estimate the likely value of I&E losses at § 316(b)-regulated facilities. Further, because regulators and local experts can often quickly assess whether appropriate and necessary information exists for the valuation of I&E resources, streamlining may offer many opportunities to broaden the evaluation of I&E to include ecological and related public services, even when facing significant time and budgetary constraints.

Chapter I6: Benefits Analysis for the Monroe Facility

This chapter presents the results of EPA's evaluation of the economic benefits associated with reductions in estimated current I&E at the Monroe facility. The economic benefits reported here are based on the values presented in Chapters I4 and I5, and EPA's estimates of I&E at the facility (see Chapter I3). Section I6-1 presents a summary of I&E losses and associated monetized losses. Section I6-2 presents estimated economic benefits of reduced I&E, and Section I6-3 discusses the uncertainties in the analysis.

CHAPTER CONTENTS

I6-1 Overview of I&E and Associated Losses I6-1
I6-2 Potential Economic Benefits due to Regulations ... I6-1
I6-3 Summary of Omissions, Biases, and Uncertainties in the Benefits Analysis I6-5

I6-1 Overview of I&E and Associated Economic Values

The flowchart in Figure I6-1 summarizes how the economic values of I&E losses at Monroe were derived from the I&E estimates in Chapter I3. Figures I6-2 and I6-3 indicate the distribution of I&E losses by species category and associated economic values. These diagrams reflect baseline losses based on current technology. All dollar values and percentages of losses reflect midpoints of the ranges for the categories of commercial, recreational, nonuse, and forage values.

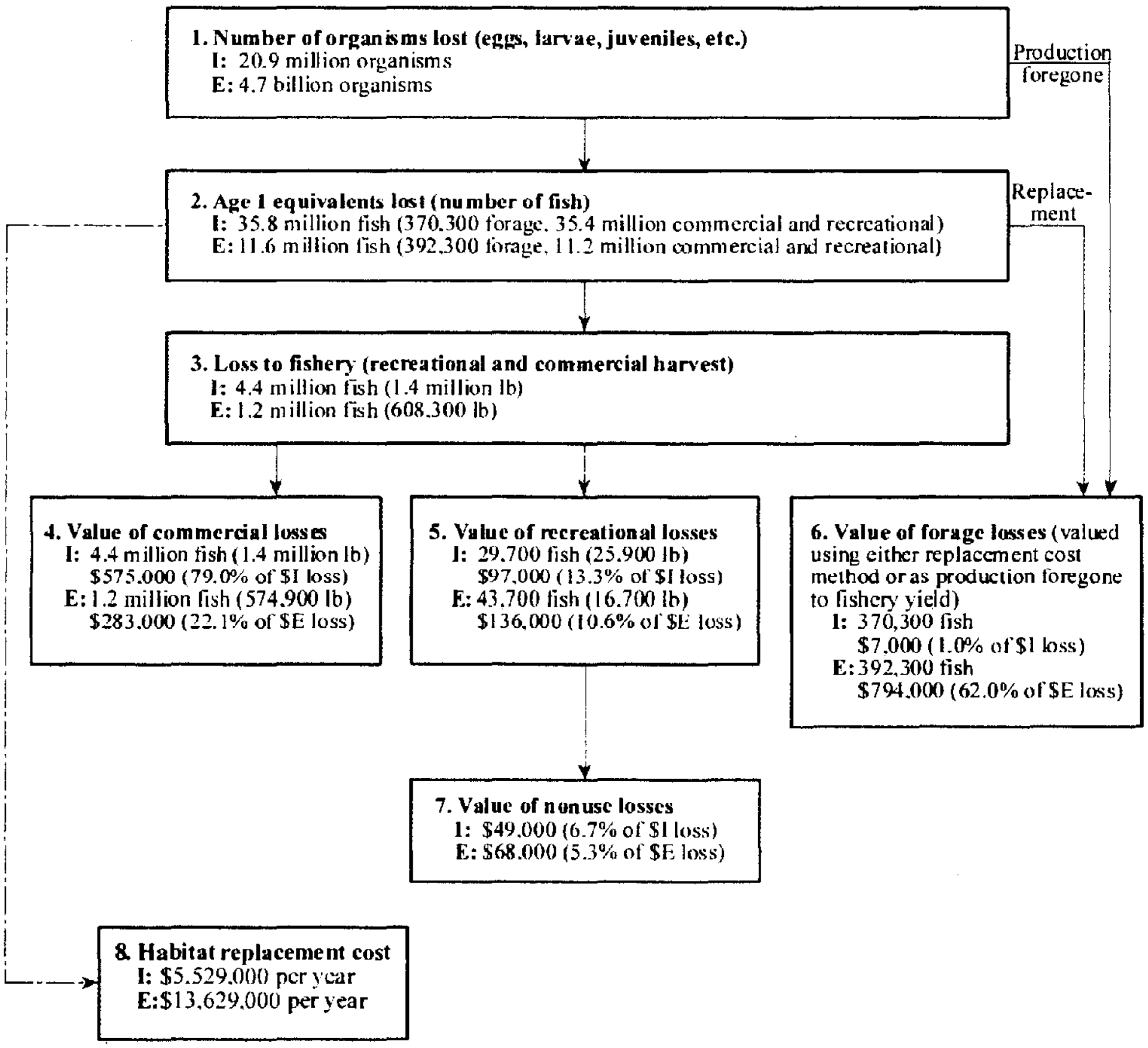
Baseline economic losses due to I&E at Monroe were calculated in Chapters I4 and I5. In Chapter I4, total economic loss was estimated using a benefits transfer approach to estimate the commercial, recreational, forage, and nonuse values of fish lost to I&E. This is a demand-driven approach, i.e., it focuses on the values that people place on fish. In Chapter I5, total economic loss was estimated by calculating the cost to increase fish populations using habitat restoration techniques (HRC approach). This is a supply-driven approach, i.e., it focuses on the costs associated with producing fish in natural habitats.

The total annual economic losses associated with each method are summarized in Table I6-1. These values range from $727,000 to $5,529,000 for impingement, and from $1,281,000 to $13,629,000 for entrainment. The range of economic loss is developed by taking the midpoint of the benefits transfer results and the 90th percentile species results from the HRC approach.

I6-2 Potential Economic Benefits due to Regulations

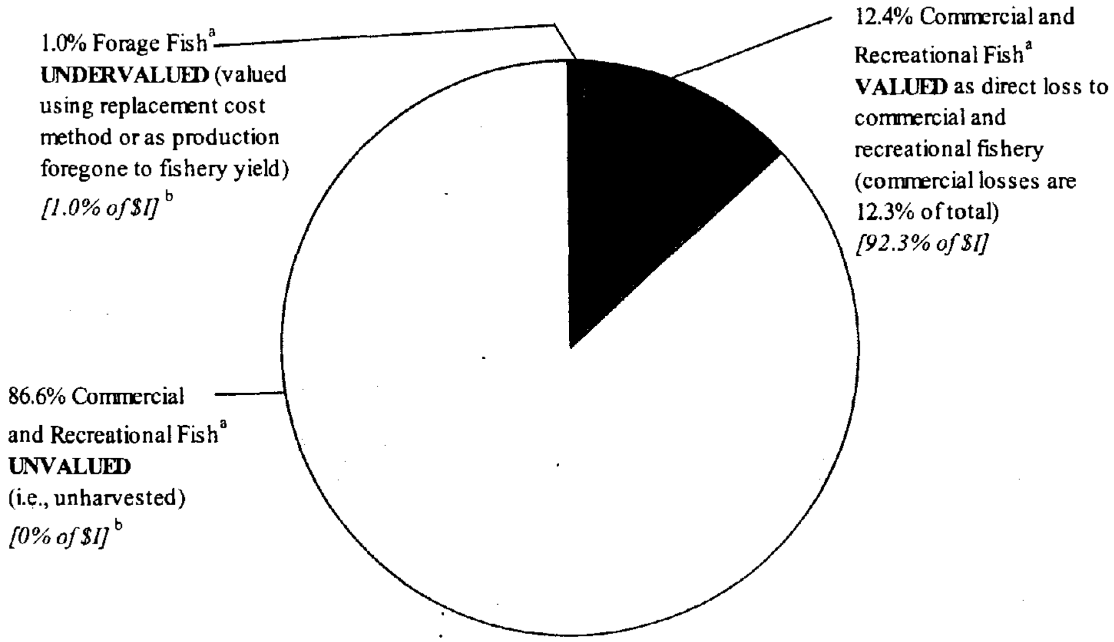
Table I6-2 summarizes the total annual benefits from I&E reductions under scenarios ranging from 10 percent to 90 percent reductions in I&E. Table I6-3 indicates that the benefits are expected to range from $582,000 to $4.4 million for a 80 percent reduction in impingement and from $640,000 to $6.8 million for a 50 percent reduction in entrainment.

Figure I6-1: Overview and Summary of Average Annual I&E and Associated Economic Values for the Monroe Facility (all results are annualized)[a,b]



[a] All dollar values are the midpoint of the range of estimates.
[b] I&E loss estimates are from Tables I4-2, I4-3, I4-9, and I4-10 in Chapter I4.
Note: Species with I&E < 1% of the total I&E were not valued.

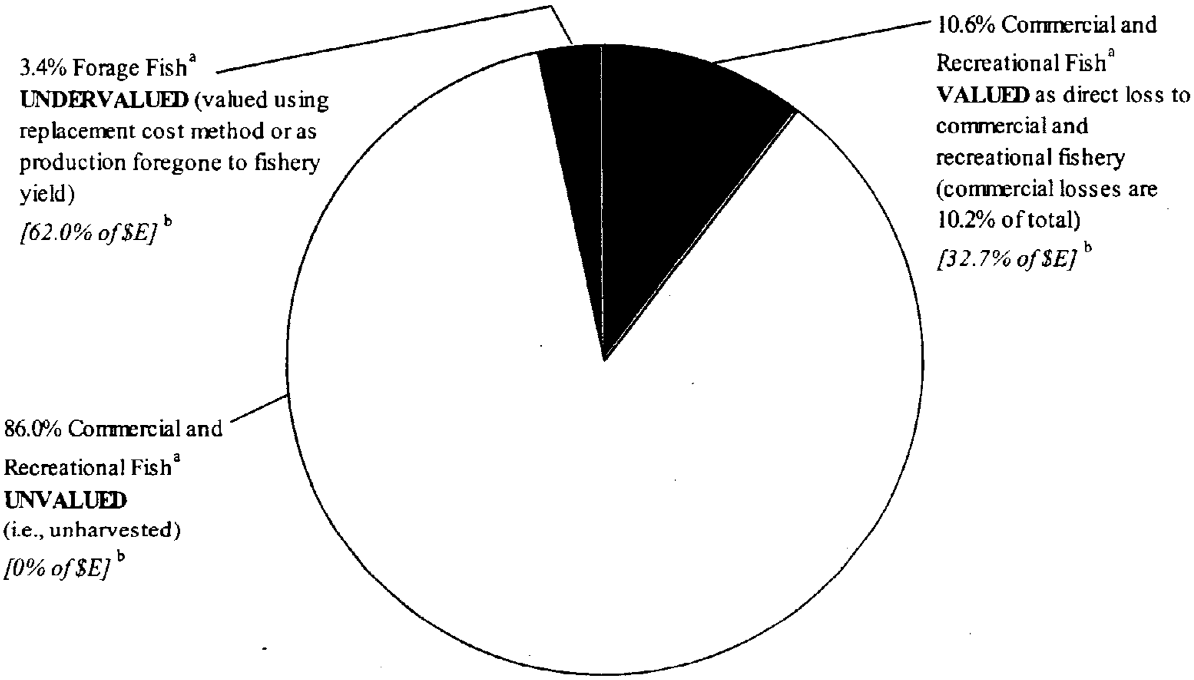
Figure I6-2: Monroe: Distribution of Impingement Losses by Species Category and Associated Economic Values



Total: 35.8 million fish per year (age 1 equivalents)[a]
Total impingement value: $727,500[b]

[a] Impacts shown are to age 1 equivalent fish, except impacts to the commercially and recreationally harvested fish include impacts for all ages vulnerable to the fishery.
[b] Midpoint of estimated range. Nonuse values are 6.7% of total estimated $I loss.

Figure I6-3: Monroe: Distribution of Entrainment Losses by Species Category and Associated Economic Values



Total: 11.6 million fish per year (age 1 equivalents)[a]
Total entrainment value: $1.3 million[b]

[a] Impacts shown are to age 1 equivalent fish, except impacts to the commercially and recreationally harvested fish include impacts for all ages vulnerable to the fishery.
[b] Midpoint of estimated range. Nonuse values are 5.3% of total estimated $E loss.

Table I6-1: Total Baseline Economic Loss from I&E (2000$, annually)

	Impingement	Entrainment
Benefits transfer approach (demand driven approach from Chapter I4)[a]	$727,000	$1,281,000
Habitat replacement cost approach (supply driven approach from Chapter I5)[b]	$5,529,000	$13,629,000
Range	$0.7 million to $5.5 million	$1.3 million to $13.6 million

[a] Midpoint of Range from Chapter I4.
[b] Based on cost to restore 90th percentile species impacted. Note that the lower bound estimates from the HRC approach reflect restoration of only half the impacted fish species (i.e., the 50th percentile). As such, the low end values for HRC were not considered in establishing the range of losses.

Table I6-2: Summary of Current Economic Losses and Benefits of a Range of Potential I&E Reductions at Monroe Facility ($2000)

		Impingement	Entrainment	Total
Baseline losses	low	$727,000	$1,281,000	$2,008,000
	high	$5,529,000	$13,629,000	$19,158,000
Benefits of 10% reductions	low	$73,000	$128,000	$201,000
	high	$553,000	$1,363,000	$1,916,000
Benefits of 20% reductions	low	$145,000	$256,000	$402,000
	high	$1,106,000	$2,726,000	$3,832,000
Benefits of 30% reductions	low	$218,000	$384,000	$602,000
	high	$1,659,000	$4,089,000	$5,747,000
Benefits of 40% reductions	low	$291,000	$512,000	$803,000
	high	$2,211,000	$5,452,000	$7,663,000
Benefits of 50% reductions	low	$364,000	$640,000	$1,004,000
	high	$2,764,000	$6,815,000	$9,579,000
Benefits of 60% reductions	low	$436,000	$769,000	$1,205,000
	high	$3,317,000	$8,177,000	$11,495,000
Benefits of 70% reductions	low	$509,000	$897,000	$1,406,000
	high	$3,870,000	$9,540,000	$13,410,000
Benefits of 80% reductions	low	$582,000	$1,025,000	$1,607,000
	high	$4,423,000	$10,903,000	$15,326,000
Benefits of 90% reductions	low	$655,000	$1,153,000	$1,807,000
	high	$4,976,000	$12,266,000	$17,242,000

Table I6-3: Summary of Benefits of Potential I&E Reductions at Monroe Facility ($2000)

		Impingement	Entrainment	Total
80% impingement reductions and 50% entrainment reductions	low	$582,000	$640,000	$1,222,000
	high	$4,423,000	$6,815,000	$11,238,000

I6-3 SUMMARY OF OMISSIONS, BIASES, AND UNCERTAINTIES IN THE BENEFITS ANALYSIS

Table I6-4 presents an overview of omissions, biases, and uncertainties in the benefits estimates. Factors with a negative impact on the benefits estimate bias the analysis downward, and therefore would raise the final estimate if they were properly accounted.

Table I6-4: Omissions, Biases, and Uncertainties in the Benefits Estimates

Issue	Impact on Benefits Estimate	Comments
Long-term fish stock effects not considered	Understates benefits[a]	EPA assumed that the effects on stocks are the same each year, and that the higher fish kills would not have cumulatively greater impact.
Effect of interaction with other environmental stressors	Understates benefits[a]	EPA did not analyze how the yearly reductions in fish may make the stock more vulnerable to other environmental stressors. In addition, as water quality improves over time because of other watershed activities, the number of fish impacted by I&E may increase.
Recreation participation is held constant[a]	Understates benefits[a]	Recreational benefits estimated via benefits transfer reflect only anticipated increase in value per activity outing; increased levels of participation are omitted.
Boating, bird-watching, and other in-stream or near-water activities are omitted[a]	Understates benefits[a]	The only impact to recreation considered is fishing.
Effect of change in stocks on number of landings	Uncertain	EPA assumed a linear stock to harvest relationship, that a 13 percent change in stock would have a 13 percent change in landings; this may be low or high, depending on the condition of the stocks.
Nonuse benefits	Uncertain	EPA assumed that nonuse benefits are 50 percent of recreational angling benefits.
Use of unit values from outside the Great Lakes	Uncertain	The recreational and commercial values used are not all studies from the Great Lakes specifically.
HRC based on capture data assumed to represent age 1 fish	Understates benefits[a]	High percent of less than age 1 fish observed in capture data, thereby leading to potential underestimate of scale of restoration required
HRC monitoring program costs for wetland restoration not consistent with evaluating fish production/abundance	Understates benefits[a]	A monitoring program to determine wetland production (abundance of fish) would be more labor intensive than current monitoring program.

[a] Benefits would be greater than estimated if this factor were considered.

Chapter I7: Conclusions

As summarized in Chapter I3, EPA estimates that impingement at the Monroe facility is 35.8 million age 1 equivalents or 1.4 million pounds of lost fishery yield per year. Entrainment impact amounts to 11.6 million age 1 equivalents or 608,300 pounds of lost fishery yield each year.

The results of EPA's evaluation of the dollar value of I&E at Monroe (as calculated using benefits transfer, in Chapter I4) indicate that baseline economic losses range from $492,400 to $962,500 per year for impingement and from $308,400 to $2,253,400 per year for entrainment (all in $2000).

EPA also developed an HRC analysis to examine the costs of restoring I&E losses at Monroe. The HRC results for impingement ($5.5 million) and entrainment ($13.6 million) were used for upper bounds, and the midpoints from the benefits transfer method were used for lower bounds. Combining these approaches, the value of I&E losses at Monroe range from approximately $0.7 million to $5.5 million per year for impingement and from $1.3 million to $13.6 million per year for entrainment (all in $2000).

EPA also estimated the economic benefit of the proposed rule for the Monroe facility (Chapter I6). The resulting estimates of the economic value of benefits for the proposed rule range from $582,000 to $4.4 million per year for 80 percent impingement reductions, and from $769,000 to $8.2 million per year for 60 percent entrainment reductions (all in $2000).

For a variety of reasons, EPA believes that the estimates developed here underestimate the total economic benefits of reducing I&E at the Monroe facility. EPA assumed that the effects of I&E on fish populations are constant over time (i.e., that fish kills do not have cumulatively greater impacts on diminished fish populations). EPA also did not analyze whether the number of fish affected by I&E would increase as populations increase in response to improved water quality or other improvements in environmental conditions. In the economic analyses, EPA also assumed that fishing is the only recreational activity affected.

Appendix I1: Monroe Life History Parameter Values

The tables in this appendix present the life history parameter values used by EPA to calculate age 1 equivalents, fishery yields, and production foregone from I&E data for the Monroe facility.

Table I1-1: Alewife Parameters

Stage Name	Natural Mortality (per stage)[a]	Fishing Mortality (per stage)[b]	Fraction Vulnerable to Fishery[b]	Weight (lb)
Eggs	11.5	0	0	0.000022[c]
Larvae	5.5	0	0	0.011[c]
Age 1+	0.5	0	0	0.016[a]
Age 2+	0.5	0	0	0.0505[a]
Age 3+	0.5	0	0	0.0764[a]
Age 4+	0.5	0	0	0.0941[a]
Age 5+	0.5	0	0	0.108[a]
Age 6+	0.5	0	0	0.13[a]
Age 7+	0.5	0	0	0.149[a]

[a] Spigarelli et al., 1981.
[b] Not a commercial or recreational species, thus no fishing mortality.
[c] Assumed based on Spigarelli et al. (1981).

Table I1-2: Bluegill Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[d]	Fraction Vulnerable to Fishery[e]	Weight (lb)[f]
Eggs	1.73[a]	0	0	0.0000000108[g]
Larvae	0.576[a]	0	0	0.00000156[g]
Age 0+	4.62[a]	0	0	0.00795[h]
Age 1+	0.39[b]	0	0	0.00992[h]
Age 2+	0.151[c]	0	0	0.032[h]
Age 3+	0.735[d]	0.735	0.5	0.0594[h]
Age 4+	0.735[d]	0.735	1	0.104[h]
Age 5+	0.735[d]	0.735	1	0.189[h]
Age 6+	0.735[d]	0.735	1	0.193[h]
Age 7+	0.735[d]	0.735	1	0.209[h]
Age 8+	0.735[d]	0.735	1	0.352[h]
Age9+	0.735[d]	0.735	1	0.393[h]

[a] Bartell and Campbell, 2000.
[b] Froese and Pauly, 2001.
[c] Calculated from survival (Carlander, 1977) using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[d] Carlander, 1977. Assumed half of total mortality was natural and half was fishing.
[e] Recreational species. Fraction vulnerable assumed.
[f] Weight calculated from length using the formula: $(4.33 \times 10^{-6}) * \text{Length(mm)}^{3.209}$ = weight(g) (Froese and Pauly, 2001).
[g] Length from Wang (1986a).
[h] Length from Carlander (1977).

Table I1-3: Bullhead Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[c]	Fraction Vulnerable to Fishery[d]	Weight (lb)[e]
Eggs	2.3[a]	0	0	0.000000559[f]
Larvae	4.61[b]	0	0	0.00018[g]
Age 0+	1.39[b]	0	0	0.00132[h]
Age 1+	0.223[c]	0.223	0.5	0.0362[h]
Age 2+	0.223[c]	0.223	1	0.0797[h]
Age 3+	0.223[c]	0.223	1	0.137[h]
Age 4+	0.223[c]	0.223	1	0.233[h]
Age 5+	0.223[c]	0.223	1	0.402[h]
Age 6+	0.223[c]	0.223	1	0.679[h]
Age 7+	0.223[c]	0.223	1	0.753[h]
Age 8+	0.223[c]	0.223	1	0.815[h]
Age9+	0.223[c]	0.223	1	0.823[i]

[a] Calculated from assumed survival using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Calculated from survival for channel catfish (Geo-Marine Inc., 1978) using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[c] Calculated from survival for brown bullhead (Carlander, 1969) using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality). Assumed half of total mortality was natural and half was fishing.
[d] Commercial species. Fraction vulnerable assumed.
[e] Weight calculated from length using the formula for black bullhead: $(8.797 \times 10^{-6})*\text{Length(mm)}^{3.06} = \text{weight(g)}$ (Froese and Pauly, 2001).
[f] Length for black bullhead from Wang (1986a).
[g] Length assumed based on Wang (1986a) and Carlander (1969).
[h] Length for black bullhead from Carlander (1969).
[i] Length assumed based on Carlander (1969).

Table I1-4: Burbot Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[c]	Fraction Vulnerable to Fishery[d]	Weight (lb)[e]
Eggs	2.3[a]	0	0	0.0000000120[f]
Larvae	8.05[b]	0	0	0.00000144[f]
Age 1+	0.462[c]	0.1	0.5	0.129[g]
Age 2+	0.462[c]	0.1	1	0.513[g]
Age 3+	0.462[c]	0.1	1	0.842[g]
Age 4+	0.462[c]	0.1	1	1.23[g]
Age 5+	0.462[c]	0.1	1	1.99[g]
Age 6+	0.462[c]	0.1	1	2.68[g]
Age 7+	0.462[c]	0.1	1	2.97[g]
Age 8+	0.462[c]	0.1	1	3.35[g]
Age9+	0.462[c]	0.1	1	3.57[g]
Age 10+	0.462[c]	0.1	1	4.09[g]

[a] Calculated from assumed survival using the using the eqation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Calculated from extrapolated survival using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[c] Calculated from survival using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality). Fishing mortality rate assumed based on minimal mortality (Schram et al., 1998).
[d] Commercial and recreational species. Fraction vulnerable assumed.
[e] Weight calculated from length using the formula: $(2.084 \times 10^{-6})*\text{Length(mm)}^{3.208} = \text{weight(g)}$ (Schram et al., 1998).
[f] Length from Snyder (1998).
[g] Length from Scott and Crossman (1998).

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[c]	Fraction Vulnerable to Fishery[d]	Weight (lb)[e]
Eggs	2.3[a]	0	0	0.000000143[f]
Larvae	4.61[b]	0	0	0.0000118[f]
Age 0+	1.39[b]	0	0	0.0225[g]
Age 1+	0.13[c]	0.13	0.5	0.79[g]
Age 2+	0.13[c]	0.13	1	1.21[g]
Age 3+	0.13[c]	0.13	1	1.81[g]
Age 4+	0.13[c]	0.13	1	5.13[g]
Age 5+	0.13[c]	0.13	1	5.52[h]
Age 6+	0.13[c]	0.13	1	5.82[h]
Age 7+	0.13[c]	0.13	1	6.76[g]
Age 8+	0.13[c]	0.13	1	8.17[g]
Age9+	0.13[c]	0.13	1	8.55[h]
Age 10+	0.13[c]	0.13	1	8.94[h]
Age 11+	0.13[c]	0.13	1	9.76[h]
Age 12+	0.13[c]	0.13	1	10.2[h]
Age 13+	0.13[c]	0.13	1	10.6[h]
Age 14+	0.13[c]	0.13	1	11.1[h]
Age 15+	0.13[c]	0.13	1	11.5[h]
Age 16+	0.13[c]	0.13	1	12[h]
Age 17+	0.13[c]	0.13	1	12.5[h]

Table I1-5: Carp Parameters

[a] Calculated from assumed survival using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Calculated from survival (Geo-Marine Inc., 1978) using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[c] Froese and Pauly, 2001. Assumed half of total mortality was natural and half was fishing.
[d] Commercial species. Fraction vulnerable assumed.
[e] Weight calculated from length using the formula: $(1.095x10^{-5})*Length(mm)^{3.025}$ = weight(g) (Froese and Pauly, 2001).
[f] Length from Wang (1986a).
[g] Length from Carlander (1969).
[h] Length assumed based on Carlander (1969).

Table I1-6: Channel Catfish Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[c]	Fraction Vulnerable to Fishery[d]	Weight (lb)[e]
Eggs	2.3[a]	0	0	0.000000408[f]
Larvae	4.61[b]	0	0	0.0000191[f]
Age 0+	1.39[b]	0	0	0.00987[g]
Age 1+	0.41[c]	0.41	0.5	0.0554[g]
Age 2+	0.41[c]	0.41	1	0.189[g]
Age 3+	0.41[c]	0.41	1	0.436[g]
Age 4+	0.41[c]	0.41	1	0.71[g]
Age 5+	0.41[c]	0.41	1	1.22[g]
Age 6+	0.41[c]	0.41	1	1.55[g]
Age 7+	0.41[c]	0.41	1	2.27[g]
Age 8+	0.41[c]	0.41	1	2.66[g]
Age 9+	0.41[c]	0.41	1	3.41[g]
Age 10+	0.41[c]	0.41	1	5.59[g]
Age 11+	0.41[c]	0.41	1	5.81[h]
Age 12+	0.41[c]	0.41	1	5.92[g]

[a] Calculated from assumed survival using the using the eqation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Calculated from survival (Geo-Marine Inc., 1978) using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[c] Calculated from survival (Geo-Marine Inc., 1978) using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality). Assumed half of total mortality was natural and half was fishing.
[d] Commercial and recreational species. Fraction vulnerable assumed.
[e] Weight calculated from length using the formula: $(2.945 \times 10^{-6})*\text{Length(mm)}^{3.133}$ = weight(g) (Froese and Pauly, 2001).
[f] Length from Wang (1986a).
[g] Length from Carlander (1969).
[h] Length assumed based on Carlander (1969).

Table I1-7: Crappie Parameters

Stage Name	Natural Mortality (per stage)[a]	Fishing Mortality (per stage)[b]	Fraction Vulnerable to Fishery[c]	Weight (lb)[d]
Eggs	1.8[a]	0	0	0.0000000179[e]
Larvae	0.498[a]	0	0	0.00000857[e]
Age 0+	2.93[a]	0	0	0.012[f]
Age 1+	0.292[b]	0.292	0.5	0.128[f]
Age 2+	0.292[b]	0.292	1	0.193[f]
Age 3+	0.292[b]	0.292	1	0.427[f]
Age 4+	0.292[b]	0.292	1	0.651[f]
Age 5+	0.292[b]	0.292	1	0.888[f]
Age 6+	0.292[b]	0.292	1	0.925[f]
Age 7+	0.292[b]	0.292	1	0.972[f]
Age 8+	0.292[b]	0.292	1	1.08[f]
Age9+	0.292[b]	0.292	1	1.26[f]

[a] Bartell and Campbell, 2000. Black crappie.
[b] Bartell and Campbell, 2000. Black crappie. Assumed half of total mortality was natural and half was fishing.
[c] Recreational species. Fraction vulnerable assumed.
[d] Weight calculated from length using the formula for black crappie: $(1.014 \times 10^{-5})*\text{Length(mm)}^{3.066}$ = weight(g) (Froese and Pauly, 2001).
[e] Length for black crappie from Wang (1986a).
[f] Length for black crappie from Carlander (1977).

Table I1-8: Freshwater Drum Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[b]	Fraction Vulnerable to Fishery[c]	Weight (lb)
Eggs	2.27[a]	0	0	0.0000011[d]
Larvae	6.13[a]	0	0	0.00000295[a]
Age 0+	1.15[a]	1.15	0.5	0.0166[a]
Age 1+	0.155[b]	0.155	1	0.05[e]
Age 2+	0.155[b]	0.155	1	0.206[e]
Age 3+	0.155[b]	0.155	1	0.438[e]
Age 4+	0.155[b]	0.155	1	0.638[e]
Age 5+	0.155[b]	0.155	1	0.794[e]
Age 6+	0.155[b]	0.155	1	0.95[e]
Age 7+	0.155[b]	0.155	1	1.09[e]
Age 8+	0.155[b]	0.155	1	1.26[e]
Age9+	0.155[b]	0.155	1	1.44[e]
Age 10+	0.155[b]	0.155	1	1.6[e]
Age 11+	0.155[b]	0.155	1	1.78[e]
Age 12+	0.155[b]	0.155	1	2[e]

[a] Bartell and Campbell, 2000.
[b] Froese and Pauly, 2001. Assumed half of total mortality was natural and half was fishing.
[c] Commercial species. Fraction vulnerable assumed.
[d] Assumed based on Bartell and Campbell (2000).
[e] Scott and Crossman, 1973.

Table I1-9: Gizzard Shad Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[c]	Fraction Vulnerable to Fishery[d]	Weight (lb)
Eggs	2.3[a]	0	0	0.0000022[e]
Larvae	6.33[b]	0	0	0.00000663[b]
Age 0+	0.511[b]	0	0	0.0107[b]
Age 1+	1.45[c]	1.45	0.5	0.141[b]
Age 2+	1.27[c]	1.27	1	0.477[b]
Age 3+	0.966[c]	0.966	1	0.64[b]
Age 4+	0.873[c]	0.873	1	0.885[b]
Age 5+	0.303[c]	0.303	1	1.17[b]
Age 6+	0.303[c]	0.303	1	1.54[b]

[a] Calculated from assumed survival using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Wapora, 1979.
[c] Wapora, 1979. Assumed half of total mortality was natural and half was fishing.
[d] Commercial species. Fraction vulnerable assumed.
[e] Assumed based on Wapora (1979).

Table I1-10: Logperch Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[d]	Fraction Vulnerable to Fishery[d]	Weight (lb)[e]
Eggs	2.3[a]	0	0	3.09E-09[f]
Larvae	1.9[b]	0	0	0.000276[g]
Age 0+	1.9[b]	0	0	0.00345[f]
Age 1+	0.7[c]	0	0	0.0128[f]
Age 2+	0.7[c]	0	0	0.0274[f]
Age 3+	0.7[c]	0	0	0.0443[f]

[a] Calculated from assumed survival using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Calculated from extrapolated survival using thc using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[c] Frocse and Pauly, 2001.
[d] Not a commercial or recreational species, thus no fishing mortality.
[e] Weight calculated from length using the formula: $(5.240 \times 10^{-7}) * \text{Length(mm)}^{6.641}$ = weight(g) (Carlander, 1997).
[f] Length from Carlander (1997).
[g] Length assumed based on Carlander (1997).

Table I1-11: Muskellunge Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[d]	Fraction Vulnerable to Fishery[e]	Weight (lb)[f]
Eggs	1.08[a]	0	0	0.000000205[g]
Larvae	5.49[b]	0	0	0.0133[h]
Age 0+	5.49[b]	0	0	0.0451[g]
Age 1+	0.15[c]	0	0	0.365[g]
Age 2+	0.15[c]	0	0	1.1[g]
Age 3+	0.15[c]	0	0	1.53[g]
Age 4+	0.15[c]	0	0	2.72[g]
Age 5+	0.15[c]	0	0	6.19[g]
Age 6+	0.15[c]	0	0	7.02[g]
Age 7+	0.15[c]	0	0	8.92[g]
Age 8+	0.15[c]	0	0	12.3[g]
Age9+	0.15[c]	0	0	13.9[g]
Age 10+	0.075[d]	0.075	0.5	16.6[g]
Age 11+	0.075[d]	0.075	1	19[g]
Age 12+	0.075[d]	0.075	1	24.2[g]
Age 13+	0.075[d]	0.075	1	25.3[g]
Age 14+	0.075[d]	0.075	1	30[g]
Age 15+	0.075[d]	0.075	1	32.4[g]
Age 16+	0.075[d]	0.075	1	34.3[g]
Age 17+	0.075[d]	0.075	1	45.6[g]
Age 18+	0.075[d]	0.075	1	45.8[h]
Age 19+	0.075[d]	0.075	1	47.7[g]
Age 20+	0.075[d]	0.075	1	48.8[h]
Age 21+	0.075[d]	0.075	1	48.9[h]
Age 22+	0.075[d]	0.075	1	49[h]
Age 23+	0.075[d]	0.075	1	49.1[h]
Age 24+	0.075[d]	0.075	1	49.2[h]
Age 25+	0.075[d]	0.075	1	49.3[h]
Age 26+	0.075[d]	0.075	1	49.4[h]
Age 27+	0.075[d]	0.075	1	49.4[h]

[a] Calculated from survival (Carlander, 1997) using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Calculated from extrapolated survival using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[c] Froese and Pauly, 2001.
[d] Froese and Pauly, 2001. Assumed half of total mortality was natural and half was fishing.
[e] Recreational species. Fraction vulnerable assumed based on Pennsylvania (1999).
[f] Weight calculated from length using the formula: (5.590×10^{-6})*Length(mm)$^{3.016}$ = weight(g) (Froese and Pauly, 2001).
[g] Length from Carlander (1969).
[h] Length assumed based on Carlander (1969).

Table I1-12: Shiner Species Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[c]	Fraction Vulnerable to Fishery[c]	Weight (lb)[d]
Eggs	2.3[a]	0	0	0.000000252[e]
Larvae	4.61[b]	0	0	0.0016[e]
Age 0+	0.776[b]	0	0	0.0135[f]
Age 1+	0.371[b]	0	0	0.026[f]
Age 2+	4.61[b]	0	0	0.0478[f]
Age 3+	4.61[b]	0	0	0.106[f]

[a] Calculated from assumed survival using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] (Wapora, 1979). Emerald shiner.
[c] Not a commercial or recreational species, thus no fishing mortality.
[d] Weight calculated from length using the formula for emerald shiner: (1.144×10^{-4})*Length(mm)$^{2.922}$ = weight(g) (Fuchs, 1967).
[e] Length assumed based on (Trautman, 1981).
[f] Length from (Trautman, 1981).

Table I1-13: Smallmouth Bass Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[c]	Fraction Vulnerable to Fishery[d]	Weight (lb)[e]
Eggs	1.9[a]	0	0	0.000000331[f]
Larvae	2.7[b]	0	0	0.0000198[f]
Age 0+	0.446[a]	0	0	0.0169[g]
Age 1+	0.86[c]	0.23	0.5	0.202[g]
Age 2+	1.17[c]	0.322	1	0.518[g]
Age 3+	0.755[c]	0.208	1	0.733[g]
Age 4+	1.05[c]	0.288	1	1.04[g]
Age 5+	0.867[c]	0.238	1	1.44[g]
Age 6+	0.867[c]	0.238	1	2.24[g]
Age 7+	0.867[c]	0.238	1	2.56[h]
Age 8+	0.867[c]	0.238	1	2.92[h]
Age9+	0.867[c]	0.238	1	3.3[g]

[a] Calculated from survival (Carlander, 1977) using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Bartell and Campbell, 2000.
[c] Carlander, 1977.
[d] Recreational species. Fraction vulnerable assumed.
[e] Weight calculated from length using the formula: (2.494×10^{-5})*Length(mm)$^{2.917}$ = weight(g) (Froese and Pauly, 2001).
[f] Length from Wang (1986a).
[g] Length from Carlander (1977).
[h] Length assumed based on Carlander (1977).

Table I1-14: Smelt Parameters

Stage Name	Natural Mortality (per stage)[a]	Fishing Mortality (per stage)[a]	Fraction Vulnerable to Fishery[b]	Weight (lb)[c]
Eggs	11.5	0	0	0.0000000115[d]
Larvae	5.5	0	0	0.00000233[d]
Age 1+	0.4	0.03	0.5	0.0195[e]
Age 2+	0.4	0.03	1	0.041[f]
Age 3+	0.4	0.03	1	0.177[f]
Age 4+	0.4	0.03	1	0.338[g]
Age 5+	0.4	0.03	1	0.537[g]
Age 6+	0.4	0.03	1	0.597[g]

[a] Spigarelli et al., 1981.
[b] Commercial and recreational species. Fraction vulnerable assumed.
[c] Weight calculated from length using the formula for rainbow smelt: (5.23×10^{-6})*Length(mm)$^{3.114}$ = weight(g) (Froese and Pauly, 2001).
[d] Length for rainbow smelt from Able and Fahay (1998).
[e] Length assumed based on Able and Fahay (1998) and Scott and Scott (1988).
[f] Length for rainbow smelt from Scott and Scott (1988).
[g] Length assumed based on Scott and Scott (1988).

Table I1-15: Sucker Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[b]	Fraction Vulnerable to Fishery[c]	Weight (lb)[d]
Eggs	2.05[a]	0	0	0.0000000135[e]
Larvae	2.56[a]	0	0	0.00000198[e]
Age 0+	2.3[a]	0	0	0.000145[f]
Age 1+	0.274[b]	0.274	0.5	0.0447[f]
Age 2+	0.274[b]	0.274	1	0.249[f]
Age 3+	0.274[b]	0.274	1	0.305[f]
Age 4+	0.274[b]	0.274	1	0.609[f]
Age 5+	0.274[b]	0.274	1	0.823[f]
Age 6+	0.274[b]	0.274	1	0.929[f]

[a] Bartell and Campbell, 2000.
[b] Bartell and Campbell, 2000. Assumed half of total mortality was natural and half was fishing.
[c] Commercial species. Fraction vulnerable assumed.
[d] Weight calculated from length using the formula for river carpsucker: (6.130×10^{-6})*Length(mm)$^{3.099}$ = weight(g) (Froese and Pauly, 2001).
[e] Length assumed based on Carlander (1969).
[f] Length from Carlander (1969).

Table I1-16: Sunfish Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[c]	Fraction Vulnerable to Fishery[d]	Weight (lb)[e]
Eggs	1.71[a]	0	0	0.00000000736[f]
Larvae	0.687[b]	0	0	0.000000994[f]
Age 0+	0.687[b]	0	0	0.000878[g]
Age 1+	1.61[a]	0	0	0.00666[g]
Age 2+	1.61[a]	0	0	0.0271[g]
Age 3+	1.5[c]	1.5	0.5	0.0593[g]
Age 4+	1.5[c]	1.5	1	0.0754[g]
Age 5+	1.5[c]	1.5	1	0.142[g]
Age 6+	1.5[c]	1.5	1	0.18[g]
Age 7+	1.5[c]	1.5	1	0.214[g]
Age 8+	1.5[c]	1.5.	1	0.232[g]

[a] Calculated from survival for pumpkinseed (Carlander, 1977) using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Calculated from extrapolated survival using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[c] Calculated from survival for pumpkinseed (Carlander, 1977) using the using the equation: (natural mor0tality) = -LN(survival) - (fishing mortality). Assumed half of total mortality was natural and half was fishing.
[d] Recreational species. Fraction vulnerable assumed.
[e] Weight calculated from length using the formula for pumpkinseed: (3.337×10^{-6})*Length(mm)$^{3.262}$ = weight(g) (Froese and Pauly, 2001).
[f] Length for pumpkinseed from Bartell and Campbell (2000).
[g] Length for pumpkinseed from Carlander (1977).

Table I1-17: Walleye Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[c]	Fraction Vulnerable to Fishery[d]	Weight (lb)[e]
Eggs	1.05[a]	0	0	0.00000000506[f]
Larvae	3.55[b]	0	0	0.0000768[g]
Age 0+	1.93[b]	0	0	0.03[g]
Age 1+	0.7[c]	0.1	0.5	0.328[g]
Age 2+	0.7[c]	0.1	1	0.907[g]
Age 3+	0.7[c]	0.1	1	1.77[g]
Age 4+	0.7[c]	0.1	1	2.35[g]
Age 5+	0.7[c]	0.1	1	3.37[g]
Age 6+	0.7[c]	0.1	1	3.97[g]
Age 7+	0.7[c]	0.1	1	4.66[g]
Age 8+	0.7[c]	0.1	1	5.58[f]
Age 9+	0.7[c]	0.1	1	5.75[g]

[a] Calculated from survival (Carlander, 1997) using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Bartell and Campbell, 2000.
[c] Thomas and Haas, 2000.
[d] Recreational species. Fraction vulnerable assumed.
[e] Weight calculated from length using the formula: (2.297×10^{-6})*Length(mm)$^{3.23}$ = weight(g) (Froese and Pauly, 2001).
[f] Length assumed based on Carlander (1997).
[g] Length from Carlander (1997).

Table I1-18: White Bass Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[d]	Fraction Vulnerable to Fishery[e]	Weight (lb)
Eggs	2.3[a]	0	0	0.0000000266[f]
Larvae	4.61[b]	0	0	0.00000174[f]
Age 0+	1.39[b]	0	0	0.174[g]
Age 1+	0.42[c]	0.7	0	0.467[g]
Age 2+	0.42[c]	0.7	0.5	0.644[g]
Age 3+	0.42[c]	0.7	1	1.02[g]
Age 4+	0.42[c]	0.7	1	1.16[g]
Age 5+	0.42[c]	0.7	1	1.26[g]
Age 6+	0.42[c]	0.7	1	1.66[g]
Age 7+	0.42[c]	0.7	1	1.68[h]

[a] Calculated from assumed survival using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[b] Calculated from survival (Geo-Marine Inc., 1978) using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).
[c] Froese and Pauly, 2001.
[d] McDermot and Rose, 2000.
[e] Commercial and recreational species. Fraction vulnerable assumed.
[f] Weight calculated from assumed length based on (Carlander, 1997) using the formula: $(1.206 \times 10^{-5}) * \text{Length(mm)}^{3.132} = \text{weight(g)}$ (Van Oosten, 1942).
[g] Carlander, 1997.
[h] Assumed based on Carlander (1997).

Table I1-19: Whitefish Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[c]	Fraction Vulnerable to Fishery[d]	Weight (lb)[e]
Eggs	2.3[a]	0	0	0.000000252[f]
Larvae	8.2[b]	0	0	0.000171[g]
Juvenile	0.25[c]	0	0	0.0117[g]
Age 1+	0.25[c]	0.997	0.5	0.705[f]
Age 2+	0.25[c]	0.997	1	1.27[f]
Age 3+	0.25[c]	0.997	1	2.32[f]
Age 4+	0.25[c]	0.997	1	2.85[f]
Age 5+	0.25[c]	0.997	1	3.52[f]
Age 6+	0.25[c]	0.997	1	4.09[f]
Age 7+	0.25[c]	0.997	1	4.76[f]
Age 8+	0.25[c]	0.997	1	5.7[f]
Age 9+	0.25[c]	0.997	1	5.73[h]
Age 10+	0.25[c]	0.997	1	5.85[f]
Age 11+	0.25[c]	0.997	1	6.1[f]
Age 12+	0.25[c]	0.997	1	6.83[f]
Age 13+	0.25[c]	0.997	1	7.11[f]
Age 14+	0.25[c]	0.997	1	7.29[f]
Age 15+	0.25[c]	0.997	1	7.32[h]
Age 16+	0.25[c]	0.997	1	8.66[f]

[a] Calculated from assumed survival using the using the equation: (natural mortality) = -LN(survival) - (fishing mortality).

[b] Froese and Pauly, 2001.

[c] Schorfhaar and Schneeberger, 1997.

[d] Commercial and recreational species. Fraction vulnerable assumed.

[e] Weight calculated from length using the formula for lake whitefish: (4.721×10^{-6})*Length(mm)$^{3.152}$ = weight(g) (Froese and Pauly, 2001).

[f] Length from Scott and Crossman (1998).

[g] Length from Fish (1932).

[h] Length assumed based on Scott and Crossman (1998).

Table I1-20: Yellow Perch Parameters

Stage Name	Natural Mortality (per stage)	Fishing Mortality (per stage)[c]	Fraction Vulnerable to Fishery[d]	Weight (lb)
Eggs	2.75[a]	0	0	0.0000022[e]
Larvae	3.56[b]	0	0	0.00000384[b]
Age 0+	2.53[b]	0	0	0.0232[b]
Age 1+	0.361[b]	0	0	0.0245[b]
Age 2+	0.248[b]	0	0	0.0435[b]
Age 3+	0.844[b]	0.36	0.5	0.0987[b]
Age 4+	0.844[b]	0.36	1	0.132[b]
Age 5+	0.844[b]	0.36	1	0.166[b]
Age 6+	0.844[b]	0.36	1	0.214[b]

[a] PSEG, 1999c.

[b] Wapora, 1979.

[c] Thomas and Haas, 2000.

[d] Recreational species. Fraction vulnerable assumed.

[e] Assumed based on Wapora (1979).

Glossary

7Q10: The lowest average seven-consecutive-day low flow with an average recurrence frequency of once in 10 years determined hydrologically.

Adipose fin: A small, fleshy fin behind the main dorsal fin in bony fish; most common in trout and salmon.

Adverse environmental impact (AEI): Within the context of this case study and the §316(b) regulation, adverse environmental impacts are said to occur whenever there is entrainment or impingement of aquatic organisms due to the operation of a specific cooling water intake structure.

Aerobic: Requiring the presence of free oxygen to support life.

Agnathan: Any member of the vertebrate class Agnatha, the jawless fishes.

Air/swim bladder: A large, thin-walled sac in many fish species that may function in several ways, e.g., as a buoyant float, a sound producer and receptor, and a breathing organ.

Anal fin: The median, unpaired fin on the ventral margin between the anus and the caudal fin in fishes.

Alevin(s): A young fish; especially a newly hatched salmon when still attached to the yolk sac; In North America alevins are sometimes called 'sac-fry.'

Algal blooms: The exponential growth of algal populations in response to excessive nutrient input. Algal blooms can adversely affect water quality.

Amphipods: A group of mostly small (5 to 20 mm), predominantly marine crustacean species characterized by a laterally-compressed, many-segmented body; most live on or in bottom substrates.

Anadromous: Pertaining to fish that spend a part of their life cycle in the sea and return to freshwater streams to spawn, for example, salmon, steelhead, and shad. Contrast with catadromous.

Anoxic: Absence of oxygen. Usually used in reference to an aquatic habitat.

Anthropogenic: Coming from or associated with human activities.

Anus: The opening at the lower end of the alimentary canal, through which the solid refuse of digestion is excreted to the outside.

Aortic arch: One member of a series of paired, curved blood vessels that arise from the ventral aorta, pass through the gills, and join with the dorsal aorta.

Arteries: Blood vessels that carry blood away from the heart to all parts of the body.

Arterioles: The smallest branches of an artery, which eventually merge with capillaries.

Arthropods: An extremely large group of related terrestrial and aquatic invertebrate species; well-known aquatic representatives, all of them crustaceans, include shrimps, copepods, crabs, mysids, and amphipods.

Atrium: A muscular heart chamber that receives blood from the veins and in turn pumps it into the ventricle.

Axial musculature: The large muscle mass that runs from head to tail on both sides of the body in fish. It is the power plant responsible for swimming, and typically represents up to half the mass of a fish.

Bayou: A sluggish marshy inlet or outlet associated with a lake, river, or other surface water body.

Benefits transfer: An approach to valuing an environmental improvement in which the results of existing research on the benefits of an environmental improvement are applied to estimate the benefits in a different, but similar, situation.

Benthic: Adjective that refers to something of or pertaining to benthos. See also: Benthos.

Benthic invertebrates: Those animals without backbones (e.g. insects, crayfish, etc.) that live on or in the sediments of an aquatic habitat.

Benthic zone: The lowermost region of a freshwater or marine profile in which the benthos resides. In bodies of deep water where little light penetrates to the bottom the zone is referred to as the benthic abyssal region and productivity is relatively low. In shallower (i.e. coastal) regions where the benthic zone is well lit, the zone is referred to as the benthic littoral region and it supports some of the world's most productive ecosystems.

Benthos: Plants or animals that live in or on the bottom of an aquatic environment such as an estuary.

Bequest (value): The value that people place on conserving a natural resource for use by future generations.

Best technology available (BTA): The best technology treatment techniques for field application, taking cost into consideration.

Bile: A bitter, alkaline, yellow or greenish liquid secreted by the liver, that aids in absorption and digestion, especially of fats.

Biocide: A chemical which can kill or inhibit the growth of living organisms such as bacteria, fungi, molds, and slimes.

Biological oxygen demand (BOD): The amount of dissolved oxygen consumed by microorganisms as they decompose organic material in polluted water.

Biological surplus: In fisheries, the annual excess of organisms that can be harvested without reducing future productivity.

Biomass: (1) the amount of living matter in an area, including plants, large animals and insects; (2) plant materials and animal waste used as fuel.

Blood: The fluid pumped throughout the body by the heart; it consists of plasma in which red blood cells, white blood cells, thrombocytes, and other specialized cell types are suspended.

Blood plasma: The plasma or liquid portion of blood.

Brackish: Having a salinity between that of fresh and sea water.

Branchial cavity: The area in the mouth containing the gills in fish.

Buccal cavity: The inner cavity associated with the mouth.

Buoyancy: The ability to float or rise in a fluid.

Buoyant: Having buoyancy; capable of floating.

Cannibalism: Animals eating other members of their own species.

Capillaries: Tiny blood vessels, usually < 1mm long, with a diameter no wider than a single red blood cell; they form dense networks that connect arterioles and venules, and are the site for physiological exchange with individual cells.

Carapace: Shell, as in a turtle shell or crab shell.

Cartilage: A firm, elastic, flexible type of connective tissue of a translucent whitish or yellowish color.

Cartilaginous: Pertaining to cartilage.

Cartilaginous ray: A supporting rod in fish fins made from cartilage.

Catadromous: Descriptive of fish species which mature in freshwater environments but migrate to the ocean to spawn.

Caudal fin: The tail of a fish, used mainly to generate forward propulsion.

Caudal peduncle: A narrow, stalk-like structure connecting the tail to the posterior end of the fish's body.

Central nervous system (CNS): The part of the nervous system comprising the brain and spinal cord.

Chloride cell: A specialized cell located in the gills and used by both salt- and freshwater fish to regulate internal salt balances.

Chondrichthyes: The class of vertebrates composed of cartilaginous fish species, including sharks, rays, skates and chimaeras.

Chromatophores: A group of specialized pigment cells located in the dermis, partially responsible for coloration in fish.

Circulatory vessels: A tube of the circulatory system, such as an artery or vein, which contains or conveys blood.

Closed-cycle (cooling system): A cooling water system in which heat is transferred by recirculating water contained within the system.

Cohort: A group of individuals having a statistical factor (as age or class membership) in common in a demographic study.

Colonial: Term describing the habit by certain bird species to nest in large groups called colonies.

Combined sewer overflow (CSO): Discharge of a mixture of storm water and domestic waste when the flow capacity of a combined sewer system is exceeded during rainstorms.

Cone: One of two types of light-sensitive cells located in the retina of the eye; sensitive to color and light intensity.

Confluence: The area where two or more streams or rivers join together

Conjoint analysis: A method for using surveys to determine the values that people place on a good by asking them to choose between several combinations of environmental quality and the cost of providing that level of quality.

Consumer surplus: The extra value that consumer would be willing to pay for a good beyond the good's actual sale price.

Consumptive use: The loss of water through various processes, including:

Consumptive use (of water): Refers to water use practices whereby water is not returned to its source due to loss from evaporation, evapotranspiration, or incorporation in a manufacturing process.

Continental shelf: Part of the continental margin. the ocean floor from the coastal shore of continents to the continental slope, usually to a depth of about 200 meters. The continental shelf usually has a very slight slope, roughly 0.1 degrees.

Contingent valuation method (CVM): A stated preference method for using surveys to ask people what they would be willing pay for a non-market good (especially an environmental good) contingent on a specific hypothetical scenario and description of the good.

Conus arteriosus: Muscular heart chamber responsible for passing blood from the ventricle into the ventral aorta, toward the gills.

Cooling water intake structures (CWISs): The total physical structure and any associated constructed waterways used to withdraw water from waters of the U.S. The cooling water intake structure extends from the point at which water is withdrawn from the surface water source to the first intake pump or series of pumps.

Copepods: A large group of planktonic or benthic crustacean species; one defining characteristic of this group are the single or double egg sacs carried posteriorally by the females.

Cornea: The transparent, exterior part of the eye located in front of the pupil.

Countercurrent exchange: The transfer of heat or gases between currents of blood passing by one another in capillary beds; the beds run parallel to each other but in opposite directions.

Cranium: The part of the skull that encloses the brain.

Critical habitat: Term used in the Federal Endangered Species Act to denote the whole or any part or parts of an area or areas of land comprising the habitat of an endangered species, an endangered population or an endangered ecological community that is essential for the survival of the species, population or ecological community.

DDT: Dichlorodiphenyltrichloroethane is a chlorinated pesticide which is banned in the U.S.

Demersal: (1) Dwelling at or near the bottom of a body of water, such as demersal fish. (2) Sinking to or deposited near the bottom of a body of water, such as demersal fish eggs.

Demersal egg: A fish or aquatic invertebrate egg that sinks to the bottom.

Dermal denticles: Small, toothlike scales covering the skin of most sharks, skates, and rays, giving their skin the feel of sandpaper.

Dermis: The dense inner layer of skin underneath the epidermis.

Dermo: A disease caused by a single-cell organism (protozoan) that infects oysters. (http://www.bayjournal.com/95-04/oyster1.htm)

Desiccation: The loss of water from pore spaces of sediments through compaction or through evaporation caused by exposure to air.

Diatoms: Any of the microscopic unicellular or colonial algae constituting the class Bacillarieae. They have a silicified cell wall, which persists as a silica skeleton after death and forms kieselguhr (loose or porous diatomite). Diatoms occur abundantly in fresh and salt waters, in soil, and as fossils. They form a large part of plankton.

Dinoflagellates: Any of numerous, chiefly marine, plankton of the phylum Pyrrophyta (or, in some classification schemes, the order Dinoflagellata), usually having flagella, one in a groove around the body and the other extending from its center.

Direct use benefits: The benefits that people derive from the use (or consumption) of a good.

Dissolved oxygen (DO): Oxygen gas which is dissolved in the water column and available for breathing by aquatic organisms; DO levels vary by temperature, salinity, turbulence, photosynthetic activity and internal oxygen demand.

Diurnal: Pertaining to fish and other species that are active during the day (opposed to nocturnal).

Dorsal aorta: A major blood vessel in fish, which carries oxygenated blood from the gills to the rest of the body.

Dorsal fin: The fin(s) present on the back of most fish.

Dorsal musculature: That part of the axial musculature located above the horizontal septum.

Ecological niche: The portion of the environment which a species occupies. A niche is defined in terms of the conditions under which an organism can survive, and may be affected by the presence of other competing organisms.

Ecosystem: All the organisms in a particular region and the environment in which they live. The elements of an ecosystem interact with each other in some way, and so depend on each other either directly or indirectly.

Effector cell: A cell that carries out a response to a nerve impulse.

Effluent: Wastewater — treated or untreated — that flows out of a treatment plant, sewer, or industrial outfall. Generally refers to wastes discharged into surface waters.

Endemism: Native to a particular area or region.

Endocrine system: An integrated group of glands that releases hormones into the blood stream.

Endolymph: The fluid contained within the canals and sacs of the inner ear.

Entrainment: The incorporation of fish, eggs, larvae, and other plankton with intake water flow entering and passing through a cooling water intake structure and into a cooling water system.

Environmental stressor: A physical or chemical disturbance that changes the quality of terrestrial or aquatic habitats

Epidermis: The outer layer of the skin.

Epipelagic (zone): The uppermost, normally photic layer of the ocean between the ocean surface and the thermocline, usually between depths of 0-200 m; living or feeding on surface waters or at midwater to depths of 200 m.

Epithelium: Any animal tissue that covers a surface or lines a cavity, and which performs various secretory, transporting, or regulatory functions.

Equilibrium population: Population in a state of balance.

Esophagus: A muscular tube connecting the mouth to the stomach.

Estuarine: Living mainly in the lower part of a river or estuary; coastlines where marine and freshwaters meet and mix; waters often brackish (i.e., mixohaline, with salt content 0.5 - 30%).

Euryhaline: Descriptive term for an organisms that can tolerate wide ranges in salt concentrations.

Eutrophication: The uncontrolled growth of aquatic plants in response to excessive nutrient inputs to surface waters; the process of enrichment of water bodies by nutrients.

Evapotranspiration: The loss of water from the soil both by evaporation and by transpiration from the plants growing in the soil.

Existence value: The value that people derive from knowledge that a good exists, even if they do not use it and have no plans to use it.

Exotic species: Species that evolve in one region of the world but are intentionally or accidentally introduced in another, where they lack natural enemies and can take over local ecosystems.

Extinction: The death of an entire species.

Fecundity: Number of eggs an animal produces during each reproductive cycle; the potential reproductive capacity of an organism or population.

Filter feeding: A food gathering strategy which consists of passing water over gill structures to strain out food particles.

Fish consumption advisories: Limitations imposed by regulatory agencies on the number of fish or shellfish meals that can be consumed by particular segments of the general population, due to the presence of chemical residues in the target organisms.

Fledging: Period in a bird's life from hatching to first flight.

Fledgling: Young bird in the fledging stage.

Food web: All the interactions of predator and prey, included along with the exchange of nutrients into and out of the soil. These interactions connect the various members of an ecosystem, and describe how energy passes from one organism to another.

Forage: Prey or food species of an animal.

Fry: Newly hatched young fish.

Gall bladder: A small sac, located in the liver, that stores and concentrates bile.

Gill bar: One of a series of bony or cartilaginous arches on each side of the pharynx that support the gills; also referred to as "branchial arches."

Gill filament: One of a series of structures that project out of a gill bar and support numerous gill lamellae.

Gill lamellae: Tiny, parallel, thin-walled and leaf-like projections which cover the gill filaments; these are the actual locations within the gill where gases are exchanged between water and blood.

Gill netting: A passive fish capturing device which uses vertical walls of netting set out in a straight line; capture is based on the fortuitous encounter of aquatic organisms with the net.

Gill raker: Stiff projections along the inner margins of the branchial arches; some fish species use these structures to strain incoming food particles.

Gill septum: Flap-like gill cover in cartilaginous fish, which prevents oxygen-poor water from being drawn back into the branchial cavity during breathing.

Glycogen: The principal carbohydrate storage material in animals.

Gonads: Generic name for sex organs (ovaries and testes).

Growth rate: Rate of change over time the body mass or body length of a species.

Habitat-based replacement costs (HRC): Method which determines the cost of offsetting ecological losses by increasing production of those resources through restoration of natural habitats.

Habitat equivalency analysis (HEA): A service-to service approach for restoration scaling that quantifies changes in the flow of services from natural resources while accounting for the magnitude, timing, and duration of those service flow changes over time.

Haemal spines: The ventral spine in the caudal vertebra.

Heart: A hollow, multi-chambered, muscular organ used for pumping blood throughout the circulatory system.

Hemoglobin: Iron-rich protein packed in red blood cells; responsible for carrying oxygen to the tissues and removing carbon dioxide.

Heteroskedasticity: A condition in regression analysis in which the size of the error term is correlated with one or more explanatory variables, potentially creating biased regression estimates.

Horizontal septum: A tough membrane dividing the axial musculature into dorsal and ventral halves.

Hybridize: To crossbreed between two different species.

Hydrodynamics: The study of fluid motion and fluid-boundary interaction.

Ichthyoplankton: Earliest life stages (chiefly eggs and larvae) of certain fish species which remain suspended in the water column as plankton for up to several weeks.

Imbricate scale: A type of scale in fish, which overlaps like tiles on a roof.

Impingement: The entrapment of aquatic organisms on the outer part of an intake structure or against a screening device during periods of intake water withdrawal.

Inelastic: Not elastic; slow to react or respond to changing conditions.

Inner ear: Equilibrium organ located in the skull.

Integument: Covering or skin.

Intertidal: The area along the coastline exposed to the air and submerged by the sea during each tidal cycle.

Intestine: The lower part of the alimentary canal, extending from the pyloric caeca to the anus.

Invertebrate: Animals that lack a spinal column or backbone, including mollusks (e.g., clams and oysters), crustaceans (e.g., crabs and shrimp), insects, starfish, jellyfish, sponges, and many types of worms.

Invertebrate drift: Invertebrates that float with the current.

Kidneys: In fish, a pair of elongated organs that run along the dorsal part of the abdominal cavity; they form and excrete urine, regulate fluid and electrolyte balance, and act as endocrine glands.

Lacustrine: Related to open freshwater bodies such as lakes, reservoirs, and impounded rivers.

Lateral line: The line, or system of lines, of sensory organs located along the head and sides by which fish detect water current and pressure changes and vibrations.

Lens: A transparent spherical object in the eye, situated behind the iris, which focuses incoming light on the retina.

Leptocephali: A colorless, transparent, flattened larva, esp. of certain eels and ocean fishes.

Leptoid scale: A type of scale found mostly in higher bony fish.

Limnetic (zone): Surface layer where most photosynthesis takes place.

Littoral (zone): Shallow nearshore region defined by the band from 0 depth to the outer edge of rooted plants.

Liver: A large, reddish-brown, glandular organ with multiple functions, including: bile secretion, fat and carbohydrate storage, yolk manufacture, blood detoxification, blood cell production, and other metabolic processes.

Lymph: A clear, yellowish fluid formed from liquid constituents of blood that have leaked out of capillaries and into the surrounding tissues.

Lymphatics: A network of vessels for returning lymph back to the circulatory system.

Macula: A sensory tissue found in inner ear sacs and canals.

Mangrove: One of several different species of semi-aquatic trees growing along marine and estuarine shorelines in tropical and subtropical regions of the world; also refers to the habitat created by these trees.

Marine: Refers to the ocean.

Mean: Arithmetic average computed by dividing the sum of a set of terms by the number of terms.

Mean annual flow: The average of daily flows over a calendar year.

Median: A value in an ordered set of values below and above which there is an equal number of values or which is the arithmetic mean of the two middle values if there is no one middle number.

Median fin: See vertical fin.

Mesohaline: Water with a salt content ranging between 5 and 18 parts per thousand (ppt).

Metric: A standard of measurement.

Migration: The movement of animals in response to seasonal changes or changes in the food supply.

Mollusks: A large group of invertebrate species; major subgroups in freshwater habitats are represented by gastropods (i.e., snails) and bivalves (i.e., clams and mussels).

Monetization: In the context of this rulemaking, the process of placing a monetary value on a physical environmental change.

Monte Carlo: A stochastic modeling technique that involves the random selection of sets of input data for use in repetitive model runs. Probability distributions are generated as the output of a Monte Carlo simulation.

Mortality rate: Death rate. Includes **Natural mortality Rate** and **Fishing mortality rate**.

Mosaic scale: *An arrangement whereby scales do not overlap but instead abut each other like pieces in a mosaic.*

Mouth: The opening through which food and water passes into the buccal cavity of fish.

MSX: A disease caused by a protozoan that infects oysters.

Mud flats: An intertidal area characterized by soft, muddy substrate; typically found along tidal creeks or in quiet backwaters.

Muscle segment: a.k.a. myomeres; a block of muscles, the contraction of which produces movement in the body.

Myomeres: Individual W-shaped muscle blocks that are a part of the axial musculature.

Mysids: Small (<3 cm), shrimp-like crustaceans of the order Mysidacea that go by the common name of opossum shrimp; they are morphologically similar to crayfish but have greatly elongated and modified appendages for use in active swimming.

Nasal pit: One or two small depressions in the head region of fish, which contain the olfactory epithelium.

Navigation pool: A long stretch of river maintained at a minimum depth by a dam, and accessible via one or more gated locks.

Nearctic: Designates a biogeographic subregion which includes the arctic and temperate parts of North America and Greenland.

Nematodes: Unsegmented round worms, some of which are parasitic.

Neritic Province: Area over the continental shelf.

Neural circuitry: The intricate and interconnected web of nerves that make up the nervous system.

Neural spine: A thin, upward-facing bony outgrowth of the vertebrae in most fish species.

Neuromast: A group of sensory cells that together make up the lateral line.

Non-consumptive use (of water): Refers to water use practices whereby water is returned to its source after it has been used.

Non-native species: a.k.a. exotic or invasive species; these terms refer species which evolve in one region of the world but are intentionally or accidentally introduced in another where they lack natural enemies and can take over local ecosystems.

Non-response bias: Potential bias in survey results that occurs when people who choose not to respond to a survey would have answered in ways that significantly differ from those who did respond.

Nonuse benefits: The value that people derive from a good that they do not use (types of non-use benefits include bequest value, existence value, and option value).

Notochord: A stiff, rod-like structure that provides the major axial support in the body of adult lower chordates, including cyclostomes.

Nursery habitat: Any one of a number of aquatic habitats used by the early lifestages of many fish and invertebrate species to complete their development or find food and shelter.

Oceanic Province: A pelagic division of the ocean, located beyond the continental shelf.

Ocular fluid: The transparent liquid that fills the inside of the eye.

Olfaction: The sense used to perceive and distinguish odors.

Olfactory bulbs: That part of the brain involved with the sense of smell.

Olfactory cell: A specialized cell used to detect the presence of odor molecules.

Olfactory epithelium: The collection of olfactory cells, supporting cells, mucus glands, and nerve endings located inside the nasal pit.

Oligohaline: Water with salinity ranging between 0.5 to 5 parts per thousand (ppt) .

Omnivorous: Feeding on both animals and plants.

Open-cycle (cooling system): A cooling water system in which heat is transferred using water (fresh or saline) that is withdrawn from a river, stream or other water body (man-made or natural), or a well, that is passed through a steam condenser one time, and then returned to the stream or water body some distance from the intake. Typically, such waters are required to be cooled in cooling ponds before returning to a stream or other body of water. Also referred to as once-through cooling.

Operculum: The bony gill cover of fishes which prevents oxygen-poor water from being drawn back into the branchial cavity during breathing.

Optic nerve: A bundle of sensory tissue that conducts electrical impulses from the retina to the brain.

Ornithological: Of, or relating to birds.

Osmoregulation: The process by which organisms maintain a proper internal fluid and salt balance.

Osmoregulatory adjustment: An change in the internal fluid and salt balance of fish in response to fluctuations in external salt concentrations.

Ossified: Hardened like or into bone.

Osteichthyes: The class of lower vertebrates comprising the bony fishes.

Otolith: A small mass of calcified material deposited on top of the macula within the inner ear.

Ova: Plural of ovum; egg or female gamete.

Paired fins: Pectoral fins, placed just behind the gills, and the pelvic fins, variable in position and sometimes lacking entirely.

Pancreas: A gland, situated near the stomach, that secretes digestive juices into the intestine through one or more ducts.

Parr: Life stage of fish between the fry and smolt stages where ovoid parr markings are well developed along the side of the fish; a young salmon or trout living and feeding in freshwater, before the migration to a sea.

Pathogen: An organism (usually microbial) capable of inducing disease in humans or wildlife receptors.

Pectoral fin: Either of a pair of fins usually situated behind the head, one on each side of the fish.

Pelagic: Referring to the open sea at all depths (pelagic animals live in the open sea and are not limited to the ocean bottom).

Pelagic egg: A fish or aquatic invertebrate egg that stays suspended in the water column for part or whole of its development.

Pelvic fin: Either of a pair of fins on the lower surface of the body located behind the pectoral fins.

Pelvic girdle: A bony or cartilaginous arch supporting the pelvic fins.

Percentile: A value on a scale of one hundred that indicates the percent of a distribution that is equal to or below it.

Peripheral nervous system: The portion of the nervous system lying outside the brain and spinal cord.

Pharyngeal region: The area of the mouth located near the pharynx.

Pharynx: The part of the throat into which the gill slits open.

Photic (zone): Zone where light is sufficient for photosynthesis; in oceanic waters above approximately 200 m in depth.

Photosynthesis: The process in green plants and certain other organisms by which carbohydrates are synthesized from carbon dioxide and water using light as an energy source. Most forms of photosynthesis release oxygen as a byproduct. Chlorophyll typically acts as the catalyst in this process.

Phytoplankton: Small, often single-celled plants that live suspended in bodies of water (e.g., estuaries).

Piscivorous: Feeding on fish.

Placoid scale: Another name for dermal denticle.

Planktivorous: Feeding on plankton.

Planktonic: Free-floating. Plankton are tiny free-floating organisms.

Pneumatic duct: The duct connecting the air bladder to the gut in the adults of certain fish species.

Polychaetes: Scientific name for marine worms.

Polychlorinated biphenyls (PCBs): A large group of related chemicals with oil-like properties which were widely used in the past in electrical transformers.

Polycyclic aromatic hydrocarbons (PAHs): A large group of related chemicals characterized by multiple ring structures; derived mainly from crude oil or from combustion processes.

Potamodramous: Fish that migrate from lakes up rivers or streams, like salmon, walleye, and white bass.

Predator: Organism which hunts and eats other organisms. This includes both carnivores, which eat animals, and herbivores, which eat plants.

Prey: Organism hunted and eaten by a predator.

Primary consumer: An organism that feeds mostly on plant material; all herbivores are primary consumers.

Primary productivity: Transformation of chemical or solar energy to biomass. Most primary production occurs through photosynthesis, whereby green plants convert solar energy, carbon dioxide, and water to glucose and eventually to plant tissue.

Producer surplus: The extra value that producers receive for a good beyond the price they would be willing to sell the good for.

Profundal (zone): Deep-water zone in lakes or oceans that is not penetrated by sunlight.

Propagule: A floating structure used for reproduction in sea grasses and other aquatic plant species; the propagule is transported by currents and takes root when reaching a favorable habitat.

Protrusible mouth: A mouth that projects forward as a tube when opened.

Purse seine: A large seine, for use generally by two boats, that is drawn around a school of fish and then closed at the bottom by means of a line passing through rings attached along the lower edge of the net.

Pyloric caeca: A number of finger-like extensions located at the end of the stomach in bony fish species, which probably help in food digestion and absorption.

Recall bias: Potential bias in a survey results that occurs when participants provide false information because they cannot (or incorrectly) remember their actions in the past.

Receptor cells: A class of cells of the nervous system that specialize in detecting external stimuli.

Recruitment: Usually refers to the addition of new individuals to the fished component of stock. It may also refer to new additions to sub-components, e.g., 'recruitment to the fishery' refers to fish entering the actual fishery, and this is determined by the size and age at which they are first caught.

Rectum: The comparatively straight, terminal section of the intestine, ending in the anus.

Red blood cells: One of several types of cells that make up blood; they are packed with hemoglobin and carry oxygen to the cells and tissues and carbon dioxide back to the respiratory organs.

Red body: The blood-rich organ that secretes gases into the swim bladder.

Red tide: The explosive growth of toxic unicellular algae which can cause the affected surface waters to turn reddish.

Replacement cost: The cost of replacing the services provided by an environmental good that has been damaged or destroyed.

Restoration: The return of an ecosystem or habitat to its original community structure, natural complement of species, and natural functions.

Rete mirabile: A dense bundle of countercurrent capillaries located in the red body; it extracts gases from the incoming blood for secretion into the swim bladder.

Retina: The light-sensitive tissue at the back of the eye that receives the image produced by the lens; contains the rods and cones.

Revealed preference: Refers to a class of valuation methods that analyze consumer purchases of a good (especially housing) to determine the values they place on the characteristics of the good.

Riparian: Having to do with the edges of streams or rivers.

River debit: The volume of water which flows downstream during a certain period of time.

Riverine: Living in a river; living in flowing water.

Rod: One of two types of light-sensitive cells located in the retina; provides vision in dim light or semidarkness.

Rotifer: Any microscopic animal of the phylum (or class) Rotifera, found in fresh and salt waters, having one or more rings of cilia on the anterior end.

Salinity: A measure of the salt concentration of water. Higher salinity means more dissolved salts.

Salt barrens: A type of habitat created when low lying land along a coastline is flooded by spring tides; the area develops into a hyper saline habitat that supports salt resistant terrestrial plants after the sea water recedes or evaporates.

Salt marsh: A tidally-influenced semi-aquatic habitat which supports salt tolerant plant species.

Secchi disk: A 20 cm-wide black and white round plastic disk which is lowered into the water to measure the transparency of the water column.

Sedge: Any rushlike or grasslike plant of the genus Carex, growing in wet places.

Sedimentation: (1) Strictly, the act or process of depositing sediment from suspension in water. Broadly, all the processes whereby particles of rock material are accumulated to form sedimentary deposits. Sedimentation, as commonly used, involves not only aqueous but also glacial, aeolian, and organic agents. (2) (Water Quality) Letting solids settle out of wastewater by gravity during treatment.

Sinus venosus: The heart region that collects incoming oxygen-poor blood and passes it on to the atrium.

Skull: The bony framework or skeleton of the head, enclosing the brain and supporting the face.

Smolt: The post-parr form in which the young of sea-going fish (especially trout and salmon) migrate from freshwater to the sea.

Spartina: A genus of salt-tolerant grasses found in coastal regions.

Spawning / spawn: Release or deposition of spermatozoa or ova, of which some will fertilize or be fertilized to produce offspring; fish reproduction process characterized by females and males depositing eggs and sperm into the water simultaneously or in succession so as to fertilize the eggs.

Speciation: Formation of new species, through reproductive isolation?

Species diversity: Number, evenness, and composition of species in an ecosystem; the total range of biological attributes of all species present in an ecosystem.

Species evenness: The distribution of individual organisms among the species present in a sample or area; evenness is low when most individuals belong to a few species, as is often the case in disturbed or contaminated environments. Evenness increases when the organisms belong to many different species, as is the case in more pristine environments.

Species richness: The number of species present in a sample.

Sphincter: A circular band of voluntary or involuntary muscle that encircles an orifice of the body or one of its hollow organs.

Spinal cord: The thick bundle of nerve tissue that comes from the brain and extends through the spinal column.

Spine: The spinal or vertebral column; also referred to as the backbone.

Spiral valve: A structure located in the intestine of all Chondrichthyes and some primitive bony fish species, which controls the flow of digested food and enhances the absorption of food molecules.

Spleen: A highly vascular, glandular, ductless organ that serves as a blood reservoir; it also forms mature lymphocytes and removes old red blood cells from the circulatory system.

Squalene: Oil found in the liver of many shark species, which creates buoyancy.

Staging area: Places where birds temporarily stay, feed, and rest during their annual migrations.

Stated preference: Refers to a class of valuation methods that use surveys to elicit the value that people place on non-market good.

Static: Not changing.

Stochastic: Random.

Stock: Group of individuals of a species which can be regarded as an entity for management or assessment purposes; a separate breeding population of a species; term used to identify a management unit of fishery species.

Stomach: A sac-like enlargement of the alimentary canal, forming an organ for storing, diluting, and digesting food.

Stratified random sample: A sample in which the survey population is separated into several groups (or strata) and then subjects are randomly selected from each group.

Striated muscle: The skeletal portion of the muscle tissue; striated muscle forms the bulk of the body's muscle tissue and gives the body its general shape.

Subsistence (fishing or angling): Fishing primarily to supply food (as opposed to fishing for recreation).

Substrate: "Supporting surface" on which an organism grows. The substrate may simply provide structural support, or may provide water and nutrients. A substrate may be inorganic, such as rock or soil, or it may be organic, such as wood.

Subtidal: The area of the ocean or estuary starting at the low tide line and extending outwards; the subtidal zone remains submerged, even during low tide.

Suspended solids: Minute particles (e.g., clay flecks or unicellular algae) present in the water column, which are small enough to resist rapid settling.

Swale: A low place in a tract of land, usually moister and often having ranker vegetation than the adjacent higher land.

Sympatric: Occurring in the same area; capable of occupying the same geographic ranges without loss of identity by interbreeding

Tailwater: The turbulent river water immediately adjacent to or just downstream of a lock and dam (L&D) structure; it includes areas around the lock flushing valves and the dams themselves.

Tapetum: A highly-reflective membrane located in the back of the retina, which enhances night vision.

Taste bud: One of numerous small, flask-shaped bodies, chiefly in the epithelium of the tongue, which are responsible for detecting taste molecules.

Taste pore: The opening of the taste bud to the outside world.

Taxa: Plural of taxon; a taxon is a group of organisms comprising one of the categories in taxonomnic classification (i.e., phylum, class, order, family, genus, or species). The term is used when organisms cannot be identified at the species level. Such organisms include larval or juvenile lifestages that do not yet have their adult forms; they can be designated with certainty only at a higher taxonomic level.

Teleost: A subgroup of the bony fish; includes most species of aquarium, sport, and food fish.

Temperate: Moderate climate with long, warm summers and short, cold winters.

Terminal mouth: A mouth located in the front of a fish (as opposed to a sub-terminal mouth, located underneath the head).

Threatened and endangered (species) (T&E): Animals, birds, fish, plants, or other living organisms recognized as threatened with extinction by anthropogenic (man-caused) or other natural changes in the environment. Used interchangeably in this document with "special status species."

Thrombocytes: One of the three principal types of blood cells found in blood plasma; they help initiate the clotting process.

Tidal range: The difference in height between the average low tide and high tide line.

Trophic cascade: An impact that trickles down through the food web with repercussions for the larger ecosystem; top-down effect of predators on the biomass of organisms at lower trophic levels.

Trophic level: A feeding level in an ecological community; plant eaters are at a lower trophic level than meat eaters.

Trophic transfer efficiency: Proportion of production of prey that is converted to production of consumers at the next trophic level.

Tropical: Climate characterized by high temperature, humidity and rainfall, found in a belt on both sides of the equator.

Turbidity: Suspended particles in a water sample causing light to scatter or absorb; high turbidity may be harmful to aquatic life because it can decrease light penetration and inhibits photosynthesis in the water column.

Urea: A toxic compound occurring in urine as a product of protein metabolism.

Variance: The square of the standard deviation. A measure of the dispersion of data or how much values in a sample differ from the sample average.

Vegetative growth: An asexual reproductive strategy used by sea grasses and other plants; it consists of sending out one or more shoots that grow into new plants in the immediate vicinity of its "parent."

Vein: One of the system of branching vessels conveying blood from various parts of the body back to the heart.

Ventral aorta: The artery that carries blood from the heart to the aortic arches (Kimmel et al., 1995).

Ventral fin: Either of a pair of fins on the lower surface of the body in fish; variable in position and sometimes lacking entirely.

Ventral musculature: Part of the axial musculature that is located below the horizontal septum.

Ventricle: A muscular heart chamber that receives blood from the atrium and pumps it into the conus arteriosus

Venule: A small vein.

Vertebrae: The bones or segments composing the backbone.

Vertebrate: Any species having vertebrae; having a backbone or spinal column; examples include fish, amphibians, reptiles, birds, and mammals.

Vertical fins: Fins situated along the centerline of the body; include dorsal, anal, and caudal fins.

Visceral nervous system: An additional component of the nervous system that serves the gut, circulatory system, glands, and other internal organs.

Visual pigments: Light-sensitive molecules found in rods and cones within the retina.

Water withdrawal: The removal of water from the ground or diversion from a surface water source for use by agriculture, municipalities, or industries.

Watershed: Drainage area of a stream, river, or lake leading to a single outlet for its runoff; synonymous with catchment.

Weberian ossicles: A chain of bony processes of the anterior vertebrae that connect the swim bladder to the head region in certain fish species.

Welfare gain: In the context of this rulemaking, the benefit to society from an environmental improvement.

White blood cells: One of the three principal types of blood cells found in blood plasma; they fight bacterial infections and other diseases.

Willingness-to-pay: The value that people will pay to obtain a good (usually associated with the results of a stated preference study).

Zooplankton: A generic term referring to the small life stages (i.e., eggs, larvae, juveniles, and adults) of many fish and invertebrate species.

(Sources: Cole, 1983; Goldman and Horne, 1983; Nicholson, 1994; Maryland Department of Natural Resources, 1995; Madigan et al., 1997; San Diego Natural History Museum, 1998; Shaw, 1998; U.S. EPA, 1998c; Water Quality Association, 1999; Childrens Mercy Hospital, 2000; Washington Tourist.com, 2000; Froese and Pauly, 2001; Lackey, 2001; Madzura, 2001; Mouratov, 2001; University of Wisconsin Sea Grant Institute, 2001; Badman's Tropical Fish, 2002; Chapin, 2002; Chudler, 2002; Eckhardt, 2002; Ehlinger, 2002; Encyclopedia Britannica Online, 2002; European Environment Agency, 2002; Fish Endocronology Research Group, 2002; Greenhalgh, 2002; King and Mazzotta, 2002; Lexico LLC, 2002; Lycos, Inc., 2002; Merriam-Webster Online, 2002; Nature Conservation Council of NSW, 2002; NRDC, 2002; UCMP, 2002; U.S. EPA, 2002c)

References

Able, K.W. and M. P. Fahay. 1998. The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight. Rutgers University Press, New Brunswick, NJ.

AFS (American Fisheries Society). 1993. Sourcebook for Investigation and Valuation of Fish Kills. American Fisheries Society, Bethesda, MD.

Agnello, R. 1989. The Economic Value of Fishing Success: An Application of Socioeconomic Survey Data. *Fishery Bulletin*. Vol. 87:1.

Akçakaya, H.R., and L.R. Ginzburg. 1991. Ecological risk analysis for single and multiple populations. In A. Seitz, and V. Loeschcke, eds., *Species Conservation: A Population-Biological Approach*. Birkhaeuser Verlag, Basel, Switzerland, pp. 73-87.

Alaska Department of Fish and Game. 1999. White-winged Scoters! What are they? Alaska Department of Fish and Game website. http://www.state.ak.us/adfg/wildlife/duck/scoter/wwscoter.htm Accessed 4/1/02.

Allan, J.D. 1995. Stream Ecology, Structure and Function of Running Waters. Chapman & Hall, New York.

Allen, D.M., J.H. Hudson, and T.J. Costello. 1980. Postlarval shrimp (Penaeus) in the Florida Keys: Species, size, and seasonal abundance. *Bulletin of Marine Science* 30(1):21-33.

American Electric Power Company, Inc. (AEP). 2001. American Electric Power Company, Inc. (AEP). http://www.aep.com/about/facts.htm October 25, 2001.

American Electric Power Service Corporation. 1981. Cardinal Plant Demonstration Document for P.L. 92-500 Section 316(b). Ohio Power Company of the American Electric Power System and Buckeye Power, Inc. March 30.

Arrow, K., R. Solow, P. Portney, E. Leamer, R. Radner, and H. Schuman. 1993. Report of the NOAA panel on contingent valuation. *Federal Register* 58(10):4602-4614.

Atlantic States Marine Fisheries Commission. 2000a. Interstate Fisheries Management Program: Atlantic Croaker. http://www.asmfc.org/Programs/Fish%20Mgnt/croaker1.html Accessed July 12, 2000.

Atlantic States Marine Fisheries Commission. 2000b. Interstate Fisheries Management Program: Shad and River Herring. http://www.asmfc.org/Programs/Fish%20Mgnt/SHAD6.html. Accessed July 13, 2000.

Atlantic States Marine Fisheries Commission. 2000c. Interstate Fisheries Management Program: Spot. http://www.asmfc.org/Programs/Fish%20Mgnt/SPOT1.html. Accessed 7/13/00.

Atlantic States Marine Fisheries Commission. 2000d. Interstate Fisheries Management Program: Striped Bass. http://www.asmfc.org/Programs/Fish%20Mgnt/STRBASS6.html. Accessed 7/13/00.

Atlantic States Marine Fisheries Commission. 2000e. Interstate Fisheries Management Program: Tautog. http://www.asmfc.org/Programs/Fish%20Mgnt/TAUTOG1.html. Accessed 11/27/00.

Atlantic States Marine Fisheries Commission. 2000f. Interstate Fisheries Management Program: Weakfish. http://www.asmfc.org/Programs/Fish%20Mgnt/WEAKFISH1.html. Accessed 7/13/00.

Atlantic States Marine Fisheries Commission. 2000g. Review of the Fishery Management Plan for Striped Bass. http://www.asmfc.org/Programs/Fish%20Mgnt/2000%20FMP%20Reviews/StrBassFMPRev2000_FMP.html. Accessed 7/12/00.

Atlantic States Marine Fisheries Commission. 2000h. Review of the ASMFC Fishery Management Plan for Tautog (*Tautoga onitis*). http://www.asmfc.org/Programs/Fish%20Mgnt/FMP%20Reviews/2000%20Tautog%20Reviews.htm. Accessed 11/00.

Atlantic States Marine Fisheries Commission. 2001a. Interstate Fisheries Management Program: Atlantic Herring. http://www.asmfc.org/Programs/Fish%20Mgnt/AHERRING1.html. Accessed 2/12/01.

Atlantic States Marine Fisheries Commission. 2001b. Review of the Fishery Management Plan for Atlantic Menhaden. http://www.asmfc.org/Programs/Fish%20Mgnt/2000%20FMP%20Reviews/menhaden2000_FMP.HTM. Accessed 3/19/01.

Ault, J.S., G.A. Diaz, S.G. Smith, J. Luo, and J.E. Serafy. 1999. An efficient sampling survey design to estimate pink shrimp population abundance in Biscayne Bay, Florida. *North American Journal of Fisheries Management* 19:696-712.

Auster, P.J. 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North and Mid-Atlantic) Tautog and Cunner, Biological Report 82.

Author Unknown. 2001. Blue Mussel Morphology and Anatomy, Physiology, Life Cycle and Reproduction. From the home page for the study of Blue Mussel (*Mytilus edulis*) aquaculture industry in Green Bay, Newfoundland. A compilation of research done by students of Indian River High School. http://www.irhs.k12.nf.ca/index.htm. Accessed 06/30/01.

Badman's Tropical Fish. 2002. Glossary of Terms. http://badmanstropicalfish.com/glossary.html. Accessed 3/29/02.

Bailey, R.M. and G.E. Smith. 1981. Origin and geography of the fish fauna of the Laurentian Great Lakes. *Canadian Journal of Fisheries and Aquatic Science* 38:1539–1561.

Baird, P.H. 1990. Influence of abiotic factors and prey distribution on diet and reproductive success of three seabird species in Alaska. *Ornis Scand.* 21:224-235.

Balletto, J.H. and H.W. Brown. 1980a. Kammer Plant Demonstration Document for P.L. 92-500 Section 316(b). Prepared for the Ohio Power Company of the American Electric Power System by the American Electric Power Service Corporation. May 20.

Balletto, J.H. and H.W. Brown. 1980b. Philip Sporn Plant Demonstration Document for P.L. 92-500 Section 316(b). Prepared for the Appalachian Power Company and Ohio Power Company of the American Electric Power System. March 7.

Balletto, J.H. and S.A. Zabel. 1978a. Clifty Creek Station Demonstration Document for P.L. 92-500 Section 316(b). Prepared for Indiana - Kentucky Electric Corporation. September 26.

Balletto, J.H. and S.A. Zabel. 1978b. Tanners Creek Plant Demonstration Document for P.L. 92-500 Section 316(b). Prepared for Indiana & Michigan Electric Company.

Barnthouse, L.B. 2000. Impacts of power-plant cooling systems on estuarine fish populations: the Hudson River after 25 years. *Environmental Science & Policy* 3:S341-348.

Barrett, R.T. and Y.V. Krasnov. 1996. Recent responses to changes in stocks of prey species by seabirds breeding in the southern Barents Sea. *J. Mar. Sci.* 53:713-722.

Bartell, S.M. and K.R. Campbell. 2000. Ecological Risk Assessment of the Effects of the Incremental Increase of Commercial Navigation Traffic (25, 50, 75, and 100 Percent Increase of 1992 Baseline Traffic) on Fish. ENV Report 16. Prepared for U.S. Army Engineer District, Rock Island. July. http://www.mvr.usace.army.mil/pdw/nav_study/env_reports/ENVRPT16.htm. Accessed 2000.

Bason, W.H. 1971. Ecology and Early Life History of Striped Bass, *Morone saxatilis*, in the Delaware Estuary. Bulletin No. 4. Thesis. Middletown, DE. 122 pp.

BCCVB. 2002. Southeastern Massachusetts. Bristol County Convention & Visitors Bureau. http://www.southofboston.org/bristol/home.htm. Accessed 1/02.

BEA. 1998. Bureau of Economic Analysis National Accounts Data: Gross Product by Industry. http://www.bea.doc.gov/bea/dn2/gpoc.htm

Beardsley, G.L. Jr. 1970. Distribution of migrating juvenile pink shrimp, *Penaeus duorarum duorarum* Burkenroad, in Burronwood Canal, Everglades National Park, Florida. *Transactions of the American Fisheries Society* 99(2):401-408.

Beauchamp, D.A., M.F. Shepard and G.B. Pauley. 1983. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest): Chinook Salmon. FWS/OBS-82/11.6. Prepared for U.S. Fish and Wildlife Service. October.

Beck, M.W. 1995a. Size-specific shelter limitation in stone crabs: a test of the demographic bottleneck hypothesis. *Ecology*. 76(3):968-980.

Beck, S. 1995b. White Perch. In: *Living Resources of the Delaware Estuary*. L.E. Dove and R.M. Nyman (eds.). pp. 235-243.

Becker, P.H., T. Troschje, A. Behnke, and M. Wagener. 1997. Starvation of common tern Sterna hirundo fledglings during heat waves. *J. Fur Ornithologie* 138:171-182.

Beckman, D.W., A.L. Stanley, J.H. Render, and C.A. Wilson. 1990. Age and growth of black drum in Louisiana waters of the Gulf of Mexico. *Transactions of the American Fisheries Society* 119:537-544.

Beever, J.W. 1997. The regional wildlife habitat plan in the Tampa Bay region: Accomplishments and Assessment. p.115-128. In: *Proceedings of the Tampa Bay Area Scientific Information Symposium 3: Applying Our Knowledge*, October 21-23, 1996 (S.F. Treat, ed.), Tampa Bay National Estuary Program.

Begon, M., and M. Mortimer. 1986. Population Ecology: A Unified Study of Animals and Plants. Sinauer Associates, Sunderland, MA.

Beintema, A.J. 1997. European black terns (*Chlidonias niger*) in trouble: Examples of dietary problems. *Colon. Waterbirds* 20:558-565.

Ben-Akiva, Moshe, and Steven R. Lerman. 1985. Discrete Choice Analysis: Theory and Applications to Travel Demand. Cambridge, Massachusetts: the MIT Press.

Benda, R.S. and W.C. Houtcooper. 1977. Impingement Studies at 16 Electric-Generating Plants in Michigan. In: Ecological Analysts Inc. *Third National Workshop on Entrainment and Impingement: Section 316(b) — Research and Compliance.* L.D. Jensen (eds.). New York, NY. 425 pp.

Bert, T.M. and J.M. Stevely. 1989. Population characteristics of the stone crab, *Menippe mercenaria*, in Florida Bay and the Florida Keys. *Abstract. Bull. Mar. Sci.* 44(1):515.

Bert, T.M., R.E. Warner and L.D. Kessler. 1978. The Biology and Florida Fishery of the Stone Crab, *Menippe mercenaria* (Say), With Emphasis on Southwest Florida. Technical Paper No. 9. State University System of Florida Sea College Program. October. 82 pp.

Bielsa, L.M., W.H. Murdich, and R.F. Labisky. 1983. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Florida) — Pink Shrimp. FWS/OBS-82/11.17. October.

Bigelow, H.B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. *U.S. Fish and Wildlife Service Fisheries Bulletin*, Volume 53, 577 pp.

Bishop, R.C., S.R. Milliman, K.J. Boyle, and B.L. Johnson. 1990. Benefit-Cost Analysis of Fishery Rehabilitation Projects: A Great Lakes Case Study. *Ocean & Shoreline Management* 13, no. 3&4, 253-274.

Bockstael, N.E., W.M. Hanemann, and C.L. Kling. 1987. Estimating the Value of Water Quality Improvements in a Recreational Demand Framework, *Water Resources Research* 23, No. 5: 951-960.

Bockstael, N.E., K.E. McConnell and I.E. Strand. 1991. In: *Measuring the Demand for Environmental Quality*, John B. Braden and Charles D. Kolstad (eds.). New York: Elsevier Science Publishers B.V.

Bodola, A. 1966. Life history of the gizzard shad, *Dorosoma cepedianum* (Le Sueur), in western Lake Erie. *Fishery Bulletin* 65(2):391-425.

Boler, R.N., R.C. Malloy, and E.M. Lesnett. 1991. Surface water quality monitoring by the environmental protection commission of Hillsborough County. pp. 111-135. In: *Proceedings, Tampa Bay Area Scientific Information Symposium* 2. February 27-March 1, 1991, Tampa, FL (S.F. Treat and P.A. Clark, eds.), 528 pp.

Bone, Q. and N.B. Marshall. 1995. Biology of Fishes. Blackie Academic & Professional, UK.

Boreman, J. 1977. Impacts of Power Plant Intake Velocities on Fish. FWS/OBS-76/20.1. U.S. Department of the Interior, Fish and Wildlife Service, Biological Services Program.

Boreman, J. 1993. Evaluation of the PSE&G Estimates of Entrainment and Impingement Mortality at the Salem Nuclear Plant. Prepared for Delaware Department of Natural Resources and Environmental Control. December.

Boreman, J. 2000. Surplus production, compensation, and impact assessments of power plants. *Environmental Science & Policy* 3:S445-S449.

Boschker, E. 2001. Pictures of Saltmarshes and Seagrass Beds http://www.nioo.knaw.nl/homepages/boschker/Picturesl[illegible].htm. Accessed 11/20/01.

Boston Edison Company. 1991. Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report Number 37, January 1990-December 1990. April 30.

Boston Edison Company. 1992. Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report Number 39, January 1991-December 1991. April 30.

Boston Edison Company. 1993. Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report Number 41, January 1992-December 1992. April 30.

Boston Edison Company. 1994. Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report Number 43, January 1993-December 1993. April 30.

Boston Edison Company. 1995a. Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report Number 45, January 1994-December 1994. April 30.

Boston Edison Company. 1995b. Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report Number 46, January 1995-June 1995. October 31.

Boston Edison Company. 1996. Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report Number 47, January 1995-December 1995. April 30.

Boston Edison Company. 1997a. Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report Number 49, January 1996-December 1996. April 30.

Boston Edison Company. 1997b. Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report Number 50, January 1997-June 1997. October 31.

Boston Edison Company. 1998. Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report Number 51, January 1997-December 1997. April 30.

Boston Edison Company. 1999. Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report Number 53, January 1998-December 1998. April 30.

Boyd, J., D. King, and L.A. Wainger. 2001. Compensation for Lost Ecosystem Services: The Need for Benefit-Based Transfer Ratios and Restoration Criteria. *Stanford Environmental Law Journal* 20(2):393-412.

Boydstun, L.B., R.J. Hallock, and T.J. Mills. 1992. Anadromous Fishes: Salmon. Pages 60-65 in Leet, W.S., C.M. Dewees, and C.W. Haugen (eds.), *California's Living Marine Resources and their Utilization*. California Sea Grant, Sea Grant Extension Publication UCSGEP-92-12. California Sea Grant Extension Program, University of California, Davis, CA.

Boyle, K.J. and R.C. Bishop. 1987. Valuing Wildlife in Benefit-Cost Analyses: A Case Study Involving Endangered Species.

Boyle, K.J., B. Roach, and D.G. Waddington. 1998. 1996 Net Economic Values for Bass, Trout and Walleye Fishing, Deer, Elk and Moose Hunting, and Wildlife Watching: Addendum to the 1996 National Survey of Fishing, Hunting and Wildlife-Associated Recreation. Prepared by the U. S. Fish and Wildlife Service, Report 96-2. August.

Brazner, J.C. 1997. Regional, Habitat, and Human Development Influences on Coastal Wetland and Beach Fish Assemblages in Green Bay, Lake Michigan. *Journal of Great Lakes Research* 23(1):36-51.

Breffle, W.S., and R.D. Rowe. 2002. Comparing Choice Question Formats for Evaluating Natural Resource Tradeoffs. *Land Economics* forthcoming, May 2002.

Broome, S.W. and C.B. Craft. 2000. Tidal salt marsh restoration, creation, and mitigation. Chapter 37 in *Reclamation of Drastically Disturbed Lands*. American Society of Agronomy, Madison, WI.

Brown, H. W. and J. H. VanHassel. 1981. Kyger Creek Station Demonstration Document for P.L.92-500 Section 316(b). Prepared for the Ohio Valley Electric Corporation and American Electric Power Service Corporation. June 24.

Buckley, J. 1989a. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic). Rainbow Smelt, *Biological Report* 82(11.106). 11 p.

Buckley, J. 1989b. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic). Winter flounder. *U.S. Fish and Wildlife Service Biological Report* 82(11.87). U.S. Army Corps of Engineers, TR EL-82-4. 12 pp.

Buckley, L.J. 1982. Effects of temperature on growth and biochemical composition of larval winter flounder *Pseudopleuronectes americanus*. *Marine Ecology Progress Series* 8:181-186.

Bur, M.T. 1982. Food of freshwater drum in western Lake Erie. *Journal of Great Lakes Research* 8(4):672-675.

Burgman, M.A., S. Ferson, and H.R. Akçakaya. 1993. Risk Assessment in Conservation Biology. Chapman & Hall, London.

Buzzards Bay Project National Estuary Program. 2001a. Atlas of Tidally Restricted Salt Marshes: Buzzards Bay Watershed, Massachusetts. Draft Final. Prepared for Massachusetts Wetlands Restoration Program, Boston, MA and Massachusetts Environmental Trust. January.

Buzzards Bay National Estuary Program 2001b. "buzzbay2001sma-atlas-public.xls". Summary of the tidally restricted wetlands in the Buzzards Bay watershed as of the fall of 2001. Estimates of the acres of phragmites at each location are included along with an initial restoration cost estimate and description of the nature of the tidal restriction. Received from Joe Costa, Buzzards Bay National Estuary Program. 2001.

CALFED. 2000a. Ecosystem Restoration Program Plan. Response to Comments, Volume II. July.

CALFED. 2000b. Ecosystem Restoration Program Plan. Volume I - Ecological Attributes of the San Francisco Bay-Delta Watershed. http://calfed.water.ca.gov/environmental_docs/july2000_eis.html. July.

CALFED. 2002. CALFED Bay-Delta Program. http://calfed.ca.gov/. Accessed 1/02.

California Department of Fish and Game 2001a. "grandtabXL.xls": Received from California Department of Fish and Game, Native Anadromous Fish and Watershed Branch

California Department of Fish and Game 2001b. "Green Sturgeon.xls": Received from California Department of Fish and Game, Central Valley Bay-Delta Branch.

California Department of Fish and Game 2001c. "Steelhead - ALLCOUNT.xls" :Received from California Department of Fish and Game

California Department of Fish and Game. 2002a. The economic importance of sport fishing. http://www.dfg.ca.gov/fishing/econ/sprtfsh.html. Accessed 1/18/02.

California Department of Fish and Game 2002b. Marine Sportfish Identification Pictures. http://www.dfg.ca.gov/mrd/msfindx1.html. Accessed 1/21/02.

California Department of Fish and Game. 2002c. Wildlife Gallery-Anadromus Species Resources. http://www.delta.dfg.ca.gov/gallery/anad.html. Accessed 1/21/02.

California Department of Fish and Game. 2002d. Young-of-the-year Striped Bass Abundance Indices http://www.delta.dfg.ca.gov/data/mwt99/charts.html. Accessed 1/02.

California Energy Commission. 2001. Contra Costa Unit 8 Power Project, Application for Certification (00-AFC-1). May 2001.

Campana, S.E., G.A. Chouinard, J.M. Hanson, and A. Fréchet. 1999. Mixing and migration of overwintering Atlantic cod (*Gadus morhua*) stocks near the mouth of the Gulf of St. Lawrence. *Canadian Journal of Fisheries and Aquatic Sciences* 56:1873-1881.

Campbell, J.S. and H.R. MacCrimmon. 1970. Biology of the emerald shiner, *Notropis atherinoides* Rafinesque in Lake Simcoe, Canada. *Journal of Fish Biology*, v. 2, p. 259-273.

Carlander, K.D. 1969. Handbook of Freshwater Fishery Biology: Life History Data on Freshwater Fishes of the United States and Canada, Exclusive of the Perciformes. Iowa State University Press, Ames.

Carlander, K.D. 1977. Handbook of Freshwater Fishery Biology: Life History Data on Centrarchid Fishes of the United States and Canada, Volume Two, Ames, IA, Iowa State University Press.

Carlander, K.D. 1997. Handbook of Freshwater Fishery Biology: Life History Data on Icthyopercid and Percid Fishes of the United States and Canada, Volume Three, Ames, IA, Iowa State University Press.

Carr, R.S., E.R Long, H.L. Windom, D.C. Chapman, G. Thursby, G.M. Sloane, and D.A. Wolfe. 1996. Sediment quality assessment studies of Tampa Bay, Florida. *Environ. Toxicol. Chem.* 15(7):1218-1231.

Carson, R.T. and R.C. Mitchell. 1993. The value of clean water: The public's willingness to pay for boatable, fishable, and swimmable quality water. *Water Resources Research* 29(7): 2445-2454.

Carson, R.T., N.E. Flores, and R.C. Mitchell. 1999. The Theory and Measurement of Passive Use Value. In *Valuing Environmental Preferences: Theory and Practice of the Contingent Valuation Method in the US, EU, and Developing Countries*. Edited by Ian J. Bateman and Kenneth G. Willis. New York: Oxford University Press.

Carson, R.T., N.E. Flores, K.M. Martin, and J.L. Wright. 1996. Contingent Valuation and Revealed Preference Methodologies: Comparing the Estimates for Quasi-Public Goods. *Land Economics*. 72(1):80-99.

Carson, R., W.M. Hanneman, R.J. Knopp, J.A. Krosnick, R.C. Mitchell, S. Presser, P.A. Ruud, and V.K. Smith. 1994. Prospective Interim Lost Use Value Due to DDT and PCB Contamination in the Southern California Bight. Prepared by Natural Resource Damage Assessment, Inc. for NOAA. La Jolla, CA.

Castro, L.R. and R.K. Cowen. 1991. Environmental factors affecting the early life history of bay anchovy *Anchoa mitchilli* in Great South Bay, New York. *Marine Ecology Progress Series* 76:235-247.

Castro, K.M., J.S. Cobb, R.A. Wahle, and J. Catena. In Press. Habitat addition and stock enhancement for American lobsters, Homarus americanus. *Marine and Freshwater Research.*

Caton, P.A. 2001. Developing an Effluent Trading Program to Address Nutrient Pollution in the Providence and Seekonk Rivers, Working Draft (12/6/01). http://envstudies.brown.edu/thesis/2002/caton/Trading/.

CDWR (California Department of Water Resources). 1994. Effects of the Central Valley Project and State Water Project on Delta Smelt and Sacramento Splittail. Biological Assessment prepared for the U.S. Fish and Wildlife Service, Ecological Services, Sacramento Field Office by California Department of Water Resources and U.S. Bureau of Reclamation, Mid Pacific Region, August 1994.

Chadwick, H.K., D.E. Stevens, and L.W. Miller. 1977. Some factors regulating the striped bass population in the Sacramento-San Joaquin Estuary, California. Pages 18-35 in: W. Van Winkle (ed.), *Proceedings of the Conference on Assessing the Effects of Power Plant Induced Mortality on Fish Populations*, Gatlinburg, Tennessee, May 3-6, 1977. Pergamon Press, NY.

Chang, S., P.L. Berrien, D.L. Johnson, and W.W. Morse. 1999. Essential Fish Habitat Source Document: Windowpane, *Scophthalmus aquosus*, Life History and Habitat Characteristics. NOAA Technical Memorandum NMFS-NE-137. September. 32 pp. http://www.nefsc.nmfs.gov/nefsc/publications/.

Chao, L.N. and J.A. Musick. 1977. Life history, feeding habits, and functional morphology of juvenile sciaenid fishes in the York River estuary. *Virginia. Fish. Bull.* 75(4):657-702.

Chapin, F.S, III. 2002. Textbook: Principles of Ecosystem Ecology (draft): Glossary. http://www.faculty.uaf.edu/fffsc/Ecotext.html. Accessed 4/1/02.

Charbonneau, J.J. and M. Hay. 1978. Determinants and Economic Values of Hunting and Fishing. Nationwide. Published by Wildlife Management Institute, Washington, DC.

Cherry, D.A. and R.J. Currie. 1998. Effects of Impingement/Entrainment at the Kanawha River Plant on the Fish Community Structure of the Kanawha River: Reflections on the 20 Year Study. In: *EPRI Clean Water Act Section 316(b) Technical Workshop.* EPRI Clean Water Act Section 316(b) Technical Workshop, September 22-24, Berkeley Springs, WV. D. Dixon and K. Zammit (eds.).

Cheung, T.S. 1969. The environmental and hormonal control of growth and reproduction in the adult female stone crab, *Menippe mercenaria* (Say). *Biological Bulletin* 136:327-346.

Childrens Mercy Hospital. 2000. Strata: What is a stratified random sample and why would I want to use one? http://www.cmh.edu/stats/ask/strata.htm Accessed 4/2/02.

Chittenden, M.E., Jr. 1971. Status of the striped bass, *Morone saxatilis*, in the Delaware River. *Chesapeake Sci.* 12:131-136.

Christensen, S.W., and C.P. Goodyear. 1988. Testing the validity of stock-recruitment curve fits. *American Fisheries Society Monograph* 4:219-231.

Christensen, S.W., D.L. DeAngelis, and A.G. Clark. 1977. Development of a stock-progeny model for assessing power plant effects on fish populations. In W. Van Winkle, ed. *Proceedings of the Conference on Assessing the Effects of Power-Plant Induced Mortality on Fish Populations*. Pergamon Press, New York, pp. 196-226.

Chudler, E.H. 2002. Adventures in Neuroanatomy: Divisions of the Nervous System. http://faculty.washington.edu/chudler/nsdivide.html Accessed 4/1/02.

Churchill, E.P. 1921. Life history of the blue crab. *Bulletin of the U.S. Bureau of Fisheries* 36:95-128.

Cincinnati Gas & Electric Company. 1979. 316(b) Demonstration, Walter C. Beckjord and Miami Fort Power Stations.

Clark, C.W. 1990. Mathematical Bioeconomics. The Optimal Management of Renewable Resources (2nd edition). John Wiley, New York.

Clark, K.E. 1995. Osprey. In: *Living Resources of the Delaware Estuary*. L.E. Dove and R.M. Nyman, (eds.) The Delaware Estuary Program. pp. 395-400.

Clark, P.A. 1991. Management directions and needs for Tampa Bay tidal tributaries. pp.497-510. In: *Proceedings, Tampa Bay Area Scientific Information Symposium 2*. February 27-March 1, 1991, Tampa, FL. (S.F. Treat and P.A. Clark, eds.), 528 pp.

Clayton, G., C. Cole, S. Murawski, and J. Parrish. 1978. Common Marine Fishes of Coastal Massachusetts. Contribution No. 54 of the Massachusetts Cooperative Fishery Research Unit. 231 pp.

Cleland and Bishop. 1984. An Assessment of the Economic Conditions of the Bay Mills Indian Community, Sault Saint Marie Tribe of Chippewa Indians, and Grand Traverse Band of Ottawa and Chippewa Indians, and a Cost-Return Analysis of Treaty Commercial Fishermen - 1981.

CMS Energy Corporation (CMS). 2001. Form 10-K for the Fiscal Year Ended December 31, 2000, filed on March 23, 2001.

Cohen, M.A. 1986. The Costs and Benefits of Oil Spill Prevention and Enforcement. *Journal of Environmental Economics and Management* 13:167-188.

Colarusso, P. 2000. Winter Flounder Life History Information. Draft. From Phil Colarusso, EPA Region 1. Brayton Point TAC Meeting, 11/17/00.

Cole, G.A. 1983. Textbook of Limnology. Third Edition. Waveland Press, Inc. Prospect Heights, Illinois.

Cole, R. 1995. Bluefish. In: *Living Resources of the Delaware Estuary*. L.E. Dove and R.M. Nyman (eds.). The Delaware Estuary Program. pp. 147-150.

Cole, R.A. 1978. Entrainment at a Once-Through Cooling System on Western Lake Erie, Volume I. EPA-600/3-78-070. July.

Conectiv. 2001. 10-K, filed on March 15, 2001.

Conservation Consultants Inc. 1977. Ecological Studies at Big Bend Steam Electric Station (Tampa Electric Company): An Analysis and Summary of Studies on the Effects of the Cooling Water System on Aquatic Fauna: A 316 Demonstration Biological Study. Volume III (Volume 3 of Final Report of Biological Surveys of the Big Bend Area). August.

Consolidated Edison Company of New York Inc. 1975. Environmental Report to Accompany Application for Facility License Amendment for Extension of Operation with Once-Through Cooling for Indian Point Unit No. 2.

Consolidated Edison Company of New York Inc. and New York Power Authority. 1983. Hudson River Ecological Study in the Area of Indian Point: 1982 Annual Report.

Consumers Power Company. 1984. Report of Deterrent Net Performance, J R Whiting Plant. Prepared for the Michigan Water Resources Commission. June.

Consumers Power Company. 1988. Report of Deterrent Net Performance, J R Whiting Plant. Prepared for the Michigan Water Resources Commission.

Consumers Power Company. 1992. Summary of Deterrent Net Performance at JR Whiting Plant.

Consumers Power Company. 1994. Luddington Pumped Storage Project: 1994 Annual Report of Barrier Net Operation. December 22.

Contra Costa County. 2002. About the County. http://www.co.contra-costa.ca.us/about.html. Industry and Employment. Accessed 1/18/02.

Correia, S.J., A.B. Howe, T.P. Currier, and S.X. Cadrin. 1993. Stock Assessment of Winter Flounder in Massachusetts Waters: An Update. Resource Assessment Project. August 16.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon et al. 1997. The Value of the World's Ecosystem Services and Natural Capital. *Nature* 387:253-260.

Costello, T.J. and D.M. Allen. 1966. Migrations and geographic distribution of pink shrimp, *Penaeus duorarum*, of the Tortugas and Sanibel grounds, Florida. *Fishery Bulletin* 65(2):449-459.

Costello, T.J. and D.M. Allen. 1970. Synopsis of Biological Data on the Pink Shrimp. In: *Proceedings of the World Scientific Conference on the Biology and Culture of Shrimps and Prawns. Volume IV: Species Synopses.*, Mexico City, June 12-21, 1967. FAO Fisheries Reports No. 57, Vol 4. pp. 1499-1537.

Cowan, J.H., Jr. and R.S. Birdsong. 1995. Seasonal occurrence of larval and juvenile fishes in a Virginia Atlantic coast estuary with emphasis on drums (Family Sciaenidae). *Estuaries* 8(1):48-59.

Crawford, R.J., and B.M. Dyer. 1995. Responses by four seabird species to a fluctuating availability of Cape Anchovy *Engraulis capensis* off South Africa. *Ibis* 137:329-339.

Cummings, W.C. 1961. Maturation and spawning of the pink shrimp, *Penaeus duorarum* Burkenroad. *Transactions of the American Fisheries Society* 90:462-468.

Cummings, R., Ganderton, P. and McGuckin, T., 1994. Substitution effects in CVM values. *Am. J. Agric. Economics.*, 76: 205-214.

Cushing, D.H. 1982. Climate and Fisheries. Academic Press, London.

Daiber, F.C. 1953. Notes on the spawning population of the freshwater drum (*Aplodinotus grunniens* Rafinesque) in western Lake Erie. *American Midland Naturalist* 50(1):159-171.

Dames & Moore. 1977a. 316(b) Demonstration for the Cayuga and Wabash River Generating Stations. Prepared for Public Service Indiana. August 30.

Dames & Moore. 1977b. Miami Fort and Walter C. Beckjord Generating Stations 316(b) Study: First Quarterly Data Presentation, April 1, 1977 to June 30, 1977.

Dames & Moore. 1977c. Miami Fort and Walter C. Beckjord Generating Stations 316(b) Study: Second Quarterly Data Presentation, July 7, 1977 to September 28, 1977.

Dames & Moore. 1978. Miami Fort and Walter C. Beckjord Generating Stations 316(b) Study: Third and Fourth Quarterly Data Presentation, October 1, 1977 to March 31, 1978.

Daniels, R. A. and P. B. Moyle. 1983. Life history of splittail (Cyprinidae: *Pogonichthys macrolepidotus*) in the Sacramento-San Joaquin Estuary. *Fishery Bulletin* 81(3):647-654.

Davis, G., M.D. Nichols, and T.M. Hannigan. 1999. Management of the California State Water Project. Department of Natural Resources. Bulletin 231-98. November.

Day, J.W., Jr., C.A.S. Hall, W.M. Kemp, and A. Yáñez-Arancibia. 1989. Estuarine Ecology. John Wiley & Sons, New York.

DDNREC (Delaware Department of Natural Resources and Environmental Control). 2000. Striped Bass Spawning Stock Assessment., Project: F-47-R-9 Anadromous Species Investigations.

de Sylva. D.P., F. Kalber, Jr., and C.N. Shuster, Jr. 1962. Fishes and Ecological Conditions in the Shore Zone of the Delaware Estuary, with Notes on Other Species Collected in Deeper Water. Info. Ser. Publ. No. 5. University of Maryland Mar. Lab.

DeAlteris, J.T., M. Gibson, and L.G. Skrobe, 2000. Fisheries of Rhode Island Narragansett Bay Summit 2000 White Paper, Working Draft (4/14/00). http://www.nbep.org/summit/pdf/Fisheries.PDF.

DeHart, R.E. 1994. Brayton Point Station Technical Advisory Committee Meeting Summary, October 20.

Delaware Estuary Program. 1996. Discover its Secrets — A Management Plan for the Delaware Estuary.

Delaware Estuary Program. 2001. Delaware Estuary Indicators. http://www.delep.org/shad.pdf. Accessed 10/8/01.

Delorme 1993. Maryland/Delaware Atlas & Gazetteer. Freeport, ME. 1993

Delorme 1995. Ohio Atlas & Gazetteer. Freeport, ME.

Delorme 1997. Florida Atlas and Gazetteer, Yarmouth, ME. 1997.

Delorme 1999. New Jersey Atlas & Gazetteer. Yarmouth, ME. 1999.

Desfosse, J., H. Austin, L. Daniel, W. Laney, and H. Speir. 1999. 1999 Review of the Fishery Management Plan for Atlantic Croaker (***Micropogonias undulatus***). http://www.asmfc.org/Programs/Fish%20Mgnt/croaker98_FMP.HTM.

Desvouges. 1992. Benefits Transfer: Conceptual Problems in Estimating Water Quality Benefits Using Existing Studies. *Water Resources Research* 3:675-683.

Detroit Edison. 2002. Power Plants. http://www.detroitedison.com/company/powerPlants.html. Accessed 2/5/02.

Dew, C.B. 1976. A contribution to the life history of the cunner, *Tautogolabrus adspersus*, in Fishers Island Sound, Connecticut. *Chesapeake Science* 17:101-113.

Dietrich, C.S. 1979. Fecundity of the Atlantic menhaden, *Brevoortia tyrannus*. *Fishery Bulletin* 77(1):308-311.

Dionne, M., F.T. Short, and D. M. Burdick. 1999. Fish utilization of restored, created, and reference salt-marsh habitat in the Gulf of Maine. In: *Fish Habitat: Essential Fish Habitat and Rehabilitation*. American Fisheries Society, Bethesda, MD, pp. 384-404.

Dixon, D.A. 1999. Catalog of Assessment Methods for Evaluating the Effects of Power Plant Operations on Aquatic Communities. Final Report. Report number TR-112013.

Dodge, D. and R. Kavetsky. 1995. Aquatic Habitat and Wetlands of the Great Lakes. SOLEC Working Paper presented at State of the Great Lakes Ecosystem Conference. August. EPA 905-R-95-014. Chicago, Ill.: U.S. Environmental Protection Agency. http://www.epa.gov/grtlakes/solec/94habitat/.

Dodge, K.E. 1998. River Raisin Assessment. Michigan Department of Natural Resources, Fisheries Division, Special Report 23. Ann Arbor, MI. http://www.dnr.state.mi.us/www/ifr/ifrlibra/special/reports/sr23/sr23Text.pdf. Accessed 2/5/02.

Dorsey, S.E., E.D. Houde, and J.C. Gamble. 1996. Cohort abundances and daily variability in mortality of eggs and yolk-sac larvae of bay anchovy, *Anchoa mitchilli*, in Chesapeake Bay. *U.S. Fish. Bull.* 94:257-267.

Doyle, M.J. 1977. A morphological staging system for the larval development of the herring, *Clupea harengus*. L.J. *Journal of the Marine Biological Association of the U.K.* 57:859-867.

DRBC (Delaware River Basin Commission). 1996. 1996 Delaware River Withdrawal and Consumptive Use Estimates (Tidal Estuary Portion). http://www.state.nj.us/drbc/withdrawals96.htm.

DRBC (Delaware River Basin Commission). 1998. Delaware River and Bay Water Quality Assessment: 1996-1997 305(b) Report.

DRBC (Delaware River Basin Commission). 2001. Ecological Significance of Delaware Bay. http://www.state.nj.us/drbc/shorebirds/ecolog.htm. Accessed 2001.

DTE Energy Company 2002. DTE Energy Company. Annual Report 2000. http://www.dteenergy.com/investors/annual/ar2000/results.html. March 6, 2002.

Durbin, A.G., E.G. Durbin, T.J. Smayda, and P.G. Verity. 1983. Age, size, growth, and chemical composition of Atlantic menhaden, *Brevoortia tyrannus*, from Narragansett Bay, Rhode Island. *Fishery Bulletin* 81(1):133-141.

EA Engineering Science and Technology. 1986. Entrainment and Impingement Studies at Oyster Creek Nuclear Generating Station 1984-1985. Prepared for GPU Nuclear Corporation. July.

EA Engineering, Science, and Technology. 1989. Indian Point Generating Station 1988 Entrainment Survival Study. Final. Prepared for Consolidated Edison Company of New York Inc. and New York Power Authority. August.

EA Engineering, Science and Technology. 1997. Encina Power Plant Supplemental 316(b) Assessment Report. Final. Prepared for San Diego Gas & Electric.

EA Engineering Science and Technology. 2000. Review of Entrainment Survival Studies: 1970-2000. Prepared for Electric Power Research Institute, Inc.

EA Engineering Science and Technology. 2001. 2000 Ohio River Ecological Research Program. Final Report. Prepared for American Electric Power Service Corporation, Cinergy, Indiana Kentucky Electric Corporation, Buckeye Power Inc. October.

EA Engineering Science and Technology and E. Perry. 2001. Leslie-Matrix Modeling of Possible 316(b) Effects on Selected Ohio River Fishes. Prepared for American Electric Power, American Municipal Power-Ohio, Buckeye Power, Cinergy, First Energy, Ohio Valley Electric Corporation, Southern Indiana Gas & Electric Co. January. 26 p.

EA Science and Technology. 1986. Indian Point Generating Station Entrainment Survival Study. 1985 Annual Report. Prepared under contract with Consolidated Edison Company of New York Inc. and New York Power Authority.

EA Science and Technology. 1987. Final Report: Clifty Creek Station Impingement Study and Impact Assessment.

EA Science and Technology. 1990. Results of Entrainment and Impingement Studies Conducted at the Braidwood Nuclear Station and the Adjacent Kankakee River. Prepared for Commonwealth Edison Company.

Eckhardt, G.A. 2002. The Edwards Aquifer Homepage: Glossary of Water Resource Terms. http://www.edwardsaquifer.net/glossary.html. Accessed 3/29/02.

Ecological Analysts Inc. 1978a. Impact of the Cooling Water Intake at the Indian River Power Plant: A 316(b) Evaluation. Prepared for Delmarva Power & Light Co. May.

Ecological Analysts Inc. 1978b. Port Jefferson Generating Station Entrainment Survival Study. Prepared for Long Island Lighting Company. December.

Ecological Analysts Inc. 1980a. Entrainment Survival Studies at the Cayuga Generating Plant. Prepared for Public Service of Indiana. March.

Ecological Analysts Inc. 1980b. Potrero Power Plant Cooling Water Intake Structures 316(b) Demonstration. Prepared for Pacific Gas and Electric Company. January.

Ecological Analysts, Inc. 1981a. Contra Costa Power Plant Cooling Water Intake Structures 316b Demonstration. Prepared for PG&E.

Ecological Analysts Inc. 1981b. Indian Point Generating Station Entrainment Survival and Related Studies 1979 Annual Report. Prepared for Consolidated Edison Company of New York and Power Authority of the State of New York. April.

Ecological Analysts, Inc. 1981c. Pittsburg Power Plant Cooling Water Intake Structures 316b Demonstration. Prepared for PG&E.

Ecological Analysts Inc. 1982. Indian Point Generating Station Entrainment Survival and Related Studies 1980 Annual Report. Prepared for Consolidated Edison Company of New York and Power Authority of the State of New York. January.

Edsall, T.A. 1967. Biology of the freshwater drum in western Lake Erie. *Ohio Journal of Science* 67(6):321-340.

Edwards, E.A., D.A. Krieger, G. Gebhart, and O.E. Maughan. 1982. Habitat suitability index models: White Crappie. U.S. DOI Fish and Wildlife Service. FWS/OBS-82/10.7.

Edwards, R.E. 1991. Nursery habitats of important early-juvenile fishes in the Manatee River estuary system of Tampa Bay. p. 237-252. In: *Proceedings, Tampa Bay Area Scientific Information Symposium 2*. February 27-March 1, 1991, Tampa, FL. (S.F. Treat and P.A. Clark, eds.), 528 p.

Egerton, F.N. 1985. Overfishing or Pollution? Case History of a Controversy on the Great Lakes. *Great Lakes Fishery Commission Technical Report* No. 41. January.

Ehlinger, T. 2002. General Glossary Homepage. http://www.uwm.edu/People/ehlinger/glossary.htm. Accessed 3/29/02.

Ehrhardt, N.M., D.J. Die and V.R. Restrepo. 1990. Abundance and impact of fishing on a stone crab (*Menippe mercenaria*) population in Everglades National Park, *Florida. Bull. Mar. Sci.* 46(2):311-323.

Electric Power Research Institute. 1987. Gizzard Shad. In: *Compensatory Mechanisms in Fish Populations: Literature Reviews Volume 2: Compensation in Fish Populations Subject to Catastrophic Impact*. Prepared for Electric Power Research Institute, Palo Alto, California by University of Rhode Island, Narragansett, RI. EPRI EA-5200, Project 1633-6. pp. 3-18-3-27.

Emmett, R.L., S.L. Stone, S.A. Hinton, and M.E. Monaco. 1991. Distribution and Abundance of Fishes and Invertebrates in West Coast Estuaries, Volume II: Species Life History Summaries. ELMR (Estuarine Living Marine Resources) Report No. 8. NOAA/NOS Strategic Environmental Assessments Division, Rockville, MD.

Encyclopedia Britannica Online. 2002. Encyclopedia Britannica Online. http://www.eb.com. Accessed 4/1/02.

Energy Impact Associates Inc. 1978a. Fish Impingement and Entrainment Studies at Clifty Creek Station. Final Report.

Energy Impact Associates Inc. 1978b. Fish Impingement and Entrainment Studies at Tanners Creek Power Plant: Final Report (Tanners Creek Plant Demonstration Document for P.L. 92-500 316(b), Volume II, Appendix B). Prepared for Indiana & Michigan Electric Company.

ENSR. 2000. Redacted Version 316 Demonstration Report - Pilgrim Nuclear Power Station. Prepared for Entergy Nuclear Generation Company.

Entergy Corporation. 2001. About Entergy. http://www.entergy.com/about/default.asp October 2, 2001.

Entergy Nuclear Generation Company. 2000. Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report Number 55, January 1999-December 1999.

Entergy Nuclear General Company, 2001. Marine ecology studies related to the operation of pilgrim station. Report number 57. January 2000-December 2000.

Environment Canada. 2001. Double-crested cormorant. Environment Canada website. http://www.qc.ec.gc.ca/faune/oiseaux_de_mer/html/double-crested_cormorant.html. Accessed 4/1/02.

Environmental Science & Engineering Inc. 1991. 1990 Ohio River Ecological Research Program: Executive Summary. Prepared for American Electric Power Service Corporation, Ohio Edison Company, Ohio Valley Electric Corporation, Cincinnati Gas & Electric Company, Indiana Kentucky Electric Corporation, Tennessee Valley Authority. October.

Environmental Science Associates. 1998. Draft Environmental Impact Report for Pacific Gas and Electric Company's Application for Authorization to Sell Certain Generating Plants and Related Assets (Application No. 98-01-008 to the State of California Public Utilities Commission).

Environmental Systems Research Institute, Inc. 2000. ArcView GIS 3.2a; ArcView Spatial Analyst 2.0. Redlands, CA.

Epifanio, C.E. 1995. Atlantic Blue Crab. In: *Living Resources of the Delaware Estuary*. L.E. Dove and R.M. Nyman (eds.). pp. 43-49.

Ernst Peebles, St. Petersburg (FL) 2001. "peebles.florida.ELS.xls": ambient density data at Tampa Bay.

ESSA Technologies (ESSA Technologies Ltd.). 2000. Review of Portions of New Jersey Pollutant Discharge Elimination System (NJPDES) Renewal Application for the Public Service Electric & Gas' (PSE&G) Salem Generating Station. Final Report. (Attachment A: Permit No. NJ0005622 Discharge to Surface Water, Surface Water Permit Renewal Action). Prepared for New Jersey Department of Environmental Protection.

Estevez, E.D. and M.J. Marshall. 1997. A landscape-level method to assess estuarine impacts of freshwater inflow alterations. p. 217-236. In: *Proceedings of the Tampa Bay Area Scientific Information Symposium 3: Applying Our Knowledge,* October 21-23, 1996 (S.F. Treat, ed.), Tampa Bay National Estuary Program.

Estevez, E.D., R.E. Edwards, and D.M. Hayward. 1991. An ecological overview of Tampa Bay's tidal rivers, p. 263-275. In: *Tampa Bay Area Scientific Information Symposium 2.* February 27-March 1, 1991 (Treat, S.F. and P.A. Clark, eds.), 528 p.

European Environment Agency. 2002. EUNIS Habitat classification. February. http://mrw.wallonie.be/dgrne/sibw/EUNIS/home.html. Accessed 3/29/02.

Fahay, M.P., P.L. Berrien, D.L. Johnson, W.W. Morse. 1999. Essential Fish Habitat Source Document: Atlantic Cod, *Gadus morhua*, Life history and Habitat Characteristics. NOAA Technical Memorandum NMFS-NE-124. Website. http://www.nefsc.nmfs.gov/nefsc/publications/text/nefseseries/current/techmemo/AtlanticCod124.pdf. Accessed 11/2/01.

Farber, S. 1987. The Value of Coastal Wetlands for Protection of Property against Hurricane Wind Damage. *Journal of Environmental Economics and Management* 14:143-151.

Fay, C.W., R.J. Neves, and G.B. Pardue. 1983a. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic): Alewife / Blueback Herring, FWS/OBS-82/11.9. Prepared for U.S. Fish and Wildlife Service. October. 25 pp.

Fay, C.W., R.J. Neves, and G.B. Pardue. 1983b. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic) Atlantic Silverside. FWS/OBS-82/11.10.

Fay, C.W., R.J. Neves, and G.B. Pardue. 1983c. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic). Striped bass. Report No. FWS/OBS-82/11.8. U.S. Fish and Wildlife Service, Div. Biol. Serv.

Feather, Peter M.; Daniel Hellerstein; and Theodore Thomaso. 1995. A Discrete-Count Model of Recreational Demand. *Journal of Environmental Economics and Management*, 29: 214-227.

Feinerman, E., and K. Knapp. 1983. Benefits from Groundwater Management: Magnitude, Sensitivity, and Distribution. *American Journal of Agricultural Economics* 65(4):703-710.

Fell, P.E., R.S. Warren, and W.A. Niering. 2000. Restoration of salt and brackish tidelands in southern New England. In: *Concepts and Controversies in Tidal Marsh Ecology.* M.P. Weinstein and D.A. Kreeger (eds.). Kluwer Academic Publishers, Boston, MA, pp. 845-858.

Finkel, A.M. 1990. Confronting Uncertainty in Risk Management. Center for Risk Management, Resources for the Future. Washington, DC, p. 68

Fischman, R.L. 2001. The EPA's NEPA Duties and Ecosystem Services. *Stanford Environmental Law Journal* 20(2):497-536.

Fish Endocrinology Research Group. 2002. Endocrine Control of Teleost Osmoregulation. University of St. Andrews. http://www.st-and.ac.uk/~seeb/ferg/teleost.htm. Accessed 4/1/02.

Fish, M.P. 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie, and its tributary waters. *Bulletin of the Bureau of Fisheries* 47:293-398.

Fisher, A. and R. Raucher. 1984. Intrinsic benefits of improved water quality: Conceptual and empirical perspectives. *Advances in Applied Micro-Economics* 3:37-66.

Fitzhugh, G.R., B.A. Thompson, and T.G. Snider III. 1993. Ovarian development, fecundity, and spawning frequency of black drum *Pogonias cromis* in Louisiana. *Fishery Bulletin* 91(2):244-253.

FL DEP (Florida Department of Environmental Protection). 2000. Meeting between EPA, contractors, and Florida Department of Environmental Protection. December.

Flannery, M.S., H.C. Downing, G.A. McGarry, and M.O. Walters. 1991. Increased nutrient loading and baseflow supplementation in the Little Manatee River watershed, p. 369-395. In: *Tampa Bay Area Scientific Information Symposium 2.* February 27-March 1, 1991 (Treat, S.F. and P.A. Clark, eds.), 528 p.

Fletcher, R.I., and R.B. Deriso. 1988. Fishing in dangerous waters: remarks on a controversial appeal to spawner-recruit theory for long-term impact assessment. *American Fisheries Society Monograph* 4:232-244.

Florida Fish and Wildlife Conservation Commission. 2001. Fishing Lines Fish Identification Section. http://marinefisheries.org/fishinglines/fish_id2.pdf. Accessed 12/12/01.

Florida Fish and Wildlife Conservation Commission. 2002a. Marine Fisheries. http://marinefisheries.org/fish/silverper.jpg. Accessed 1/02.

Florida Fish and Wildlife Conservation Commission. 2002b. Status and Trends 2001 Report - Florida's Nearshore and Inshore Species. http://www.floridamarine.org/features/view_article.asp?id=4961. Accessed 1/02.

Florida Power Corporation. 1985. Crystal River Units 1, 2 and 3§316 Demonstration. Final Report — Appendix.

Fogarty, M.J., A.A Rosenberg,.and M.P. Sissenwine. 1992. Fisheries risk assessment: A case study of Georges Bank haddock. *Environmental Science and Technology* 26(3):440-447.

Fogarty, M.J., M.P. Sissenwine, and E.B. Cohen. 1991. Recruitment variability and the dynamics of exploited fish populations. *Trends in Ecology and Evolution* 6:241-246.

Fonferek, W.J. 1997. Dredged material management - a federal perspective, p. 95-99. In: *Proceedings of the Tampa Bay Area Scientific Information Symposium 3: Applying Our Knowledge*, October 21-23, 1996 (S.F. Treat, ed.), Tampa Bay National Estuary Program.

Fonseca, M.S. 1992. Restoring seagrass systems in the United States. In: *Restoring the Nation's Marine Environment*, G.W. Thayer (ed.). Maryland Sea Grant College, College Park, MD, pp. 79-109.

Foster, K.L., F.W. Steimle, W.C. Muir, R.K. Kropp, and B.E. Conlin. 1994. Mitigation potential of habitat replacement: Concrete artificial reef in Delaware Bay — Preliminary results. Bulletin of Marine Science 55(2-3):783-795.

Fraser, S., V. Gotceitas, and J.A. Brown. 1996. Interactions between age-classes of Atlantic cod and their distribution among bottom substrates. *Canadian Journal of Fisheries and Aquatic Sciences* 53:305-314.

Freeman, R.F. and R.K. Sharma. 1977. Survey of Fish Impingement at Power Plants in the United States Volume II: Inland Waters. Prepared by Argonne National Laboratory. ANL/ES-56 Volume II. March. 323 pp.

Friedman, S. Morgan 2002. The Inflation Calculator. http://www.westegg.com/inflation/infl.cgi

Froese, R. and D. Pauly, Eds. 2000. FishBase 2000. International Center for Living Aquatic Resources Management. Los Baños, Laguna, Phillippines.

Froese, R. and D. Pauly (eds.) 2001. FishBase. World Wide Web electronic publication. http://www.fishbase.org. Accessed 10/01.

Fuchs, E. H. 1967. Life history of the emerald shiner, *Notropis atherinoides*, in Lewis and Clark Lake, South Dakota. *Transactions of the American Fisheries Society* 96:247-256.

Galbraith, H., I.C.T. Nisbet, J.J. Hatch, and T.H. Kunz. 1999. Age-related changes in efficiency among breeding common terns *Sterna hirundo*: Measurement of energy expenditure using doubly-labeled water. *J. Avian Biol.* 30:85-96.

Garwood, G.P. 1968. Notes on the life histories of the silversides, *Menidia beryllina* (Cope) and *Membras martinica* (Valenciennes) in Mississippi Sound and adjacent water. *Proceedings of the Southeastern Association of Game and Fish Commissioners* 21:314-323.

Geo-Marine Inc. 1978. 316(b) Demonstration for the W. H. Sammis Generating Station. Prepared for Ohio Edison Company. September 8.

Getz, W.M., and R.G. Haight 1989. Population Harvesting. Demographic Models of Fish, Forest, and Animal Resources. Princeton University Press. Princeton, New Jersey.

Gibson, M. 1996. Comparisons of Trends in the Finfish Assemblage of Mt. Hope Bay and Narragansett Bay in Relation to Operations at the New England Power Brayton Point Station. June 1995. Revised August 1996.

Gibson, M. 2001. Letter to Phil Colarusso of the U.S. Environmental Protection Agency-New England re: Winter Flounder Regulations in Rhode Island. October 3, 2001.

Ginzburg, L.R., L.B. Slobodkin, K. Johnson, and A.G. Bindman. 1982. Quasi-extinction probabilities as a measure of impact on population growth. *Risk Analysis* 2:171-181.

Goldman, C.R. and A.R. Horne. 1983. Limnology. McGraw-Hill, Inc., New York.

Goodyear, C.D. 1978. Evaluation of 316(b) Demonstration: Detroit Edison's Monroe Power Plant. Final Report for the Period April 1977 through December 1977. Prepared for the Great Lakes Area Office, Office of Ecological Services, U.S. Fish and Wildlife Service. Administrative Report No. 83-3.

Goodyear, C.P. 1977a. Assessing the impact of power plant mortality on the compensatory reserve of fish populations. In W. Van Winkle, ed. *Proceedings of the Conference on Assessing the Effects of Power-Plant Induced Mortality on Fish Populations*. Pergamon Press, New York, pp. 186-195.

Goodyear, C.P. 1977b. Mathematical Methods to Evaluate Entrainment of Aquatic Organisms by Power Plants. Report No. FWS/OBS-76/20.3. U.S. Fish and Wildlife Service, National Power Plant Team, Ann Arbor, MI.

Goodyear, C.P. 1978. Entrainment Impact Estimates Using the Equivalent Adult Approach. FWS/OBS - 78/65, U.S. Department of the Interior, Fish & Wildlife Service, Washington, DC. Prepared by U.S. Fish and Wildlife Service. July.

Goodyear, C.P. 1980. Compensation in fish populations. In: C.H. Hocutt and J.R. Stauffer, Jr., eds. *Biological Monitoring of Fish*. Lexington Books, Lexington, MA, pp. 253-280.

Gotceitas, V., S. Fraser, and J.A. Brown. 1997. Use of eelgrass beds (*Zostera marina*) by juvenile Atlantic cod (*Gadus morhua*). *Canadian Journal of Fisheries and Aquatic Sciences* 54:1306-1319.

Gottholm, B.W. and D.D. Turgeon. 1992. Toxic Contaminants in the Gulf of Maine. National Status and Trends Program for Marine Environmental Quality, NOAA. 15 p.

Government of Canada. 2001. The Fisheries Then and Now: Prince Edward Island. Species website. http://collections.ic.gc.ca/peifisheries/species/. Accessed 12/12/01.

Government of Newfoundland and Labrador. 2002. Fisheries and Aquaculture. Pelagics. http://www.gov.nf.ca/fishaq/Species/Pelagics/[illegible]. Accessed 1/11/02.

Government of Nova Scotia. 2000. Nova Scotia Canada. Natural Resources. http://www.gov.ns.ca/natr/[illegible]. Accessed 1/30/02.

Grant, S.M. and J.A. Brown. 1998. Diel foraging cycles and interactions among juvenile Atlantic cod (*Gadus morhua*) at a nearshore site in Newfoundland. *Canadian Journal of Fisheries and Aquatic Sciences* 55:1307-1316.

Great Lakes Commission. 2001. Great Lakes Information Network. http://www.great-lakes.net. Accessed 2001.

Great Outdoor Recreation Pages. 1999. Destinations: Bombay Hook National Wildlife Refuge website. http://www.gorp.com/gorp/resource/us_nwr/de_bomba.htm. Accessed August, 2001.

Greene, William H. 1995. Limdep Version 7 User's Manual. Plainview, NY: Econometric Software, Inc.

Greenhalgh, M. 2002. The Wild Trout: Glossary. http://www.wild-trout.co.uk/glossary.htm. Accessed 3/29/02.

Grigalunas, T.A., J.J. Opaluch, D. French, and M. Reed. 1988. Measuring Damages to Marine Natural Resources from Pollution Incidents under CERCLA: Applications of an Integrated Ocean Systems/Economic Model. *Marine Resources Economics* 5:1-21.

Grimes, B.H., M.T. Huish, J.H. Kerby, and D. Moran. 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic) Summer and Winter Flounder., *Biological Report* 82(11.112). 18 p.

Griswold, C.A. and M.J. Silverman. 1992. Fecundity of the Atlantic mackerel (*Scomber scombrus*) in the Northwest Atlantic in 1987. *Journal of Northwest Atlantic Fishery Science* 12:35-40.

Gulland, J.A. 1974. The Management of Marine Fisheries. University of Washington Press, Seattle, WA.

Haab, Timothy C., John Whitehead, and Ted McConnell 2000. The Economic Value of Marine Recreational Fishing in the Southeast United States: 1997 Southeast Economic Data Analysis. Final Report. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. July.

Hafner, H., P.J. Dugan, M. Kersten, O. Pinneau, and J.P. Wallace. 1993. Flock feeding and food intake in little egrets *Egretta garzetta* and their effects on food provisioning and reproductive success. *Ibis* 25-32.

Hagen, D., J. Vincent, and P. Welle. 1992. Benefits of Preserving Old Growth Forests and the Spotted Owl. *Contemporary Policy Issues* 10:13-25.

Hales, L.S. and M.J. Van Den Avyle. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Atlantic) — Spot. U.S. Fish and Wildlife Service Biological Report 82(11.91). U.S. Army Corps of Engineers TR EL-82-4.

Hall, W.R. 1995. Atlantic Menhaden. In: *Living Resources of the Delaware Estuary*. L.E. Dove and R.M. Nyman (eds.). The Delaware Estuary Program. pp. 219-225.

Hanemann, M., J. Loomis, and B. Kanninen. 1991. Statistical Efficiency of Double-Bounded Dichotomous Choice Contingent Valuation. *American Journal of Agricultural Economics* 73(4):1255-1263.

Hansen, D.F. 1951. Biology of the white crappie in Illinois. *Illinois Natural History Survey Bulletin* 25(4):211-265.

Harpman et al., 1993. Nonuse economic Value: Emerging Policy Analysis Tool. Rivers, Volume 4, Number 4, 280-291.

Harrison, P. 1983. Seabirds — An Identification Guide. Houghton Mifflin, Boston.

Hausman, J.A., G.K. Leonard, and D. McFadden 1995. A Utility-Consistent, Combined Discrete Choice and Count Model: Assessing Recreational Use Losses Due to Natural Resource Damage. *Journal of Public Economics* 56: 1-30.

Hazleton Environmental Science Corporation. 1978. The Survival of Entrained Icthyoplankton at Quad-Cities Station 1978. Prepared for Commonwealth Edison Company, Chicago, Illinois.

Heal, G., G.C. Daily, P.R. Ehrlich, J. Salzman, C. Boggs, J. Hellmann, J. Hughes, C. Kremen, and T. Ricketts. 2001. Protecting Natural Capital Through Ecosystem Service Districts. *Stanford Environmental Law Journal* 20(2):333-364.

Heck, K.L., K.W. Able, M.P. Fahay, and C.T. Roman. 1989. Fishes and decapod crustaceans of Cape Cod eelgrass meadows: Species composition, seasonal abundance patterns and comparison with unvegetated substrates. *Estuaries* 12(2):59-65.

Helfman, G.S., B.B. Collette, and D.E. Facey. 1997. The diversity of fishes. Blackwell Science. 528 pp.

Hendrickson, L. 2000. Windowpane Flounder. NOAA. http://www.nefsc.nmfs.gov/sos/spsyn/fldrs/window. Accessed 2/1/02.

Herbold, B., and P.B. Moyle. 1989. The Ecology of the Sacramento-San Joaquin Delta: A Community Profile. U.S. Fish and Wildlife Service, Biological Report No 85(7.22).

Herbold, B., A. Jassby, and P.B. Moyle. 1992. Status and Trends Report on Aquatic Resources of the San Francisco Bay Estuary. Technical Report, U.S. Environmental Protection Agency, San Francisco, CA.

Herman, J.S., D.C. Culver, and J. Salzman. 2001. Groundwater Ecosystems and the Service of Water. *Stanford Environmental Law Journal* 20(2):479-496.

Heyl, M.G. and J.A. Zimmerman. 1997. Manatee River salinity response to reservoir releases, p. 209-215. In: *Proceedings of the Tampa Bay Area Scientific Information Symposium 3: Applying Our Knowledge*, October 21-23, 1996 (S.F. Treat, ed.), Tampa Bay National Estuary Program.

Hicks, D.B. 1977. Statement of Findings for the Coleman Power Plant, Henderson, Kentucky. October 14. 5 pp.

Hicks, R., S. Steinback, A. Gautam, and E. Thunberg 1999. Volume II: The Economic Value of New England and Mid-Atlantic Sportfishing in 1994. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. NOAA Technical Memorandum NMFS-F/SPO-38.

Hilborn, R. 1987. Living with uncertainty in resource management. *North American Journal of Fisheries Management* 7:1-5.

Hilborn, R. and C.J. Walters. 1992. Quantitative Fisheries Stock Assessment, Choice, Dynamics and Uncertainty. Chapman and Hall, London and New York.

Hildebrand, M.1974. 1974. Analysis of Vertebrate Structure. John Wiley and Sons, Inc. 710 p.

Hildebrand, S.F. 1922. Notes on habits and development of eggs and larvae of the silversides *Menidia menidia* and *Menidia beryllina*. *Fishery Bulletin* 38:113-120.

Hildebrand, S.F. and W.C. Schroeder. 1928. Fishes of Chesapeake Bay. Bull. *U.S. Bur. Fisheries* 43 (Part 1):1-388.

Hill, J., J.W. Evans, and M.J. Van Den Avyle. 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Atlantic) Striped Bass. *U.S. Fish and Wildlife Service Biol. Rep.* 82(11.118). U.S. Army Corps of Engineers TR EL-82-4. 35 pp.

Holling, C.S. 1996. Surprise for science, resilience for ecosystems, and incentives for people. *Ecological Applications* 6:733-735.

Holmlund, C.M., and M. Hammer. 1999. Ecosystem services generated by fish populations. *Ecological Economics* 29:253-268.

Holt, M.T. and R.C. Bishop. 2002. A semiflexible normalized quadratic inverse demand system: An application to the price formation of fish. *Empirical Economics*. Forthcoming.

Hoover's Online. 2001a. Company capsule for American Electric Power Company, Inc. http://www.hoovers.com/co/capsule/4/0,2163,10084,00.html. Accessed 10/25/01.

Hoover's Online. 2001b. Company capsule for Cinergy Corp. http://www.hoovers.com/co/capsule/1/0,2163,42531,00.html. Accessed 10/25/01.

Hoover's Online. 2001c. Company capsule for CMS Energy Corporation. http://www.hoovers.com/co/capsule/3/0,2163,10263,00.html. Accessed 10/18/01.

Hoover's Online. 2001d. Company capsule for Conectiv. http://www.hoovers.com/co/capsule/9/0,2163,56339,00.html. Accessed 9/28/01.

Hoover's Online. 2001.e Company capsule for Entergy Corporation. http://www.hoovers.com/co/capsule/4/0,2163,10524,00.html. Accessed 10/2/01.

Hoover's Online. 2001f. Company capsule for FirstEnergy Corp. http://www.hoovers.com/co/capsule/3/0,2163,11113,00.html. Accessed 10/25/01.

Hoover's Online. 2001g. Company capsule for Northeast Utilities. http://www.hoovers.com/co/capsule/8/0,2163,11088,00.html. Accessed 10/2/01.

Hoover's Online. 2001h. Company capsule for PG&E Corporation. http://www.hoovers.com/co/capsule/5/0,2163,11145,00.html. Accessed 10/10/01.

Hoover's Online. 2001i. Company capsule for Progress Energy, Inc. http://www.hoovers.com/co/capsule/6/0,2163,10296,00.html. Accessed 10/16/01.

Hoover's Online. 2001j. Company capsule for TECO Energy, Inc. http://www.hoovers.com/co/capsule/9/0,2163,11429,00.html. Accessed 10/16/01.

Hoover's Online. 2002. Company capsule for DTE Energy Company. http://www.hoovers.com/co/capsule/3/0,2163,10453,00.html. Accessed 3/6/02.

Horst, T.J. 1975a. The assessment of impact due to entrainment of ichthyoplankton. Fisheries and Energy Production Symposium.

Horst, T.J. 1975b. The Equivalent Adult Model. A General Model for Fisheries Impact Assessment.

Houde, E.D., W.J. Richards, and V.P. Saksena. 1974. Description of eggs and larvae of scaled sardine, *Harengula jaguana*. *Fishery Bulletin* 72(4):1106-1122.

Howe, A. and P. Coates. 1975. Winter flounder movements, growth, and mortality off Massachusetts. *Transactions of the American Fisheries Society* 104:13-29.

Howell, P., A. Howe, M. Gibson, and S. Ayvanzian. 1992. Fishery Management Plan for Inshore Stocks of Winter Flounder (Pleuronectes americanus). Fishery Management Report 21, of the Atlantic States Marine Fisheries Commission, 138 pp.

Hughes, J.E., L.A. Deegan, J.C. Wyda, and A. Wright. 2000. An Index of Biotic Integrity Based on Fish Community Structure Applied to Rhode Island and Connecticut Estuaries. The Ecosystems Center, Marine Biological Laboratory, Woods Hole, MA.

Hundley, Kris. 1999. St. Petersburg Times, Problems have halted plant before. April 9, 1999.

Hunter Environmental Services Inc. 1989. Ohio River Ecological Research Program Final Report. 1988.

Huppert, D. 1989. Measuring the Value of Fish to Anglers: Application to Central California Anadromous Species. *Marine Resource Economics*. Vol. 6.

Huppert, D.D. 1990. Economic Benefits from Commercial Fishing. Draft report to National Marine Fisheries Service.

Hutchings, J.A. 1996. Spatial and temporal variation in the density of northern cod and a review of hypotheses for the stock's collapse. *Canadian Journal of Fisheries and Aquatic Sciences* 53:943-962.

Hutchings, J.A. and R.A. Myers. 1994. What can be learned from the collapse of a renewable resource? Atlantic cod, *Gadus morhua*, of Newfoundland and Labrador. *Canadian Journal of Fisheries and Aquatic Sciences* 51:2126-2146.

Hynes, H.B.N. 1970. The Ecology of Running Water. University of Toronto Press. 555 pp.

Information Please LLC. © 1999. 2001. At: http://infoplease.lycos.com. Accessed 4/02.

InfoMI. 2001. Monroe County, Michigan. http://www.multimag.com/county/mi/monroe. Accessed 10/11/01.

Institute for Marine Research. 2002. Institute for Marine Research, Kiel Larvalbase. http://www.larvalbase.org. Accessed 1/02.

Iowa Department of Natural Resources. 2001. Iowa Department of Natural Resources. 2001. Fishes of Iowa. http://www.state.ia.us/dnr/organiza/fwb/fish/iafish/iafish.htm. Accessed 11/5/01.

Jackson, H.W. and R.E. Tiller. 1952. Preliminary Observations on Spawning Potential in the Striped Bass, *Roccus saxatilis* (Walbaum). *Md. Dep. Res. Educ.* No. 93. 15 pp.

Jacobson, P.M., E. Lorda, D.J. Danila, J.D. Miller, C.A. Tomichek, and R.A. Sher. 1998. Studies of Cooling Water Intake Effects at Two Large Coastal Nuclear Power Stations in New England. In: *EPRI Clean Water Act Section 316(b) Technical Workshop*. D. Dixon and K. Zammit (eds.). EPRI Clean Water Act Section 316(b) Technical Workshop, September 22-24, Berkeley Springs, WV.

Jenkins, D. and L.A. Gelvin-Innvaer. 1995. Colonial wading birds. In: *Living Resources of the Delaware Estuary*. L.E. Dove and R.M. Nyman, (eds.). The Delaware Estuary Program. pp. 335-345.

Johansson, J.O.R. 1991. Long-term trends of nitrogen loading, water quality and biological indicators in Hillsborough Bay, Florida, p.157-176. In: *Proceedings, Tampa Bay Area Scientific Information Symposium 2*. February 27-March 1, 1991, Tampa, FL. (S.F. Treat and P.A. Clark, eds.), 528 p.

Johnson, D.R. and W. Seaman. 1986. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Florida): Spotted Seatrout., U.S. Fish and Wildlife Service Biological Report 82(11.43). 30 p. http://www.nwrc.gov/wdb/pub/0139.pdf.

Jones, C. 1985. Within-season differences in growth of total larval Atlantic herring, *Clupea harengus*. *Fishery Bulletin* 83:289-298.

Jones, P.W., F.D. Martin, and J.D. Hardy, Jr. 1978. Development of fishes of the Mid-Atlantic Bight: An atlas of egg, larval, and juvenile stages. Vol. I. Acipenseridae through Ictaluridae. Chesapeake Biological Laboratory, Center for Environmental and Estuarine Studies University of Maryland. Prepared for U.S. Fish and Wildlife Services. U.S. Government Printing Office, Washington.

Jones & Stokes Associates Inc. 1998. Environmental Assessment for PG&E's Multispecies Habitat Conservation Plan for Pittsburg and Contra Costa Power Plants. Draft. August 10, 1998. (JSA 97-144.) Sacramento, CA. Prepared for the U.S. Fish and Wildlife Service, Sacramento, California and the National Marine Fisheries Service, Santa Rosa, California.

Jordan, F., S. Coyne, and J.C. Trexler. 1997. Sampling fishes in vegetated habitats: effects of habitat structure on sampling characteristics of the 1-m2 throw trap. *Transactions of the American Fisheries Society* 126:1012-1020.

Joseph, E.B. 1972. Status of Sciaenid stocks of the middle Atlantic coast. *Chesapeake Sci.* 13(2):87-100.

Jude, D.J., P.J. Mansfield, and M. Perrone, Jr. 1983. Impingement and entrainment of fish and effectiveness of the fish return system at the Monroe Power Plant, western Lake Erie, 1982-1983. University of Michigan, Great Lakes Research Division, Special Report 101, Ann Arbor.

Jude, D.J., P.J. Mansfield, P.J. Schneeberger, and J.A. Wojcik. 1987a. Compensatory Mechanisms in Fish Populations: Literature Reviews. Volume 2: Compensation in Fish Populations Subject to Catastrophic Impact. EA-5200, Volume 2, Research Project 1633-6. Final Report, May 1987. Electric Power Research Institute, Palo Alto, CA.

Jude, D.J., F.J. Tesar, S.F. Deboe, and T.J. Miller. 1987b. Diet and selection of major prey species by Lake Michigan salmonines, 1973-1982. *Transactions of the American Fisheries Society* 116(5):677-691.

Jury, S.H., J.D. Field, S.L. Stone, D.M. Nelson, and M.E. Monaco. 1994. Distribution and Abundance of Fishes and Invertebrates in North Atlantic Estuaries. ELMR Rep. No. 13. NOAA/NOS Strategic Environmental Assessments Division, Silver Spring, MD. 221pp.

Kaiser, S.C. and M.J. Neuman. 1995. Flounder. In: *Living Resources of the Delaware Estuary*. L.E. Dove and R.M. Nyman (eds.) The Delaware Estuary Program.

Kaoru, Y. 1993. Differentiating Use and Nonuse Values for Coastal Pond Water Quality Improvements. *Environmental and Resource Economics* 3:487–494.

Kaplan, C. 2000. Condenser and Cooling Tower Make-Up Flows for a 1000 MW Steam Electric Power Plant. Memo to Tetra Tech, Inc. June 26, 2000.

Kaufman, K. 1996. Lives of North American Birds. Houghton Mifflin, Boston.

Keller, A.A. and G. Klein-MacPhee. 2000. Impact of elevated temperature on the growth, survival, and trophic dynamics of winter flounder larvae: A mesocosm study. *Canadian Journal of Fisheries and Aquatic Sciences* 57:2382-2392.

Keller, A.A., C.A. Oviatt, H.A. Walker, and J.D. Hawk. 1999. Predicted impact of elevated temperature on the magnitude of the winter-spring phytoplankton bloom in temperate coastal waters: a mesocosm study. *Limnology and Oceanography* 44:344-356.

Kelly, K.H. and J.R. Moring. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic)- Atlantic herring. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.38). U.S. Army Corps of Engineers, TR EL-82-4. 22pp.

Kelly, J.F., and B. Van Horne. 1997. Effects of food supplementation on the timing of nest initiation in belted kingfishers. *Ecology* 78:2504-2511.

Kelly, B., R. Lawton, V. Malkoski, S. Correia, and M. Borgatti. 1992. Pilgrim Nuclear Power Station Marine Environmental Monitoring Program Report Series No. 6. Final Report on Haul-Seine Survey and Impact Assessment of Pilgrim Station on Shore-Zone Fishes, 1981-1991. Prepared by the Department of Fisheries, Wildlife, and Environmental Law Enforcement, Massachusetts Division of Marine Fisheries for Boston Edison Company. December 30. 31 pp.

Kelso, J.R.M.,and G.S. Milburn. 1979. Entrainment and impingement of fish by power plants in the Great Lakes which use the once-through cooling process. *Journal of Great Lakes Research* 5:182–194.

Kennish, M.J. 2000. Chapter 5, Case Study 4: San Francisco Estuary Project. Pages 255-336 in: M.J. Kennish (ed.) *Estuary Restoration and Maintenance: The National Estuary Program*. CRC Press LLC, Boca Raton, FL.

Kimmel, C.B., W. W. Ballard, S. R. Kimmel, B. Ullmann, and T. F. Schilling. 1995. Stages of Embryonic Development of the Zebrafish. *Developmental Dynamics* 203:253-310 (1995). Reprinted only by permission of Wiley-Liss, a subsidiary of John Wiley & Sons, Inc. At: http://zfin.org/zf_info/zfbook/stages/stages.html.

Kimmerer, W.J. 1999. How density-dependence can be important and still be lost in the noise. Paper presented at Power Generation Impacts on Aquatic Resources Conference, April 12-15, 1999, Renaissance Waverly Hotel, Atlanta, GA. Conference organizers: Electric Power Research Institute and U.S. Department of Energy.

King, D.M. and Mazzotta, M. 2002. Ecosystem Valuation. Methods, Section 6: Contingent Valuation Method. http://www.cbl.umces.edu/~dkingewcn/contingent_valuation.htm. Accessed 4/2/02.

Kitts, A. and E. Thunberg. 1998. Description and Impacts of Northeast Groundfish Fishery Buyout Programs. *Northeast Fisheries Science Center Reference Document* 98-12. November.

Kjesbu, O.S. 1989. The spawning activity of cod, *Gadus morhua L. Journal of Fish Biology* 34:195-206.

Kleinholz, C.W. 2000. Species Profile: Bigmouth Buffalo. SRAC Publication No. 723. Southern Regional Aquaculture Center. June.

Kocik, J.. 2000. River Herring. From: Status of Fisheries Resources off Northeastern United States website. http://www.wh.whoi.edu/sos/spsyn/af/herring/ Accessed 3/26/01.

Kotchen, M. J. and S.D. Reiling 2000. Environmental attitudes, motivations, and contingent valuation of nonuse values: a case study involving endangered species. *Ecological Economics* 32:93-107.

Lackey, R.T. 2001. Fisheries: History, Science, and Management. National Health and Environmental Effects Research Laboratory. November. http://www.epa.gov/wed/pages/staff/lackey/pubs/history.htm. Accessed 4/1/02.

Lane, J.A., C.B. Portt, and C.K. Minns. 1996a. Adult habitat characteristics of Great Lakes Fishes. *Canadian Manuscript Report of Fisheries and Aquatic Sciences* 2358.

Lane, J.A., C.B. Portt, and C.K. Minns. 1996b. Nursery habitat characteristics of Great Lakes fishes. *Canadian Manuscript Report of Fisheries and Aquatic Sciences* 2338.

Laney, R.W. 1997. The relationship of submerged aquatic vegetation (SAV) ecological value to species managed by the Atlantic States Marine Fisheries Commission (ASMFC): Summary for the ASMFC SAV subcommittee. In: *Atlantic Coastal Submerged Aquatic Vegetation: A Review of its Ecological Role, Anthropogenic Impacts, State Regulation, and Value to Atlantic Coastal Fish Stocks*, C.E. Stephen and T.E. Bigford (eds.). ASMFC Habitat Management Series #1, Atlantic States Marine Fisheries Commission.

Lassuy, D.R. 1983. Species Profiles: Life Histories and Environmental Requirements (Gulf of Mexico)- Spotted Seatrout. USFWS FWS/OBS-82/11.4.

Laughlin, R.A. 1982. Feeding habits of the blue crab, *Callinectes sapidus* Rathbun, in the Apalachicola estuary. *Florida. Bull. Mar. Sci.* 32:807-822.

Lawler, J.P. 1988. Some considerations in applying stock-recruitment models to multiple-age spawning populations. *American Fisheries Society Monograph* 4:204-218.

Lawler J.P., W.T. Hogarth, B.J. Copeland, M.P. Weinstein, R.G. Hodson, and H.Y. Chen. 1980. Techniques for Assessing the Impact of Entrainment and Impingement as Applied to the Brunswick Steam Electric Plant. Pages 3-307 in L.D. Jensen (ed.) *Paired Position Papers, Issues Associated with Impact Assessment: Proceedings of the Fifth National Workshop on Entrainment and Impingement.* Ecological Analysts Inc. and Electric Power Research Institute, Palo Alto, CA.

Lawler Matusky & Skelly Engineers. 1975. 1974 Hudson River Aquatic Ecology Studies - Bowline Point and Lovett Generating Stations. Prepared for Orange and Rockland Utilities, Inc.

Lawler Matusky & Skelly Engineers. 1976. 1975 Hudson River Aquatic Ecology Studies — Bowline Point and Lovett Generating Stations: Vol. I: Chapters I-IX. Prepared for Orange and Rockland Utilities, Inc.

Lawler Matusky & Skelly Engineers. 1983. 1979 and 1980 Data Analyses and Application of Empirical Models of Hudson River Fish Populations. Prepared for Consolidated Edison Company of New York, Inc. August.

Lawler Matusky & Skelly Engineers. 1985. 2.0 Entrainment Survival Studies. In: *Quad Cities Aquatic Program 1984 Annual Report.* Prepared for Commonwealth Edison, Chicago, Illinois.

Lawler Matusky & Skelly Engineers. 1987. Brayton Point Station Unit 4 Angled Screen Intake Biological Evaluation Program: Volume I. October.

Lawler Matusky & Skelly Engineers. 1989. Biological Evaluation of Chambers Works Water Intake Located at Atlantic City Electric Company's Deepwater Generating Station. September.

Lawler Matusky & Skelly Engineers. 1991. 1990 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities Inc.

Lawler Matusky & Skelly Engineers. 1993. Impingement and Entrainment Study at Zion Nuclear Generating Station July 1991 - July 1993. Prepared for Commonwealth Edison Company. October.

Lawler Matusky & Skelly Engineers. 1999. Brayton Point Power Station Entrainment Survival Study, 1997-1998. Draft. Prepared for US Gen New England, Inc., Brayton Point Station, Somerset, MA. Pearl River, NY.

Lawton, R., B. Kelly, P. Nitschke, J. Boardman, and V. Malkoski. 2000. Final Report Studies (1990-1997) and Impact Assessment of Pilgrim Station on Cunner in Western Cape Cod Bay. Massachusetts Dept. of Fisheries, Wildlife, and Environmental Law Enforcement. Division of Marine Fisheries.

Layton, D., and G. Brown. 1998. Heterogenous Preferences Regarding Global Climate Change. Presented at NOAA Applications of Stated Preference Methods to Resource Compensation Workshop, Washington, D.C.

Lazaroff, C. 2000. Environment News Service, Florida Utility Agrees to $1 Billion Pollution Control Program. March 1, 2000.

Leak, J.C. and E.D. Houde. 1987. Cohort growth and survival of bay anchovy, *Anchoa mitchilli*, larvae in Biscayne Bay, Florida. *Marine Ecology Progress Series* 37:109-122.

Leard, R., R. Matheson, K. Meador, W. Keithly, C. Luquet, M. Van Hoose, C. Dyer, S. Gordon, J. Robertson., D. Horn, and R. Scheffler. 1993. The black drum fishery of the Gulf of Mexico, United States: A regional management plan. Gulf States Marine Fisheries Commission. Report Number 28, Ocean Springs, MS. May.

Lee, D.S., Gilbert, C.R., Hocutt, C.H., Jenkins, R.E., McAllister, D.E., and J.R. Stauffer. 1980. Atlas of North American freshwater fishes. Publication #1980-12 of the North Carolina Biological Survey.

Lewis R. and G. Seegert. 1998. Entrainment and impingement studies at two powerplants on the Wabash River in Indiana. In: *EPRI Clean Water Act Section 316(b) Technical Workshop*. D. Dixon and K. Zammit (eds.). EPRI Clean Water Act Section 316(b) Technical Workshop, September 22-24, Berkeley Springs, WV.

Lewis, R.M., E.P. Wilkins, and H.R. Gordy. 1972. A description of young Atlantic menhaden, *Brevoortia tyrannus*, in the White Oak River estuary, North Carolina. *Fishery Bulletin* 70(1):115-118.

Lewis, R.R., III, and E.D. Estevez. 1988. The ecology of Tampa Bay, Florida: an estuarine profile. *U.S. Fish Wildl. Serv. Biol. Rep.* 85(7.18). 132 pp.

Lexico LLC. 2002. Dictionary.com. http://www.dictionary.com Accessed 4/2/02.

Liermann, M., and R. Hilborn. 1997. Depensation in fish stocks: A hierarchic Bayesian meta-analysis. *Canadian Journal of Fisheries and Aquatic Sciences* 54:1976-1984.

Liermann, M., and R. Hilborn. 2001. Depensation: evidence, models and implications. *Fish and Fisheries* 2:33-58.

Lindberg, W.J. and M.J. Marshall. 1984. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Florida) – Stone Crab. U.S. Fish Widl. Serv. FWS/OBS-82/11.21. U.S. Army Corps of Engineers, TR EL-82-4. 17 pp.

Loesch, J.G. and W.A. Lund, Jr. 1977. A contribution to the life history of the blueback herring, *Alosa aestivalis*. *Trans. Am. Fish. Soc.* 106:583-589.

Lohner, T. 1998. Fish Entrainment, Impingement, and Long-term Monitoring Studies at Ohio River Power Plants. Presentation at EPRI Clean Water Act Section 316(b) Technical Workshop, September 22-24, Berkeley Springs, WV.

Loomis, J. 1988. The Bioeconomic Effects of Timber Harvesting on Recreational and Commercial Salmon and Steelhead Fishing: A Case Study of Siuslaw National Forest. *Marine Resource Economics*. Vol. 5.

Loomis, J., and E. Ekstrand. 1997. Economic Benefits of Critical Habitat for the Mexican Spotted Owl: A Scope Test Using a Multiple Bounded Contingent Valuation Survey. *Journal of Agricultural and Resource Economics* 22(2):356-366.

Loomis, J. B. and White, D. S. 1996. Economic benefits of rare and endangered species: Summary and meta-analysis. *Ecological Economics* 18:197-206.

Loomis, J., P. Kent, E. M. Strange, K. Fausch, and A. Covich. 2000. Measuring the total economic value of restoring ecosystem services in an impaired river basin: results from a contingent valuation survey. *Ecological Economics* 33:103-117.

Lough, R.G. and D.C. Potter. 1993. Vertical distribution patterns and diel migrations of larval and juvenile haddock *Melanogrammus aeglefinus* and Atlantic cod, *Gadus morhua*, on Georges Bank. *Fishery Bulletin* 91:281-303.

Ludwigs, J.D. 1998. Kleptoparasitism in common terns Sterna hirundo as an indicator of food shortage. Vogelwelt 119:193-203.

Lycos, Inc. 2002. Infoplease.com. http://infoplease.lycos.com . Accessed 4/1/02.

Mace, P.M. 1994. Relationships between common biological reference points used as thresholds and targets of fisheries management strategies. *Canadian Journal of Fisheries and Aquatic Sciences* 51:110-122.

Maddala, G.S. 1983. Limited-Dependent and Qualitative Variables in Econometrics. Cambridge: Cambridge University Press.

MADEP. (Massachusetts Department of Environmental Protection). 2000. Selected Federal and State Grant Funded Indicative Project Summaries: FFY 1996-2000. January 2000.

Madigan, M.T., J.M. Martinko, and J. Parker. 1997. Brock Biology of Microorganisms. Prentice Hall, Upper Saddle River, NJ.

Manomet Center for Conservation Sciences. 2001. Southeastern Massachusetts Natural Resource Atlas. March 2001. http://www.manomet.org/semass/atlas.html. Accessed 11/29/01.

Mansueti, R.J. and E.H. Hollis. 1963. Striped Bass in Maryland Tidewater. University of Maryland Natural Resources Institute. Educ. Ser. 61. 28 pp.

MAPC. 2001. Atlas of Tidal Restrictions on the South Shore of Massachusetts. Prepared by Metropolitan Area Planning Council for the Massachusetts Wetlands Restoration Program, Boston. June 20.

Marcy, B. C., A. D. Beck, and R. E. Ulanowicz. 1978. Effects and Impacts of Physical Stress on Entrained Organisms. In: *Power Plant Entrainment: A Biological Assessment*. Academic Press, New York, NY. pp. 136-188.

Marine Research Inc. and New England Power Company. 1981. New England Power Company Brayton Point Generating Station, Mount Hope Bay, Somerset, Massachusetts: Final Environmental Impact Report and Sections 316(a) and 316(b) Demonstrations with the Proposed Conversion of Generating Unit No. 4 from Closed-Cycle Cooling to Once-Through Cooling. June.

Martosubroto, P. 1974. Fecundity of pink shrimp, *Penaeus duorarum* Burkenroad. *Bulletin of Marine Science* 24(3):606-627.

Maryland Department of Natural Resources Fisheries Service. 2002. Black drum. http://www.dnr.state.md.us/fisheries/education/blackdrum/blackdrum.html. Accessed 1/21/02.

Masnik, M. T. and J. H. Wilson. 1980. Assessment of the Impacts of the Salem and Hope Creek Stations on Shortnose Sturgeon, *Acipenser brevirostrum* LeSueur. Prepared by the U. S. Nuclear Regulatory Commission. April.

Mason, D. 2002. Natural Recruitment of Salmonids in the Muskegon River, Michigan. NOAA Great Lakes Environmental Research Laboratory Salmonid Recruitment in the Muskegon. http://www.glerl.noaa.gov/res/Task_rpts/edymason09-4.html. Accessed 1/21/02.

Massachusetts Office of Coastal Zone Management. 1994. The Coastal Nonpoint Source Pollution Control Program in Massachusetts: *Coastal Brief* Volume No. 12, 1994. http://www.state.ma.us/czm/npstoc.htm. Accessed 11/15/01.

Matthews, W.J. 1998. Patterns in Freshwater Fish Ecology. Chapman & Hall, New York.

May, A.W. 1967. Fecundity of Atlantic cod. *Journal of the Fisheries Research Board of Canada* 24(7):1531-1551.

Madzura, T. 2001. Glossary of Water-Related Terms. University of Missouri Outreach and Extension. http://outreach.missouri.edu/mowin/Resources/glossary/glossary.html. Accessed 3/29/02.

Maryland Department of Natural Resources. 1995. About Oyster Diseases. Bay Journal Vol. 5, No. 2. April. http://www.bayjournal.com/95-04/oyster1.htm Accessed 4/1/02.

McBride, R.S. 1995. Marine Forage Fish. In: *Living Resources of the Delaware Estuary*. L.E. Dove and R.M. Nyman (eds.) The Delaware Estuary Program. pp. 211-217.

McCambridge, J.T. Jr. and R.W. Alden, III. 1984. Growth of juvenile spot, *Leiostomus xanthurus* Lacepede, in the nursery region of the James River, Virginia. *Estuaries* 7(4B):478-486.

McConnell, K. and I. Strand. 1994. The Economic Value of Mid and South Atlantic Sportfishing: Volume 2. Cooperative Agreement #CR-811043-01-0 between the University of Maryland at College Park, the Environmental Protection Agency, the National Marine Fisheries Service, and the National Oceanic and Atmospheric Administration.

McCrimmon, H.R. 1968. Carp in Canada. Fisheries Research Board of Canada Bulletin 165. Ottawa, Ontario. 93 pp.

McDermot, D. and K.A. Rose. 2000. An individual-based model of lake fish communities: Application to piscivore stocking in Lake Mendota. *Ecological Modelling* 125:67-102.

McEwan, D. 1992. Pages 67-70 in Leet, W.S., C.M. Dewees, and C.W. Haugen (eds.), *California's Living Marine Resources and Their Utilization*. California Sea Grant, Sea Grant Extension Publication UCSGEP-92-12. California Sea Grant Extension Program, University of California, Davis, CA.

McFadden, D. 1981. Econometric Models of Probabilistic Choice. In: C.F. Manski and D.L. McFadden, Eds., *Structural Analysis of Discrete Data*. Cambridge, MA; MIT Press.

McFadden, J.T., and J.P. Lawler, eds. 1977. Supplement 1 to influence of Indian Point Unit 2 and other steam electric generating plants on the Hudson River estuary, with emphasis on striped bass and other fish populations. Unpublished report prepared for Consolidated Edison Co. of New York.

McMichael, R.H., Jr. and K.M. Peters. 1989. Early life history of spotted seatrout *Cynoscion nebulosus* (Pisces: Sciaenidae) in Tampa Bay, Florida. *Estuaries* Vol. 12, No. 2, p. 98-110.

MDCH. 2001. Michigan 2001 Fish Advisory: Important Facts to Know if You Eat Michigan Fish. Michigan Department of Community Health. http://www.mdch.state.mi.us/pha/fish/FishAdvisory.pdf. Accessed 12/01.

MDHCD. 2001. Community Profiles. Massachusetts Department of Housing and Community Development. http://www.state.ma.us/dhcd/iprofile/273.pdf. Accessed 10/18/01.

Meadows, P.S. and J.I. Campbell. 1978. An Introduction to Marine Science. John Wiley and Sons, New York.

Meffe, G.K. 1992. Techno-arrogance and halfway technologies: salmon hatcheries on the Pacific Coast of North America. *Conservation Biology* 6:350-354.

Meng, L., and P.B. Moyle. 1995. Status of splittail in the Sacramento-San Joaquin Estuary. *Transactions of the American Fisheries Society* 124:538-549.

Mercer, L.P. 1987. Fishery Management Plan for Spot. Fisheries Management Report of the Atlantic States Marine Fisheries Commission, No. 11. North Carolina Department of Natural Resources and Community Development, Morehead City.

Meredith Simas (Brayton Point Station) 2002. "brayton.ENT1973.1985.xls": Entrainment data at Brayton Point from 1973 to 1985

Meredith, W.H. and V.A. Lotrich. 1979. Production dynamics of tidal creek population of *Fundulus heteroclitus* (linnaeus). *Estuaries and Coastal Marine Science* 8:99-118.

Merriam-Webster Online. 2002. Collegiate Dictionary. http://www.m-w.com/dictionary.htm Accessed 4/1/02.

Messieh, S.N. 1976. Fecundity studies on Atlantic herring from the southern Gulf of St. Lawrence and along the Nova Scotia Coast. *Transactions of the American Fisheries Society* 105:384-394.

Michaud D.T. 1998. Wisconsin Electric's Experience with Fish Impingement and Entrainment Studies. In: *EPRI Clean Water Act Section 316(b) Technical Workshop*. D. Dixon and K. Zammit (eds.). EPRI Clean Water Act Section 316(b) Technical Workshop, September 22-24, Berkeley Springs, WV.

Miller, E.E. 1966. Channel Catfish. In: *Inland Fisheries Management*. California Department of Fish and Game, pp. 440-463.

Miller, J.P. 1995. American shad. In: *Living Resources of the Delaware Estuary*. L.E. Dove and R.M. Nyman, (eds.). The Delaware Estuary Program. pp. 251-257.

Miller, R.R. 1960. Systematics and biology of the gizzard shad (*Dorosoma cepedianum*) and related fishes. *Fishery Bulletin* 60:371-392.

Miller, R.W. 1995. Striped Bass. In: *Living Resources of the Delaware Estuary*. L.E. Dove and R.M. Nyman (eds.). The Delaware Estuary Program. pp. 135-141.

Milliman, S.R., B.L. Johnson, R.C. Bishop, and K.J. Boyle. 1992. The bioeconomics of resource rehabilitation: A commercial-sport analysis for a Great Lakes fishery. *Land Economics* 68(2):191-210.

Milon, J.W., E. Thunberg, C.M. Adams, and C.T.J. Lin. 1994. Recreational Anglers' Valuation of Near-Shore Marine Fisheries in Florida. Florida Sea Grant College Program. Technical paper-73. January.

Mirant Corporation. 2001a. Mirant Completes Spin-Off From Southern Company. News Release, April 2, 2001.

Mirant Corporation 2001b. Mirant Corporation. Mirant Unsure of Start Date for Plant Expansion. News Release, June 1, 2001.

Mirant Corporation. 2001c. Southern Energy, Inc. 8-K, filed on January 19, 2001.

MIT Sea Grant. 2001. "Marine Bio Invaders", http://massbay.mit.edu. Accessed 11/19/2001.

Mitchell, R.C. and R.T. Carson. 1986. The Use of Contingent Valuation Data for Benefit/Cost Analysis of Water Pollution Control. Resources for the Future, Washington, DC. September.

Mitsch, W. J. and J. G. Gosselink. 1993. Wetlands, 2nd ed. John Wiley & Sons, New York.

Monaghan, P., J.D. Uttley, M.D. Burns, C. Thaine, and J. Blackwood. 1989. The relationship between food supply, reproductive effort and breeding success in arctic terns *Sterna paradisaea*. *J. Anim. Ecol.* 58:261-274.

Monteleone, D.M. 1992. Seasonality and abundance of ichthyoplankton in Great South Bay, New York. *Estuaries* 15(2):230-238.

Mood, Alexander M., Franklin A. Graybill, and Duane C. Boes. 1974. Introduction to the Theory of Statistics. McGraw-Hill, New York.

Morey, Edward R. 1999. Two RUMS unCLOAKED: Nested Logit Models of Site Choice and Nested Logit Models of Participation and Site Choice. In: Herriges and Kling, Eds., *Valuing Recreation and the Environment.* Edward Elgar, pp. 65-120.

Morse, W.W. 1980a. Maturity, spawning, and fecundity of the Atlantic croaker, *Micropogonias undulatus*, occurring North of Cape Hatteras, North Carolina. *U.S. Fish. Bull.* 78(1):190-195.

Morse, W.W. 1980b. Spawning and fecundity of Atlantic mackerel, *Scomber scombrus*, in the Middle Atlantic Bight. *Fishery Bulletin* 78:103-108.

Morton, Timothy. 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic): Bay Anchovy. *U.S. Fish and Wildlife Service Biological Report* 82(11.97). February, 1989.

Mouratov, D. 2001. MarineReference.com: Marine Glossary. http://www.marinereference.com/glossary/. Accessed 4/1/02.

Moyle, P. B. 1976. Inland Fishes of California. University of.California Press, Berkeley, CA.

Moyle, P.B. and J.J. Cech. 1996. 1996. Fishes: An introduction to ichthyology, 3rd ed. Prentice Hall. 590 pp.

Moyle, P.B., B. Herbold, D. E Stevens, and L. W. Miller. 1992. Life history and status of delta smelt in the Sacramento-San Joaquin Estuary, California. *Transactions of the American Fisheries Society* 121:67-77.

Muncy, R.J. 1984. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Gulf of Mexico): Pinfish., FWS/OBS-82/11.26. 30 p. http://www.nwrc.gov/wdb/pub/0166.pdf.

Murphy, M.D. and R.G. Taylor. 1989. Reproduction and growth of black drum, *Pogonias cromis*, in northeast Florida. *Northeast Gulf Science* 10:127-137.

Murphy, M.D. and R.G. Taylor. 1994. Age, growth, and mortality of spotted seatrout in Florida waters. *Transactions of the American Fisheries Society* 123:482-497.

Murphy, M.D., G.A. Nelson, and R.G. Muller. 2000. Florida's Inshore and Nearshore Species: 2000 Status and Trends Report. 37 p. http://floridamarine.org.

Murphy, R.C. 1952. Oceanic Birds of South America. Am. Mus. Nov., New York.

Myers, R.A. 2001. Compensation in Fish: A Review. Appendix B of Utility Water Act Group comments on the § 316(b) new sources rule. Unpublished manuscript.

Myers, R.A., and N.J. Barrowman. 1996. Is fish recruitment related to spawner abundance? *Fisheries Bulletin* 94:707-724.

Myers, R.A., and N.G. Cadigan. 1993. Density-dependent juvenile mortality in marine demersal fish. *Canadian Journal of Fisheries and Aquatic Sciences* 50:1576-1590.

Myers, R.A., K.G. Bowen, and N.J. Barrowman. 1999. Maximum reproductive rate of fish at low population sizes. *Canadian Journal of Fisheries and Aquatic Sciences* 56:2404-2419.

Myers, R.A., J. Bridson, and N.J. Barrowman. 1995. Summary of worldwide stock and recruitment data. *Canadian Technical Reports in Fisheries and Aquatic Science* 2024:1-327.

Myers, R.A., N.J. Barrowman, J.A. Hutchings, and A.A. Rosenberg. 1996. Population dynamics of exploited fish stocks at low population levels. *Science* 26:1106-1108.

Narragansett Estuarine Research Reserve 2001. "Prudence_Island_data.xls". Estimates of the abundance of species captured in sampling efforts within the tidal wetlands of the Coggeshall marsh on Prudence Island in the Narragansett Estuarine

Research Reserve in July and September 2000. Received from Kenny Raposa of the Narragansett Estuarine Research Reserve, 2001.

National Audubon Society. 2000. Refuge map. Florida. http://www.audubon.org/campaign/refuge/refuges/florida.html. Accessed 1/02.

National Geographic Society. 1969. 1969. Wondrous World of Fishes, 2nd edition. Washington, DC.

National Geographic Society. 1999. Field Guide to the Birds of North America, National Geographic Society, Washington, D.C. (1999).

Natural Heritage Network 2001. Natural Heritage Network at http://www.natureserve.org/nhp/us_programs.htm. (3/3/00)

Nature Conservation Council of NSW. 2002. Environmental Glossary: Glossary Item: Critical Habitat. http://www.nccnsw.org.au/glossary/Criticalhabitat.html. Accessed 3/29/02.

NatureServe. 2002. Natural Heritage Central Databases. Arlington, VA . U.S.A.

NBC. 2001. Narragansett Bay: An Introduction. Narragansett Bay Commission. http://narrabay.com. Accessed 10/16/01.

NBEP. 1998. Working Across the Watershed: 1998 Report. Narragansett Bay Estuary Program http://www.nbep.org/pubs/pdf/watw98.pdf. Accessed 12/05/01.

NBEP. 2001. About the Bay. Narragansett Bay Estuary Program. http://www.nbep.org/bay/index.html Accessed 10/16/01.

Neckles, H. and M. Dionne (eds.). 1999. Regional Standards to Identify and Evaluate Tidal Wetland Restoration in the Gulf of Maine: A GPAC Workshop, June 2-3. Prepared for the Global Programme of Action Coalition for the Gulf of Maine (GPAC) and the Commission for Environmental Cooperation. The Wells National Estuaries Research Reserve, Wells, ME.

NEFSC (Northeast Fisheries Science Center). 2000a. Report of the 30th Northeast Regional Stock Assessment Workshop (30th SAW) Stock Assessment Review Committee (SARC) consensus summary of assessments. Northeast Fish. Sci. Cent. Ref. Doc. 00-03.

NEFSC (Northeast Fisheries Science Center). 2000b. Status of the Fishery Resources off the Northeastern United States. Atlantic cod. http://www.nefsc.nmfs.gov/sos/spsyn/pg/cod/. Accessed 1/16/02.

NEFSC (Northeast Fisheries Science Center). 2000c. Status of the Fishery Resources off the Northeastern United States. Atlantic herring. http://www.nefsc.nmfs.gov/sos/spsyn/pp/herring/. Accessed 1/16/02.

NEFSC (Northeast Fisheries Science Center). 2000d. Status of the Fishery Resources off the Northeastern United States. Winter flounder. Northeast Fisheries Science Center. http://www.nefsc.nmfs.gov/sos/spsyn/fldrs/winter/. Accessed 1/16/02.

NEFSC (Northeast Fisheries Science Center). 2001. NMFS Northeast Fisheries Science Center Presents...Fish FAQ. http://www.nefsc.nmfs.gov/faq/fishfaq2a.html. Accessed 1/16/02.

Nelson, D.M. (ed.). 1992. Distribution and Abundance of Fishes and Invertebrates in Gulf of Mexico Estuaries. Volume I: Data Summaries. ELMR Report Number 10. NOAA/NOS Strategic Environmental Assessments Division. Rockville, MD. 273 pp.

Nelson, G.A. 1998. Abundance, growth, and mortality of young-of-the-year pinfish, *Lagodon rhomboides*, in three estuaries along the gulf coast of Florida. *Fishery Bulletin* 96:315-328.

Nelson, G.A., R.H. McMichael, T.C. MacDonals, and J.R. O'Hop. 1997. Fisheries monitoring and its use in fisheries resources management, p. 43-56. In: *Proceedings of the Tampa Bay Area Scientific Information Symposium 3: Applying Our Knowledge*, October 21-23, 1996 (S.F. Treat, ed.), Tampa Bay National Estuary Program.

Nelson, J.S. 1994. 1994. Fishes of the world, 3rd ed. John Wiley and Sons. 600 pp.

Nevada Division of Water Planning. 1997. Water Words Dictionary – A Compilation of Technical Water, Water Quality, Environmental, and Water-Related Terms. At: http://www.state.nv.us/cnr/ndwp/dict-1/waterwds.htm.

New England Power Company and Marine Research Inc. 1995. Brayton Point Station Annual Biological and Hydrological Report, January-December 1994. August.

New England Power Company and Marine Research Inc. 1998. New England Power Company Brayton Point Station 1997 Annual Biological and Hydrological Report. August.

New Hampshire Estuaries Project. 2002. Draft Technical Characterization. http://webster.state.nh.us/nhep/. Accessed 1/02.

New Hampshire Yankee Electric Company. 1986. Seabrook Station: Facility Description. 37 pp.

New Jersey Division of Fish and Wildlife. 2002. New Jersey Division of Fish and Wildlife. http://www.state.nj.us/dep/fgw/ensphome.htm. March 3.

New York Sportfishing and Aquatic Resources Education Program. 2001. Selected Fishes of New York State. http://www.dnr.cornell.edu/sarep/fish/fish.html. Accessed 9/19/01.

New York State Department of Environmental Conservation. 2000. Unpublished tables of impingement data for steam electric stations in New York. Provided to U.S. EPA by Ed Radle, New York State Department of Environmental Conservation, January 2000.

Newell, R.I.E. 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North and Mid-Atlantic) Blue Mussel., Biological Report 82(11.102). 25 p.

Nicholson, W. 1994. Intermediate Microeconomics and its application. Sixth Edition. The Dryden Press. Fort Worth Texas.

Nieland, D.L. and C.A. Wilson. 1993. Reproductive biology and annual variation of reproductive variables of black drum in the northern Gulf of Mexico. *Transactions of the American Fisheries Society* 122:318-327.

NIH (National Institute of Health). 1999. Research Services Branch. National Institute of Mental Health. Images. http://rsb.info.nih.gov/ij/images/Diatoms.jpg. Accessed 1/30/02.

Niles, L.J. 1995. Bald eagle. In: *Living Resources of the Delaware Estuary*. L.E. Dove and R.M. Nyman (eds.). The Delaware Estuary Program. pp. 359-366.

NJDEP (New Jersey Department of Environmental Protection). 2000. Fact Sheet for a Draft NJPDES Permit Including Section 316(a) Variance Determination and Section 316(b) Decision. Permit No. NJ0005622, Salem Generating Station. 83 pp.

NMFS (National Marine Fishery Service). 1994. National Marine Fishery Service (NMFS). http://www.st.nmfs.gov/st1/econ/rec_econ.html

NMFS (National Marine Fishery Service. 1997. National Marine Fishery Service (NMFS). http://www.st.nmfs.gov/st1/econ/rec_econ.html.

NMFS (National Marine Fisheries Service). 1999a. Marine Recreational Fisheries Statistics: Data User's Manual. Office of Science and Technology, Fisheries Statistics and Economics Division 1999. http://www.st.nmfs.gov/st1/recreational/research/procedures.html, July 12.

NMFS (National Marine Fisheries Service). 1999b. Our Living Oceans. Report on the status of U.S. living marine resources, 1999. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-F/SPO-41, 301 pp.

NMFS (National Marine Fisheries Service). 2001a. Annual Commercial Landing Statistics website. http://www.st.nmfs.gov/st1/commercial/. Accessed 9/01.

NMFS (National Marine Fisheries Service). 2001b. The Marine Recreational Fisheries Statistics Survey Page of the National Marine Fisheries Service Website. http://www.st.nmfs.gov/st1/recreational/survey/index.html. Accessed 3/01.

NMFS. (National Marine Fishery Service). 2001c. National Marine Fishery Service (NMFS). http://www.st.nmfs.gov/st1/econ/rec/econ.html.

NMFS (National Marine Fisheries Service) 2001d. Office of Protected Resources. Shortnose Sturgeon. National Marine Fishery Service (NMFS) Office of Protected Resources. http://www.nmfs.noaa.gov/prot_res/species/fish/Shortnose_sturgeon.html

NMFS (National Marine Fisheries Service) 2001e. Sea Turtle Protection and Conservation. Office of Protected Resources. http://www.nmfs.noaa.gov/prot_res/PR3/Turtles/turtles.html

NOAA (National Oceanic and Atmospheric Administration). 1993. Status of the Fishery Resources Off the Northeastern United States for 1993. NOAA Technical Memorandum NMFS-F/NEC 101. National Marine Fisheries Service. 140 pp.

NOAA (National Oceanic and Atmospheric Administration).2001a. Bay Anchovy. NOAA Coastal Service Center website. http://www.csc.noaa.gov/acebasin/specgal/bayanch.htm. Accessed 10/18/01.

NOAA (National Oceanic and Atmospheric Administration).. 2001b. NOAA Chesapeake Bay Office Species Information website. http://noaa.chesapeakebay.net/fisheries/species.htm. Accessed 12/01.

NOAA (National Oceanic and Atmospheric Administration).. 2001c. Status of the Fishery Resources off the Northeastern United States. http://www.nefsc.nmfs.gov/sos/. Accessed 11/01.

NOAA (National Oceanic and Atmospheric Administration).. 2002a. Characterization Of The Ashepoo-Combahee-Edisto (Ace) Basin, South Carolina. Species Gallery. http://www.csc.noaa.gov/acebasin/specgal/fish.htm. Accessed 1/30/02.

NOAA (National Oceanic and Atmospheric Administration).. 2002b. NOAA National Marine Fisheries Service Alaska Regional Office. Pink Shrimp (*Pandalus borealis*). http://www.fakr.noaa.gov/trawl/shr/shrimps.htm. Accessed 1/17/02.

NOAA (National Oceanic and Atmospheric Administration). 2002c. NOAA Photo Library. http://www.photolib.noaa.gov/historic/nmfs/figb0346.htm. Accessed 1/11/02.

NOAA (National Oceanic and Atmospheric Administration).. 2002d. NOAA's Biogeography Program. Gulf of Mexico Essential Fish Habitat: LA/MS/AL. http://biogeo.nos.noaa.gov/projects/efh/gom-efh/mmerc.gif. Accessed 1/17/02.

NOAA (National Oceanic and Atmospheric Administration).. 2002e. Stellwagen Bank National Marine Sanctuary. Research Programs. http://stellwagen.nos.noaa.gov/research/programs.html. Accessed 1/11/02.

Normandeau Associates Inc. 1984. Hudson River Ecological Study in the Area of Indian Point: 1983 Annual Report. Prepared for Consolidated Edison Company of New York, Inc., and New York Power Authority.

Normandeau Associates. 1990. Seabrook Environmental Studies, 1989. A Characterization of Baseline Conditions in the Hampton-Seabrook Area, 1975-1989. A Preoperational Study for Seabrook Station. Prepared for Public Service Company of New Hampshire, New Hampshire Yankee Division. September.

Normandeau Associates. 1991. Seabrook Environmental Studies, 1990. A Characterization of Environmental Conditions in the Hampton-Seabrook Area During the Operation of Seabrook Station. Prepared for Public Service Company of New Hampshire, New Hampshire Yankee Division. November.

Normandeau Associates. 1993. Seabrook Environmental Studies, 1992. A Characterization of Environmental Conditions in the Hampton-Seabrook Area During the Operation of Seabrook Station. Prepared for North Atlantic Energy Service Corporation. August.

Normandeau Associates. 1994a. Evaluation of Seabrook Station Estuarine Benthos Program. Prepared for North Atlantic Energy Service Corporation. October. Bedford, NH.

Normandeau Associates. 1994b. Seabrook Environmental Studies 1993. A Characterization of Environmental Conditions in the Hampton-Seabrook Area During the Operation of Seabrook Station. Prepared for North Atlantic Energy Service Corporation. September.

Normandeau Associates. 1995. Seabrook Station 1994. Environmental Studies in the Hampton-Seabrook Area. A Characterization of Environmental Conditions During the Operation of Seabrook Station. Prepared for North Atlantic Energy Service Corporation. October.

Normandeau Associates. 1996a. Seabrook Station 1995. Environmental Studies in the Hampton-Seabrook Area. A Characterization of Environmental Conditions During the Operation of Seabrook Station. Prepared for North Atlantic Energy Service Corporation. August.

Normandeau Associates. 1996b. Seabrook Station 1996. Environmental Monitoring in the Hampton-Seabrook Area. A Characterization of Environmental Conditions During the Operation of Seabrook Station. Prepared for North Atlantic Energy Service Corporation. January.

Normandeau Associates. 1997. Seabrook Station 1997. Environmental Monitoring in the Hampton-Seabrook Area. A Characterization of Environmental Conditions During the Operation of Seabrook Station. Prepared for North Atlantic Energy Service Corporation. September.

Normandeau Associates. 1999. Seabrook Station 1998. Environmental Monitoring in the Hampton - Seabrook Area. A Characterization of Environmental Conditions During the Operation of Seabrook Station. Prepared for North Atlantic Energy Service Corporation. October.

Normandeau Associates Inc. 2000. Impingement and Entrainment at the Cooling Water Intake Structure of the Delaware City Refinery, April 1998 - March 2000. Prepared for Motiva Enterprises LLC, Delaware City Refinery, Delaware City, DE. August.

North Atlantic Energy Service Corporation. 1999. Seabrook Station Sea Duck Entrapment Report. March 22, 1999.

North Dakota Game and Fish Department. 1986. Fishes of North Dakota. North Dakota Game and Fish Department, Bismarck, ND. Northern Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov/resource/tools/ndfishes/ndfishes.htm (Version 02FEB98).

Northeast Utilities. 2001a. 2000 Summary Annual Report, filed on April 12, 2001.

Northeast Utilities. 2001b. Form 10-K for the Fiscal Year Ended December 31, 2000, filed on March 28, 2001.

Northeast Utilities Environmental Laboratory. 1999. Monitoring the Marine Environment of Long Island Sound at Millstone Nuclear Power Station 1998 Annual Report. 274 pp.

Norton, V., T. Smith, and I. Strand (eds.). 1983. Stripers: The Economic Value of the Atlantic Coast Commercial and Recreational Striped Bass Fisheries. Maryland Sea Grant Publication. UM-SG-TS-83-12.

NRC (National Research Council). 1993. Managing Wastewater in Costal Urban Areas. National Academy Press, Washington, DC.

NRDC. 2002. Glossary of environmental terms. http://www.nrdc.org/reference/glossary/b.asp. Natural Resources Defense Council. Accessed 3/29/02.

NSW Department of Land and Water Conservation (New South Wales State Government Department of Land and Water Conservation). 2001. Caring for our Natural Resources. http://www.dlwc.nsw.gov.au/care/wetlands/facts/paa/algae/. Accessed 1/30/02.

O'Brien, L. 2000. American Plaice. NOAA, 5 p. http://www.nefsc.nmfs.gov/sos/spsyn/fldrs/plaice/. Accessed 06/30/01.

Ohio Department of Natural Resources. 1996. Ohio Public Hunting & Fishing Areas. ODNR, 1996.

Ohio Department of Natural Resources. 2001a. Division of Wildlife Fish Identification. http://www.dnr.state.oh.us/wildlife/fishing/fishid/default.htm. Accessed 8/28/01.

Ohio Department of Natural Resources. 2001b. Life History Notes. http://www.dnr.state.oh.us/wildlife/resources/default.htm. Accessed 03/20/01.

Ohio Department of Natural Resources. 2001c. Ohio River Fishing Regulations and License Reciprocity. http://www.dnr.state.oh.us/wildlife/fishing/fishregs/fshe.html. Accessed 2001.

Ohio Department of Natural Resources. 2001d. Ohio River Offers Excellent Sportfishing Opportunities. http://www.dnr.state.oh.us/00fish-pkt/ohioriver.html. Accessed 10/26/2001.

Ohio Department of Natural Resources. 2001e. Recreational Sportfishing Pumps More Than $2 Billion Into Ohio's Economy. http://www.dnr.state.oh.us/00fish-pkt/econo-fi.html. Accessed 2001.

Ohio Department of Natural Resources. 2002. Fishing Prospect Report 2002. http://www.dnr.state.oh.us/wildlife/fishing/fishpro/prosoh.html. Accessed 2002.

Ohio EPA 1988. Biological Criteria for the Protection of Aquatic Life: Volume II: Users Manual for Biological Field Assessment of Ohio Surface Waters. State of Ohio Environmental Protection Agency, Ecological Assessment Section Division of Water Quality Planning and Assessment, Columbus, Ohio.

Ohio EPA 1996. Ohio Waste Resource Inventory. Ohio EPA, Division of Surface Water, Monitoring and Assessment Section.

Ohio Valley Electric Corporation (OVEC) 2000. Ohio Valley Electric Corporation (OVEC). Annual Report – 2000, Ohio Valley Electric Corporation and subsidiary Indiana-Kentucky Electric Corporation. 2000.

Olla, B.L., A.J. Bejda, and A.D. Martin. 1975. Activity, movements, and feeding behavior of the cunner, *Tautogolabrus adspersus*, and comparison of food habits with young tautog, *Tautoga onitis*, off Long Island, New York. *Fishery Bulletin* 73(4):895-900.

Olla, B.L., A.J. Bejda, and A.D. Martin. 1979. Seasonal dispersal and habitat selection of cunner, *Tautogolabrus adspersus*, and young tautog, *Tautoga onitis*, in Fire Island Inlet, Long Island, New York. *Fishery Bulletin*, Vol.77(1):255-261.

Olsen, D.; Richards, J., and Scott, D. R. 1991. Existence and sport values for doubling the size of Columbia River Basin salmon and steelhead runs. *Rivers* 2(1):44-56.

Oro, D. 1996. Interspecific kleptoparasitism in Audouin's gull *Larus audouinii* at the Ebro Delta, northeast Spain: A behavioral response to low food availability. *Ibis* 138:218-221.

ORSANCO. 1962. Aquatic life resources of the Ohio River. An inventory and evaluation of fish populations, limnological conditions, commercial fishing, and sports fishing, with historical notes. Ohio River Valley Water Sanitation Commission.

ORSANCO. 1990. Assessment of nonpoint source pollution of the Ohio River. Ohio River Valley Water Sanitation Commission.

ORSANCO. 1998. Biennial assessment of Ohio river water quality conditions for water years 1996 and 1997. Ohio River Valley Water Sanitation Commission.

ORSANCO. 2001. Ohio River Facts. ORSANCO Web Page. http://www.orsanco.org/rivinfo/facts.htm. Ohio River Valley Water Sanitation Commission. Accessed 10/22/01.

Ouellet, P. 1997. Characteristics and vertical distribution of Atlantic cod (*Gadus morhua*) eggs in the northern Gulf of St. Lawrence, and the possible effect of cold water temperature on recruitment. *Canadian Journal of Fisheries and Aquatic Sciences* 54:211-223.

Overholtz, W. 2002. Northeast Fisheries Science Center. Status of the Fishery Resources off the Northeastern United States. Atlantic Mackerel. http://www.nefsc.nmfs.gov/sos/spsyn/pp/mackerel/. Accessed 1/11/02.

Overholtz, W.J., R.S. Armstrong, D.G. Mountain, and M. Tercerio. 1991. Factors Influencing Spring Distribution, Availability, and Recreational Catch of Atlantic Mackerel (*Scomber scombrus*) in the Middle Atlantic and Southern New England Regions., NOAA Technical Memorandum NMFS-F/NEC-85. 13 pp.

Parsons, G. and A. Hauber 1997. Spatial Boundaries and Choice Set Definition in a Random Utility Model of Recreational Demand. *Land Economics* 76(1): 86-89.

Parsons, G. and M.J. Kealy 1992. Randomly Drawn Opportunity Sets in a Random Utility Model of Land Recreation. *Land Economics* 68(1): pp 93-106.

Parsons, G.R. and M.S. Needelman 1992. Site Aggregation in a Random Utility Model of Recreation. *Land Economics* 68(4): 418-433.

Parsons, G.R., P.M. Jakus, and T. Tomasi 1999. A Comparison of Welfare Estimates from Four Models for Linking Seasonal Recreational Trips to Multinomial Logit Models of Site Choice. *Journal of Environmental Economics and Management* 38: 143-157.

Pattillo, M.E., T.E. Czapla, D.M. Nelson, and M.E. Monaco. 1997. Distribution and abundance of fishes and invertebrates in Gulf of Mexico estuaries, Volume II: Species life history summaries. ELMR Report No.11. NOAA/NOS Strategic Environmental Assessments Division, Silver Spring, MD. 377 p.

Peacock, B. 1999. Habitat Equivalency Analysis: Conceptual Background and Hypothetical Example. National Park Service Report. April 30.

Peebles, E.B., J.R. Hall, and S.G. Tolley. 1996. Egg production by the bay anchovy *Anchoa mitchilli* in relation to adult and larval prey fields. *Marine Ecology Progress Series* 131:61-73.

Peebles, E.B., M.S. Flannery, R.E. Matheson, and J.P. Rast. 1991. Fish nursery utilization of the Little Manatee River estuary: relationships to physicochemical gradients and the distribution of food resources, p. 341-367. In: *Proceedings, Tampa Bay Area Scientific Information Symposium 2.* February 27-March 1, 1991, Tampa, FL. (S.F. Treat and P.A. Clark, eds.), 528 p.

Pennsylvania. 1999. Rules and Regulations: Title 58-Recreation, Fish and Boat Commission [58 PA. Code CHS. 61 and 65] (http://www.pabulletin.com/secure/data/vol29/29-28/29_28_rr.pdf). Accessed 11/01.

Pennsylvania Department of Conservation and Natural Resources. 2002. Pennsylvania Department of Conservation and Natural Resources. http://www.dcnr.state.pa.us/wrcf/franda.htm. Accessed 3/3/02.

Pérez Farfante, I. 1969. Western Atlantic shrimps of the genus Penaeus. *U.S. Fish Wildl. Serv. Fish Bull.* 67:461-591.

Peters, K.M. and R.H. McMichael, Jr. 1990. Early life history of the black drum *Pogonias cromis* (Pisces: Sciaenidae) in Tampa Bay, Florida. *Northeast Gulf Science* 11(1):39-58.

Peterson, C.H., and J. Lubchenco. 1997. Marine ecosystem services. Pages 177-194 in: G.C. Daily, ed., *Nature's Services, Societal Dependence on Natural Ecosystems*. Island Press, Washington, DC.

Pettigrew, L. 1998. New Jersey Wildlife Viewing Guide. Falcon Publishing.

PG&E (Pacific Gas and Electric Company). 1995. Best Technology Available 1995 Technical Report for the Contra Costa and Pittsburg Power Plants. Submitted to the Central Valley Regional Water Quality Control Board and the San Francisco Bay Regional Water Quality Control Board.

PG&E (Pacific Gas and Electric Company). 1997. Best Technology Available 1996 Technical Report for the Pittsburg and Contra Costa Power Plants. Submitted to the San Francisco Bay Regional Water Quality Control Board and the Central Valley Regional Water Quality Control Board.

PG&E (Pacific Gas and Electric Company). 1998. Best Technology Available 1997 Technical Report for the Pittsburg and Contra Costa Power Plants. Submitted to the San Francisco Bay Regional Water Quality Control Board and the Central Valley Regional Water Quality Control Board.

PG&E (Pacific Gas and Electric Company). 1999. Best Technology Available 1998 Technical Report for the Pittsburg and Contra Costa Power Plants. Submitted to the Central Valley Regional Water Quality Control Board and the Regional Water Quality Control Board.

PG&E (Pacific Gas and Electric Company). 2001. Form 10-K for the Fiscal Year Ended December 31, 2000, filed on April 17, 2001.

PG&E Generating and Marine Research Inc. 1999. 1998 Annual Report, Brayton Point Station, Somerset, Massachusetts. September.

PG&E National Energy Group. 2001. Brayton Point Station permit renewal application, NPDES permit no. MA0003654. 316(a) and (b) demonstration. Executive summary and appendices. November.

Phillips, J.M., M.T. Huish, J.H. Kerby, and D.P. Moran. 1989. Species Profiles: life histories and environmental requirements of coastal fishes and invertebrates (mid-Atlantic) — Spot. U.S. Fish Widl. Serv. Biol. Rep. 82111.98. U.S. Army Corps of Engineers, TR EL-82-4. 13 pp.

Pierce, D.J., B. Mahmoudi, and R.R. Wilson, Jr. 2001. Age and growth of the scaled herring, ***Harengula jaguana***, from Florida waters, as indicated by microstructure of the sagittae. ***Fish. Bull.*** 99:202-209. http://fishbull.noaa.gov/991/18.pdf. Accessed 12/13/01.

Pollock, J. 2001. Jeffery Pollock for Congress: Dam Issues. http://www.pollock4congress.com/issues/dam.html. Accessed 11/21/01.

Port Manatee. 2000. Port Manatee. http://www.portmanatee.com. Accessed 1/02.

Postel, S., and S. Carpenter. 1997. Freshwater ecosystem services. Pages 195-214 in: G.C. Daily, ed., *Nature's Services, Societal Dependence on Natural Ecosystems*. Island Press, Washington, DC.

Potter, W.A. 1978. Assessment of the Effects of Impingement and Entrainment on the Fish Community of the New River, Virginia. Master's thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA. 70 pp.

Potter, W.A., E.D. Maruhnich, R.L. Shema, and C. J. Cook. 1979a. Cardinal Plant Fish Impingement and Entrainment Studies.

Potter, W.A., E.D. Maruhnich, R.L. Shema, and C.J. Cook. 1979b. Kammer Plant Demonstration Document for P.L. 92-500 Section 316(b) Volume II: Kammer Plant Fish Impingement and Entrainment Studies.

Potter, W.A., E.D. Maruhnich, R.L. Shema, and C.J. Cook. 1979c. Kyger Creek Station Fish Impingement and Entrainment Studies.

Potter, W.A., E.D. Maruhnich, R.L. Shema, and C.J. Cook. 1979d. Philip Sporn Plant Demonstration Document for P.L. 92-500 Section 316(b) Volume II, Appendix B: Philip Sporn Plant Fish Impingement and Entrainment Studies.

Pottle, R.A. and J.M. Green. 1979. Field observations on the reproductive behaviour of the cunner, *Tautogolabrus adspersus* (Waldbaum), in Newfoundland. *Canadian Journal of Zoology* 57:247-256.

PR Newswire - USA. 2001. http://www.globalarchive.ft.com/globalarchive/articles.html?id=010807007201.

Progress Energy. 2001. Form 10-K for the Fiscal Year Ended December 31, 2000, filed on March 29, 2001.

PSEG (Public Service Electric and Gas Company). 1989. Assessment of the Impacts of the Salem and Hope Creek Generating Stations on Kemp's Ridley (*Lepidochelys kempi*) and Loggerhead (*Caretta caretta*) Sea Turtles.

PSEG (Public Service Electric and Gas Company). 1999a. Permit Renewal Application NJPDES Permit No. NJ0005622. Public Service Electric and Gas Company Salem Generating Station. Appendix C: Attachments C-1 through C-2 March 4.

PSEG (Public Service Electric and Gas Company). 1999b. Permit Renewal Application NJPDES Permit No. NJ0005622. Public Service Electric and Gas Company Salem Generating Station. Appendix C: Attachments C-9 through C-14. March 4.

PSEG (Public Service Electric and Gas Company). 1999c. Permit Renewal Application NJPDES Permit No. NJ0005622. Public Service Electric and Gas Company Salem Generating Station. Appendix F, Section 316(b) Demonstration (Volume 2).

PSEG (Public Service Electric and Gas Company). 1999d. Permit Renewal Application NJPDES Permit No. NJ0005622. Public Service Electric and Gas Company Salem Generating Station. Appendix J: Analysis of Trends for Selected Finfish and Blue Crab.

PSEG (Public Service Electric and Gas Company). 1999e. Permit Renewal Application NJPDES Permit No. NJ0005622. Public Service Electric and Gas Company Salem Generating Station. Appendix L: Data Set Descriptions.

PSEG (Public Service Electric and Gas Company). 1999f. Salem NPDES Permit Application, Appendix H.

PSEG (Public Service Electric and Gas Company). 2001a. About PSEG Power. http://www.pseg.com/companies/power/about.html. Accessed 9/28/01.

PSEG (Public Service Electric and Gas Company). 2001b. PSEG Response to ESSA Report on the 1999 Salem Permit Application.

PSEG (Public Service Electric and Gas Company). 2001c. PSEG's Specific Comments on Proposed Terms and Conditions and Fact Sheet, Part 2. Draft NJPDES Permit No. NJ0005622, Salem Generating Station.

PSEG (Public Service Electric and Gas Company). 2001d. Public Service Enterprise Group Inc. 10-K405 filed on 03/06/2001.

PSEG (Public Service Electric and Gas Company). 2001e. PSEG. http://www.pseg.com/companies/power/overview.html. Accessed 9/28/01.

PSEG (Public Service Electric and Gas Company). 2001f. Salem Generating Station Historical Annual Water Withdrawal. Graph and data table. Received via e-mail from J.H. Balletto, Public Service Electric and Gas Company, 12/4/2001.

QuanTech, Survey Research Center 1998. 1997 AMES Telephone Follow-Up Survey Coding Handbook.

Quinn, T.J., II. and R.B. Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press, Oxford and New York.

R.G. Otto & Associates and Science Applications International Corporation. 1987. Mechanisms of Compensatory Response of Fish Populations: Workshop Proceedings. EA-5202, Research Project 1633, Proceedings, June 1987. Electric Power Research Institute, Palo Alto, CA.

Rago, P.J. 1984. Production forgone: An alternative method for assessing the consequences of fish entrainment and impingement losses at power plants and other water intakes. *Ecological Modelling* Vol. 24. pp. 79-111.

Rakoczy, G.P. and R.F. Svoboda. 1997. Sportfishing Catch and Effort from the Michigan waters of Lakes Michigan, Huron, Erie, and Superior, April 1, 1994-March 31, 1995.

Rakoczy, G.P. and D. Wesander-Russell. 1998. Charter Boat Catch and Effort from the Michigan Waters of the Great Lakes, 1997. Michigan Department of Natural Resources, Fisheries Technical Report No. 98-3.

Raposa, K.B. In press. Early responses of fishes and crustaceans to restoration of a tidally restricted New England salt marsh. *Restoration Ecology*.

Reid, R.N., L.M. Cargnelli, S.J. Griesbach, D.B. Packer, D.L. Johnson, C.A. Zetlin, W.W. Morse, and P.L. Berrien. 1999. Essential fish habitat source document: Atlantic herring, *Clupea harengus*, life history and habitat characteristics., NOAA Technical Memorandum NMFS-NE-126. September.

Resource Data International (RDI) 2001. Resource Data International (RDI). 2001. NEWGen Database. Plant Data Sheet for Gannon power plant. November 2001.

Restrepo, V.R. 1989. Growth estimates for male stone crabs along the southwest coast of Florida: A synthesis of available data and methods. *Trans. Am Fish. Soc.* 118:20-29.

Restrepo, V.R. 1992. A mortality model for a population in which harvested individuals do not necessarily die: The stone crab. *Fish Bull., U.S.* 90:412-416.

Rettig, R. and B. McCarl. 1985. Potential and Actual Benefits from Commercial Fishing Activities. In: *Making Information More Useful for Salmon and Steelhead Production Decisions*. NOAA Technical Memorandum NMFS F/NWR-8. National Marine Fisheries Service, Portland, Oregon. pp. 199-212.

Rhode Island Department of Environmental Management. 2001a. "Mthopebay_RIjuvfinfishsurvey.xls". Annual abundance estimates for tautog and winter flounder from various sampling sites in and near Mt. Hope Bay for the period 1990-2000 that were developed from data collected as part of the Rhode Island juvenile finfish survey program. Received from Chris Powell, Rhode Island Department of Environmental Management - Fish and Wildlife Division, 2001.

Rhode Island Department of Environmental Management. 2001b. "RIsaltpond_templesampling.xls". Winter flounder capture and abundance estimates from sampling conducted from 1994 - 2001 as part of the Rhode Island coastal pond survey program. Received from Jennifer Temple, Rhode Island Division of Fish and Wildlife, 2001.

Richkus, W.A. and R. McLean. 1998. Historical Overview of the Efficacy of Two Decades of Power Plant Fisheries Impact Assessment Activities in Chesapeake Bay. In: *EPRI Clean Water Act Section 316(b) Technical Workshop*. D. Dixon and K. Zammit (eds.). EPRI Clean Water Act Section 316(b) Technical Workshop, September 22-24, Berkeley Springs, WV.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada, Bulletin 191.

RIEDC. 1999. The Rhode Island Economy. Rhode Island Economic Development Corporation http://www.riedc.com/pdfpubs/RI%20Economy.PDF. Accessed 1/29/02.

RIEDC. 2000. Rhode Island Annual Economic Trends. Rhode Island Economic Development Corporation http://www.riedc.com/pdfpubs/Annual%20Trends.PDF. Accessed 1/29/02.

Robinette, H.R. 1983. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Gulf of Mexico): Bay anchovy and striped anchovy. U.S. Fish and Wildl. Serv., Div. Biol. Serv., Rep. No. FWS/OBS-82/11.14. U.S. Army Corps of Engineers, Rep. No. TR EL-82-4.

Rogers, B.A., D.T. Westin, and S.B. Saila. 1977. Life Stage Duration Studies on Hudson River Striped Bass , *Morone saxatillis* (Walbaum). University of Rhode Island, Applied Mar. Res. Group, NOAA Sea Grant, Mar. Tech. Rep. 31. 111 pp.

Roman, C.T., K.B. Raposa, S.C. Adamowicz, M.-J. James-Pirri, and J.G. Catena. Submitted 2000. Quantifying vegetation and nekton response to tidal restoration of a New England salt marsh. Submitted to Restoration Ecology.

Ronafalvy, J.P., R.R. Cheesman, and W.M. Matejek. 2000. Circulating water traveling screen modifications to improve impinged fish survival and debris handling at the Salem Generating Station. *Environmental Science and Policy* Volume 3, Supplement 1, pages S377-S382.

Rose, K.A. and J.H. Cowan. 1993. Individual-based model of young-of-the-year striped bass population dynamics. I. Model description and baseline simulations. *Transactions of the American Fisheries Society* 122:415-438.

Rose, K.A., J.H. Cowan, Jr., K.O. Winemiller, R.A. Myers, and R. Hilborn. 2001. Compensatory density-dependence in fish populations: Importance, controversy, understanding, and prognosis. In Press, *Fish and Fisheries*.

Ross, D.A. 1995. 1995. Introduction to Oceanography. Harper Collins College Publishers. 496 pp.

Rothschild, B.J. 1986. Dynamics of Marine Fish Populations. Harvard University Press, Cambridge, MA.

Rottmann, R. W., R. Francies-Floyd, and R. Durborow. 1992. The Role of Stress in Fish Disease., SRAC Publication No. 474. Southern Regional Aquaculture Center, Stoneville, MS. February. 3 p. http://ag.ansc.purdue.edu/aquanic/publicat/usda_rac/efs/srac/474fs.pdf.

Rowe, R.D., W.D. Shaw, and W. Schulze. 1992. Nestucca Oil Spill. In: *Natural Resource Damages*, edited by K. Ward and J. Duffield. New York: Wiley and Sons.

Rozas, L.P. 1992. Bottomless lift net for quantitatively sampling nekton on intertidal marshes. *Marine Ecology Progress Series* 89:287-292.

Ruhl, J.B., and R.J. Gregg. 2001. Integrating Ecosystem Services into Environmental Law: A Case Study of Wetlands Mitigation Banking. *Stanford Environmental Law Journal* 20(2):365-392.

Ruppert, D., R.L. Reish, R.B. Deriso, and R.J. Carroll. 1985. A stochastic population model for managing the Atlantic menhaden (*Brevoortia tyrannus*) fishery and assessing managerial risks. *Canadian Journal of Fisheries and Aquatic Sciences* 42:1371-1379.

SAIC (Science Applications International Corporation). 1993. Review of San Diego Gas & Electric Encina Power Plant 316(b) Demonstration. Draft. Prepared for U.S. EPA Region 9. 18 pp.

SAIC (Science Applications International Corporation). 1994. Background Paper Number 3: Cooling Water Intake Technologies. Prepared for U.S. EPA Office of Wastewater Enforcement and Compliance, Permits Division by Science Applications International Corporation, Falls Church, VA.

SAIC (Science Applications International Corporation). 1995. Preliminary Draft Working Paper: Biological Impacts from the Intake of Cooling Water. Prepared for U.S. EPA Office of Wastewater Enforcement and Compliance, Permits Division by Science Applications International Corporation, Falls Church, VA.

SAIC (Science Applications International Corporation). 1996a. Background Paper Number 2: Cooling Water Use for Selected U.S. Industries. Prepared for U.S. EPA Office of Wastewater Enforcement and Compliance, Permits Division by Science Applications International Corporation, Falls Church, VA.

SAIC (Science Applications International Corporation).. 1996b. Supplement to Background Paper Number 3: Cooling Water Intake Technologies. Prepared for U.S. EPA Office of Wastewater Management by Science Applications International Corporation, Falls Church, VA.

Saila, S.B. and E. Lorda. 1977. Sensitivity analysis applied to a matrix model of the Hudson River striped bass population. In: *Proceedings of a Conference on Assessing the Effects of Power Plant Induced Mortality on Fish Populations,* Gatlinburg, Tennessee, May 3-6, 1977. W. Van Winkle (ed.). Pergamon Press, NY. pp. 311-332.

Saila, S.B., X. Chen, K. Erzini, and B. Martin. 1987. Compensatory Mechanisms in Fish Populations: Literature Reviews. Volume 1: Critical Evaluation of Case Histories of Fish Populations Experiencing Chronic Exploitation or Impact. EA-5200, Volume 1, Research Project 1633-6. Final Report, May 1987. Electric Power Research Institute, Palo Alto, CA.

Saila, S.B., E. Lorda, J.D. Miller, R.A. Sher, and W.H. Howell. 1997. Equivalent adult estimates for losses of fish eggs, larvae, and juveniles at Seabrook Station with use of fuzzy logic to represent parametric uncertainty. *North American Journal of Fisheries Management* 17:811-825.

Salzman, J., B.H. Thompson, Jr., and G.C. Daily. 2001. Protecting Ecosystem Services: Science, Economics, and Law. *Stanford Environmental Law Journal* 20(2):309-332.

Samples, K.C. and R.C. Bishop. 1985. Estimating the Value of Variations in Angler's Success Rates: An Application of the Multiple-Site Travel Cost Method. *Marine Resource Economics* 2(1):55-74.

San Diego Natural History Museum. 1998. Shark Glossary. http://www.sdnhm.org/kids/sharks/glossary.html Accessed 4/1/02.

Sanders, L.D., R.G. Walsh, and J.B. Loomis. 1990. Toward Empirical Estimation of the Total Value of Protecting Rivers. *Water Resources Research* 26(7):1345-1357.

Santoro, E.D. 1998. Delaware Estuary Monitoring Report. Delaware Estuary Program.

Saucier, M.H. and D.M. Baltz. 1993. Spawning site selection by spotted seatrout, *Cynoscion nebulosus*, and black drum, *Pogonias cromis*, in Louisiana. *Environmental Biology of Fishes* 36:257-272.

Save the Bay. 2001. Eelgrass: A Critical Narragansett Bay Habitat. http://www.savebay.org/bayissues/eelgrass.htm. Accessed 10/12/01.

Savidge, I.R., J.B. Gladden, K.P. Campbell, and J.S. Ziesenis. 1988. Development and sensitivity of impact assessment equations based on stock-recruitment theory. *American Fisheries Society Monograph* 4:182-190.

Scherer, M.D. 1972. The Biology of the Blueback Herring, *Alosa aestivalis* (Mitchill) in the Connecticut River above the Holyoke Dam, Holyoke, Massachusetts. Master's Thesis. University of Massachusetts, Amherst.

Schoelkopf, R. And E. Stetzar. 1995. Marine turtles. Pages 305-309 in: L.E. Dove and R.M. Nyman, eds. *Living Resources of the Delaware Estuary*. The Delaware Estuary Program.

Schorfhaar, R.G. and P.J. Schneeberger. 1997. Commercial and Sport Fisheries for Lake Whitefish in Michigan Waters of Lake Superior, 1983-96. State of Michigan Department of Natural Resources, Fisheries Division Research Report Number 2034. June 30. http://www.dnr.state.mi.us/www/ifr/ifrlibra/research/reports/2034rr.pdf.

Schram, S.T., T.N. Halpern, and T.B. Johnson. 1998. Ecology of Burbot in Western Lake Superior. In: *Biology and Management of Burbot*, V. Paragamian and D. MacKinlay (eds). International Congress on the Biology of Fish, Baltimore, MD, July 27-30. http://www-heb.pac.dfo-mpo.gc.ca/congress/Burbot.pdf.

Schultz, Ken 2001. The Angling Authority; Species Encyclopedia.

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. *Fisheries Research Board of Canada Bulletin* 184.

Scott, W.B. and E.J. Crossman. 1998. Freshwater Fishes of Canada. *Fisheries Research Board of Canada Bulletin* 184 ed. Galt House, Oakville, Ontario, Canada.

Scott, W.B. and M.G. Scott. 1988. Atlantic fishes of Canada. *Can. Bull. Fish. Aquat. Sci.* 219. 731 pp.

Seagraves, R.J. 1995. Weakfish. In: *Living Resources of the Delaware Estuary*. L.E. Dove and R.M. Nyman, (eds.). The Delaware Estuary Program. pp. 293-298.

Serchuk, F. and C. Cole. 1974. Age and growth of the cunner, *Tautogolabrus adspersus* (Waldbaum), Pisces (Labridae), in the Weweantic River Estuary, Massachusetts. Chesapeake Science 15(4):205-213.

Setzler, E.M., W.R. Boynton, K.V. Wood, H.H. Zion, L. Lubbers, N.K. Mountford, P. Frere, L. Tucker, and J.A. Mihursky. 1980. Synopsis of Biological Data on Striped Bass, *Morone saxatilis* (Walbaum). NOAA Technical Report NMFS Circular 433. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, June 1980.

Sharma, R.K. and R.F. Freeman. 1977. Survey of Fish Impingement at Power Plants in the United States Volume I: The Great Lakes. ANL/ES-56 Volume I. Argonne National Laboratory, Argonne, IL, 218 pp.

Shaw, M. 1998. Biology 71.125 Glossary. http://www.umanitoba.ca/faculties/science/biological_sciences/labgloss.html Accessed 4/1/02.

Shaw, W.N., T.J. Hassler, and D.P. Moran. 1988. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest): California Sea Mussel and Bay Mussel., *U.S. Fish and Wildlife Service Biological Report* 82(11.84). 16 p.

Shepherd, J.G., and D.H. Cushing. 1990. Regulation in fish populations: myth or mirage. *Philosophical Transactions of the Royal Society, London* B 330:151-164.

Shepherd, G.R. and C.B. Grimes. 1983. Geographic and historic variations in growth of weakfish, *Cynoscion regalis*, in the Middle Atlantic Bight. *U.S. Fish. Bull.* 81(4):803-813.

Shepherd, G.R. and C.B. Grimes. 1984. Reproduction of weakfish, *Cynoscion regalis*, in the New York Bight and evidence for geographically specific life history characteristics. *U.S. Fish. Bull.* 82(3):501-511.

Sheridan, P. 1996. Forecasting the fishery for pink shrimp, *Penaeus duorarum*, on the Tortugas grounds, Florida. *Fishery Bulletin* 94:743-755.

Shirey, C. A., C. C. Martin, and E. J. Stetzar. 1997. Abundance of sub-adult Atlantic sturgeon and areas of concentration within the lower Delaware River. Final Report, Grant No. NA66FG0326. Prepared for the Delaware Division of Fish and Wildlife.

Short, R., R. Davis, and D. Burdick. 1997. Eelgrass (*Zostera marina L.*) habitat restoration in New Bedford Harbor, Massachusetts. Scope of work in proposal submitted to the New Bedford Harbor Trustee Council. Prepared by the Department of Natural Resources, University of New Hampshire. July 17.

Simmons, R.L., A.V. Zale, and D.M. Leslie. 1997. Physical and biological factors affecting seasonal double-crested cormorant densities at Oklahoma reservoirs. *Colonial Waterbirds* 20:31-40.

Smith, C.L. 1985. The inland fishes of New York State. The New York State Department of Environmental Conservation (ISBN 0-9615433-0-2), 522 pp.

Smith-Root. 2001. Online Store. http://www.smith-root.com/store/. Accessed 12/01.

Snyder, D.E. 1998. Burbot — Larval Evidence for More than One North American Species? In: *Biology and Management of Burbot*, V. Paragamian and D. MacKinlay (eds). International Congress on the Biology of Fish, Baltimore, MD, July 27-30. http://www-heb.pac.dfo-mpo.gc.ca/congress/Burbot.pdf.

Sorg, C.F., J.B. Loomis, D.M. Donnelly, G.L. Peterson, and L.J. Nelson. 1985. Net Economic Value of Cold and Warm Water Fishing in Idaho. USDA Forest Service Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO Resource Bulletin RM-11. November.

South Carolina Department of Natural Resources. 2001. Marine Resources Research Institute. SEAMAP Target Species website. http://water.dnr.state.sc.us/marine/mrri/seamap/species.htm. Accessed 12/12/01.

South Florida Water Management District. 2002. Coastal Ecosystems. Photos. http://www.sfwmd.gov/org/wrp/wrp_ce/2_wrp_ce_info/2_wrp_ce_photos.html. Accessed 1/30/02.

Southern California Edison Company. 1987. Report on 1987 Data: Marine Environmental Analysis and Interpretation: San Onofre Nuclear Generating Station. 27 pp.

Southern Energy California. 2000. Best Technology Available 1999 Technical Report for the Contra Costa and Pittsburg Power Plants. Submitted to the Central Valley Regional Water Quality Control Board and the San Francisco Bay Regional Water Quality Control Board.

Southern Energy Delta, LLC. 2000. Multispecies Habitat Conservation Plan, Pittsburg and Contra Costa Power Plants. Draft-Revision 5, June 30, 2000. Prepared for the U.S. Fish & Wildlife Service, Sacramento, CA, and the National Marine Fisheries Service, Santa Rosa, CA.

Spicer G., T. O'Shea, and G. Pichler. 1998. Entrainment, Impingement and BTA Evaluation for an Intake Located on a Cooling Water Reservoir in the Southwest. In: *EPRI Clean Water Act Section 316(b) Technical Workshop*. D. Dixon and K. Zammit (eds.). EPRI Clean Water Act Section 316(b) Technical Workshop, September 22-24, Berkeley Springs, WV.

Spigarelli, S.A., A.J. Jensen, and M.M. Thommes. 1981. An Assessment of the Impacts of Water Intakes on Alewife, Rainbow Smelt, and Yellow Perch Populations in Lake Michigan. Prepared by Argonne National Laboratory and U.S. EPA. ANL/ES-109. EPA-905/3-81-001. March.

Spratt, J.D. 1992. Pacific Herring. Pages 86-89 in: Leet, W.S., C.M. Dewees, and C.W. Haugen (eds.), *California's Living Marine Resources and their Utilization*. California Sea Grant, Sea Grant Extension Publication UCSGEP-92-12. California Sea Grant Extension Program, University of California, Davis, CA.

Springer, V.G. and K.D. Woodburn. 1960. An ecological study of the fishes of the Tampa Bay area. *Mar. Lab. Prof. Pap., Fla. St. Bd. Conserv., Ser.* 1:1-104.

Standard & Poor's. 2001a. Public Service Enterprise Group — Stock Report. September 1, 2001.

Standard & Poor's. 2001b. Stock Report for PG&E Corporation. September 29, 2001.

Stanley, J.G. and D.S. Danie. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (north Atlantic):white perch. U.S. Fish and Wildlife Service Biological Services Program FWS/OBS-82/11.7. 12 pp.

State of Maine Department of Marine Resources. 2001a. Maine Division of Marine Resources. 2001. Saltwater Anglers Guide, Know Your Catch. Family Clupeidae, Herrings. http://www.state.me.us/dmr/recreational/fishes/shad.htm. Accessed 7/18/01.

State of Maine Department of Marine Resources. 2001b. Maine Division of Marine Resources. 2001. Saltwater Anglers Guide, Know Your Catch. Family Labridae, Wrasses, Cunner. http://www.state.me.us/dmr/recreational/fishes/cunner.htm. Accessed 2/6/01.

State of Maine Department of Marine Resources. 2001c. Maine Division of Marine Resources. 2001. Saltwater Anglers Guide, Know Your Catch. Family Labridae, Wrasses, Tautog. http://www.state.me.us/dmr/recreational/fishes/tautog.htm. Accessed 2/6/01.

State of Maine Department of Marine Resources. 2001d. Maine Division of Marine Resources. 2001. Saltwater Anglers Guide, Know Your Catch. Family Pleuronectidae, righteye flounders. http://www.state.me.us/dmr/recreational/fishes/winterflounder.htm. Accessed 2/6/01.

State of Massachusetts. 2002. Plymouth, Plymouth County. http://www.state.ma.us/dhcd/iprofile/239.pdf. Accessed 1/9/02.

State of New York, Department of Environmental Conservation. 2001. State of New York, Department of Environmental Conservation. List of Endangered, Threatened and Special Concern Fish & Wildlife Species of New York State. http://www.dec.state.ny.us/website/dfwmr/wildlife/endspec/etsclist.html Accessed 3/3/01.

Steimle, F.W. and P.A. Shaheen. 1999. Tautog (*Tautoga onitis*) life history and habitat requirements. NOAA Technical Memorandum NMFS-NE-118. National Marine Fisheries Service.

Steiner, L. 2000. Pennsylvania Fishes. Pennsylvania Fish Commission, Harrisburg, PA. http://sites.state.pa.us/PA_Exec/Fish_Boat/fishhtms/chapindx.htm Accessed 10/30/2001.

Stevens, D.E. 1992. Striped Bass. Pages 72-75 in: Leet, W.S., C.M. Dewees, and C.W. Haugen (eds.), *California's Living Marine Resources and their Utilization*. California Sea Grant, Sea Grant Extension Publication UCSGEP-92-12. California Sea Grant Extension Program, University of California, Davis, CA.

Stevens, D.E., L.W. Miller, and B.C. Bolster. 1990. Report to the Fish and Game Commission: A Status Review of Delta Smelt (*Hypomesus transpacificus*) in California. California Department of Fish and Game. Candidate Species Status Report 90-2.

Stevens, T. H.; Field, M. K.; More, T. A., and Glass, R. J. 1994. Contingent valuation of rare and endangered species: An assessment. W-133 Benefits and Cost Transfer in Resource Planning.

Stevens, T.H., J. Echeverria, R.J. Glass, T. Hager, and T.A. More. 1991. Measuring the Existence Value of Wildlife: What Do CVM Estimates Really Show? *Land Economics* 67:390-400.

Stewart, N.H. 1926. Development, growth, and food habits of the white sucker, *Catostomus commersonii* Lesueur. *Fishery Bulletin* 42:147-184.

Stone & Webster Engineering Corporation. 1977. Supplemental Assessment in Support of the 316 Demonstration, Pilgrim Nuclear Power Station Units 1 and 2, Boston Edison Company, Boston, MA.

Stone & Webster Engineering Corporation. 1980a. 316(A) and (B) Demonstration Big Bend Station - Unit 4. Volume I and Volume II, Appendices. Prepared for Tampa Electric Company. August 1.

Stone & Webster Engineering Corporation. 1980b. Fine Mesh Screen Prototype Study Final Report: Big Bend Power Station Unit 4, Tampa Electric Company. Prepared for Tampa Electric Company. November 1980.

Strange, E. M., K. D. Fausch, and A. P. Covich. 1999. Sustaining ecosystem services in human-dominated watershed: biohydrology and ecosystem processes in the South Platte River Basin. *Environmental Management* 24(1):39-54.

Strange, E.M., H. Galbraith, S. Bickel, D. Mills, D. Beltman, and J. Lipton. 2002. Determining ecological equivalence in service-to-service scaling of salt marsh restoration. *Environmental Management* 29(2): 290-300.

Studholme, A.L., D.B. Packer, P.L. Berrien, D.L. Johnson, C.A. Zetlin, and W.W. Morse. 1999. Essential fish habitat document: Atlantic Mackerel, *Scomber scombrus*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-141.

Stupka, R.C. and R.K. Sharma. 1977. Survey of Fish Impingement at Power Plants in the United States Volume III: Estuaries and Coastal Waters. ANL/ES-56 Volume III. Argonne National Laboratory, Argonne, IL, 305 pp.

Suddaby, D. and N. Ratcliffe. 1997. The effects of fluctuating food availability on breeding arctic terns *Sterna paradisaea*. *The Auk* 114:524-530.

Sullivan, J.R. 1979. The Stone Crab, *Menippe mercenaria*, in the Southwest Florida Fishery. Florida Marine Research Publications Number 36. Florida Department of Natural Resources Marine Research Laboratory, St. Petersburg, Florida.

Summers, J.K. 1989. Simulating the indirect effects of power plant entrainment losses on an estuarine ecosystem. *Ecological Modelling*, 49 (1989). pp. 31-47.

Sutherland, R.J. and R.G. Walsh. 1985. Effect of Distance on the Preservation Value of Water Quality. *Land Economics* 61(3) 282-291.

Sutter, F.C., R.S. Waller and T.D. McIlwain. 1986. Species profiles: life histories and environmental requirements of coastal fisheries and invertebrates (Gulf of Mexico)-Black Drum. *U.S. Fish Widl. Serv. Biol. Rep.* 82(11.51), U.S. Army Corps of Eng. TR LE-82-4. 10 pp.

Swedberg, D.V. and C.H. Walburg. 1970. Spawning and early life history of the freshwater drum in Lewis and Clark Lake, Missouri River. *Transactions of the American Fisheries Society* 99:560-570

Swee, U.B. and H.R. McCrimmon. 1966. Reproductive biology of the carp, *Cyprinus carpio L.*, in Lake St. Lawrence, Ontario. *Transactions of the American Fisheries Society* 95(4):372-380.

Systec Engineering, Inc. 1987. Compensatory Mechanisms in Fish Populations: Literature Reviews. Volume 3: A Critical Review of Mathematical Models for Fish Compensation Mechanisms. EA-5200, Volume 3, Research Project 1633-6. Final Report, May 1987. Electric Power Research Institute, Palo Alto, CA.

Taft, E.P. 1999. Fish protection technologies: A status report. Presentation at Power Generation Impacts on Aquatic Resources Conference, Atlanta Georgia, April 12-15, 1999.

Tagatz, M.E. 1968. Biology of the blue crab, *Callinectes sapidus* Rathbun in the St. John's River, Florida. *Fish Bulletin, U.S.* 67(1):17-33.

Tampa Bay Beaches Chamber of Commerce. 2001. Tampa Bay Beaches Chamber of Commerce Website. http://www.gulfbeaches-tampabay.com/sports.asp. Accessed 8/01.

TBNEP (Tampa Bay National Estuary Program). 1992a. Distribution of selected fish species in Tampa Bay. TBNEP Technical Publication #05-92.

TBNEP (Tampa Bay National Estuary Program). 1992b. Synthesis of basic life histories of Tampa Bay species. TBNEP Technical Publication #10-92.

TBNEP (Tampa Bay National Estuary Program). 1994. Physical impacts to habitats in Tampa Bay. TBNEP Technical Publication #03-93.

TBNEP (Tampa Bay National Estuary Program). 1995. Benthic infauna of Tampa Bay, summer 1993: A technical data report. TBNEP Technical Publication #02-95.

TBNEP (Tampa Bay National Estuary Program). 1996a. Charting The Course: The Comprehensive Conservation and Management Plan for Tampa Bay. 262 pp.

TBNEP (Tampa Bay National Estuary Program). 1996b. Estimates of total nitrogen, total phosphorus, and total suspended solids to Tampa Bay, Florida. Technical Appendix: 1992-1994 total nitrogen loadings to Tampa Bay, Florida. Final Report. TBNEP Technical Publication #19-96.

TBNEP (Tampa Bay National Estuary Program). 1996c. Setting priorities for Tampa Bay habitat protection and restoration: restoring the balance. TBNEP Technical Publication #09-95.

TBNEP (Tampa Bay National Estuary Program). 2001. Tampa Estuary Program. Charting the Course. http://www.tbep.org/portrait/fastfacts.html. Accessed 1/02.

TECO (TECO Energy, Inc.). 2002. Tampa Electric Vital Statistics. http://www.tampaelectric.com/TENWVitalStats.html. 1/22/02.

Tennessee Division of Forestry, Fisheries, and Wildlife Development. 1976. Volume 5: Effects of the Gallatin Steam Plant Cooling Water Intake on the Fish Populations of Old Hickory Reservoir. Tennessee Division of Forestry, Fisheries, and Wildlife Development, Fisheries and Waterfowl Resources Branch, Norris, TN. June 30.

Tennessee Valley Authority. 1977. 316 (a) and 316(b) Demonstration, Cumberland Steam Plant: Volume 5, Effects of the Cumberland Steam Plant Cooling Water Intake on the Fish Populations of Barkley Reservoir.

Tetra Tech Inc. 1978. Biological Effects of Once-Through Cooling Part I, Volume 2: The Marine Environment. Prepared by the Utility Water Act Group. Submitted to U.S. EPA. June.

Texas Instruments Inc. 1980. Hudson River Ecological Study in the Area of Indian Point: 1979 Annual Report. Prepared for Consolidated Edison Company on New York, Inc.

Texas Instruments Inc. and Lawler, Matusky, and Skelly Engineers. 1978. Biological Effects of Once-Through Cooling Part I, Volume 5: Great Lakes Basin and Connecting Water Bodies. Prepared for the Utility Water Act Group. Submitted to U.S. EPA.

Thayer, G.W., M.S. Fonseca, and J.W. Kenworthy. 1997. Ecological value of seagrasses: A brief summary for the ASMFC habitat committee's SAV subcommittee. In: *Atlantic Coastal Submerged Aquatic Vegetation: A Review of its Ecological Role, Anthropogenic Impacts, State Regulation, and Value to Atlantic Coastal Fish Stocks*, C.D. Stephen and T.E. Bigford (eds.). ASMFC Habitat Management Series #1, Atlantic States Marine Fisheries Commission, pp. 7-12.

Thomas M.V. and R.C. Haas. 2000. Status of Yellow Perch and Walleye Populations in Michigan Waters of Lake Erie, 1994-98. Michigan Department of Natural Resources, Fisheries Division, Fisheries Research Report 2054, August.

Thomas, P. 2001. Thomas Research Group. Species Information. http://www.utmsi.utexas.edu/people/staff/thomas/species_information.htm. Accessed 1/30/02.

Thurber, N.J. and D.J. Jude. 1985. Impingement Losses at the D.C. Cook Nuclear Power Plant during 1975-1982 with a Discussion of Factors Responsible and Possible Impact on Local Populations. Special Report No. 115 of the Great Lakes Research Division, Great Lakes and Marine Waters Center, University of Michigan.

Tofflemire, T.J., S.O. Quinn, and I.G. Carcich. 1980. Sediment and Water Sampling and Analysis for Toxics: Relative to PCB in the Hudson River, New York State Department of Environment Conservation Technical Paper No. 64. 23 pp.

Towery Publishing. 2000. introTampaBay. http://www.introtampabay.com/entertainment/bea.html. Accessed 8/00.

Townsend, D.W. and P.F. Larsen (eds.). 1992. The Gulf of Maine: Proceedings of a Seminar Held May 22, 1989, Washington, D.C., NOAA Coastal Ocean Program Regional Synthesis Series Number 1. NOAA, Washington, D.C. 135 p.

TPA (Tampa Port Authority). 2002. News Release. Tampa Port Authority Announces Port of Tampa Reaches its Zenith. http://www.tampaport.com/pdf.asp?PAGE_NAME=News-and-Events. Accessed 1/31/02.

Trautman, M.B. 1981. The Fishes of Ohio, with Illustrated Keys, Revised ed. Ohio State University Press.

Tupper, M. and R.G. Boutilier. 1995. Effects of conspecific density on settlement, growth and post-settlement survival of a temperate reef fish. *Journal of Experimental Marine Biology and Ecology* 191:209-222.

Twomey, K.A., K.L. Williamson, and P.C. Nelson. 1984. Habitat suitability index models and instream flow suitability curves: White sucker. U.S. Fish and Wildlife Service. FWS/OBS-82/10.64.

UCMP. 2002. UCMP Glossary. University of California, Berkeley, Museum of Paleontology. http://www.ucmp.berkeley.edu. Accessed 4/1/02.

University of Wisconsin Sea Grant Institute. 2001. Fish of the Great Lakes: Fish Glossary. http://seagrant.wisc.edu/greatlakesfish/glossary.html. Accessed 3/29/02.

U.S. Bureau of Labor Statistics, Division of Consumer Prices and Price Indexes 2001. Consumer Price Index (CPI) data: U.S. Bureau of Labor Statistics, Division of Consumer Prices and Price Indexes. CPI-U, Not Seasonally Adjusted. http://www.bls.gov/cpi/home.htm. Accessed 2001.

U.S. Census Bureau 2000. ss00002.uf1. ftp://ftp2.census.gov/census_2000/datasets/Summary_File_1 Accessed 12/21/01.

U.S. Census Bureau. 2001. State and County QuickFacts, http://quickfacts.census.gov. Last Revised: Friday, 07-Sep-2001 13:28:41 EDT.

U.S. Census Bureau 2002a. "2khxx.zip". Demographic data. ftp://ftp2.census.gov/census_2000/datasets/demographic_profile/0_All_State/. Downloaded in February, 2002.

U.S. Census Bureau 2002b. Small Area Income and Poverty Estimates. State and County Estimates. http://www.census.gov/hhes/www/saipe/estimatetoc.html. Downloaded February, 2002.

U.S. Circuit Court. 1989. State of Ohio v. U.S. Department of the Interior. U.S. District Court, District of Columbia.

U.S. Department of Energy (U.S. DOE). 2001a. Energy Information Administration (EIA). Form EIA-767. Steam-Electric Plant Operation and Design Report. Accessed for 1999.

U.S. Department of Energy (U.S. DOE). 2001b. Energy Information Administration (EIA). Form EIA-860A (1999). Annual Electric Generator Report – Utility. Accessed for the years 1999 and 2000.

U.S. Department of Energy (U.S. DOE). 2001c. Form EIA-860B. Annual Electric Generator Report - Nonutility. Accessed for the year 1999.

U.S. Department of Energy (U.S. DOE). 2001d. Energy Information Administration (EIA). Form EIA-906. Power Plant Report. (Effective January 2001, the Form EIA-906, Power Plant Report, superseded Form EIA-759, Monthly Power Plant Report, and Form EIA-900, Monthly Nonutility Power Plant Report. Accessed for the years 1970-2000.

U.S. Department of Energy (U.S. DOE). 2001e. Federal Energy Regulatory Commission (FERC). FERC Form No. 1: Annual Report of Major Electric Utilities, Licensees and Others. Select data 1995-1999.

U.S. Department of Energy (U.S. DOE). 2001f. Form EIA-861. Annual Electric Generator Report - Utilities. Accessed for the year 1999.

U.S. Department of Energy (U.S. DOE). 2002. U.S. Department of Energy, Energy Information Administration (EIA). Roster of Nuclear Generating Units Operable as of December 31, 1995. http://www.eia.doe.gov/cneaf/nuclear/pub_summaries/npg96_apen_c.html. Accessed 4/4/02.

U.S. Department of Housing and Urban Development. 2001. Treasury Bill Rates. http://www.hud.gov/offices/pih/divisions/ffmd/fm/tbill.cfm. Accessed 12/12/01.

U. S. District Court. 1997. United States of America, Plaintiff, V. Melvin A. Fisher, Kane Fisher, Salvors, Inc., a Florida Corporation, M/V/ Bookmaker, M/V Dauntless, M/V Tropical Magic, Their Engines, Apparel, Tackle, Appurtenances, Stores and Cargo, in Rem, Defendants; Motivation, Inc, Plaintiff V. Unidentified, Wrecked and Abandoned Sailing Vessel, Etc., Defendant: Findings of Fact and Conclusions of Law. Case No. 92-10027-CIV-DAVIS; Case No. 95-10051-CIV-DAVIS. 7/1903.

U.S. District Court. 1999. United States of America, Plaintiff, V. Great Lakes Dredge & Dock Co., Defendant; Board of Trustees of the International Improvement Trust Fund of the State of Florida and Florida Department of Environmental Protection, Plaintiff, V. Great Lakes Dredge & Dock Co., Defendant: Findings of Fact and Conclusions of Law. Case No. 97-2510-CIV-Davis/Brown; 97-10075-CIV-Davis/Brown. U.S. District Court, Southern District of Florida. September 27.

U.S. DOI (Department of Interior). 1997. 1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census. U.S. Government Printing Office, Washington, DC.

U.S. EPA (U.S. Environmental Protection Agency). 1976. Development Document for Best Technology Available for the Location, Design, Construction, and Capacity of Cooling Water Intake Structures for Minimizing Adverse Environmental Impact. Office of Water and Hazardous Materials, Effluent Guidelines Division, U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA (U.S. Environmental Protection Agency). 1981. Environmental Impact Statement, Tampa Electric Company Big Bend Unit 4. Technical Reference Document Volume II. Draft., EPA 904/9-81-070b.

U.S. EPA (U.S. Environmental Protection Agency). 1982a. Determination Regarding Modification of NPDES Permit No. MA0003654 for Brayton Point Station, Somerset, MA. 107 pp.

U.S. EPA (U.S. Environmental Protection Agency). 1982b. U.S. EPA Reach File Version 1.0 (RF1) for the Conterminous United States (CONUS). GIS coverage.

U.S. EPA (U.S. Environmental Protection Agency). 1991. Technical Support Document for Water Quality-Based Toxics Control. EPA/505/2-90-001. U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA (U.S. Environmental Protection Agency). 1994a. National Demand for Water-Based Recreation Survey. Washington, D.C.: Office of Policy Evaluation and Information, U.S. Environmental Protection Agency. 1998 Database Retrieval.

U.S. EPA (U.S. Environmental Protection Agency). 1994b. Survey of National Demand for Water Based Recreation. U.S. EPA Office of Policy.

U.S. EPA (U.S. Environmental Protection Agency) 1997. USEPA Reach File Version 1.0 (RF1) for the Conterminous United States. http://nsdi.epa.gov/nsdi/projects/rf1_meta.html.

U.S. EPA (U.S. Environmental Protection Agency). 1998a. 316(b) Industry Screener Questionnaire: Phase I Cooling Water Intake Structures, October 1998.

U.S. EPA (U.S. Environmental Protection Agency). 1998b. Guidelines for Ecological Risk Assessment. EPA/630/R-95/002F. Risk Assessment Forum, U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA (U.S. Environmental Protection Agency). 1998c. Terms of Environment at http://www.epa.gov/OCEPAterms/. As of May 13, 1998. Accessed 1/02.

U.S. EPA (U.S. Environmental Protection Agency). 2000. Lake Erie Lakewide Management Plan 2000. U.S. Environmental Protection Agency. http://www.epa.gov/glnpo/lakeerie/lamp2000/. Accessed 12/01.

U.S. EPA (U.S. Environmental Protection Agency). 2001a. Coastal Wetlands of the Great Lakes. U.S. Environmental Protection Agency. http://www.epa.gov/glnpo/solec/96/coastal/status_of_cw.html. Accessed 12/01.

U.S. EPA (U.S. Environmental Protection Agency). 2001b. River Raisin Area of Concern. http://www.epa.gov/grtlakes/aoc/rvraisin.html. Last Revised December 18, 2001. Accessed 2/5/02.

U.S. EPA (U.S. Environmental Protection Agency). 2001c. Survey Data from Detailed Industry Questionnaire: Phase II Cooling Water Intake Structures.

U.S. EPA (U.S. Environmental Protection Agency). 2002a. Indian River Lagoon. National Estuary Program. Fishes of the IRL. http://www.epa.gov/owow/oceans/lagoon/herring.html. Accessed 1/11/02.

U.S. EPA (U.S. Environmental Protection Agency). 2002b. Indian River Lagoon National Estuary Program. Drums. http://www.epa.gov/owow/oceans/lagoon/drum.html Accessed 1/17/02.

U.S. EPA (U.S. Environmental Protection Agency). 2002c. Total Maximum Daily Load (TMDL) Program: Glossary. Environmental Protection Agency Office of Water. http://www.epa.gov/owow/tmdl/pathogen/glossary.htm. Accessed 4/1/02.

U.S. EPA/ORD (U.S. Environmental Protection Agency/Office of Research and Development). 1998. Condition of the Mid-Atlantic Estuaries. EPA 600-R-98-14.

U.S. FDA. 2001. U.S. Food & Drug Administration Seafood Products Research Center. Center for Food Safety & Applied Nutrition. Regulatory Fish Encyclopedia website. http://vm.cfsan.fda.gov/~frf/rfe0cb.html. Accessed 10/18/01.

U.S. Fish and Wildlife Service. 1996a. The Endangered Species Act of 1973. A Summary of the ESA and Implementation Activities. Updated October 1996. http://endangered.fws.gov/esasum.html. Accessed 10/10/00.

U.S. Fish and Wildlife Service. 1996b. Recovery Plan for the Sacramento-San Joaquin Delta Native Fishes. U.S. Fish and Wildlife Service, Portland, OR.

U.S. Fish and Wildlife Service and National Marine Fisheries Service. 2000. Habitat conservation planning and incidental take permit processing handbook http://endangered.fws.gov/hcp/hcpbook.html Accessed 3/6/00.

U.S. Fish and Wildlife Service and Stratus Consulting. 2000. Restoration and Compensation Determination Plan (RCDP). Lower Fox River / Green Bay Natural Resource Damage Assessment. Prepared for U.S. Fish and Wildlife Service, U.S. Department of the Interior, U.S. Department of Justice, Oneida Tribe of Indians of Wisconsin, National Oceanic and Atmospheric Administration, Little Traverse Bay Bands of Odawa Indians, Michigan Attorney General. October 25.

University of California Museum of Paleontology. 2001. University of California Museum of Paleontology and the Regents of the University of California. Glossary of Natural History Terms. http://www.ucmp.berkeley.edu/glossary/glossary.html. Accessed 4/02.

University of Saskatchewan. 2002. Lake Whitefish. (*Coregonus clupeaformis*). http://interactive.usask.ca/skinteractive/modules/fisheries/fish/types/whitefish.html. Accessed 2/6/02.

University of Wisconsin Sea Grant. 2001. Fish of Lake Erie. http://www.seagrant.wisc.edu/greatlakesfish/LakeErie.htm. Accessed 10/29/01

US Army Corps Engineers. 1997. UMR-IWW System Navigation Study. Waterway Traffic Forecasts for the Upper Mississippi River Basin. Volume I: Summary Contract No. DACW72-95-D-004. Task Order 0003. Final Report. April 7, 1997. http://www.mvr.usace.army.mil/pdw/nav_study/econ/reports/wattor/finrep.htm#back8

US Army Corps Engineers. 2000. Integrated Decision Document and Environmental Assessment. U.S. Army Corps of Engineers, Great Lakes and Ohio River Division. Produced for the Oho River Ecosystem Restoration Program. Cincinnati. October.

US Army Corps Engineers. 2001a. Huntington District Navigational Charts. http://cac.lrh.usace.army.mil/River/Charts/default.htm. Accessed 12/5/01.

US Army Corps Engineers. 2001b. Pittsburgh District Navigational Charts. http://www.lrp.usace.army.mil/navindex.htm. Accessed 12/5/01.

USFS (U.S. Forest Service). 1997. National Outdoor Recreation Supply Information System. Database created by the U.S. Forest Service Recreation, Wilderness, and Urban/Wildland Interface Research Group. Atlanta, GA.

USGen New England. 2001. Variance Request Application and Partial Demonstration Under the Clean Water Act, Section 316(a) and (b) in Support of Renewal of NPDES Permit No. MA 000 3654 for USGen New England, Inc.'s Brayton Point Station. May 24.

USGS (U.S. Geological Survey). 1995. National Water-Use Data Files. http://water.usgs.gov/watuse/spread95.html. U.S. Geological Survey. Accessed 2/02.

USGS (U.S. Geological Survey). 2000. Federal Land Features of the United States (polygon). Reston, VA. 2000.

USGS (U.S. Geological Survey). 2001a. Alaska Science Center - Biological Science Office. Marine Habitat. http://www.absc.usgs.gov/research/seabird&foragefish/marinehabitat/home.html. Accessed 1/30/02.

USGS (U.S. Geological Survey). 2001b. National Water-Quality Assessment Program — Lake Erie - Lake St. Clair Basin. Fact Sheet 94-056. USGS National Water-Quality Assessment (NAWQA) Program. http://www-oh.er.usgs.gov/nawqa/fs.94056.html. Accessed 2/5/02.

USGS (U.S. Geological Survey). 2001c. Total Pounds and Dollar Value of Commercial Catch in U.S. Waters of the Great Lakes by Year, State, Lake, and Species. U.S. Geological Survey. http://www.glsc.usgs.gov/data/commercialfishingreports.htm. Accessed 12/01.

Van den Avyle, M.J. and D.L. Fowler. 1984. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Atlantic)- blue crab. U.S. Fish Wildlife Service Biological Report, USFWS/OBS-82/11, 16p.

Van Hassel, J.H., R.J. Reash, and H.W. Brown. 1988. Distribution of Upper and Middle Ohio River fishes, 1973-1985: I. Associations with water quality and ecological variables. *J. Freshw. Ecol.* 4(4):441-458.

Van Oosten, J. 1942. The age and growth of the Lake Erie white bass, *Lepibema chrysops* (Refinesque): *Papers of the Michigan Academy of Science Arts and Letters*, v. 27, p. 307-334.

Van Winkle, W., L.W. Barnthouse, B.L. Kirk, and D.S. Vaughan. 1980. Evaluation of Impingement Losses of White Perch at the Indian Point Nuclear Station and Other Hudson River Power Plants. Prepared by Oak Ridge National Laboratory for the U.S. Nuclear Regulatory Commission. Environmental Sciences Division Publication No. 1480. NUREG/CR-1100. 133 pp.

Vaughan, D.S, J.W. Smith, and M.H. Prager. 2000. Population Characteristics of Gulf Menhaden, *Brevoortia patronus*. NOAA Technical Report NMFS 149. U.S. Department of Commerce, Seattle WA. April.

Versar Inc. 1990. Evaluation of the Section 316 Status of Delaware Facilities with Cooling Water Discharge. Final Report. Prepared for Delaware Department of Natural Resources. April

Vouglitois, J.J., K.W. Able, R.J. Kurtz, and K.A. Tighe. 1987. Life history and population dynamics of the bay anchovy in New Jersey. *Trans. Am. Fish. Soc.* 116 (2):141-153.

Wahl, D.H. and L.A. Neilsen, 1985. Feeding ecology of the Sauger (*Stizostedion canadense*) in a large river. *Canadian Journal of Fisheries and Aquatic Sciences*, v. 42, p. 120-128.

Wainger, L.A., D. King, J. Salzman, and J. Boyd. 2001. Wetland Value Indicators for Scoring Mitigation Trades. *Stanford Environmental Law Journal* 20(2):413-478.

Walburg, C.H. 1960. Abundance and life history of the shad, St. Johns River, Florida. *U.S. Fish. Bull.* 60(177):487-501.

Wallace, D.C. 1971. Age, growth, year class strength, and survival rates of the white perch, *Morone americana* (Gmelin) in the Delaware River in the vicinity of Artificial Island. *Chesapeake Science.* 12(4): 205-218.

Wallus, R., B. L. Yeager, and T. P. Simon. 1990. Reproductive Biology and Early Life History of Fishes in the Ohio River Drainage, Volume I: Acipenseridae through Esocidae. Tennessee Valley Authority, Chattanooga, TN.

Walsh, R., Bjonback, R.D., Rosenthal, T.D. and Aiken, R., 1985. Public Benefits of Programs to Protect Endangered Wildlife in Colorado Symposium on Issues and Technology in the Management of Impacted Western Wildlife. Thorne Ecological Institute, Glenwood Springs, CO.

Walsh, R.G., D.M. Johnson, and J.R. McKean. 1990. Nonmarket Values from Two Decades of Research on Recreation Demand. In: *Advances in Applied Micro-Economics*. V.K. Smith and A.N. Link (eds.). JAI Press.

Walsh, R.G., J.B. Loomis, and R.A. Gillman. 1984. Valuing Option, Existence, and Bequest Demands for Wilderness. *Land Economics* 60(1):14-29.

Wang, J.C.S. 1986a. Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories. Prepared by the CA Dept. of Water Resources, CA Dept. of Fish and Game, U.S. Bureau of Reclamation, and U.S. Fish and Wildlife Service. Technical Report 9 (FS/B10-4ATR 86-9). Prepared for the Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary. January. World Wide Web electronic publication. http://elib.cs.berkeley.edu/kopec/tr9/html/home.html. Accessed 11/01.

Wang, J.C.S. 1986b. Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories. Technical Report 9 (FS/B10-4ATR 86-9). Prepared for the Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary.

Wang, J.C.S. and R.J. Kernehan. 1979. Fishes of the Delaware estuaries: A guide to early life histories. E.A. Communication. Ecological Analysts, Inc., Towson, MD.

Wapora. 1979. Impingement and Entrainment Assessment Using the Production Foregone Analysis at J.R. Whiting Plant During 1978. Prepared for Consumers Power Company. October.

Wapora. 1980. Impingement, Entrainment and Net Deterrent Studies at the J.R. Whiting Plant During 1979. Final. Prepared for Consumers Power Company. June. 68 pp.

Ware, D.M. and T.C. Lambert. 1985. Early life history of Atlantic mackerel (*Scomber scombrus*) in the southern Gulf of St. Lawrence. *Canadian Journal of Fisheries and Aquatic Sciences* 42:577-592.

Warke, G.M., K.R. Day, J.E. Greer, and R.D. Davidson. 1994. Cormorant (*Phalacrocorax carbo*) populations and patterns of abundance at breeding and feeding sites in northern Ireland, with particular reference to Lough Neagh. *Hydrobiologia* 279:91-100.

Warren, R.S., P.E. Fell, R. Rozsa, A.H. Brawley, A.C. Orsted, E.T. Olson, V. Swamy, and W.A. Niering. 2001. Salt marsh restoration in Connecticut: 20 years of science and management. Submitted to *Restoration Ecology*.

Washington Department of Fish and Wildlife. 2002. 2001-2002 Fishing Regulations Pamphlet. http://www.wa.gov/wdfw/fish/regs/fishregs.htm. Accessed 1/30/02.

Washington Tourist.com. 2000. Salmon Glossary. http://www.washingtontourist.com/salmon/journey/glossary.html. Accessed 3/29/02

Water Quality Association. 1999. Water Quality Glossary. http://www.wqa.org/glossary.cfm Accessed 3/29/02.

Waterfield, G.B. 1995. River Herrings. In: *Living Resources of the Delaware estuary*, L.E. Dove and R.M. Nyman, eds. pp. 191-197.

Weisberg, S.B. and W.H. Burton. 1993. Spring distribution and abundance of ichthyoplankton in the tidal Delaware river. *Fishery Bulletin* 91:788-797.

Weisberg, S.B., H.T. Wilson, R. Allen, P. Himchak, and T. Baum. 1996. Temporal trends in abundance of fish in the tidal Delaware river. *Estuaries* 19:723-729.

Wetzel, R.G. 1983. 1983. Limnology, 2nd ed. CBS College Publishing. 858 pp.

White, M. 1999. National Geographic Guide to Birdwatching Sites. Eastern U.S. National Geographic Society, Washington, D.C.

White, M.L. and M.E. Chittenden, Jr. 1977. Age determination, reproduction, and population dynamics of the Atlantic croaker, *Micropogonias undulatus*. *U.S. Fishery Bull.* 75(1):109-123.

White, R.J., J.R. Karr, and W. Nehlsen. 1997. Hatchery Reform in the Northwest: Issues, Opportunities, and Recommendations. Report prepared for Oregon Trout, Portland, Oregon.

Whitehead, J.C., and G.C. Blomquist. 1991. Measuring Contingent Values for Wetlands: Effects of Information About Related Environmental Goods. *Water Resources Research* 27(10):2523-2531.

Whitehead, J.C., and G.C. Blomquist. 1992. Ex ante willingness to pay with supply and demand uncertainty: implications for valuing a sea turtle protection programme. *Applied Economics*, 24: 981-988.

Wilber, D.H. and W.F. Herrnkind. 1986. The fall emigration of stone crabs *Menippe mercenaria* (Say) from an intertidal oyster habitat and temperature's effect on locomotory activity. *J. Exp. Mar. Biol. Ecol.* 102: 209-221.

Williams, A.B. 1958. Substrates as a factor in shrimp distribution. *Limnological Oceanography* 3:283-290.

Williams, A.B., and D.L. Felder. 1986. Analysis of stone crabs: *Menippe mercenaria* (Say), restricted, and a previously unrecognized species described (Decapoda: Xanthidae). *Proceedings of the Biological Society of Washington* 99:517-543.

Williamson, K.L. and P.C. Nelson. 1985. Habitat Suitability Index Models and Instream Flow Suitability Curves: Gizzard Shad. *U.S. Fish and Wildlife Service Biological Report* 82(10.112). 33 pp.

Winkelmann, Rainer 2000. Econometric Analysis of Count Data. New York: Springer.

Woods Hole Marine Biological Laboratory 2001. "RIcoastalpond.xls". Raw capture data and associated abundance estimates for species captured in sampling of SAV (sub-aquatic vegetation) in a group of coastal salt ponds in Rhode Island during July 1999. Received from Jeff Hughes, Woods Hole Marine Biological Laboratory, 2001.

Woodward, R.T., and Y.S. Wui. 2001. The Economic Value of Wetland Services: A Meta-Analysis. *Ecological Economics* 37:257-270.

Wootton, R.J. 1990. Ecology of Teleost Fishes. Chapman & Hall, London.

Wyda, J.C., L.A. Deegan, J.E. Hughes, and M.J. Weaver. In press. The response of fishes to submerged aquatic vegetation complexity in two ecoregions of the Mid-Atlantic Bight: Buzzards Bay and Chesapeake Bay. *Estuaries*.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 1996. Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California. In: *Status of the Sierra Nevada: Sierra Nevada Ecosystem Project Final Report to Congress, Volume 3: Assessments, Commissioned Reports, and Background Information*. Accessed on the internet 08/29/01. Regents of the University of California, Davis, CA.

Zarbock, H., J. Schulten, E. Long, and D. MacDonald. 1997. Sediment contamination in Tampa Bay - sources, risks, and management, p. 281-293. In: *Proceedings of the Tampa Bay Area Scientific Information Symposium 3: Applying Our Knowledge*, October 21-23, 1996 (S.F. Treat, ed.), Tampa Bay National Estuary Program.

Zastrow, C.E., E.D. Houde, and L.G. Morin. 1991. Spawning, fecundity, hatch-date frequency and young-of-year growth of bay anchovy *Anchoa mitchilli*, in mid-Chesapeake Bay. *Mar. Ecol. Prog. Ser.* 73:161-171.