United States
Environmental Protection
Agency

Environmental and Economic Benefits Analysis for Proposed Section 316(b) Existing Facilities Rule

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1 Introduction

EPA is proposing regulations implementing Section 316(b) of the Clean Water Act (CWA) to address the environmental impacts of cooling water intake structures (CWISs). The withdrawal of cooling water from streams, rivers, estuaries and coastal marine waters by CWISs causes adverse environmental impacts (AEI) to aquatic biota and communities in these waterbodies. These impacts are caused through several means, including impingement mortality (where fish and other aquatic life are trapped on equipment at the entrance to the CWIS) and entrainment mortality (where aquatic organisms, including eggs, and larvae are taken into the cooling system, passed through the heat exchanger, then discharged back into the source body). Additional adverse effects are often associated with CWIS operation, including nonlethal effects of impingement, thermal discharges, chemical effluents, flow modifications caused by these plants, and other impacts of variable and unknown magnitudes.

The Proposed Section 316(b) Regulation would establish national performance requirements for the location, design, construction, and capacity of CWISs (Clean Water Act 1972). This regulation is designed to minimize the adverse environmental impacts caused by CWIS through reduction of volume, frequency, and/or seasonality of water withdrawals. The proposed regulations will significantly reduce impingement and entrainment (I&E) mortality, as well as reduce the magnitude of other impacts (i.e., thermal, chemical, and flow alteration) on aquatic ecosystems. Thus, changes in CWIS design or operation resulting from Section 316(b) regulation are likely to result in enhanced ecosystem function and increased ecological services provided by affected waterbodies.

The two broad categories of existing facilities are considered to be within the Proposed rule's scope include: (1) electric generators and (2) manufacturers. In-scope 316(b) facilities include existing electric generators and manufacturers with a design intake flow (DIF) of at least 2 million gallons per day (MGD) that use at least 25 percent of the water they withdraw (measured on an average annual basis for each calendar year) exclusively for cooling purposes.

EPA is required to conduct a benefit-cost analysis under Executive Order 12866 for economically significant rules. This report presents the methods EPA used for the environmental assessment and for the benefits analysis of the regulatory options. EPA's analysis had three main objectives: (1) to develop a national estimate of the baseline magnitude of I&E mortality at in-scope facilities; (2) to estimate changes in the I&E mortality of fish and invertebrates as a result of regulation; and (3) to estimate the national economic benefits of reduced I&E mortality.

This report describes the regulatory options that EPA considered, and the study design. It identifies the types of economic benefits that are likely to be generated by improved ecosystem functioning under different regulatory options for in-scope facilities. The report also presents the basic concepts involved in analyzing these economic benefits—including benefit categories and benefit taxonomies associated with market and nonmarket goods and services likely to flow from reduced I&E mortality. Specific chapters of the report detail the methods used to estimate values for reductions in I&E mortality.

The organization of this report is described in Section 1.3.

1.1 Summary of the Proposed Regulation and Other Evaluated Options

EPA is considering three regulatory options for existing facilities based on two technologies. The three options would regulate only existing facilities with a DIF for cooling water of 2 MGD or greater. Each option evaluated in developing this proposed regulation is described below.

- **Option 1: I Everywhere.** Establish Impingement Mortality Controls at All Existing Facilities that Withdraw over 2 MGD; Determine Entrainment Controls for Facilities Greater than 2 MGD DIF On a Site-specific Basis.
- **Option 2: I Everywhere and E for Facilities > 125 MGD.** Establish Impingement Mortality Controls at All Existing Facilities that Withdraw over 2 MGD DIF; Require Flow Reduction Commensurate with Closed-cycle Cooling By Facilities Greater Than 125 MGD DIF.
- **Option 3: I&E Mortality Everywhere.** Establish Impingement Mortality Controls at All Existing Facilities that Withdraw over 2 MGD DIF; Require Flow Reduction Commensurate with Closed-Cycle Cooling at All Existing Facilities over 2 MGD DIF.

1.2 Study Design

EPA's analysis of the regulatory options examined CWIS impacts and regulatory benefits in seven study regions (California,[1] North Atlantic, Mid-Atlantic, South Atlantic, Gulf of Mexico, Great Lakes, and Inland). The study regions were chosen based on regional similarities within ecosystems, aquatic species, and characteristics of commercial and recreational fishing activities. Regional results were then combined to develop national estimates. The geographical extent of the seven regions, and the water body types within each region, are described below in Section 1-3. Table 1-1 presents the number of in-scope facilities and total actual intake flow by study region.

EPA has determined that 158 in-scope facilities currently use closed-cycle cooling water systems that minimize entrainment losses by greatly reducing the total volume of cooling water withdrawn from nearby waterbodies. Of these facilities, 59 also meet water intake velocity requirements that minimize impingement mortality. Although these 59 facilities would be subject to the requirements of the Proposed Rule, they would not be required to install additional technologies to reduce I&E mortality under the Proposed Rule. Thus, these facilities do not influence the occurrence and magnitude of benefits.

[1] Includes four in-scope facilities in Hawaii.

Table 1-1: In-Scope Facilities and Actual Intake Flow (AIF) by Region (billions of gallons per day)

Region	Number of In-Scope Facilities[a]	Flow Without Recirculation	Recirculated Flow	Total Flow
California[b]	8	1.19	0.00	1.2
Great Lakes	67	18.81	0.24	19.0
Inland[c]	669	134.87	3.89	138.8
Mid-Atlantic	54	28.10	0.07	28.2
Gulf of Mexico	30	12.89	0.00	12.9
North Atlantic	26	7.04	0.00	7.0
South Atlantic	17	7.42	0.05	7.5
All Regions	871	210.30	4.25	214.5

[a] This table presents the unweighted number of facilities because weighted facilities counts are not estimated separately by benefits region. The estimated total weighted number of potentially regulated facilities is 1152 (including baseline closures).

[b] The California region includes manufacturing facilities in the state of California and four facilities in Hawaii. It excludes coastal electric generating facilities in the state of California due to state regulation of cooling water intakes for these facilities. There are no coastal facilities in Oregon and a single facility in Washington classified as a baseline closure.

[c] A facility in Texas has intakes located in both the Inland and Gulf of Mexico regions. It is included within the Inland region within the current table to prevent the double counting of facilities.

Source: U.S. EPA analysis for this report.

1.2.1 Coastal Regions

The five coastal regions (California, North Atlantic, Mid-Atlantic, South Atlantic, and Gulf of Mexico) correspond to those of the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS). These regions include facilities that withdraw cooling water from estuaries, tidal rivers and ocean facilities within the NMFS regions. All facilities that withdraw cooling water from non-coastal waterbodies, such as lakes, rivers, and reservoirs, regardless of geographical location, are included in the Inland Region (Section 1.2.3)

Coastal regions are defined as follows: the California region includes all estuary/tidal river and ocean manufacturing facilities in California.[2] plus four facilities in Hawaii. The North Atlantic region encompasses coastal facilities in Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut. The Mid-Atlantic region includes coastal facilities in New York, New Jersey, Pennsylvania, Delaware, Maryland, the District of Columbia, and Virginia. The South Atlantic region includes coastal facilities in North Carolina, South Carolina, Georgia, and the east coast of Florida. Finally, the Gulf of Mexico region includes coastal facilities in Texas, Louisiana, Mississippi, Alabama, and the west coast of Florida. Coastal regions include a total of 152 facilities.

1.2.2 Great Lakes Region

The Great Lakes region is defined in accordance with the Clean Water Act to include facilities withdrawing cooling water from Lake Superior, Lake Michigan, Lake Huron (including Lake St. Clair), Lake Erie and Lake Ontario, and the connecting channels (Saint Mary's River, Saint Clair River, Detroit

[2] The California region includes manufacturing facilities in the state of California and four facilities in Hawaii, It excludes coastal electric generating facilities in the state of California due to state regulation of cooling water intakes for these facilities. There are no coastal facilities in Oregon and a single facility in Washington classified as a baseline closure.

River, Niagara River, and Saint Lawrence River to the Canadian border) (Great Lakes 1990). The Great Lakes region is comprised of 67 facilities.

1.2.3 Inland Region

The Inland region includes all in-scope facilities that withdraw water from all inland waterbodies (excluding those included within the Great Lakes Region) regardless of geographical location. There are 669 such facilities in 39 states (including states with both coastal and inland facilities).

1.3 Organization of the Document

Chapter 2 provides information on the baseline conditions of the water bodies affected by in-scope facilities. To obtain regional I&E mortality estimates, EPA extrapolated loss rates from facilities for which I&E mortality data are available (hereafter model facilities), to all in-scope facilities within the same region. EPA's methods for, and results from, regional I&E mortality models are described in Chapter 3.

Chapters 4 through 9 describe EPA's analysis of the regional economic benefits of Section 316(b) regulatory options. EPA provides an overview of all benefits (Chapter 4) and investigates several benefit categories in detail, including: benefits from improved protection of threatened and endangered (T&E) species (Chapter 5), commercial fishing benefits (Chapter 6), recreational fishing benefits (Chapter 7), nonuse benefits (Chapter 8), EPA also assesses I&E mortality losses and benefits using habitat equivalency analyses (Chapter 9), and summarizes total national benefits for in-scope facilities based on the results of the regional analyses (Chapter 10). Chapter 11 presents results for a fourth regulatory option not documented in previous chapters.

Additional details regarding EPA's benefits analysis are presented in Appendix A through Appendix J. Appendix A presents the extrapolation methods used by EPA to analyze the benefits from reducing I&E mortality at in-scope facilities; Appendix 2.1.1.1AB describes potential ecological effects due to thermal discharges; Appendix C presents detailed output from I&E mortality models; Appendix D discusses economic discounting and the expected timing of benefits; Appendix E presents a list of T&E species likely impacted by I&E mortality; Appendix F provides extra details on the methodologies used to estimate the effects of I&E mortality on T&E species, and the benefits from proposed 316(b) regulation; Appendix G presents EPA's analysis of the potential for I&E mortality reductions to impact the market price of commercially fished species; Appendix H presents details of the benefits of I&E mortality on commercial fishing by region; Appendix I presents detailed regional results of the effects of I&E mortality on recreational fishing benefits; and Appendix J presents extra details on the habitat based methodology for estimating nonuse values of I&E mortality.

2 Baseline Impacts

2.1 Introduction

This chapter provides a brief summary of adverse environmental impacts from the impingement and entrainment (I&E) mortality of fish and invertebrates in cooling water intake structures (CWISs) used by electric power plants and manufacturing facilities subject to regulation under Section 316(b) of the Clean Water Act (CWA).

CWIS impacts do not occur in isolation from other ongoing physical, chemical, and biological stressors on aquatic habitats and biota in the receiving waterbody. Additional anthropogenic stressors may include, but are not limited to: degraded water and sediment quality, low dissolved oxygen (DO), eutrophication, fishing activities, channel or shoreline (habitat) modification, hydrologic regime changes, invasive species, etc. For example, many aquatic organisms subject to the effects of cooling water withdrawals reside in impaired (i.e., CWA 303(d) listed) waterbodies. Accordingly, they are potentially more vulnerable to cumulative impacts from other anthropogenic stressors (USEPA 2006a). The effect of these anthropogenic stressors on local biota may contribute to or compound the local impact of I&E mortality, depending on the influence of location-specific factors. In addition to multiple stressors acting on biota near a single CWIS, multiple facilities and CWISs located in close proximity along the same waterbody may have additive or cumulative effects on aquatic communities (USEPA 2006a).

Although it is difficult to measure, EPA believes that an aquatic population's compensatory ability—the capacity for a species to increase survival, growth, or reproduction rates in response to decreased population —is likely compromised by impingement and entrainment (I&E) mortality losses and the cumulative impact of other stressors in the environment over extended periods of time (USEPA 2006a). These cumulative impacts may lead to subtle, less-easily observed changes in aquatic communities and ecosystem function. These secondary impacts are difficult to isolate from background variability, partly because of the limited scope and inherent limitations of the data available to characterize I&E mortality.

Since the aquatic habitat quality and health of the biotic community are shaped by the cumulative effect of many factors, it is important to characterize the environmental context of baseline impacts. This will permit comparisons between the relative influences of CWIS-related stressors and other factors, and result in a more accurate estimate of the environmental impact of the Section 316(b) regulation.

This chapter provides a qualitative description of baseline I&E mortality impacts and anthropogenic stressors found in aquatic environments affected by CWISs.

2.2 Major Anthropogenic Stressors in Aquatic Ecosystems

All ecosystems and their biota are subject to natural variability in environmental conditions (e.g., seasonal perturbations), as well as periodic large-scale disturbances in environmental settings (e.g., drought, flood, fire, disease). Indigenous aquatic species and communities are adapted to this natural variability, such that large-scale events elicit a predictable loss, response and recovery cycle. Conversely, anthropogenic stressors tend to be more chronic in nature and often do not lead to recognizable recovery phases. Instead these stressors often lead to long-term environmental degradation associated with lowered biodiversity, reduced primary and secondary production, and a lowered capacity or resiliency of the ecosystem to recover to its original state in response to natural perturbations (Rapport and Whitford 1999).

Anthropogenic stressors are present to some degree in all major waterbodies of the United States, and are the result of many different impacts (Table 2-1). Four of the more important stressors include: (i) habitat loss; (ii) degraded water quality and sediment contamination; (iii) extractive uses of aquatic resources; and (iv) invasion by non-indigenous species (Rapport and Whitford 1999). CWIS-related impacts are considered here as a separate, fifth category of anthropogenic stress, one with many apparent similarities to overharvesting. Other large-scale stressors, such as change in watershed land use and engineering diversions, may be present. Thus, the true impact of CWISs on an aquatic community may be partly masked, or difficult to detect, due to the influence of other stressors on the receiving water.

The remainder of this section summarizes effects of these four anthropogenic stressors on the waterbodies affected by in-scope 316(b) facilities. CWIS impacts on the aquatic ecosystems are summarized in Section 2.3.

Table 2-1: Anthropogenic Stressors Impacting Aquatic Ecosystems Potentially Affected, Both Directly and Indirectly, by 316(b) Option Scenarios

	Impacted by Regulation			
Anthropogenic Stressor	**Option 1**	**Option 2**	**Option 3**	**Scale of Stressor**
CWIS	Yes: Direct	Yes: Direct	Yes: Direct	Local/Regional/National
Habitat loss				
Development	No	No	No	Local
Eutrophication	Yes: Indirect	Yes: Indirect	Yes: Indirect	Local/Regional
Climate change	No	No	No	Regional/National/Global
Engineering (below)	No	Yes: Direct	Yes: Direct	Local/Regional
Engineering diversions				
Re-routing	No	No	No	Local/Regional
Flow adjustments/removals/ modifications	No	Yes: Direct	Yes: Direct	Local/Regional
Water impoundments/damming	No	No	No	Local/Regional
Water quality				
Eutrophication	Yes: Indirect	Yes: Indirect	Yes: Indirect	Local/Regional
Loss of riparian buffer zones	No	No	No	Local/Regional
Sedimentation	No	Yes: Direct	Yes: Direct	Local/Regional
Chemical pollution (organics, heavy metals, etc.)	No	Yes: Direct	Yes: Direct	Local/Regional
Non-native / invasive species	Yes: Indirect	Yes: Indirect	Yes: Indirect	Local/Regional
Extractive uses (e.g. fishing)	Yes: Indirect	Yes: Indirect	Yes: Indirect	Local/Regional

Note: Option 1 is I Everywhere, Option 2 is I Everywhere and E for Facilities > 125 MGD, and Option 3 is I&E Mortality Everywhere.

2.2.1 Habitat Loss

Structural aquatic habitat is generally recognized as the most significant determinant of the nature and composition of aquatic communities. Human occupation and restructuring of shorelines; construction and maintenance of harbors; installation of dams, canals, and other navigational infrastructure; draining of wetlands for agriculture and residential uses; and degradation of critical fish habitats have all taken a heavy toll on the numbers and composition of local fish and shellfisheries. Most 316(b) facilities have been built on shoreline locations where power-generation buildings, roadways, CWISs, canals, impoundments, and other water storage or conveyance structures have often been constructed at the cost of natural habitat, including terrestrial, aquatic, and wetlands.

The loss of coastal and estuarine wetlands that serve as important fishery spawning and nursery areas is particularly severe, with an estimated historical loss of 100 million acres of wetlands since the late 1700s (Bromberg and Bertness 2005; USEPA 2010b). Critical fishery habitat loss is not restricted to nearshore environments. Decades of fishing activities have degraded offshore bottom habitats (Auster and Langton 1999; Turner et al. 1999).

The main impact of aquatic habitat loss is a reduction in the number of fish in the environment, a concentration of fishery spawning and nursery areas to fewer locations, shifts in species dominance based on available habitat, and local extirpation of historical fish species. Habitat loss in adjacent shoreline areas exacerbates the effect of CWIS losses, since many fish species affected by I&E mortality (e.g., bay anchovy, winter flounder) rely on coastal wetlands as nursery areas.

In riverine environments, the effects of channelization and navigation can also lead to habitat loss. For example, Tondreau et al. (1982) conducted a 10-year study of the aquatic ecosystem of the Missouri River near the Neal Generating facility, Sioux City, IA. The investigators found that the combined effects of channelization, heavy barge traffic, and high river flow rates had resulted in a significant loss of fish habitat. As a result, reported I&E mortality losses were relatively minor, because local fish populations were already greatly diminished.

2.2.2 Water Quality

Water quality is a major stressor of aquatic biota and habitats. Degraded surface water and sediment contaminants reflect current and historical industrial, agricultural and residential land use as well as discharges from wastewater treatment plants. Poor water quality can limit the numbers, composition, and distribution of fish and invertebrates; reduce spawning effort and growth rates; select for pollution-tolerant species; cause periodic fishkills; or result in adverse effects to piscivorous wildlife.

CWA Section 303(d) listings inventory, on a state-by-state basis, the locations of impaired waters not meeting designated uses and the known or suspected source(s) of impairment. Figure 2-1 identifies 316(b) facilities that are within two miles of a 303(d)-listed waterbody (blue shapes), as well as those that are impaired for temperature (red shapes). The map clearly shows that facilities along the coasts, Great Lakes, and major waterways such as the Mississippi, Missouri, and Ohio rivers are located in the vicinity of impaired waterbodies.

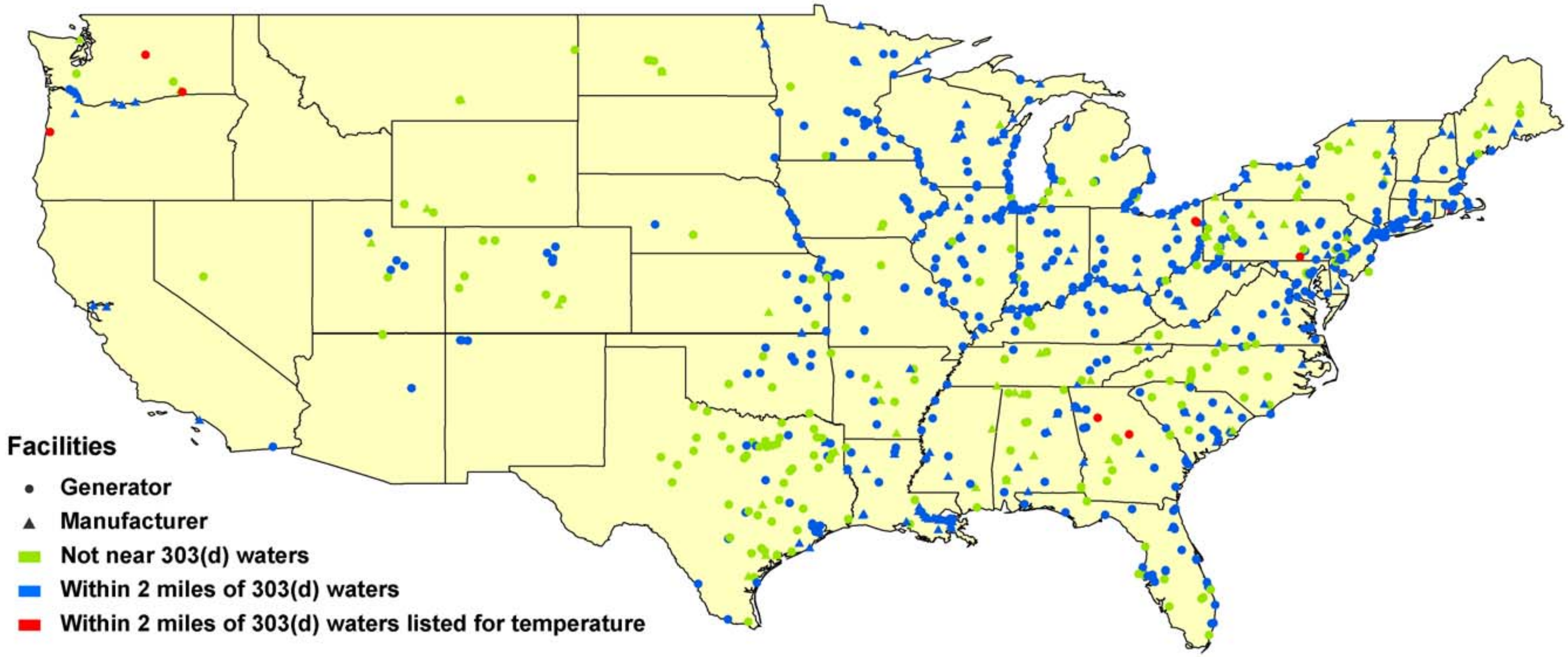

Figure 2-1: Map of Facilities Located on 303(d) Waters and Those Listed for Temperature

EPA's analysis of the 316(b) facilities location demonstrated that the majority of facilities, including 71 percent of generators and 79 percent of sampled manufacturing facilities, are within two miles of a 303(d)-listed waterbody (Abt Associates 2010b). Table 2-2 summarizes the number of 316(b) facilities on waterbodies impaired by any cause, by region. These include impairment due to chemical, physical, and biological factors, categorized into biological stressors, nutrients, organic enrichment/loading, bioaccumulation, toxics, unknown causes, and general water quality impairment.

The most common causes of impairment for waterbodies serving as 316(b) source waters are polychlorinated biphenyls (PCBs), pathogens, mercury, as well as organic enrichment/oxygen depletion and nutrients. The entire universe of all 303(d) water quality impairment causes is much too diverse to cover fully in this section. However, below we discuss some of the more common and important physico-chemical impairments in aquatic environment where 316(b) facilities potentially draw cooling water from and discharge to 303(d) listed waters.

- An oversupply of nutrients can result in excessive algal production, reduced light clarity, more frequent outbreaks of harmful algal blooms (HABs), high internal loads of biochemical oxygen demand (BOD), and spatial and temporally variable DO levels. In addition, eutrophication can reduce or eliminate habitat-formers such as coral reefs and submerged aquatic vegetation (SAV), and create other adverse ecological effects. Thermal discharges from 316(b) facilities can increase receiving water temperature, which may favor formation of blue-green algal blooms.
- Low levels of dissolved oxygen (hypoxia) may be present in many estuaries and coastal waters (IWG 2010), in the hypolimnia of eutrophic lakes, and in areas of high organic loading (e.g., below wastewater treatment plant outfalls). DO concentrations may be further decreased in or downstream of thermal plumes arising from cooling water return discharges from 316(b) facilities. Low DO can limit the distribution of fish and macroinvertebrates, reduce growth rates, and alter nutrient and carbon recycling.
- Persistent, bioaccumulative and toxic substances (PBTs) such as mercury or PCBs may be present in waterbodies near 316(b) facilities, due to atmospheric deposition of local air emissions or from historical uses of PCBs in electrical transformer units, in addition to other urban or industrial sources. These PBTs can impair water uses by regulatory restrictions or advisories regarding acceptable ingestion of fish consumption (see below), as well as affecting higher trophic level predators in the food chain.
- Toxic pollutants, such as metals, polycyclic aromatic hydrocarbons (PAHs), pesticides, biofouling chemicals, or chlorine may be present in the discharge of 316(b) facilities. This could lead to local extirpation of sensitive species, or to greatly altered biological communities due to chronic impacts on viability, growth, reproduction, and resistance to other stressors.

In addition to the 303(d) listings, many of the waterbodies in which the CWIS are located are subject to fish advisories. Fish advisories are issued by States to protect their citizens from the risk of eating contaminated fish or wildlife (USEPA 2009a). Fish advisories are recommendations and do not carry regulatory authority, but they indicate the presence of bioaccumulative chemicals which may pose risk for humans and piscivorous wildlife and which may also interfere with reproduction and survival of lower taxa as well.

Table 2-2: Number of 316(b) Facilities on 303(d)-listed Waterbodies, by Impairment and Region								
Impairment	**California**	**Great Lakes**	**Inland**	**Mid-Atlantic**	**Gulf of Mexico**	**North Atlantic**	**South Atlantic**	**Total**
Biological Stressors								
Noxious Aquatic Plants			2					2
Nuisance Exotic Species	2	9						11
Pathogens	1	15	99	5	1	12	6	139
Nutrients								
Algal Growth			1					1
Nutrients		15	47	3	1	2	9	77
Organic Enrichment / Loading								
Organic Enrichment/Oxygen Depletion		7	56	1	5	4	9	82
Sediment		9	18	2				29
Persistent, Bioaccumulative, Toxic (PBTs)								
Dioxins	1	14	13			2		30
Fish Consumption Advisory - Pollutant Unspecified			8				1	9
Mercury	2	28	96		4	2	3	135
PCBs	3	57	142	13		2	1	218
Pesticides	8	12	16					36
Physical Alterations								
Flow Alteration			7					7
Habitat Alteration		6	12					18
Temperature			9			3		12
Turbidity			27		1		3	31
Toxics								
Ammonia			3			1		4
Chlorine			2					2
Metals (Other Than Mercury)	3	4	43	7		1		58
Total Toxicity	2		5	2		1		15
Toxic Inorganics			1			1		2
Toxic Organics		3	12			3		18
Unknown / Other Causes								
Cause Unknown			11			1		12
Cause Unknown - Fish Kills			1					1
Cause Unknown - Impaired Biota	1	3	14	2				20
Other Cause			1					1
Water Quality Use Impairments (General)								
Oil And Grease			6			3		9
pH		3	8					11
Salinity/TDS/Sulfates/Chlorides	1	1	7					9
Taste, Color And Odor			4			1		5

EPA's 2008 National Listing of Fish Advisories (NLFA) database indicates that 97% of the advisories are due (in order of importance) to: mercury, PCBs, chlordane, dioxins, and DDT (USEPA 2009a). Fish advisories have been issued for 39 percent of the total river miles (approximately 1.4 million river miles) and 100 percent of the Great Lakes and connecting waterways (USEPA 2009a). Fish advisories have been steadily increasing over the NLFA period of record (1993-2008), but these increases are interpreted to reflect the increase in the number of waterbodies being monitored by States and advances in analytical methods rather than in increasing levels of these problematic chemicals.

The water quality impacts arising from the combination of operations and/or discharges of 316(b) facilities and other anthropogenic sources (as indicted by the presence of widespread fish advisories) could result in highly degraded or altered aquatic communities that may be further reduced by I&E mortality.

2.2.3 Overharvesting

Overharvesting is a general term given to describe the exploitation of an aquatic population (e.g., fish, shellfish, and kelp) in an unsustainable fashion to the point of reducing or even eliminating much of the population. Stocks of commercial and recreationally important species are reduced as a result of fishing, but such fish catches may be sustainable if sufficient recruitment of juveniles into the fishery can replace population losses from fishing and other stressors. Unfortunately for many aquatic species, overharvesting has a long history and in many instances has preceded impacts by other competing anthropogenic stressors by several centuries (Jackson et al. 2001).

Given that many fisheries are being overfished on a continual basis, overharvesting continues to be a problem when considering stocks subject to I&E mortality. For example, the NMFS 2009 status report indicated that 15 percent of federally monitored fish stocks were being fished at rates above the maximum sustainable yield ("overfishing"), while 23 percent of species are considered over-exploited ("overfished") (NMFS 2010a). Table 2-3 lists 21 groups of overfished, depleted, or rebuilding commercial fish stocks occurring in I&E mortality data reported from a subset of in-scope facilities (NMFS 2010a). Further, this assessment does not include many important fishery species not subject to federal regulation that may be subject to high I&E mortality such as shad, menhaden, and American lobster. Moreover, this assessment does not consider any threatened and endangered (T&E) species.

Severe overfishing can drive species to ecological insignificance, where the overfished populations no longer interact meaningfully in the food web with other species in the community, or even to extinction (Jackson et al. 2001). The collapse of the Great Lakes whitefish fisheries has been shown to be principally due to overfishing, although habitat alteration and introduction of a non-indigenous (exotic) invader (sea lamprey) were also contributory (Rapport and Whitford 1999).

2.2.4 Invasive Species

Non-indigenous, invasive species (NIS) are a significant and increasingly prevalent stressor in both freshwater and marine environments (Cohen and Carlton 1998; Ruiz et al. 1999). Approximately 300 NIS are established in marine and estuarine habitats of the continental U.S., and that rate of invasion is rapidly increasing (Ruiz et al. 2000). Aquatic NIS are taxonomically diverse and include: plants, fish, crabs, snails, clams, mussels, bryozoans, and nudibranchs. Analysis of freshwater NIS indicated that between 10-15 percent are nuisance species with undesirable effects (Ruiz et al. 1999). The adverse implications of marine and coastal NIS are generally not as well-characterized as those in freshwater settings.

Table 2-3: Depleted Commercial Fish Stocks Subject to I&E Mortality					
Stock or Stock Complex	**Overfishing [a]**	**Overfished [b]**	**Approaching Overfished[c]**	**Rebuilding**	**Stock Region**
American Plaice	No	Yes		Yes	North/Mid-Atlantic
Atlantic Cod	Yes	Yes		Yes	North/Mid-Atlantic
Atlantic Sturgeon	No	Yes		Yes	Atlantic
Black Sea Bass	Yes	Yes		Yes	South Atlantic
Boccacio	No	No	No	Yes	California
Butterfish	No	Yes		Yes	Mid-Atlantic
Gag	Yes	No	Yes	No	South Atlantic/Gulf of Mexico
Grouper species	Yes	Yes		Yes	Gulf of Mexico
Haddock	No	Yes		Yes	North/Mid-Atlantic
Ocean Pout	No	Yes		Yes	North/Mid-Atlantic
Pink Shrimp	No	Yes		No	South Atlantic
Pollock	No	No	No	Yes	North/Mid-Atlantic
Porgy	No	Yes		Yes	South Atlantic
Rockfish species	Yes	Yes		Yes	California
Skate species	No	Yes		Yes	North/Mid-Atlantic
Spiny Dogfish	No	No	No	Yes	North/Mid-Atlantic
Summer Flounder	No	No	No	Yes	Mid-Atlantic
Tautog	Yes	Unknown	Unknown	N/A	Atlantic
White Hake	Yes	Yes		Yes	North/Mid-Atlantic
Windowpane	No	Yes		Yes	North/Mid-Atlantic
Winter Flounder	Yes	Yes		Yes	North/Mid-Atlantic
Yellowtail Flounder	Yes	Yes		Yes	North/Mid-Atlantic

[a] Fishing mortality exceeds sustainable levels.
[b] Stock size is below a sustainable biomass threshold.
[c] Estimated that the stock will be in an overfished condition by the 4th quarter of 2010.
[d] Stock is rebuilding to attain a level consistent with maximum sustainable yield (MSY).
Source: National Marine Fisheries Service (NMFS) (2010a).

Interactions between NIS and other anthropogenic stressors are likely to affect the colonization and distribution of native species subject to CWIS impacts. Thermal discharges from 316(b) facilities may extend the seasonal duration of non-resident organisms, allowing transient summer species to become permanently established in geographic areas beyond their historical range. For example, in Mount Hope Bay, increased water temperature due to the Brayton Point Station facility led to an increase in abundance of the predacious ctenophore *Mneimiopsis leidyi* as well as increased overwintering in the Bay for this formerly seasonal resident (USEPA 2002b).

2.3 CWIS Impacts to Aquatic Ecosystems

EPA has determined that multiple types of adverse environmental impacts may be associated with CWIS operations at 316(b) regulated facilities, depending on site-specific conditions at an individual facility's site. Many of these facilities employ once-through cooling water systems that impinge fishes and other aquatic organisms on intake screens if the intake velocity exceeds these organisms' locomotive ability to move away. Impinged organisms may be killed, injured or weakened, depending on the nature and capacity of the plant's filter screen configuration, cleaning and backwashing operations, and fish return system used to return organisms back to the source water. In addition, early life stage fish or planktonic organisms can be entrained by the CWIS and subjected to death or damage due to high velocity and pressure, increased temperature, and chemical anti-biofouling agents in the system. This I&E mortality can act in concert with the other stressors identified above.

The magnitude and regional importance of I&E mortality is generally a function of the operational intake volumes and the characteristics of the aquatic community in the region (see Chapter 3 for details). I&E mortality can contribute to: impacts to T&E species (Chapter 5); reductions in ecologically critical aquatic organisms, including important elements of an ecosystem's food chain; diminishment of organism populations' compensatory reserves; losses to populations, including reductions of indigenous species population levels, commercial fisheries (Chapter 6), and recreational fisheries (Chapter 7); and stresses to overall communities and ecosystems, as evidenced by reductions in diversity or other changes in ecosystem structure or function. In addition, fish and other species affected directly and indirectly by CWIS can provide other valuable ecosystem goods and services, including nutrient cycling and ecosystem stability.

The impacts of I&E mortality occur at many levels of ecological organization and across a wide range of environmental scales. Table 2-4 presents a summary of direct and indirect impacts of CWISs and I&E mortality. The effects are identified as direct, indirect, or a combination. This table also indicates the relative scale (local, regional, national) of the particular effect. In most cases, EPA was unable to estimate the magnitude of these effects due to a lack of data. In this section, we discuss a subset of these effects.

2.3.1 Losses of Fish from I&E Mortality

The most visible direct impact of I&E mortality is the loss of large numbers of aquatic organisms, distributed non-uniformly among fish, benthic invertebrates, phytoplankton, zooplankton, and other susceptible aquatic taxa (e.g., sea turtles). This has immediate and direct effects on the population size and age distribution of affected species, and may cascade through food webs. The direct impacts on populations and age structure are described for commercially (Chapter 6) and recreationally important fish species (Chapter 7).

Populations of aquatic organisms decline when recruitment rates are lower than mortality rates. Natural sources of mortality for fish species include predation, food availability, injury, climatic factors and disease. Anthropogenic sources of fish mortality, both proximate and ultimate, include fishing, habitat modification, pollution, and I&E mortality at CWISs. EPA believes that reducing I&E mortality will contribute to the health and sustainability of fish populations by lowering the total mortality rate for these populations.

In some cases, I&E mortality has been shown to be a significant source of anthropogenic mortality to depleted stocks of commercially targeted species (see Table 2-2). For example, I&E mortality (expressed as age-1 equivalents) equal approximately 10 percent of the average annual recruitment to the Southern New England/Massachusetts stock of winter flounder (*Pseudopleuronectes americanus*) (I&E mortality values from Chapter 3; recruitment data from Terceiro (2008)).

Table 2-4: CWIS Effects on Ecosystem Functions/Cumulative Impacts Potentially Affected, Both Directly and Indirectly, by 316(b) Regulations

Category	Direct/Indirect	Local/Regional/National
A. Impingement and Entrainment (direct and indirect effects)		
Effects on Individuals		
Loss of billions of individuals (direct effects)	Direct	Regional/National
Phytoplankton	Direct	Local/Regional/National
Zooplankton (excluding fish larvae/eggs)	Direct	Local/Regional/National
Invertebrates	Direct	Local/Regional/National
Fish	Direct	Local/Regional/National
Non-fish vertebrates	Direct	Local/Regional/National
Species and Population-Level Effects		
Alteration of phenology of system (function of % water reduction in stream)	Direct	Local/Regional/National
Altered distribution of populations	Direct	Local
Altered niche space	Direct	Local/Regional
Altered stable age distributions of populations	Direct	Regional
Loss of keystone species	Direct	Local
Loss of T&E species	Direct	Regional
Novel selection pressure (e.g., negatively buoyant or stationary eggs)	Direct & Indirect	Local
Reduced/altered genetic diversity	Direct & Indirect	Regional/National
Reduced lifetime ecological function of individuals	Direct	Local/Regional
Community and Trophic Relationships		
Altered competitive interactions	Direct & Indirect	Local
Disrupted trophic relationships	Direct & Indirect	Local
Disrupted control of disease-harboring insects (e.g., mosquito larvae, etc.)	Indirect & Direct	Local/Regional
Increased quantity of detritivores	Indirect	Local
Loss of ecosystem engineers (due to trophic interactions)	Indirect & Direct	Local
Reduced potential for energy flows (e.g. trophic transfers)	Indirect	Local/Regional
Species diversity and richness	Direct & Indirect	Local/Regional/National
Trophic cascades	Indirect & Direct	Local/Regional
Ecosystem Function		
Altered ecosystem succession	Indirect & Direct	Local/Regional
Decreased ability of ecosystem to control nuisance species (algae, macrophytes)	Indirect	Local
Disrupted cross-ecosystem nutrient exchange (e.g., up/downstream, aquatic/terrestrial)	Indirect	Regional
Disrupted nutrient cycling	Indirect & Direct	Local/Regional
Reduced compensatory ability to deal with environmental stress (resilience)	Direct & Indirect	Regional
Reduced ecosystem resistance	Indirect	Local/Regional
Reduced ecosystem stability (alternate states)	Indirect	Local/Regional
Sediment regulation	Indirect	Local/Regional
Substrate regulation	Indirect	Local
B. Thermal Effects (direct and indirect)		
Novel selection pressure (e.g., thermal optima, location of breeding, etc.)	Direct & Indirect	Regional/National
Altered phenology	Direct	Local/Regional
Links between temperature and metabolism		
Dissolved oxygen (physical)	Direct	Local
Dissolved oxygen (bacterial, respiratory rates)	Indirect	Local

Table 2-4: CWIS Effects on Ecosystem Functions/Cumulative Impacts Potentially Affected, Both Directly and Indirectly, by 316(b) Regulations

Category	Direct/Indirect	Local/Regional/National
Ecological energetic demands	Indirect	Local/Regional
Ecological nutrient demands	Indirect	Local/Regional
Altered algal productivity	Direct & Indirect	Local/Regional
Shifted nutrient cycling	Indirect & Direct	Local/Regional
C. Chemical Effects (anti-foulants, etc.)		
Altered survival/growth/production	Indirect & Direct	Local
Altered food web dynamics	Indirect	Local
D. Altered Flow Regimes (local and system-wide)		
Altered flow velocity	Direct & Indirect	Local/Regional
Altered turbulence regime	Direct & Indirect	Local/Regional
E. Cumulative Impacts (as a concentrated number of facilities)		
May push systems over the edge of nonlinearities in the system	Direct/Indirect	Local/Regional
Intensified CWIS effects (as above, Section B.)	Direct/Indirect	Local/Regional
Intensified thermal effects (as above, Section B.)	Direct/Indirect	Local/Regional

In addition to its impact on stocks of marine commercial fish species, I&E mortality increases the pressure on native freshwater species, such as lake whitefish (*Coregonus clupeaformi*) and yellow perch (*Perca flavescens*), whose populations have seen dramatic declines in recent years (USDOI 2008; Wisconsin DNR 2003). Although recovery of these species is greatly affected by fisheries policy (e.g., NFSC 2008), I&E mortality represent an additional source of mortality to fish populations being harvested at unsustainable levels.

Overall, EPA believes that I&E mortality is likely to contribute to reduction in the population sizes of species targeted by commercial and recreational fishers, particularly for stocks that are undergoing rebuilding. Although these reductions may be small in magnitude compared to fishing pressure (Lorda et al. 2000), and often difficult to measure due to the low statistical power of fisheries surveys, a reduction in mortality rates on overfished populations is likely to increase the rate of stock recovery. Thus, reducing I&E mortality may lead to more-rapid stock recovery, a long-term increase in commercial fish catches, increased population stability following periods of poor recruitment and, as a consequence of increased resource utilization, an increased ability to minimize the invasion of exotic species[3] (Shea and Chesson 2002; Stachowicz and Byrnes 2006).

For many fish species, I&E mortality may not lead to measurable reductions in adult populations. These losses, however, are likely to reduce the compensatory ability of populations to respond to environmental variability, including temperature extremes, heavy predation, disease, or years with low recruitment. Additionally, since predation rates are often directly related to the concentration of available prey, I&E mortality may lead to indirect population effects, whereby reductions in a prey fish may indirectly result in reductions to predator species or increases to species in apparent competition (Holt 1977).

[3] For the last response, there is evidence to support the theory that biodiversity deceases the probability of invasion by an NIS, particularly in resource-limited environments (Stachowicz and Byrnes 2006).

Moreover, I&E mortality represents a novel selective pressure for fish populations. Consequently, populations may be selected for resistance to I&E mortality (through behavioral or physiological changes) at the expense of other, more "natural" evolutionary pressures. Although this may help sustain populations in the short term, it may reduce genetic diversity and population stability in the long-term.

2.3.2 I&E Mortality Effects on T&E species

T&E species are species vulnerable to future extinction or at risk of extinction in the near future, respectively. Due to low population sizes, I&E mortality from CWISs may represent a substantial portion of the annual reproduction of T&E species. Consequently, I&E mortality may either lengthen population recovery time, or hasten the demise of these species. For this reason, the population-level and social values of T&E losses are likely to be more important than the absolute number of losses that occur.

Adverse effects on T&E species due to water withdrawals by CWISs may occur in several ways:

- Populations of T&E species may suffer increased mortality as a consequence of I&E mortality.
- T&E species may suffer indirect harm if the CWIS substantially alters the food web in which these species interact.
- T&E species may suffer indirect harm if the CWIS substantially alters habitat that is critical to their long-term survival.

Chapter 5 provides detail on CWIS impacts on T&E species.

2.3.3 Thermal Effects

One byproduct of once-through cooling water systems is a release of a heated effluent. Concerns about the impacts of heated effluents are addressed by provisions of CWA Section 316(a) regulations. Most of the facilities subject to 316(b) I&E mortality concerns have also been required to address the impact of thermal pollution in the discharge-receiving waters (Abt Associates 2010b).

Thermal pollution has long been recognized as having effects upon the structure and function of ecosystems (Abt Associates 2009a). Numerous studies have shown that thermal discharges may substantially alter the structure of the aquatic community by modifying photosynthetic (Bulthuis 1987; Chuang et al. 2009; Martinez-Arroyo et al. 2000; Poornima et al. 2005), metabolic, and growth rates (Leffler 1982), and reducing levels of DO. Thermal pollution may also alter the location and timing of fish behavior including spawning (Bartholow et al. 2004), aggregation, and migration (USEPA 2002b), and may result in thermal shock-induced mortality for some species (Ash et al. 1974; Deacutis 1978; Smythe and Sawyko 2000). Thus, thermal pollution is likely to alter the ecological services provided by ecosystems surrounding facilities returning heated cooling water into nearby waterbodies.

Adverse temperature effects may also be more pronounced in aquatic ecosystems that are already subject to other environmental stressors such as high biochemical oxygen demand (BOD) levels, sediment contamination, or pathogens. Thermal discharges may have indirect effects on fish and other vertebrate populations through increasing pathogen growth and infection rates. Langford (1990) reviewed several studies on disease incidence and temperature, and while he found no simple, causal relationship between the two, he did note that it was clear that warmer water enhances the growth rates and survival of pathogens, and that infection rates tended to be lower in cooler waters.

The magnitude of thermal effects on ecosystem services is related to facility-specific factors, including the volume of the waterbody from which cooling water is withdrawn and returned, other heat loads, the rate of water exchange, the presence of nearby refugia, and the assemblage of nearby fish species. In addition to reducing total I&E mortality, cooling towers reduce thermal pollution. Consequently, the installation of closed-system cooling towers could have geographically variable effects on ecosystems, ranging from comprehensive changes in community structure and habitat type (Schiel et al. 2004), to localized changes in the relative proportion of species adapted to warm and cold water (Millstone Environmental Laboratory 2009). Further information on thermal discharges is provided in Appendix 2.1.1.1B.

2.3.4 Chemical Effects

One of the environmental impacts associated with power plant operations is the release of chemicals in the discharge of once-through cooling waters. These chemicals include metals from internal corrosion of pipes, valves and pumps (e.g., chromium, copper, iron, nickel, and zinc), additives (anti-fouling, anti-corrosion, and anti-scaling agents) and their byproducts, and materials from boiler blowdown and cleaning cycles.

EPA used the beta version of the Discharge Monitoring Report Pollutant Loading Tool (DMR-PLT)[4] to obtain estimated annual pollutant loadings for facilities regulated under Section 316(b). EPA extracted data for all facilities in selected Standard Industry Classification (SIC) codes: manufacturing (SIC 20 through 39), electric power generation (SIC 4911), and selected other sectors to which 316(b) facilities have been assigned. Of the 871 facilities in the 316(b) master list, 707 have annual loading estimates in DMR-PLT; of these, nearly 85 percent are electric power generators. A summary table was generated of total annual loads for all in-scope facilities. Table 2-5 lists the top 20 pollutants discharged by 316(b) facilities in 2007, sorted by mass. These chemicals represent pollutants generated by the operation and maintenance of the facility and other location-specific activities. The most common pollutants include: total suspended solids, oil & grease, BOD_5, total iron and fecal coliform.

In addition to these pollutants, facilities also discharge anti-fouling agents. Biofouling is also a serious operational concern for power plants. Microbial biofouling on surfaces in cooling water systems can accelerate metal corrosion, increase resistance to heat transfer energy, and increase fluid frictional resistance (Cloete et al. 1998). Sessile macrofouling-organisms such as algae, insects, hydroids, polychaetes, barnacles, mussels and tunicates can colonize intake pipes, bulkheads, and filter screens, and may clog pipes and reduce intake flows or filter-screen effectiveness. Further, some of these infestations produce larvae, which can colonize downstream equipment including pipelines, valves, and heat exchangers. Severe macrofouling-associated problems can include intake flow reduction, increased pressure drop across heat exchangers, and equipment breakdown.

4 http://app6.erg.com/icisloader/dmrLoadingsAdvSearch.cfm. Note that DMR-PLT is currently in beta testing and there is only limited documentation on how the loading estimation methodology is implemented in the tool. This tool does not currently provide discharge estimates categorized by the North American Industry Classification System (NAICS).

Table 2-5. Top 20 pollutants discharged by 316(b) facilities, by total annual loadings in 2007.

	Parameter	Number of facilities	Total Loading ('000 pounds/yr)
1	Solids, total dissolved	46	5,416.4
2	Hardness, total (as CaCO3)	48	2,842.6
3	Solids, total suspended	619	1,100.6
4	Solids, total dissolved (at 180 deg. C)	13	922.5
5	Residue, total filterable (at 105 C)	6	527.8
6	Sulfate, total (as SO4)	54	416.2
7	Chloride (as Cl)	47	403.5
8	Calcium Chloride	1	175.8
9	BOD, 5-day, 20 deg. C	227	111.6
10	Chemical Oxygen Demand (COD)	33	105.6
11	Oil & grease	274	84.5
12	Carbon, total organic (TOC)	76	45.1
13	Oxygen demand, chem. (high level) (COD)	45	44.7
14	Oil and grease, hexane extraction method	80	42.0
15	Sulfate (as S)	11	41.1
16	Iron, total (as Fe)	220	33.9
17	Fluoride, total (as F)	34	29.9
18	Coliform, fecal MF, MFC broth, 44.5 C	19	26.0
19	Oxygen demand, chem. (low level) (COD)	11	25.5
20	Coliform, fecal general	108	21.2

Source: Discharge Monitoring Report Pollutant Loading Tool (DMR-PLT)

These anti-fouling and cleaning chemicals potentially pose a risk to organisms downstream of the CWIS discharge. Adverse effects to aquatic organisms may include acute and residual effects of biocides used as anti-fouling agents in condenser tubes, or from chemicals resulting from corrosion or use in cleaning of either stream or cooling cycles (Kelso and Milburn 1979). A typical biofouling procedure is continuous low-level chlorination at chronic toxicity levels with an occasional high ("shock") dose. The use of oxidants (chlorine, bromide) can give rise to residuals and/or disinfection byproducts (DBPs) such as trihalomethanes, haloacetic acid, bromoform, and others (Taylor 2006). Concentrations of released chemicals are variable among facilities, and are a function of treatment dose, CWIS design, rates of degradation, and the volume and flushing rate of the receiving water.

With the exception of chlorination impacts (Taylor 2006), the potential effects of chemicals in power plants' cooling water discharges on local aquatic ecosystems are not well-characterized. In most cases, chemical effects are considered, along with thermal and mechanical effects, as a component of the cumulative stress of entrainment on organisms. Little information is available on the chronic or low-level effects of these discharge chemicals on local ecosystems or in concert with other anthropogenic stressors.

Review of the effects of chemical treatment and discharge into the environment suggests that direct ecotoxicity in discharge plumes is relatively rare beyond the point of discharge or mixing zone near the pipe outlet (Poornima et al. 2005; Taylor 2006). However, concentrations of these chemicals may be additive to low-level chronic adverse effect with other anthropogenic stressors identified above.

2.3.5 Effects of Flow Alteration

The operation of CWISs and discharge returns significantly alter patterns of flow within receiving waters both in the immediate area of the CWIS intake and discharge pipe, and in mainstream waterbodies, particularly in inland riverine settings. In ecosystems with strongly delineated boundaries (i.e., rivers, lakes, enclosed bays, etc.), CWISs may withdraw and subsequently return a substantial proportion of water available to the ecosystem. For example, of the 521 facilities that are located on freshwater streams or rivers, 31 percent (164) of these facilities have average intake greater than 5 percent of the mean annual flow of the source waters. Even in situations when the volume of water downstream of in-scope facilities changes relatively little, the flow characteristics of the waterbody, including turbulence and water velocity, may be significantly altered. This is particularly true in locations with multiple CWISs located close to each other.

Altered flow velocities and turbulence may lead to several changes in the physical environment, including sediment deposition (Hoyal et al. 1995), sediment transport (Bennett and Best 1995), and turbidity (Sumer et al. 1996), each of which play a role in the physical structuring of ecosystems. Biologically, flow velocity is a dominant controlling factor in aquatic ecosystems. Flow has been shown to alter feeding rates, settlement and recruitment rates (Abelson and Denny 1997), bioturbation activity (Biles et al. 2003), growth rates (Eckman and Duggins 1993), and population dynamics (Sanford et al. 1994).

In addition to flow rates, turbulence plays an important role in the ecology of small organisms, including fish eggs and larvae, phytoplankton, and zooplankton. In many cases, the turbulence of a waterbody directly affects the behavior of aquatic organisms, including fish, with respect to swimming speed (Lupandin 2005), location preference with a waterbody (Liao 2007), predator-prey interactions (Caparroy et al. 1998; MacKenzie and Kiorboe 2000), recruitment rates (MacKenzie 2000; Mullineaux and Garland 1993), and the metabolic costs of locomotion (Enders et al. 2003). The sum of these effects may result in changes to the food web or the location of used habitat, and thereby substantially alter the aquatic environment.

Climate change is predicted to have variable effects on future river discharge in different regions of the United States, with some rivers expected to have large increases in flood flows while other basins will experience water stress. For example, Palmer et al. (2008) predict that mean annual river discharge is expected to increase by about 20 percent in the Potomac and Hudson River basins but to decrease by about 20 percent in Oregon's Klamath River and California's Sacramento River. Thus, the adverse effects of flow alteration may increase or decrease over longer periods for larger rivers, depending on their national location.

2.4 Community-level or Indirect Effects of CWISs

In addition to the direct effects of CWISs, I&E mortality may alter a wide range of aquatic ecosystem functions and services at the community-level (Table 2-4). Most of these impacts to aquatic community function and service are poorly characterized, given the limited scope of I&E mortality studies and an incomplete knowledge of baseline or pre-operational conditions within affected waters.

For example, fish are essential for energy transfer in aquatic food webs (Summers 1989), and for the regulation of food web structure. Fish play important roles in nutrient cycling (Wilson et al. 2009) and sediment processes, and are known to play key roles in the maintenance of aquatic biodiversity (Holmlund and Hammer 1999; Peterson and Lubchenco 1997; Postel and Carpenter 1997; Wilson and Carpenter 1999).

While I&E mortality losses of commercially or recreationally important fish species can be quantified and monetized (Chapters 3, 6 and 7), the accompanying loss of other aquatic organisms may be poorly characterized (e.g., lumped into broad taxa such as "forage fish" or "other") or simply not reported. In addition, I&E mortality on species of lower concern may create unrealized ripples of ecological effect within the aquatic community. Species may respond to altered ecological circumstances such as reduced predation, altered food concentrations, or slower nutrient recycling, etc. Therefore, the removal of selected fish species or considerable biomass by I&E mortality may substantially affect these processes.

Several examples of ecological services indirectly affected by I&E mortality are described below, although others listed in Table 2-4 may be of equal importance for individual ecosystems.

2.4.1 Altered Community Structure and Patchy Distribution of Species

The role of some aquatic species may be more critical in shaping the structure and composition of the community than that of others. These *keystone species* are species that have an effect on community structure disproportionate to their population (Paine 1966; Paine 1969). Consequently, the loss or reduction of keystone species may lead to substantial changes in aquatic food webs, and decrease overall ecosystem stability. Thus, the potential for ecosystem impacts resulting from, for example, the loss of an important predator fish due to I&E mortality may not be strictly proportional to the number or biomass of lost fish or foregone fish production.

The operation of CWISs by generating facilities can lead to localized areas of depressed fish and shellfish abundance. Power plants (and the intake volume they represent) are distributed in a non-uniform manner along coastlines and rivers, and may be clustered (Section 2.5), such that I&E mortality and the populations they affect are geographically heterogeneous. This can result in a highly localized and patchy distribution of aquatic organisms in regional areas. A secondary effect is increased probability of colonization and establishment by NIS due to niche space availability caused by a local reduction in the density of native organisms (Byrnes et al. 2007; Ovaskainen and Cornell 2006).

2.4.2 Altered Food Webs

Sources of mortality, including I&E mortality, may disrupt established predator-prey relationships and the niche space available to species through direct pathways (i.e., mortality of the organism) or indirectly (i.e., alterations to the food web). The loss of young-of-year (YOY) predators (e.g., striped bass) or important forage fish (e.g., menhaden and bay anchovy) is likely to affect trophic relationships and alter food webs. These changes may alter the realized species niche and life history traits due to alterations in inter- and intra-specific interactions (e.g., predator-prey, competition, mate selection, etc.) (Fortier and Harris 1989; Hixon and Jones 2005; Jirotkul 1999). These alterations in trophic interactions and food webs, combined with other CWIS-related impacts such as thermal pollution (Section 2.2.3) or flow alteration (Section 2.3.5), may lead to rapid changes in life history strategies as a consequence of facultative (Ball and Baker 1996) or evolutionary changes (Hairston et al. 2005; Reznick and Endler 1982).

2.4.3 Reduced Taxa and Genetic Diversity

I&E mortality may lead to reductions in local community biodiversity (due to destruction of selected species) or in a loss of genetic diversity in individual fish populations. I&E mortality represents a novel selective pressure on early life stages that may reduce the genetic diversity of resident fish and prevent the recovery of depleted stocks (Stockwell et al. 2003; Swain et al. 2007; Walsh et al. 2006). Since many populations stocks are differentiated by oceanic region and/or timing of migratory movements, I&E mortality could alter the seasonal timing and movement (i.e., phenology) of overall fish populations, which could have ramifications for predator species.

2.4.4 Nutrient Cycling Effects

I&E mortality impacts may alter the pace of nutrient cycling, and energy transfer through food webs. Fish species have been shown to have substantial effects on nitrogen, phosphorous, and carbon cycling due to storage effects (i.e., large quantities of nutrients are found within fish biomass) and translocation effects (i.e., fish migrate, moving large quantities of nutrients to new ecosystems) (Kitchell et al. 1979; Vanni et al. 1997). These alterations in nutrient cycling could lead to redirection of nutrient flows to other components of the ecosystem including water column phytoplankton, benthic macroalgae and attached epiphytes, with subsequent changes to the condition of critical ecosystem habitats, such as submerged aquatic vegetation. Juvenile (age-0) Atlantic menhaden (*Brevoortia tyrannus*) are capable of significantly grazing down plankton concentrations in Chesapeake Bay, leading to more-rapid regeneration of nutrients and enhanced primary production. Removal of the age-0 menhaden by I&E mortality would lead to reduced grazing and turnover of nutrients and increased algal density in the water column (Gottlieb 1998). The amount of nitrogen and phosphorus regenerated in facility discharge water due to nutrient recycling of I&E mortality biota might also lead to areas of localized nutrient enrichment near outfalls (Abt Associates 2010a). Additionally, the preferential removal of upper water column species by I&E mortality could increase energy flow to benthic organisms, and thereby increase the relative importance of detritivores in bottom communities.

2.4.5 Reduced Ecological Resistance

The effect of long-term or chronic I&E mortality may lead to a decrease in ecosystem resistance and resilience (i.e., ability to resist and recover from disturbance including invasive species) (Folke et al. 2004; Gunderson 2000). That is, I&E mortality is likely to reduce the ability of ecosystems to withstand and recover from adverse environmental impacts, whether those impacts are due to anthropogenic effects or natural variability.

2.5 Cumulative Impacts of Multiple Facilities

Cumulative effects of CWISs are likely to occur if multiple facilities are located in close proximity such that they impinge or entrain aquatic organisms within the same source waterbody, watershed system, or along a migratory pathway of a specific species (e.g., striped bass in the Hudson River) (USEPA 2004c). The cumulative impacts of CWISs may be exacerbated by the presence of other anthropogenic stressors discussed above (Section 2.2).

EPA analyses suggest that approximately 20 percent of all in-scope facilities are located on waterbodies with multiple CWISs (USEPA 2004c). Inspection of geographic locations of 316(b) facilities (approximated by CWIS latitude and longitude) indicates that facilities in inland settings are clustered around rivers to a greater extent than marine and estuarine facilities (see Figure 2-1).

2.5.1 Clustering of Facilities and CWISs on Major Rivers

To illustrate the potential for cumulative impacts, data from five major U.S. rivers with clustered concentrations of facilities were reviewed (Table 2-6). Based on the non-uniform distribution of facilities, locations were noted where the potential for cumulative impacts is high (Abt Associates 2010b).

Table 2-6: U.S. Rivers with Largest Withdrawals by In-scope Facilities						
River	**Avg. Annual* Flow (MGD)**	**Facilities**	**Cumulative DIF (MGD)**	**DIF as % Avg. Annual Flow**	**Cumulative AIF (MGD)**	**AIF as % Avg. Annual Flow**
Mississippi	383,266	57	22,436	5.9	13,170	3.4
Ohio	181,615	47	19,315	10.6	13,384	7.4
Missouri	49,249	23	10,718	21.8	6,598	13.4
Illinois	8,079	11	6,259	77.5	1,605	19.9
Delaware	7,562	11	3,585	47.4	1,485	19.6
* Source: (USGS 1990)						

For example, the Mississippi River provides source water for cooling water for 57 facilities along its length, with 27 facilities located in Louisiana upstream of the Mississippi River delta. Using facility intake coordinates as location markers, the relative distances between facilities were estimated (Abt Associates 2010b). In upper Louisiana, facilities are typically separated by tens of miles; inter-facility distance decreases downstream of Baton Rouge, LA. Several locations along the Mississippi River have clusters of facilities:

- Between Ascension and St. James Parishes, a 13-mile span of the river hosts six manufacturing facilities, three of which have intakes located within the same mile. These facilities have a combined DIF of nearly 270 MGD.
- Fifteen miles downstream, near Garyville, LA, there is a cluster of three facilities within six miles of the river stretch.
- Seven miles further downstream near Laplace, LA, six facilities occur on a six-mile stretch of the river. Four of these facilities, with a combined DIF exceeding 5 BGD (three generators and one manufacturer), are located within a 1.7 mile section of river.
- Further downstream in Chalmette, LA (just east of New Orleans), three manufacturers, capable of withdrawing up to 457 MGD, are clustered within four river miles.

Therefore, the potential for cumulative impacts is high, and investigating ecosystem effects by extrapolating results on a per facility basis may likely underestimate the true effects.

2.5.2 Implications of Clustered Facilities for Cumulative Impacts

The cumulative impact of clustered facilities may be significant, due to the concentrated I&E mortality, combined intake flows, and the potential for other impacts such as thermal discharges. It should also be noted that power generation demand and cooling intake water volume is typically at its annual maximum during mid-late summer, which is also a period of seasonal low flows and highest in-stream temperatures. The effect of cumulative impacts may be greater in inland or Great Lakes waters due to the following factors:

- The majority of national AIF is associated with freshwater CWISs.
- Freshwater plants use a greater relative volume of available fish habitat than marine or estuarine counterparts.
- Seasonal variation in power demand and river flow may increase entrainment potential during low-flow periods of the year (NETL 2009). Although low flows are traditionally in late summer

to early fall, drought conditions and manipulations of water levels may lead to low flow during other periods. This may be locally significant if periods of low flow overlap with seasonal concentrations of eggs, developing YOY, and migrating juveniles.

- Freshwater facilities are more likely to be clustered along a waterbody, and pose a greater risk of cumulative impacts. This is exacerbated by the presence of numerous impoundments associated with navigational lock and dam structures located on larger river (e.g., Mississippi, Missouri, Ohio, etc). These impoundments result in slow or slack water conditions with a lower effective volume than free-flowing reaches or periods of higher flow.

2.6 Case Studies of Facility I&E Mortality Impacts

While the information provided in this chapter provides a broad overview of potential impacts associated with CWISs, it is highly informative to evaluate these impacts in the context of actual facilities to see how and to what extent these impacts and I&E mortality are realized, how site-specific factors come into play, the effects of cumulative impacts, and what has been learned with regard to community-level effects. Case studies provide useful, detailed information for evaluating I&E mortality and major stressors in the context of a specific waterbody or region.

As part of the Phase II regulations, review and analyses of I&E mortality data and environmental information was presented in case studies in EPA's 2002 *Case Study Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule*. The document provided detailed analyses of CWIS impacts in major regional waterbodies throughout the U.S. These cases studies included:

- Delaware Estuary Watershed
- Ohio River Watershed
- Tampa Bay Watershed
- San Francisco Bay/Delta Estuary
- Brayton Point Facility
- Seabrook and Pilgrim Facilities
- J.R. Whiting Facility
- Monroe Facility

These regional case studies provide a set of information describing the variety of CWIS impacts under marine, coastal, and riverine environmental settings. The following sections present three additional case studies to provide examples of facility-specific CWIS impacts in settings including freshwater coastal (Bay Shore, Oregon, OH), estuarine (Indian Point, Buchanan, NY), and estuarine-coastal (Indian River, Sussex County, DE) environments. These brief case studies also illustrate the quantitative levels of I&E mortality, the indirect effects of I&E mortality on local aquatic ecosystems, and the cumulative effects of combined effects (I&E mortality and thermal). Additional information is available each of these examples.

2.6.1 Bay Shore Power Station

The Bay Shore power station is a 631 megawatt (MW) facility located on the south shore of Lake Erie near the confluence of the Maumee River and Maumee Bay, OH. Cooling water for the four coal-fired steam-electric units is withdrawn from Maumee River/Maumee Bay via an open intake channel of approximately 3,700 ft in length, and enters the plant via a shoreline surface CWIS. Approximately 749 million gallons per day (MGD) is withdrawn, including once-through cooling water and sluice water used for transporting bottom ash from the boilers to ash settling ponds (OEPA 2010). Major environmental concerns for the facility include I&E mortality and thermal impacts.

Bay Shore Power Station I&E Mortality Losses: Medium-sized Plant with Large-Scale Impacts
A comprehensive demonstration study, conducted in 2005-2006, estimated annual impingement at greater than 46 million fish per year, the majority of which were forage fish species—emerald shiner and gizzard shad. Annual estimates for entrainment were equally impressive—209 million fish eggs, 2,247 million fish larvae, and 14 million juvenile fish (OEPA 2010). As noted on the NDPES fact sheet, "It is likely that Bay Shore Station impinges and entrains more fish than all other power stations in Ohio combined." Notably, the plant does not currently employ any technologies to reduced I&E mortality (OEPA 2010).

In addition to I&E mortality effects, concerns have also been raised regarding the size and impact of the thermal discharge plume—a focus of concern for local residents and commercial fishermen. Depending on wind patterns and hydrological factors, the thermal plume extends to the south shore of Maumee Bay (over 1 mile from the facility). The Ohio Environmental Protection Agency (OEPA) assessed the results from a 2002 thermal mixing zone study, and concluded that the thermal discharge exceeded Ohio water quality standards for temperature within the thermal plume (>85^{o}F in Maumee Bay), but that the impacts on aquatic life and designated uses in Maumee River/Bay did not justify reduction of the thermal mixing zone. However, it did find that the thermal activity could restrict recreational activities in certain areas of the plant and required the plant owners to conduct a two-year study of the benthic community within the mixing zone (OEPA 2010).

2.6.2 Indian Point Nuclear Power Plant

The Indian Point nuclear power plant is a 2,045 MW facility located in Buchanan, Westchester County, New York, on the east shoreline of the Hudson River. Cooling water (up to 2,500 MGD) for the two nuclear-fired steam-electric units (Units 2 and 3) is withdrawn from the estuarine portion of the Hudson River through three intake structures on the shoreline (NYSDEC 2003a). The heated non-contact cooling water is discharged through sub-surface diffuser ports in a discharge canal located downstream of the intake structures.

Due to concerns regarding impact to fish, particularly anadromous striped bass populations, as well as a high level of involvement and litigation from local stakeholder groups, the Indian Point power generation plant (along with other Hudson River power plants) has been particularly well-characterized in terms of I&E mortality impacts. Accordingly, the Hudson River aquatic community has been sampled and studied over many decades, with detailed investigation starting in the 1970s.

Results suggest that I&E mortality impacts to the local and transient anadramous fish species are substantial. For example, studies of fish entrainment in 1980 predicted fish class reductions ranging from 6 to 79 percent, depending on fish species (Boreman and Goodyear 1988). Subsequent sampling work predicted year-class reductions due to I&E mortality of 20 percent for striped bass, 25 percent for bay anchovy, and 43 percent for Atlantic tomcod. The Final Environmental Impact Statement (FEIS) prepared by the New York State Department of Environmental Conservation (NYSDEC) concluded these levels of mortality “could seriously deplete any resilience or compensatory capacity of the species needed to survive unfavorable environmental conditions” (USEPA 2004a).

Indian Point Final Environmental Impact Statement (FEIS) details cumulative effects:

The FEIS estimated, from samples collected between 1981 and 1987 for three facilities (Indian Point, Roseton, Bowline Point), that the average annual entrainment losses from these plants included 16.9 million American shad, 303.4 million striped bass, 409.6 million bay anchovy, 468 million white perch, and 826.2 million river herring (NYSDEC 2003b). The loss of such large numbers of forage fish species and the potential impact on higher level piscivores is of high concern. The FEIS also viewed the overall effect of the CWIS impacts on the aquatic community as analogous to habitat degradation rather than overfishing. This judgment was based on evidence that the entire aquatic community was affected rather than only specimens of higher trophic level species.

The FEIS considered the role of other major environmental factors currently or historically present in the Hudson River. These factors have the capacity to affect fish populations either positively (enhancements) or negatively (stressors). Relevant factors include, but are not limited to: improvements to water quality due to upgrades to sewage treatment plants, invasions by exotic species (e.g., zebra mussel), chemical contamination by toxins (e.g., PCBs and heavy metals), global climate shifts such as increases in annual mean temperatures and higher frequencies of extreme weather events (e.g., the El Nino-Southern Oscillation), and stricter management of individual species stocks such as striped bass (USEPA 2004a).

Recently (April 2010), the NYSDEC denied a request by Indian Point for a CWA Section 401Water Quality Certificate. The CWA requires that, prior to any federal agency issuing a license or permit for a particular project (in this case, the approval of the State Discharges Permit Elimination System [SPDES] permit), it must certify that the project meets State water quality standards. The NYSDEC denial letter cited, among other concerns, continuing concerns over I&E mortality including potential impacts to two sensitive species—the Shortnose Sturgeon (currently listed as endangered) and the Atlantic Sturgeon (under consideration for endangered species status).

2.6.3 Indian River Power Plant

The Indian River Generating Station (IRGS) is a 784 MW facility located in Sussex County, Delaware, on the south shore of the Indian River. Cooling water for three of the IRGS’s four coal-fired steam-electric units is withdrawn upstream from the freshwater portion of Indian River via an intake canal at a maximum rate of 411 MGD, or 21 times the average flow rate of Indian River. Heated return water is discharged via a canal into the upper reaches of Island Creek, a small tributary of Indian River, entering at Ward Cove. Island Creek and Ward Cove are part of a large estuarine stretch (approximately 150 acres) of Indian River that provides important fish and crab habitat. Its lower salinity and location in the estuary make it attractive to important species such as bay anchovy, spot, menhaden larvae, and young blue crabs.

Indian River Power Plant has impact on important local species:

The 2003 316(b) Comprehensive Demonstration Study for the Indian River Power Plant reported I&E mortality for a number of important species (Entrix 2003, as described in Bason 2008). This I&E mortality has been recalculated by a local stakeholder group as age-1 equivalents for bay anchovy (1.6 million), blue crab (300,000), croaker (270,000), and menhaden (60,000) (Bason 2008).

Due to the size of the heated discharge relative to the receiving water, thermal effects of the plant were also investigated. Based upon monitoring data collected from 1998-1999, the 316(a) report assessed the effects of elevated water temperatures on ecosystem communities with a focus on eight important fish species: bay anchovy, menhaden, winter and summer flounder, croaker, spot, striped bass, and weakfish. This report determined that juvenile and adult target species, although able to avoid areas of high water temperature, were not permanently restricted from most stretches of the Indian River, nor did they suffer loss of habitat services associated with these segments. The study concluded an overall condition of no adverse effect, or no appreciable harm, on the fish and shellfish populations in the Indian River and Delaware Bay (Entrix 2001).

Despite the overall conclusion of no adverse effect, there were documented localized thermal impacts of consequence. For example, during warmer months, the thermal discharge reached potential adverse levels in Island Creek, often extending downstream to Ware Cove (Entrix 2001). The mortality associated with sub-adult stages of fish and crabs and the avoidance of the area by sub-adult and adult fish were substantial issues. In addition to direct thermal impacts to biota, temperature-related reductions in DO were observable (mean reduction = 0.6 mg/l) in the discharge canal. These reductions contributed to the amplitude of the day-night (diel) cycle of DO concentrations, already widely fluctuating due to cumulative effects of eutrophication in the river (Bason 2008).

2.7 Conclusions

Considerable information is available on the direct effects of CWISs and I&E mortality (Chapter 3) on commercially (Chapter 6) and recreationally important (Chapter 7) species derived from the accumulated data from facility-specific basis 316(b) studies and investigations. This has allowed EPA to monetize the potential environmental benefits that would arise as reduction in water withdrawals occur based of future 316(b) regulations.

However, as demonstrated in this section, there is much less information and high uncertainty regarding the magnitude and importance of indirect and/or cumulative impacts of CWISs, particularly effects on lower trophic organisms or ecosystem functions. This condition is due to the limitations of 316(b) sampling programs, as well as the failure of permitting process to consider the additive or cumulative effects of other major anthropogenic stressors. While EPA can identify and hypothesize regarding the direction and relative importance of impacts of CWISs on the totality of the aquatic ecosystem (i.e., not just focused on selected higher trophic level predator species and common prey), EPA is currently unable to connect these effects with quantifiable environmental benefits. Thus, it is highly likely that the total environmental and monetary impacts of CWISs are significantly underestimated, and that characterization of the fuller spectrum of benefits arising from reducing or eliminating I&E mortality will await future, targeted research efforts.

3 Assessment of Impingement and Entrainment Mortality

3.1 Introduction

This chapter discusses the methods EPA used to convert results from impingement and entrainment mortality (I&E mortality) sampling studies into metrics suitable as inputs for EPA's Section 316(b) benefits analysis.[5] Section 3.2 provides a brief overview of impingement and entrainment (I&E) loss metrics, and outlines how they were used in benefits analysis. Section 3.3 presents I&E mortality losses, by region, under baseline conditions, and the reductions in these losses under alternative regulatory options. Section 3.4 discusses limitations and uncertainties in the I&E mortality analysis.

EPA's I&E mortality assessment methods are discussed in detail in Chapter A-1 of the *Regional Benefits Analysis for the Final Section 316(b) Phase III Existing Facilities Rule* (*Regional Benefits Analysis)* (USEPA 2006b). Changes in methodology since EPA's Phase III analysis include: (1) the addition of new I&E mortality data for several California facilities, (2) engineering reductions for power generators were estimated for sample facilities that received the detailed questionnaire rather than for all in-scope generators, and (3) changes in the proportionate reduction in I&E mortality under new regulatory options were estimated. Other modifications are identified in relevant portions of Section 3.2.

3.2 Methods

3.2.1 Objectives of I&E Mortality Analysis

EPA's evaluation of I&E mortality data had four main objectives:

- To develop regional and national estimates of the magnitude of I&E mortality
- To standardize I&E mortality rates using common biological metrics that allow comparison across species, years, facilities, and geographical regions
- To provide I&E mortality metrics suitable for use in national economic benefits analysis
- To estimate changes in metrics as a result of estimated reductions in I&E mortality under alternative regulatory options.

EPA's use of these methods for national rulemaking does not imply that these methods are the best or most suitable for studies of single facilities. In many cases, site-specific details on local fish populations and waterbody conditions may make other assessment approaches, such as population or ecosystem modeling, possible.

[5] For the purposes of its national analysis, EPA assumed 100 percent impingement mortality and 100 percent entrainment mortality. This assumption is discussed at length in Chapter A7 of the Regional Analysis Document for the Final Section 316(b) Existing Facilities Rule (USEPA 2004b). Briefly, EPA assessed 37 entrainment survival studies and found them variable, unpredictable, unreliable, and not defensible. As such, these studies support an assumption of 0 percent survival for entrained organisms in benefits assessments.

3.2.2 I&E Mortality Loss Metrics

Three loss metrics were derived from facility I&E mortality monitoring data available to EPA: (1) age-1 equivalents, (2) forgone fishery yield, and (3) production forgone. These metrics are described briefly below. Equations used to calculate metrics and other details are provided in Chapter A-1 of EPA's *Regional Benefits Analysis* (USEPA 2006b).

3.2.2.1 Age-1 Equivalents

The Equivalent Adult Model (EAM) is a method for converting organisms of different ages (life stages) into an equivalent number of individuals in any single age (Goodyear 1978; Horst 1975). For its 316(b) analyses, EPA standardized all I&E mortality losses into equivalent numbers of 1-year-old fish, a value termed age-1 equivalents (A1Es). This conversion allows losses to be compared among species, years, facilities, and regions.

To conduct EAM calculations requires a life history schedule, for each species, incorporating age-specific mortality rates. Using these species-specific survival tables, a conversion rate between all life history stages and age 1 is calculated. For life history stages younger than 1 year of age, the conversion rate is calculated as the product of all stage-specific survival rates between the stage at which I&E mortality occurs and age 1. Consequently, the loss of an individual younger than age 1 results in a conversion rate less than 1. For individuals older than 1 year, the conversion rate is calculated as the quotient of all stage-specific survival rates between the stage at which I&E mortality occurs and age 1. Consequently, the loss of an individual older than age 1 results in a conversion rate greater than 1.

Additional details on the EAM calculation are provided in Chapter A-1 of EPA's *Regional Benefits Analysis* (USEPA 2006b). For the results presented in this chapter, the treatment of early life stages in this calculation considers all larval life stages reported in the original I&E mortality studies.

3.2.2.2 Forgone Fishery Yield of Commercial and Recreational Species

Fishery yield is a measure of the biomass harvested from a cohort of fish.[6] EPA expressed I&E mortality of harvested species in terms of forgone (lost) fishery yield. To convert losses to forgone fishery yield, EPA used the Thompson-Bell equilibrium yield model (Ricker 1975). EPA's application of the Thompson-Bell model assumed that 1) I&E mortality losses reduce the future yield of harvested adults, and 2) reductions in I&E mortality rates will lead to an increase in harvested biomass.

The Thompson-Bell model is based on the principles used to estimate the expected yield in any harvested fish population (Hilborn and Walters 1992; Quinn and Deriso 1999). The general procedure involves multiplying age-specific harvest rates by age-specific weights to calculate an age-specific expected yield. The lifetime expected yield for a cohort of fish is the sum of all age-specific expected yields. Details of these calculations are provided in Chapter A-1 of EPA's *Regional Benefits Analysis* (USEPA 2006b).

3.2.2.3 Production Forgone for All Species

Production forgone is an estimate of the biomass that would have been produced had individuals not been impinged or entrained (Rago 1984). It is calculated for all forage species from species- and age-specific growth rates and survival probabilities. This forgone biomass represents a decrease in prey availability for predator species, and is calculated because I&E mortality losses for forage species are not included in the forgone fishery yield calculations. Additional details regarding the calculation of production forgone are provided in Chapter A-1 of EPA's *Regional Benefits Analysis* (USEPA 2006b).

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6 A cohort of fish refers to fish produced in the same year, also referred to as a year-class of fish.

3.2.3 Valuation Approach

EPA's benefits analysis focused on increased commercial and recreational fishery harvests estimated from projected reductions in I&E mortality losses. For consistency with reported harvest data, commercial harvest is reported in pounds and recreational harvest is reported in numbers of fish. To project changes in fishery harvests, EPA integrated two components of fishery yield that change as a consequence of I&E mortality: direct contributions of commercially and recreationally harvested species (hereafter fishery species), and indirect contributions of forage species consumed by fishery species (Figure 3-1). The direct contribution of fishery species to yield (left side of Figure 3-1) is calculated by converting A1E losses to forgone yield as described in Section 3.2.2. The contribution of forage species to fishery yield is measured as a biotic transfer of mass through the food web to fishery species that are subsequently harvested (right side of Figure 3-1). EPA used a simple trophic transfer model for this purpose (discussed in Chapter A-1 of EPA's *Regional Benefits Analysis* (USEPA 2006b), assuming a trophic transfer efficiency of 0.10 (Pauly and Christensen 1995).[7] Trophic transfer efficiency represents the fraction of forage species biomass incorporated into predator (fishery) species biomass. EPA estimated total changes to commercial and recreational harvest yield as the sum of the contributions of fishery and forage species. For benefits analysis, total yield was separated into commercial and recreational fractions based on the proportion of harvest occurring within each type of fishery, and benefits were calculated for harvestable adult fish. Details of the commercial and recreational fishing benefits analysis are provided in Chapters 6 and 7 of this report, respectively.

3.2.4 Rationale for EPA's Approach for Valuation of I&E mortality losses

EPA's approach to estimating changes in fish harvest assumed that I&E mortality losses result in a reduction in the number of harvestable adults, and that I&E mortality reductions result in increases to future fish harvests. This approach estimates incremental fishery yield forgone because of I&E mortality and does not require knowledge of population size or total yield of a fishery.

EPA's forgone fishery yield analysis requires species- and stage-specific schedules of natural mortality (M), fishing mortality (F), and weight-at-age. The yield model assumes that these key parameters (F, M, and weight-at-age) are independent of I&E mortality rates for all species. EPA recognizes that this assumption does not fully reflect the dynamic nature of fish populations. However, by conducting benefits analysis using estimates of foregone yield, EPA was able to use a simple and direct measure of the potential economic value associated with each I&E-related death. EPA believes that this approach was warranted given: (1) the scope and objectives of its analysis of harvested species, (2) data availability, and (3) difficulties in distinguishing the causes of population changes. Each of these factors is discussed below.

3.2.4.1 Scope and Objectives of EPA's Analysis of Harvested Species

EPA's overall objective was to develop regional- and national-scale estimates of the magnitude of I&E mortality at hundreds of facilities that are in the scope of the proposed rule nationwide. As a consequence of the large geographic scope and multiple ecosystems involved, EPA modeled fishery yield using a relatively simplified approach to estimate the vulnerability of dozens of species to I&E mortality on a

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7 EPA notes that its model of trophic transfer is a very simple and idealized representation of trophic dynamics; it is not intended to capture the details of trophic transfer in actual aquatic ecosystems. In reality, food webs and trophic dynamics are much more complex than EPA's simple model implies, and include details that are specific to each particular aquatic ecosystem. This complexity was beyond the scope of EPA's analysis and the available data.

national scale. Although sufficient data may exist to model the effects of I&E mortality on population and community-level impacts, sufficient data do not exist at the national scale to make such studies feasible.

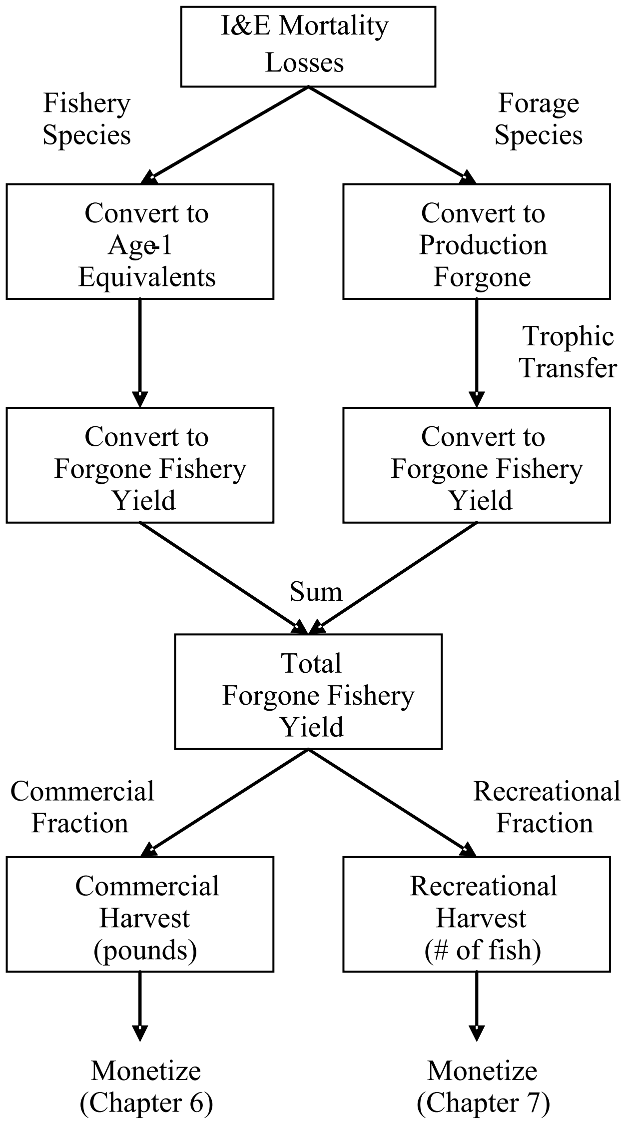


Figure 3-1: General Approach Used to Evaluate I&E Mortality Losses as Forgone Fishery Yield

3.2.4.2 Data Availability and Uncertainties Related to Modeling Fish Harvest

Forgone fishery yield and production forgone models used by EPA required age-specific life history data for all species analyzed. EPA acknowledges that many fish population models are available, and that these models may produce more accurate population-level impacts of I&E mortality. EPA did not pursue the development of species-specific population models for several reasons:

- Constructing population models requires a large set of parameters and numerous assumptions about the nature of stock dynamics for each species, including current stock size, stock-recruitment relationships, changes to growth and mortality rates as a function of stock size, and the separation of certain species into geographically based stock units. Because of these limitations, fewer than 40 percent of U.S.-managed commercially harvested fish stocks have been fully assessed (NMFS 2009; NMFS 2010b). As such, the information necessary to build more-complex population models is available only for a subset of harvested species, which represent a minor fraction of I&E mortality.

- Numerous difficulties exist in the definition of the size and spatial extent of fish stocks. As a result, it is often unclear how I&E mortality losses at particular cooling water intake structures (CWISs) can be related to specific stocks at a regional scale. For example, juvenile Atlantic menhaden (*Brevoortia tryannus*) found in Delaware Bay recruit from both local and long distances (Light and Able 2003). As a result, estimating the effects of local I&E mortality on recruitment rates would not be sufficient to understand the stock-recruitment relationship for Delaware Bay menhaden.

Consequently, due to issues of data availability and difficulties estimating the effects of localized I&E mortality on regional-scale fish stocks, EPA determined that the construction of population models for all species subject to I&E mortality was not feasible. The level of uncertainty that would accompany the construction of such models (if constructing them were even possible) would be difficult to defend with available data at both the national and population level for many species.

3.2.4.3 Difficulties Distinguishing Causes of Population Changes

It is fundamentally difficult to demonstrate a causal relationship between a single stressor and changes in fish population sizes. Fish populations are affected by multiple nonlinear stressors and are constantly in flux. As such, determining whether changes to fish populations are the consequence of an identifiable stressor due to natural fluctuation around an equilibrium stock size is difficult. Fish recruitment is a multidimensional process, and identifying and distinguishing the causes of variance in fish recruitment remains a fundamental problem in fisheries science, stock management, and impact assessment (Boreman 2000; Hilborn and Walters 1992; Quinn and Deriso 1999). Consequently, resolving issues of population fluctuation was beyond the scope and objectives of EPA's Section 316(b) benefits analysis.

3.2.5 Extrapolation of I&E Mortality to Develop Regional Estimates

EPA examined I&E mortality losses and the economic benefits of reducing these losses at a regional scale. Estimated benefits were then aggregated across all regions to produce a national benefits estimate. Regions were based on regions used by fisheries management agencies such as the National Marine Fisheries Service (NMFS). The geographical scope of all regions is described in Chapter 1 (Section 1.2).

To obtain regional I&E mortality estimates, EPA extrapolated losses observed at 97 facilities with I&E mortality data (hereafter model facilities) to all in-scope facilities within the same region. Extrapolation of I&E mortality rates was necessary because only a subset of all in-scope facilities have conducted I&E mortality studies. To allow extrapolation, EPA assumed that all facilities, regardless of size, have similar I&E mortality rates after normalization by flow. I&E mortality data were extrapolated on the basis of operational flow, in millions of gallons per day (MGD), where MGD is the average operational flow over the period 1996-1998 as reported by facilities in response to EPA's *Section 316(b) Detailed Questionnaire and Short Technical Questionnaire*. Operational flow at all facilities was scaled using a multiplicative factor that reflected the effectiveness of in-place technologies used to reduce I&E mortality. During the extrapolation procedure, EPA also applied weighting factors to in-scope facilities based on questionnaire results. Weighting factors for the current analysis were based on results of the *Detailed Questionnaire*. Additional details of EPA's extrapolation methods are provided in Appendix A.

The assumption that I&E mortality is proportional to flow is consistent with other published I&E mortality studies and models. Power plants on the Great Lakes exhibit an increasing relationship (on a log-log scale) between plant size (measured as electrical output) and I&E mortality rates (Kelso and Milburn 1979), and Goodyear (1978) predicted entrainment on the basis of the ratio of cooling water flow to source water flow. Additionally, the Spawning and Nursery Area of Consequence (SNAC) model, used as a screening tool for assessing potential I&E mortality impacts at Chesapeake Bay facilities, assumes that entrainment is proportional to cooling water withdrawal rates (Polgar et al. 1979).

EPA recognizes that there may be substantial variability in actual I&E mortality losses per MGD resulting from a variety of time- and facility-specific features, such as sampling date, location and type of intake structure, as well as from ecological features that affect the abundance and species composition of fish in the vicinity of each facility. Consequently, EPA's extrapolation procedure relies heavily on the assumption that I&E mortality rates recorded at model facilities are representative of I&E mortality rates at other facilities in the region. Although this assumption may not be met in some cases, limiting the extrapolation procedure within regions reduces the likelihood that model facilities are unrepresentative.

EPA believes that its method of extrapolation makes the best use of a limited amount of empirical data, and is the only feasible approach for developing a national estimate of I&E mortality, and the associated benefits of I&E mortality reduction. While acknowledging that extrapolation introduces uncertainty into I&E mortality estimates, EPA has not identified information suggesting a systematic bias in regional loss estimates based upon extrapolation.

3.3 I&E Mortality Losses By Region

3.3.1 California Region

Estimated baseline I&E mortality, and estimated reductions to I&E mortality under the three regulatory options are presented in Table 3-1 and Table 3-2. Estimated total baseline I&E mortality losses in the California region are 36.83 million A1Es per year, of which 17.56 million (47 percent) are forage fish. Approximately 5.59 percent of total baseline A1E losses are assigned a direct use value from recreational or commercial fishing (Table 3-1). Table C-1of Appendix C presents species-specific data on impingement and entrainment losses under the baseline conditions and estimated reductions under all options. Among commercially and recreationally-harvested species, the greatest losses occur in crabs, rockfishes, and sea basses (Appendix Table C-1).

The majority of I&E mortality in the California region occur due to entrainment (Appendix Table C-1). Because Option 1 does not reduce entrainment losses in the majority of facilities, it reduces baseline I&E mortality of A1E by only 1.9 percent (Table 3-1). Conversely, by requiring the installation of closed-cycle cooling towers, which effectively reduce entrainment mortality, Options 2 and 3 reduce A1E losses by 85.5 and 89.4 percent, respectively, providing over 40 times the reduction in A1E losses (Table 3-1).

Table 3-1: Summary of Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in California, and Reductions Under Option Scenarios

IM&EM Loss Metric (per year)	Baseline Losses	Reductions in Losses Option 1	Option 2	Option 3
All Species (million A1E)	36.83	0.69	31.50	32.92
Forage Species (million A1E)	17.56	0.18	14.99	15.67
Commercial & Recreational Species (million A1E)	19.28	0.52	16.51	17.25
Commercial & Recreational Harvest (million fish)	2.06	0.06	1.76	1.84
A1E Losses with Direct Use Value (%)	5.59	7.96	5.60	5.60

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

Production foregone due to baseline I&E mortality is estimated to be 14.05 million pounds of fish, leading to a decrease in fishery yield of more than 3.28 million pounds per year (Table 3-2). Option 1 is estimated to result in increased fishery yields of 0.02 million pounds per year. Under Options 2 and 3, however, estimated increases to fishery yields are more than 100 times greater, at 2.80 and 2.93 million pounds per year, respectively (Table 3-2).

Table 3-2: Baseline Losses in Fishery Yield, Catch, and Production Forgone as a Consequence of I&E Mortality at All In-scope Facilities (Manufacturing and Generating) in California, and Reductions Under Option Scenarios

IM&E Loss Metric (million per year)	Baseline Losses	Reductions in Losses Option 1	Option 2	Option 3
Foregone Fishery Yield (lbs)	3.28	0.02	2.80	2.93
Foregone Commercial Catch (lbs)	1.38	<0.01	1.18	1.23
Foregone Recreational Catch (fish)	1.02	0.04	0.88	0.92
Production Foregone (lbs)	14.05	0.10	11.99	12.54

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

Raw numbers of I&E mortality losses in California can be found in Appendix Table C-2.

3.3.2 North Atlantic Region

Estimated baseline I&E mortality, and estimated reductions to I&E mortality under the three regulatory options are presented in Table 3-3 and Table 3-4. Estimated total baseline I&E mortality losses in the North Atlantic region are 60.00 million A1Es per year, 78 percent of which are forage fish. Approximately 2.06 percent of total baseline A1E losses are assigned a direct use value from recreational or commercial fishing (Table 3-3). Table C-3 of Appendix C presents species-specific data on impingement and entrainment losses under the baseline conditions and estimated reductions under all options. Briefly, the vast majority (99 percent) of all A1E losses in the North Atlantic occur as a consequence of entrainment mortality (Appendix Table C-3). Notably, the combined I&E mortality of winter flounder, cunner, and sculpins account for 97 percent of all I&E mortality of commercially and recreationally-harvested species.

Because Option 1 does not reduce entrainment losses, it reduces baseline I&E mortality A1E losses by less than 1 percent (Table 3-3). Conversely, by requiring the installation of closed-cycle cooling towers, which effectively reduce entrainment mortality, Options 2 and 3 reduce A1E losses by 81.7 and 85.7 percent, respectively, providing more than 100 times the benefits of Option 1 by A1E (Table 3-3).

Table 3-3: Baseline I&E Mortality Losses and I&E Mortality Reductions at All In-scope Facilities (Manufacturing and Generating) in the North Atlantic, and Reductions Under Option Scenarios

IM&EM Loss Metric (per year)	Baseline Losses	Reductions in Losses		
		Option 1	Option 2	Option 3
All Species (million A1E)	60.00	0.43	49.02	51.40
Forage Species (million A1E)	47.02	0.38	38.42	40.29
Commercial & Recreational Species (million A1E)	12.98	0.06	10.60	11.11
Commercial & Recreational Harvest (million fish)	1.23	<0.01	1.01	1.06
A1E Losses with Direct Use Value (%)	2.06	1.52	2.06	2.06

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

Production foregone due to baseline I&E mortality is estimated to be 26.99 million pounds of fish, leading to a decrease in fishery yield of 1.02 million pounds per year (Table 3-4). Option 1 is estimated to result in increased fishery yields of less than 0.01 million pounds per year. Under Options 2 and 3, however, estimated increases to fishery yields are more than 100 times greater, at 0.83 and 0.87 million pounds per year, respectively (Table 3-4).

Table 3-4: Baseline Losses in Fishery Yield, Catch, and Production Forgone as a Consequence of I&E Mortality at All In-scope Facilities (Manufacturing and Generating) in the North Atlantic, and Reductions Under Option Scenarios

IM&E Loss Metric (million per year)	Baseline Losses	Reductions in Losses		
		Option 1	Option 2	Option 3
Foregone Fishery Yield (lbs)	1.02	<0.01	0.83	0.87
Foregone Commercial Catch (lbs)	0.45	<0.01	0.37	0.39
Foregone Recreational Catch (fish)	0.76	<0.01	0.62	0.65
Production Foregone (lbs)	26.99	0.03	22.01	23.09

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

Raw numbers of I&E mortality losses in the North Atlantic can be found in Appendix Table C-4.

3.3.3 Mid-Atlantic

Estimated baseline I&E mortality, and estimated reductions to I&E mortality under the three regulatory options are presented in Table 3-5 and Table 3-6. Estimated total baseline I&E mortality losses in the Mid-Atlantic region are 990.06 million A1Es per year, including 751.07 million A1Es of forage fish (75.9 percent). Approximately 3.11 percent of total baseline A1E losses are assigned a direct use value from recreational or commercial fishing (Table 3-5). Table C-5 of Appendix C presents species-specific data on impingement and entrainment losses under the baseline conditions and estimated reductions under all options. Briefly, the vast majority (95 percent) of all A1E losses in the Mid-Atlantic occur as a consequence of entrainment mortality. Nearly half (45.9 percent) of the I&E mortality estimated for commercially- and recreationally-harvested species occurs in Blue Crab, and substantial I&E mortality (i.e., greater than 20 million A1E) is estimated for Atlantic Croaker, Atlantic Menhaden, Spot, and White Perch.

Because of the high proportion of I&E mortality losses attributed to entrainment mortality, it is estimated that Options 2 and 3 will reduce I&E mortality by 91.9 and 93.0 percent, respectively (Table 3-5). Conversely, Option 1 is projected to reduce I&E mortality by approximately 3.9 percent, more than 20 times smaller than the reductions estimated to occur under Options 2 and 3.

Table 3-5: Baseline I&E Mortality Losses and I&E Mortality Reductions at All In-scope Facilities (Manufacturing and Generating) in the Mid-Atlantic, and Reductions Under Option Scenarios

IM&EM Loss Metric (per year)	Baseline Losses	Reductions in Losses		
		Option 1	Option 2	Option 3
All Species (million A1E)	990.06	38.69	909.74	920.90
Forage Species (million A1E)	751.07	14.27	688.96	697.59
Commercial & Recreational Species (million A1E)	238.98	24.42	220.78	223.31
Commercial & Recreational Harvest (million fish)	30.77	6.09	28.66	28.95
A1E Losses with Direct Use Value (%)	3.11	15.75	3.15	3.14

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

The I&E mortality model projects that baseline I&E mortality results in 80.73 million pounds of foregone production, and decreases fishery yield by 22.53 million pounds per year (Table 3-6). Option 1 is estimated to result in increased fishery yields of 5.40 million pounds per year. Under Options 2 and 3, increased fishery yields are 21.01 and 21.22 million pounds per year, respectively (Table 3-6).

Table 3-6: Baseline Losses in Fishery Yield, Catch, and Production Forgone as a Consequence of I&E Mortality at All In-scope Facilities (Manufacturing and Generating) in the Mid-Atlantic, and Reductions Under Option Scenarios

IM&E Loss Metric (million per year)	Baseline Losses	Reductions in Losses		
		Option 1	Option 2	Option 3
Foregone Fishery Yield (lbs)	22.53	4.73	21.01	21.22
Foregone Commercial Catch (lbs)	11.59	3.75	10.91	11.01
Foregone Recreational Catch (fish)	9.08	0.55	8.36	8.46
Production Foregone (lbs)	80.73	10.16	74.73	75.56

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

Raw numbers of I&E mortality losses in the Mid-Atlantic region can be found in Appendix Table C-6.

3.3.4 South Atlantic Region

Estimated baseline I&E mortality, and estimated reductions to I&E mortality under the three regulatory options are presented in Table 3-7 and Table 3-8. Estimated total baseline I&E mortality losses in the South Atlantic region are estimated to be 33.40 million A1Es per year, including 31.22 million forage fish A1Es. Approximately 1.03 percent of total baseline A1E losses are assigned a direct use value from recreational or commercial fishing (Table 3-7). Table C-7 of Appendix C presents species-specific data on impingement and entrainment losses under the baseline conditions and estimated reductions under all options. Unlike other regions, the majority (67 percent) of all A1E losses in the South Atlantic occur as a consequence of impingement mortality. Among commercially- and recreationally-harvested species, I&E mortality is greatest in Drums and Croakers and Blue Crab.

Due to the high proportion of I&E mortality lost to impingement, Option 1 is projected to reduce I&E mortality by 42.5 percent. However, because the installation of closed-cycle cooling towers reduces water usage, Options 2 and 3 are projected to reduce I&E mortality by approximately 84.6 and 84.7 percent (Table 3-7), approximately double the estimated reductions of Option 1.

Table 3-7: Baseline I&E Mortality Losses and I&E Mortality Reductions at All In-scope Facilities (Manufacturing and Generating) in the South Atlantic, and Reductions Under Option Scenarios

IM&EM Loss Metric (per year)	Baseline Losses	Reductions in Losses		
		Option 1	Option 2	Option 3
All Species (million A1E)	33.40	14.20	28.28	28.30
Forage Species (million A1E)	31.22	13.43	26.43	26.45
Commercial & Recreational Species (million A1E)	2.19	0.77	1.85	1.85
Commercial & Recreational Harvest (million fish)	0.35	0.11	0.29	0.29
A1E Losses with Direct Use Value (%)	1.03	0.75	1.03	1.03

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

Production foregone due to baseline I&E mortality is estimated to be 0.86 million pounds per year, leading to a decrease in fishery yield of approximately 0.16 million pounds per year. Option 1 is estimated to result in increased fishery yields of 0.05 million pounds per year. Under Options 2 and 3, however, estimated increases to fishery yields are more than 2 times greater, at 0.13 and 0.13 million pounds per year, respectively (Table 3-8).

Table 3-8: Baseline Losses in Fishery Yield, Catch, and Production Forgone as a Consequence of I&E Mortality at All In-scope Facilities (Manufacturing and Generating) in the South Atlantic, and Reductions Under Option Scenarios

IM&E Loss Metric (million per year)	Baseline Losses	Reductions in Losses		
		Option 1	Option 2	Option 3
Foregone Fishery Yield (lbs)	0.16	0.05	0.13	0.13
Foregone Commercial Catch (lbs)	0.10	0.05	0.08	0.08
Foregone Recreational Catch (fish)	0.13	0.02	0.11	0.11
Production Foregone (lbs)	0.86	0.14	0.72	0.72

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

Raw numbers of I&E mortality losses in the South Atlantic region can be found in Appendix Table C-8.

3.3.5 Gulf of Mexico

Estimated baseline I&E mortality, and estimated reductions to I&E mortality under the three regulatory options are presented in Table 3-9 and Table 3-10. Estimated total baseline I&E mortality losses in the Gulf of Mexico are estimated to be 135.64 million A1Es per year, including 47.75 million forage fish A1Es. Approximately 8.56 percent of total baseline A1E losses are assigned a direct use value from recreational or commercial fishing (Table 3-9). Table C-9 of Appendix C presents species-specific data on impingement and entrainment losses under the baseline conditions and estimated reductions under all options. The majority (67 percent) of all A1E losses in the Gulf of Mexico occur as a consequence of entrainment mortality. Among commercially- and recreationally-harvested species, I&E mortality is greatest in Blue Crab, and Pink Shrimp, which together account for 68 percent of A1E losses with direct use value. Other fish species with substantial I&E mortality (i.e., greater than 5 million A1E) include Black Drum, Menhaden, and Silver Perch (Appendix Table C-9).

Due to the low proportion of I&E mortality lost to impingement, Option 1 is projected to reduce I&E mortality by only 25.4 percent. In contrast, Options 2 and 3 are projected to reduce I&E mortality by 78.2 and 78.3 percent, respectively (Table 3-9), approximately triple the estimated reductions of Option 1.

Table 3-9: Baseline I&E Mortality Losses and I&E Mortality Reductions at All In-scope Facilities (Manufacturing and Generating) in the Gulf of Mexico, and Reductions Under Option Scenarios

IM&EM Loss Metric (per year)	Baseline Losses	Reductions in Losses		
		Option 1	Option 2	Option 3
All Species (million A1E)	135.64	34.50	106.02	106.21
Forage Species (million A1E)	47.75	4.31	34.09	34.16
Commercial & Recreational Species (million A1E)	87.89	30.19	71.94	72.05
Commercial & Recreational Harvest (million fish)	11.61	4.59	9.75	9.76
A1E Losses with Direct Use Value (%)	8.56	13.29	9.20	9.19

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

Production foregone due to baseline I&E mortality is estimated to be 76.06 million pounds per year, 43 percent of which is foregone fishery yield. Option 1 is estimated to reduce foregone fishery yields by 2.99 million pounds, while Options 2 and 3 are estimated to reduce foregone fishery yields by 23.43 and 23.48 million pounds, respectively (Table 3-10).

Raw numbers of I&E mortality losses in the Gulf of Mexico can be found in Appendix Table C-10.

Table 3-10: Baseline Losses in Fishery Yield, Catch, and Production Forgone as a Consequence of I&E Mortality at All In-scope Facilities (Manufacturing and Generating) in the Gulf of Mexico, and Reductions Under Option Scenarios				
	Baseline	**Reductions in Losses**		
IM&E Loss Metric (million per year)	**Losses**	**Option 1**	**Option 2**	**Option 3**
Foregone Fishery Yield (lbs)	32.81	2.99	23.43	23.48
Foregone Commercial Catch (lbs)	5.56	1.46	4.36	4.37
Foregone Recreational Catch (fish)	2.85	0.67	2.20	2.21
Production Foregone (lbs)	76.06	5.77	53.84	53.96

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

3.3.6 Great Lakes Region

Estimated baseline I&E mortality, and estimated reductions to I&E mortality under the three regulatory options are presented in Table 3-11 and Table 3-12. Estimated total baseline I&E mortality losses in the Great Lakes are 53.50 million A1Es per year, including 46.46 million A1E of forage fish. Approximately 1.50 percent of total baseline A1E losses are assigned a direct use value from recreational or commercial fishing (Table 3-11). Table C-11 of Appendix C presents species-specific data on impingement and entrainment losses under the baseline conditions and estimated reductions under all options. Briefly, among commercially and recreationally-harvested species, the greatest losses occur in Smelts and Sunfish.

The vast majority (83 percent) of I&E mortality losses in the Great Lakes occur due to impingement (Appendix Table C-11). Accordingly, Option 1 reduces baseline A1E I&E mortality by 71.5 percent (Table 3-11). By requiring the installation of closed-cycle cooling towers, which reduce the volume of water required for cooling purposes, Options 2 and 3 reduce A1E losses by 95.7 and 96.0 percent, respectively (Table 3-11).

Table 3-11: Baseline I&E Mortality Losses and I&E Mortality Reductions at All In-scope Facilities (Manufacturing and Generating) in the Great Lakes, and Reductions Under Option Scenarios				
	Baseline	**Reductions in Losses**		
IM&EM Loss Metric (per year)	**Losses**	**Option 1**	**Option 2**	**Option 3**
All Species (million A1E)	53.50	38.23	51.13	51.35
Forage Species (million A1E)	46.46	33.46	44.46	44.64
Commercial & Recreational Species (million A1E)	7.04	4.77	6.67	6.70
Commercial & Recreational Harvest (million fish)	0.80	0.49	0.75	0.75
A1E Losses with Direct Use Value (%)	1.50	1.28	1.47	1.47

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

Production foregone due to baseline I&E mortality is estimated to be 32.02 million lbs of fish, leading to a decrease in fishery yield of 0.70 million pounds per year (Table 3-12). Option 1 is estimated to result in increased fishery yields of 0.42 million pounds per year. Under Options 2 and 3, however, estimated increases to fishery yields are approximately 50 percent greater, at 0.65 and 0.65 million pounds per year, respectively (Table 3-12).

Table 3-12: Baseline Losses in Fishery Yield, Catch, and Production Forgone as a Consequence of I&E Mortality at All In-scope Facilities (Manufacturing and Generating) in the Great Lakes, and Reductions Under Option Scenarios

	Baseline	Reductions in Losses		
IM&E Loss Metric (million per year)	**Losses**	**Option 1**	**Option 2**	**Option 3**
Foregone Fishery Yield (lbs)	0.70	0.42	0.65	0.65
Foregone Commercial Catch (lbs)	0.35	0.23	0.33	0.33
Foregone Recreational Catch (fish)	0.35	0.18	0.32	0.32
Production Foregone (lbs)	32.02	7.34	27.19	27.49

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

Raw numbers of I&E mortality losses in the Great Lakes region can be found in Appendix Table C-12.

3.3.7 Inland Region

Estimated baseline I&E mortality, and estimated reductions to I&E mortality under the three regulatory options are presented in Table 3-13 and Table 3-14. Estimated total baseline I&E mortality losses in the Inland region are 879.49 million A1Es per year, including 713.71 million A1E of forage fish. Approximately 1.43 percent of total baseline A1E losses are assigned a direct use value from recreational or commercial fishing (Table 3-13). Table C-13 of Appendix C presents species-specific data on impingement and entrainment losses under the baseline conditions and estimated reductions under all options. Briefly, the majority (66.4 percent) of all A1E losses in the Inland region occur as a consequence of impingement mortality (Appendix Table C-13). Notably, the I&E mortality of sunfish account for 78.4 percent of the I&E mortality of commercially and recreationally-harvested species.

Option 1 reduces baseline I&E mortality A1E losses by 55.5 percent (Table 3-13). The installation of closed-cycle cooling towers under Options 2 and 3 reduce A1E losses by 91.6 and 93.5 percent, respectively, providing a benefit more than 60 percent larger than the benefits of Option 1 (Table 3-13).

Table 3-13: Baseline I&E Mortality Losses and I&E Mortality Reductions at All In-scope Facilities (Manufacturing and Generating) in the Inland Region, and Reductions Under Option Scenarios

	Baseline	Reductions in Losses		
IM&EM Loss Metric (per year)	**Losses**	**Option 1**	**Option 2**	**Option 3**
All Species (million A1E)	879.49	488.22	805.86	822.46
Forage Species (million A1E)	713.71	459.64	665.29	676.63
Commercial & Recreational Species (million A1E)	165.78	28.59	140.57	145.83
Commercial & Recreational Harvest (million fish)	12.59	4.32	11.06	11.39
A1E Losses with Direct Use Value (%)	1.43	0.89	1.37	1.38

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

The decrease in production due to baseline I&E mortality is estimated to be 407.08 million pounds of fish, leading to a decrease in fishery yield of 11.01 million pounds per year (Table 3-14). Option 1 is estimated to result in increased fishery yields of 3.77 million pounds per year. Under Options 2 and 3, however, estimated increases to fishery yields are more than two times greater, at 9.67 and 9.96 million pounds per year, respectively (Table 3-14).

Table 3-14: Baseline Losses in Fishery Yield, Catch, and Production Forgone as a Consequence of I&E Mortality at All In-scope Facilities (Manufacturing and Generating) in the Inland Region, and Reductions Under Option Scenarios

IM&E Loss Metric (million per year)	Baseline Losses	Reductions in Losses		
		Option 1	Option 2	Option 3
Foregone Fishery Yield (lbs)	11.01	3.77	9.67	9.96
Foregone Commercial Catch (lbs)	<0.01	<0.01	<0.01	<0.01
Foregone Recreational Catch (fish)	12.59	4.32	11.06	11.39
Production Foregone (lbs)	407.08	102.90	351.01	362.84

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

Raw numbers of I&E mortality losses in the Inland region can be found in Appendix Table C-14.

3.3.8 National Estimates

Estimated baseline I&E mortality, and estimated reductions to I&E mortality under the three regulatory options are presented in Table 3-15 and Table 3-16. Estimated total baseline I&E mortality losses nationally are 2,188.92 million A1Es per year, including 1,654.78 million A1E of forage fish. Approximately 2.71 percent of total baseline A1E losses are assigned a direct use value from recreational or commercial fishing (Table 3-15). Table C-13 of Appendix C presents species-specific data on impingement and entrainment losses under the baseline conditions and estimated reductions under all options. Briefly, the majority (65.8 percent) of all A1E losses nationally occur as a consequence of entrainment mortality (Appendix Table C-13).

Option 1 reduces baseline I&E mortality A1E losses by 28.1 percent (Table 3-15). The installation of closed-cycle cooling towers under Options 2 and 3 reduce A1E losses by 90.5 and 92.0 percent, respectively, providing a benefit approximately three times larger than the benefits of Option 1 (Table 3-15).

Table 3-15: Baseline I&E Mortality Losses and I&E Mortality Reductions at All In-scope Facilities (Manufacturing and Generating) Nationally, and Reductions Under Option Scenarios

IM&EM Loss Metric (per year)	Baseline Losses	Reductions in Losses		
		Option 1	Option 2	Option 3
All Species (million A1E)	2188.92	614.97	1981.55	2013.55
Forage Species (million A1E)	1654.78	525.66	1512.64	1535.44
Commercial & Recreational Species (million A1E)	534.15	89.31	468.91	478.11
Commercial & Recreational Harvest (million fish)	59.41	15.66	53.28	54.05
A1E Losses with Direct Use Value (%)	2.71	2.55	2.69	2.68

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

The decrease in production due to baseline I&E mortality is estimated to be 637.78 million pounds of fish, leading to a decrease in fishery yield of 71.50 million pounds per year (Table 3-16). Option 1 is estimated to result in increased fishery yields of 11.99 million pounds per year. Under Options 2 and 3, however, estimated increases to fishery yields are more than four times greater, at 58.52 and 59.24 million pounds per year, respectively (Table 3-16).

Table 3-16: Baseline Losses in Fishery Yield, Catch, and Production Forgone as a Consequence of I&E Mortality at All In-scope Facilities (Manufacturing and Generating) Nationally, and Reductions Under Option Scenarios

IM&E Loss Metric (million per year)	Baseline Losses	Reductions in Losses		
		Option 1	Option 2	Option 3
Foregone Fishery Yield (lbs)	71.50	11.99	58.52	59.24
Foregone Commercial Catch (lbs)	19.43	5.49	17.23	17.41
Foregone Recreational Catch (fish)	26.79	5.77	23.55	24.06
Production Foregone (lbs)	637.78	126.44	541.48	556.20

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

Raw numbers of national I&E mortality losses can be found in Appendix Table C-16.

3.4 Limitations and Uncertainties

There are four major kinds of uncertainty that may lead to imprecision and bias in EPA's I&E mortality analysis: data, structural, statistical, and engineering uncertainty. Data limitations and uncertainty refers to uncertainty and inconsistency in sampling methodologies used in facility-specific I&E mortality studies. Structural uncertainty reflects the simplification built into any model of a complex natural system. Parameter uncertainty refers to uncertainty in the numeric estimates of model parameters. Finally, engineering uncertainty refers to the fact that facilities do not operate identically on an annual basis.

3.4.1 Data Limitation and Uncertainty

Quantification of regional and national I&E mortality losses is based on cumulative data generated by collection at individual facilities. In turn, these data are heterogeneous products of location-specific investigations set in differing geographic and ecological provinces. Interpretation of the significance and trends of I&E mortality at regional and national scales (and of the accompanying ecological benefits upon mitigation) must consider the strengths and weaknesses of this data.

The I&E mortality data from model facilities constitute a heterogeneous composite of results from many facility-specific studies. Sampling effort and data quality control vary tremendously among I&E mortality studies and baseline source water characterization programs. While there is broad EPA guidance as to the overall objectives and requirements for facility-specific data collection, there is little uniformity among studies as to the intensity, frequency and duration of data collection as well as the scope of target biota collected, identified, and enumerated. Sampling regimes may be properly adjusted to ensure that changes in local biotic activity associated with diurnal, tidal, and lunar cycles are incorporated; or may reflect regularly spaced sampling points with little concern paid to capturing environmental variability.

In addition to the differences in environmental scope, sampling methods are not uniform among studies with regard to the types and meshes of sampling nets, deployment location of sampling nets (e.g., outside or within the intake structure), length and weight measurements, observations of field conditions, characterization of reference areas, etc. In addition to different sampling methods and timing, some sampling programs are designed primarily to estimate I&E mortality losses for a select suite of recreational or commercially important aquatic organisms. Studies differ in their taxonomic sorting classes and specificity of identification of impinged and entrained organisms (e.g., eggs, ichthyoplankton, zooplankton, etc.). Thus, many I&E mortality studies are poorly suited to provide insight into the direct and indirect impacts to forage fish species, non-vertebrate organisms (zooplankton, tunicates, algae, worms, etc.), or community/ecosystem impacts. For older facilities, sampling data commonly lack pre-operational (i.e., baseline) samples or community surveys to compare to the results of more-current I&E mortality data. Finally, few I&E mortality studies are designed to allow evaluation of community impacts or ecosystem effects (Section 2.4).

Within regions, studies of I&E mortality from model facilities are typically composed of data from a relatively limited number of facilities. Most facility-specific I&E mortality studies are limited to one or two years, and are rarely replicated within a time period that allows direct comparison of trends without historical complications due to fishery stock trends, climatic changes, or shifts in collection methods or water quality. Thus, studies within a regional database may not accurately represent average climatic and oceanographic conditions (e.g., El Nino years). Additionally, studies within the database may include historical (>20 years) and recent data, thus incorporating considerable uncertainty due to the annual variability of highly dynamic fish stocks. Thus, extrapolation from regional collections of facility-specific studies may not provide a true regional estimate because the available data may or may not be fully representative of regional trends and/or of associated ecological benefits derived from mitigating I&E mortality impacts.

3.4.2 Structural Uncertainty

The models EPA used to evaluate I&E mortality simplify complex processes. The degree of simplification is substantial, but necessary, because of limited data availability and the need to generate estimates on a national scale. Simplification occurs with respect to many processes within the model, to ensure computational tractability and national applicability (Table 3-17).

EPA recognizes these uncertainties, but believes that addressing each of these uncertainties in a defensible way would require data that does not currently exist (see Section 3.2.4.2), would be time-consuming and resource-intensive to develop, and would lead to greater parameter uncertainty (Section 3.4.3).

Table 3-17: Structural Uncertainties

Aspect of Model	General Description	Specific Treatment in Model
Biological submodels	Life history traits are fixed	Life history parameters in the models (i.e., growth, survival) are constant through time and are thus independent of biological conditions (e.g., fish densities, seasonality, weather, recruitment variability, food availability, fisheries pressure, etc.).
	No trophic effects	Indirect food web effects such as trophic cascades, growth and population limitations due to a lack of food, etc., are not considered. Trophic transfer is treated simplistically.
	Outside impacts not addressed	I&E mortality loss rates are affected by a variety of outside influences not included in the model (e.g., fisheries pressure, pollution, future development, invasive species, climate change, etc.).
Valuation structure	National nonuse benefits not addressed	Fish species grouped into two categories: harvested or not harvested (i.e., forage for harvested species). Only commercial and recreational harvests are assigned monetary values at the national level. Nonuse values of I&E mortality is estimated for the North Atlantic and Mid-Atlantic regions only.
	Fishing pressure constant	The valuation procedure assumes that fisheries harvests will increase proportionately to decreases in I&E mortality losses, independent of Federal and State policies on commercial and recreational fishing (i.e., fisheries quotas, closures, bag limits, etc.).

3.4.3 Parameter Uncertainty

Parameter uncertainty refers to variability in the value of parameters used in biological and economic modeling. All parameters must be estimated from sampling studies that cannot identify the true values of interest due to statistical and logistical limitations. These limitations are broadly driven by three processes, including parameter fluctuation through time, geographic location, and sampling.

The true value of many biological parameters fluctuates on an annual basis, due to changes in weather, food availability, indirect food-web effects, and compensatory population dynamics. Consequently, parameter values used within biological submodels, despite being based upon the best available data obtained from the scientific literature, cannot be without error due to annual variability in fish growth and (natural and fisheries) mortality rates. Similarly, because I&E mortality rates are driven by a combination of intake flow and the presence of vulnerable fish, actual I&E mortality cannot remain constant through time.

True values of biological parameters and facility I&E mortality vary geographically. Biological parameters may vary substantially within regions due to changes in substrate, water temperature and salinity, etc., while facility I&E mortality data may be strongly connected to local substrates, distance from shore, depth, etc. It follows, then, that using biological data and extrapolating facility-specific I&E mortality rates to the regional scale will result in parameter variability based solely on geographic considerations.

Finally, all model parameters contain uncertainty because they are small samples from a much larger dataset. Biological parameters such as mortality rates must be estimated using incomplete sampling data. Facility-reported I&E mortality studies necessarily subsample cooling water, and often do not take replicate samples across tidal periods, seasons, time of day, and between years. Moreover, these studies often present I&E mortality with limited taxonomic detail (i.e., the identification of eggs, larvae, and juveniles is not species-specific), and do not have standard methodologies. As is the case with retrospective data, these studies also reflect the biological and physical state of the waterbody when studies were conducted. In some cases, the state of the waterbody itself has changed substantially since sampling was conducted.

EPA recognizes many sources of parameter uncertainty in its models (Table 3-18), all of which lead to uncertainty in point estimates of I&E mortality losses. The nature of these uncertainties, however, does not inherently bias the point estimate. EPA believes that all biological and physical parameters were reported in good faith, and as such, parameter estimates are unlikely to be biased in aggregate, but distributed both above and below true parameter values. Thus, EPA believes that parameter uncertainty has resulted in imprecision rather than inaccuracy in model output.[8]

3.4.4 Engineering Uncertainty

EPA's evaluation of I&E mortality was also affected by uncertainty about the engineering and operating characteristics of the study facilities. It is unlikely that plant operating characteristics (e.g., seasonal, diurnal, or intermittent changes in intake water flow rates) are constant throughout any particular year. As such, the timing of sampling, and the annual repeatability of I&E mortality, may be biased by facility operating conditions. EPA assumed that the facilities' loss estimates were provided in good faith and did not include any biases or omissions that significantly modified loss estimates.

[8] Accuracy refers to the degree of closeness of model results to the actual value. Precision refers to the reproducibility of model output, or the degree to which repeated measurements (or samples, for example from different model facilities) under similar conditions will result in the same model output.

Table 3-18: Parameters Included in EPA's I&E Mortality Analysis Subject to Uncertainty

Model Aspect	Parameter	Description
I&E mortality monitoring /loss rate estimates	Sampling regimes	Sampling regimes are subject to numerous plant-specific details. No established guidelines or performance standards for how to design and conduct sampling regimes. Not all sampling studies measured both impingement and entrainment mortality.
	Extrapolation assumptions	Extrapolation of monitoring data to annual I&E mortality rates assumes sampling occurred under average conditions, and that diurnal/seasonal/annual cycles in fish presence and vulnerability and various technical factors (e.g., net collection efficiency; hydrological factors affecting I&E mortality rates) do not play a substantial role in the accuracy of extrapolation. No established guidelines or consistency in sampling regimes.
	Species selection	Criteria for the selection of species evaluated in I&E mortality studies are not well-defined nor uniform across facilities. At many facilities, I&E mortality data was collected for only a subset of species, usually only fish and shellfish.
	Sensitivity of fish to I&E mortality	Entrainment mortality was assumed by EPA to be 100%. Back-calculations were done in cases where facilities reported entrainment rates that assumed <100% mortality. These calculations were limited by data reporting (i.e., species-specific survival rates were not always provided). Impingement survival was included if presented in facility documents.
Biological/life history	Natural mortality rates	Natural mortality rates (M) difficult to estimate, and vary with time and geography. Model results are highly sensitive to M.
	Growth rates	Simple exponential growth rates or simple size-at-age parameters used, and assumed constant across all locations and years.
	Geographic considerations	Migration patterns; I&E mortality occurring during spawning runs or larval out-migration; location of harvestable adults; intermingling with other stocks.
	Forage valuation	Harvested species assumed to be food limited; trophic transfer efficiency to harvested species estimated by EPA based on general models; no consideration of trophic transfer to species not impinged and entrained.
Fish stock characteristics	Fishery yield	For most harvested species, only one species-specific value for fishing mortality rate (F) was used for all stages subject to harvest. Used stage-specific constants for fraction vulnerable to fishery.
	Harvest behavior	No assumed dynamics among harvesters to alter fishing rates or preferences in response to changes in stock size. Recreational access assumed constant (no changes in angler preferences or effort).
	Stock interactions	I&E mortality losses assumed to be part of reported fishery yield rates on a statewide basis. No consideration of possible substock harvest rates or interactions, no unreported catch.
Ecological system	Fish community	Long-term trends in fish community composition or abundance were not considered (general food webs assumed to be static), nor were indirect trophic interactions. Used constant value for trophic transfer efficiency, and specific trophic interactions were not considered. Trophic transfer to organisms not impinged and entrained is not considered.
	Spawning dynamics	Sampled years assumed to be typical with respect to choice of spawning areas and timing of migrations that could affect vulnerability to I&E mortality (e.g., presence of larvae in vicinity of intake structure).
	Hydrology	Sampled years assumed to be typical with respect to flow regimes and tidal cycles that could affect vulnerability to I&E mortality (e.g., presence of larvae in vicinity of CWIS).
	Meteorology	Sampled years assumed to be typical with respect to vulnerability to I&E mortality (e.g., presence of larvae in vicinity of intake structure).

4 Economic Benefit Categories Associated with I&E Mortality Reduction

Changes in CWIS design or operations resulting from the regulatory options for the proposed Section 316(b) regulation for in-scope facilities are expected to increase the numbers of aquatic organisms present and increase local and regional fishery populations. They will do this by reducing impingement and entrainment (I&E) mortality of fish, shellfish, and other aquatic organisms.

The aquatic organisms affected by CWISs provide a wide range of ecosystem services. Ecosystem services are the physical, chemical, and biological functions performed by natural resources and the human benefits derived from those functions, including both ecological and human use services (Daily 1997; Daily et al. 1997). Scientific and public interest in protecting ecosystem services is increasing with the recognition that these services are vulnerable to a wide range of human activities and are difficult, if not impossible, to replace with human technologies (Meffe 1992).

In addition to their importance in providing food and other goods of direct use to humans, the organisms lost to impingement and entrainment mortality (I&E mortality) are critical to the continued functioning of the ecosystems of which they are a part. Fish are essential for energy transfer in aquatic food webs, regulation of food web structure, nutrient cycling, maintenance of sediment processes, redistribution of bottom substrates, the regulation of carbon fluxes from water to the atmosphere, and the maintenance of aquatic biodiversity (Holmlund and Hammer 1999; Peterson and Lubchenco 1997; Postel and Carpenter 1997; Wilson and Carpenter 1999). Many of these ecosystem services can be maintained only by the continued presence of all life stages of fish and other aquatic species in their natural habitats. Section 2.3 provided detail on potential CWIS impacts on aquatic ecosystems. Due to a lack of data, many of these impacts could not be successfully evaluated or monetized.

4.1 Economic Benefit Categories Applicable to the Regulatory Options for In-Scope Facilities

The economic benefits of reducing I&E mortality at in-scope facilities stem from both market and nonmarket goods and services that the affected resources provide. These benefits can be divided into the following categories (Table 4-1, below).

- **Market benefits:** Market benefits are positive welfare impacts that can be quantified using money-denominated measures of consumer and producer surplus. The most obvious example of market benefits from reduced I&E mortality is benefits to commercial fisheries. Changes in I&E mortality will directly affect the price, quantity, and/or quality of fish harvests; and the monetary value of the changes can be measured directly through market measures of consumer and producer behavior. Market benefits may be further categorized in terms of direct and indirect benefits. By definition, all market benefits are use benefits, as they involve either direct or indirect uses of goods or services.
    - **Market direct use benefits:** Market direct use benefits are benefits related to goods directly used, and bought and sold in markets; for example, fish caught for sale to consumers.
    - **Market indirect use benefits:** Indirect use benefits are those that contribute indirectly to an increase in welfare for users of the resource. Market indirect use benefits are benefits that

occur through indirect or secondary effects on marketed goods. For example, an increase in the number of forage fish may increase the population of commercially valuable species, which are marketed to consumers. Thus, reducing I&E mortality of forage species can indirectly result in welfare gains for commercial fishers and consumers who purchase fish.

- **Nonmarket benefits:** Nonmarket benefits consist of goods and services that are not traded in the marketplace, but are nonetheless positively affected by reduced I&E mortality. Higher catch rates for recreational fishing are an obvious nonmarket benefit. Anglers place a high value on catching fish during their fishing trips, so higher catch rates from reduced I&E mortality will translate directly to greater utility from participation in recreational fishing. Because the monetary value of these improvements cannot be established by observing market transactions, nonmarket valuation techniques must be employed to estimate such benefits. Nonmarket benefits may be further categorized in terms of direct and indirect use benefits, and nonuse benefits.
  - **Nonmarket direct use benefits:** Nonmarket direct use benefits consist of goods and services that have direct uses, but are not traded in the marketplace. Higher catch rates for recreational fishing provide a typical nonmarket direct use benefit.
  - **Nonmarket indirect use benefits:** Nonmarket indirect use benefits contribute indirectly to an increase in welfare for nonmarketed uses of a resource. For example, the options' positive impacts on local fisheries may generate an improvement in the population levels and diversity of fish-eating bird species. In turn, avid bird watchers might obtain greater enjoyment from their outings, as they are more likely to see a wider mix or greater numbers of birds. The increased welfare of the bird watchers is thus an indirect consequence of the regulatory options' initial impact on fish..
  - **Nonuse benefits:** Nonuse, or passive, benefits occur when individuals value improved environmental quality without any past, present, or anticipated future use of the resource in question. Individuals may gain utility simply from knowing that a particular good exists (existence value), or from knowing that a good is available for others to use now and in the future (bequest value). Nonuse benefits of reduced I&E mortality may include increased biodiversity, improved conditions for the recovery of T&E species that have no direct or indirect uses, and welfare gains to nonusers when reduced I&E mortality to forage species improve overall ecosystem function.

Table 4-1 displays the benefit categories expected to be affected by the regulatory options considered for the Section 316(b) regulation for in-scope facilities. The table also reveals the various data needs, data sources, and estimation approaches associated with each category. Many ecosystem services with potential nonuse values could not be quantified or monetized due to a lack of sufficient data. A complete list of the ecosystem services potentially affect by reduction in I&E mortality is presented in Chapter 2 (Table 2-4).

Table 4-1: Summary of Benefit Categories' Data Needs, Potential Data Sources, Approaches, and Analyses Completed

Benefit Category	Basic Data Needs	Potential Data Sources/ Approaches/Analyses Completed
Market Goods, Direct Use		
➢ Increased commercial landings	➢ Estimated change in landings of specific species ➢ Estimated change in total economic impact	➢ Based on facility-specific I&E mortality data and ecological modeling. ➢ Changes in commercial fishery landings are estimated using a market-based approach. ➢ Indirect economic impacts are not estimated due to data constraints.
Market Goods, Indirect Use		
Increase in: ➢ Equipment sales, rental, and repair ➢ Bait and tackle sales ➢ Consumer market choices ➢ Choices in restaurant meals ➢ Property values near the water ➢ Ecotourism (charter trips, festivals, other organized activities with fees such as riverwalks)	➢ Estimated change in landings of specific species ➢ Relationship between increased fish/shellfish landings and secondary markets ➢ Local activities and participation fees Estimated numbers of participating individuals	➢ Indirect market impacts are not estimated, due to data constraints such as lack of information on the relationship between increased fish/shellfish yield and secondary impacts.
Nonmarket Goods, Direct Use		
➢ Improved value of a recreational fishing trip due to increased catch of targeted/preferred species and incidental catch ➢ Improved value of subsistence fishing	➢ Estimated number of affected anglers ➢ Value of an improvement in catch rate	➢ Changes in the value of a recreational fishing trip are estimated based on benefit transfer (including recreational use values of selected T&E species). ➢ Changes in the value of subsistence fishing is not estimated.
➢ Increase in recreational fishing participation	➢ Estimated number of affected anglers or estimate of potential anglers ➢ Value of a fishing day	➢ Not estimated due to data constraints.
Nonmarket Goods, Indirect Use		
Increase in value of boating, scuba-diving, and near-water recreational experience from: ➢ Enjoying observing fish while boating, scuba-diving, hiking, or picnicking ➢ Watching aquatic birds fish or catch aquatic invertebrates	➢ Estimated number of affected near-water recreationists, divers, and boaters ➢ Value of boating, scuba-diving, and near-water recreation experience	➢ Not estimated due to data constraints such as number of affected recreational users.
➢ Increase in boating, scuba-diving, and near-water recreation participation	➢ Estimated number of affected boating, scuba-diving, and near-water recreationists ➢ Value of a recreation day	➢ Not estimated. Changes in recreational participation are expected to be negligible at the regional level because fishery yield impacts are generally small.
Nonuse Goods		
Increase in nonuse values such as: ➢ Existence (stewardship) ➢ Altruism (interpersonal concerns) ➢ Bequest (interpersonal and intergenerational equity) motives ➢ Appreciation of the importance of ecological services apart from human uses or motives (Table 2-4)	➢ I&E mortality estimates ➢ Primary valuation research using stated preference approach ➢ Applicable studies upon which to conduct benefit transfer ➢ Location of CWISs and T&E species ranges	➢ Estimate nonuse values for an increase in relative fish abundance within two benefits regions using benefits transfer. Not estimated for other regions due to a lack of applicable studies. ➢ Used geographic information system (GIS) data to identify T&E species potentially impacted by CWISs based on the overlap of CWIS locations and T&E species ranges.

4.2 Market and Nonmarket Direct and Indirect Use Benefits from Reduced I&E Mortality

Direct use benefits are the simplest to envision. The welfare of commercial, recreational, and subsistence fishers is improved when fish stocks increase and their catch rates rise or effort decreases. Higher catch rates increase the revenue and growth of commercial fisheries, the enjoyment of recreational fishing trips, and the availability of food for subsistence fishers—all of which are quantifiable benefits arising directly from changes in I&E mortality. Methodologies for estimating use values for recreational and commercial species are well developed, and some of the species affected by I&E mortality have been extensively studied. As a result, estimation of associated use values is often considered to be straightforward.

Indirect use benefits refer to welfare improvements for those individuals whose activities are enhanced as an indirect consequence of fishery or habitat improvements generated by the regulatory options for in-scope facilities. For example,an improvement in the population of a forage fish species may not be of any direct consequence to recreational or commercial fishers. However, the increased presence of forage fish will have an indirect effect on commercial and recreational fishing values if it increases food supplies for commercial and recreational predatory species. Thus, improvements in forage species populations can result in a greater number (and/or greater individual size) of those fish that are targeted directly by recreational or commercial fishers. In such an instance, the incremental increase in recreational and commercial fishing benefits would be an indirect consequence of the regulatory options' effect on forage fish populations.

The following sections discuss the benefits estimates presented in each chapter of this report, and techniques for estimating benefits of reduced I&E mortality for each category of benefits.[9]

4.2.1 Commercial Fisheries

Commercial fishing benefits include both direct and indirect market use values. The social benefits derived from increased landings by commercial fishers can be valued by examining the markets through which the landed fish are sold. The first step of the analysis involves a fishery-based assessment of I&E mortality-related changes in commercial landings (pounds of commercial species as sold dockside by commercial harvesters). The changes in landings are then valued according to market data from relevant fish markets (dollars per pound) to derive an estimate of the change in gross revenue to commercial fishers. The final steps entail converting the I&E mortality-related changes in gross revenues into estimates of social benefits. These social benefits consist of the sum of the producers' and consumers' surpluses that are derived as the changes in commercial landings work their way through the multi-market commercial fishery sector.

Indirect use values in markets occur through increases in commercial species caused by increased numbers of forage fish. An improvement in the population of a forage fish species may not be of any direct consequence to commercial fishers. However, the increased presence of forage fish will have an indirect effect on commercial fishing values if it increases food supplies for commercial predatory species. Thus, improvements in forage species populations can result in a greater number (and/or greater individual size) of those fish that are targeted directly by commercial fishers. In such an instance, the

9 Many of the fish species affected by I&E mortality at CWIS sites are harvested both recreationally and commercially. To avoid double-counting the economic impacts of I&E mortality of these species, EPA determined, based on historic NMFS landings data, the proportions of total species landings attributable to recreational and commercial fishing, and applied these proportions to the total number of affected fish.

incremental increase in commercial fishing benefits would be an indirect consequence of the regulatory options' effect on forage fish populations. See Chapter 3 for a discussion on the indirect influence of forage fish on abundance of commercial and recreational species.

Chapter 6 of this report provides more detail on EPA's analysis of commercial fishing benefits from reducing I&E mortality at the in-scope facilities' cooling water intakes.

4.2.2 Recreational Fisheries

Recreational fishing benefits include both direct and indirect nonmarket use values. The benefits of recreational use cannot be tracked in the market, since much of the recreational activity associated with these fisheries occurs as nonmarket events. However, a variety of nonmarket valuation methods exist for estimating use value, including both "revealed" and "stated" preference methods (Freeman III 2003). These methods use other observable behavior to infer users' value for environmental goods and services. Examples of revealed preference methods include travel cost, hedonic pricing, and random utility models. Compared to nonuse values, nonmarket use values are often considered relatively easy to estimate, due to their relationship to observable behavior, the variety of revealed preference methods available, and public familiarity with the recreational services that surface waterbodies provide.

To evaluate the recreational benefits of the regulatory options for in-scope facilities, EPA developed a benefit transfer approach based on a meta-analysis of recreational fishing valuation studies. The analysis was designed to measure the various factors that determine willingness to pay (WTP) for catching an additional fish per trip. The estimated meta-model allows calculation of the marginal value per fish for different species, based on resource and policy context characteristics.

Indirect use values for forage species occur through increases in recreational species caused by increased numbers of forage fish. An improvement in the population of a forage fish species may not be of any direct consequence to recreational anglers. However, the increased presence of forage fish will have an indirect effect on recreational fishing values if it increases food supplies for recreational predatory species. Thus, improvements in forage species populations can result in a greater number (and/or greater individual size) of those fish that are targeted directly by recreational anglers. In such an instance, the incremental increase in recreational fishing benefits would be an indirect consequence of the regulatory options' effect on forage fish populations. See Chapter 3 for a discussion on the indirect influence of forage fish on abundance of commercial and recreational species.

Chapter 7 of this report provides detail on the application of the meta-regression model to estimating recreational fishing benefits from the alternative regulatory options.

4.2.3 Subsistence Fishers

Subsistence fisheries benefits include both direct and indirect nonmarket use values. Subsistence use of fishery resources can be an important issue in areas where socioeconomic conditions (e.g., the number of low-income households) or the mix of ethnic backgrounds make such fishing economically or culturally important to a component of the community. In cases of Native American use of affected fisheries, the value of an improvement can sometimes be inferred from settlements in legal cases (e.g., compensation agreements between affected tribes and various government or other institutions in cases of resource acquisitions or resource use restrictions). For more-general populations, the value of improved subsistence fisheries may be estimated from the costs saved in acquiring alternative food sources (assuming the meals are replaced rather than foregone). This method may underestimate the value of a subsistence-fishery meal to the extent that the store-bought foods may be less preferred by some individuals than consuming a fresh-caught fish. Subsistence-fishery benefits are not included in EPA's benefits regional analyses. Impacts on subsistence fishers may constitute an important environmental justice consideration, leading to underestimation of the total benefits of the regulatory options. EPA's analysis of the regulation's impacts on low-income populations and subsistence fishers is presented in Chapter 9 of the Economic Analysis of the Proposed 316(b) Regulation.

4.2.4 Benefits from Improved Protection to T&E Species

T&E and other special status species can be adversely affected in several ways by CWISs. T&E species can suffer direct harm from I&E mortality; they can suffer indirect impacts if I&E mortality at CWISs adversely affects another species upon which the T&E species relies within the aquatic ecosystem (e.g., as a food source); or they can suffer impacts if the CWIS disrupts their critical habitat (e.g., via thermal discharges). The loss of individuals of listed species from CWISs is particularly important because, by definition, these species are already rare and at risk of irreversible decline because of other stressors.

Benefits from improved protection of T&E species can include both direct and indirect nonmarket use values, as well as nonuse values. EPA identified nine special status fish species, six in California and three in the Inland region, for which I&E mortality data were available. Due to their special status as well as the fact that most of these species have either very limited or no direct uses, the major portion of the values for T&E species are nonuse values. However, some of these species have potentially significant recreational and commercial use values (e.g., sturgeon and paddlefish). EPA applied benefit transfer to estimate recreational use values for a subset of T&E species for which limited catch and release fisheries exist. EPA did not estimate potential commercial use values of these species due to the lack of market data.

Chapter 5 of this report provides more detail on EPA's analysis of T&E species benefits from reducing I&E mortality at in-scope facilities' cooling water intakes.

4.3 Nonuse Benefits from Reduced I&E Mortality

Comprehensive estimates of total resource value include both use and nonuse values, such that the resulting total value estimates may be compared to total social cost. Recent economic literature provides substantial support for the hypothesis that nonuse values, such as option and existence values, are greater than zero. In fact, small per capita nonuse values held by a substantial fraction of the population can be very large in the aggregate. "Nonuse values, like use values, have their basis in the theory of individual preferences and the measurement of welfare changes. According to theory, use values and nonuse values are additive" (Freeman III 1993).[10] Consequently, both EPA's own Guidelines for Preparing Economic Analysis and OMB's Circular A-4, governing Regulatory Analysis, support the need to assess nonuse values (USEPA 2000a; USOMB 2003). Excluding nonuse values from consideration is likely to substantially understate total social values.

Reducing I&E mortality of fish and shellfish may result in both use and nonuse benefits. Of the organisms that are anticipated to be protected by the regulatory options for the Section 316(b) regulation for in-scope facilities, only a tiny fraction will eventually be harvested by commercial and recreational fishers and therefore can be valued with direct use valuation techniques. Unharvested fish, which were not assigned direct use value in this analysis, constitute the majority—97 percent—of the total loss, as

[10] This additive property holds under traditional conditions related to resource levels and prices for substitute goods in the household production model (Freeman III 1993).

summarized in Table 4-2 which reports total I&E mortality losses and reduction in I&E mortality losses by four loss categories: all species, forage species, total commercial and recreational species, harvested commercial and recreational species. Although unlanded forage fish contribute to the yield of harvested fish and therefore have an indirect use value that is captured by the direct use value of the commercial species, this indirect use value represents only a portion of the total value of unlanded fish. Society also values both landed and unlanded fish for reasons unrelated to their use value—for example, individual welfare may be affected simply by knowing these fish exist. Additionally, nonuse values are likely to be substantial because fish and other species found within aquatic habitats impacted directly and indirectly by CWISs provide other valuable ecosystem goods and services. These include nutrient cycling and ecosystem stability. Therefore, a comprehensive estimate of the welfare gain from reducing I&E mortality must include an estimate of nonuse benefits.

In contrast to direct and indirect use values, nonuse values are often considered more difficult to estimate. Stated preference methods, or benefit transfer based on stated preference studies, are the generally accepted techniques for estimating these values (USEPA 2000a; USOMB 2003). Stated preference methods rely on carefully designed surveys, which either (1) ask people about their WTP for particular ecological improvements, such as increased protection of aquatic species or habitats with particular attributes, or (2) ask people to choose between competing hypothetical "packages" of ecological improvements and household cost where their choice implies a WTP value. In either case, values are estimated by statistical analysis of survey responses.

Table 4-2: Summary of Baseline National I&E Mortality Losses and Reductions in I&E Mortality Losses, by Regulatory Option

IM&EM Loss Metric (per year)	Baseline Losses	Reductions in Losses		
		Option 1	Option 2	Option 3
All Species (million A1E)	2188.92	614.97	1981.55	2013.55
Forage Species (million A1E)	1654.78	525.66	1512.64	1535.44
Commercial & Recreational Species (million A1E)	534.15	89.31	468.91	478.11
Commercial & Recreational Harvest (million fish)	59.41	15.66	53.28	54.05
A1E Losses with Direct Use Value (%)	2.71	2.55	2.69	2.68

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

Nonuse values may be more difficult to assess than use values for several reasons. First, nonuse values are not associated with easily observable behavior. Second, nonuse values may be held by both users and nonusers of a resource. Because nonusers may be less familiar with particular services provided by a resource, their values may be different from the nonuse values for users of the same resource. Third, the development of a defensible stated preference survey is often a time- and resource-intensive process. Fourth, even carefully designed surveys may be subject to certain biases associated with the hypothetical nature of survey responses (Mitchell and Carson 1989). Finally, efforts to disaggregate total WTP into its use and nonuse components have proved troublesome (Carson et al. 1999).

Although EPA is not always able to estimate changes in affected resources' nonuse service values as part of regulatory development, an extensive body of environmental economics literature reveals that the public holds significant value for service flows from natural resources well beyond those associated with direct uses (Boyd et al. 2001; Fischman 2001; Heal et al. 2001; Herman et al. 2001; Ruhl and Gregg 2001; Salzman et al. 2001; Wainger et al. 2001). Studies have documented public values for the nonuse services provided by a variety of natural resources potentially affected by environmental impacts, including fish and wildlife (Loomis et al. 2000; Stevens et al. 1991); wetlands (Woodward and Wui 2001); wilderness (Walsh et al. 1984); critical habitat for T&E species (Hagen et al. 1992; Loomis and Ekstrand 1997; Whitehead and Blomquist 1991); shoreline quality (Grigalunas et al. 1988); and beaches, shorebirds, and marine mammals (Rowe et al. 1992), among others. However, given EPA's regulatory schedule, developing and implementing stated preference surveys to elicit total value (i.e., nonuse and use) of environmental quality changes resulting from environmental regulations is often not feasible.[11]

Existing stated preference studies suggest that nonuse benefits of aquatic habitat improvements may be significant. For example, results from a study of public values of migratory fish restoration projects in Rhode Island showed that nonuse motives such as existence and bequest values were rated as "important" or "very important" by 62 and 76 percent of survey respondents, respectively. Use motives such as commercial and recreational fishing, on the other hand, were rated as "important" or "very important" by only 38 and 43 percent of the survey respondents, respectively (Johnston et al. 2009, unpublished data). Additional detail regarding Johnston et al. (2009) is provided in Chapter 8, Section 8.3.1.

Many ecosystems impacted by CWISs provide goods and services that contribute to well-being (see Chapter 2), but may be generally unrecognized because of their indirect nature. As such, valuations based on stated preferences are unlikely to capture the full complement of ecologically-based services with economic value (Costanza and Folke 1997). Despite these limitations, benefit transfers based on stated preference studies are the generally accepted techniques for estimating nonuse values. EPA was able to identify a single study that could be used to estimates total values (nonuse and use values) for reductions in I&E mortality in some regions. Chapter 8 of this report provides more detail on EPA's quantitative analysis of nonuse benefits from reducing I&E mortality at the in-scope facilities' cooling water intakes.

[11] EPA designed a stated preference survey to separately estimate total value (including use and nonuse value) of potential aquatic resource improvements that might occur because of the proposed 316(b) regulation. However EPA did not have sufficient time to fully develop and deploy this survey and derive reliable quantitative estimates of the monetary value of reducing those impacts at the national level. Benefit transfer of values from existing stated preference studies was used by EPA in the absence of an original study. For more details on development of the survey, see the Information Collection Request entitled "Development of Willingness to Pay Survey Instrument for Section 316(b) Cooling Water Intake Structures".

5 Impacts and Benefits on Threatened and Endangered Species

5.1 Introduction

Threatened and endangered (T&E) species are species vulnerable to future extinction or at risk of extinction in the near future, respectively. These designations may be made because of low or rapidly declining population levels, loss of essential habitat, or life history stages that are particularly vulnerable to environmental alteration. In addition to T&E labels, the designation "species of concern" includes species that warrant special protection due to inherent vulnerabilities to habitat modification, disturbance, or other human impacts. Together, these stressors may result in the species becoming threatened or endangered in the foreseeable future.[12]

The withdrawal of cooling water from streams, rivers, estuaries and coastal marine waters leads to the impingement and entrainment (I&E) of a large number of aquatic organisms. For species vulnerable to future extinction, impingement and entrainment mortality (I&E mortality) from cooling water intake structures (CWISs) may represent a substantial portion of annual reproduction. Consequently, I&E mortality may either lengthen recovery time, or hasten the demise of these species. For this reason, the population-level and social values of T&E losses are likely to be disproportionately higher than the absolute number of losses that occur.

Adverse effects of CWISs on T&E species may occur in several ways:

- Populations of T&E species may suffer direct harm as a consequence of I&E mortality. This direct loss of individuals may be particularly important because T&E species have severely depressed population levels that are approaching local, national, or global extinction.
- T&E species may suffer indirect harm if the CWIS substantially alters the food web in which these species interact. This might occur as a result of altered populations of predator or prey species, the removal of foundation species, or (for species with parasitic life history stages) the loss of a host species.
- CWISs may alter habitat that is critical to the long-term survival of T&E species. This might occur as a consequence of changes in the thermal characteristics of local waterbodies, altered flow regimes, turbidity, or changes in substrate characteristics as a consequence of any of these changes (Chapter 2).

By definition, T&E species are characterized by low population levels. As such, it is unlikely that these species will be recorded in I&E mortality monitoring studies due to the logistical limitations of sampling and identification effort, time of day, season, and year. For T&E species to be recorded in monitoring studies, 1) an individual of a T&E species must be captured by a CWIS during the (often short) sampling window, and 2) the organism must be identifiable. Thus, despite the fact that the population impacts of I&E mortality on T&E species may be high, they are difficult to ascertain and quantify within a framework designed for common, more-abundant species. Thus, EPA identifies spatial overlap between CWISs and T&E species to estimate the potential for adverse I&E mortality impacts on T&E species.

[12] To simplify the discussion, in this chapter EPA uses the terms "T&E species" and "special status species" interchangeably to mean all species that are specifically listed as threatened or endangered, plus other species with special status designation at the state or federal level.

From an economic perspective, T&E species affected by CWISs may have both use and nonuse values. However, despite the existence of T&E species with potentially high use values (e.g., Pacific Salmonids), the majority of T&E species affected by I&E mortality are obscure, relatively unknown, and may not have any direct uses (e.g., delta smelt). Given the protected nature of T&E species and the fact that the majority of T&E species do not have direct uses, the majority of the economic value for T&E species must come from nonuse values. Strictly speaking, species-specific estimates of nonuse values held for the protection of T&E species can be derived only by primary research using stated preference techniques. However, the cost, administrative burden, and time required to develop primary research estimates to value effects of the 316(b) regulation on T&E species are beyond the schedule and resources available to EPA for this rulemaking. As an alternative, EPA considered a benefit transfer approach that relies on information from existing studies (USEPA 2000a).

EPA was able to use a benefit transfer approach to estimate changes in recreational use values for a subset of T&E species that are highly valued by recreational anglers (i.e., paddlefish[13] and sturgeon). Commercial and nonuse values are not monetized for any of the affected species. Therefore, benefit estimates presented in this chapter are incomplete and likely to be highly conservative (i.e., low).

In this chapter, EPA explores the extent to which CWISs may affect species protected by the Endangered Species Act on national and regional scales (Section 5.2), documents the value society places on the protection of T&E species (Section 5.3), and applies economic valuation studies of T&E species to case studies of sea turtles and finfish in the Inland region (Section 5.4).

5.2 T&E Species Affected by CWISs

To assess the potential impacts of CWISs on T&E species, EPA constructed a database that identifies spatial overlap between CWISs and vulnerable life history stages of all aquatic T&E species for which data are available. The database allowed EPA to estimate the potential for adverse I&E mortality impacts on T&E species.

5.2.1 T&E Species Identification and Data Collection

First, all species currently listed or in consideration for listing under the Endangered Species Act (as of January 16, 2010) with aquatic life history stages were identified using the US Fish and Wildlife Service Environmental Conservation Online System (USFWS 2010b). This primary list of all T&E species was filtered to include only species with life history stages vulnerable to CWIS mortality according to life history data. Examples of vulnerable stages include planktonic egg stages, free-swimming larval stages, and adult life history stages that occur near shore. Life history data used to exclude species from further consideration was obtained from a wide variety of sources (AFSC 2010; ASMFC 2010; Froese and Pauly 2009; NatureServe 2009; NEFSC 2010; PIFSC 2010a; PIFSC 2010b; SEFSC 2010; SWFSC 2010; USFWS 2010b). After filtering by life history data, the list of T&E species potentially affected by I&E mortality contained 247 species.

Whenever possible, the geographical distribution of T&E species susceptible to I&E mortality was obtained in geographic information system (GIS) format as polygon (shape) files, line files (for

[13] Note: the American Paddlefish is listed on T&E species lists for many states, but is not currently protected nationally under the US Endangered Species Act. A review of the species' status in 1992 revealed that although the species did not then meet the requirements to be listed as threatened at the federal level, the US Fish and Wildlife Service expressed its concern for the future of the species.

inhabitants of small creeks and rivers) and as a subset of geodatabase files. Data sources include the US Fish and Wildlife Service (USFWS 2010a), NOAA's Office of Response and Restoration (NOAA 2010a), NatureServe (NatureServe 2009), and NOAA NMFS (NMFS 2010b; NMFS 2010c; NMFS 2010d). For several freshwater species, geographic ranges were available only as 6-digit hydrologic unit codes (HUC) (NatureServe 2009; USFWS 2010a). For these species, GIS data layers were generated using a GIS HUC database obtained from the USGS (Steeves and Nebert 1994). For several species, no GIS data could be acquired. For these species, species distribution descriptions were compared with mapped CWISs, and inspected for geographic overlap. In all such cases (e.g., the "inarticulated brachiopod," *Lingula reevii*, endemic to Kaneohe Bay, HI) there were no in-scope CWISs within 10 kilometers, and further inspection was not warranted.

5.2.2 Number of T&E Species Affected per Facility

To investigate the potential for individual facilities to affect a wide variety of T&E species, EPA calculated the number of T&E species affected on a per-facility basis. This calculation allowed EPA to assess the magnitude of differences between regions of CWIS effects on T&E species.

Nationally, 88 of the 247 aquatic T&E species assessed or 36 percent had vulnerable life history stages that either overlapped with CWISs, or had records of entrainment or impingement mortality (Appendix E). These species overlapped with 446 of 871 in-scope facilities (51 percent). Among facilities, the variability in the number of T&E species potentially affected ranges between 0 and 26 species (Table 5-1), with more than 90 percent of facilities affecting fewer than 5 T&E species, and more than 99 percent of facilities affecting fewer than 12 species (Figure 5-1).

Excluding facilities whose CWISs do not overlap with at least one T&E species, the average number of species per facility is 3.89 (minimum 0, maximum 26) (Table 5-1). Sea turtles and freshwater mussels had the highest overlap rate on a per-facility basis, averaging 4.83 and 3.53 species per facility, respectively. Anadromous, freshwater, and marine fish had lower overlap rates with facility CWISs, averaging slightly higher than 1 species per interacting facility (Table 5-1).

Driven by the high number of I&E mortality freshwater mussels overlapping with facility CWISs, the majority of all species by facility interactions occur in the inland region. However, the shape of cumulative distribution plots is similar among regions after accounting for sample size, suggesting that the overall probability of a facility affecting one or more T&E is not a function of geographic region (Figure 5-2).

Table 5-1: Number of T&E Species with Geographical Distributions Overlapping In-scope CWISs, on a Per-facility Basis

Subset of Affected Species[1]	# Species	T&E Species per Facility[3] All Facilities Avg	All Facilities Max	Interacting Facilities[2] Avg	Interacting Facilities[2] Max
All T&E Species	88	1.99	26	3.89	26
T&E Freshwater Mussels	43	1.14	22	3.53	22
T&E Sea Turtles	6	4.83	5	4.83	5
T&E Anadromous Fish	13	0.13	3	1.08	3
Other T&E Freshwater Fish	21	0.09	4	1.33	4
Other T&E Marine Fish	3	0.13	2	1.42	2

[1] T&E species included species of concern and species under review for listing by the US Fish and Wildlife Service (freshwater) or NOAA National Marine Fisheries Service (marine). Only species overlapping with a minimum of one CWIS are included.

[2] Interacting Facilities = all facilities with CWIS inside the range of at least one T&E species

[3] Avg = average, Max = maximum

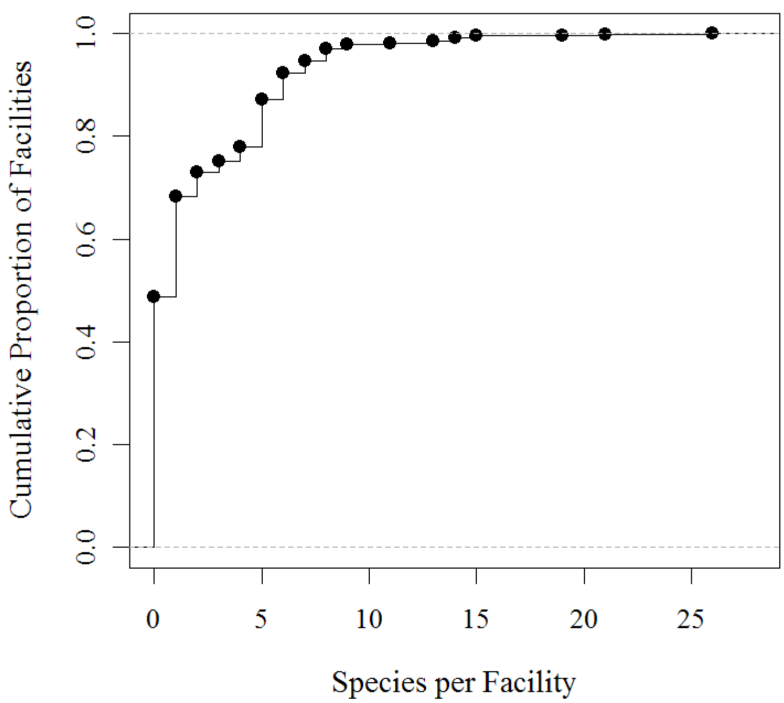


Figure 5-1: Empirical cumulative distribution function plot of the number of T&E species potentially affected on a per-facility basis by in-scope facilities nationwide.

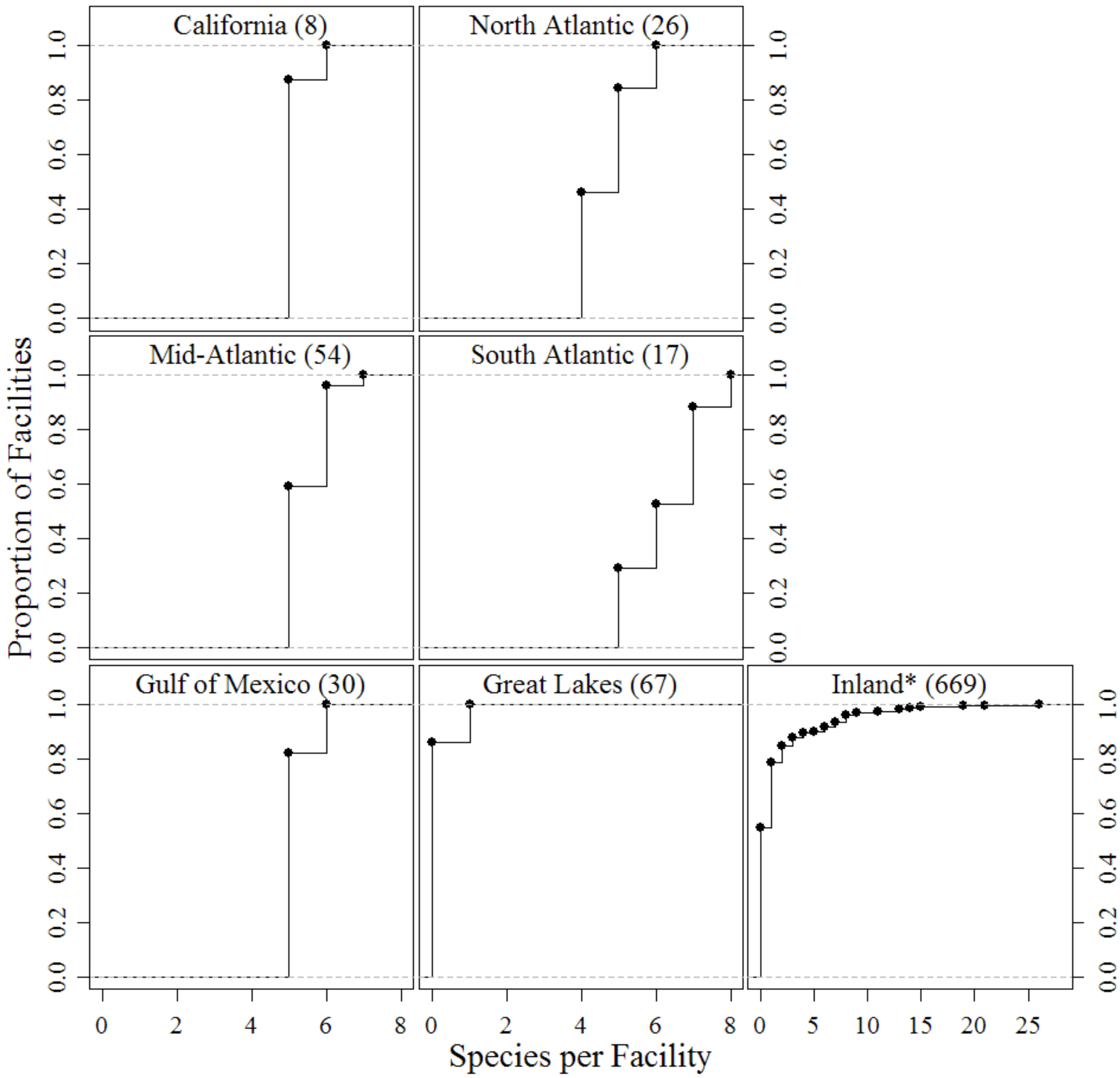


Figure 5-2: Cumulative distribution plot of the number of T&E species potentially affected on a per-facility basis by in-scope facilities nationwide. Sample sizes (i.e., number of in-scope facilities) are noted in parentheses. The horizontal axis is equivalent in all plots, with the exception of the Inland region (noted with an asterisk *).

5.2.3 Number of Facilities Affecting Individual T&E Species

To investigate the cumulative potential for CWISs to affect individual T&E species, EPA calculated the number of facilities affecting each T&E species. There are 1,734 examples of species by facility interactions across 88 T&E species nationally, resulting in an average of 19.7 facilities per species (Table 5-2). Consequently, many T&E species are likely to be affected by a large number of facilities. Thus, even if individual facilities have low I&E mortality of T&E species, the cumulative effect of in-scope 316(b) facilities on these populations may be substantial. The variation among species was large and ranged between 1 and 135 facilities per species (Table 5-2). Overall, 19 percent of species are affected by 1 facility, 50 percent of species affected by fewer than 6 facilities, 80 percent of species affected by fewer than 24 facilities, and 90 percent affected by fewer than 44 facilities (Figure 5-3).

Table 5-2: Number of Facilities with CWISs Within the Geographical Distribution of T&E Species, on a Per-species Basis

Subset of Affected Species[1,2]	Species	Interactions	Facilities per T&E Species[3] Avg	Max
All T&E Species	88	1734	19.70	135
T&E Sea Turtles	6	652	108.67	135
T&E Freshwater Mussels	43	836	19.44	85
T&E Anadromous Fish	13	115	8.85	64
Other T&E Freshwater Fish	21	64	3.05	7
Other T&E Marine Fish	3	17	5.67	11

[1] T&E species included species of concern and species under review for listing by the US Fish and Wildlife Service (freshwater) or NOAA National Marine Fisheries Service (marine). Only species overlapping with a minimum of one CWIS are included.

[2] Two species of coral are included in the 'All Species' category, and not in any subcategory

[3] Avg = average, SD = standard deviation, Med = median, Max = maximum

When species were analyzed within life history trait, sea turtles had the highest average number of overlapping facilities (108.7) (Table 5-2), a value skewed by these species' extensive ranges (i.e., entire Atlantic, Gulf of Mexico, and/or Pacific coast), and the potential for I&E mortality impacts at all life stages. The six sea turtle species examined were the six species with the highest number of overlapping CWISs. Following sea turtles, freshwater mussels had the highest average number of overlapping facilities (19.4 facilities per species). Excepting turtles, freshwater mussels accounted for 9 of the top 10 species sorted by the count of CWISs affecting them (Figure 5-4). Following freshwater mussels, anadromous fish species were most likely to be affected, with an average of 8.9 facilities per species (Table 5-2). This average, however, is highly skewed by a single species of fish (the pallid sturgeon,

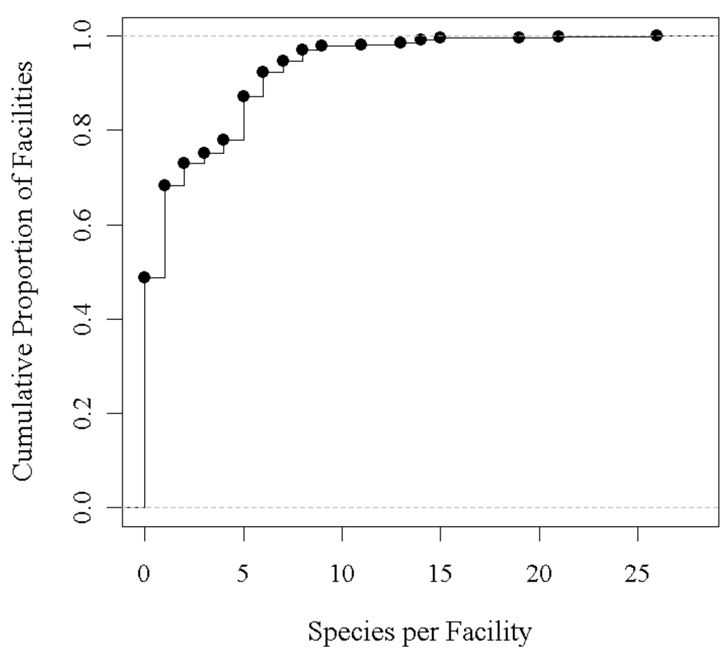


Figure 5-3: Empirical cumulative distribution function plot of the number of facilities that overlap geographically with vulnerable life history stages of T&E species. Species represented on the plot are those that overlap with a minimum of one in-scope facility. Sample size is 88.

Scaphirhynchus albus) which accounted for 54 percent of all overlap between facilities and anadromous fish species (Figure 5-4). Excepting the pallid sturgeon, anadromous fish had a similar level of potential exposure to I&E mortality as non-diadromous fish: freshwater and marine fish species averaged approximately 3.5 facilities with potential I&E mortality per species (Table 5-2, Figure 5-4). In addition to finfish and shellfish, elkhorn and staghorn corals (*Acropora palmata* and *A. cervicornis*) also have the potential for I&E mortality impacts: both species have the potential to be affected by 25 facilities.

5.2.4 Summary of Overlap Between Cooling Water Intake Structures and T&E Species

Nationally, 36 percent of T&E species assessed have vulnerable life history stages that overlap with a minimum of one CWIS (Table 5-1), suggesting a high probability of T&E populations' being affected by I&E mortality. The potential for these impacts is widespread: T&E species overlap CWISs in all geographical regions of the country (Figure 5-2), in all waterbody types, and across multiple life histories (Figure 5-4). Overall, 51 percent of in-scope facilities overlap with at least one T&E species (Table 5-1), while 36 percent of aquatic endangered species overlap with at least one CWIS. Finally, our analysis includes only federally listed T&E species. Thus, the number of T&E species (including those species defined as threatened or endangered under state law) affected by I&E mortality is understated.

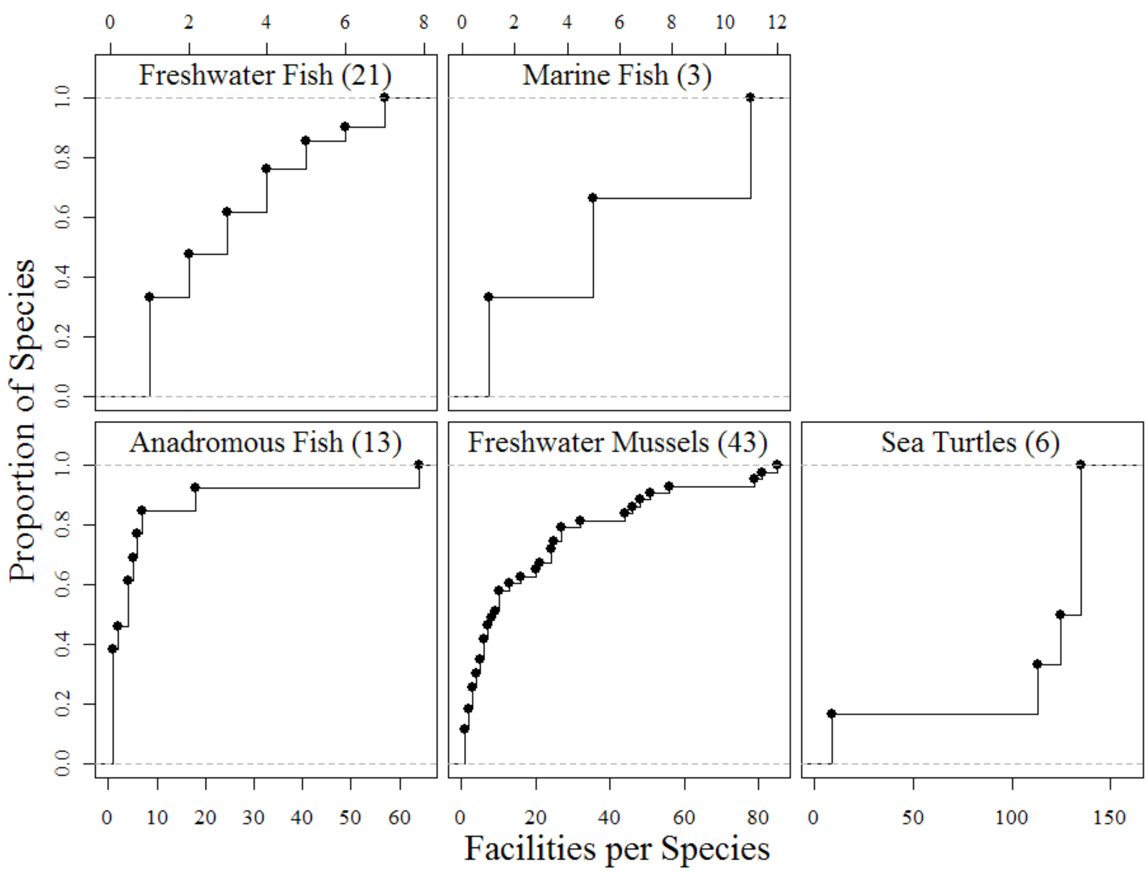


Figure 5-4: Cumulative distribution plots of the number of facilities likely to affect individual threatened or endangered species, grouped by species life history trait. Sample sizes (species per life history trait) are in parentheses, and represent those species potentially affected by a minimum of one in-scope facility.

5.2.5 Species with Documented I&E Mortality

EPA identified several T&E species with documented I&E mortality (Table 5-3). In addition to documented instances of T&E mortality, EPA identified I&E mortality not identified to species but whose genus matched T&E species overlapping with the reporting facility's CWIS (Table 5-3). Although these are not confirmed I&E mortality of T&E species, they provide evidence that additional T&E species are likely to be directly affected by I&E mortality.

Including only individuals identified to species, EPA identified more than 130,000 baseline losses of T&E species (Table 5-3). However, for several reasons, T&E species suffering I&E mortality are likely to be underreported. First, T&E species are found at low population densities, and the volume of water sampled by facility-level impingement and entrainment studies is low. Thus, it is likely that many T&E species suffered I&E mortality outside of sampling periods and are never recorded. Second, because a high proportion of all I&E mortality occur during early life history stages (i.e., egg, larvae) when species identification is more challenging, T&E species may not be recognized during sampling (e.g., endangered species of darter, including the Cherokee and duskytail darters, may be reported as "darter," or "unidentified darter").

5.3 Societal Values for Preservation of T&E Species Affected by I&E Mortality

This section examines governmental spending, policy decisions, and private donations on the preservation and restoration of T&E species. It provides evidence of societal preferences for T&E preservation and spending related to ensuring sustainability of T&E species.

The U.S. Fish and Wildlife Service (FWS) annually reports expenditures for the conservation of T&E species. Using the report for fiscal year 2008 (USFWS 2009) EPA calculated total government (federal and state) expenditures for the 88 federally listed T&E species with vulnerable life history stages that overlap CWISs (Table 5-4). Excluding expenditures on T&E species not subject to I&E mortality, expenditures on T&E species potentially affected by CWISs exceeded $465 million, and accounted for 86 percent of all governmental spending on Fish, Marine Reptiles, Crustaceans, Corals and Clams listed under the Endangered Species Act (ESA) during FY 2008 (USFWS 2009).

In addition to direct governmental spending associated with the protection of T&E species that overlap with CWISs, the presence of these species often guides policy discussions, and may require the installation of abatement technologies that reduce T&E species mortality and allow these species to migrate. For example, the life history of the American paddlefish (*Polyodon spathula*) (listed on many state T&E species lists, but not protected under the ESA) is occasionally discussed during Federal Energy Regulatory Commission relicensing of dams, because of the animal's highly migratory life history. In the Wisconsin River, for example, Alliant Energy has been required to install a multi-million dollar fishway at the Prairie du Sac dam, primarily to allow the passage of paddlefish and lake sturgeon (WPLC v. FERC 2004).

Table 5-3: T&E species with documented I&E mortality. Species are separated by the taxonomic resolution reported for the I&E mortality loss.

Resolution	Common Name	Latin Name	Baseline I&E Mortality
Species	Atlantic Salmon	*Salmo salar*	Qualitative
	Chinook Salmon	*Oncorhynchus tshawytscha*	5,470[b]
	Coho Salmon	*Oncorhynchus kisutch*	Qualitative
	Delta Smelt	*Hypomesus transpacificus*	62,526[b]
	Green Sea Turtle	*Chelonia mydas*	Qualitative
	Hawksbill Sea Turtle	*Eretmochelys imbricata*	Qualitative
	Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	Qualitative
	Leatherback Sea Turtle	*Dermochelys coriacea*	Qualitative
	Loggerhead Sea Turtle	*Caretta caretta*	5-50[b]
	Longfin Smelt	*Spirinchus thaleichthys*[a]	24,919[b]
	Olive Ridley Sea Turtle	*Lepidochelys olivacea*	Qualitative
	Pallid Sturgeon	*Scaphirhynchus albus*	50
	Sacramento Splittail	*Pogonichthy macrolepidotus*[a]	45,188[b]
	Steelhead Trout	*Oncorhynchus mykiss*	5[b]
	Topeka Shiner	*Notropis Topeka*	15[b]
Genus	Alabama Sturgeon	*Scaphirhynchus suttkusi*	8,174[b]
	Atlantic Sturgeon	*Acipenser oxyrinchus oxyrinchus*	785,667
	Blackside Dace	*Phoxinus cumberlandensis*	10[b]
	Blue Shiner	*Cyprinella caerulea*	94,608,786
	Boulder Darter	*Etheostoma wapiti*	3,529,746
	Cherokee Darter	*Etheostoma scotti*	3,529,746
	Chum Salmon	*Oncorhynchus keta*	22
	Duskytail Darter	*Etheostoma percnurum*	3,529,746
	Etowah Darter	*Etheostoma etowahae*	3,529,746
	Green Sturgeon	*Acipenser medirostris*	785,667
	Gulf Sturgeon	*Acipenser oxyrinchus desotoi*	785,667
	Neosho Madtom	*Noturus placidus*	41,021[b]
	Palezone Shiner	*Notropis albizonatus*	19,421,686[b]
	Pygmy Madtom	*Noturus stanauli*	41,021[b]
	Scioto Madtom	*Noturus trautmani*	41,021[b]
	Shortnose Sturgeon	*Acipenser brevirostrum*	785,667
	Snail Darter	*Percina tanasi*	259,500[b]
	Unarmored Threespine Stickleback	*Gasterosteus aculeatus williamsoni*	2,922[b]

Notes: Species listed as threatened or endangered under state laws, such as the American Paddlefish (*Polyodon spathula*), are not included in this list.
"Qualitative" indicates the species is reported by name from a minimum of one facility, but no loss estimates are provided.
Baseline losses reported for genera reflect losses for all species within the genus. Losses are likely dominated by more-common congeners.

[a] This species is under review for listing under the Endangered Species Act
[b] This estimate is not derived using extrapolation procedures

Considerations for T&E species have also been responsible for changes in water diversions on the San Joaquin-Sacramento River delta, limiting water for downstream users. Under current regulations, the volume of water removed from the San-Joaquin-Sacramento River at the Banks Pumping Plant is limited from December to June, to protect Delta Smelt (NRDC v. Kempthorne 2007). This restriction limits the volume of water available for consumption as drinking water and for use in large-scale irrigation projects. Water restrictions, due to the potential for negative effects on Delta Smelt populations, have been estimated to result in the loss of 21,100 farm-related jobs and $703 million in agricultural revenue in 2009 alone (Boxall 2010; Howitt et al. 2009).[14]

Table 5-4: Federal and State Expenditures for T&E Species Overlapping with CWIS

Life History	Expenditure (2009$, millions)
Anadromous Fish	$ 383.2
Corals	$ 0.3
Freshwater Fish	$ 44.4
Freshwater Mussels	$ 5.6
Marine and Estuarine Fish	$ 0.2
Sea Turtles	$ 33.9
All Species Overlapping CWIS	$ 467.6
All Fish, Marine Reptile, Crustacean, Coral, and Clam Species	$ 541.7

Although government spending and policy decisions made to protect or enhance stocks of T&E species are not direct indications of economic benefits, they indicate that society does place a significant value on protecting and restoring species of concern.

5.4 Assessment of Benefits to T&E Species

5.4.1 Economic Valuation Methods

For several reasons, it is difficult to estimate the benefits of preserving T&E species by reducing I&E mortality. First, the contribution to ecosystem stability, ecosystem function, and life history remain relatively unknown for many T&E species. Second, because much of the wildlife economic literature focuses on commercial and recreational benefits that are not relevant for many protected species (i.e., use values), there is a paucity of economic data focused on the benefits of preserving T&E species. Consequently, nonuse values comprise the principal source of benefit estimates for most T&E species.

To obtain an accurate estimate of the nonuse values of T&E species affected by I&E mortality, 1) quantitative I&E mortality impacts, and the benefits of policy options, must be estimated for T&E species; and 2) an economic value must be obtained for the value of reducing I&E mortality as a consequence of increased population sizes, extinction avoidance, and, for certain species (e.g., Salmonids), the potential for re-establishment of a commercial fishery.

[14] Water diversion in the San Joaquin-Sacramento River is currently undergoing active litigation. See *San Luis & Delta-Mendota Water Authority, et al. v. Salazar, et al.,* USDC Case No. 1:09-CV-407 OWW GSA, and consolidated cases.

Benefit transfer involves extrapolating existing estimates of nonmarket values to geographic locations or species that differ from the original analytical situation. Thus, the approach transfers estimates of values for preserving T&E species in one region to another region, or to a similar species. Ideally, the resource (i.e. species), policy variable (e.g., change in species status, recovery interval, population size, etc.), and the benefitting population (i.e., defined human population) are identical. Such a match rarely occurs. Despite discrepancies in these variables, however, a benefits transfer approach can provide useful insights into the social benefits gained by reducing I&E mortality of T&E species.[15]

5.4.2 Case Studies

EPA attempted to estimate the benefits of regulation for all T&E species with documented and quantified losses at CWIS. In most cases, EPA was unable to locate or calculate key components of the analysis necessary to apply a benefits transfer approach. However, EPA was able to obtain sufficient data to estimate the economic benefits to two categories of T&E species: a subset of T&E fish species in the inland region, and loggerhead sea turtles. The case studies of potential economic benefits from a decrease in T&E mortality are discussed below.

5.4.2.1 Inland Region

Baseline Losses of Special Status Species and Reductions in Losses Due to Regulatory Options

EPA estimated losses for three T&E species in the Inland region: pallid sturgeon, American paddlefish, and Topeka shiner. However, sufficient data were available to estimate the benefits of regulation for only the pallid sturgeon (*Scaphirhynchus albus*), and the American paddlefish (*Polyodon spathula).* As such, benefits estimates address only 80–84 percent of documented T&E A1E losses in the Inland region (Table 5-5).

The pallid sturgeon is listed as an endangered species under the ESA; the American paddlefish is not listed federally. In the early 1990s, the U.S. FWS conducted a review of the paddlefish for threatened status, but ultimately did not list the species (Allardyce 1991). However, the review noted that immediate efforts were needed to restore stocks and degraded habitats (Allardyce 1991). Although not currently protected federally, paddlefish are protected by 11 states.

The American paddlefish is a large (85 inches length and more than 220 lbs) species with roe suitable for caviar. The species once supported a large commercial fishery in the Mississippi Valley, and currently supports a limited recreational fishery in some states. Likewise, the pallid sturgeon is one of the largest (30-60 inches) fishe found in the Missouri-Mississippi River drainage, with specimens weighing up to 85 pounds. Because their large size makes them a desirable commercial and trophy sport fish, and because they have roe suitable for caviar, both pallid sturgeon and American paddlefish have potentially significant direct use values. All extractive uses of the pallid sturgeon, however, are prohibited under the ESA.

To estimate total baseline losses due to I&E mortality, EPA used the EAM to model A1Es for each of the three T&E species (Chapter 3).[16] The choice of facilities used to extrapolate I&E mortality from model facilities was based on species' historic ranges and current distributions. In addition to baseline estimates of I&E mortality for pallid sturgeon, paddlefish, and Topeka shiner, EPA calculated reductions in losses under three regulatory options (Table 5-5).

[15] Types of benefit transfer studies are discussed at length in U.S. EPA (2000a).

[16] Paddlefish and pallid sturgeon losses were observed at nine and two model facilities, respectively.

Table 5-5: Annual Baseline I&E Mortality and Reductions in Baseline I&E Mortality of T&E Species at In-scope Facilities in the Inland Region, by Regulatory Option (A1E)

Species	Value Type	Baseline[a]	Option 1	Option 2	Option 3
Pallid Sturgeon	Nonuse	17,628	8,631	15,946	16,317
Paddlefish	Use and Nonuse	88	73	85	86
Topeka Shiner	Nonuse	3,669	3,069	3,546	3,581
Total		21,384	11,773	19,577	19,984

[a] The I&E mortality data used to develop regional estimates are from sampling at the Wabash and Cayuga facilities in 1976, the only year of sampling data for these facilities.

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

Benefit Transfer Approach: Estimated WTP for Protection of Inland T&E Species

A Nonuse Values

EPA identified two studies that estimated both nonuse and use values for sturgeon. One study found that citizens of Maine are willing to pay $37.02 (2009$) as a one-time tax to create a self-sustaining population of shortnose sturgeon (Kotchen and Reiling 2000), a species listed as endangered under the ESA (NMFS 2004). A separate study found that lake sturgeon is a popular wildlife-viewing species in Wisconsin, and that viewers place a substantial value on protection of lake sturgeon populations. The average viewer's WTP to maintain the current sturgeon population of Wisconsin's Lake Winnebago system was $121.30 (2009$). Since the estimated number of sturgeon viewers in 2002 was 3,176 individuals, total WTP for sturgeon-viewing opportunities in the Winnebago system was $0.39 million (2009$). Together, the results of these studies indicate that nonuse values for preservation of sturgeon are likely to be significant. However, EPA was unable to monetize total nonuse benefits from reduced I&E mortality, because reliable population estimates needed to transfer the values were unavailable.

B Use Values

Pallid sturgeon and paddlefish have potentially high commercial use values as sources of roe. This value has increased dramatically owing to the collapse of Caspian Sea sturgeon populations (Speer et al. 2000). Paddlefish roe have been reported to sell for more than $300 per pound, and as much as 3 lbs of roe may be harvested from a large female (McKean 2007). Despite these reports, EPA was unable to reliably quantify total commercial values for these species due to a lack of market data.

Recreational use values for sturgeon and paddlefish caught in inland waters or paddlefish were not available. Based on a review of literature describing these species, EPA determined that sturgeon species (including white, green, and pallid sturgeons) and paddlefish share many characteristics, including roe suitable for caviar, and their value as game fish. Consequently, WTP values for sturgeon obtained in California were used to value recreational use of these species in the Inland region. A limited recreational fishery (mostly catch and release) exists for paddlefish in several states; although harvesting pallid sturgeon is illegal, the species is sometimes caught by recreational anglers.

To estimate recreational use values for paddlefish and pallid sturgeon, EPA applied estimates from a random utility model (RUM) analysis conducted to evaluate recreational fishing benefits of the 2004 Section 316(b) Phase II Final Rule. Model results indicate that California anglers were willing to pay

$69.88 (2009$) to catch a sturgeon (USEPA 2004b), a value transferred to anglers for pallid sturgeon and paddlefish in the Inland region (Table 5-6).[17]

The undiscounted recreational use value from eliminating baseline I&E mortality is approximately $1,238 thousand, while use values from reducing pallid sturgeon and paddlefish I&E mortality range from $608 thousand to $1,146 thousand for the three regulatory options considered. Annualized benefits range from $498 to $719 thousand at a 3 percent discount rate, and from $454 to $561 thousand at a 7 percent discount rate. EPA notes that these value estimates underestimate total values of reducing I&E mortality to T&E species in the Inland region, because both nonuse and commercial values, likely to be substantial, are not incorporated.

Table 5-6: Estimated Annual WTP for Eliminating or Reducing I&E Mortality of Special Status Fish Species at In-scope Facilities in the Inland Region, by Regulatory Option (2009$)

T&E Species	Annual Benefits (2009$, thousands)			
	Baseline	Option 1	Option 2	Option 3
Pallid Sturgeon	$1,231.8	$603.1	$1,114.3	$1,140.3
Paddlefish	$6.1	$5.1	$5.9	$6.0
Total Undiscounted	**$1,238.0**	**$608.2**	**$1,120.2**	**$1,146.2**
3% Discount Rate				
Annualized Value	**$1,144.3**	**$498.0**	**$719.0**	**$717.8**
7% Discount Rate				
Annualized Value	**$1,140.0**	**$454.3**	**$560.7**	**$549.7**

[a] The I&E mortality data used to develop regional estimates are from sampling at the Wabash and Cayuga facilities in 1976, the only year of sampling data for these facilities.
Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

5.4.2.2 Potential Nonuse Values for T&E Species in the Inland Region

To illustrate the potential magnitude of nonuse values for T&E species affected by I&E mortality in the Inland region, EPA applied a WTP meta-analytical model (Richardson and Loomis 2009) to hypothetical scenarios. Because EPA does not currently have region-wide I&E mortality for all T&E species, nor population models to estimate the effect of I&E mortality on population size, estimates are presented only to assess the range of benefits potentially resulting from 316(b) regulatory options. The modeled scenarios estimate the WTP for 0.25 percent and 0.5 percent increases for all T&E fish populations in the Inland region.

EPA estimated nonuse values using benefit transfer according to Richard and Loomis (2009) (details in Appendix F, Section F.3). Excepting all policy-relevant variables, EPA used the mean values for all model parameters, and converted estimates to 2009$ using the Consumer Price Index (USBLS 2010).

For a 0.25 percent change in T&E fish population size, projected WTP per household per year is $1.02 (2009$). With 59.6 million households[18], total WTP for T&E fish in the Inland region is $60.31 million.

[17] The Phase II analysis did not estimating WTP for catching a sturgeon in other states. Given similarity in species characteristics EPA used WTP for sturgeon caught in California to value sturgeon and paddlefish species in the Inland region.

[18] Household number in the Inland region is calculated for states where at least T&E species affected by I&E mortality is found.

For a 0.5 percent change in T&E fish populations, WTP per household is $1.85 per year, resulting in WTP values of $110.25 million in the Inland region (all values 2009$).

5.4.2.3 Sea Turtles

Six species of sea turtles are found in U.S. waters: green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), Kemp's Ridley (*Lepidochelys kempii*), leatherback (*Dermochelys coriacea*), loggerhead (Caretta caretta), and Olive Ridley (*Lepidochelys olivacea*) sea turtles. All have extensive ranges, migrate long distances during their lifetime, and are listed as either threatened or endangered (T&E) under the ESA. Because of these large ranges, there is substantial overlap between sea turtle habitat and CWISs for in-phase power generating and manufacturing facilities. Additionally, since individuals of all ages and sizes are susceptible to impingement and entrainment (Norem 2005), there are more than 730 potential species x CWIS interactions that may result in the injury or death of these T&E species (Table 5-1, details in Appendix Section F.1).

Evidence for Public Values for Sea Turtles

In addition to research sponsored by the National Science Foundation and various private philanthropic organizations, federal and state governmental spending on sea turtle protection under the ESA totaled $33.8 million in FY2008 (Table 5-4). Moreover, there are dozens of academic, nonprofit, and ecotourism organizations that recruit thousands of volunteers every year to participate in sea turtle conservation and research projects (Appendix Table F-2). Volunteers are often required to undergo substantial training at their own expense and commit to long hours (often during the night). For example, the nonprofit group Earthwatch matches volunteers with academic researchers working at field stations around the world. By paying to spend time working with scientists on research projects, volunteers support sea turtle research and conservation both financially and logistically, working to gain first-hand experience of conservation issues. Trips may last from days to several weeks, and often require a commitment of 10 or more hours work per day. For example, on one 10-day volunteer trip with a cost of $2,450 (plus airfare), volunteers spend time tagging, measuring, and weighing leatherback seat turtles in Trinidad, patrolling beaches from sundown to the early hours of the morning (Earthwatch Institute 2010).

Baseline Losses of Special Status Species and Reductions in Losses Due to Regulatory Options

There are several passive-use (e.g., wildlife viewing and photography) and nonuse values associated with U.S. sea turtle populations. Many households express passive use value by participating in ecotourism activities, such as visiting sea turtle nesting areas, or by participating in sea turtle conservation activities (Frazer 2005). Additionally, a high proportion of governmental expenditures on T&E species are for turtle species (Table 5-4), suggesting that the public values the preservation of sea turtle populations.

Power plants are known to entrain and impinge all six species of sea turtles found in U.S. waters (Norem 2005), with more than 730 occurrences of overlap between species ranges and CWISs (Table 5-1). Incidences of mortality have been reported at facilities in California, Texas, Florida, South Carolina, North Carolina, and New Jersey (National Research Council 1990; Plotkin 1995). These facilities span a wide range of intake flows (fewer than 30 to more than 1,400 million gallons per day average intake flow), suggesting that sea turtle mortality is not limited to large intakes. Although quantitative reports are available from a few power stations, high-quality data is available from only one source, the St. Lucie Nuclear Power Plant, at Hutchinson Island, FL, where annual capture rates range from 350 to 1,000 turtles (Appendix Table F-1). Despite the fact that mortality rates due to entrainment are estimated to be < 3 percent, approximately 85 percent of entrained organisms show evidence of injury as a result of entrainment (Norem 2005). As such, true mortality rates from CWISs may be higher than reported, particularly for individuals who are recaptured repeatedly (37 percent of green and 13 percent of loggerhead sea turtles entrained between May and December 2000 were recaptured individuals) (Norem 2005).

Although the magnitude of I&E mortality is believed to be small relative to fishing-related mortality, the cumulative impact of I&E mortality is unclear. The only study presenting a quantitative estimate of annual I&E mortality estimated mortality rates to be between 5 and 50 individuals per year (Plotkin 1995). Consequently, EPA does not believe sufficient data exist to estimate baseline sea turtle mortality due to entrainment and impingement at regional or national scales. However, due to lower population sizes, long life-span, and high reproductive potential of adult turtles (Crouse et al. 1987), EPA believes the effect of 316(b) regulation is likely to have a small effect on the long-term viability of turtle populations.

Benefit Transfer Approach: Potential WTP for Protection of Sea Turtle Species

A Per-household WTP

EPA identified a study that used a stated preference valuation approach to estimate the total economic value (i.e., use and nonuse values) of a management program designed to reduce the risk of extinction for loggerhead sea turtles (Whitehead 1993). The mail survey asked North Carolina households whether they were willing to pay a bid amount for a management program that reduces the probability that loggerhead sea turtles will be extinct in 25 years.

EPA used Whitehead (1993) to assess the range of benefits potentially resulting from 316(b) regulatory options (detailed methodology in Appendix Section F.2). Available data sources and biological models were reviewed to assess the potential impact of baseline losses and reductions on the probability of sea turtle extinction over 25 years. Although analyses of sea turtle extinction risk have been conducted (e.g., Conant et al. 2009), EPA was unable to identify an existing model or analysis that could be readily used in conjunction with available mortality data to estimate the marginal impacts of CWISs on sea turtle extinction risk. Estimates from the literature suggest that I&E mortality is of relatively low importance compared to other human-induced mortality such as shrimp trawling and other fisheries (Plotkin 1995). However, Crouse *et al.* (1987) found that mortality at juvenile and subadult life stages can have a substantial effect on population growth, suggesting that small changes in survivorship at these age classes could have a measurable impact on extinction risk. EPA believes that the marginal change in extinction probability of loggerhead sea turtles due to 316(b) regulatory options is unlikely to be lower than 0.01 (i.e., a 1 percent decrease in the probability over 25 years). This assessment is based upon reports that I&E mortality may result in the loss of more than 100 turtles per year (Appendix Table E-1), and because turtle population growth rates are known to be sensitive to changes in juvenile and subadult mortality (Crouse et al. 1987).

EPA used a value of 0.01 within Whitehead's (1993) modeling framework to bound household values for changes in extinction risk for loggerhead sea turtles as a consequence of 316(b) regulation (details of this calculation are in Appendix Section F.2). Although this assessment is not based on formal quantitative analysis of extinction risk, it is intended to illustrate the range of potential benefits associated with reductions in sea turtle losses. Using the published mean values for all other model parameters, EPA calculated an annual household value of $0.35 (2009$). Estimates were converted to 2009 dollars using the consumer price index (USBLS 2010).

B Total WTP for all Households

Whitehead's (1993) study for loggerhead sea turtle management activities was based on a state-wide survey of North Carolina residents. However, the large geographic range of sea turtles suggests that households of many coastal states through their U.S. range would value activities that decrease their extinction risk. There is also the potential for differential values within and across states. Households farther from the resource may value sea turtle survival less than households near the ocean, due to lower likelihood of participation in passive uses of the resource. Although EPA recognizes that the application of the benefit transfer may overestimate household values for states with population centers far from sea turtle habitat, evidence from the literature suggests that households may value changes in environmental resource that are occurring at great distances. For example, Pate and Loomis (1997) found that respondents were willing to ascribe stated preference values to environmental amenity changes in other states. As such, by focusing on residents of coastal states only, estimated benefits may undervalue national willingness to pay for the preservation of loggerhead sea turtles.

For the purposes of assessing potential benefits from improvements to a sea turtle population, EPA focused solely on impacts to loggerhead sea turtles (one of six T&E sea turtle species in the US). By focusing only on loggerhead sea turtles, EPA notes that estimated benefits are likely to be lower than those held by individuals for all T&E turtle species. This species of turtles was chosen because they are late-maturing, have an existing population model (Crouse et al. 1987), an existing valuation study (Whitehead 1993), and are the most commonly affected species of turtle (Appendix Table F-1). The U.S. range of loggerhead sea turtles includes the Gulf of Mexico, South Atlantic, Mid-Atlantic, and North Atlantic 316(b) regions (USFWS 2010c). Assuming affected populations include all households within states with 316(b) existing facilities that potentially have an impact loggerhead sea turtles, 53.35 million households would be willing to pay for improved protection of this species (Table 5-7). By applying the mean household value of $0.35 (2009$) across all four regions, the total annual WTP for a 1 percent increase in the survival probability of loggerhead sea turtles annualized at a 3% discount rate over 25 years is $16.6 million. Annualized benefits for each region are presented in Table 5-7, assuming that benefits begin to accrue in 2012 and continue throughout the compliance period. Because EPA does not currently have accurate national estimates of I&E mortality for turtle species, nor are population models available that estimate the effect of 316(b) regulation on population size and extinction risk, estimates are presented only to assess the potential range of benefits, and are not included in national totals. Actual benefits may be higher or lower than these estimates, with Option 2 and Option 3 likely to provide substantially greater benefits than Option 1.

Table 5-7: Monetized Benefits of a 1 Percent Increase in the Probability that Loggerhead Sea Turtles Will Not Be Extinct in 25 Years

Region	States Included	Number of Households (millions)	Annualized Benefits (2009$, millions)	
			3% Discount Rate	7 % Discount Rate
North Atlantic	CT, MA, ME, NH, RI	5.40	$1.67	$1.62
Mid-Atlantic	DE, MD, NJ, NY, PA, VA	20.97	$6.51	$6.31
South Atlantic	FL, GA, NC, SC	11.85	$3.67	$3.56
Gulf of Mexico[a]	FL, LA, MS, TX	15.13	$4.69	$4.40
Total	**-**	**53.35**	$16.55	$16.04

[a] Florida households are included in both the South Atlantic and Gulf of Mexico regions. To prevent double-counting, Florida households were apportioned between these regions based on relative AIF.

Note: Because of uncertainty in estimates of increased survival probability, and because benefits were not calculated for options, these values are not included in national totals.

5.4.3 Limitations and Uncertainties

Table 5-8 summarizes the caveats, omissions, biases, and uncertainties known to affect the estimates developed for the benefits analysis of sea turtles (Section 5.4.2.3), and T&E finfish in the Inland (Section 5.4.2.1) region.

Table 5-8: Caveats, Omissions, Biases, and Uncertainties in the T&E Species Benefits Estimates

Issue	Impact on Benefits Estimate	Comments
Change in T&E populations due to I&E mortality is uncertain	Uncertain	Projected changes in number of fish affected may be underestimated because neither cumulative impacts of I&E mortality over time nor interactions with other stressors are considered.
I&E mortality effects are not estimated for all T&E species and all regions	Estimates understated	EPA was unable to estimate I&E mortality of T&E species for all regions, due to lack of data. The large amount of overlap between T&E ranges and CWIS suggests that many affected species are likely to be missing from I&E mortality reports.
Benefit estimates include only a subset of species identified as affected	Estimates understated	EPA was unable to apply benefit transfer of values for all affected species. Benefits estimates address 80–84 percent of documented T&E A1E losses in the Inland region.
Benefit estimates used in benefit cost analysis include only recreational use values	Estimates understated	EPA applied recreational use values to estimate benefits for the species included in the analysis. T&E species have primarily nonuse values, which were not monetized. In addition, some of the affected species have commercial use values, which were not estimated.
Benefit transfer introduces uncertainties	Uncertain	EPA applied a recreational use value for sturgeon in California to value sturgeon and paddlefish in the Inland region. This value may over- or understate recreational values in the Inland region.
Ecological consequences of reduced numbers of T&E species	Estimates understated	WTP values are unlikely to include damage to food-webs and ecosystem stability as a consequence of the removal or restoration of T&E species.
Effects of thermal impacts from CWIS on T&E populations is uncertain	Uncertain	EPA has no data with respect to the effect of thermal discharge on T&E species.

6 Commercial Fishing Benefits

Commercial fisheries can be adversely affected by impingement and entrainment mortality (I&E mortality) in addition to many other stressors. Commercially landed fish are exchanged in markets with observable prices and quantities; however, estimating the change in economic surplus from increases in the number of commercially landed fish requires consideration of various conceptual and empirical issues. This chapter provides an overview of these issues, and indicates how EPA estimated the change in commercial fisheries-related economic surplus associated with the elimination of baseline I&E mortality and reduction in baseline I&E mortality under the regulatory options considered for the Section 316(b) regulation. The chapter includes a review of the concept of economic surplus, and describes economic theory and empirical evidence regarding the relationship between readily observable dockside prices and quantities and the economic welfare measures of producer and consumer surplus that are suitable for benefit-cost estimation.

Section 6.1 describes the methodology used to estimate the commercial fisheries-related benefits including conceptual and empirical discussions of producer and consumer surplus. Section 6.2 presents the commercial fisheries-related benefits by region; and Section 6.3 presents the limitations and uncertainties associated with EPA's analysis.

6.1 Methodology

The methodology employed to estimate the commercial fishing benefits associated with the regulatory options for the proposed Section 316(b) regulation closely follows the analysis conducted for the Section 316(b) Phase III Final Rule (USEPA 2006b). Changes from that analysis include updated estimates of I&E mortality losses and reductions, and updated dockside prices. The dockside prices are now estimated based on the 5-year average price between 2005 and 2009, from commercial fishing landings data obtained from the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS).

EPA measured commercial fishing benefits as changes in producer surplus. EPA considered estimating consumer surplus values associated with reductions in I&E mortality, but found that dockside prices would not change enough to produce measurable shifts in consumer surplus. The details of this analysis and the estimated price changes are presented in Section 6.2 and in Appendix G.

6.1.1 Estimating Consumer and Producer Surplus

The total loss to the economy from I&E mortality impacts on commercially harvested fish species is determined by the sum of changes in both producer and consumer surplus (Hoagland and Jin 2006). EPA modeled I&E mortality losses using the methods presented in Chapter 3 of this document. EPA assumed a linear relationship between stock and harvest. That is, if 10 percent of the current commercially targeted stock were harvested, EPA assumes that 10 percent of any increase in that species due to lower I&E mortality losses would be harvested. Thus, the percentage increase in harvest is assumed to be the same as the percentage increase in fish. The percentage of fish harvested is based on historical fishing mortality rates. EPA used historical NMFS landings data on commercial and recreational catch to determine the proportions of total species landings attributable to recreational and commercial fishing. EPA applied these proportions to the estimated total change in harvest to distribute benefits between commercial and recreational fisheries.

Producer surplus provides an estimate of the economic benefits to commercial fishers, but welfare changes can also be expected to accrue to final consumers of fish and to commercial consumers (including processors, wholesalers, retailers, and middlemen) if the projected decrease in catch is accompanied by an increase in price. These impacts can be expected to flow through the tiered commercial fishery market (as described in Holt and Bishop (2002)).

This study used a fishery market model to estimate changes in welfare as a result of changes in the level of the commercial fishing harvest. The market model takes as inputs the expected change in harvest and baseline gross revenues, and provides as outputs the expected change in producer and consumer surplus. In general, the analysis of market impacts involves the following steps (Bishop and Holt (2003)):

1. Assessing the net welfare changes for fish consumers due to changes in fish harvest and the corresponding change in fish price.
2. Assessing net welfare changes for fish harvesters due to the change in total revenue, which could be positive or negative.
3. Calculating the increase in net social benefits when the fish harvest changes.

Figure 6-1 illustrates a simplified fishery market model as shown in Bishop and Holt (2003). For simplicity, the model assumes that the fishery is managed on quota basis with the baseline quota shown as F^1 and baseline dockside or ex-vessel price as P^1. It uses an inverse demand function, *P(F)*, because fish are perishable with the quantity harvested driving price in the short run.

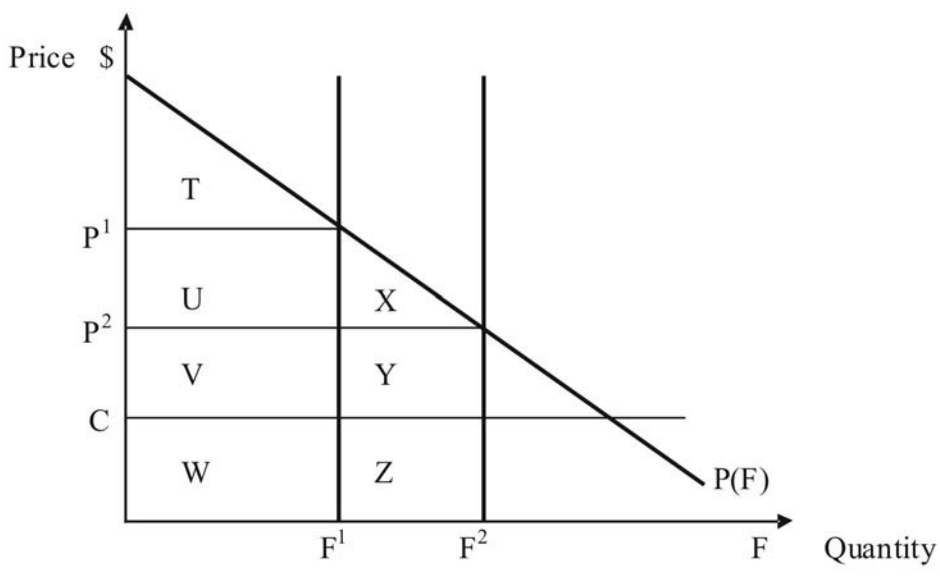


Figure 6-1: Fishery Market Model, reproduced from Bishop and Holt (2003)

6.1.1.1 Step 1: Assessing Benefits to Consumers

The downward sloping line labeled *P(F),* depicted in Figure 6-1, represents a general equilibrium demand function that accounts for markets downstream of commercial fishers. As described above, the vertical curve F^1 is the quantity of fish supplied to the market by commercial fishers under the baseline conditions. Equilibrium is attained at the point where *P(F)* equals F^1. The intersection of these two lines gives the price P^1 at which quantity F^1 is sold. In this case the total amount paid by consumers for fish is equal to $P^1 \times F^1$, which is equal to the area of the boxes $U + V + W$ in the graph. The consumer surplus or benefit to consumers is equal to the area of the triangle T.

The measurement of the benefits from reducing I&E mortality relies on the assumption that a decrease in mortality of fish, larvae, and eggs under a scenario of reduced I&E mortality would increase fish populations and the quantity of fish supplied to consumers (i.e., an increase from F^1 to F^2). If the quantity of fish available to the market increases from F^1 to F^2, this in turn would result in a lower market price for fish (i.e., P^2). This changes the total amount paid by consumers to $P^2 \times F^2$, which is equal to the area of the boxes $V + W + Y + Z$. This may be less than or greater than area $U + V + W$, but unequivocally increases the consumer surplus so that it is equal to the area of the triangle $T + U + X$. The difference in consumer surplus between the reduced I&E mortality scenario and the current baseline scenario (i.e., $U + X$) is the measure of benefits to consumers from reducing I&E mortality.

Estimating the change in price of fish from changes in commercial fish harvest requires the following input data: (1) An estimate of the baseline prices and quantities of the commercial fishing harvest, (2) the estimated change in the commercial fishing harvest under the reduced I&E mortality scenario, and (3) an understanding of the price elasticity of demand for fish. The baseline commercial fishing prices and harvest quantities were estimated from NMFS landings data from 2005 to 2009 for regional markets for relevant species. Chapter 3 describes the methods and data used in estimating baseline I&E mortality losses and reductions under the regulatory options.[19] The price elasticity of demand for fish measures the percentage change in demand in response to a percentage point change in fish price. Thus, the inverse elasticity, or price flexibility, measures the percent change in price for a given percent change in quantity.

EPA did not include estimates of changes in consumer surplus for commercial species. Prices must change in order for consumer surplus to change. EPA estimated the expected price changes from eliminating baseline levels of I&E mortality losses, and found them to small, ranging from 0.13 percent to 2.1 percent. Appendix G of this document presents the detailed calculations and results. Consumer surplus measures that have been estimated by NMFS for past environmental impact statements tend to be quite low. [20] Most species of fish have numerous close substitutes, and most fisheries are price-takers in the world market. Therefore, if harvest of one or several species increases, prices are unlikely to change by a significant amount.

6.1.1.2 Step 2: Assessing Producer Surplus

In an unregulated fishery, the long-run change in producer surplus due to an increase in fish stocks will be zero percent of the change in gross revenues, because in open access fisheries, excess profits are always driven to zero at the margin. Most fisheries are, however, regulated with quotas or restrictive permits to prevent overfishing. Thus, there are lasting economic benefits to commercial fishers from reductions in I&E mortality and the subsequent increase in harvest. Fishery regulations seek to create sustainable harvests that maximize resource rents.[21] In a regulated fishery, I&E mortality impacts reduce the number of fish available to harvest. This may lead to more-stringent regulations and decreases in harvest. In this

[19] For several species, the predicted changes in harvest were quite large. EPA increased scrutiny on results for species with 10 percent or greater predicted change in harvest, to determine whether such increases were in fact reasonable estimates. In some cases, EPA capped the predicted harvest increases. The methods used and caps are described in Section 6.2.

[20] Personal communications with NMFS economists Cindy Thomson (2008), Eric Thunberg (2008), and Steve Freese (2008).

[21] In addition, even in open access fisheries, inframarginal rents are earned by at least some boats (personal communication, Thunberg 2008).

case, the change in producer surplus can be related to the change in harvest and the resulting gross revenue.

In Figure 6-1, the line C represents the cost to the producer of supplying a pound of fish. The model assumes that average cost is equal to marginal cost, that is, C is constant for all pounds produced.[22] When the supply of fish is equal to F^1, the commercial fishers sell F^1 pounds of fish at a price of P^1 and earn revenues equal to $U + V + W$. The area between P^1 and C is the producer surplus that accrues to producers for each pound of fish. Total producer surplus realized by producers is equal to $(P^1 - C) \times F^1$. In the example, this producer surplus is equal to the area of $U + V$. The area W is the amount that producers pay for capital and labor and to suppliers if the harvest equals F^1 (e.g., fishing gear and the costs of operating in the market).

When supply increases to F^2, the producers sell F^2 pounds of fish at a price of P^2. The total cost to produce F^2 increases from W to $W + Z$. The total producer surplus changes from $U + V$ to $V + Y$. This change may be either positive or negative, depending on the relative elasticity of demand, which changes the relative sizes of areas U and Y.

In theory, producer surplus is equal to normal profits (total revenue minus fixed and variable costs), minus the opportunity cost of capital. The fixed costs and inputs are incurred independently of the expected marginal changes in the level of fish landings (Squires et al. 1998; Thunberg and Squires 2005). Total variable costs including labor, fuel, ice, and other supplies, however, *vary directly* with the level of landings. Furthermore, since the opportunity cost of capital is estimated to be only about 0.4 to 2.6 percent of producer surplus, normal profits are assumed to be a sufficient proxy for producer surplus (USEPA 2004b). As a result, assessment of producer surplus is reduced to a relatively straightforward calculation in which the change in producer surplus is calculated as a species- and region-specific fraction of the change in gross revenue due to increased landings.

The change in producer surplus, captured by "normal profits," is assumed to be equivalent to a fixed proportion of the change in gross revenues, as estimated from the change in the commercial harvest due to reducing I&E mortality and the change in prices associated with the increased commercial harvest. As discussed above, EPA estimated price changes to be negligible, and therefore did not include price changes in the model. EPA estimated species- and region-specific Net Benefits Ratios which represent the fractional share of gross revenue associated with net benefits. EPA's approach for estimating Net Benefits Ratios using available data on variable costs from sources such as the National Marine Fisheries Service is described in more detail in Section A4-10 of US EPA (2006b). EPA then applied the Net Benefits Ratio to the estimated change in gross revenue under the 316(b) regulatory options to estimate the increase in producer surplus. The Net Benefits Ratios are shown by region and species in Table 6-1 through Table 6-6; they range from 0.15 to 0.85.[23,24] See Chapter 1, Section 1.2 for a definition of the seven study regions. The Inland region is excluded from the analysis due to a negligible commercial fishing harvest in this region. EPA notes that this approach yields an estimate of benefits to commercial

[22] If marginal cost increases as harvest increases, some of the producer surplus per unit will be lost due to the increased costs.

[23] Positive Net Benefits Ratios reflect the assumption that there will be rents (profits) to commercial fishers in regulated fisheries. When calculating the Net Benefits Ratios, EPA assumed that the predicted changes in harvest are such that fixed costs and variable costs per ton will not change. If costs remain constant, a marginal change in harvest is more likely to result in increases in profit and positive producer surplus.

[24] In the case of species aggregates (e.g., forage species), EPA assumed that the net benefit ratio is equal to the simple average of all empirically estimated net benefit ratios in the region. Species aggregates are listed as "Other" in Table 6-1 to Table 6-6.

fisherman, not benefits to society as a whole. As described in Section 6.1.1.1, EPA did not estimate changes in consumer surplus.

Table 6-1: California Region, Species-Specific Gear Type, Status of Stock, and Net Benefits Ratio

Species	Main Management Method	Main Gear Type	Status of Stock	Net Benefits as a Ratio of Gross Revenue (NBRatio)
Anchovies	Annual landings	Roundhaul	Unknown	0.64
Cabezon	Total allowable catch	Hook-and-line	Not overfished or subject to overfishing	0.52
Crabs	Seasonal closures	Pots and traps	Unknown	0.74
Drums and Croakers	Permits	Nets	Unknown	0.42
Dungeness Crab	Size, no females, closed during molting season	Traps	Unknown	0.74
Flounders	Quotas	Bottom trawl	Not overfished or subject to overfishing	0.64
California Halibut	Total allowable catch	Longline	Not overfished or subject to overfishing	0.58
Other	N/A	N/A	N/A	0.53
Rockfishes	Quotas	Trawls	Overfished or subject to overfishing	0.62
California Scorpionfish	Quotas	Otter trawl	Unknown	0.47
Sculpins	Nonrestrictive permits	Trawls	Unknown	0.64
Sea Basses	Season, size, gear restrictions	Gillnets	Unknown	0.66
Shad, American	None	Nets	Not overfished or subject to overfishing	0.00
Shrimp	Seasonal closures	Trawl	Unknown	0.15
Smelts	Seasonal closures	Nets	Overfished or subject to overfishing	0.66
Surfperches	Quotas	Handlines	Unknown	0.37

Table 6-2: North Atlantic Region, Species-Specific Gear Type, Status of Stock, and Net Benefits Ratio

Species	Main Management Method	Main Gear Type	Status of Stock	Net Benefits as a Ratio of Gross Revenue (NBRatio)
Bluefish	Quotas	Gillnets	Not overfished or subject to overfishing	0.63
Butterfish	Quotas	NA	Unknown	0.64
Atlantic Cod	Time/area closures	Otter trawl	Overfished or subject to overfishing	0.66
Crabs	Size, sex, season	Traps	Not overfished or subject to overfishing	0.57
American Plaice	Size	Otter trawl	Overfished or subject to overfishing	0.63
Windowpane	Time/area closures	Bottom trawl	Overfished or subject to overfishing	0.63
Winter Flounder	Quotas	Otter trawls	Overfished or subject to overfishing	0.64
Flounders	Total allowable landing	Bottom trawl	Overfished or subject to overfishing	0.63
Red Hake	Quotas	Otter trawls	Not overfished or subject to overfishing	0.62
Silver Hake	Quotas	Otter trawls	Not overfished or subject to overfishing	0.63
Atlantic Herring	Total allowable catch	Purse seine	Not overfished or subject to overfishing	0.76
Atlantic Mackerel	Annual quota	Unknown	Not overfished or subject to overfishing	0.77
Atlantic Menhaden	Not reg. In this area	Unknown	Not overfished or subject to overfishing	0.68
Other	N/A	N/A	N/A	0.57
White Perch	Size limits	Unknown	Unknown	0.82
Pollock	Time/area closures	Bottom trawl	Not overfished or subject to overfishing	0.71
Sculpins	Open access	Unknown	Unknown	0.00
Scup	Quotas	Otter trawls	Overfished or subject to overfishing	0.69
Searobin	Open access (by catch)	Unknown	Unknown	0.00
Shad, American	Mortality targets	Unknown	Fully exploited	0.60
Skates	Catch limits	Otter trawl	Overfished or subject to overfishing	0.68
Tautog	Possession limits	Otter trawl	Overfished or subject to overfishing	0.46
Weakfish	Size limits	Trawls	Not overfished or subject to overfishing	0.76

Table 6-3: Mid-Atlantic Region, Species-Specific Gear Type, Status of Stock, and Net Benefits Ratio				
Species	**Main Management Method**	**Main Gear Type**	**Status of Stock**	**Net Benefits as a Ratio of Gross Revenue (NBRatio)**
Alewife	Bans, species of concern	Fish weirs	Overfished or subject to overfishing	0.85
American Shad	Chesapeake fishery closed	Unknown	Overfished or subject to overfishing except for small by-catch allowance	0.84
Atlantic Croaker	Gear restrictions	Gillnets	Not overfished or subject to overfishing	0.74
Atlantic Menhaden	Open access	Purse seine, otter trawl, gill net	Unknown	0.67
Black Drum	Quotas	Unknown	Unknown	0.70
Blue Crab	Limits on female crabs, size	Pots	Overfished or subject to overfishing	0.57
Bluefish	Quotas	Gillnets	Not overfished or subject to overfishing	0.63
Butterfish	Quotas	Unknown	Overfished or subject to overfishing	0.64
Crabs	Season, size	Unknown	Unknown	0.57
Drums and Croakers	Gear restrictions, quotas	Nets	Unknown	0.74
Flounders	Quotas	Bottom trawl	Overfished or subject to overfishing	0.65
Other	N/A	N/A	N/A	0.73
Red Hake	Quotas	Otter trawls	Not overfished or subject to overfishing	0.62
Scup	Quotas	Otter trawls	Overfished or subject to overfishing	0.69
Searobin	Open access	Unknown	Unknown	0.00
Silver Hake	Quotas	Otter trawls	Not overfished or subject to overfishing	0.63
Spot	License	Haul seines	Unknown	0.84
Striped Bass	Quotas	Gill nets	Not overfished or subject to overfishing	0.67
Striped Mullet	Gear restrictions	Cast nets	Not overfished or subject to overfishing	0.70
Tautog	Possession limits	Otter trawl	Overfished or subject to overfishing	0.46
Weakfish	Size limits	Trawls	Not overfished or subject to overfishing	0.76
White Perch	Size limits	Unknown	Unknown	0.82

Table 6-4: South Atlantic Region, Species-Specific Gear Type, Status of Stock, and Net Benefits Ratio				
Species	**Main Management Method**	**Main Gear Type**	**Status of Stock**	**Net Benefits as a Ratio of Gross Revenue (NBRatio)**
Blue Crab	Size limits	Pots	Overfished or subject to overfishing	0.57
Crabs	Size, sex, season	Traps	Not overfished or subject to overfishing	0.57
Drums and Croakers	Open access (by catch)	Otter trawl bottom, gill nets	Overfished	0.54
Atlantic Menhaden	Five year annual cap on reduction fishery in Chesapeake	Unknown	Unknown	0.76
Other	N/A	N/A	N/A	0.59
Spot	License	Haul seines	Unknown	0.70
Stone Crab	Size	Traps	Not overfished or subject to overfishing	0.58
Weakfish	Size limits	Trawls	Not overfished or subject to overfishing	0.64

Table 6-5: Gulf of Mexico Region, Species-Specific Gear Type, Status of Stock, and Net Benefits Ratio				
Species	**Main Management Method**	**Main Gear Type**	**Status of Stock**	**Net Benefits as a Ratio of Gross Revenue (NBRatio)**
Blue Crab	Limited entry, pot limits	Pots	Overfished or subject to overfishing	0.72
Black Drum	Limited access permits	Hand lines, gill nets	Unknown	0.69
Leatherjacket	N/A	Rod/reel, hand and long lines, pots and traps	Unknown	0.00
Mackerels	Quotas	Hook-and-line	Not overfished or subject to overfishing	0.75
Menhaden	Seasonal/area closures	Purse seines	Fully exploited	0.76
Other	N/A	N/A	N/A	0.46
Sea Basses	Quotas	Traps	Overfished or subject to overfishing	0.72
Sheepshead	Size	Cast net	Not overfished or subject to overfishing	0.84
Shrimp	Same as pink shrimp	Unknown	Not overfished or subject to overfishing	0.43
Spot	License	Haul seines	Unknown	0.54
Stone Crab	Size	Traps	Not overfished or subject to overfishing	0.71
Striped Mullet	Gear restrictions	Strike nets	Not overfished or subject to overfishing	0.79

Table 6-6: Great Lakes Region, Species-Specific Gear Type, Status of Stock, and Net Benefits Ratio

Species	Main Management Method	Main Gear Type	Status of Stock	Net Benefits as a Ratio of Gross Revenue (NBRatio)
Bullhead	State specific	Gill and trap nets	Unknown	0.29
Freshwater Drum	State specific	Gill and trap nets	Unknown	0.29
Other	State specific	Gill and trap nets	Unknown	0.29
Smelt	State specific	Gill and trap nets	Unknown	0.29
White Bass	State specific	Gill and trap nets	Unknown	0.29
Whitefish	State specific	Gill and trap nets	Unknown	0.29
Yellow Perch	State specific	Gill and trap nets	Unknown	0.29

6.1.1.3 Step 3: Estimating Net Social Benefits When the Fishing Harvest Increases

The change in net social benefits when the commercial fishing harvest increases from F^1 to F^2 is estimated by adding the results from Steps 1 and 2. Because area *U* is a transfer from commercial fishers to consumers, it does not affect social benefits.[25] Therefore, the change in net social benefits is area $X + Y$ (see Figure 6-1). However, if demand elasticity is such that changes in price are negligible, area *X* will be negligible relative to *Y,* and total social benefits will be measured by area *Y.* See Appendix G on EPA's analysis of the estimated price changes due to reducing I&E mortality losses at CWIS sites by region and species.

6.2 Benefits Estimates for Regional Commercial Fishing

The first step of the analysis of commercial fishing benefits involves a fishery-based assessment of I&E mortality-related changes in harvested species landings. Many of the fish species affected by I&E mortality at CWIS sites are harvested both recreationally and commercially. As described in Section 6.1.1, EPA assumed a linear relationship between stock and harvest and used historical NMFS landings data on commercial and recreational catch to determine the proportions of total species harvest attributable to recreational and commercial fishing. EPA applied these proportions to the estimated total change in harvest to distribute benefits between commercial and recreational fisheries. The estimated change in commercial fishery harvest was then used as a basis for estimating changes in producer surplus in the commercial fishing industry.

EPA further assessed species with estimated harvest increases from the elimination of I&E mortality exceeding10 percent of baseline harvest from 2005 to 2009. This was done to evaluate whether potential harvest increases under 316(b) regulatory options are reasonable when compared to historic harvest data. Table 6-7 lists the species and potential percent increases in harvest over baseline harvest from eliminating baseline I&E mortality losses for the fourteen species found to exceed 10 percent. The species of concern are cabezon, California halibut, rockfishes, and sculpins in the California region; sculpins in the North Atlantic region; drums and croakers, spot, and weakfish in the Mid-Atlantic region; black drum, drums and croakers, leatherjacket, spot, and striped mullet in the Gulf of Mexico region; and smelt in the Great Lakes region. No species with 10 percent or greater potential change in harvest were found in the South Atlantic region. The increases range from 12 percent for striped mullet in the Gulf of Mexico to 25,110 percent for sculpins in the North Atlantic.

[25] Note that in the model shown in Figure 6-1, X + Y = U + X + [(V + Y) – (U + V)] = U + X + (Y – U)

Table 6-7: Potential Harvest Increase from Eliminating I&E Mortality Losses as a Percentage of Total Harvest and Potential Harvest Capping Rules Used in EPA's Analysis

Region and Species	Baseline Harvest (thousand lbs)	Baseline I&E Losses (thousand lbs)	Potential % Increase in Harvest	Maximum Harvest 1979-2009 (thousand lbs)	90th Percentile of Max. Harvest (thousand lbs)	MSY or Other Capping Rule (thousand lbs)	Cap Used
California Cabezon	55.6	54.4	98%	374.2	256.7	207.2[a]	Don't cap
California Halibut	629.9	126.4	20%	1,337.1	1,256.3	1,158.5[b]	Don't cap
California Rockfishes	2,668.4	1,168.7	44%	58,189.5	43,216.7	77,161.8[c]	Don't cap
California Sculpins	3.5	2.6	74%	19.5	7.1	482.8 [d]	Don't cap
North Atlantic Sculpins	<0.1	25.1	25,110%	4.8	**4.0**		Cap at 90^{th}
Mid-Atlantic Drums and Croakers	11,430.1	1,519.2	13%	16,575.2	16,252.9		Don't cap
Mid-Atlantic Spot	3,286.9	2,033.0	62%	4,766.2	**4,398.3**		Cap at 90^{th}
Mid-Atlantic Weakfish	497.0	741.9	149%	15,389.6	7,023.5		Don't cap
Gulf of Mexico Black Drum	4,397.3	1,885.2	43%	10,347.2	6,977.2		Don't cap
Gulf of Mexico Drums and Croakers	81.0	40.3	50%	1,787.4	1,193.3		Don't cap
Gulf of Mexico Leatherjacket	65.6	90.7	138%	509.3	437.5		Don't cap
Gulf of Mexico Spot	18.1	40.0	221%	442.8	299.1		Don't cap
Gulf of Mexico Striped Mullet	10,347.7	1,278.3	12%	33,141.6	27,395.6		Don't cap
Great Lakes Smelts	522.2	105.9	20%	4,107	3,520		Don't cap

a. MSY (maximum sustainable yield).
b. Average of most recent four peaks in harvest.
c. MSY for rockfishes for the West Coast.
d. MSY for all scorpionfish and sculpins.
Sources: EPA estimates of I&E mortality losses; NMFS data on baseline harvest, historical landings, and MSY.

Economists and biologists with NMFS recommended using either maximum sustainable yield (MSY), allowable biological catch (ABC), or historical harvest to determine reasonable caps on projected total harvest under the post-compliance scenario.[26] NMFS scientists recommended using 25 years or more of historical catch, because many populations peaked around 25 years ago—at that time there were virgin, non-exploited populations, so that maximum harvests were achievable. Using historical catch data from NMFS, EPA determined the maximum landings for the years 1979 through 2009, and calculated the 90^{th} percentile of landings for those years. NMFS biologists provided MSY where available (for California cabezon and all West Coast rockfishes). NMFS biologists suggested that sculpins in California be evaluated in combination with scorpionfish, as these species are grouped when determining the MSY. They also noted that halibut harvests fluctuate greatly, as the stock is highly variable. There is no stock assessment for halibut, so NMFS biologists suggested averaging the most recent four peaks in harvest.[27]

[26] Cindy Thomson, NMFS, personal communication (2008).

[27] Cindy Thomson, NMFS, personal communication (2008).

MSY or ABC data were not available for the species of interest in the other regions.[28] Therefore, EPA capped potential harvest increase at the 90th percentile of annual harvest from 1979 to 2009. The only species for Based on this criteria and the NMFS scientists' recommendations, EPA capped estimated harvest increases for two species when estimated commercial fishing benefits, sculpins in the North Atlantic and spot in the Mid-Atlantic.

The following sections present estimated benefits from commercial harvest changes in six of the seven study regions. The Inland region is excluded from the analysis due to a negligible commercial fishing harvest in this region.

6.2.1 California

Baseline levels of I&E mortality account for 1,379 thousand pounds of commercial fishing losses annually in the California region, as shown in Table 6-8. Rockfishes account for the major portion of overall losses in this region. The annual undiscounted commercial fishing benefits of eliminating baseline I&E mortality losses are estimated to be approximately $1,394 thousand, as shown in Table 6-8. Applying a 3 percent discount rate, the annualized benefits of eliminating baseline I&E mortality losses are estimated to be $1,236 thousand. Applying a 7 percent rate, these annualized benefits are approximately $1,195 thousand.

As shown in Table 6-8, annual commercial harvest is estimated to increase by approximately 7 thousand pounds under Options 1, 1,176 thousand pounds under Option 2, and 1,230 thousand pounds under Option 3. Discounted at 3 percent, the estimated annualized benefits to commercial fishers are approximately $4 thousand under Option 1, $751 thousand under Option 2, and $776 thousand under Option 3. Discounted at 7 percent, the estimated annualized benefits to commercial fishers are approximately $3 thousand under Option 1, $573 thousand under Option 2, and $589 thousand under Option 3. (Table 6-8). Appendix Table H-1 presents species-specific results for the estimated annual increase in harvest and monetary benefits to commercial fishers.

Table 6-8: Commercial Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the California Region, by Regulatory Option (2009$)

Regulatory Option	Annual Increase in Commercial Harvest (thousand lbs)	Annualized Benefits from Increase in Commercial Harvest (2009$, thousands)		
		Undiscounted	3% Discount Rate	7% Discount Rate
Baseline	1,379	1,394	1,236	1,195
Option 1	7	5	4	3
Option 2	1,176	1,189	751	573
Option 3	1,230	1,243	776	589

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere

[28] Based on information from NMFS and other Web sites, and personal communication with Nichola Meserve of the Atlantic States Marine Fisheries Commission (2008).

6.2.2 North Atlantic

Baseline levels of I&E mortality account for 430 thousand pounds of annual commercial fishing losses in the North Atlantic region, as shown in Table 6-9, with flounders playing a particularly important role. EPA estimated the annual undiscounted benefits to commercial fishers from eliminating baseline I&E mortality losses to be approximately $471 thousand, as shown in Table 6-9. Total annualized benefits from eliminating baseline I&E mortality losses, applying a 3 percent discount rate, are estimated to be $418 thousand. Applying a 7 percent rate, these annualized benefits are approximately $404 thousand.

As shown in Table 6-9, annual commercial harvest is estimated to increase by approximately 3 thousand pounds under Option 1, 352 thousand pounds under Option 2, and 369 thousand pounds under Option 3. Discounted at 3 percent, the estimated annualized benefits to commercial fishers are approximately $2 thousand under Options 1, $231 thousand under Option 2, and $242 thousand under Option 3. Discounted at 7 percent, the estimated annualized benefits to commercial fishers are approximately $1 thousand under Option 1, $171 thousand under Option 2, and $179 thousand under Option 3 (Table 6-9). Appendix Table H-2 presents species-specific results for the estimated annual increase in harvest and monetary benefits to commercial fishers.

Table 6-9: Commercial Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the North Atlantic Region, by Regulatory Option (2009$)

Regulatory Option	Annual Increase in Commercial Harvest (thousand lbs)	Annualized Benefits from Increase in Commercial Harvest (2009$, thousands)		
		Undiscounted	3% Discount Rate	7% Discount Rate
Baseline	430	471	418	404
Option 1	3	2	2	1
Option 2	352	385	231	171
Option 3	369	403	242	179

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere

6.2.3 Mid-Atlantic

Baseline levels of I&E mortality account for approximately 10,672 thousand pounds of commercial fishing losses annually in the Mid-Atlantic region, as shown in Table 6-10. Atlantic menhaden, blue crab, drums and croakers, spot, and weakfish are the primary drivers of I&E mortality losses in the Mid-Atlantic region. The annual undiscounted benefits to commercial fishers from eliminating baseline I&E mortality losses are estimated to be $3,192 thousand, as shown in Table 6-10. Applying a 3 percent discount rate, annualized benefits from eliminating baseline I&E mortality losses are estimated to be $2,831 thousand. Applying a 7 percent rate, these annualized benefits are approximately $2,737 thousand.

As shown in Table 6-10, annual commercial harvest is estimated to increase by approximately 3,750 thousand pounds under Option 1, 10,152 thousand pounds under Option 2, and 10,224 thousand pounds under Option 3. Discounted at 3 percent, the estimated annualized benefits to commercial fishers are $342 thousand under Options 1, $1,615 thousand under Option 2, and $1,629 thousand under Option 3. Discounted at 7 percent, the estimated annualized benefits to commercial fishers are approximately $303 thousand under Option 1, $1,124 thousand under Option 2, and $1,134 thousand under Option 3 (Table 6-10). Appendix Table H-3 presents species-specific results for the estimated annual increase in harvest and monetary benefits to commercial fishers.

Table 6-10: Commercial Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the Mid-Atlantic Region, by Regulatory Option (2009$)

Regulatory Option	Annual Increase in Commercial Harvest (thousand lbs)	Annualized Benefits from Increase in Commercial Harvest (2009$, thousands)		
		Undiscounted	3% Discount Rate	7% Discount Rate
Baseline	10,672	3,192	2,831	2,737
Option 1	3,750	436	342	303
Option 2	10,152	3,010	1,615	1,124
Option 3	10,224	3,035	1,629	1,134

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere

6.2.4 South Atlantic

Baseline levels of I&E mortality account for more than 99 thousand pounds of commercial fishing losses in the South Atlantic region, as shown in Table 6-11. The estimated undiscounted annual commercial fishing benefits of eliminating baseline I&E mortality losses are driven primarily by spot, followed by Atlantic menhaden, blue crab, and stone crab, and total $23 thousand, as shown in Table 6-11. Applying a 3 percent discount rate, the annualized benefits of eliminating baseline I&E mortality losses are estimated to be $21 thousand. Applying a 7 percent rate, these annualized benefits are $20 thousand.

As shown in Table 6-11, annual commercial harvest is estimated to increase by approximately 84 thousand pounds under Options 2 and 3 and 45 thousand pounds under Option 1. Discounted at 3 percent, the estimated annualized benefits to commercial fishers are $12 thousand under Options 2 and 3, and $8 thousand under Option 1. Discounted at 7 percent, the estimated annualized benefits to commercial fishers are approximately $8 thousand under Options 2 and 3, and $7 thousand under Option 1 (Table 6-11). Appendix Table H-4 presents species-specific results for the estimated annual increase in harvest and monetary benefits to commercial fishers.

Table 6-11: Commercial Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the South Atlantic Region, by Regulatory Option (2009$)

Regulatory Option	Annual Increase in Commercial Harvest (thousand lbs)	Annualized Benefits from Increase in Commercial Harvest (2009$, thousands)		
		Undiscounted	3% Discount Rate	7% Discount Rate
Baseline	99	23	21	20
Option 1	45	10	8	7
Option 2	84	20	12	8
Option 3	84	20	12	8

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere

6.2.5 Gulf of Mexico

Baseline levels of I&E mortality account for more than 5,559 thousand pounds of commercial fishing losses in the Gulf of Mexico region annually, as shown in Table 6-12. These losses are driven by black drum, Atlantic menhaden, and striped mullet. The estimated undiscounted annual commercial fishing benefits from eliminating baseline I&E mortality losses are approximately $3,747 thousand, as shown in Table 6-12. Applying a 3 percent discount rate, estimated commercial fishing benefits from eliminating baseline I&E mortality losses are estimated to be $3,463 thousand. Applying a 7 percent rate, these annualized losses are approximately $3,450 thousand.

As shown in Table 6-12, annual commercial harvest is estimated to increase by approximately 4,400 thousand pounds under Options 2 and 3, and 1,500 thousand pounds under Option 1. Discounted at 3 percent, the estimated annualized benefits to commercial fishers are approximately $588 thousand under Option 1 and $1,800 under Options 2 and 3. Discounted at 7 percent, the annualized benefits to commercial fishers are estimated to be approximately $1,400 thousand under Options 2 and 3, and $537 thousand under Option 1 (Table 6-12). Appendix Table H-5 presents species-specific results for the estimated annual increase in harvest and monetary benefits to commercial fishers.

Table 6-12: Commercial Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the Gulf of Mexico Region, by Regulatory Option (2009$)

Regulatory Option	Annual Increase in Commercial Harvest (thousand lbs)	Annualized Benefits from Increase in Commercial Harvest (2009$, thousands)		
		Undiscounted	3% Discount Rate	7% Discount Rate
Baseline	5,559	3,747	3,463	3,450
Option 1	1,459	719	588	537
Option 2	4,364	2,832	1,806	1,394
Option 3	4,371	2,837	1,804	1,390

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere

6.2.6 The Great Lakes

Baseline levels of I&E mortality account for more than 346 thousand pounds of commercial fishing losses in the Great Lakes region annually, as shown in Table 6-13. These losses are driven by the impingement of smelts and whitefish. The annual undiscounted commercial fishing benefits from eliminating baseline I&E mortality losses in this region are estimated to be approximately $87 thousand, as shown in Table 6-13. Total annualized commercial benefits from eliminating baseline I&E mortality losses, applying a 3 percent discount rate, are estimated to be $80 thousand. Applying a 7 percent rate, these annualized losses are approximately $80 thousand as well.

As shown in Table 6-13, annual commercial harvest is estimated to increase by approximately 330 thousand pounds under Options 2 and 3, and 227 thousand pounds under Option 1. The increase in commercial harvest under Option 1 is relatively close to Options 2 and 3 due to the relative importance of impingement mortality compared to total I&E mortality in the Great Lakes region. Discounted at 3 percent, the estimated annualized benefits to commercial fishers are approximately $53 thousand under Options 2 and 3 and by $48 thousand under Option 1. Discounted at 7 percent, the annualized benefits to commercial fishers are estimated to be approximately $44 thousand under Option 1 and $41 thousand under Options 2 and 3 (Table 6-13). Appendix Table H-6 presents species-specific results for the estimated annual increase in harvest and monetary benefits to commercial fishers.

Table 6-13: Commercial Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the Great Lakes Region, by Regulatory Option (2009$)

Regulatory Option	Annual Increase in Commercial Harvest (thousand lbs)	Annualized Benefits from Increase in Commercial Harvest (2009$, thousands)		
		Undiscounted	3% Discount Rate	7% Discount Rate
Baseline	346	87	80	80
Option 1	227	58	48	44
Option 2	326	82	53	41
Option 3	328	83	53	41

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere

6.3 Limitations and Uncertainties

Table 6-14 summarizes the caveats, omissions, biases, and uncertainties known to affect the estimates that were developed for the benefits analysis.

Table 6-14: Caveats, Omissions, Biases, and Uncertainties in the Commercial Benefits Estimates

Issue	Impact on Benefits Estimate	Comments
Change in commercial landings due to I&E mortality is uncertain	Uncertain	Projected changes in harvest may be underestimated because cumulative impacts of I&E mortality over time, interactions with other stressors, and population changes are not considered.
Some estimates of commercial harvest losses due to I&E mortality under current conditions are not region/species-specific	Uncertain	EPA estimated the impact of I&E mortality in the case study analyses based on data provided by the facilities. The most current data available were used. However, in some cases these data are 20 years old or older. Thus, they may not reflect current conditions.
Effect of change in stocks on landings is not considered	Uncertain	EPA assumed a linear stock to harvest relationship, so that a 10% change in stock would have a 10% change in landings; this may be low or high, depending on the condition of the stocks. Region-specific fisheries regulations also will affect the validity of the linear assumption.
Effect of uncertainty in estimates of commercial landings and prices is unknown	Uncertain	EPA assumes that NMFS landings data are accurate and complete. In some cases prices and/or quantities may be reported incorrectly.

7 Recreational Fishing Benefits

7.1 Introduction

This chapter presents the estimated benefits to recreational anglers from improved recreational fishing opportunities due to reductions in impingement and entrainment mortality (I&E mortality) under the regulatory options considered for the Section 316(b) regulation. For this analysis, EPA used a benefit transfer approach based on a meta-analysis of economic studies of recreational fishing benefits from improved catch rates. Benefit transfer involves adapting research conducted for another purpose to address the policy questions at hand (Bergstrom and De Civita 1999). Because benefit-cost analysis of environmental regulations rarely affords sufficient time to conduct original stated or revealed preference studies specific to policy effects, benefit transfer is often the only remaining option for providing information to inform policy decisions. EPA notes that Smith *et al.* (2002, p.134) state that "…nearly all benefit cost analyses rely on benefit transfers…."

Boyle and Bergstrom (1992) define benefit transfer as "the transfer of existing estimates of nonmarket values to a new study which is different from the study for which the values were originally estimated." There are four types of benefit transfer studies: point estimate, benefit function, meta-analysis, and Bayesian techniques (USEPA 2000a). These may be categorized into three fundamental classes: (1) transfer of an unadjusted fixed value estimate generated from a single study site; (2) the use of expert judgment to aggregate or otherwise alter benefits to be transferred from a site or set of sites; and (3) estimation of a value estimator model derived from study site data, often from multiple sites (Bergstrom and De Civita 1999). Recent studies have shown little support for the accuracy or validity of the first method, leading to increased attention to, and use of, *adjusted values* estimated by one of the remaining two approaches (Bergstrom and De Civita 1999). The third class of benefit transfer approaches includes meta-analysis techniques, which have been increasingly explored by economists as a potential basis of policy analysis conducted by various government agencies charged with the stewardship of natural resources.[29]

Section 7.2 provides a brief overview of the benefit transfer methodology used for estimating the recreational fishing benefits, and highlights the updates to methodology. Chapter A5 of EPA's Regional Benefits Analysis of the Final Section 316(b) Phase III Existing Facilities Rule (USEPA 2006b) provides a detailed description of the benefit transfer methodology that is employed in this analysis. Section 7.3 presents the recreational fishing benefits by region, and Section 7.4 summarizes the limitations and uncertainties inherent in EPA's analysis of recreational fishing benefits.

7.2 Methodology

EPA's analysis of recreational fishing benefits from reducing I&E mortality at cooling water intake structures (CWISs) at the in-scope facilities includes the following general steps:

1. **Estimate the forgone catch of recreational fish (in number of fish) attributable to I&E mortality under current conditions.** EPA modeled these losses using the methods presented in

[29] Meta-analysis is "the statistical analysis of a large collection of results from individual studies for the purposes of integrating the findings" (Glass 1976).

Chapter 3 of this document. EPA's estimates of recreational fish losses are expressed as the number of harvestable adults, rather than age-1 equivalents (A1Es), so as to not overstate the increases in catch resulting from 316(b) regulatory options.[30] Many of the fish species affected by I&E mortality at CWIS sites are harvested both recreationally and commercially. EPA used the proportion of total species landings attributable to recreational fishing to estimate baseline welfare losses to recreational anglers from current levels of I&E mortality and benefits from reducing I&E mortality under alternative policy options.

2. **Estimate the marginal value per fish.** EPA used the estimated meta-regression described in Chapter A5 of EPA (USEPA 2006b) to estimate marginal values per fish for the species affected by I&E mortality at Phase II facilities. To calculate the marginal value per fish for the affected species, EPA chose input values for the independent variables based on the affected species characteristics, study regions, and demographic characteristics of the affected angling populations. The study design variables were selected based on current economic literature. This step is described in more detail in Section 7.2.1.
3. **Estimate the value of forgone recreational catch lost to I&E mortality under the baseline scenario** by multiplying the marginal value per fish by the number of recreational fish currently lost to I&E mortality that would otherwise be caught by recreational anglers.
4. **Estimate recreational fishing benefits from reducing I&E mortality losses at the in-scope facilities' CWISs** by multiplying the marginal value per fish by the reduction in recreational fishing losses under the alternative policy options.

7.2.1 Estimating Marginal Value per Fish

To estimate marginal values per fish for the species affected by I&E mortality at in-scope facilities, EPA used a benefit transfer function based on meta-analysis of recreational fishing studies from the Section 316(b) Phase III Final Rule. The general approach follows standard methods illustrated by Johnston *et al.* (2006) and Shrestha *et al.* (2007), among many others (Rosenberger and Phipps 2007). This function allows EPA to forecast willingness to pay (WTP) based on assigned values for model variables, chosen to best represent a resource change in the 316(b) policy context. EPA's meta-analysis results imply a simple benefit function of the following general form:

$$\ln(WTP) = \text{intercept} + \sum(\text{coefficient}_i)(\text{Independent Variable Values}_i) \quad \text{(Eq. 7-1)}$$

Here, ln*(WTP)* is the dependent variable in the meta-analysis—the natural log of WTP for catching an additional fish. The independent variables included in the meta-analysis characterize the species being valued, study location, baseline catch rate, elicitation and survey methods, demographics of survey respondents, and other specific characteristics of each study.

To calculate the marginal value per fish for the species affected by in-scope facilities, EPA chose input values for the independent variables based on the affected species' characteristics, study regions, and demographic characteristics of the affected angling populations. The study design variables were selected based on current economic literature. Table 7-1 provides the independent variable names, the estimated variable coefficients ($coefficient_i$), and the assigned input values for each of the independent variables in the model.

[30] Adult fish of harvestable age means that they are the age at which they can legally be harvested.

EPA followed Johnston *et al.* (2006) in assigning values for methodological attributes (i.e., variables characterizing the study methodology used in the original source studies), which are set at mean values from the metadata except in cases where theoretical considerations dictate alternative specifications. This follows general guidance from Bergstrom and Taylor (2006) that meta-analysis benefit transfer should incorporate theoretical expectations and structures, at least in a weak form. In this instance, two of the methodology variables, *RUM_nest* and *high_resp_rate*, are included with an assigned value of one. *RUM_year* is given the value of 9.37, which corresponds to the average study year, 1985.

EPA decided not to include the error term when using the regression equation to predict marginal values per fish. Bockstael and Strand (1987) argue that if the econometric error in an equation is primarily due to omitted variables, the error term should be included, but if the error is primarily due to random preferences, it should be excluded. EPA did not conclude whether the error is primarily due to omitted variables or random preferences. Because the error term is positive, the empirical effect of including this term is to increase the predicted marginal values. Therefore, EPA excluded the error term in order to result in more- conservative estimates. EPA also notes that when the error term is excluded, the values predicted by the regression equation are more consistent with those from the underlying studies.

Table 7-2 presents region- and species-specific values for the input variables that vary across regions and Table 7-3 presents the estimated marginal value per fish for all species affected by I&E mortality in each region.

Table 7-1: Independent Variable Assignments for Regression Equation

Variable	Coefficient	Assigned Value	Explanation
Intercept	-1.4568	1	The equation intercept was set to one by default.
SP_conjoint	-1.1672	0	Current academic literature suggests that nested RUM models produce the most accurate valuation results, so *RUM_nest* was set to one, and the other study methodology variables were set to zero.
SP_dichot	-0.9958	0	
TC_individual	1.1091	0	
TC_zonal	2.0480	0	
RUM_nest	1.3324	1	
RUM_nonnest	1.7892	0	
sp_year	0.08754	0	*RUM_year* was set equal to the average value across the studies in the analysis, 9.37.
tc_year	-0.03965	0	
RUM_year	-0.00291	9.37	
sp_mail	0.5440	0	Since *RUM_nest* was the model specified above, *sp_mail* and *sp_phone* were set to zero.
sp_phone	1.0859	0	
high_resp_rate	-0.6539	1	High survey response rates are desirable because they may provide more-accurate estimates, so *high_response_rate* was set to one.
inc_thou	0.003872	Varies	*Inc_thou* was set to the median household income for each study region evaluated, based on U.S. Census data.
age42_down	0.9206	0.0972	*Age42_down* and *age43_up* were set to their sample means.
age43_up	1.2221	0.2711	
trips19_down	0.8392	0.1100	*Trips19_down* and *trips20_up* were set to their sample means.
trips20_up	-1.0112	0.3350	
nonlocal	3.2355	0	Because the default (zero) value for the *nonlocal* dummy variable represents a combination of local and nonlocal anglers, *nonlocal* was set to zero.

Table 7-1: Independent Variable Assignments for Regression Equation

Variable	Coefficient	Assigned Value	Explanation
big_game_pac	2.2530	Varies	Species-targeted variables were assigned input values based on characteristics of the species affected by I&E mortality and the study region. In general, the match between the affected species and the variables in the meta-analysis equation was good.
big_game_natl	1.5323	Varies	
big_game_satl	2.3821	Varies	
small_game_pac	1.6227	Varies	
small_game_atl	1.4099	Varies	
flatfish_pac	1.8909	Varies	
flatfish_atl	1.3797	Varies	
other_sw	0.7339	Varies	
musky	3.8671	Varies	
pike_walleye	1.0412	Varies	
bass_fw	1.7780	Varies	
trout_GL	1.8723	Varies	
trout_nonGL	0.8632	Varies	
salmon_pacific	2.3570	Varies	
salmon_atl_morey	5.2689	Varies	
salmon_GL	2.2135	Varies	
steelhead_pac	2.1904	Varies	
steelhead_GL	2.3393	Varies	
cr_nonyear	-0.08135	Varies	The variable *cr_nonyear* was assigned species and region-specific values for the coastal and Great Lakes regions based on catch rates data provided by the National Marine Fisheries Service (NMFS 2002; 2003) and the Michigan Department of Natural Resources (MDNR 2002). For the Inland region, EPA assigned values to the *cr_nonyear* variable based on the average values for each species from the studies. The variable *spec_cr* was set to one. *Cr_year* and *catch_year* were set to zero, since catch per trip and catch per day are more common measures of angling quality.
cr_year	-0.05208	0	
catch_year	1.2693	0	
spec_cr	0.6862	1	
shore	-0.1129	Varies	*Shore* was assigned values based on NMFS (2002; 2003) and U.S. Fish and Wildlife Service (USDOI and USDOC 2002) survey data indicating the average percentage of anglers who fish from shore in each region.

Source:U.S. EPA (2006b)

Table 7-2: Region- and Species-specific Variable Assignments for the Regression Equation								
Variable		**Region**						
		California	**North Atlantic**	**Mid-Atlantic**	**South Atlantic**	**Gulf of Mexico**	**Great Lakes**	**Inland**
inc_thou		54.385	55.000	51.846	40.730	36.641	44.519	58.240
Shore		24.0	24.0	23.1	30.0	25.0	48.0	57.0
Species	**Species Type Dummy Variable**[a]	**Baseline Catch Rate, Expressed in Fish per Day** (*cr_nonyear*)						
Small game[b]	*small_game_atl*, *small_game_pac*	2.7	1.6	1.6	2.2	2.2		2.1
Flatfish[c]	*flatfish_atl*, *flatfish_pac*	1.3	1.0	1.0	1.5			
Other saltwater	*other_sw*	1.7	1.7	1.7	1.7	1.7		
Salmon	*Salmon_GL*						0.2	0.2
Walleye/pike	*pike_walleye*						0.8	0.8
Bass	*bass_fw*						0.2	0.2
Panfish[d]				4.7			4.7	4.7
Trout							3.2	3.2
Unidentified		1.7	1.7	1.7	1.7	1.9	1.9	3.8

[a] This column indicates which species type dummy variable was set to one to represent each species.
[b] For "small game" fish in the North Atlantic, Mid-Atlantic, South Atlantic, Gulf of Mexico, and Inland regions, *small_game_atl* was set to one. For "small game" fish in the California region, *small_game_pac* was set to one.
[c] For "flatfish" in the North Atlantic, Mid-Atlantic, South Atlantic, Gulf of Mexico, Great Lakes, and Inland regions, *flatfish_atl* was set to one. For flatfish in the California region, *flatfish_pac* was set to one.
[d] To indicate that the target species was "panfish," all species type dummy variables were set to zero.
Source: U.S. EPA (2006b)

Table 7-3: Marginal Recreational Value per Fish, by Region and Species[a]

Species	California	North Atlantic	Mid-Atlantic	South Atlantic	Gulf of Mexico	Great Lakes	Inland
Small game	$7.23	$5.92	$5.88	$5.70	$5.61		$5.34
Flatfish	$9.73	$5.94	$5.60	$5.60			
Other saltwater	$2.95	$2.97	$2.91	$2.84	$2.76		
Salmon						$13.22	$13.22
Walleye/pike						$4.10	$4.09
Bass						$8.53	$8.98
Panfish			$1.06			$1.32	$1.06
Trout						$9.41	$2.81
Unidentified	$3.09	$3.00	$3.23	$2.86	$3.65	$6.20	$2.22

[a] All values are in 2009$.
Source: U.S. EPA (2006b), converted to 2009$ using the Consumer Price Index (USBLS 2010),

7.2.2 Calculating Recreational Fishing Benefits

EPA estimated the recreational welfare gain from eliminating current I&E mortality losses and the recreational welfare gain from the regulatory options by combining estimates of the marginal value per fish with the estimated recreational fishing losses under the baseline level of I&E mortality and the reduction in recreational fishing losses attributable to each regulatory option. To calculate the recreational welfare gain from eliminating baseline I&E mortality losses, EPA multiplied the marginal value per fish by the number of fish that are lost due to baseline I&E mortality that would otherwise be caught by recreational anglers. To calculate the recreational welfare gain from each analyzed option, EPA multiplied the marginal value per fish by the estimated additional number of fish caught by recreational anglers that would have been impinged or entrained in the absence of the regulation. As explained in Chapter 3 of this report, these calculations express recreational fish losses as the number of harvestable adults.

7.2.3 Sensitivity Analysis Based on the Krinsky and Robb (1986) Approach

The meta-analysis model briefly described above can be used to predict mean WTP for catching an additional fish. However, estimates derived from regression models are subject to some degree of error and uncertainty. To better characterize the uncertainty or error bounds around predicted WTP, EPA adopted the statistical procedure described by Krinsky and Robb in their 1986 *Review of Economics and Statistics* paper, "Approximating the Statistical Property of Elasticities." The procedure involves sampling from the variance-covariance matrix and means of the estimated coefficients. WTP values are then calculated for each drawing from the variance covariance matrix, and an empirical distribution of WTP values is constructed. By varying the number of drawings, it is possible to generate an empirical distribution with a desired degree of accuracy (Krinsky and Robb 1986). The lower or upper bound of WTP values can then be identified based on the 5th and 95th percentile of WTP values from the empirical distribution. These bounds may help decision-makers understand the uncertainty associated with the benefit results.

The results of EPA's calculations are shown in Table 7-4. The table presents 95th percentile upper confidence bounds and 5th percentile lower confidence bounds for the marginal value per fish for each species in each region. These bounds can be used to estimate upper and lower confidence bounds for the WTP for improvements in recreational catch rates from eliminating baseline I&E mortality losses or reducing I&E mortality losses under each regulatory analysis option. Refer to EPA (2006b) for more detail on the specific calculations. The 5th percentile values shown in Table 7-4 show that, with the exception of panfish, even the lowest estimates of recreational value are greater than $1 per fish.

Table 7-4: Confidence Bounds on Marginal Recreational Value per Fish, Based on the Krinsky and Robb Approach[a]

Species	California	North Atlantic	Mid-Atlantic	South Atlantic	Gulf of Mexico	Great Lakes	Inland
5th Percentile Lower Confidence Bounds[b]							
Small game	$4.19	$2.12	$2.26	$2.71	$2.86		$1.60
Flatfish	$5.10	$3.80	$3.74	$3.86			
Other saltwater	$1.78	$1.78	$1.84	$2.14	$2.13		
Salmon	$8.40					$8.12	$8.12
Walleye/pike						$2.17	$11.98
Bass						$4.41	$4.27
Panfish			$0.53			$0.69	$0.53
Trout						$6.08	$1.51
Unidentified	$1.85	$1.80	$1.90	$2.14	$2.36	$3.32	$1.08
95th Percentile Upper Confidence Bounds[b]							
Small game	$12.40	$16.70	$15.46	$11.99	$11.00		$18.00
Flatfish	$18.56	$9.40	$8.49	$8.25			
Other saltwater	$4.87	$4.96	$4.58	$3.77	$3.60		
Salmon	$28.70					$21.53	$21.53
Walleye/pike						$7.77	$8.49
Bass						$16.56	$19.01
Panfish			$2.10			$2.48	$2.10
Trout						$14.61	$5.27
Unidentified	$5.16	$5.01	$5.71	$3.81	$5.89	$11.67	$4.58

[a] All values are in 2009$.

[b] Upper and lower confidence bounds based on results of the Krinsky and Robb (1986) approach.

Source: U.S. EPA (2006b), converted to 2009$ using the Consumer Price Index (USBLS 2010).

7.3 Benefits Estimates for Recreational Fishing by Region

7.3.1 California

Table 7-5 shows the results of EPA's analysis of the recreational fishing losses from I&E mortality under the baseline conditions at in-scope facilities in California. Baseline recreational fishing losses from I&E mortality in the California region amount to 1.0 million fish per year. The majority of recreational losses from I&E mortality under baseline conditions are attributable to entrainment of rockfish and sea bass. Table 7-5 shows the results of EPA's analysis of the potential welfare gain to recreational anglers from eliminating baseline recreational fishing losses at in-scope facilities in California. The estimated mean annual welfare gain to California anglers from eliminating all of these losses is $2.9 million and $2.8 million evaluated at 3 percent and 7 percent discount rates, respectively. The majority of the monetized recreational benefits from eliminating baseline I&E mortality are attributable to eliminating entrainment of "other saltwater" fish[31]. Appendix I presents additional species-specific results.

[31] The "other saltwater" species group includes banded drum, black drum, chubby, cod family, cow cod, croaker, grouper, grunion, grunt, high-hat, kingfish, lingcod, other drum, perch, porgy, rockfish, sablefish, sand drum, sculpin, sea bass, smelt, snapper, spot, spotted drum, star drum, white sea bass, wreckfish, other bottom species, other coastal pelagics, and "no target" saltwater species.

As shown in Table 7-5, the estimated reduction in I&E mortality leads to an estimated annual increase in recreational fishery harvest of less than 0.1 million fish under Option 1 and approximately 0.9 million fish per year under Options 2 and 3. Discounted at 3 percent, the estimated mean annualized welfare gain to California anglers is approximately $0.1 million under Option 1, $1.7 million under Option 2, $1.8 million under Option 3. Discounted at 7 percent, the estimated mean annualized welfare gain is $1.3 million and $1.4 million under Options 2 and 3, and $0.1 million under Option 1 (Table 7-5). Appendix I presents additional species-specific results.

Table 7-5: Recreational Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the California Region, by Regulatory Option (2009$)

Regulatory Option	Annual Increase in Recreational Harvest (harvestable adult fish)	Annualized Benefits from Increase in Recreational Harvest (2009$, thousands)					
		3 % Discount Rate			7 % Discount Rate		
		5th	Mean	95th	5th	Mean	95th
Baseline	1,022,339	$1,740	$2,923	$4,917	$1,681	$2,823	$4,750
Option 1	36,438	$51	$85	$141	$46	$75	$125
Option 2	876,841	$1,037	$1,741	$2,929	$792	$1,330	$2,237
Option 3	915,750	$1,096	$1,840	$3,095	$832	$1,396	$2,349

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere; Option 4 = I for Facilities > 50 MGD

7.3.2 North Atlantic Region

Table 7-6 shows the results of EPA's analysis of the recreational fishing losses from I&E mortality under the baseline conditions at in-scope facilities in the North Atlantic region. Baseline recreational fishing losses from I&E mortality in the North Atlantic region amount to 0.8 million fish per year. The majority of recreational losses from I&E mortality under baseline conditions are attributable to entrainment of winter flounder, cunner, and sculpin. Table 7-6 shows the results of EPA's analysis of the potential welfare gain to recreational anglers from eliminating baseline recreational fishing losses at in-scope facilities in the North Atlantic. The estimated mean annual welfare gain to North Atlantic anglers from eliminating all of these losses is $2.8 million and $2.7 million evaluated at 3 percent and 7 percent discount rates, respectively. The majority of the monetized recreational benefits from eliminating baseline I&E mortality are attributable to eliminating the entrainment of "flatfish" and "other saltwater" fish. Appendix I presents additional species-specific results.

As shown in Table 7-6, the estimated reduction in I&E mortality leads to an estimated annual increase in recreational fishery harvest of less than 0.1 million fish under Option 1, 0.6 million fish under Option 2, and 0.7 million fish under Option 3. Discounted at 3 percent, the estimated mean annualized welfare gain to North Atlantic anglers is less than $0.1 million under Option 1, $1.5 million under Option 2, and $1.6 million under Option 3. Discounted at 7 percent, the estimated mean annualized welfare gain is less than $0.1 million under Option 1, $1.1 million under Option 2, and $1.2 million under Option 3 (Table 7-6). Appendix I presents additional species-specific results.

Table 7-6: Recreational Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the North Atlantic Region, by Regulatory Option (2009$)

Regulatory Option	Annual Increase in Recreational Harvest (harvestable adult fish)	Annualized Benefits from Increase in Recreational Harvest (2009$, thousands)					
		3 % Discount Rate			7 % Discount Rate		
		5th	Mean	95th	5th	Mean	95th
Baseline	761,183	$1,765	$2,838	$4,596	$1,705	$2,742	$4,440
Option 1	1,495	$3	$5	$9	$3	$5	$8
Option 2	620,929	$939	$1,510	$2,446	$698	$1,122	$1,817
Option 3	651,307	$1,018	$1,638	$2,652	$756	$1,216	$1,969

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere; Option 4 = I for Facilities > 50 MGD

7.3.3 Mid-Atlantic Region

Table 7-7 shows the results of EPA's analysis of the recreational fishing losses from I&E mortality under the baseline conditions at in-scope facilities in the Mid-Atlantic region. Baseline recreational fishing losses from I&E mortality in the Mid-Atlantic region amount to 9.1 million fish per year. The majority of recreational losses from I&E mortality under baseline conditions are attributable to I&E mortality of spot, Atlantic croaker, and "other saltwater" fish. Table 7-7 shows the results of EPA's analysis of the potential welfare gain to recreational anglers from eliminating baseline recreational fishing losses at in-scope facilities in the Mid-Atlantic. The estimated mean annual welfare gain to Mid-Atlantic anglers from eliminating all of these losses is $25.6 million and $24.7 million evaluated at 3 percent and 7 percent discount rates, respectively. The majority of the monetized recreational benefits from eliminating baseline I&E mortality are attributable to eliminating the entrainment of other saltwater fish. Appendix I presents additional species-specific results.

As shown in Table 7-7, the estimated reduction in I&E mortality leads to an estimated annual increase in recreational fishery harvest of approximately 0.6 million fish under Option 1, 8.4 million fish under Option 2, and 8.5 million fish under Option 3. Discounted at 3 percent, the estimated mean annualized welfare gain to Mid-Atlantic anglers is $14.1 million and $14.4 million under Options 2 and 3, and $1.6 million under Option 1. Discounted at 7 percent, the estimated mean annualized welfare gain is $9.8 million and $10.0 million under Options 2 and 3, and $1.4 million under Option 1 (Table 7-7). Appendix I presents additional species-specific results.

Table 7-7: Recreational Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the Mid-Atlantic Region, by Regulatory Option (2009$)

Regulatory Option	Annual Increase in Recreational Harvest (harvestable adult fish)	Annualized Benefits from Increase in Recreational Harvest (2009$, thousands)					
		3 % Discount Rate			7 % Discount Rate		
		5th	Mean	95th	5th	Mean	95th
Baseline	9,081,061	$15,239	$25,569	$44,467	$14,721	$24,701	$42,958
Option 1	549,015	$846	$1,577	$3,136	$749	$1,396	$2,776
Option 2	8,359,591	$8,381	$14,073	$24,501	$5,831	$9,792	$17,049
Option 3	8,459,880	$8,584	$14,410	$25,078	$5,975	$10,030	$17,456

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere; Option 4 = I for Facilities > 50 MGD

7.3.4 South Atlantic Region

Table 7-8 shows the results of EPA's analysis of the recreational fishing losses from I&E mortality under the baseline conditions at in-scope facilities in the South Atlantic region. Baseline recreational fishing losses from I&E mortality in the South Atlantic region amount to 0.1 million fish per year. The majority of recreational losses from I&E mortality under baseline conditions are attributable to I&E mortality of "other saltwater" fish, especially spot and croakers. Table 7-8 shows the results of EPA's analysis of the potential welfare gain to recreational anglers from eliminating baseline recreational fishing losses at in-scope facilities in the South Atlantic. The estimated mean annual welfare gain to South Atlantic anglers from eliminating all of these losses is approximately $0.3 million evaluated at both 3 percent and 7 percent discount rates. The majority of the monetized recreational benefits from eliminating baseline I&E mortality are attributable to eliminating impingement of "other saltwater" fish. Appendix I presents additional species-specific results.

As shown in Table 7-8, the estimated reduction in I&E mortality leads to an estimated annual increase in recreational fishery harvest of approximately 0.1 million fish under Options 2 and 3, and less than 0.1 million fish per year under Option 1. Discounted at 3 percent, the estimated mean annualized welfare gain to South Atlantic anglers is $0.2 million under Options 2 and 3, and less than $0.1 million under Option 1. Discounted at 7 percent, the estimated mean annualized welfare gain is $0.1 million under Options 2 and 3, and less than $0.1 million under Option 1 (Table 7-8). Appendix I presents additional species-specific results.

Table 7-8: Recreational Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the South Atlantic Region, by Regulatory Option (2009$)

Regulatory Option	Annual Increase in Recreational Harvest (harvestable adult fish)	Annualized Benefits from Increase in Recreational Harvest (2009$, thousands)					
		3 % Discount Rate			7 % Discount Rate		
		5th	Mean	95th	5th	Mean	95th
Baseline	133,897	$257	$346	$469	$249	$335	$453
Option 1	15,882	$28	$37	$50	$24	$33	$45
Option 2	112,139	$141	$190	$257	$103	$139	$188
Option 3	112,301	$141	$190	$257	$103	$139	$188

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere; Option 4 = I for Facilities > 50 MGD

7.3.5 Gulf of Mexico

Table 7-9 shows the results of EPA's analysis of the recreational fishing losses from I&E mortality under the baseline conditions at in-scope facilities in the Gulf of Mexico region. Baseline recreational fishing losses from I&E mortality in the Gulf of Mexico region amount to 2.9 million fish per year. The majority of recreational losses from I&E mortality under baseline conditions are attributable to the impingement of spotted seatrout and the entrainment of black drum and "other saltwater" fish. Table 7-9 shows the results of EPA's analysis of the potential welfare gain to recreational anglers from eliminating baseline recreational fishing losses at in-scope facilities in the Gulf of Mexico. The estimated mean annual welfare gain to Gulf of Mexico anglers from eliminating all of these losses is $8.9 million and $8.8 million evaluated at 3 percent and 7 percent discount rates, repectively. The majority of the monetized recreational benefits from eliminating baseline I&E mortality are attributable to both the impingement of "small game" fish and the entrainment of "other saltwater" species. Appendix I presents additional species-specific results.

As shown in Table 7-9, the estimated reduction in I&E mortality leads to an estimated annual increase in recreational fishery harvest of approximately 2.2 million fish under Options 2 and 3, and 0.7 million fish per year under Option 1. Discounted at 3 percent, the estimated mean annualized welfare gain to Gulf of Mexico anglers is $2.4 million under Option 1, and $4.9 million under Options 2 and 3. Discounted at 7 percent, the estimated mean annualized welfare gain is $2.2 million under Option 1, and $3.8 million under Options 2 and 3 (Table 7-9). Appendix I presents additional species-specific results.

Table 7-9: Recreational Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the Gulf of Mexico Region, by Regulatory Option (2009$)

Regulatory Option	Annual Increase in Recreational Harvest (harvestable adult fish)	Annualized Benefits from Increase in Recreational Harvest (2009$, thousands)					
		3 % Discount Rate			7 % Discount Rate		
		5th	Mean	95th	5th	Mean	95th
Baseline	2,851,347	$6,022	$8,852	$13,506	$5,999	$8,818	$13,456
Option 1	665,697	$1,398	$2,422	$4,334	$1,275	$2,210	$3,953
Option 2	2,204,063	$3,225	$4,866	$7,642	$2,491	$3,760	$5,908
Option 3	2,208,009	$3,258	$4,906	$7,690	$2,510	$3,781	$5,926

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere; Option 4 = I for Facilities > 50 MGD

7.3.6 Great Lakes Region

Table 7-10 shows the results of EPA's analysis of the recreational fishing losses from I&E mortality under the baseline conditions at in-scope facilities in the Great Lakes region. Baseline recreational fishing losses from I&E mortality in the Great Lakes region amount to 0.3 million fish per year. The majority of recreational losses from I&E mortality under baseline conditions are attributable to impingement of whitefish and entrainment of "unidentified" species. Table 7-10 shows the results of EPA's analysis of the potential welfare gain to recreational anglers from eliminating baseline recreational fishing losses at in-scope facilities in the Great Lakes. The estimated mean annual welfare gain to Great Lakes anglers from eliminating all of these losses is $2.0 million evaluated at both 3 percent and 7 percent discount rates. The majority of the monetized recreational benefits from eliminating baseline I&E mortality are attributable to eliminating the impingement of "other trout" and "unidentified" fish. Appendix I presents additional species-specific results.

As shown in Table 7-10, the estimated reduction in I&E mortality leads to an estimated annual increase in recreational fishery harvest of approximately 0.2 million fish per year under Option 1, and 0.3 million fish under Options 2 and 3. Discounted at 3 percent, the estimated mean annualized welfare gain to Great Lakes anglers is $1.3 million under Options 2 and 3, and $1.0 million under Option 1. Discounted at 7 percent, the estimated mean annualized welfare gain is $1.0 million under Options 2 and 3, and $0.9 million under Option 1 (Table 7-10). Appendix I presents additional species-specific results.

Table 7-10: Recreational Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the Great Lakes Region, by Regulatory Option (2009$)

Regulatory Option	Annual Increase in Recreational Harvest (harvestable adult fish)	Annualized Benefits from Increase in Recreational Harvest (2009$, thousands)					
		3 % Discount Rate			7 % Discount Rate		
		5th	Mean	95th	5th	Mean	95th
Baseline	349,648	$1,127	$1,984	$3,544	$1,123	$1,977	$3,530
Option 1	176,089	$561	$951	$1,638	$511	$867	$1,495
Option 2	317,974	$720	$1,261	$2,241	$559	$979	$1,739
Option 3	320,196	$725	$1,271	$2,261	$561	$984	$1,750

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere; Option 4 = I for Facilities > 50 MGD

7.3.7 Inland Region

Table 7-11 shows the results of EPA's analysis of the recreational fishing losses from I&E mortality under the baseline conditions at in-scope facilities in the Inland region. Baseline recreational fishing losses from I&E mortality in the Inland region amount to 12.6 million fish per year. The majority of recreational losses from I&E mortality under baseline conditions are attributable to I&E mortality of "bass," "panfish," and "unidentified" species groups. Table 7-11 shows the results of EPA's analysis of the potential welfare gain to recreational anglers from eliminating baseline recreational fishing losses at in-scope facilities in the Inland region. The estimated mean annual welfare gain to Inland anglers from eliminating all of these losses is $34.4 million and $34.2 million evaluated at 3 percent and 7 percent discount rates, respectively. The majority of the monetized recreational benefits from eliminating baseline I&E mortality are attributable to eliminating I&E mortality of "bass," "panfish," and "unidentified" fish. Appendix I presents additional species-specific results.

As shown in Table 7-11, the estimated reduction in I&E mortality leads to an estimated annual increase in recreational fishery harvest of approximately 11.1 million fish and 11.4 million fish under Options 2 and 3, and 4.7 million fish per year under Option 1. Discounted at 3 percent, the estimated mean annualized welfare gain to Inland anglers is $19.9 million and $20.7 million under Options 2 and 3, and $10.5 million under Option 1. Discounted at 7 percent, the estimated mean annualized welfare gain is $9.6 million under Option 1, $15.3 million under Option 2, and $15.8 million under Option 3 (Table 7-11). Appendix I presents additional species-specific results.

Table 7-11: Recreational Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the Inland Region, by Regulatory Option (2009$)							
Regulatory Option	**Annual Increase in Recreational Harvest (harvestable adult fish)**	**Annualized Benefits from Increase in Recreational Harvest (2009$, thousands)**					
		3 % Discount Rate			**7 % Discount Rate**		
		5th	**Mean**	**95th**	**5th**	**Mean**	**95th**
Baseline	12,592,464	$16,566	$34,376	$71,653	$16,504	$34,247	$71,384
Option 1	4,321,037	$5,071	$10,545	$22,049	$4,626	$9,619	$20,115
Option 2	11,061,370	$9,578	$19,879	$41,449	$7,361	$15,277	$31,856
Option 3	11,389,049	$9,966	$20,684	$43,122	$7,592	$15,755	$32,847

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere; Option 4 = I for Facilities > 50 MGD

7.4 Limitations and Uncertainties

A number of limitations and uncertainties are common to all WTP values predicted using benefit transfer. To better characterize the uncertainty or error bounds around predicted WTP, EPA adopted the statistical procedure described by Krinsky and Robb in their 1986 *Review of Economics and Statistics* paper "Approximating the Statistical Property of Elasticities." This procedure was used to generate lower and upper bound WTP values identified as the 5th and 95th percentile of values from the empirical distribution. Additional detail regarding the Krinsky and Robb approach is provided in Section 7.2.3. These bounds may help decision-makers understand the uncertainty associated with the benefit results for the elimination of baseline I&E mortality losses and 316(b) regulatory options.

Specific limitations and uncertainties associated with the estimated regression model and the underlying studies are discussed in Section A5-3.3 of EPA (2006b). Additional limitations and uncertainties associated with implementation of the meta-analysis approach are addressed below.

7.4.1 Variable Assignments for Independent Regressors

The per-fish values estimated from the model depend on the values of the input variables in the meta-analysis. EPA assigned values to the input variables based on established economic theory and characteristics of the affected species and regions. However, because the input values for some variables are uncertain, the resulting per-fish values and benefits estimates also include some degree of uncertainty.

7.4.2 Exclusion of Error Term from Regression Equation to Predict Marginal Values

EPA decided not to include the error term when using the regression equation to predict marginal values per fish. Bockstael and Strand (1987) argue that if the source of econometric error in an equation is primarily due to omitted variables, the error term should be included, but if the error is primarily due to random preferences, it should be excluded. EPA did not conclude whether the error is primarily due to omitted variables or random preferences. Because the error term is positive, the empirical effect of including this term is to increase the predicted marginal values. Therefore, EPA excluded the error term in order to result in more- conservative estimates. EPA also notes that when the error term is excluded, the values predicted by the regression equation are more consistent with those from the underlying studies. This indicates that convergent validity is greater when the error term is excluded.

7.4.3 Other Limitations and Uncertainties

In addition to the limitations and uncertainties involved with the study data and model estimation, which are discussed in Section A5-3.3e of EPA (2006b), there are limitations and uncertainties involved with the calculation of per-fish values from the model, and with the use of those values to estimate the welfare gain resulting from the regulatory options considered for the final Section 316(b) regulation for existing Phase II facilities.

The validity and reliability of benefit transfer—including that based on meta-analysis—depends on a variety of factors. While benefit transfer can provide valid measures of use benefits, tests of its performance have provided mixed results (e.g., Desvousges et al. 1998; Smith et al. 2002; Vandenberg et al. 2001). Nonetheless, benefit transfers are increasingly applied as a core component of benefit-cost analyses conducted by EPA and other government agencies (Bergstrom and De Civita 1999; Griffiths undated). Smith et al. (2002, p.134) state that "nearly all benefit cost analyses rely on benefit transfers, whether they acknowledge it or not."

An important factor in any benefit transfer is the ability of the study site or estimated valuation equation to approximate the resource and context for which benefit estimates are desired. As is common, the meta-analysis model presented here provides a close but not perfect match to the context in which values are desired.

The final area of uncertainty related to the use of the regression results to calculate regulatory benefits is uncertainty in the estimates of I&E mortality. There are a number of reasons why recreational losses due to I&E mortality may be higher or lower than expected. Projected changes in recreational catch may be underestimated because cumulative impacts of I&E mortality over time are not considered. In particular, I&E mortality estimates include only individuals directly lost to I&E mortality, not their progeny. Additionally, the interaction of I&E mortality with other stressors may have either a positive or negative effect on recreational catch. Finally, in estimating recreational fishing losses, EPA used the most current I&E mortality data available provided by facilities, which in some cases may not reflect current conditions.

8 Nonuse Benefits of Reducing I&E Mortality

8.1 Introduction

Comprehensive estimates of total resource value include both use and nonuse values, such that the resulting total value estimate may be compared to total social cost. "Non-use values, like use values, have their basis in the theory of individual preferences and the measurement of welfare changes. According to theory, use values and non-use values are additive" (Freeman III 1993). Consequently, excluding nonuse values from consideration is likely to substantially understate total social values. Recent economic literature provides substantial support for the hypothesis that nonuse values are greater than zero for many types of environmental improvements. Moreover, when a substantial fraction of the population holds even small per capita nonuse values, these nonuse values can be very large in the aggregate. As stated by Freeman (1993), "there is a real possibility that ignoring non-use values could result in serious misallocation of resources." Consequently, both EPA's own Guidelines for Preparing Economic Analysis and OMB's Circular A-4, governing regulatory analysis, support the need to assess nonuse values (USEPA 2000a; USOMB 2003).

The vast majority (97 percent) of current (i.e., baseline) impingement and entrainment mortality (I&E mortality) losses at cooling water intake structures (CWISs) consist of forage species or unlanded individuals of recreational and commercial species (Chapter 3). Although these forage fish and unlanded fish do not have direct use values, they may be valued by users (commercial fishers and recreational anglers) and nonusers of fisheries resources. Additionally, the nonuse values are likely to be substantial, because fish and other species found within aquatic habitats impacted directly and indirectly by CWISs provide other valuable ecosystem goods and services, including nutrient cycling and ecosystem stability. Therefore, a comprehensive estimate of the welfare gain from reducing I&E mortality losses must include an estimate of nonuse benefits.

The following sections present EPA's qualitative and quantitative assessments of nonuse benefits. EPA qualitatively evaluated the public's nonuse values for aquatic habitats by considering evidence from existing aquatic restoration and protection programs (Section 8.2). This chapter also presents EPA's benefit transfer approach for the quantification of nonuse benefits associated with reductions in I&E mortality of fish, shellfish, and other aquatic organisms under the 316(b) regulatory options in the North Atlantic and Mid-Atlantic Regions (Section 8.3). Section 8.4 presents estimated nonuse benefits under the 316(b) regulatory options.

8.2 Public Policy Significance of Ecological Improvements from the Proposed 316(b) Regulation for Existing Facilities

Changes to CWIS design and operation resulting from 316(b) regulation of existing facilities is expected to reduce I&E mortality losses of fish, shellfish, and other aquatic organisms. These direct benefits are believed to lead to increases in local and regional fishery populations and ecosystem stability. Moreover, many indirect ecosystem goods and services are affected by I&E mortality, thermal effects, and flow alteration. Due to the wide-ranging nature of these indirect effects, EPA believes that regulation is likely to enhance the value of ecosystem goods and services provided by aquatic habitats, and that regulation will help reduce the overall impact of anthropogenic effects on aquatic systems affected by CWISs. Table 2-4 provides a detailed list of ecosystem services potentially affected by the proposed 316(b) regulation.

EPA assessed the potential magnitude of nonuse benefits that are quantified, but not monetized using information regarding government spending on the protection, restoration, and regulation of various aquatic habitats. This included Marine Protected Areas (Section 8.2.2) and a subset of freshwater ecosystems undergoing large-scale restoration efforts (Section 8.2.3). This spending serves as a lower bound of nonuse values in a subset of geographical locations

8.2.1 Effects on Depleted Fish Populations

EPA believes that reducing fish mortality from impingement and entrainment (I&E) would contribute to the health and sustainability of the affected fish populations by lowering the overall level of mortality for these populations. Fish populations suffer from numerous sources of mortality, both natural and anthropogenic. Natural sources include weather, predation by other fish, and the availability of food. Human impacts that affect fish populations include fishing, pollution, habitat changes, and I&E mortality losses at CWISs. Fish populations decline when they are unable to sufficiently compensate for their overall level of mortality. Although it is difficult to measure, EPA believes that an aquatic population's compensatory ability—the capacity for a species to increase survival, growth, or reproduction rates in response to decreased population —is likely compromised by impingement and entrainment mortality (I&E mortality) losses and the cumulative impact of other stressors in the environment over extended periods of time (USEPA 2006a). Lowering the overall mortality level increases the probability that a population will be able to compensate for mortality at a level sufficient to maintain its long-term health. In some cases, I&E mortality losses may be a significant source of anthropogenic mortality to already-depleted stocks of commercially targeted species (see Table 2-3). Depleted saltwater fish stocks affected by I&E mortality include winter flounder, Atlantic Cod, and rockfishes, for example (NMFS 2010a). As discussed in Section 2.3.1, I&E mortality also increases the pressure on freshwater species native to the Great Lakes, such as lake whitefish and yellow perch, whose populations have dramatically declined in recent years (USDOI 2008; Wisconsin DNR 2003).

The federal government and the states have recognized the public importance of maintaining sustainable fisheries, achieving recovery of depleted fish stocks, and ensuring that functioning ecosystems are passed to future generations. Actions these governments have taken include buying fishing licenses and fishing vessels from individual fishers when stocks appear depressed, imposing restrictions on commercial and recreational harvests, conducting large-scale ecosystem restoration projects (USDOI 2008), and creating a national system of marine protected areas (Executive Order No. 13158 2001). Together, these governmental actions suggest that the public holds substantial nonuse values for aquatic habitats.

To summarize, EPA believes that reducing fish mortality from I&E mortality along with other measures would contribute to the recovery of damaged fish populations.

8.2.2 Marine Protected Areas

A Marine Protected Area (MPA) is “any area of the marine environment that has been reserved by federal, state, tribal, territorial, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein” (Executive Order No. 13158 2001). In some states, the majority of coastal waters are found within MPAs (e.g., Massachusetts, Hawaii). The ecological importance of MPAs varies widely because of their broad focus on the preservation and maintenance of cultural and natural resources, and/or sustainable production (NMPAC 2006). Consequently, evaluating the impact of CWISs on the entire universe of MPAs may overstate the nonuse values for the ecological benefits associated with reductions in I&E mortality. For this reason, EPA focused on MPAs within the National

Estuary Program (NEP). The NEP was established in the 1987 amendments to the Clean Water Act (CWA) because the "Nation's estuaries are of great importance to fish and wildlife resources and recreation and economic opportunity [and because maintaining] the health and ecological integrity of these estuaries is in the national interest" (Water Quality Act 1987). In addition to the 28 estuaries designated under the NEP (USEPA 2010a), EPA included facilities found in Chesapeake Bay (itself protected by the Chesapeake Bay Program [CBP]).

Substantial federal and state resources have been directed to the NEP and Chesapeake Bay Program to enhance conservation of and knowledge about estuaries. From 2005 to 2007, NEP budgeted $965 million to protect and restore aquatic habitat, conduct outreach and research, upgrade stormwater infrastructure, and implement other priority actions to benefit the health of the 28 constituent estuaries. Approximately $130 million (13.5 percent) of the funding was designated for restoration programs (USEPA 2008). Between fiscal years 1995 and 2004, direct funding by federal and state governments to restore Chesapeake Bay averaged $366 million (GAO 2005), with an additional $131 million in direct spending in fiscal year 2005 (CBP 2007). Moreover, recent governmental action is likely to increase federal spending on restoration efforts in the future (Executive Order No. 13508 2009). All told, these expenditures reflect high public values for restoring (or protecting) the biological integrity of these ecosystems.

A total of 116 Section 316(b) facilities exist on 75 waterbodies within MPAs designed to preserve natural resources and/or to ensure sustainable production (NOAA 2010b) (Figure 8-2; Table 8-1). Although these facilities are found in fresh, brackish, and marine waters, and in all regions of the country except California, the vast majority of 316(b) facilities occurring within MPAs occur in coastal waters, and are most highly concentrated in the Northeastern United States (i.e. both coastal and inland facilities) (Figure 8-2; Table 8-1). Under Option 1, 87 percent of in-scope facilities found within MPAs obtain reductions in impingement mortality (IM), while entrainment mortality (EM) is not reduced at any facilities (Table 8-1). Under Options 2 and 3, impingement mortality is reduced at 92 and 97 percent of 316(b) facilities in MPAs, while the addition of closed-cycle cooling results in reduced entrainment mortality at 72 and 92 percent of in-scope facilities found in MPAs, respectively (Table 8-1).

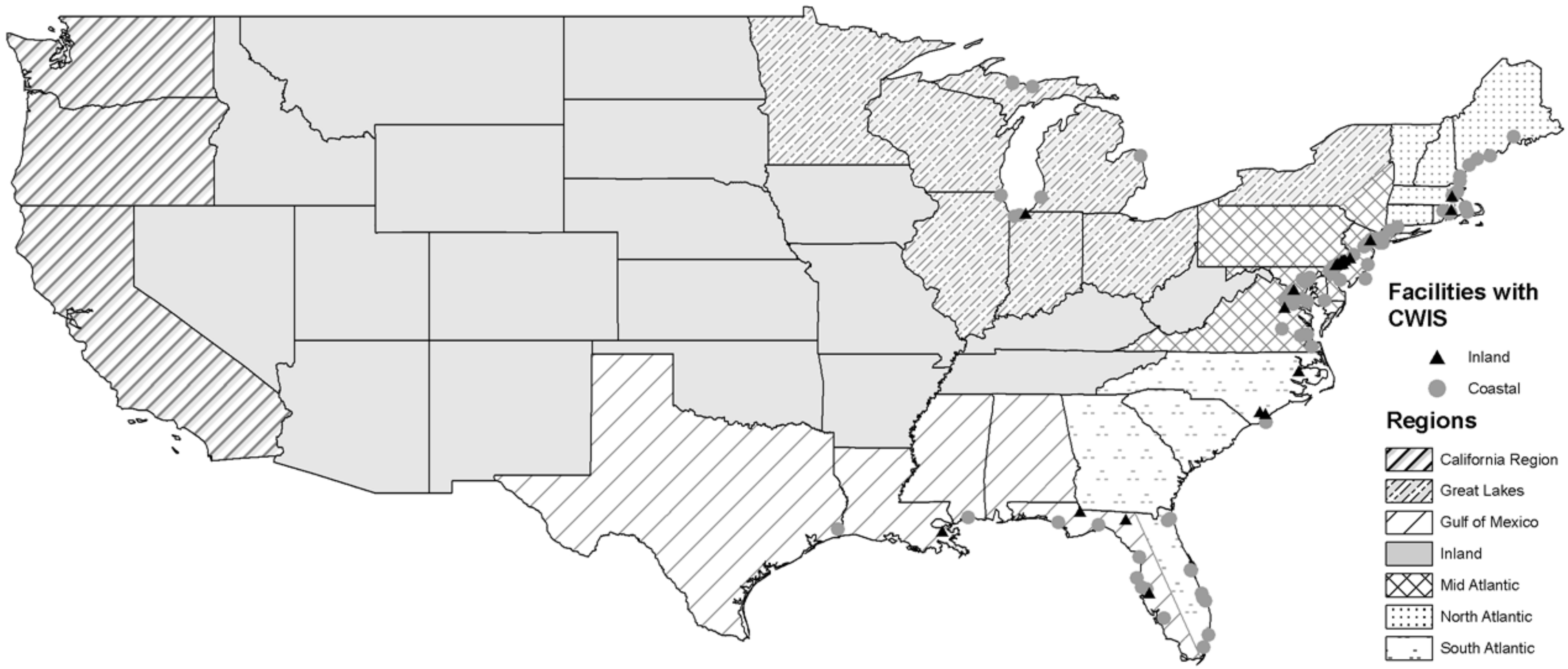


Figure 8-2: In-scope Facilities with CWISs Located In Marine Protected Areas.

Table 8-1: 316(b) Facilities in Marine Protected Areas, and Improvements in I&E Mortality Technologies by Regulatory Option

Benefits Region	Affected Waterbodies	Baseline 316(b) Facilities[a]	Number of Facilities with Improved Technologies by Policy Option					
			Option 1		Option 2		Option 3	
			I Mortality	E Mortality	I Mortality	E Mortality	I Mortality	E Mortality
California	0	0	0	0	0	0	0	0
North Atlantic	18	9	17	0	19	16	20	20
Mid-Atlantic	24	10	40	0	41	31	43	40
South Atlantic	5	23	10	0	10	9	10	9
Gulf of Mexico	9	44	8	0	10	10	10	10
Great Lakes	3	20	8	0	9	8	9	9
Inland	14	10	18	0	18	9	20	18
Total	**73**	**116**	**101**	**0**	**107**	**83**	**112**	**106**

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1= I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere.

8.2.3 Restoration of Freshwater Ecosystems

Reducing the effect of CWISs at 316(b) facilities is likely to benefit aquatic ecosystems nationwide, but the largest magnitude of improvements may occur in areas of the Great Lakes Basin and Mississippi River, with their high density of facilities. These freshwater bodies are subject to large-scale ecosystem restoration efforts that indicate public support for restoring the ecological health of these ecosystems (Northeast Midwest Institute 2010; USDOI 2008; USFWS 2011; Upper Mississippi River Basin Association 2004).

Nationally, ecosystem restoration efforts focus on many issues, including coastal habitat restoration, protection of fish species, and conservation of migratory birds. For example, the federal government provided in excess of $1.7 billion for sport fish restoration between fiscal years 2005-2009 (USFWS 2010d), and has initiated a 5-year multi-agency initiative to restore the ecosystems of the Great Lakes, for which $475 million was appropriated in fiscal year 2010 (CEQ et al. 2010). The restoration of major inland river ecosystems has been recognized as a worthwhile goal, with more than $100 million spent on restoring ecosystems along the Mississippi River (Brescia 2002; USEPA 2004c). Additionally, substantial federal funding for river restoration has been proposed for FY2011, with more than $730 million requested for major projects in the Missouri, Mississippi, Columbia, and Kissimmee rivers (USOMB 2010a; USOMB 2010b). These projects include the construction of fish ladders, restoration of wetland nursery habitat, and the reduction of pollution. These expenditures indicate a high value placed on the maintenance and restoration of ecosystem function and the integrity of freshwater ecosystems.

8.2.4 Summary of Evidence for Nonuse Values of Ecosystems Impacted by CWISs

Overall, the public appears to hold substantial nonuse values for ecosystems and species impacted by CWISs. For example, governments at various levels have committed to the designation of MPAs at large scales. Governments also have committed substantial resources to the restoration of degraded aquatic ecosystems. This evidence suggests that the nonuse benefits of 316(b) regulation, although unquantified, are substantial. Additional discussion of nonuse impacts occurring under baseline conditions is provided in Chapter 2.

8.3 Quantitative Assessment of Ecological Nonuse Benefits

Stated preference (SP) methods and benefit transfers based on SP studies are the generally accepted techniques for estimating nonuse values. SP methods rely on surveys that ask people to state their willingness to pay (WTP) for particular ecological improvements, such as increased protection of aquatic species or habitats with particular attributes. As mentioned above, EPA is in the process of developing a SP survey to estimate total WTP for improvements to fishery resources affected by I&E mortality from in-scope 316(b) facilities. This survey will provide estimates of total WTP which includes both use and nonuse values, will allow estimates of value associated with specific choice attributes (following standard methods for choice experiments), and will provide insight into the relative importance of use versus nonuse values in the 316(b) context. EPA did not have sufficient time before this notice of proposed rulemaking to fully develop and deploy this survey and thus derive estimates of the monetary value of reducing I&E mortality impacts at the national level. In the absence of original study values, EPA identified a recent SP study conducted by Johnston et al. (2009) that is closely related to the 316(b) policy context. Johnston et al. (2009) developed a Bioindicator-Based Stated Preference Valuation (BSPV) method specifically for applications to ecological systems.[32] Like EPA's planned survey, this study addresses policy changes that introduce forage fish to aquatic habitat but for which ultimate population effects are unknown. The study was originally developed to address Rhode Island residents' preferences for the restoration of migratory fish passage over dams within an in-state watershed. It estimates nonuse values by asking respondents to consider changes in ecological indicators reflecting quantity of habitat, abundance of wildlife, ecological condition, and abundance of migratory fish species.

EPA used Johnston et al. (2009) to conduct a benefits transfer to quantify nonuse benefits associated with reductions in I&E mortality under the 316(b) regulatory options for the North Atlantic and Mid-Atlantic benefits regions. The study's choice experiment allows direct estimation of households' WTP for policies that increase the number of fish in watersheds by changing human industrial uses of aquatic ecosystems. Section 8.3.1 describes Johnston et al. (2009) and BSPV methods in greater detail. This is followed by a description of EPA's benefits transfer methods using Johnston et al. (2009) (Section 8.3.2) and estimated benefits for 316(b) regulatory options (Section 8.4).

8.3.1 Description of Johnston et al. (2009) and BSPV Methods

Johnston et al. (2009) developed the BSPV method to promote ecological clarity and closer integration of ecological and economic information within SP studies. The study's focus on improved ecological valuation is an EPA priority as described in findings of EPA's Science Advisory Board on valuing the protection of Ecological System and Services (USEPA 2009b). In contrast to traditional SP valuation, BSPV employs a more structured and formal use of ecological indicators to characterize and communicate welfare-relevant changes. It begins with a formal basis in ecological science, and extends to relationships between attributes in respondents' preference functions and those used to characterize policy outcomes. Specific BSPV guidelines ensure that survey scenarios and resulting welfare estimates are characterized by (1) a formal basis in established and measurable ecological indicators, (2) a clear structure linking these indicators to attributes influencing individuals' well-being, (3) consistent and meaningful interpretation of ecological information, and (4) a consequent ability to link welfare measures to measurable and unambiguous policy outcomes. The welfare measures provided by the BSPV method can be unambiguously linked to models and indicators of ecosystem function, are based on measurable

[32] The study was funded by the EPA's Science to Achieve Results (STAR) competitive grant program.

ecological outcomes, and are more easily incorporated into benefit cost analysis. It also provides a means to estimate values for ecological outcomes that individuals might value, even though they may not fully understand all relevant ecological science.

Johnston et al. (2009) developed the BSPV methods for a case study addressing public preferences for the restoration of migratory fish passage in Rhode Island's Pawtuxet Watershed. The BSPV survey (*Rhode Island River: Migratory Fishes and Dams*) was designed to estimate WTP of Rhode Island residents for options that would provide fish passage over dams and access to between 225 and 900 acres of historical habitat within the Pawtuxet Watershed to which there is currently no fish passage. The watershed currently provides no spawning habitat for migratory fish; access to all 4,347 acres of potential habitat is blocked by 22 dams and other obstructions (Erkan 2002).

The survey was developed and tested over 2½ years through a collaborative process involving interactions of economists and ecologists; meetings with resource managers, natural scientists, and stakeholder groups; and 12 focus groups with 105 total participants. In addition to survey development and testing in focus groups, individual interviews were conducted with both ecological experts and non-experts. These included cognitive interviews (Kaplowitz et al. 2004), verbal protocols (Schkade and Payne 1994) and other pretests conducted to gain additional insight into respondents' understanding and interpretation of the survey. Careful attention to development and testing helped ensure that the survey language and format would be easily understood by respondents, that respondents would have similar interpretations of survey terminology and scenarios, and that the survey scenarios captured restoration outcomes viewed as relevant and realistic by both respondents and natural scientists. In all cases, survey development paid particular attention to the use and interpretation of ecological indicators and related information in the survey.

The choice scenarios and restoration options presented within the survey were informed in part by data and restoration priorities in the *Strategic Plan for the Restoration of Anadromous Fishes to Rhode Island Coastal Streams* (Erkan 2002). Additional information was drawn from the ecological literature on fish passage restoration, interviews with ecologists and policy experts, and other sources described below. Consistent with the strategic plan, the choice experiment within the survey addressed restoration methods that neither require dam removal nor would cause appreciable changes in river flows; considered options included fish ladders, bypass channels and fish lifts. The choice experiment addresses forage species such as alewife and blueback herring that neither are subject to current recreational or commercial harvest in Rhode Island nor are charismatic species. Hence, the species affected are a close analog to the forage fish affected in the 316(b) policy context. Moreover, the policy context of Johnston et al. (2009) involves changes to technologies used within in-water structures (i.e., the use of fish ladders or fish lifts at dams), providing another parallel to the 316(b) context, which also involves the use of new technologies within in-water structures to mitigate harm to aquatic organisms.

The choice experiment asked respondents to consider alternative options for the restoration of migratory fish passage in the Pawtuxet Watershed. Respondents were provided with two multiattribute restoration options, "Restoration Project A" and "Restoration Project B," as well as a status quo option that would result in no policy change and zero household cost. An example choice question is presented in Figure 8-3. Prior to administration of the choice experiment questions, the survey provided information: (1) describing the current status of Rhode Island river ecology and migratory fish compared to historical baselines, (2) characterizing affected ecological systems and linkages, (3) describing the methods and details of fish passage restoration, and (4) providing the definitions, derivations and interpretations of ecological indicators used in the survey scenarios, including the reason for their inclusion. All survey language and graphics were pretested carefully to ensure respondent comprehension.

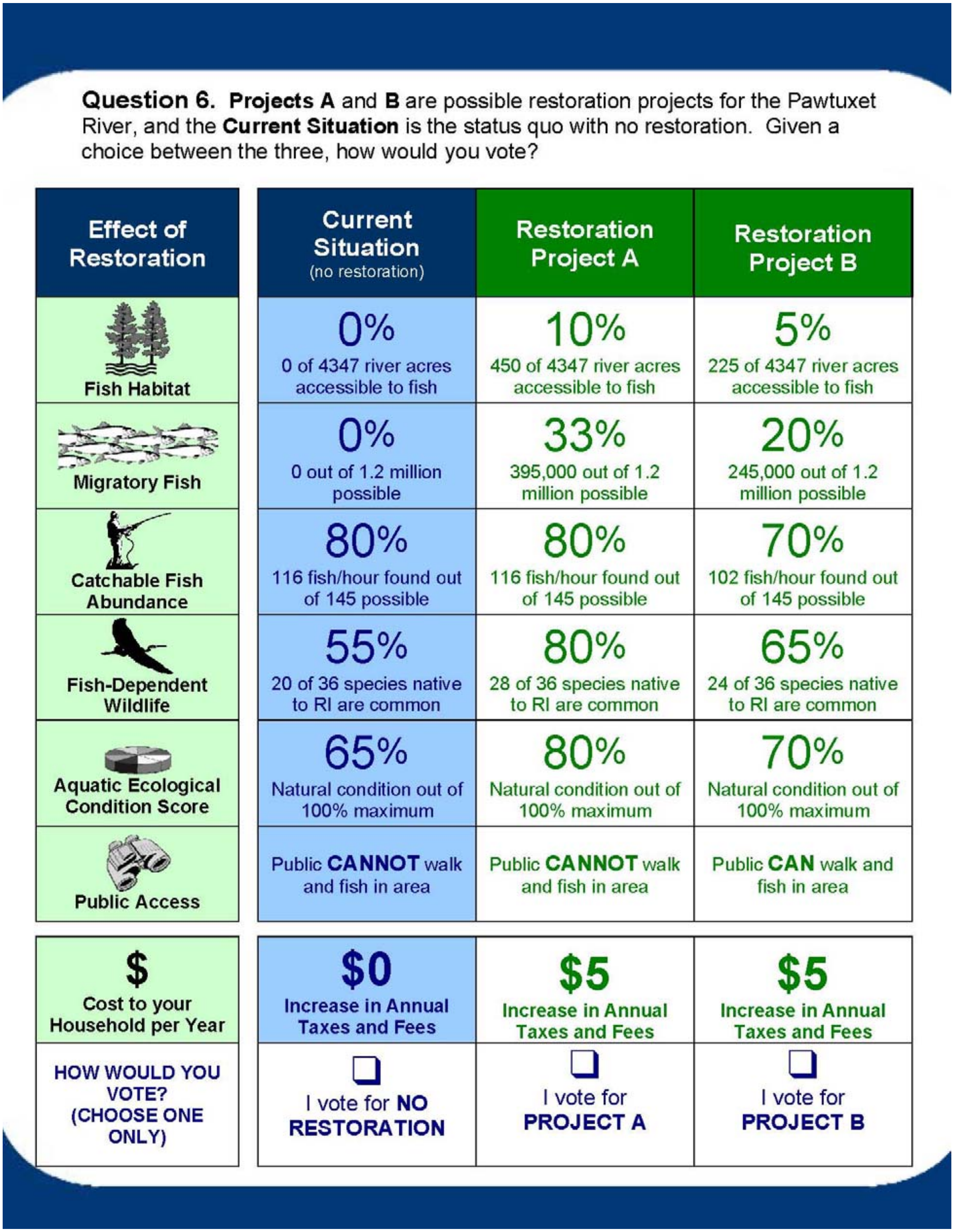
The restoration options are characterized by seven attributes, including five ecological indicators, one attribute characterizing public access, and one attribute characterizing unavoidable household cost. The included ecological indicators characterize: (1) the quantity of river habitat accessible to migratory fishes, (2) the number of fish migrating to upstream habitat, (3) the abundance of fish suitable for recreational harvest, (4) the abundance of fish-dependent wildlife, (5) and overall ecological condition.

8.3.2 Benefits Transfer Methodology

The following subsections describe EPA's benefits transfer methods using the BSPV study. Section 8.3.2.1 describes the estimation of WTP for a percentage increase in fish numbers using the BSPV study, and Section 8.3.2.2 describes the application of BSPV WTP values to I&E mortality reductions under 316(b) regulatory options.

8.3.2.1 Estimating WTP for a Percentage Increase in Fish Numbers

As shown in Figure 8-3, within Johnston et al. (2009)'s choice scenarios each ecological attribute is expressed in relative terms with regard to upper and lower reference conditions (i.e., best and worst possible in the Pawtuxet) as defined in survey informational materials. Relative scores represent percent progress towards the upper reference condition (100 percent), starting from the lower reference condition (0 percent). This also implies bounds on the potential attribute levels that might occur in the choice questions, following guidance in the literature to provide visible choice sets (Bateman et al. 2004). The number of fish affected by 316(b) regulations is many times larger than that considered by Johnston et al. (2009) — therefore it would be inappropriate to apply the Johnston et al. (2009) values per fish to the 316(b) fish reduction estimates (which exceed the maximum reference condition for Johnston et al. (2009)) to obtain a WTP value for this rulemaking. In order to conduct a benefit transfer that closely follows Johnston et al. (2009)'s study design for the Pawtuxet Watershed, resource improvements should be expressed as a percentage improvement relative to the existing resource condition. A variant of Johnston et al.'s (2009) model was hence used to conduct a benefit transfer predicated on percentage improvements in the fish condition, relative to the reference condition for each ecosystem. As improvements are bounded by the 100 percent reference condition in all cases, this at least partially ameliorates the scale concern described above. The remainder of this section describes EPA approach for estimating WTP per percentage improvement based on Johnston et al. (2009).



Question 6. **Projects A** and **B** are possible restoration projects for the Pawtuxet River, and the **Current Situation** is the status quo with no restoration. Given a choice between the three, how would you vote?

Effect of Restoration	Current Situation (no restoration)	Restoration Project A	Restoration Project B
Fish Habitat	0% 0 of 4347 river acres accessible to fish	10% 450 of 4347 river acres accessible to fish	5% 225 of 4347 river acres accessible to fish
Migratory Fish	0% 0 out of 1.2 million possible	33% 395,000 out of 1.2 million possible	20% 245,000 out of 1.2 million possible
Catchable Fish Abundance	80% 116 fish/hour found out of 145 possible	80% 116 fish/hour found out of 145 possible	70% 102 fish/hour found out of 145 possible
Fish-Dependent Wildlife	55% 20 of 36 species native to RI are common	80% 28 of 36 species native to RI are common	65% 24 of 36 species native to RI are common
Aquatic Ecological Condition Score	65% Natural condition out of 100% maximum	80% Natural condition out of 100% maximum	70% Natural condition out of 100% maximum
Public Access	Public **CANNOT** walk and fish in area	Public **CANNOT** walk and fish in area	Public **CAN** walk and fish in area
$ Cost to your Household per Year	**$0 Increase in Annual Taxes and Fees**	**$5 Increase in Annual Taxes and Fees**	**$5 Increase in Annual Taxes and Fees**
HOW WOULD YOU VOTE? (CHOOSE ONE ONLY)	❑ I vote for **NO RESTORATION**	❑ I vote for **PROJECT A**	❑ I vote for **PROJECT B**

Figure 8-3: Example Choice Experiment Question from Johnston et al. (2009)

When specifying mixed logit models for SP choice experiments, economic theory provides guidance regarding certain aspects of model specification. For example, the parameter on program cost is expected to have a negative sign, reflecting a positive marginal utility of income. To ensure an appropriate sign for this parameter within mixed logit models, a common solution is to specify a lognormal distribution on the sign-reversed cost parameter. This solution, however, leads to well-known ambiguities for WTP estimation related to the long right-hand tail of the lognormal distribution, and often unrealistic mean WTP estimates over the entire distribution (Hensher and Greene 2003; Johnston and Duke 2007). As a result of this well-established problem, Hensher and Greene (2003, p. 148) recommend alternatives including the bounded triangular distribution for the program cost parameter.

Here, following Hensher and Greene (2003), the random utility model is estimated using maximum likelihood ML with Halton draws in the likelihood simulation. Coefficients on program cost (*cost*) and *migrants* (the percentage point increase in the number of migratory fish able to reach watershed habitat) are important for estimating WTP for a percentage increase in fish numbers. Coefficients on all variables except that on program cost (*cost*) are specified as random with a normal distribution. This includes the variable *migrants.* The coefficient on annual household cost (*cost*) is specified as random with a bounded triangular distribution as specified above with the mean equal to the spread (m=s), ensuring a positive marginal utility of income. Sign-reversal is applied to the cost variable prior to estimation, so that the expected parameter sign is positive (Hensher and Greene 2003).[33] Table 8-2 presents model results.

Because the mixed logit model includes random coefficients, EPA estimated WTP using the welfare simulation approach of Johnston and Duke (2007; 2009) following Hensher and Greene (2003). The procedure begins with a parameter simulation following the parametric bootstrap of Krinsky and Robb (1986), with R=1000 draws taken from the mean parameter vector and associated covariance matrix. For each draw, the resulting parameters are used to characterize asymptotically normal empirical densities for fixed and random coefficients. For each of these R draws, a coefficient simulation is then conducted for each random coefficient, with S=1000 draws taken from simulated empirical densities. Here, all coefficient simulations draw from a normal distribution except for that on cost, which draws from a bounded triangular distribution with m=s=0.05148015. Because the use of a triangular distribution on program cost ameliorates the "long tails" problem of the lognormal distribution, and also due to differences in the estimated functional form, these results provide lower WTP estimates, particularly for relatively small increases in fish numbers. Welfare measures are calculated for each draw, resulting in a combined empirical distribution of $R \times S$ observations from which summary statistics are derived. The resulting empirical distributions accommodate both the sampling variance of parameter estimates and the estimated distribution of random parameters. Here, we follow Hu et al. (2005) and simulate welfare estimates as the mean over the parameter simulation of mean WTP calculated over the coefficient simulation (i.e., mean of mean WTP).

[33] Because the mixed logit model includes random coefficients, we estimate WTP using the welfare simulation approach of Johnston and Duke (2007; 2009) following Hensher and Greene (2003). The resulting empirical distributions accommodate both the sampling variance of parameter estimates and the estimated distribution of random parameters. We follow Hu et al. (2005) and simulate welfare estimates as the mean over the parameter simulation of mean WTP calculated over the coefficient simulation (i.e., mean of mean WTP).

Table 8-2: Results of Mixed Logit Maximum Likelihood Estimation (Bounded Triangular Cost)

Variable	Coefficient	Standard Error	b/ St. Er.	P[|Z|>z]
Random parameters in utility functions				
NEITHER	-5.412	1.489	-3.635	0.000
ACRES	0.047	0.013	3.637	0.000
MIGRANT	0.028	0.009	3.266	0.001
ACCESS	1.538	0.274	5.609	0.000
CATCH	-0.004	0.008	-0.474	0.635
WILD	0.024	0.009	2.755	0.006
IBI	0.016	0.017	0.957	0.338
COST	0.051	0.009	5.998	0.000
Derived standard deviations of parameter distributions				
NsNEITHER	5.424	1.140	4.760	0.000
NsACRES	0.076	0.028	2.686	0.007
NsMIGRANT	0.004	0.017	0.214	0.831
NsACCESS	1.950	0.372	5.239	0.000
NsCATCH	0.030	0.031	0.981	0.326
NsWILD	0.031	0.024	1.279	0.201
NsIBI	0.043	0.036	1.181	0.238
TsCOST	0.051	0.009	5.998	0.000

Parameter Descriptions:
neither – Alternative specific constant (ASC) associated with the status quo, or a choice of neither plan.
acres – The number of acres of river habitat accessible to migratory fish.
migrant - The percentage point increase in the number of migratory fish able to reach watershed habitat.
access – Indicates whether the restored area is accessible to the public for walking and fishing.
catch – The number of catchable-size fish in restored areas.
wild – Number of fish-eating wildlife species that are common in restored areas.
IBI – Index of biotic integrity (IBI) score reflecting the similarity of the restored area to the most undisturbed watershed in Rhode Island.
cost – The household annual cost required to implement the restoration program.

Estimated benefit functions from the EPA/STAR choice experiment survey allow one to distinguish benefits associated with resource uses from those associated primarily with nonuse motives. Within the benefit transfer application, WTP is quantified for increases in non-harvested fish alone based on the implicit price for migratory fish changes. This transfer holds constant all effects related to identifiable human uses (e.g., effects on catchable fish, public access, observable wildlife, etc.). The remaining welfare effects—derived purely from effects on forage fish with little or no direct human use—may therefore be most accurately characterized as a nonuse benefit realized by households.

The above simulation provides a WTP estimate of $0.76 per percentage point increase in migratory fish, where zero represents no fish and 100 percent represents the maximum possible number of fish that may be supported by the ecosystem, following Johnston et al. (2009). Results for total household WTP for a series of percentage improvements in fish numbers are shown below in Table 8-3.[34] These percentage improvements do not represent population increases; rather, they reflect new fish within a specific habitat

[34] Within the Pawtuxet Watershed study area (the original study location), each percentage point increase in migratory fish is equivalent to 12,250 individual fish.

area that may be counted. EPA transferred this estimate of $0.76 per percentage improvement to estimate nonuse benefits of 316(b) regulatory options.

Table 8-3: WTP per Percentage Increase in the Number of Fish

Percentage Point Increase in Number of Fish	WTP per % Increase in the Number of Fish	Total WTP per Household
1	$0.76	$0.76
12	$0.76	$9.13
20	$0.76	$15.21
33	$0.76	$25.10
100	$0.76	$76.05

8.3.2.2 Estimating Total WTP for Eliminating or Reducing I&E Mortality at CWISs

The BSPV study was developed as a case study is for a watershed-level policy in Rhode Island. While it provides parameterized benefit functions that require the fewest assumptions to implement for benefit extrapolation to the 316(b) case, estimates are likely to be representative of nonuse values held by individuals residing in the Northeast U.S. EPA expects that it would provide less accurate estimates of nonuse values for residents of other U.S. regions outside the Northeast. EPA was unable to identify valuation studies conducted in other regions which would provide benefit functions of comparable quality and applicability to the 316(b) regulatory context. Although other studies in the literature value changes in aquatic resources, they don't provide a good match to the 316(b) policy scenario in terms of the expected resource change. The large number of assumptions required for developing benefits transfer based on these studies would result in greater uncertainties compared to application of the BSPV study. Therefore, EPA restricted the benefits transfer to the North Atlantic and Mid-Atlantic EPA 316(b) study regions.

The structure of the BVSP choice experiment dictates that WTP estimates for each species are not additive. Rather the overall WTP should be evaluated based on the single species that would experience the greatest relative increase in abundance from restoration. To match the original valuation scenario to the 316(b)policy scenario , EPA evaluated model results and available biological data to determine the species for which relative abundance is most affected by I&E mortality. By comparing baseline age-1 equivalent losses to an estimate of total baseline fish abundance. EPA identified winter flounder as the species suffering the greatest from baseline I&E mortality in the Northeast U.S. (i.e., North Atlantic and Mid-Atlantic regions). EPA's analysis was limited to species with readily available estimates of spawning stock biomass for the Northeast U.S. from stock assessments conducted by the NOAA Northeast Fisheries Science Center. This included a review of four species:winter flounder, striped bass, bluefish, and Atlantic butterfish. (Table 8-4). All four species are harvested commercially, however fish of commercial species may be forage during early life-stages and have nonuse values. The total baseline I&E mortality in the North-Atlantic and Mid-Atlantic regions were evaluated together to represent the Northeast U.S. for consistency with the available stock assessments, which include waters from Maine south to North Carolina.

Table 8-4: Baseline I&E Mortality Losses and Estimated Fish Numbers for the Northeast U.S. (North Atlantic and Mid-Atlantic Regions)		
Species	**Baseline I&E Losses (millions of A1E)**	**Estimated Fish Numbers (millions)[a]**
Winter Flounder	6.502	21.1
Striped Bass	1.399	14.3
Bluefish	0.001	116.1
Atlantic Butterfish	0.008	28.9

[a] Estimated population size was calculated by applying a conversion factor (lbs per fish) to an esitmate of spawning stock biomass.

EPA expects that decreasing I&E mortality will lead to increased fish abundance in affected waterbodies. EPA assumes that the total number of fish introduced to local habitats throughout the Northeast under each regulatory option would be equivalent to the sum of age-1 equivalent reductions for the North Atlantic and Mid-Atlantic regions. Application of the BSPV model results requires that the increases be expressed as a percentage improvement from current conditions relative to a maximum number of fish that could be supported by the ecosystem. EPA assumed a maximum of 99 million fish based on the estimated biomass maximum sustainable yield from the Northeast Fisheries Science Center assessment of the Southern New England stock (NOAA 2006) and a conversion factor of 1.2 lbs pounds per fish.

EPA's calculation of nonuse values from eliminating or reducing I&E mortality losses for each regulatory option involved the following steps:

1. Calculate the percent change increase in total winter flounder numbers in the Northeast U.S. (the North Atlantic and Mid-Atlantic regions combined) by comparing age-1 equivalent reductions under each regulatory option relative to a baseline of 99 million fish.
2. Multiply the percentage change in fish numbers by $0.76 (Table 8-3) to calculate the WTP per household per year for the relative increase in winter flounder numbers resulting from the regulatory option.
3. Calculate regional WTP for each regulatory option by multiplying WTP per household by the total number of households within the North Atlantic and Mid-Atlantic regions, respectively.

The results from implementing these steps for each of the 316(b) regulatory options are described in Section 8.4.

8.4 Estimates of Total WTP by Option and Region

Table 8-5 summarizes EPA's estimates of WTP for increased fish numbers resulting from the 316(b) regulatory options in the North Atlantic and Mid-Atlantic regions. EPA estimates that elimination of baseline losses would increase the number of winter flounder in the Northeast U.S. by more than 6.5 million fish. This is equivalent to a 6.6 percent increase in winter flounder relative to a maximum of 99 million fish (i.e., 6.5 million divided by 99.0 million). Multiplying the 6.6 percent increase by a value of $0.76 per percentage increase (as presented in Table 8-3) yields a household WTP of $4.99 per year. Applying the household WTP values to the number of households in each region results in annualized WTP values of $26.3 million and $102.3 million for the North Atlantic and Mid-Atlantic regions, respectively, using a discount rate of 3 percent. Annualized WTP values are $26.8 million for the North Atlantic and $104.0 million for the Mid-Atlantic using a discount rate of 7 percent.

EPA estimates that Option 1 would increase winter flounder numbers by less than 0.1 percent in the North Atlantic and Mid-Atlantic waters. Applying per household WTP to this percent increase in the number of winter flounder ($0.02) to the number of households in each region yields the total WTP for improvements in winter flounder abundance. The estimated annualized WTP values are approximately $0.1 million and $0.4 million for the North Atlantic and Mid-Atlantic regions, respectively, using both 3 percent and 7 percent discount rates (Table 8-5). Table 8-5 also presents household WTP and annualized WTP for Option 2 and Option 3.

Table 8-5: Nonuse Value of Eliminating or Reducing Baseline I&E Mortality Losses by Regulatory Option for All In-scope Facilities in the North Atlantic and Mid-Atlantic Regions

	Baseline	**Option 1**	**Option 2**	**Option 3**
Reduction in Northeast IM&EM (millions of age-1 equivalents)	6.50	0.03	5.32	5.57
Maximum Population (millions of fish)	99.0	99.0	99.0	99.0
Percentage Increase in Fish within Northeast Waters	6.56%	0.03%	5.37%	5.63%
Household WTP per Percent Increase in Fish Numbers (2009$)	$0.76	$0.76	$0.76	$0.76
Annual WTP per Household (2009$)	$4.99	$0.02	$4.08	$4.28
North Atlantic				
Number of Households (millions)	5.4	5.4	5.4	5.4
Annual WTP (millions of 2009$)	$26.9	$0.1	$22.0	$23.1
Annualized WTP (3% discount rate; millions of 2009$)	**$26.3**	**$0.1**	**$14.8**	**$15.5**
Annualized WTP (7% discount rate; millions of 2009$)	**$26.8**	**$0.1**	**$11.5**	**$12.0**
Mid-Atlantic				
Number of Households (millions)	21.0	21.0	21.0	21.0
Annual WTP (millions of 2009$)	$104.6	$0.5	$85.6	$89.7
Annualized WTP (3% discount rate; millions of 2009$)	**$102.3**	**$0.4**	**$57.3**	**$60.0**
Annualized WTP (7% discount rate; millions of 2009$)	**$104.0**	**$0.4**	**$44.5**	**$46.5**

Scenarios: Baseline = Elimination of Baseline I&E Mortality losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities with > 125 MGD; Option 3 = I&E Mortality Everywhere

8.5 Limitations and Uncertainties

A number of issues are common to all benefit transfers. Benefit transfer involves adapting research conducted for another purpose in the available literature to address the policy questions at hand. Because benefits analysis of environmental regulations rarely affords enough time to develop original SP surveys that are specific to the policy effects, benefit transfer is often the only option to inform a policy decision. Some of the limitations and uncertainties associated with implementing a benefits transfer using Johnston et al. (2009) are addressed below. Broader limitations and uncertainties associated with benefit transfer in general are discussed by Johnston and Rosenberger (2010).

8.5.1 Scale of Fishery Improvements

Given the scale of the Johnston et al. (2009) survey upon which these results are based, the most reliable results apply within the range of the choice experiment data (e.g., fish percentage point increases < 33 percent). Again, the maximum possible increase within the Pawtuxet policy context, 100 percent, is defined as the maximum number of fish that can be supported by the Pawtuxet Watershed with fish passage. Transfer to increases in fish below this magnitude may introduce uncertainty in the WTP estimate per percentage increase in fish numbers.

8.5.2 Scale and Characteristics of the Affected Population

The results of Johnston et al. (2009) reflect WTP for improvements in nearby watersheds, and there may be a decline in WTP as policy areas become more distant. The most reliable application of these results would be to calculate WTP for I&E mortality reductions in a single local watershed. However, the 316(b) regulation would reduce I&E mortality losses and would improve fish populations in multiple watersheds within some states. As noted, it was assumed for these purposes that households have consistent values for improvements in multiple watersheds within their state or region. Moreover, for transfers based on absolute fish numbers, it is assumed that the per household WTP for changes in the numbers of fish for all watersheds located within their state, including watersheds that are shared by multiple states, would be at least equal to the WTP value for improvements in a single watershed. Hence, estimated per household WTP is based on the average watershed improvement within the state—an approach to scale effects that likely provides conservative welfare estimates.

The Johnston et al. (2009) study context was a single watershed in Rhode Island. Using the benefits transfer approaches outlined here, the benefit function is applied to all states in the North Atlantic and Mid-Atlantic regions without adjustment, based on mean household income or local watershed characteristics. Some heterogeneity in WTP would be expected across states and regions due to diversity in species and public values. EPA did not extend the benefits transfer beyond the North Atlantic and Mid-Atlantic regions because of the potential for substantial differences in preferences, demographics, and species characteristics in other regions compared to the original context of Johnston et al. (2009).

8.5.3 Fish Population Size, Type and Improvement from the Elimination of I&E Mortality

For the purposes of the benefit transfer it was assumed that the number of fish gained by eliminating I&E mortality would be equal to baseline I&E mortality losses and reductions under each option. These increases are not intended to represent changes in fish population.

There is some uncertainty regarding the geographic range of species included in the analysis. Based on information from NOAA Northeast Fisheries Science Center, the range of species included here extends south of the Mid-Atlantic region to North Carolina. The lack of adjustment based on the additional geographic range factor leads to more-conservative estimates of benefits to the North Atlantic and Mid-Atlantic regions.

Finally, while both the study and policy contexts involve forage fish, the specific species compositions involved differ between Johnston et al. (2009) and 316(b). For example, most of the fish affected within Johnston et al. (2009) are migratory fish such as river herring, while such species may make up a smaller proportion of those affected by CWISs. If WTP is sensitive to the specific type of forage fish involved, this could be a potential source of generalization error.

9 Habitat Based Methodology for Estimating Nonuse Values of Fish Production Lost to I&E Mortality

9.1 Introduction

The loss of commercially- or recreationally-important aquatic species due to impingement and entrainment mortality (I&E mortality) at CWISs is typically valued as a direct use loss (e.g., commercial and recreational harvest). However, aquatic species without any direct uses account for 97.3 percent of I&E mortality at cooling water intake structures (CWIS) (Chapter 3). Therefore, estimating the total (inclusive of nonuse) value of these losses is important when determining the benefits of reducing impingement and entrainment (I&E) mortality.

One way to estimate the value of direct I&E mortality is to approximate the area of habitat required to produce and support these organisms. Because fish habitat has been valued by many existing studies, habitat provides an indirect basis for valuing the nonuse values of fish. These values may be transferred because members of the general public are aware of the fish production services provided by eelgrass (submerged aquatic vegetation, SAV) and wetlands; individuals express support for programs that include increasing SAV and wetland areas with the expressed goal of restoring depleted fish and shellfish populations (Mazzotta 1996; Opaluch et al. 1995; 1998).

Thus, the habitat-based method for estimating nonuse values of fish lost to I&E mortality is a two-step process. First, the area of habitat required to replace fish and shellfish lost to I&E mortality is estimated. The public's WTP for this habitat is then assessed. When combined, these data yield an estimate of household values for improvements in fish and shellfish habitat, which in turn provides an indirect estimate of the benefits of reducing or eliminating I&E mortality.

This benefit transfer approach involves four general steps:

1. Estimate the area of habitat necessary to support the number of organisms lost to I&E mortality.
2. Develop WTP values for fish production services of habitat ecosystems.
3. Estimate the total value of baseline nonuse I&E mortality by multiplying WTP values for fish and shellfish services by the area of habitat required to offset I&E mortality.
4. Estimate the direct nonuse benefits of proposed regulatory options, in terms of the value of decreased I&E mortality, by multiplying WTP values for fish and shellfish services by the area of habitat required to offset I&E mortality.

This methodology estimates only those nonuse values related to I&E mortality of organisms, and not any indirect ecosystem effects of I&E mortality, or or chemical effects of CWISs (Chapter 2). EPA does not include values generated using this habitat based approach within its estimates of total benefits for eliminating or reducing I&E mortality under the 316(b) regulatory options. While they illustrate the potential magnitude of nonuse values, EPA does not consider HEA appropriate for a primary analysis of nonuse benefits. The remainder of this chapter describes the methodology and estimates of total WTP values for lost aquatic organisms, using a habitat equivalency analysis in conjunction with a benefit transfer of habitat values. It also includes a description of limitations and uncertainties of this approach.

9.2 Estimating the Amount of Habitat Needed to Offset I&E Mortality

The first step in the habitat-based method for valuing nonuse I&E mortality values is estimating the area of habitat needed to offset I&E mortality. The process of quantitatively adjusting the size of the restoration action such that the services that it provides equal those that were lost due to I&E mortality of aquatic organisms is referred to as restoration scaling (NOAA 2006; Strange et al. 2002). A restoration project is correctly "scaled" when it achieves ecological equivalence. Ecological equivalence is met when the magnitude of a restoration reproduces the ecological services provided by a resource prior to injury.

Restoration scaling approaches are based on the principles of Habitat Equivalency Analysis (HEA). HEA was developed by the National Oceanic and Atmospheric Administration (NOAA) to determine public compensation for natural resource losses following natural resource damage assessments (NRDAs) that occur under the auspices of the Oil Pollution Act (OPA). HEA is a service-to-service scaling approach: it does not assume a one-to-one trade-off in resources, but instead in the natural resource services that these resources provide (NOAA 2006). In order to fully compensate for natural resource damages, restoration action must provide services of the same type and quality as those lost. Discounting is used to account for time lags between the loss of services and their restoration.[35]

To estimate the impact of I&E mortality and the benefits of regulation using a habitat-based methodology, EPA selected a trophic transfer approach to scale restoration. The trophic transfer approach is based on food-web connectivity that occurs between primary producers and the production of resident and transient fish (French McCay and Rowe 2003; Kneib 2003). Using this approach, the area of habitat necessary to provide fish and shellfish lost due to I&E mortality is calculated through food-web interactions to estimate the area of habitat necessary to compensate for these losses. Such an approach has been used to scale restoration to compensate for injuries to aquatic resources under various NRDAs as well as for estimating restoration necessary to compensate for I&E mortality under the National Pollutant Discharge Elimination System (NPDES) permitting process (Balletto et al. 2005; French McCay et al. 2002; NOAA 2009; Penn and Tomasi 2002; PSEG 2006; Teal and Weinstein 2002). The trophic transfer approach requires four basic steps to estimate the area of habitat restoration necessary to compensate for I&E mortality (Figure 9-1).

EPA estimated values in each region using a single habitat characteristic of the region. Although the Agency recognizes that many species lost to I&E mortality rely upon more than one habitat during their life history, a single habitat was chosen as most representative for each region to ensure data availability, ensure calculation simplicity, and provide a representative habitat required by many species in the region.

9.2.1 Quantify the Mass of Production Lost to I&E Mortality

The first step in application of the trophic transfer is estimating the mass of production lost to I&E mortality. This calculation requires estimating the number of organisms lost to I&E mortality on an annual basis (Chapter 3) as well as determining the annual reduction of productivity as a consequence of these losses. Additionally, this step requires estimating the benefits projected to accrue as a result of regulation.

[35] "The discount rate incorporates the standard economic assumptions that people place a greater value on having resources available in the present than on having their availability delayed until the future" (p.7) (NOAA 2006). For the methods discussed, the standard discount rate is 3%.

Within the trophic transfer framework, losses are calculated as the annual biomass production associated with organisms lost to I&E mortality. The vast majority of organisms lost to I&E mortality are less than 1 year of age at the time of loss (numerically, the greatest losses occur for eggs and larvae, as discussed in Chapter 3). For this reason and to simplify computation, EPA converted all I&E mortality to age-1 equivalents. These losses were then multiplied by the mass of age-1 equivalents and the ratio of dry to wet mass to estimate the dry mass of lost productivity on an annual basis (Appendix Equation J-1).

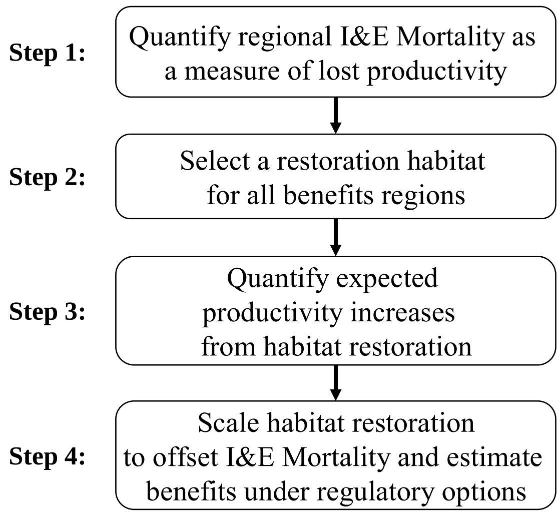


Figure 9-1: Implementation of the Trophic Transfer Approach

9.2.2 Production per Unit of Habitat

The second step for implementation of the trophic transfer is the calculation of production per unit of habitat. Each acre of restored habitat generates some quantity of primary productivity per year, measured here as the annual accumulation rate of dry biomass (i.e., kg dry mass per acre per year). Some proportion of this productivity is exported from the ecosystem due to factors such as water movement; this productivity is not available to the ecosystem. Remaining primary productivity is then converted to secondary productivity using trophic conversion based on a highly simplified four-level food chain (Figure 9-2). Trophic conversion efficiencies (or trophic transfers) refer to the inefficiency of energy exchange between trophic levels. They can be thought of as the production rate of biomass of predatory organisms per unit biomass of food (Penn and Tomasi 2002; Strange 2008). EPA assumed that all consumers in the simplified food chain model are food-limited, and that the production of consumers is proportional to gains in prey abundance based on trophic conversion efficiencies (French McCay and Rowe 2003).

EPA specified all I&E mortality species as secondary consumers when scaling restoration.[36] Thus, to compare fish production lost to I&E mortality to production gained through habitat restoration, primary productivity from habitat must to be converted to an equivalent amount of production of secondary

[36] EPA's assumption that I&E mortality species are secondary consumers is consistent with PSEG's assumptions when scaling restoration for the Salem facility (e.g., Balletto et al. 2005; PSEG 2006) and assumptions in multiple NRDAs when scaling restoration to compensate for fish losses due to oil spills (e.g., French McCay et al. 2002; Penn and Tomasi 2002).

consumer. This calculation requires estimated values for primary production, carbon export, and conversion efficiencies from primary production to detritus, detritus to primary consumers, and primary consumers to secondary consumers (Appendix Equation J-2). The remainder of this section describes these parameters in detail, and how EPA obtained estimates of these values.

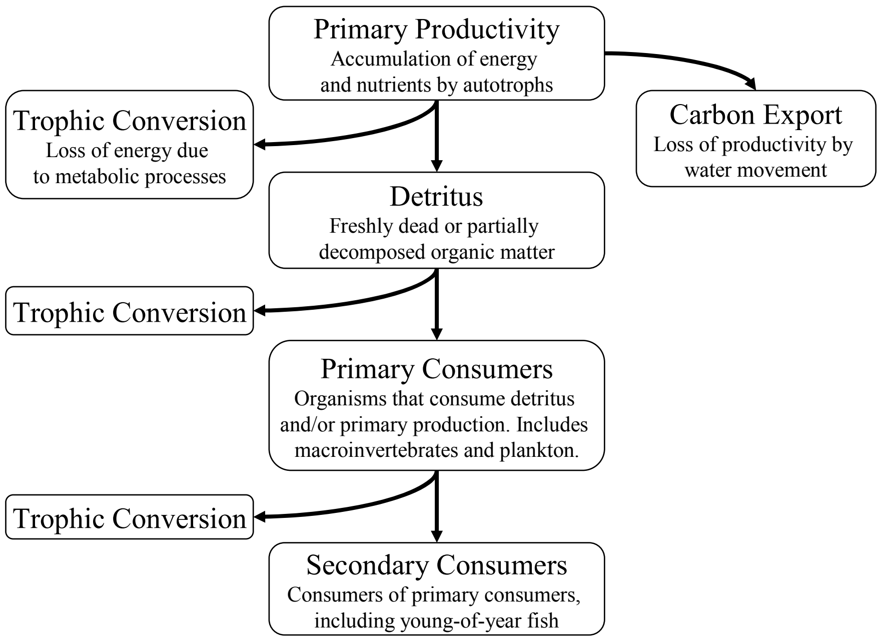


Figure 9-2: Trophic Levels and Processes Calculated with the Simplified, Four Level Trophic Transfer Model

9.2.2.1 Primary Production per Acre

EPA identified five habitat types for scaling regional I&E mortality losses based on (1) importance as foundation species (i.e., species involved in habitat formation) with trophic linkages to secondary production, (2) regional geographic distribution, and (3) the availability of published values of primary productivity (Section 9.2.3). These habitats include: eelgrass (*Zostera marina*) meadows in the North Atlantic; saltmarsh dominated by smooth cordgrass *(Spartina alterniflora*) in the Mid-Atlantic, South Atlantic and Gulf of Mexico; giant kelp (*Macrocystis pyrifera*) forests in California; and wetlands dominated by broadleaf cattail (*Typha latifolia*) in the Inland and Great Lakes regions.

Although estimates of primary productivity (*PP*) are best generated through site-specific study, it is common for analysts to use estimates from the literature when scaling restoration (e.g., French McCay et al. 2002; Penn and Tomasi 2002). EPA identified peer-reviewed sources for each habitat type used to scale I&E mortality. For each of the seven 316(b) regions, EPA compiled net primary productivity (NPP) values from the primary scientific literature as well as reviews or past compilations of primary productivity values. EPA standardized these values to the metric of kg dry mass per acre per year. In cases when multiple sites were measured within an investigation, EPA used the average value.

Primary production depends on several factors, including but not limited to the conditions and characteristics of the study site and study methodology. Due to geographic variations in growing season and climate, primary productivity of species may differ substantially both within and among regions (Appendix Table J-1). For example, regional productivity estimates used in past salt marsh scaling applications include 2,204 kg dry mass acre^{-1} in Rhode Island (French McCay and Rowe 2003), 6,636 kg dry mass acre^{-1} yr^{-1} in New Jersey, (PSEG 2006; Strange 2008), and 11,716 kg dry mass acre^{-1} in Louisiana (Penn and Tomasi 2002) (Appendix Table J-1).37 To obtain regionally-applicable values for primary productivity, EPA used an average of habitat-specific productivity values from a minimum of four published values in all calculations (Appendix Table J-1).

The NPP fraction most easily converted to detritus (freshly dead or partially decomposed organic matter (Ricklefs 2001)), and therefore available for secondary production, is above-substrate primary production. Consequently, EPA included above-substrate primary production in its calculations. This includes all emergent stems and leaf tissue in cordgrass and cattail, and leaf tissue for eelgrass and turtle grass. For giant kelp, which uses a benthic holdfast, all biomass production in the water column was included in estimates of NPP.38 Estimates of NPP also include primary production of epiphytic periphyton or macroalgae (e.g., attached to root stalks in wetland and saltmarsh, or to submerged leaves of eelgrass or kelp). Additionally, EPA included algal productivity in NPP estimates. In the North and Mid-Atlantic regions, NPP estimates include 533 kg dry mass acre-1 yr-1 of algal productivity [based on scaling assessments conducted in Rhode Island, New Jersey and Delaware salt marshes (French McCay and Rowe 2003; PSEG 2006; Strange 2008)]. This is equivalent to 16 percent of average mean aboveground macrophyte productivity within the North Atlantic and Mid-Atlantic regions (Appendix Table J-1).39 For all other habitats, the contribution of epiphytes and algae was set to 10 percent of annual aboveground NPP of the foundation species.

9.2.2.2 Trophic Conversion Efficiencies

Trophic conversion efficiencies (or trophic transfer) account for the relative inefficiency of energy transfer between trophic levels (Penn and Tomasi 2002; Strange 2008). Trophic conversion efficiency is normally described as the production of predator per unit of prey or food item. Using a highly simplified trophic structure, trophic conversion efficiencies were applied to three trophic steps:

- Primary productivity to detritus
- Detritus to primary consumers
- Primary consumers to secondary consumers

There is evidence that algae and vascular plant detritus[40] is important for production at higher trophic levels (Kneib 2003). However, there is substantial uncertainty regarding the most appropriate specification of the trophic conversion efficiency from primary productivity to detritus. For example, the trophic conversion efficiency of smooth cordgrass (*S. alterniflora*) biomass to detrital material has been estimated to be between 0.50 and 0.60. EPA conservatively assigned a transfer efficiency of 0.40 from

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[37] Estimates of NPP were converted to kg dry mass/acre/year. Measurements reported as g carbon (C)/area/time were converted using a species-specific organic carbon content and appropriate adjustment for areal and time increments. Although EPA recognizes that the proportion of organic carbon in vascular plants is seasonally dynamic, this variability was not considered critical for estimation.

[38] This assumption is likely to underestimate NPP for some species, since it does not consider conversion of roots and rhizomes to the organic detritus pool that may be used by the secondary consumers.

[39] French McCay and Rowe (2003) assumed 429 kg dry mass acre^{-1} yr^{-1} when scaling salt marsh in Rhode Island, while PSEG assumed 636 kg dry mass acre^{-1} yr^{-1} while scaling salt marsh in New Jersey and Delaware (PSEG 2006; Strange 2008).

[40] Vascular plant detritus includes dead organic material from plants having a vascular system of xylem and phloem (Walker 1995) such as *S. alterniflora*.

primary productivity to detritus to account for uncertainty regarding the importance of detritus for nekton production.[41] Some past NRDAs have not explicitly included this trophic step (e.g., French McCay et al. 2002; Penn and Tomasi 2002), but have included a low efficiency from primary productivity to primary consumers, reflecting the fact that a high percentage of primary productivity is broken down by decomposers such as bacteria, molds and fungi (French McCay and Rowe 2003).

In its simplified trophic model, EPA assumed that primary consumers subsist off the detrital complex, which includes macroinvertebrates and zooplankton. A trophic conversion efficiency of 0.2 is assumed in the transfer of detritus material to primary consumers. Conversion efficiencies for fish and invertebrate consumers in freshwater and marine environments range from 0.1 to 0.3 (French et al. 1996). EPA used a value of 0.2, the mid-point of the range commonly used for scaling injuries (e.g., Balletto et al. 2005; French McCay et al. 2002; Penn and Tomasi 2002).

Secondary consumers are assumed to include fish in their first year (i.e., young-of-year; defined as age-0 fish). EPA assumed a trophic conversion efficiency of 0.2 from primary to secondary consumers, consistent with past scaling assessments (e.g., Balletto et al. 2005; French McCay et al. 2002; Penn and Tomasi 2002).[42]

9.2.2.3 Carbon Export

Although quantifying local production is necessary to develop estimates of restoration area, it is not realistic to assume that all NPP remains within the local ecosystem. Export from aquatic ecosystems may be substantial, particularly in open or semi-enclosed ecosystems with substantial riverine or tidal flux. In these systems, tidal exchange and flushing may remove a large proportion of the local productivity before it is consumed and assimilated by local consumers (e.g., Cebrian 2002; Teal 1962). Consequently, if NPP export is not considered in trophic transfer models, the amount of habitat restoration required to compensate for lost ecosystem goods and services is likely to be underestimated. Although some scaling calculations conducted as part of NRDAs do not explicitly include an export adjustment (e.g., French McCay et al. 2002; Penn and Tomasi 2002), others acknowledge that productivity many be transported out of the area (French McCay and Rowe 2003).[43]

The rate at which net primary productivity is exported (*E*) depends on site-specific characteristics including marsh height, tidal flushing dynamics, and species mix. An examination of annual NPP from a variety of U.S. and international studies in wetlands had a median value of 22 percent NPP export (Appendix Table J-2). The uncertainty inherent in estimating carbon flux from ecosystems is large (Cebrian 2002) and variability in carbon export high. Accordingly, estimating trophic transfer values for habitats with unknown nutrient dynamics is fraught with uncertainty. EPA recognizes that the amount of NPP exported from the habitats (1) is not available locally to sponsor trophic transfer and secondary production, and (2) will be highly variable from site to site, depending on several factors including tidal or riverine flushing, droughts, storm events, and year-to-year variability in plant production. Recognizing

[41] The assumed value of 0.40 is consistent with the trophic transfer model that PSEG used to scale habitat restoration for the Salem facility. PSEG refers to its trophic model as the “Aggregate Food Chain Model” (PSEG 2006; Strange 2008).

[42] The trophic steps outlined match those used by PSEG for the Aggregate Food Chain Model (Balletto et al. 2005; PSEG 2006), and are generally consistent with those used in miscellaneous NRDAs (e.g., French McCay et al. 2002; Penn and Tomasi 2002).

[43] The PSEG AFCM assumed that 45% of primary productivity is lost to the ocean and was not converted to fish and invertebrate secondary productivity (PSEG 2006; Strange 2008), based on values from a Georgia salt marsh (Teal 1962).

these limitations, EPA assumed, in all habitats, that 25 percent of net primary production is exported from the system and is not transferred to higher trophic levels.

9.2.3 Select Preferred Restoration Habitat

To best compensate for I&E mortality, restored habitats should produce the full complement of impacted species in each region. However, uncertainties regarding the species-specific benefits of restoration actions make scaling habitat loss on a per-species basis impractical. EPA's application of the trophic transfer approach treats the production of secondary consumers as a proxy for the provision of food and nutrient cycling considered to be important ecological services (French McCay and Rowe 2003). Under this assumption, services are considered to be restored when production of secondary consumers due to restoration is equivalent to that lost annually due to I&E mortality. It is unnecessary for restored habitats to compensate for losses on a species-by-species basis.[44] This approach underestimates restoration to the extent that the public has higher total nonuse values for individual species that may have commercial, recreational or nonuse values.

To simplify analysis, one habitat type was chosen in each region as the basis for scaling I&E mortality. To select the most appropriate habitat type within each region, a subset of species, broader taxonomic, or functional groupings that accounted for 50-90 percent of the biomass lost to I&E mortality (typically, the top 5-6 species/groupings) for each 316(b) region were identified. Nursery habitat and life history traits for young-of-year fish were obtained (Fishbase 2009), and a habitat type that benefitted the greatest percentage of A1E losses was selected in each region (Appendix Section J.3). Because many aquatic organisms experience I&E mortality early in their life history (e.g., eggs, larvae, and juveniles), this step directly addresses the life stages most at risk of I&E mortality. Where available information for ecological habitat and nursery characteristics did not indicate a preferred habitat, ecosystems characterized with higher primary productivity per acre were favored.

Table 9-1: Summary of Productivity Values of Preferred Scaling Habitats by Region (kg dry mass acre^{-1} yr^{-1})

Region	Species	Sample Size	Macrophyte NPP	Algal NPP	Total NPP
California	Giant kelp *Macrocystis pyrifera*	4	7,300	730	8,030
North Atlantic	Eelgrass *Zostera marina*	6	3,750	375	4,125
Mid-Atlantic	Smooth cordgrass *Spartina alterniflora*	10	3,350	533	3,880
South Atlantic	Smooth cordgrass *Spartina alterniflora*	13	6,350	533	6,883
Gulf of Mexico	Smooth cordgrass *Spartina alterniflora*	13	6,350	533	6,883
Great Lakes	Broadleaf cattail *Typha latifolia*	14	6,200	620	6,820
Inland	Broadleaf cattail *Typha latifolia*	14	6,200	620	6,820

For ease of calculation, the mean values were rounded to the nearest 50 kg dry mass per acre^{-1} yr^{-1}.

44 EPA's treatment of productivity as a proxy for important ecosystem services is consistent with the implicit assumptions of various past scaling assessments conducted as part of NRDAs (e.g., French McCay et al. 2002; French McCay and Rowe 2003; Penn and Tomasi 2002).

9.2.4 Scaling Habitat Restoration Alternatives to Offset I&E Mortality

Calculating the area required to compensate for annual I&E mortality combines estimates in increased biomass production of secondary consumers (Section 9.2.2) from preferred restoration habitats (Section 9.2.3) with quantified I&E mortality (Chapter 3; Section 3.3).

The scale of restoration required to compensate for I&E mortality is the quotient of annual I&E mortality divided by the expected increase in secondary production associated with a unit area of habitat (Appendix Equation J-3). Thus, a CWIS causing I&E mortality of 20,000 kg dry mass per year (across all species) would have to restore 200 acres of habitat that produced 100 kg dry mass of secondary production per acre per year. Conversely, if a regulatory option reduces I&E mortality by 5,000 kg dry mass per year, then its annual benefit is equivalent to 50 acres of similarly-productive habitat.

Table 9-2 presents the I&E mortality reductions and equivalent habitat restoration area for each region under the proposed regulatory options. Among regions, habitat restoration area equivalent to baseline I&E mortality ranged from 410 acres in the South Atlantic region, to 76,432 acres in the Inland region. The total habitat area equivalent to I&E mortality reductions for all regions is approximately 54,000 acres under Option 1, 127,000 acres under Option 2, and 129,000 acres under Option 3. The rank order of regions by area of habitat equivalent to estimated I&E mortality reductions due to policy options differed among options, due to differences in the effectiveness of 316(b) regulatory options. Notably, however, the equivalent habitat restoration area was always greatest in the Inland region (Table 9-2).

Table 9-2: Baseline I&E Mortality (metric tons A1E year^{-1}) and Habitat Restoration Area (acres) Equivalent to Baseline I&E Mortality, and I&E Mortality Reductions (metric tons A1E year^{-1}) and Habitat Restoration Area (acres) Equivalent to These Reductions, by Region and Regulatory Option

			Baseline		Option 1		Option 2		Option 3	
Region	**Habitat**	**Secondary Productivity (kg acre-1 year-1)**	**I&E Losses (metric tons A1E, dry weight)**	**Equivalent Restoration Area (acres)**	**I&E Losses (metric tons A1E, dry weight)**	**Equivalent Restoration Area (acres)**	**I&E Losses (metric tons A1E, dry weight)**	**Equivalent Restoration Area (acres)**	**I&E Losses (metric tons A1E, dry weight)**	**Equivalent Restoration Area (acres)**
California	Giant kelp *Macrocystis pyrifera*	96	282	2,930	3	36	241	2,503	252	2,617
North Atlantic	Eelgrass Zostera marina	50	158	3,183	1	23	129	2,601	135	2,727
Mid-Atlantic	Smooth cordgrass *Spartina alterniflora*	47	1,735	37,242	240	5,150	1,608	34,511	1,626	34,890
South Atlantic	Smooth cordgrass *Spartina alterniflora*	83	34	410	13	159	29	346	29	347
Gulf of Mexico	Smooth cordgrass *Spartina alterniflora*	83	1,252	15,158	340	4,122	988	11,958	989	11,978
Great Lakes	Broadleaf cattail *Typha latifolia*	82	463	5,654	253	3,091	425	5,195	428	5,229
Inland	Broadleaf cattail *Typha latifolia*	82	6,255	76,432	3,424	41,834	5,723	69,927	5,843	71,390
Total (All Regions)	-	-	**10,179**	**141,009**	**4,275**	**54,415**	**9,142**	**127,041**	**9,301**	**129,178**

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 DIF MGD; Option 3 = I&E Mortality Everywhere

9.3 Development of WTP Values for Fish Production Services of Habitat

The approach EPA used to develop WTP values for fish production services is to 1) estimate the number of acres of habitat required to produce fish equivalent to those lost due to I&E mortality; and 2) evaluate citizens' WTP for this habitat—not for the fish produced by the habitat. This method is consistent with NOAA's preferred methods for NRDA under the Oil Pollution Act (OPA), since NOAA's NRDA regulations focus on restoration of injured resources, rather than monetary compensation for damages. For lost interim values pending restoration, additional habitat may be restored in lieu of monetary compensation. NOAA refers to this as "compensatory restoration" (NOAA 1997). EPA calculated the amount of "service-to-service" compensatory restoration—in the form of restored habitat—required to offset losses, and then evaluated WTP for restoring this area of habitat. Whereas NOAA recommends restoring such acreage to compensate for I&E mortality, EPA does not suggest that the restoration be carried out. Instead, EPA quantifies the benefits, in the form of fish production, that the restored habitat would provide. This value provides a proxy for the nonuse values not otherwise estimated in this document.

EPA performed an in-depth search of the economic literature to identify valuation studies that estimate WTP for aquatic habitat services. From this review, EPA identified seven studies relevant for its analysis (Appendix Section J.4). For inclusion in this list, studies were required to meet the following criteria:

- **Specific Amenity Valued:** Environmental quality change being valued affects habitat similar to those habitat types included in the trophic transfer model.[45]
- **U.S. Studies:** Studies surveyed U.S. populations to value domestic resources.
- **Research Methods:** Valuation methods were supported by journal literature and inclusive of nonuse values (e.g., contingent valuation, conjoint analysis).

EPA applied values from seven studies for all 316(b) regions, based on consideration of the study location, habitat type, and services provided relative to biological scaling assumptions (i.e., Section 9.2). If a study was not applicable in a region, EPA transferred values from studies conducted in other 316(b) regions for the same habitat type. Reported WTP values per acre of habitat restored represent the average of mean values from individual valuation studies (Table 9-3).

Eelgrass habitat was selected for restoration scaling in the North Atlantic region. The Peconic Estuary study (Johnston et al. 2002a; Johnston et al. 2001; Mazzotta 1996; Opaluch et al. 1995; Opaluch et al. 1998), conducted on the East End of Long Island, NY within the Mid-Atlantic region, was the only study identified by EPA that estimates WTP per acre of eelgrass habitat. Although EPA recognizes that there is uncertainty when applying WTP values to external 316(b) regions, substantial differences in values are unlikely in this case due to the close proximity of the study area to the North Atlantic region and similarity in resource characteristics including assemblage of species supported by eelgrass habitat.

[45] Valuation studies were excluded from consideration if the habitat services provided by the study habitat were substantially different, or provided in drastically different ratios, than the restoration habitat used for scaling (e.g., Dillman et al. 1993; Roberts and Leitch 1997).

Table 9-3: Total Annual Household WTP Per Acre of Aquatic Habitat

316(b) Region	WTP acre^{-1} yr^{-1} (2009$)	Valuation Studies Applied
California	-	-
North Atlantic	0.0761	Peconic Estuary Study (Johnston et al. 2002a; Johnston et al. 2001; Mazzotta 1996; Opaluch et al. 1995; Opaluch et al. 1998)
Mid-Atlantic	0.0672	Peconic Estuary Study (Johnston et al. 2002a; Johnston et al. 2001; Mazzotta 1996; Opaluch et al. 1995; Opaluch et al. 1998)
South Atlantic	0.0431	Bauer, Cyr, and Swallow (2004), Peconic Estuary Study (Johnston et al. 2002a; Johnston et al. 2001; Mazzotta 1996; Opaluch et al. 1995; Opaluch et al. 1998)
Gulf of Mexico	0.0431	Bauer, Cyr, and Swallow (2004), Peconic Estuary Study (Johnston et al. 2002a; Johnston et al. 2001; Mazzotta 1996; Opaluch et al. 1995; Opaluch et al. 1998)
Great Lakes	0.0131	de Zoysa (1995), Mullarky (1997), Mullarky (1999), Bishop et al. (2000)
Inland	0.0118	de Zoysa (1995), Mullarky (1997), Mullarky (1999), Blomquist and Whitehead (1998), Whitehead and Blomquist (1991)

EPA was unable to identify an applicable valuation study for kelp habitat, the preferred scaling habitat for the California region.

EPA was unable to identify studies estimating the value of saltmarsh habitat in the South Atlantic and Gulf of Mexico regions. Therefore, it was necessary to apply wetland values from valuation studies conducted in other 316(b) regions: EPA identified two applicable saltmarsh habitat values, from Rhode Island (Bauer et al. 2004) and New York (Johnston et al. 2002a; Johnston et al. 2001; Mazzotta 1996; Opaluch et al. 1995; Opaluch et al. 1998). EPA recognizes that substantial uncertainty may occur when applying wetland values outside the region from which they were obtained, due to variation in habitat condition and resident preferences. However, it is not clear that application of these results will overestimate or underestimate WTP for wetland habitats.

Only one study was identified that estimated WTP for wetland restoration in the Great Lakes region (Bishop et al. 2000). However, riverine wetlands inland of the Great Lakes provide fish production, which contributes to fish populations in the Great Lakes. Consequently, EPA also applied studies that estimated WTP for riverine wetland habitat in states adjacent to the Great Lakes (de Zyosa 1995; Mullarkey 1997; Mullarkey 1999). These studies were also applied to the Inland 316(b) region.

9.3.1 Estimating the Importance of Fish Habitat as a Proportion of Habitat WTP Values: Salt Marshes

To estimate the proportion of value associated with fish habitat, EPA used data from the 2001 Survey of Rhode Island Residents. The survey instrument, *Rhode Island Salt Marsh Restoration: 2001 Survey of Rhode Island Residents,* was designed to assess tradeoffs among attributes of salt marsh restoration plans in Narragansett Bay, Rhode Island (Johnston et al. 2002b). Development involved extensive background research, interviews with experts in salt marsh ecology and restoration, and 16 focus groups with more than 100 residents (details on survey development are in Appendix Section J.5.1).

Survey data indicate that respondents favored plans that restored larger areas of salt marsh. Comparisons among specific improvements to habitat and mosquito control revealed that respondents placed the greatest weight on mosquito control, followed by habitat improvements for shellfish, fish, and birds, respectively (Johnston et al. 2002b).

From the survey data, EPA calculated the proportion of wetland restoration value associated with different wetland services. Across all scenarios presented in the survey, the proportion of WTP values associated with fish habitat, bird habitat, shellfish habitat, mosquito control, and other services were 0.256, 0.198, 0.278, 0.121, and 0.147, respectively. (Additional results and discussion are in Appendix Section J.5.2.)

EPA assumed that 25.6 percent of WTP per acre of salt marsh is associated with fish production services for all regions based on these data. EPA recognizes that the findings of the Johnston et al. (2002b) study are best applied to areas within or near the North Atlantic region for which coastal populations (i.e., preferences) are similar and salt marsh services are most similar. However, EPA was unable to identify comparable stated preference studies conducted within the Mid-Atlantic, South Atlantic, and Gulf of Mexico regions.

There is general consensus that marine tidal wetlands and seagrasses provide good to excellent fish production function for many important commercial, recreational and forage species (Graff and Middleton 2003; Street et al. 2005), by providing favorable conditions for the growth and survival of juveniles and young-of-year (Deegan et al. 2000). It is true that the precise role of such habitats as nurseries for juvenile fish has recently been critically re-examined, suggesting the need for better quantification of the precise role of nearshore ecosystems in producing more adult fish (Beck et al. 2003). However, the fish production function of tidal wetlands would be considered high. By applying survey findings from Rhode Island across these regions, EPA assumes that preferences for salt marsh restoration and salt marsh services are not substantially different among regions. However, true regional WTP values may be higher or lower than those estimated within Narragansett Bay.

9.3.2 Estimating the Importance of Fish Habitat as a Proportion of Habitat WTP Values: Freshwater Wetlands

EPA was unable to identify any studies that permitted the apportionment of WTP for freshwater wetlands among habitat services. However, EPA reviewed the published literature to identify and estimate the proportion of WTP value that is associated with fish production.

Tidal freshwater wetlands are located inland of estuaries. They experience tidal fluctuations, but are not regularly exposed to water with substantial salinity. As such, these communities are dominated by freshwater plants (e.g., cattails, bulrushes, etc). These wetlands are commonly used by freshwater, estuarine, marine and migratory fish: their dense vegetation provides refuges for juveniles, and protected spawning areas. Additionally, because nutrient cycling in these marshes is rapid, food is readily available (Graff and Middleton 2003). As described by Mitchell et al. (2009b) and consistent with the findings of Johnston et al. (2002b), EPA assumed that 25 percent of WTP per tidal marsh acre is associated with fish production services.

Non-tidal freshwater wetlands connected to large bodies of water (including the Great Lakes) may also have enhanced fish production function. For example, it has been estimated that 75 percent of fish species in the Great Lakes use coastal marshes during some part of their life cycle (Jude and Pappas 1992; Meixler et al. 2005; Stephenson 1990). Moreover, Lake Erie is reported to support the best fishery of the Great Lakes, in terms of diversity and number, partly because of its extensive system of adjoining coastal marshes (Graff and Middleton 2003). Consequently, EPA assumed that 20 percent of WTP per acre for freshwater marshes in the Great Lakes is associated with fish production services based on the generally-recognized importance of this habitat to fisheries. EPA used a value lower than recognized for marine marshes to reflect the absence of a regular tidal cycle that can provide habitat diversity within the ecosystem.

The importance of fish production in isolated non-tidal freshwater wetlands, forested wetlands (i.e., seasonally flooded areas), swamps, bogs, etc., has not been well-quantified. Although wetlands attached to lakes or fringing marshes on rivers may be locally productive, isolated shallow depressions, headwater swamps, or seepage-derived wetlands may have poor or non-existent fish production (Graff and Middleton 2003). Consequently, EPA believes the average importance of isolated non-tidal freshwater marshes is far lower than similarly-sized marshes in marine systems or freshwater marshes connected to significant water bodies. Thus, EPA conservatively assumed that 10 percent of the WTP per acre is associated with fish production services.

9.3.3 Estimated Proportion of Household WTP Estimates Attributed to Fish Production Services

EPA assumed that 25.6 percent of household WTP values for salt marsh restoration are attributable to fish production services (Section 9.3.1). Similarly, EPA assumed values of 20 percent for freshwater marshes in the Great Lakes Region, and 10 percent for wetlands in the Inland region (Section 9.3.2). Finally, because the Peconic surveys used to estimate WTP for eelgrass habitat were described specifically as fish and shellfish habitat, EPA assigned 100 percent of the estimated WTP for eelgrass restoration to fish production services. Consequently, by multiplying total WTP per acre restored habitat per year (Table 9-3) by estimates of the proportional contribution of fish production services, EPA obtained WTP per acre per year for fish production services in preferred habitats for all 316(b) regions with the exception of California (Table 9-4).

Table 9-4: Household WTP per Acre per Year for Fish Production Services

316(b) Region	Total WTP $acre^{-1}$ yr^{-1} (2009$)	% Attributed to Fish Production Services	WTP $acre^{-1}$ yr^{-1} for Fish Production Services (2009$)
California	-	-	-
North Atlantic[1]	0.0761	100.0%	0.0761
Mid-Atlantic	0.0672	25.6%	0.0172
South Atlantic	0.0431	25.6%	0.0110
Gulf of Mexico	0.0431	25.6%	0.0110
Great Lakes	0.0131	20.0%	0.0026
Inland	0.0118	10.0%	0.0012

Note: EPA was unable to identify an applicable valuation study for kelp habitat, the preferred scaling habitat for the California region.

9.4 Estimating the Value of Habitat Needed to Offset I&E Mortality

9.4.1 Determining the Extent of Nonuse Values

Evaluating the total regional WTP value per acre of wetlands or eelgrass requires estimating the extent of the population holding nonuse values for these resources. EPA defined the population as the total number of households in the state following the methods used by several published studies (e.g., Bauer et al. 2004; Blomquist and Whitehead 1998; Mullarkey 1997; Whitehead and Blomquist 1991).

Households in close proximity are likely to value gains of fish in affected waterbodies, as will households in counties that do not directly abut affected water bodies. Evidence from Johnston et al. (2002b) indicates that this value can extend to the statewide level. Analysis of data from the Rhode Island Salt

Marsh Restoration Survey (Johnston et al. 2002b) reveals that values ascribed to even relatively small-scale salt marsh restoration actions (i.e., 3-12 acres) were stated by respondents from various parts of the state. A study by Pate and Loomis (1997) found that respondents outside the state in which a study site is located were also willing to ascribe stated preference values to the amenity being studied. It compared WTP values for environmental programs designed to improve wetland habitat in the San Joaquin Valley, CA across households in the Valley, California households outside the Valley, and households in Washington State, Oregon, and Nevada. They found that CA households outside the San Joaquin Valley expressed similar WTP compared to residents of the Valley, with households outside the state even holding positive WTP for the environmental programs. Thus, it is reasonable to assume in the context of 316(b) analysis that residents within an affected state would have positive values for fish habitat improvements within state waters.

The magnitude of habitat restoration efforts sufficient to compensate for I&E mortality would require a large geographical footprint. EPA recognized that, if implemented, this footprint would be divided into many sites dispersed throughout each region. To estimate WTP for fish production services that best reflect compensation for I&E mortality, EPA assigned habitat restoration based on the estimated distribution of I&E mortality throughout each 316(b) region based on the proportion of total AIF of in-state facilities relative to total regional AIF. The proportional breakdown of restoration area by state and region is presented in Appendix Table J-7.

9.4.2 Estimating Aggregate Values

EPA calculated aggregate WTP for each 316(b) region as follows based on the area of habitat required to compensate for I&E mortality (Table 9-2), estimates of household WTP per acre per year for fish production services (Table 9-4), and the size of the affected population (Appendix Table J-7).

1. Multiply the number of regional habitat acres needed to offset I&E mortality under the baseline condition or equivalent to I&E mortality reduction effect on fish production under the proposed 316(b) regulation (Table 9-2) by the percentage of area attributed to each state within the 316(b) region (Appendix Table J-7) to obtain the magnitude of habitat restoration by state.
2. Multiply regional household value per acre of restored habitat (Table 9-4) by the estimated number of habitat acres within 316(b) region (from 1, above) to obtain total household WTP for improved fish production in the waters affected by the 316(b) regulation by state for each region.
3. For each region, multiply total WTP per household for each state (Step 2) by the number of households within the state, and sum across all states within the region to obtain unadjusted WTP for habitat restoration within the 316(b) region.

EPA recognizes that WTP per household per acre is likely to be marginally decreasing as the scale of restoration increases (e.g., Bishop et al. 2000), particularly if all statewide households are simultaneously valuing fish production services provided by large-scale restoration of multiple habitat types. Household values for policy changes may not be additive, and the sum of WTP values when policies are assessed separately may exceed the total value of policies when assessed simultaneously. Simply summing the statewide values for multiple 316(b) regions may overestimate the value of fish production services from additional habitat acreage.

Based on this assessment, EPA incorporated a weighting adjustment in order to limit the potential for overestimation of total WTP in cases where households within a given state are assigned values for multiple 316(b) benefits regions (e.g., Mid-Atlantic and Inland). State-level WTP values within a 316(b) region were adjusted based on the relative magnitude of regional restoration area compared to total restoration area assigned to the state. For example, if a state were to be assigned 100 acres from the Mid-Atlantic region and 300 acres from the Inland region, the statewide WTP for the Mid-Atlantic and Inland regions would be multiplied by factors of 0.25 (100 acres/400 acres) and 0.75 (300 acres/400 acres), respectively. In the final step of estimating aggregating values for each region, weighted WTP values were summed across all states to calculate the total annual WTP associated with each 316(b) region.

9.5 WTP Results

Table 9-5 presents the estimated WTP for habitat restoration area necessary to compensate for I&E mortality under baseline conditions, as well as estimated WTP for habitat restoration area equivalent to I&E mortality reductions under proposed regulatory options. EPA was unable to identify household WTP for the preferred scaling habitat (giant kelp) in the California region (Table 9-3). As such, national estimates of WTP are understated.

National WTP for habitat restoration to compensate for baseline I&E mortality is approximately $3.6 billion and $3.7 billion using 3 percent and 7 percent discount rates, respectively (Table 9-5). Under both discount rates, WTP for habitat restoration in the Mid-Atlantic region represents 61 percent of the national total. Despite representing 54 percent of the national area of restoration necessary to compensate for baseline I&E mortality (Table 9-2), WTP for habitat restoration in the Inland region represented only 7 percent of national WTP. This difference is in large part due to lower household WTP values for habitat restoration than values found in other regions.

At a 3 percent discount rate, total national WTP for habitat restoration equivalent to I&E mortality reductions under Option 1 is $513.3 million (Table 9-5). Because they reduce entrainment losses in the majority of facilities, and because 66 percent of national I&E mortality occurs due to entrainment mortality (Chapter 3), WTP for Options 2 and 3 is about four times greater than WTP for Option 1. Assuming a 3 percent discount rate, national WTP for both Options 2 and 3 is approximately $2.1 billion (Table 9-5).

Table 9-5: Weighted WTP for Habitat Restoration Area Equivalent to Baseline I&E Mortality, and Weighted WTP for Habitat Restoration Area Equivalent to I&E Mortality Reductions by Region and Regulatory Option

Region	Habitat	Household WTP acre^{-1} year^{-1}	Weighted WTP for Regulatory Options (2009$, millions)							
			3% Discount Rate				7% Discount Rate			
			Baseline	Option 1	Option 2	Option 3	Baseline	Option 1	Option 2	Option 3
California	Giant kelp *Macrocystis*	-	-	-	-	-	-	-	-	-
North Atlantic	Eelgrass Zostera marina	0.076	388.7	0.5	216.2	226.9	395.2	0.4	168.0	176.2
Mid-Atlantic	Smooth cordgrass *Spartina*	0.017	2,234.2	210.3	1,280.4	1,295.4	2,271.5	195.5	929.1	940.7
South Atlantic	Smooth cordgrass *Spartina*	0.011	0.8	0.4	0.5	0.5	0.8	0.3	0.4	0.4
Gulf of Mexico	Smooth cordgrass *Spartina*	0.011	732.2	153.4	390.6	389.6	744.4	142.6	305.9	305.0
Great Lakes	Broadleaf cattail *Typha latifolia*	0.003	18.9	10.4	12.2	12.2	19.2	9.7	9.6	9.6
Inland	Broadleaf cattail *Typha latifolia*	0.001	264.3	138.5	167.8	170.6	268.7	128.7	130.0	131.6
Total (All Regions)	**-**	**-**	**3,639.0**	**513.3**	**2,067.6**	**2,095.1**	**3,699.8**	**477.2**	**1,542.8**	**1,563.4**

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 DIF MGD; Option 3 = I&E Mortality Everywhere

9.6 Limitations and Uncertainties

Benefit transfer involves adapting research conducted for another purpose in the available literature to address the policy questions at hand. Because benefits analysis of environmental regulations rarely affords sufficient time to develop original stated preference surveys that are specific to the policy effects, benefit transfer is often the only option to inform a policy decision. Consequently, there are several limitations and uncertainties to this approach.

9.6.1 Estimating the Extent of the Affected Population

The magnitude of the affected population has a multiplicative effect on total WTP values for I&E mortality. EPA acknowledges that I&E mortality can have impacts not restricted to state boundaries, due to the migratory nature of fish populations, and the fact that multiple states may share impacted watersheds. EPA's approach underestimates WTP if members of a population value I&E mortality occurring in different states.

9.6.2 Not All Species and Losses Are Compensated

EPA scaled restoration to compensate total production lost annually in each region rather than on a species-specific basis. This assumes that secondary production is a proxy for important ecosystem services such as food provision and nutrient cycling. This approach is likely to underestimate needed restoration to the extent that the public has higher nonuse values for specific species (for example, threatened and endangered species) that are under-compensated when habitat restoration is scaled based on total losses.

9.6.3 Timing of Losses and Restoration

Fish production services provided by a restored habitat may increase over time as the habitat undergoes natural successional processes, or conversely, fish production services may decline or cease if habitat restoration is not successful. EPA scaled restoration using primary productivity values reflective of mature habitat: scaling based on mature habitat is consistent with valuation studies that provide WTP for marginal habitat acres. EPA is not suggesting that restoration of habitat area estimated by the described approaches actually be implemented. If restoration were implemented, primary productivity values used in the calculation would likely overestimate marginal gains of restored habitats and would therefore underestimate WTP. If available, the inclusion of site-specific information regarding the trajectory and duration of restoration benefits would improve the accuracy of scaling estimates.

9.6.4 Application of the Approach to Large Geographic Areas

Application of the habitat-based approach for compensating I&E mortality on a regional scale is uncertain because of the diversity of habitats and species within a region. Many species of fish require more than one habitat: the non-restored habitat may represent the limiting factor for fish populations. Moreover, due to site-specific effects, species losses due to I&E mortality are likely to vary both among and within regions. Similarly, people may have diverse values for habitats across a state. Although such effects exist, EPA assigned ecological parameter values based on average values for a region. Also, most valuation studies included in the analysis used statewide survey populations. Consequently, mean values reflect the diversity of valuation that occurs throughout a state.

Valuation studies were not available for all habitats and regions. Primary WTP values were applied in regions when a reasonable value for the restored habitat was unavailable. Valuation studies are most accurately applied to areas near the original study location, and may underestimate or overestimate values in other states or regions.

Uncertainty also exists in estimates of proportionate habitat value associated with fish production services. Application of the Johnston et al. (2002b) study may lead to overestimation or underestimation of WTP for fish habitat services of wetlands outside Rhode Island: the study is most appropriately transferred within southern New England and nearby areas where coastal populations (i.e., preferences) and coastal wetland conditions (i.e., ecology) are similar. In the absence of comparable studies conducted within individual regions, however, the estimate of Johnston et al. (2002b) was applied across regions for saltmarsh habitat.

9.6.5 Specification of Parameter Assumptions

EPA's implementation of a trophic transfer approach required the estimation of several parameter inputs (e.g., primary productivity values, carbon export, trophic conversion efficiencies). These values represent extrapolations from different scales, regions, or ecosystems, and are dependent on many simplifying assumptions. Scaling results may exhibit substantial sensitivity to these assumptions. For example, EPA applied a simple four-level food chain to all fish species, and used mean value for trophic transfer efficiencies across all habitats (French et al. 1996). The scientific literature indicates substantial uncertainty in values estimated in local habitats, and fish species vary greatly in their position in natural food webs. Additionally, natural variability will impact production and consumption in all habitats. Consequently, productivity estimates cannot be viewed as representing anything more than a simplified average value.

10 National Benefits

10.1 Introduction

This chapter summarizes the results of the seven regional analyses, and presents EPA's estimates of the national benefits of the regulatory options for in-scope 316(b) facilities:

- **Option 1: I Everywhere.** Establish Impingement Mortality Controls at All Existing Facilities that Withdraw over 2 MGD DIF; Determine Entrainment Controls for Facilities Greater than 2 MGD DIF On a Site-specific Basis.
- **Option 2: I Everywhere and E for Facilities > 125 MGD.** Establish Impingement Mortality Controls at All Existing Facilities that Withdraw over 2 MGD DIF; Require Flow Reduction Commensurate with Closed-cycle Cooling By Facilities Greater Than 125 MGD DIF.
- **Option 3: I&E Mortality Everywhere.** Establish Impingement Mortality Controls at All Existing Facilities that Withdraw over 2 MGD DIF; Require Flow Reduction Commensurate with Closed-Ccycle Cooling at All Existing Facilities over 2 MGD DIF.

Greater detail on the methods and data used in the regional analyses is provided in the previous chapters of this report. See Chapter 3 for a discussion of the methods used to estimate impingement mortality and entrainment (I&E mortality), and a summary of the estimated baseline I&E mortality losses and reductions in I&E mortality under the proposed 316(b) regulatory options. See Chapters 5 through 8 for a discussion of the methods used to estimate the value of I&E mortality losses and the benefits of the alternative policy options.

EPA was unable to estimate monetized nonuse benefits for I&E mortality losses in all regions. Therefore, the benefits estimates presented in this section do not reflect total benefits associated with reducing I&E mortality at in-scope facilities, and overall national benefits may accordingly be higher. Section 10.2 describes EPA's methodology for aggregating benefits at the national level; Section 10.3 summarizes baseline losses and expected reductions in I&E mortality; Section 10.4 presents national benefits; and Section 10.5 discusses nonuse benefits and presents a break-even analysis.

10.2 Methodology

EPA notes that quantifying and monetizing the benefits that result from reductions in I&E mortality under the regulatory options considered for the Section 316(b) facilities rulemaking is challenging. The preceding sections of this report discuss specific limitations and uncertainties associated with estimating reductions in I&E mortality losses and monetized benefits. EPA estimated national-level benefits by summing benefit estimates over the seven study regions. Thus, national benefit estimates are subject to the same uncertainties inherent in the valuation approaches used for assessing each of the four benefit categories (threatened and endangered species, commercial fishing, recreational fishing, and nonuse values). The national benefits estimates do not include habitat-based values presented in Chapter 9; the habitat-based analysis was conducted for illustrative purposes to demonstrate the potential magnitude of total value inclusive of nonuse values. The combined effect of these uncertainties is of unknown magnitude and direction (i.e., the estimates may over- or understate the anticipated national level of use benefits). Nevertheless, EPA has no data to indicate that the results for any of the benefit categories are atypical or unreasonable.

10.3 Summary of Baseline Losses and Expected Reductions in I&E Mortality

Based on the results of the regional analyses, EPA calculated total I&E mortality losses under baseline (i.e., pre- regulatory) conditions and the total amount by which losses would be reduced under each of the regulatory options. The number of fish lost at in-scope facilities is presented in terms of age-1 equivalent (A1E) losses (i.e., the number of individual fish of different ages impinged and entrained by facility intakes, expressed as A1Es).

Table 10-1 presents baseline impingement, entrainment, and total I&E mortality losses. The table shows that total national losses for all in-scope facilities are 2.2 billion fish in terms of A1Es. EPA notes that the count of total lost organisms is larger than values expressed in A1Es. This table shows that about 46 percent of all A1E losses, or 1.0 billion fish, occur in the Mid-Atlantic region, followed by the Inland region with 0.9 billion fish lost. More-detailed discussions of the I&E mortality losses in each region are provided in Chapter 3 of this report.

Table 10-1: Baseline National A1E Losses at All In-scope Facilities (millions of A1Es)

Region	Impingement Mortality	Entrainment Mortality	I&E Mortality
California	0.8	36.0	36.8
North Atlantic	0.6	59.4	60.0
Mid-Atlantic	50.7	939.4	990.1
South Atlantic	22.5	10.9	33.4
Gulf of Mexico	45.1	90.6	135.6
Great Lakes	44.1	9.4	53.5
Inland	583.6	295.9	879.5
National Total	**747.4**	**1,441.5**	**2,188.9**

EPA also calculated the total national I&E mortality losses prevented by each of the regulatory options. These prevented losses are based on the expected reductions in I&E mortality at each facility due to technology installation required under each option. Table 10-2 through Table 10-4 present expected reductions in I&E mortality, expressed as A1Es, by region, under regulatory options considered in EPA's analysis. The tables show that at in-scope facilities, Option 1 reduces A1E losses by 0.6 billion fish. In comparison, Option 2 and Option 3 both reduce A1E losses by approximately 2.0 billion fish.

Table 10-2: Reductions in National A1E Losses for All In-scope Facilities (millions of A1Es) Under Option 1 (I Everywhere)

Region	Impingement Mortality	Entrainment Mortality	I&E Mortality
California	0.7	0.0	0.7
North Atlantic	0.4	0.0	0.4
Mid-Atlantic	38.7	0.0	38.7
South Atlantic	14.2	0.0	14.2
Gulf of Mexico	34.5	0.0	34.5
Great Lakes	38.2	0.0	38.2
Inland	488.2	0.0	488.2
National Total	**615.0**	**0.0**	**615.0**

Table 10-3: Reductions in National A1E Losses for All In-scope Facilities (million A1Es) Under Option 2 (I Everywhere and E for Facilities > 125 MGD)

Region	Impingement Mortality	Entrainment Mortality	I&E Mortality
California	0.8	30.7	31.5
North Atlantic	0.6	48.4	49.0
Mid-Atlantic	49.5	860.3	909.7
South Atlantic	19.2	9.1	28.3
Gulf of Mexico	44.7	61.3	106.0
Great Lakes	43.7	7.5	51.1
Inland	564.1	241.8	805.9
National Total	**722.5**	**1,259.0**	**1,981.6**

Table 10-4: Reductions in National A1E Losses for All In-scope Facilities (millions of A1Es) Under Option 3 (I&E Mortality Everywhere)

Region	Impingement Mortality	Entrainment Mortality	I&E Mortality
California	0.8	32.1	32.9
North Atlantic	0.6	50.8	51.4
Mid-Atlantic	49.6	871.3	920.9
South Atlantic	19.2	9.1	28.3
Gulf of Mexico	44.8	61.4	106.2
Great Lakes	43.8	7.6	51.3
Inland	569.6	252.9	822.5
National Total	**728.3**	**1,285.2**	**2,013.5**

Table 10-5 presents EPA's estimates of the current level of total annual I&E mortality losses and the reduction in total annual I&E mortality by option for the three metrics presented in Section 3.2.2. Option 3 (I&E Mortality Everywhere) results in the greatest reduction in I&E mortality, followed by Option 2 (I Everywhere and E for Facilities > 125 MGD) and Option 1 (I Everywhere), respectively, for all of the metrics.

Table 10-5: Baseline National I&E Mortality and I&E Mortality Reductions for All In-scope Facilities by Regulatory Option

Regulatory Option	Millions of A1Es	Forgone Fishery Yield (million lbs)	Biomass Production Forgone (million lbs)
Baseline	2,188.9	71.5	637.8
Option 1	615.0	13.3	137.6
Option 2	1,981.6	58.6	542.2
Option 3	2,013.5	59.2	556.2

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere

As shown for all regions in Table 10-6, and by region in Chapter 3 of this report, the harvested commercial and recreational fish species that have direct use values comprise between 1 and 9 percent of baseline I&E mortality losses in each region, resulting in a national average of only 3 percent of I&E mortality losses receiving a monetary value based on direct use. The remaining 97 percent of I&E mortality losses include unharvested recreational and commercial fish and forage fish which do not have direct use values. EPA's nonuse analysis was limited two of the seven benefits regions and nonuse values were not estimated for unharvested fish in the remaining five benefits regions. The total estimated benefits are likely to be significantly understated due to the regional limitations of EPA's nonuse analysis and the relatively large fraction of I&E mortality reductions which are not commercially or recreationally harvested.

Table 10-6: Distribution of National I&E Mortality for All In-scope Facilities by Regulatory Option

Regulatory Option	(a) All Species (millions of A1Es)	(b) Forage Species (millions of A1Es)	(c) Commercial and Recreational Species (millions of A1Es)	(d) Harvested Commercial and Recreational Species (millions of fish harvested)[a]	A1E Fish Assigned a Direct Use Value as Percentage of Total (column d / column a)
Baseline	2,188.9	1,654.8	534.1	59.4	2.7%
Option 1	615.0	525.7	89.3	15.7	2.5%
Option 2	1,981.6	1,512.6	468.9	53.3	2.7%
Option 3	2,013.5	1,535.4	478.1	54.0	2.7%

[a] Harvestable fish are adult fish of the age at which they can legally be harvested.

Scenarios: Baseline = Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities > 125 MGD; Option 3 = I&E Mortality Everywhere

10.4 National Monetized Benefits from Eliminating and Reducing I&E Mortality Losses

EPA's estimates of total national baseline losses and total national benefits under each option are based on EPA's regional estimates of monetized baseline losses and regulatory option benefits. To address the differences in the timing of benefits and costs, EPA developed a time profile of total benefits from all in-scope facilities that reflects when benefits from compliance-related changes at each facility would be realized. The methodology that EPA used to develop this time profile is detailed in Appendix D. For each study region, EPA first calculated the undiscounted benefits (i.e., commercial and recreational fishing benefits, including recreational fishing benefits from an increased abundance of T&E species) from the expected annual I&E mortality reductions under the regulatory options, based on the assumptions that all facilities in each region would achieve compliance and that benefits would be realized immediately following compliance. Then, since there would be regulatory and biological time lags between promulgation of the regulatory options and the realization of benefits, EPA created a time profile of benefits that takes into account the fact that benefits do not begin immediately. Using this time profile of benefits, EPA discounted the total benefits generated in each year of the analysis to 2012, the year when the rule becomes effective, using discount rates of 3 percent and 7 percent.[46] Appendix D of this report provides detail on EPA's development of the time profile of benefits.

[46] The 3 percent rate represents a reasonable estimate of the social rate of time preference. The 7 percent rate represents an alternative discount rate, recommended by the Office of Management and Budget (OMB), that reflects an estimated opportunity cost of capital.

EPA estimated mean national use values, as well as values that include the 5th percentile lower bound and 95th percentile upper bound of the recreational benefits estimates.[47] Table 10-9 through Table 10-11 present these results for each region and for the nation as a whole. As described in above, the national benefits estimates do not include habitat-based values presented in Chapter 9.

Table 10-7 shows that the total annual national value of losses due to CWIS at in-scope facilities, discounted at 3 percent, includes $76.9 million in recreational fishing losses, $8.0 million in commercial fishing losses, $1.1 million in T&E species losses, and $128.6 million in forgone nonuse benefits. The total benefits of elimination of baseline CWIS, discounted at 3 percent, are $214.7 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling $180.5 million and $281.0 million, respectively.

Discounted at 7 percent, the total annual national value of losses due to CWIS includes $75.6 million in recreational fishing losses, $7.9 million in commercial fishing losses, $1.1 million in T&E species losses, and $130.8 million in forgone nonuse benefits. The total use value of fishery resources lost, discounted at 7 percent, is $215.5 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling $181.8 million and $280.8 million, respectively. Total monetized losses are greatest in the Mid-Atlantic region. More-detailed discussions of the valuation of impacts under the baseline conditions in each region are provided in Chapters 5 through 8 of this document.

Table 10-8, Table 10-9, and Table 10-10 present EPA's estimates of the regional and national benefits of reducing I&E mortality under each of the regulatory options (2009$, discounted at 3 percent and 7 percent). The national value of these reductions in I&E mortality losses, evaluated at a 3 percent discount rate, is as follows:

- Option 1 (I Everywhere) results in national benefits of $17.6 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling $10.0 million and $30.3 million (Table 10-8).
- Option 2 (I Everywhere and E for Facilities > 125 MGD) results in national benefits of $120.8 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling $101.3 million and $158.7 million (Table 10-9).
- Option 3 (I&E Mortality Everywhere) results in national benefits of $125.6 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling $105.5 million and $164.9 million (Table 10-10).

Evaluated at a 7 percent discount rate, the national use benefits of the regulatory analysis options are somewhat smaller:

- Option 1 (I Everywhere) results in national benefits of $16.0 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling $9.1 million and $30.3 million (Table 10-8).
- Option 2 (I Everywhere and E for Facilities with > 125 MGD) results in national benefits of $92.2 million per year, with estimates based on the 5th percentile lower bound and 95th

[47] The lower estimates of value presented in this chapter are measured by the sum of the 5th percentile lower bound estimates of recreational values plus the mean value estimates for all other categories of value. The higher estimates of value presented in this chapter are measured by the sum of the 95th percentile upper bound estimates of recreational values plus the mean value estimates for all other categories of value.

percentile upper bound for recreational values, totaling $77.6 million and $120.6 million (Table 10-9).

- Option 3 (I&E Mortality Everywhere) results in national use benefits of $95.7 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling $80.7 million and $124.9 million (Table 10-10).

The majority of benefit values are attributable to recreational fishing and nonuse benefits. Table 10-11 provides a convenient summary of benefits for the three regulatory options. More detailed discussions of regional benefits under each option are provided in Chapters 5 through 8 of this report.

Table 10-7: Summary of National Benefits from Eliminating Baseline I&E Mortality Losses for All In-scope Facilities (2009$)

Region	Annualized Benefits[a] (2009$, millions)								
	Recreational Fishing Benefits			Commercial Fishing Benefits[c]	T&E Species Benefits[d,e]	Nonuse Benefits	Total Benefits[b]		
	Low	Mean	High				Low	Mean	High
3% Discount Rate									
California	$1.7	$2.9	$4.9	$1.2	-	-	$3.0	$4.2	$6.2
North Atlantic	$1.8	$2.8	$4.6	$0.4	-	$26.3	$28.5	$29.6	$31.3
Mid-Atlantic	$15.2	$25.6	$44.5	$2.8	-	$102.3	$120.4	$130.7	$149.6
South Atlantic	$0.3	$0.3	$0.5	$0.0	-	-	$0.3	$0.4	$0.5
Gulf of Mexico	$6.0	$8.9	$13.5	$3.5	-	-	$9.5	$12.3	$17.0
Great Lakes	$1.1	$2.0	$3.5	$0.1	-	-	$1.2	$2.1	$3.6
Inland	$16.6	$34.4	$71.7	-	$1.1	-	$17.7	$35.5	$72.8
Total	**$42.7**	**$76.9**	**$143.2**	**$8.0**	**$1.1**	**$128.6**	**$180.5**	**$214.7**	**$281.0**
7% Discount Rate									
California	$1.7	$2.8	$4.8	$1.2	-	-	$2.9	$4.0	$5.9
North Atlantic	$1.7	$2.7	$4.4	$0.4	-	$26.8	$28.9	$29.9	$31.6
Mid-Atlantic	$14.7	$24.7	$43.0	$2.7	-	$104.0	$121.5	$131.5	$149.7
South Atlantic	$0.2	$0.3	$0.5	$0.0	-	-	$0.3	$0.4	$0.5
Gulf of Mexico	$6.0	$8.8	$13.5	$3.4	-	-	$9.4	$12.3	$16.9
Great Lakes	$1.1	$2.0	$3.5	$0.1	-	-	$1.2	$2.1	$3.6
Inland	$16.5	$34.2	$71.4	-	$1.1	-	$17.6	$35.4	$72.5
Total	**$42.0**	**$75.6**	**$141.0**	**$7.9**	**$1.1**	**$130.8**	**$181.8**	**$215.5**	**$280.8**

[a] All benefits presented in this table are annualized, i.e., equal to the value of all benefits generated over the time frame of the analysis, discounted to 2012, and then annualized over the entire period of this analysis (2012 to 2062). See Appendix D for detail.

[b] A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique, to estimate the 5th and 95th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a region-and species-specific range of gross revenue, as explained in Chapter 6 of this report. EPA estimated recreational use benefits for some T&E species, as explained in Chapter 5. To calculate the total monetizable value columns (low, mean, high), the values for commercial fishing benefits and T&E species benefits are added to the respective low, mean, and high values for recreational fishing benefits.[c] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

[d] Recreational use benefits from increased abundance of T&E species with potentially high recreational use values (e.g., paddlefish and sturgeon). See Chapter 5 of this report for more detail on EPA's analysis of T&E benefits.

[e] Zeros represent values less than 1,000.

Source: U.S. EPA analysis for this report.

Table 10-8: Summary of National Benefits of Option 1 (I Everywhere) for All In-scope Facilities (2009$)

Region	Annualized Benefits[a] (2009$, millions)								
	Recreational Fishing Benefits			Commercial Fishing Benefits[c]	T&E Species Benefits[d,e]	Nonuse Benefits	Total Benefits[b]		
	Low	Mean	High				Low	Mean	High
3% Discount Rate									
California	$0.1	$0.1	$0.1	$0.0	-	-	$0.1	$0.1	$0.1
North Atlantic	$0.0	$0.0	$0.0	$0.0	-	$0.1	$0.1	$0.1	$0.1
Mid-Atlantic	$0.8	$1.6	$3.1	$0.3	-	$0.4	$1.6	$2.3	$3.9
South Atlantic	$0.0	$0.0	$0.1	$0.0	-	-	$0.0	$0.0	$0.1
Gulf of Mexico	$1.4	$2.4	$4.3	$0.6	-	-	$2.0	$3.0	$4.9
Great Lakes	$0.6	$1.0	$1.6	$0.0	-	-	$0.6	$1.0	$1.7
Inland	$5.1	$10.5	$22.0	-	$0.5	-	$5.6	$11.0	$22.5
Total	**$8.0**	**$15.6**	**$31.4**	**$1.0**	**$0.5**	**$0.5**	**$10.0**	**$17.6**	**$33.4**
7% Discount Rate									
California	$0.0	$0.1	$0.1	$0.0	-	-	$0.0	$0.1	$0.1
North Atlantic	$0.0	$0.0	$0.0	$0.0	-	$0.1	$0.1	$0.1	$0.1
Mid-Atlantic	$0.7	$1.4	$2.8	$0.3	-	$0.4	$1.4	$2.1	$3.5
South Atlantic	$0.0	$0.0	$0.0	$0.0	-	-	$0.0	$0.0	$0.1
Gulf of Mexico	$1.3	$2.2	$4.0	$0.5	-	-	$1.8	$2.7	$4.5
Great Lakes	$0.5	$0.9	$1.5	$0.0	-	-	$0.6	$0.9	$1.5
Inland	$4.6	$9.6	$20.1	-	$0.5	-	$5.1	$10.1	$20.6
Total	**$7.2**	**$14.2**	**$28.5**	**$0.9**	**$0.5**	**$0.5**	**$9.1**	**$16.0**	**$30.3**

[a] All benefits presented in this table are annualized, i.e., equal to the value of all benefits generated over the time frame of the analysis, discounted to 2012, and then annualized over the entire period of this analysis (2012 to 2062). See Appendix D for detail.

[b] A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique, to estimate the 5th and 95th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a region-and species-specific range of gross revenue, as explained in Chapter 6 of this report. EPA estimated recreational use benefits for some T&E species, as explained in Chapter 5. To calculate the total monetizable value columns (low, mean, high), the values for commercial fishing benefits and T&E species benefits are added to the respective low, mean, and high values for recreational fishing benefits.[c] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

[d] Recreational use benefits from increased abundance of T&E species with potentially high recreational use values (e.g., paddlefish and sturgeon). See Chapter 5 of this report for more detail on EPA's analysis of T&E benefits.

[e] Zeros represent values less than 1,000.

Source: U.S. EPA analysis for this report.

Table 10-9: Summary of National Benefits of Option 2 (I Everywhere and E for Facilities > 125 MGD) for All In-scope Facilities (2009$)									
	Annualized Benefits [a] (2009$, millions)								
	Recreational Fishing Benefits			Commercial Fishing Benefits[c]	T&E Species Benefits[d,e]	Nonuse Benefits	Total Benefits[b]		
Region	**Low**	**Mean**	**High**				**Low**	**Mean**	**High**
3% Discount Rate									
California	$1.0	$1.7	$2.9	$0.8	-	-	$1.8	$2.5	$3.7
North Atlantic	$0.9	$1.5	$2.4	$0.2	-	$14.8	$15.9	$16.5	$17.4
Mid-Atlantic	$8.4	$14.1	$24.5	$1.6	-	$57.3	$67.3	$73.0	$83.5
South Atlantic	$0.1	$0.2	$0.3	$0.0	-	-	$0.2	$0.2	$0.3
Gulf of Mexico	$3.2	$4.9	$7.6	$1.8	-	-	$5.0	$6.7	$9.4
Great Lakes	$0.7	$1.3	$2.2	$0.1	-	-	$0.8	$1.3	$2.3
Inland	$9.6	$19.9	$41.4	-	$0.7	-	$10.3	$20.6	$42.2
Total	**$24.0**	**$43.5**	**$81.5**	**$4.5**	**$0.7**	**$72.1**	**$101.3**	**$120.8**	**$158.7**
7% Discount Rate									
California	$0.8	$1.3	$2.2	$0.6	-	-	$1.4	$1.9	$2.8
North Atlantic	$0.7	$1.1	$1.8	$0.2	-	$11.5	$12.3	$12.7	$13.4
Mid-Atlantic	$5.8	$9.8	$17.0	$1.1	-	$44.5	$51.4	$55.4	$62.7
South Atlantic	$0.1	$0.1	$0.2	$0.0	-	-	$0.1	$0.1	$0.2
Gulf of Mexico	$2.5	$3.8	$5.9	$1.4	-	-	$3.9	$5.2	$7.3
Great Lakes	$0.6	$1.0	$1.7	$0.0	-	-	$0.6	$1.0	$1.8
Inland	$7.4	$15.3	$31.9	-	$0.6	-	$7.9	$15.8	$32.4
Total	**$17.8**	**$32.4**	**$60.8**	**$3.3**	**$0.6**	**$55.9**	**$77.6**	**$92.2**	**$120.6**

[a] All benefits presented in this table are annualized, i.e., equal to the value of all benefits generated over the time frame of the analysis, discounted to 2012, and then annualized over the entire period of this analysis (2012 to 2062). See Appendix D for detail.

[b] A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique, to estimate the 5th and 95th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a region-and species-specific range of gross revenue, as explained in Chapter 6 of this report. EPA estimated recreational use benefits for some T&E species, as explained in Chapter 5. To calculate the total monetizable value columns (low, mean, high), the values for commercial fishing benefits and T&E species benefits are added to the respective low, mean, and high values for recreational fishing benefits.[c] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

[d] Recreational use benefits from increased abundance of T&E species with potentially high recreational use values (e.g., paddlefish and sturgeon). See Chapter 5 of this report for more detail on EPA's analysis of T&E benefits.

[e] Zeros represent values less than 1,000.

Source: U.S. EPA analysis for this report.

Table 10-10: Summary of National Benefits of Option 3 (I&E Mortality Everywhere) for All In-scope Facilities (2009$)

Region	Annualized Benefits[a] (2009$, millions)								
	Recreational Fishing Benefits			Commercial Fishing Benefits[c]	T&E Species Benefits[d,e]	Nonuse Benefits	Total Benefits[b]		
	Low	Mean	High				Low	Mean	High
3% Discount Rate									
California	$1.1	$1.8	$3.1	$0.8	-	-	$1.9	$2.6	$3.9
North Atlantic	$1.0	$1.6	$2.7	$0.2	-	$15.5	$16.7	$17.3	$18.3
Mid-Atlantic	$8.6	$14.4	$25.1	$1.6	-	$60.0	$70.2	$76.1	$86.7
South Atlantic	$0.1	$0.2	$0.3	$0.0	-	-	$0.2	$0.2	$0.3
Gulf of Mexico	$3.3	$4.9	$7.7	$1.8	-	-	$5.1	$6.7	$9.5
Great Lakes	$0.7	$1.3	$2.3	$0.1	-	-	$0.8	$1.3	$2.3
Inland	$10.0	$20.7	$43.1	-	$0.7	-	$10.7	$21.4	$43.8
Total	**$24.8**	**$44.9**	**$84.2**	**$4.5**	**$0.7**	**$75.5**	**$105.5**	**$125.6**	**$164.9**
7% Discount Rate									
California	$0.8	$1.4	$2.3	$0.6	-	-	$1.4	$2.0	$2.9
North Atlantic	$0.8	$1.2	$2.0	$0.2	-	$12.0	$12.9	$13.4	$14.1
Mid-Atlantic	$6.0	$10.0	$17.5	$1.1	-	$46.5	$53.6	$57.7	$65.1
South Atlantic	$0.1	$0.1	$0.2	$0.0	-	-	$0.1	$0.1	$0.2
Gulf of Mexico	$2.5	$3.8	$5.9	$1.4	-	-	$3.9	$5.2	$7.3
Great Lakes	$0.6	$1.0	$1.8	$0.0	-	-	$0.6	$1.0	$1.8
Inland	$7.6	$15.8	$32.8	-	$0.5	-	$8.1	$16.3	$33.4
Total	**$18.3**	**$33.3**	**$62.5**	**$3.3**	**$0.5**	**$58.5**	**$80.7**	**$95.7**	**$124.9**

[a] All benefits presented in this table are annualized, i.e., equal to the value of all benefits generated over the time frame of the analysis, discounted to 2012, and then annualized over the entire period of this analysis (2012 to 2062). See Appendix D for detail.

[b] A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique, to estimate the 5th and 95th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a region-and species-specific range of gross revenue, as explained in Chapter 6 of this report. EPA estimated recreational use benefits for some T&E species, as explained in Chapter 5. To calculate the total monetizable value columns (low, mean, high), the values for commercial fishing benefits and T&E species benefits are added to the respective low, mean, and high values for recreational fishing benefits.[c] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

[d] Recreational use benefits from increased abundance of T&E species with potentially high recreational use values (e.g., paddlefish and sturgeon). See Chapter 5 of this report for more detail on EPA's analysis of T&E benefits.

[e] Zeros represent values less than 1,000.

Source: U.S. EPA analysis for this report.

Table 10-11: Summary of National Benefits by Regulatory Option for All In-scope Facilities (2009$)

Regulatory Option	Annualized Benefits[a] (2009$, millions)								
	Recreational Fishing Benefits			Commercial Fishing Benefits[c]	T&E Species Benefits[d,e]	Nonuse Benefits	Total Benefits		
	Low	Mean	High				Low	Mean	High
3% Discount Rate									
Baseline	$42.7	$76.89	$143.2	$8.05	$1.14	$128.64	$180.5	$214.72	$281.0
Option 1	$8.0	$15.62	$31.4	$0.99	$0.50	$0.52	$10.0	$17.63	$33.4
Option 2	$24.0	$43.52	$81.5	$4.47	$0.72	$72.10	$101.3	$120.80	$158.7
Option 3	$24.8	$44.94	$84.2	$4.52	$0.72	$75.48	$105.5	$125.65	$164.9
7% Discount Rate									
Baseline	$42.0	$75.64	$141.0	$7.89	$1.14	$130.78	$181.8	$215.45	$280.8
Option 1	$7.2	$14.21	$28.5	$0.89	$0.45	$0.48	$9.1	$16.04	$30.3
Option 2	$17.8	$32.40	$60.8	$3.31	$0.56	$55.94	$77.6	$92.21	$120.6
Option 3	$18.3	$33.30	$62.5	$3.34	$0.55	$58.52	$80.7	$95.71	$124.9

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere

[a] All benefits presented in this table are annualized, i.e., equal to the value of all benefits generated over the time frame of the analysis, discounted to 2012, and then annualized over the entire period of this analysis (2012 through 2062). See Appendix D for detail.

[b] A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique, to estimate the 5th and 95th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a region- and species-specific range of gross revenue, as explained in Chapter 6 of this report. EPA estimated recreational use benefits for some T&E species, as explained in Chapter 5. To calculate the total monetizable value columns (low, mean, high), the values for commercial fishing benefits and T&E species benefits are added to the respective low, mean, and high values for recreational fishing benefits.

[c] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

[d] Recreational use benefits from increased abundance of T&E species with potentially high recreational use values (e.g., paddlefish and sturgeon).

See Chapter 5 of this report for more detail on EPA's analysis of T&E benefits.

Source: U.S. EPA analysis for this report.

10.5 Break-Even Analysis

Comprehensive estimates of total resource value include both use and nonuse values, such that the resulting total value estimates may be compared to total social cost. Recent economic literature provides substantial support for the hypothesis that mean nonuse values are greater than zero. Moreover, when small per-capita nonuse values are held by a substantial fraction of the population, they can be very large in the aggregate. While the general proposition is true, in this specific context we have been able to estimate nonuse values for only two of the seven benefits regions.

As shown in Table 10-6 above, nearly all—97 percent—I&E mortality losses at cooling water intake structures under current conditions (the baseline scenario) consist of either forage species or unlanded recreational and commercial species that are not harvested and thus were not assigned direct use values. Although individuals do not use these resources directly, they may value changes in the status or quality of these resources. EPA did not estimate nonuse values for forage and unlanded species occurring in five of the seven benefits regions. Due to the uncertainties of providing estimates of the magnitude of nonuse values associated with the regulatory options for all regions, this section provides an alternative approach for evaluating the potential relationship between benefits and costs. The approach used here applies a "break-even" analysis to identify what the unmonetized nonuse values would have to be in order for the proposed options to have benefits that are equal to costs.

The break-even approach uses EPA's estimates of monetized commercial and recreational use benefits for the regulatory options, and subtracts them from the estimated annual compliance costs incurred by facilities subject to the options. The resulting "net cost" enables one to work backwards to estimate what the nonuse values would need to be (in terms of willingness to pay per household per year) in order for total annualized benefits to equal annualized costs. Table 10-12 provides this assessment for the proposed options. The table shows benefit values using a 3 percent or 7 percent discount rate, respectively.

As shown in Table 10-12, for total annualized benefits to equal total annualized costs, nonuse values per household would have to be at least $3, but may be as great as $40 under the 3 percent discount rate, depending on the regulatory option. The 7 percent discount estimates show that nonuse values per household would have to be $4 to $42, depending on the regulatory option.

Table 10-12: Implicit Nonuse Value—Break-Even Analysis, 3 Percent and 7 Percent Discount Rates (2009$)

Regulatory Option[a]	Use Benefits (2009$, millions)[a]	Annual Social Cost (2009$, millions)[b]	Annual Nonuse Benefits Necessary to Break Even (2009$)[c, d]	Number of Households in States with In-scope 316(b) Facilities (millions)[e]	Annual Break-Even Nonuse WTP per Household (2009$)[f]
3% Discount Rate					
Option 1	$17.11	$383.80	$366.69	114.5	$3.20
Option 2	$48.71	$4,462.90	$4,414.19	114.5	$38.54
Option 3	$50.17	$4,631.62	$4,581.45	114.5	$40.00
7% Discount Rate					
Option 1	$15.55	$458.81	$443.26	114.5	$3.87
Option 2	$36.27	$4,699.35	$4,663.08	114.5	$40.71
Option 3	$37.19	$4,862.05	$4,824.86	114.5	$42.12

Scenarios: Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere

[a] Benefits are discounted using a 3% or 7% discount rate, respectively. Use benefits include estimated commercial fishing benefits, recreational fishing benefits, and use benefits for T&E species.

[b] The total social cost of the final rule includes facility compliance costs and administrative costs.

[c] Annualized compliance costs minus annualized use benefits.

[d] Nonuse benefits may also include unmonetized use benefits, i.e., improvements in bird watching.

[e] From U.S. Census 2000 (BLS): http://factfinder.census.gov.

[f] Dollars per household per year that, when added to use benefits, would yield a total annualized benefit (use plus nonuse) equal to the annualized costs.

While this approach of backing out the "break-even" nonuse value per household does not answer the question of what nonuse values might actually be for the regulatory options, these results do frame what the unknown values would have to be in order for benefits to equal or exceed costs. The break-even approach poses the question: "Is the true per-household willingness to pay for the nonuse amenities (existence and bequest) associated with an option likely to be greater or less than the 'break-even' benefit levels displayed in Table 10-12?" The results of EPA's Habitat Equivalency Analysis (HEA) (Chapter 9) illustrate the potential magnitude of nonuse values for 316(b) regulatory options. However, EPA does not consider HEA appropriate for a primary analysis of nonuse benefits due to limitations of the approach and assumptions required for its application to 316(b) regulatory options.

11 Option 4 Results

11.1 Introduction

In addition to the three regulatory options presented in the preceding chapters of this report, i.e., Options 1, 2, and 3, EPA analyzed an additional regulatory option – Option 4: I for Facilities > 50 MGD – in developing the Proposed 316(b) Existing Facilities Regulation. Option 4 is the same as Option 1: I Everywhere, in all respects except for not requiring I mortality control for facilities less than 50 MGD. Because EPA analyzed Option 4 *after* completing the analysis and documentation of the three main regulatory options, the analysis results for Option 4 are presented separately in this chapter. The methodology used to estimate the benefits of Option 4 are identical to those used for Options 1, 2, 3. See Chapters 3 through 9 for additional detail regarding EPA's methodology. This chapter presents the results for Option 4 in two parts:

- The expected reductions in I&E Mortality under Option 4; and
- The monetized benefits under Option 4, including recreational fishing, commercial fishing, T&E species, and nonuse benefits.

11.2 Expected Reductions in I&E Mortality under Option 4

Based on the results of the regional analyses, EPA calculated the total amount by which I&E mortality losses would be reduced under Option 4. The number of fish lost at in-scope facilities is presented in terms of age-1 equivalent (A1E) losses within Table 11-1. All reductions in I&E mortality under Option 4 are associated with reduced impingement. The reduction in national A1E losses is 602 million, or approximately 98 percent of the reductions under Option 1 (I Everywhere). The percentage of national A1E losses assigned a direct use value is 2.6 percent, slightly higher than the percentage observed under Option 1. The remaining 97 percent of I&E mortality losses include unharvested recreational and commercial fish and forage fish which are not assigned direct use values. Reductions in I&E mortality for T&E species are slightly less than Option 1 (Table 5-5). Appendix C provides additional detail regarding reductions in I&E mortality losses under Option 4.

Table 11-1: Distribution of I&E Mortality for All In-scope Facilities by Region Under Option 4 (I Everywhere without New Units Requirements)

Region	All Species (million A1E)	Forage Species (million A1E)	Commercial & Recreational Species (million A1E)	Commercial & Recreational Harvest (million fish)	A1E Losses with Direct Use Value (%)
California	0.7	0.2	0.5	0.1	8.0%
North Atlantic	0.4	0.4	0.1	<0.1	1.5%
Mid-Atlantic	38.6	14.3	24.4	6.1	15.8%
South Atlantic	14.2	13.4	0.8	0.1	0.7%
Gulf of Mexico	34.2	4.3	30.0	4.6	13.3%
Great Lakes	37.9	33.2	4.7	0.5	1.3%
Inland	476.3	448.4	27.9	4.2	0.9%
Total	**602.4**	**514.1**	**88.3**	**15.5**	**2.6%**

11.3 Monetized Benefits Under Option 4

EPA's estimation of regional and national benefits under Option 4 are based on EPA's regional estimates of reductions in I&E mortality losses. Option 4 would result in an estimated increase of approximately 5.7 million harvestable recreational fish and an estimated annual increase of 5.5 million pounds of commercial harvest (Table 11-2**Error! Reference source not found.**). Monetized nonuse benefits are based on estimated increase in winter flounder abundance of 0.03 percent, calculated using the approach described in Chapter 8. Under Option 4, recreational fishing benefits account for the majority of the national benefits similar to Option 1 (I Everywhere). As described in Chapter 10, EPA estimated mean values, as well as values that include the 5th percentile lower bound and 95th percentile upper bound of the recreational benefits estimates.

Table 11-2: Annual Increase in Recreational and Commercial Harvest Under Option 4 (I Everywhere without New Units Requirements)

Region	Annual Increase in Recreational Harvest (harvestable adult fish)	Annual Increase in Commercial Harvest (thousand lbs)
California	35,421	6.5
North Atlantic	1,495	2.9
Mid-Atlantic	548,496	3746.3
South Atlantic	15,882	45.1
Gulf of Mexico	660,672	1448.4
Great Lakes	174,601	225.1
Inland	4,215,546	-
Total	**5,652,113**	**5474.3**

Overall, monetized benefits under Option 4 are slightly less than those estimated for Option 1:

- Using a 3% discount rate, Option 4 results in national benefits of $17.3 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling $9.8 million and $32.8 million (Table 11-3). Use benefits are estimated to be $16.8 million with an annual break-even nonuse WTP of $2.70 per household based on total social costs of $326.6 million.
- Using a 7% discount rate, Option 4 results in national benefits of $15.8 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling $8.9 million and $29.8 million (Table 11-3). Use benefits are estimated to be $15.3 million with an annual break-even nonuse WTP of $3.21 per household based on total social costs of $383.1 million.

Table 11-4 summarizes results from applying the habitat-based approach described in Chapter 9. Similar to other options, the Inland region accounts for the majority of habitat acres. National weighted WTP is estimated to be $510 million and $474 million using discount rates of 3% and 7%, respectively. As described in previous chapters, EPA did not include values estimated using the habitat-based approach within its estimate of national benefits as presented in Table 11-3.

Table 11-3: Summary of National Benefits of Option 4 (I for Facilities > 50 MGD) (2009$)

Region	Annualized Benefits[a] (2009$, millions)								
	Recreational Fishing Benefits			Commercial Fishing Benefits[c]	T&E Species Benefits[d,e]	Nonuse Benefits	Total Benefits[b]		
	Low	Mean	High				Low	Mean	High
3% Discount Rate									
California	$0.1	$0.1	$0.1	$0.0	-	-	$0.1	$0.1	$0.1
North Atlantic	$0.0	$0.0	$0.0	$0.0	-	$0.1	$0.1	$0.1	$0.1
Mid-Atlantic	$0.8	$1.6	$3.1	$0.3	-	$0.4	$1.6	$2.3	$3.9
South Atlantic	$0.0	$0.0	$0.1	$0.0	-	-	$0.0	$0.0	$0.1
Gulf of Mexico	$1.4	$2.4	$4.3	$0.6	-	-	$2.0	$3.0	$4.9
Great Lakes	$0.6	$0.9	$1.6	$0.0	-	-	$0.6	$1.0	$1.7
Inland	$4.9	$10.3	$21.5	-	$0.5	-	$5.4	$10.8	$22.0
Total	**$7.8**	**$15.3**	**$30.8**	**$1.0**	**$0.5**	**$0.5**	**$9.8**	**$17.3**	**$32.8**
7% Discount Rate									
California	$0.0	$0.1	$0.1	$0.0	-	-	$0.0	$0.1	$0.1
North Atlantic	$0.0	$0.0	$0.0	$0.0	-	$0.1	$0.1	$0.1	$0.1
Mid-Atlantic	$0.7	$1.4	$2.8	$0.3	-	$0.4	$1.4	$2.1	$3.5
South Atlantic	$0.0	$0.0	$0.0	$0.0	-	-	$0.0	$0.0	$0.1
Gulf of Mexico	$1.3	$2.2	$3.9	$0.5	-	-	$1.8	$2.7	$4.5
Great Lakes	$0.5	$0.9	$1.5	$0.0	-	-	$0.6	$0.9	$1.5
Inland	$4.5	$9.4	$19.6	-	$0.4	-	$5.0	$9.8	$20.1
Total	**$7.1**	**$13.9**	**$28.0**	**$0.9**	**$0.4**	**$0.5**	**$8.9**	**$15.8**	**$29.8**

[a] All benefits presented in this table are annualized, i.e., equal to the value of all benefits generated over the time frame of the analysis, discounted to 2012, and then annualized over the entire period of this analysis (2012 to 2062). See Appendix D for detail.

[b] A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique, to estimate the 5th and 95th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a region-and species-specific range of gross revenue, as explained in Chapter 6 of this report. EPA estimated recreational use benefits for some T&E species, as explained in Chapter 5. To calculate the total monetizable value columns (low, mean, high), the values for commercial fishing benefits and T&E species benefits are added to the respective low, mean, and high values for recreational fishing benefits.[c] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

[d] Recreational use benefits from increased abundance of T&E species with potentially high recreational use values (e.g., paddlefish and sturgeon). See Chapter 5 of this report for more detail on EPA's analysis of T&E benefits.

[e] Zeros represent values less than 1,000.

Table 11-4: Weighted WTP for Habitat Restoration Area Equivalent to I&E Mortality Reductions by Region under Option 4 (I for Facilities > 50 MGD)

Region	Secondary Productivity (kg acre-1 year-1)	I&E Losses (metric tons A1E, dry weight)	Equivalent Restoration Area (acres)	Household WTP $acre^{-1}$ $year^{-1}$ (2009$)	Weighted WTP (2009$, millions)	
					3% Discount Rate	7% Discount Rate
California	96	3	35	-	0.0	0.0
North Atlantic	50	1	23	0.076	0.5	0.4
Mid-Atlantic	47	240	5,145	0.017	211.1	196.3
South Atlantic	83	13	159	0.011	0.4	0.3
Gulf of Mexico	83	338	4,091	0.011	152.7	142.0
Great Lakes	82	251	3,065	0.003	10.4	9.6
Inland	82	3,340	40,813	0.001	134.8	125.4
Total (All Regions)	**-**	**4,186**	**53,331**	**-**	**509.9**	**474.0**

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Appendix A: Extrapolation Methods

A.1 Introduction

Survey sample weights for manufacturing facilities and electric power generating facilities were used in the analysis of 316(b) Phase II and Phase III regulations (USEPA 2004b; USEPA 2006b). To account for differences between electric power facilities that received the DQ and those that received the Short Technical Questionnaire (STQ), and to account for 316(b) study regions, new weights were developed. These weights are referred to as *new benefits weights*. This appendix explains the development of these facility-level weights and their use in the benefits analysis for the proposed 316(b) regulation.

A.2 Manufacturing Facilities

The current analysis of manufacturing facilities incorporates a set of *technical weights* developed for the 2006 Final Phase III Rule. These technical weights are based on engineering information obtained from the 316(b) Manufacturers Questionnaire, including an estimate of the number of affected facilities and the cost of installing new technology. However, because technical weights do not account for facility location or intake flow, they cannot be used to directly estimate intake flow at a regional level, a key parameter for the benefits analysis. This section presents new benefits weights developed by EPA for in-scope manufacturing facilities.

New benefits weights were developed by adjusting technical weights for traditional manufacturers (MN facilities)[48] and non-utility manufacturers (MU facilities) such that estimates of regional mean operational flow are consistent with EPA's best estimates for manufacturing facilities. EPA chose this characteristic because operational intake flow is the most important factor in the benefits analysis: I&E mortality losses as a function of mean operational intake flow. EPA included eight regions when developing weights for MN and MU facilities: North Atlantic, Mid-Atlantic, South Atlantic, Gulf of Mexico, California, Pacific Northwest,[49] Great Lakes, and Inland regions.[50]

Information on total regional flow was not available for MN and MU facilities. Thus, EPA used the number of facilities present in any single region as a control variable. This presumes that the flow characteristics of these represented facilities are the same as the DQ facilities. The following two sections describe development of weight adjustment factors for MN and MU facilities, respectively.

A.2.1 Traditional Manufacturers (MN Facilities)

EPA stratified the universe of MN facilities by study region and industry category so that the regional distribution of in-scope MN facilities corresponds to the actual geographic distribution of all MN facilities

[48] MN facilities include aluminum, steel, chemical, pulp and paper, and petroleum refining manufacturing industries. Note that Food and Kindred Products is not included in this list of industries for two reasons: a) this industry was not included in the original stratification of manufacturers, and b) all facilities later identified to be in the Food and Kindred Product industries were part of the MU universe.

[49] The Pacific Northwest region is ultimately excluded from the benefits analysis because it includes a single DQ facility which is projected to close as baseline.

[50] See Chapter 1 for additional information regarding regional definitions.

in a given industry.[51] Under this approach, EPA first determined the distribution of in-scope facilities by study region, and then calculated adjusted benefits weights based on this distribution.

Determining the Distribution of In-scope Facilities by Study Region

EPA obtained latitude-longitude coordinates (lat-long) for all facilities in relevant Standard Industrial Classification (SIC) codes[52] that have NPDES permits within PCS (Permit Compliance System) and ICIS-NPDES (Integrated Compliance Information System- NPDES). Facilities within relevant SIC codes were assigned to a study region using lat-long. A map of RF1 reaches[53] was also used to indicate whether the facility location is coastal/estuarine or inland. Table A-1 presents the distribution of the facility universe according to region and industry based on the PCS/ICIS data.

The sample frame for the survey screener of manufacturing facilities did not include all facilities in the relevant SIC codes. Information on which facilities were included in the sample frame for the screener is not available. Therefore, EPA used two simplifying assumptions to develop weight adjustment factors: (1) the universe of in-scope facilities in any single industry equals the sum of DQ facilities weights and (2) the geographic distribution of NPDES permitted facilities in the relevant SIC codes is representative of the geographic distribution of in-scope facilities.

For each industry, EPA assumed that the geographic distribution of facilities included in the EPA PCS/ICIS database was equivalent to the geographic distribution of the DQ frame. To meet this assumption, EPA redistributed the weights of in-scope DQ facilities in each study region to match the geographic distribution of facilities in the PCS/ICIS database. The second and third columns in Table A-1 present the estimated distribution of in-scope MN facilities based on PCS/ICIS data.[54]

Calculating Adjusted Weights for Benefits Analysis

EPA first compared the regional distribution of weighted of in-scope DQ facilities to the distribution of facilities present in the PCS/ICIS universe. Table A-1 presents the distribution of DQ facilities based on technical weights, the weight adjustment factors for MN facilities, and the expected number of DQ facilities for all regions. The number of DQ facilities in each region was re-estimated using the PCS/ICIS distribution of facilities in that region. This adjustment factor was defined as the quotient of the number of DQ facilities within a region and industry divided by the original number of weighted DQ facilities assigned to the same stratum. If the PCS/ICIS facilities universe indicated that a region had a small number of facilities within a single industry and did not have DQ facilities (e.g., the North Atlantic region for the Aluminum sector), EPA assumed that no in-scope facilities existed within the stratum. Because regions without DQ facilities comprised a small fraction of the PCS/ICIS facility universe, this assumption is likely to introduce negligible error. If the adjusted weight for a sample DQ facility was less than one, it was assigned a weight of one so that its actual flow would be fully counted. The cost analysis

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[51]Weights were not adjusted for petroleum refineries because survey screeners were sent to the entire universe and DQs were sent to all in-scope facilities. Weights for facilities determined to be in other industries after receipt of the DQ were given weights of 1, which were not adjusted.

[52]The SIC code describes the primary activity of the facility.

[53]EPA's reach file (RF1) is a database of interconnected steam segments of "reaches" that comprise the surface water drainage system for the United States.

[54]EPA used the following databases to obtain information on the number of facilities in each SIC code: FRS (Federal Registry System), PCS (Permit Compliance System), ICIS-NPDES (Integrated Compliance Information System- NPDES) and TRI (Toxics Release Inventory). None of these databases records intake flow.

estimates 32 facilities to close under baseline conditions. Accordingly, EPA excluded the baseline closures and their weights from the benefits analysis and weights readjustment.

The final two columns of Table A-1 present estimated total flow for each sector and region when both original DQ and adjusted weights have been applied. In many sectors, estimated flow is slightly smaller due to the lack of DQ facilities combinations of region and industry. Conversely, weight-adjusted flow in the chemical sector increases slightly due to good coverage of DQ facilities which shifted weights to facilities with above-average flow.

Table A-1: MN DQ Distribution and Calculation of Weight Adjustment Factors							
Benefits Region	**Distribution of Facilities in PCS/ICIS Databases**		**Number of**			**Regional Mean Operational Flow (MGD)**	
	Number	**%**	**DQ-weighted Facilities[1]**	**Adjustment Factor**	**Adjusted Weight Estimates**	**DQ-weighted**	**Adjusted Weight Estimates**
Aluminum							
North Atlantic	7	6%	No DQs[2]		0	No DQs	0.0
Mid-Atlantic	11	9%	No DQs[2]		0	No DQs	0.0
South Atlantic	1	1%	No DQs		0	No DQs	0.0
Great Lakes	2	2%	3	0.09	1	30.3	9.7
Gulf of Mexico	1	1%	No DQs		0	No DQs	0.0
Pacific Northwest	0	0%	No DQs		0	No DQs	0.0
California	0	0%	No DQs		0	No DQs	0.0
Inland	95	81%	13	1.01	13	87.0	88.3
Total	**117**	**100%**	**16**		**14**	**117.3**	**98.0**
Chemical							
North Atlantic	16	1%	No DQs		0	No DQs	0.0
Mid-Atlantic	75	6%	4	2.14	9	28.7	61.3
South Atlantic	9	1%	4	0.26	1	56.4	14.5
Great Lakes	32	3%	17	0.23	4	331.0	77.1
Gulf of Mexico	100	8%	4	2.85	12	283.9	809.8
Pacific Northwest	4	0%	No DQs		0	No DQs	0.0
California	5	0%	4	0.14	1	1.5	0.4
Inland	951	80%	112	1.04	117	1,782.8	1,860.0
Total	**1,192**	**100%**	**146**		**144**	**2,484.3**	**2,823.1**
Paper							
North Atlantic	2	1%	No DQs		0	No DQs	0.0
Mid-Atlantic	7	2%	No DQs		0	No DQs	0.0
South Atlantic	8	2%	No DQs		0	No DQs	0.0
Great Lakes	19	5%	3	1.684	5	6.7	11.2
Gulf of Mexico	2	1%	No DQs		0	No DQs	0.0
Pacific Northwest	3	1%	No DQs		0	No DQs	0.0
California[3]	0	0%	3	1.00	3	32.2	32.2
Inland	354	90%	91	0.95	86	1,242.9	1,181.4
Total	**395**	**100%**	**96**		**94**	**1,281.8**	**1,224.8**
Steel							
North Atlantic	3	1%	No DQs		0	No DQs	0.0
Mid-Atlantic	5	2%	No DQs		0	No DQs	0.0
South Atlantic	1	0%	No DQs		0	No DQs	0.0
Great Lakes	25	10%	6	0.54	3	2,054.3	1,112.1
Gulf of Mexico	3	1%	No DQs		0	No DQs	0.0
Pacific Northwest	1	0%	No DQs		0	No DQs	0.0
California	2	1%	No DQs		0	No DQs	0.0
Inland	214	84%	28	1.03	29	519.6	535.0
Total	**254**	**100%**	**34**		**32**	**2,573.9**	**1,647.1**
Petroleum							
North Atlantic	0	0%	No DQs		0	No DQs	0.0
Mid-Atlantic	2	11%	2	1.00	2	203.4	203.4
South Atlantic	0	0%	No DQs		0	No DQs	0.0
Great Lakes	0	0%	No DQs[4]		0	No DQs	0.0
Gulf of Mexico	1	6%	1	1.00	1	42.6	42.6
Pacific Northwest	0	0%	No DQs		0	No DQs	0.0
California	1	6%	1	1.00	1	31.8	31.8
Inland	15	78%	15	1.00	15	250.7	250.7
Total	**19**	**100%**	**19**		**19**	**528.4**	**528.4**

Table A-1: MN DQ Distribution and Calculation of Weight Adjustment Factors

Benefits Region	Distribution of Facilities in PCS/ICIS Databases		Number of			Regional Mean Operational Flow (MGD)	
	Number	%	DQ-weighted Facilities[1]	Adjustment Factor	Adjusted Weight Estimates	DQ-weighted	Adjusted Weight Estimates
Other							
Inland	1	100%	1	1.00	1	4.1	4.1
Total	**1**	**100%**	**1**		**1**	**4.1**	**4.1**
Total for All Industries							
North Atlantic	28	1%	No DQs		0	No DQs	0.0
Mid-Atlantic	100	5%	6		11	232.0	264.7
South Atlantic	19	1%	4		1	56.4	14.5
Great Lakes	78	4%	29		13	2,422.3	1,210.0
Gulf of Mexico	107	5%	5		13	326.5	852.4
Pacific Northwest	8	0%	No DQs		0	No DQs	0.0
California	8	0%	8		5	65.5	64.4
Inland	1,630	82%	259		260	3,887.0	3,919.5
Total	**1,978**	**100%**	**312**		**304**	**6,989.8**	**6,325.5**

[1]EPA did not adjust weights for petroleum refineries because the DQ was a census of in-scope facilities, nor for facilities in "other" industries because they were outside the five SIC codes for which weights were developed and are not assumed to represent any other facilities.
[2]Though these regions account for more than 5% of Aluminum manufacturers but have no DQs, the average flow for Aluminum manufacturers is less than 10 MGD. Potential benefits associated with these facilities would be relatively minor.
[3]While the PCS/ICIS data did not identify any Paper facilities in the California Region, there was 1 DQ facility in this region with a weight of 3. This weight was not adjusted.
[4]There was 1 DQ refinery in the Great Lakes region. However this facility was assessed as a baseline closure in the economic analysis and thus receives an adjustment factor of 0.

A.2.2 Non-utility Manufacturers (MU Facilities)

EPA accounted for the geographic distribution of MU facilities using a methodology similar to that used for MN facilities. Weights were adjusted so that the distribution of the weighted number of DQ facilities matched the actual geographic distribution of the facility universe. Under this approach, EPA first determined the distribution of in-scope facility by study region, and then calculated adjusted weights for use in the benefits analysis.

Determining the Distribution of In-scope Facilities by Study Region

The entire universe of MU facilities was known based on the survey screener and the OTIS Facility-finder tool was used to obtain facility location data.[55] EPA distributed the universe of facilities among study regions based on the regional distribution of MU facilities with location data from OTIS Facility-finder.

Calculating Adjusted Weights for Benefits Analysis

For each study region, EPA compared the estimated number of MU facilities with the DQ-weighted number of facilities in the region. An adjustment factor was calculated as the quotient of the estimated number of facilities in each region divided by the DQ-weighted number of facilities in each region. If the adjusted weight for a facility was less than one, it was assigned a weight of one to fully account for the

[55] While the survey screener asked for facilities' flow, EPA was unable to develop adjustment factors using total flow as a control variable.

flow of the sampled facility. Adjustment factors and adjusted flow by benefits region are presented in Table A-2.

Table A-2: MU Adjustment Factors and Adjusted Flow by Benefits Region					
Benefits Region	**Estimated Facilities from In-scope Distribution**	**DQ-weighted Facilities**	**Adjustment Factor**	**Total Original Weighted Flow (MGD)**	**Total Adjusted Weighted Flow (MGD)**
MU Facilities					
North Atlantic	6	5	1.2	220.9	275.3
Mid-Atlantic	3	6	0.5	440.8	369.0
South Atlantic	2	No DQs		No DQs	0.0
Great Lakes	14	12	1.2	1,186.4	1,400.0
Gulf of Mexico	8	6	1.3	577.0	744.0
Pacific Northwest	0	1	0.0	0	0.0
California	2	1	2.0	3.6	7.3
Inland	163	174	0.9	9,464.7	8,880.9
Total	**198**	**205**		**11,893.5**	**11,676.6**
NU Facilities Determined to be Manufacturers[1]					
Inland	N/A	12	16	392.9	392.9
Paper					
Grand Total	**N/A**	**217**		**12,286.4**	**12,069.5**

[1]Two facilities that were surveyed as non-utilities (NU) were later determined to be non-utility manufacturers and are analyzed as such in the cost analysis. Their weights were not adjusted because they were not part of the original MU facility universe and are both in the inland region. Given that the majority of MU facilities are located in the Inland region the use of original weights is unlikely to bias regional benefit results

A.3 Electric Power Generating Facilities

The benefits analysis for electric power generating facilities uses a combination of weights from the 316(b) Phase II and Phase III analyses and sample weights developed to support the 2010 analysis. Weights from Phase II and Phase III accounted for non-sampled facilities and non-respondents to industry surveys and are referred to as the *original survey weights*.[56]

When estimating national-level benefits, sample weights based on facility-specific (e.g., size and engineering) characteristics can lead to conditional bias. In particular, this approach does not consider factors influencing the occurrence and size of benefits such as the location of facilities subject to the regulatory options, actual intake flow, similarities among aquatic species affected by these facilities, and characteristics of commercial and recreational fishing activities in the area. EPA used a post-stratification weight adjustment to calculate benefits weights that account for data dimensions not included in the original sample design. These benefits weights re-scale DQ-based weights using additional information from the STQ so that total regional flows represented by both weighting systems are equivalent.

The remainder of this appendix describes the post-stratification weight adjustment for electric power generating facilities. Section A.3.1 describes how the strata were defined. Section A.3.2 presents and discusses the estimates resulting from the post-stratified weighting schemes and compares these to the original DQ weights.

[56]In general, the original survey weights are numerically very low, as EPA had either DQ or STQ information for 621 out of the 634 electric generating facilities presumed to be in scope of the regulation. For more information on EPA's Section 316(b) Industry Surveys, please refer to the Information Collection Request (USEPA 2000b).

A.3.1 Defining the Strata and Control Variables

EPA included six study regions when developing benefits weights for electric power generating facilities: North Atlantic, Mid-Atlantic, South Atlantic, Gulf of Mexico, Great Lakes, Inland, and California regions. Strata characteristics used to adjust weights are presented in Table A-3.

I&E mortality losses are largely a function of mean operational intake flow and characteristics of local fishery resources. Therefore, regional non-recirculated operational flow is the most important factor in defining strata for the benefits estimation, and it is more important to group estimated total benefits by non-recirculated intake flow in a study region than by number of facilities. When calculating weights, EPA included a strata based on a 125 MGD DIF so that benefit estimates accurately reflect changes in technology under the options analyzed under the regulation.

Table A-3: Matrix of Strata and Control Variables for Adjusting DQ Weights

Strata	Mean Operational Flow (GPD)			
	Facilities *with* Recirculation Technology[1]		Facilities *without* Recirculation Technology	
	DIF < 125 MGD	DIF > 125 MGD	DIF < 125 MGD	DIF > 125 MGD
North Atlantic	0	0	238	6,510
Mid-Atlantic	68	0	257	26,518
South Atlantic	46	0	0	7,033
Gulf of Mexico	0	0	0	9,049
Great Lakes	57	181[c]	343	15,428
Inland	1,258	2,221	1,900	117,989
California[2]	0	0	0	1,135
Total	**1,429**	**2,402**	**2,738**	**183,663**

[1]Includes all electric generating facilities with recirculating technology regardless of intake velocity.
[2]Generators in the state of California were excluded from the analysis; however, the California region includes three facilities in Hawaii.

A.3.2 Comparison of Results of the Detailed Questionnaire and Post-Stratified Weighting Schemes

EPA assigned post-stratification weights (Table A-3) so that tabulations of total mean operational flow by region and DIF threshold correspond to the best estimates of operational flow based on information provided by both DQ and STQ questionnaires. Estimated mean operational flow under various weighting procedures are presented in Table A-4. Regional control total is calculated using operational flow data from DQ and STQ and facility-level *original sample weights* that account for non-sampled facilities and non-respondents. The DQ total is the total operational flow of facilities to which weights are applied. By design, the post-stratification estimate of mean operational flow equals the control total estimate. Benefits weights are determined as the quotient of the control total divided by the DQ total. The number of facilities estimated using these weights may not match the control estimate of the population of facilities. For example, when average mean operational flow in the DQ sample of facilities is lower than the total operational flow of all facilities in a given region, larger sample weights must be assigned to ensure the estimated sample-weighted operational flow is equivalent to the control total. Thus, although total operational flow is equivalent, the number of facilities estimated using these weights may be an overestimate of facilities within the region. This shortcoming is not important, however, because DQ weights are not used to estimate the number of facilities.

During the weight development process, EPA assessed the variance of the new weights to examine their reasonableness. Weights with smaller variance generally lead to estimates with smaller variance unless the larger variance of the weights reflects the characteristics on which the estimates depend. Since mean operational flow is the most important factor in determining benefits, EPA believes that accounting for this factor while minimizing the variance of the weights is the best approach. This is accomplished by assigning an equal weight to all facilities within a given stratum. One alternative would be to adjust the original DQ weight. However, adjusting original DQ weights increases the variance of new weights. The additional variance is not likely to reflect the characteristics on which the estimates depend, and therefore these weights are inferior.

Table A-4: Mean Operational Flow by Benefits Region: Post-Stratification by Mean Regional Operational Flow for Facilities Without Recirculation (MGD)

Region	Recirculating Flow				Non-recirculating Flow			
	< 125 DIF (MGD)		> 125 DIF (MGD)		< 125 DIF (MGD)		> 125 DIF (MGD)	
	DQ Total	Control Total	DQ Total	Control Total	DQ Total	Control Total	DQ Total	Control Total
North Atlantic	0	0	0	0	209	238	2,978	6,510
Mid-Atlantic	58	68	0	0	231	257	8,743	26,518
South Atlantic[1a]	0	46	0	0	0	0	3,481	7,033
Gulf of Mexico	0	0	0	0	0	0	6,751	9,049
Great Lakes	0	57	0	181[c]	120	343	5,199	15,428
Inland	528	1,258	620	2,221	1,003	1,900	51,560	117,989
Total	**587**	**1,429**	**620**	**2,402**	**1,625**	**2,799**	**80,631**	**194,997**

[1]A total of five STQ facilities with baseline (one in the South Atlantic and four in the Great Lakes) did not have a DQ facility to represent them within the region and DIF strata. Their flow was added to the respective non-recirculating totals when calculating benefits weights, and are assigned the same benefits weights as non-recirculating facilities within the same region and DIF category.

Appendix B: Consideration of Potential Ecological Effects due to Thermal Discharges

B.1 Introduction

Impacts of thermal discharges, along with other stressors, are a relevant consideration when assessing the potential impacts of electric power plant cooling water intakes (CWIS) and associated discharges. Several studies have demonstrated the adverse effects that increased temperatures or altered seasonal thermal regimes have on local biota and fauna. In some cases, studies have indicated little or no apparent harm is caused by the thermal discharges. This emphasizes the need for NPDES permit writers to consider site-specific factors when assessing the potential ecological effects due to thermal discharges.

This appendix provides information on the general effects of thermal discharges on aquatic biota and ecosystems, considers the influence of site-specific factors and environmental settings on determining the level (if any) of ecological impacts, and discusses limitation and uncertainty associated with thermal studies. It also presents three case studies from power plants in different environmental settings (Brayton Point Station, Quad Cities Nuclear Station, and Point Beach Nuclear Plant) which underwent detailed thermal studies under Clean Water Act (CWA) Section 316(a) provisions and which show the importance of site specific factors in determining the potential for appreciable harm. The Section 316(a) demonstrations described in the three case studies represent unusually complete and thorough investigations of thermal impacts to receiving aquatic ecosystems. Thermal investigations at other power plants are highly site-specific, but typically have a much reduced scope and effort compared to those portrayed by the case studies.

It should be noted that even at power plants where demonstrations of no appreciable harm have been made to regulatory authorities under Section 316(a), supporting thermal studies nonetheless often show periods during which thermal limits are exceeded. Impacts of thermal discharges should therefore be revisited on a case-by-case basis as conditions change, for example(i) if plants increase their power capacity (i.e., “uprate”) and increase thermal loads to the receiving waterbody; (ii) if the thermal assimilative capacity of the receiving waterbody is otherwise compromised; or (iii) in the face of new evidence that cooling water discharges are causing appreciable harm to the balanced, indigenous population/community of shellfish, fish, and wildlife or fail to ensure the protection or propagation of the population. Such assessments need to consider the extent, duration, timing, and frequency of adverse thermal impacts, the target threshold temperature for each species, the potential for adverse temperature effects on larger ecological processes, and other relevant site-specific factors.

B.2 General Effects of Thermal Discharges on Aquatic Biota and Ecosystems

Thermal discharges affect aquatic organisms by elevating water temperatures or altering seasonal patterns of temperature change. Temperature is considered a master environmental variable for aquatic ecosystems, affecting virtually all biota and biologically mediated processes, chemical reactions, as well as structuring the physical environment of the water column. There is a well-established scientific literature cataloguing the impacts of elevated or variable temperature on a wide spectrum of aquatic life, including numerous species-specific determinations of thermal tolerance limits for growth, survival, reproduction and behavior (e.g., Beitinger et al. 2000; Leffler 1972; McMahon 1975).

Much of the relevant primary research on power plant thermal discharges dates from the 1970's-1980's; typically based on laboratory studies, field investigations, or environmental impact assessments associated with the siting, permitting, and/or operation of power plants with significant thermal plumes (e.g., Barnett 1972; Coles 1984; Hillman et al. 1977; Langford 1990 (for review); Squires et al. 1979). These studies found that the thermal discharges may affect aquatic species growth, survival and reproduction, altered community diversity and density, and may have led to shifts in ecological habitat. The character and magnitude of the observed impacts varies among the studies, however.

Interest in this topic and relevant studies have also re-emerged in the last decade as part of a greater effort associated with the assessment and characterization of potential effects of global climate change (e.g., Schiel et al. 2004). The material below provides a representative, exemplary mix of studies on thermal effects for organisms and communities in a range of trophic levels or ecosystems with some emphasis on more recent research. The majority of the cited studies were identified from internet searches and cross-referencing appropriate permitting databases[57].

Primary Producers

Thermal discharges affect aquatic primary production through direct effects on photosynthetic activity and selection of temperature-tolerant species in phytoplankton, periphyton, macroalgae and submerged aquatic vegetation (SAV) and indirectly through temperature-related changes in nutrient availability and grazer activities. Several studies reported that thermal discharges substantially altered the local abundance and structure of the aquatic community, particularly benthos and periphyton (e.g., Chuang et al. 2009; Martinez-Arroyo et al. 2000; Schiel et al. 2004; Squires et al. 1979). Studies by Mallin et al. (1994) suggest that indirect effects of discharge altered the phytoplankton community taxonomic structure near the outfall and in general, support different communities of algae than those present in the background waters. Several authors suggest that residual chlorine (anti-fouling agent) may also influence these patterns (Choi et al. 2002; Moss Landing Marine Laboratories 2006; Poornima et al. 2005).

Primary Heterotrophs

The bacterial and microbial components of aquatic ecosystems generally have a positive response to increasing water temperature – growth rates and bacterially mediated processes are enhanced until temperature tolerance limits are approached. Most studies found that the growth rates of bacteria and water temperatures are positively correlated. In contrast, Choi et al. (2002) found lower rates of bacteria production near outfalls but attributes this effect to residual chlorine in the discharge water rather than temperature alone.

Zooplankton

Zooplankton and other pelagic macroinvertebrates typically increase their grazing activities and growth rate in response to increased temperature. Marasse et al. (1992) observed a higher rate of bacteria consumption (i.e., bacterivory) by samples of plankton that were incubated at higher temperatures. Jiang et al. (2009) suggests that copepod species with larger body sizes are more sensitive to thermal increases and that this water temperature increase induces mortalities of copepods. As noted for other organisms,

[57] Abt Associates used several general search engines for preliminary searches for scientific and grey literature including Scirus: http://www.scirus.com/; Google Scholar: http://scholar.google.com/; and Dogpile: http://www.dogpile.com/, as well as publicly available information from NPDES permits and related Section 316a/316b studies.

estuarine copepods have more tolerance to thermal stress than those from more stenothermal, deepwater environments.

Benthic Community

Benthic species and communities are often particularly vulnerable to thermal discharge due to their association with the substrate and limited ability to migrate from impacted areas. Growth rates and spawning times are usually accelerated by increased temperature (Barnett 1972). McMahon (1975) and Leffler (1972) found that snails and blue crabs, respectively, exhibit more rapid growth at higher temperatures, but both studies also observe greater species mortality. The study by Coles (1984) found a positive effect with the thermal effluent as both the number of organisms and the colonization by coral reef propagules near the outfall were significantly greater than background areas. A recent study of benthic communities and associated biota near a nuclear power plant discharge show that the thermal pollution alters composition and decreases richness in benthic cover (Teixeira et al. 2009).

Fish

Fish are extremely well-studied with regard to temperature tolerance and thermal limits in both the laboratory and field. The thermal habitat requirements of coldwater, coolwater, and warmwater fish species are well-characterized (e.g., Beitinger et al. 2000; Sullivan et al. 2000) and these may be the basis for regulatory sub-classification of water bodies. Thermal discharges can influence the spatial distribution of fish due to direct responses to altered temperature (i.e., attraction, avoidance), effect on dissolved oxygen concentrations, and impacts to prey and habitat availability (Cooke et al. 2004; Sullivan et al. 2000). Rapid fluctuations and decreases in water temperature, usually associated with steep thermal gradients in temperate winter waters, can lead to “cold shock” with reduced survival (Ash et al. 1974; Deacutis 1978). Smythe and Sawyko (2000) evaluated the effect of “cold shock” on fish and found no effect on larger predator species, though a forage species (gizzard shad) had lower survival rates. Some studies of thermal discharges have not observed significant effects in local fish communities. Hillman et al. (1977) and Krishnamoorthy et al. (2008) found that impacts on shore-zone fish and fingerlings from power station discharges were minimal. A study of salmonids by Sullivan et al. (2000) maintains that direct mortality from temperature is unlikely since acute lethal temperatures are rarely, if ever, observed in the field. Specifically, this study suggests that there is little or no risk of mortality if the annual maximum temperature is less than 26°C, but suggests a site-specific analysis when annual maximum temperatures exceed 24°C.

Ecosystem Functions and Services

In addition to the species-specific impacts, investigators have looked at the effects of thermal discharges on the structuring of species assemblages and communities, as well as secondary ecosystem function and services. Thermal discharges may have both detrimental and beneficial effects. For example, the bleaching and destruction of coral reefs by elevated thermal discharges is well documented, but Coles (1984) in the Moss Landing study found that the thermal effluent may have some beneficial effects, such as enhancing new coral regrowth or providing preferred water temperatures for avian birds and mammals.

Work in seven Southeastern U.S. cooling reservoirs indicated that direct thermal effects on phytoplankton communities were generally minimal, but that the smaller reservoirs were more prone to algal blooms due to nutrient trapping and elevated temperatures (Mallin et al. 1994). Indirect effects of excessive thermal loads in these reservoirs caused ecosystem-wide alterations arising from both top-down (higher trophic consumers) and bottom-up (primary producers) effects. Martinez-Arroyo et al. (2000) found that phytoplankton subjected to elevated water temperature exhibited lowered photosynthetic capacity and light harvesting efficiency and required more light to reach a net oxygen production. Thus, primary production and oxygen levels, both critical ecosystem functions, may be decreased as a result of elevated temperatures.

Teixeira et al. (2009) evaluated the effect of thermal discharge on fish communities and habitat structure in rocky substrates near a nuclear power plant in southeastern Brazil. Their studies indicate the heated effluents affected the habitat structure as well as fish community structure and its eco-spatial distribution. Lowered fish species richness was observed in the impacted area and this was attributed to effects to differences in benthic cover of a habitat former (i.e., reduced abundance of *Sargassum* weed).

B.3 Influence of Site-Specific Factors and Environmental Setting on Thermal Effects

As noted above, the environmental setting (i.e., the nature of the receiving waters) can have a pronounced influence on the potential for and the magnitude of adverse thermal impacts on biota. While physical features near the discharge and temporal climatic patterns usually dictate the observed level of thermal deviations for any given discharge, several environmental factors may be important in determining the magnitude of potential impacts, including: geographic location, marine vs. freshwater environments, volume of receiving water, rate of water exchange, other heat loads, and local habitats.

Geographic location

Geographic location determines the duration and intensity of annual solar heating and usually dictates the resulting maximum ambient temperatures for the receiving waters. The more southerly the facility, the higher the seasonal temperature maxima is likely to be, increasing the possibility of reaching upper thermal temperature limits for sensitive organisms. Despite acclimation, relatively few North American aquatic organisms will tolerate chronic water temperatures in excess of 35-40^{o}C (Brock 1985). Northerly receiving waters will have lower maximum ambient temperatures in summer, but will also exhibit greater seasonal variation; with a more extreme temperature gradient between discharge and surface water during winter. Conversely, sub-tropical water temperatures have less seasonal variation and a more consistent thermal gradient is maintained between discharge and ambient conditions. Adverse effects to aquatic organisms are generally most pronounced at the acute and chronic high lethal temperatures and/or due to rapid fluctuations (e.g., "cold shock").

Marine vs. Freshwater Receiving Waters

Adverse thermal impacts have been documented in both freshwater and marine ecosystems, but the likelihood of impacts may be considered slightly greater in freshwaters simply due to the presumption that marine waters constitute a greater thermal reservoir due to larger volume and tidal flushing. However, as noted above, site-specific features will dictate the effective volume and the flushing rate, which are likely to be the key to vulnerability of receiving water ecosystem to thermal impacts. Clearly, the magnitude of thermal impacts also depends on the composition of the local biota and whether such organisms are temperature-sensitive. The sensitivity of coldwater freshwater fish (e.g., trout, salmonids, darters) to increased water temperature and associated lowering of available dissolved oxygen has been well characterized (Beitinger et al. 2000; Sullivan et al. 2000). There is less temperature-sensitivity in marine estuarine fish, which are often more tolerant than offshore fish, since they are subject to regular environmental fluctuations.

Receiving Water Volume

The volume of the receiving water is a critical factor since it determines the total amount of heat that can be absorbed by a water body while still remaining at an acceptable temperature. The effective volume subject to the thermal discharge may be significantly less than that of the entire water body if it is constrained physically (e.g., narrow discharge channel, small coastal embayment) or can vary in the short term (e.g., low tide, hydropower releases), seasonally (e.g., thermally stratified lakes, salinity stratified estuary), or longer (e.g., multi-year droughts). Due to the buoyant properties of warm water, the effective mixed volume can be reduced even further if the thermal plume is not effectively or rapidly mixed into the receiving waters.

Rate of water exchange

The rate of water exchange is another factor which can compensate for a small effective volume. A short hydraulic residence time (HRT) (i.e., rapid flushing) of the receiving water at the point of the thermal discharge can rapidly dissipate a high heat load. Large fast rivers, open ocean outfalls, and coastal embayments with sweeping longshore currents, etc. can generally better tolerate thermal discharges and have limited or highly localized impacts to biota. Poorly flushed systems, those with seasonal flow minima, or episodic hydrologic inputs, are more likely to experience widespread or persistent thermal impacts. In some cases, the flow or volume of the thermal discharge may be very much greater than the receiving water.

Local land use

Local land uses may also be influential in that they can provide additional thermal loads to the water body independent of the thermal discharge. Developed urban areas having watersheds with large percentages of impervious cover may produce large storm water flows with temperatures that are well above ambient temperatures in the receiving waters. Agricultural lands and irrigation return water may also increase local thermal loading. Channelization and removal of riparian buffer vegetation can increase water temperature through lack of shading, reflective artificial substrates, and removal of deep pool habitats.

Local Habitats

Benthic biota and/or habitats (e.g., oyster reefs, eelgrass, and mussel beds) found in nearshore environments are often subject to greater impact since these largely sessile communities are affixed to the substrate. On the other hand, mobile aquatic organisms can track temperature change and fine-tune their temporal and spatial distribution (Cooke et al. 2004). Biota can sometimes avoid adverse thermal impacts by seeking out localized areas of cooler or better aerated waters (e.g., deep pool, tributary stream, bottom waters) for short-term or seasonal residence. These areas provide habitat that may allow the temperature-sensitive organisms to persist and emigrate back into the affected water body once the thermal stress is reduced. Thermal effects could be more severe in homogenous environments (e.g., open water column, unstratified reservoir) where the biota does not have access to these refugia. Thermal displacements from spawning habitat due to dam construction and operation (e.g., bottom water releases) has also been a concern in western rivers and elsewhere (Bartholow et al. 2004; Hayes et al. 2006).

B.4 Uncertainties and Limitations of Assessing Thermal Impacts

One of the major difficulties in accurately characterizing the influence of thermal discharges on aquatic communities is the uncertainty due to the potential influence of other abiotic water quality factors. Thermal discharges from power plant cooling systems often contain elevated levels of additional constituents including, but not restricted to: residual chlorine, total suspended solids, total dissolved solids, cleaning agents and surfactants, metals, and nutrients. The presence of these constituents may complicate the interpretation of the environmental factor(s) that are responsible for observed changes in biotic communities.

For example, several of our studies on thermal effects on primary producers noted that residual chlorine in the discharge may be responsible for some of the observed effects (Chuang et al. 2009; Poornima et al. 2005). Interaction of thermal effects and heavy metals was responsible for some phytoplankton taxonomic changes in one reservoir investigated by Mallin et al. (1994). Looking at the behavior of smallmouth bass, Cooke et al (2004) found that a majority of a local radio-tagged population overwintered in the warmest portions of a thermal discharge to Lake Erie. However, this area also was high in habitat complexity, had adequate flow velocity refuges, and abundant forage so selection for this habitat may not be a simple thermal preference.

Adverse temperature effects may also be more pronounced in aquatic ecosystems which are already subject to other environmental stressors such as high biochemical oxygen demand (BOD) levels, sediment contamination, or pathogens. Thermal discharges may have indirect effects on fish and other vertebrate populations through increasing pathogen growth and infection rates. Langford (1990) reviewed several studies on disease incidence and temperature, and while he found no simple, causal relationship between the two, he did note that it was clear that warmer water enhances the growth rates and survival of pathogens, and that infection rates tended to be lower in cooler waters.

B.5 Case Studies

Three case studies were selected for large power generating stations whose thermal discharges may have a potential impact to the local aquatic community/ecosystem. These three case studies provide examples of investigations of thermal impacts in different environmental settings (marine coastal embayment, coastal Great Lake, and freshwater river) and with potential effects investigated at differing spatial scales (community, habitat, ecosystem).

B.5.1 Brayton Point Station

Brayton Point Station (BPS) is a 1538 megawatt (MW) coal and oil-fired electrical generating station located in Somerset, MA. This facility takes cooling water from and discharges heated effluent to Mount Hope Bay (MHB), a large coastal embayment whose waters lie within Massachusetts and Rhode Island. Generation Unit 1 began operating in 1963, Unit 2 in 1964, Unit 3 in 1969, and Unit 4 in 1974 (Dominion 2011). One of the most thorough examinations of the individual and cumulative effects of a power plant thermal discharge was conducted as part of the regulatory review of the CWA Section 316(a) variance request application submitted in May 2001 as part of the NPDES discharge permit (Permit No. MA 003654) renewal for BPS. The permitee's 316(a) variance request application looked to keep the existing permit temperature criteria (maximum temperature of 95^{o}F; delta (departure from ambient) temperature of 22^{o} F) and to reduce the total heat load from the existing permit limits. However, these thermal criteria were still less stringent than what would be required by either technology-based or water quality-based discharge limits.

CWA 316(a) authorizes alternative thermal discharge limits when it is demonstrable that the proposed thermal limits "will assure the protection and propagation of a balanced indigenous population (BIP) of shellfish, fish and wildlife in and on that body of water." To evaluate whether the thermal limits proposed in the May 2001 316(a) variance request application would meet this protective criterion, EPA, in accordance with the 316(a) Technical Guidance Manual (USEPA 1977), conducted a review of the historical and current conditions of MHB biota on a community-by-community evaluation and considered potential thermal impacts to phytoplankton, zooplankton, habitat formers, shellfish, finfish, and other vertebrate (i.e., sea turtles and mammalian) wildlife. The findings of the community impact analyses are contained in the "*Clean Water Act NPDES Permitting Determinations for Thermal Discharge and Cooling Water Intake from Brayton Point Station in Somerset, MA*" (USEPA 2002b) dated July 22, 2002 (hereafter "*Determinations*") and summarized below.

For each of the community types, the *Determinations* provides a preliminary consideration of whether the community's nature, estuarine setting, and water column distribution within MHB relative to the location and magnitude of the BPS thermal discharge would result in a finding of "low potential impact areas" and lessened environmental concerns for the granting of the 316(a) variance. For those communities in MHB for which a "low potential impact" conclusion was not possible, the severity of the thermal effect was gauged by comparison to a list of *a priori* decision criteria for each community.

EPA judged that MBH was not a low potential impact area for phytoplankton. As seagrasses and salt marshes have historically declined in importance in MHB, the phytoplankton community is the dominant primary producer (USEPA 2002b). The recent (2001) occurrence of a nuisance blue-green algal bloom (dominated by the cyanophyte *Anacystis aeruginosa*) in MHB near BPS may be due to the high nutrients and warm water temperatures which favor formation of such bloom. It was considered likely that thermal plume from BPS was a contributing factor. Perhaps of greater importance is the finding that the MHB phytoplankton community does not undergo the typical winter-spring phytoplankton bloom cycle (Keller et al. 1999). Extensive work was conducted on plankton communities in experimental mesocosms where temperature was shifted to mimic the expected thermal conditions in MHB surface waters. Extrapolating these changes seen in the mesocosms, such changes in phytoplankton population dynamics could very likely lead to significant impacts within the trophic dynamics of the MHB food web. Redirecting carbon away from benthic consumers and into pelagic food webs could represent a reduction in prey species for benthic-feeding finfish such as winter flounder, windowpane flounder, hogchoker, and tautog.

EPA judged that MHB was not a low potential impact area for zooplankton since it is an estuary that serves as a spawning site for numerous fish and invertebrate species (USEPA 2002b). The most noticeable thermal effect in this community is the recent increase in abundance of the ctenophore *Mneimiopsis leidyi* and increased overwintering in MHB for this formerly seasonal resident. Dramatic increases in comb jellies (i.e., ctenophores) are usually indicative of stressed ecosystems with symptoms of increased water temperatures, increased nutrient levels, and depleted fish stocks (Pohl 2002). Since *M. leidyi* is a voracious consumer of pelagic fish eggs as well as zooplankton by which it competes with young-of-year winter flounder, it was concluded that BPS was significantly contributing to thermal increases in MHB and facilitating expansion of the range and time of year distribution of the comb jellies.

Eelgrass is a coldwater plant that ranges from North Carolina to Canada and grows well in soft-bottom, low energy environments. Despite the current lack of eelgrass, the EPA judged that MBH was not a low potential impact area for habitat formers since the historic presence of extensive eelgrass meadows shows that it is capable of supporting this habitat type (USEPA 2002b). Experimental work has shown that optimal temperature ranges for photosynthesis decrease with increasing turbidity (Bulthuis 1987) so that in turbid waters, eelgrass growth decreases with increased temperature, because photosynthetic rates decrease and respiration rates increase. Based on the current lack of eelgrass, it was concluded that the combination of poor water quality and increased water temperature result in an "exclusion zone" for eelgrass growth in MHB (USEPA 2002b). Since BPS helps to elevate the water temperature over significant portions of the bay, it is considered a contributory cause to this exclusion.

EPA judged that MBH was not a low potential impact area for shellfish and macroinvertebrates due to the presence of commercially important species, their "substantial" densities, the spawning and nursery areas in MHB, and the important role in ecosystem function that this community provides (USEPA 2002b). Benthic sampling indicated that there have been no significant changes in the benthic community between the 1970's and mid-1990's or over the span of time when BPS has been active and the annual heat flux was increased. The sampling also indicates a strong representation in the benthic community of the amphipod *Ampelisca* which is a preferred prey item for juvenile winter flounder. Overall, EPA found no substantial evidence of harm to shellfish and macroinvertebrates from the current thermal discharge, and any alternative which reduces the thermal discharge would be acceptable.

EPA judged that MHB was not a low potential impact area for finfish due to the presence of numerous recreational and commercially important species, the important spawning and nursery areas, and the potential for blockage of fish migration (USEPA 2002b). The analysis for finfish was specifically targeted at determining the appropriate thermal discharge limits for BPS in order to protect finfish populations and included a retrospective examination of total finfish abundance trends in relation to plant operations. The analysis determined an acceptable annual flux of heat into MHB that is protective of finfish populations, based on the temperature thresholds for acute and chronic mortality as well as for several sub-lethal effects for some representative important species (RIS).

The finfish stocks in MHB have declined precipitously since 1984-1985, a period which marked the shift of Unit 4 at BPS from closed-cycle to once-through cooling operations. Further, work by Gibson (2002) suggests that winter flounder have been declining since at least the initiation of sampling in 1972. While BPS had been operational for 9 years at that point, no fishery data are available to estimate what the finfish community was like prior to 1972. Comparison of the record of annual heat flux to MHB over that last 28 year period to records of finfish abundance led EPA to conclude that an annual heat flux of 28 trillion British thermal units (tBTU) to MHB, as proposed in the 316(a) variance request application, would be unable to stop or reverse a decline in fish populations and thus would not be protective of the finfish community.

The temperature tolerance limits of 16 RIS were reviewed to establish temperature thresholds for the more sensitive of these species (winter flounder, striped bass). These thresholds were used to establish critical temperatures for three target depth strata (surface, middle, and bottom waters) at two key seasonal periods (winter, summer). Winter corresponds to the period (March 1 -31) of active winter flounder spawning and when large numbers of larval planktonic winter flounder are present in MHB. The summer index period (July 15 – August 15) corresponds to the warmest time of the year.

Predictive hydrothermal models (CORMIX for near-field effects; WQMAP for far-field effects) of MHB provided a means of evaluating the potential thermal impacts caused by the current (i.e., existing permit), the proposed (i.e., the requested 316(a) variance), and two alternative reduced heat flux options for BPS operations, as well as a "no-plant" condition. During warm summer conditions, the proposed operational heat flux would impact 62% of the bottom water strata as compared to 4% under a no-plant scenario, while other alternative operating options would have reduced impact proportional to their proposed total heat fluxes. Using this method, it is possible to show impacts to all target depth strata during summer conditions and impacts to the bottom strata during winter.

The study also considered other heat effects on finfish caused by the thermal discharge. The first involved the attractive nuisance nature of the thermal plume (USEPA 2002b). The plume acts as an attractant for large numbers of striped bass and bluefish in the fall and winter and disrupts their seasonal migration. The crowding of large numbers of these species into a restricted area increases the potential for weakening or diseases to occur since the warm temperatures increase their metabolism at the same time there is reduced feeding due to a lack of prey. Similarly, the trapping of Atlantic menhaden in the thermal plume affects their migration and likely increases I&E losses due to longer periods spent in proximity to intake structures and which has been evidenced by several recent large winter impingement loss events. Another effect noted was the establishment in MHB of smallmouth flounder (*Etropus microstomus*) which is at the northern limit of its geographic distribution range. It is important to note that an increased abundance or distribution shift to a warm water species is not indicative of protection of a BIP.

EPA judged that MBH is a low potential impact area for other vertebrate life since it is not a significant habitat for marine mammals or sea turtles (USEPA 2002b). Overall, there is no potential for harm from the current thermal discharge and any alternative which reduces the thermal discharge would be acceptable.

A summary of current ecosystem thermal effects and predicted impacts associated with the proposed thermal flux was prepared (USEPA 2002b). The current thermal effects for which there appears to be no disagreement include:

- Appearance of nuisance algal blooms;
- Absence of normal winter-spring phytoplankton bloom;
- Overwintering of the ctenophore *Mneimiopsis leidyi*;
- Overwintering of striped bass and bluefish in discharge canal;
- Increased abundance of smallmouth flounder in MHB;
- Thermal avoidance of most of MHB by adult winter flounder; and
- Multiple fish kills as a result of large impingement events in the winter.

Evaluating the proposed 316(a) variance request, EPA predicted that, under the proposed thermal discharge under the 316(a) variance request, the following would occur:

- Large areas of MHB would be avoided by juvenile winter flounder and striped bass during warm summer months;
- Extensive areas of MHB would experience water temperatures resulting in chronic toxicity to juvenile winter flounder;
- Reduced winter flounder egg hatching success for the entire MHB for the warmest winter months;
- Increased predation on winter flounder eggs and larvae by sand shrimp; and
- Potential exclusion of eelgrass.

EPA also considered potential impacts from other stressors that could be responsible for mortality of finfish in MHB; including overfishing, predators, water quality, brown tides, and I&E (USEPA 2002b). Each of these stressors was examined for its potential role in causing or contributing to the finfish collapse. Analyses of these other potential stressors indicated that while possibly contributory, the adverse effects of each were generally exacerbated by the thermal conditions caused by the BPS plume.

Based on the hydrothermal and ecological analyses conducted and documented in the *Determinations* document, EPA concluded that a BIP has not been maintained in MHB and that the current BPS thermal discharge is a significant contributor to this problem (USEPA 2002b). Further, the proposed thermal reductions in annual heat flux contained in the 316(a) variance request application would not allow for the recovery of the winter flounder or the wider balanced indigenous ecosystem. Accordingly, EPA denied the permitee's variance request and reissued the NPDES permit in 2003 with the provision for installing closed-cycle cooling in all four of the power units.

B.5.2 Quad Cities Nuclear Station (QCNS)

Quad Cities Nuclear Station (QCNS) is a dual-unit nuclear fueled steam electric generating facility (SIC 4911) located on a 765-acre site along the Mississippi River in Cordova, Illinois. QCNS Units I (866 net megawatts (MW)) and 2 (871 net MW) began commercial production of electricity in 1973. QCNS withdraws water from the Mississippi River for non-contact condenser cooling and various service water uses. After passing through the condensers, the cooling water from Units 1 and 2 mixes and then exits to the River via a discharge canal. QCNS is located on Pool 14 of the Mississippi River, at approximate River Mile 506.5 above the confluence of the Ohio River.

The thermal discharge is authorized under the Station's NPDES Permit, issued by the ILEPA. Thermal limits in the NPDES Permit are based on Illinois environmental regulations, and studies and Demonstrations related to the thermal plume are performed under CWA Section 316(a). During the latest NDPES permit renewal cycle, QCNS requested issuance of a 316(a) variance for a proposed alternative thermal standard, specifically relaxation of a maximum thermal excursion temperature limits by 2^{o}F during late summer months (July-September), which would increase the predicted frequency of expected thermal excursions from 1% to 3%. This variance request was based on a demonstration that future operations of QCNS would assure the protection and propagation of a balanced indigenous community (BIC) of fish, wildlife, and shellfish, particularly within Pool 14.

To evaluate the potential thermal impacts of QCNS' discharge on Pool 14, a number of comprehensive studies were conducted (including thermal plume modeling and field surveys, review of current ("prospective analysis") and historic ("retrospective demonstration") biota monitoring, and water quality assessment. The thermal plume modeling is contained in "*River temperature predictions downstream of Quad Cities Nuclear Generating Station*" (Holly Jr. et al. 2004). The elements and findings of the biological and water quality assessments are contained in the "*Quad Cities Nuclear Station Adjusted Thermal Standard CWA 316(a) Demonstration. Final Draft*" (HDR 2009) dated November 2009 (hereafter "*Demonstration*") and summarized below.

The thermal plume model study was able to successfully reproduce temperature field data (collected September 2003) without any adjustment of non-physical parameters (Holly Jr. et al. 2004). The model was used to show compliance of the thermal plume with the proposed alternative standard. The model validation revealed the importance of including site-specific river-entraining structures such as wing dams and chute closure dams in the model, as they have an important influence on the thermal flow patterns in the vicinity of the QCNS and local Steamboat Island (Holly Jr. et al. 2004).

Current and past monitoring efforts have collected data on a variety of aquatic communities, including phytoplankton, zooplankton, benthic macroinvertebrates (including freshwater mussels), ichthyoplankton, and finfish, which are summarized in the *Demonstration* (HDR 2009). For the prospective assessment, QCNS conducted comprehensive literature surveys, analyzed field data, and followed EPA approved protocols for assessing potential thermal impacts on Representative Important Species (RIS) of fish. RIS species selected for the QCNS *Demonstration* included largemouth bass, channel catfish, spotfin shiner, and walleye. River and plant operating conditions were selected to provide a conservative assessment of potential power plant-related biological effects (i.e., the biothermal assessment focused on the months of June, July, August, and September). The results indicate that the proposed alternative thermal standard would have a negligible impact on largemouth bass, channel catfish, and a slightly positive one for spotfin shiner (i.e., increased growth) (HDR 2009). Walleye chronic mortality could be increased by 8.5%

immediately downstream of the mixing zone, but placed in the areal relationship of the discharge to Pool 14, this would translate to a <1% effect on the walleye population in the Pool (HDR 2009).

The retrospective assessment indicated some changes in the upper trophic levels (i.e., finfish) in Pool 14 since the Station began operating, but concluded that those changes are not attributable to the thermal input from QCNS (HDR 2009). In addition, the overall stability and health of upper trophic levels over the length of the monitoring period suggests that lower trophic levels (i.e., zooplankton, phytoplankton) have remained stable and abundant, providing an adequate food supply to allow and sustain growth of the finfish and mussel populations. The retrospective assessment also found that neither nuisance species (e.g., zebra mussel) nor heat tolerant species of fish have come to predominate in Pool 14 due to QCNS operations (HDR 2009).

In addition, the *Demonstration* examined the potential for harmful interactions between the QCNS thermal discharge and other pollutants, including dissolved organic carbon, total phosphorus, total nitrogen, biocides (i.e., anti-fouling chemicals), heavy metals, and other thermal discharges located upstream. This analysis indicated that there was no evidence to suggest that the small amount of additional heat that would be permitted to be discharged to Pool 14 under the proposed alternative standard would have an adverse synergistic effect with other pollutants (HDR 2009).

QCNS, based on their interpretation of EPA guidance documents and 316(a) Demonstrations for other facilities, maintained that the overall standard of compliance (i.e., protection of the BIC) would be demonstrated by meeting a series of functional criteria. Because this is a request for a change in the thermal standard, the *Demonstration* needed to show that these conditions will be satisfied in the future if the proposed standard was adopted:

- No substantial increase in abundance or distribution of any nuisance species or heat tolerant community;
- No substantial decreases in formerly abundant indigenous species or community structure to resemble a simpler successional stage than is natural for the locality and season, other than nuisance species;
- No unaesthetic appearance, odor, or taste of the water;
- No elimination of an established or potential economic or recreational use of the waters;
- No reduction in the successful completion of life cycles of indigenous species, including those of migratory species;
- No substantial reduction of community heterogeneity or trophic structure;
- No adverse impact on threatened or endangered species;
- No destruction of unique or rare habitat, without a detailed and convincing justification of why the destruction should not constitute a basis of denial; and
- No detrimental interaction with other pollutants, discharges, or water-use activities.

Based on the results of the thermal plume modeling study, the prospective analysis, the retrospective assessment, and the successful meeting of the criteria listed above, QCNS concluded that past or future operations have not caused appreciable harm to the BIC.

B.5.3 Point Beach Nuclear Station

Point Beach Nuclear Plant (PBNP) is located on the western shore of Lake Michigan in Two Rivers, Manitowoc County, WI. The facility consists of two nuclear powered steam electric generating units with a total net capacity of 1,540 megawatts thermal (MWt) each. Generation Unit 1 began commercial operation in December 1970 and Unit 2 in October 1972 (EA 2008). The units operate with a once-through cooling water system (EA 2008). Cooling water is withdrawn from a deep intake (22 ft contour) in Lake Michigan and current pumping capacity is estimated to be 680,000 gallons per minute. Each unit discharges the non-contact cooling water to Lake Michigan via its own outfall located at a mean temperature increase of 11.5°C (20.7°F) above the intake water temperature at the maximum flow rate (EA 2008).

PBNP planned to implement an extended power uprate (EPU) at both units in the 2010/2011 time frame that was expected to increase the existing plant output by approximately 17 percent. The proposed EPU does not result in an increase in water being withdrawn from Lake Michigan, nor will it result in an increase in the amount of water discharged to Lake Michigan (NRC 2010). However, EPU did require modification of the facility's Wisconsin Discharge Elimination System (WPDES) permit for the discharge of a pollutant from a point source into waters of the state (which includes the addition of ***heat*** from a point source). According to a modeling study performed by PBNP in 2008, the temperature of the discharge water was expected to increase by a maximum of 3.6 °F (2.0 °C) and the thermal plume expand as a result of the proposed EPU (NRC 2010).

In support of the permit modification request, PBNP prepared an assessment of the potential impacts of the thermal discharge from the planned EPU (i.e., the "Planned Change"). This assessment is summarized in "*Point Beach Nuclear Plant Evaluation of the Thermal Effects Due to a Planned Extended Power Uprate*" (EA 2008). Since there currently are no temperature limits in the PBNP WPDES permit or thermal water quality standards for Lake Michigan, this assessment represented a "good faith effort" by PBNP to demonstrate that the impacts of the EPU would not have a significant effect on the fish or shellfish communities in Lake Michigan (EA 2008).

Evaluation of the potential effects on the Lake Michigan aquatic community in the vicinity of the PBNP post-EPU discharge was based on a review of historical and current monitoring data collected in the vicinity of the facility and other power plants that utilize Lake Michigan water for once-through cooling (EA 2008). Those study results were compared to expected responses of 16 Wisconsin Department of Natural Resource (WDNR) selected Representative Important Species (RIS) to the projected higher discharge temperatures and larger thermal plume that will result from the planned EPU. The evaluation placed emphasis on the RIS and whether or not the BIC in the vicinity of the PBNP discharge would continue to be protected.

The assessment relied heavily on the findings of the Type I CWA Section 316(a) Demonstration conducted by the plant in the 1970s as well as the 1976 finding by WDNR that no appreciable harm had occurred to the local BIC due to plant operations (EA 2008). The studies involved investigations of primary and secondary trophic levels from phytoplankton through fish in both reference and thermally affected areas (EA Engineering 2008; Limnetics 1974, as cited in EA 2008).

Recent entrainment and impingement monitoring studies at PBNP indicate that the same species that were common in the vicinity of the facility during the Type I Demonstration remain common near the plant despite lake-wide changes in the Lake Michigan fish community (Kitchell 2007, as cited in EA 2008). Recent fisheries data collected from both PBNP and the Kewaunee Nuclear Power Plant (KNPP), which is located only five miles north of PBNP, show that the same species seasonally occur in nearshore areas in the vicinity of the shoreline discharge structures. These findings indicate that the BIC is protected under similar operating conditions as have occurred historically at PBNP.

Evaluation of the modeled discharge temperatures and plume configurations under the planned EPU indicates that the predicted area, volume, and behavior of the plume will not be substantially different than under current PBNP operating conditions and similar to those evaluated during the Type 1 Demonstration (EA 2008). Based on the thermal model results using a 0.2 ft/sec along-shore current, the planned EPU would expand the surface area of the 6.0ºC contour from 27 to 39 acres; the 4.0ºC contour would increase from 79 to 105 acres; and the 2.0ºC contour would increase from 315 to 390 acres (EA 2008). These projected increases in plume size are relatively small compared to the surface area available for mixing. Under critical summer conditions the buoyant plume provides an area of safety as well as a zone of passage when discharge temperatures approach or exceed upper avoidance temperatures of the RIS fish.

The RIS evaluation showed that the predicted impact of the warmer and larger thermal plume as a result of the EPU at PBNP will be negligible (EA 2008). Thermal criteria for some of the 12 RIS fish species would be exceeded in the plume, but mainly at the point of discharge or in small areas for relatively brief periods of time. Fish readily move into and out of thermal discharge plumes, depending on their thermal requirements and the thermal regime of the plume at any given time. Cool and coldwater fish species would be somewhat restricted with regard to use of the plume area, especially during summer, but they generally spend the summer well offshore. In addition, the warmwater RIS could slightly benefit from the warmer temperatures. Combining these observations with the size of the PBNP plume relative to available lake habitat, it was concluded that the larger and warmer thermal plume resulting from the planned EPU would have a minimal and insignificant impact on the fish community in Lake Michigan (EA 2008). Similar conclusions were reached for the four invertebrate RIS (shellfish and opossum shrimp).

Overall, the assessment concluded that the increased heat load to the discharge would not endanger the protection and propagation of a BIC of shellfish, fish, and wildlife in and on Lake Michigan. This conclusion was based on several lines of evidence including:

- The PBNP Type I Demonstration established that the original thermal plume did not cause "prior appreciable harm;"
- The PBNP thermal plumes resulting from the planned EPU will not be substantially larger than the original/existing plumes;
- There have been no changes in the aquatic community attributable to operation of the facility that would preclude reliance on the results of the Type I Demonstration for PBNP;
- The changes to the Lake Michigan fish community that have occurred during the past 50 years have occurred on a lake-wide basis;
- The impacts on RIS will be negligible; and
- The conclusion with respect to the effect of the planned EPU is consistent with assessments undertaken at other power plants on Lake Michigan.

While the cooling water thermal plume of PBNP was expected to be larger as a result of the proposed EPU, it was not expected to disrupt the local BIC or have a signficant impact on RIS of Lake Michigan (EA 2008). Recently, as part of the plant's operating license renewal, the Nuclear Regulatory Commission developed a draft Environmental Assessment (EA) for the power uprate. The draft EA was issued in December 2010 with a finding of no significant impact (NRC 2010).

Appendix C: Details of Regional I&E Mortality Losses

C.1 California

Table C-1: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the California Region (million A1Es per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
All forage species	0.20	0.18	0.20	0.20	0.17	17.35	<0.01	14.79	15.47	<0.01	17.56	0.18	14.99	15.67	0.17
All harvested species	0.59	0.52	0.58	0.59	0.50	18.69	<0.01	15.93	16.66	<0.01	19.28	0.52	16.51	17.25	0.50
American shad	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cabezon	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	<0.01	0.05	0.05	<0.01	0.06	<0.01	0.05	0.05	<0.01
California halibut	<0.01	<0.01	<0.01	<0.01	<0.01	0.23	<0.01	0.20	0.21	<0.01	0.23	<0.01	0.20	0.21	<0.01
California scorpionfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Crabs (other)	0.02	0.02	0.02	0.02	0.02	7.80	<0.01	6.65	6.95	<0.01	7.82	0.02	6.67	6.98	0.02
Sea Basses	<0.01	<0.01	<0.01	<0.01	<0.01	2.83	<0.01	2.41	2.52	<0.01	2.83	<0.01	2.41	2.53	<0.01
Shrimp (other)	<0.01	<0.01	<0.01	<0.01	<0.01	0.63	<0.01	0.53	0.56	<0.01	0.63	<0.01	0.54	0.57	<0.01
Drums and croakers	0.05	0.04	0.05	0.05	0.04	0.23	<0.01	0.19	0.20	<0.01	0.27	0.04	0.24	0.25	0.04
Dungeness crab	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Flounders	0.01	<0.01	0.01	0.01	<0.01	0.10	<0.01	0.08	0.09	<0.01	0.11	<0.01	0.09	0.10	<0.01
Fish (other)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01
Northern anchovy	0.34	0.30	0.34	0.34	0.29	0.03	<0.01	0.03	0.03	<0.01	0.38	0.30	0.37	0.37	0.29
Rockfishes	0.02	0.01	0.02	0.02	0.01	6.33	<0.01	5.39	5.64	<0.01	6.34	0.01	5.41	5.66	0.01
Salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sculpins	0.01	0.01	0.01	0.01	0.01	0.43	<0.01	0.36	0.38	<0.01	0.44	0.01	0.38	0.39	0.01
Smelts	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped bass	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01
Sunfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Surfperches	0.11	0.10	0.11	0.11	0.10	<0.01	<0.01	<0.01	<0.01	<0.01	0.11	0.10	0.11	0.11	0.10
Total (all species)	**0.79**	**0.69**	**0.78**	**0.79**	**0.68**	**36.04**	**<0.01**	**30.72**	**32.13**	**<0.01**	**36.83**	**0.69**	**31.50**	**32.92**	**0.68**

Scenarios: B = Baseline I&E Mortality losses, 1 = Option 1 (I Everywhere), 2 = Option 2 (I Everywhere and E for Facilities > 125 MGD), 3 = Option 3 (I&E Mortality Everywhere), 4 = Option 4 (I for Facilities > 50 MGD)

Table C-2: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the California Region (million individuals per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
American shad	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Blennies	<0.01	<0.01	<0.01	<0.01	<0.01	914.88	<0.01	389.87	407.84	<0.01	914.88	<0.01	389.87	407.84	<0.01
Bluegill	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Brown bullhead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cabezon	<0.01	<0.01	<0.01	<0.01	<0.01	6.65	<0.01	2.83	2.96	<0.01	6.65	<0.01	2.83	2.96	<0.01
California halibut	<0.01	<0.01	<0.01	<0.01	<0.01	7.71	<0.01	3.29	3.44	<0.01	7.72	<0.01	3.29	3.44	<0.01
California scorpionfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chinook salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Crabs (other)	0.05	0.02	0.03	0.03	0.02	7,238.91	<0.01	3,084.81	3,227.00	<0.01	7,238.96	0.02	3,084.83	3,227.03	0.02
Delta smelt	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Drums and croakers	0.41	0.18	0.20	0.21	0.18	915.22	<0.01	390.01	407.99	<0.01	915.63	0.18	390.22	408.20	0.18
Dungeness crab	<0.01	<0.01	<0.01	<0.01	<0.01	0.09	<0.01	0.04	0.04	<0.01	0.09	<0.01	0.04	0.04	<0.01
Fish (other)	0.09	0.04	0.04	0.04	0.04	1,299.61	<0.01	553.82	579.35	<0.01	1,299.70	0.04	553.86	579.39	0.04
Flounders	0.01	<0.01	<0.01	<0.01	<0.01	319.23	<0.01	136.04	142.31	<0.01	319.24	<0.01	136.04	142.31	<0.01
Gobies	<0.01	<0.01	<0.01	<0.01	<0.01	1,579.24	<0.01	672.98	704.00	<0.01	1,579.24	<0.01	672.98	704.00	<0.01
Herrings	0.06	0.02	0.03	0.03	0.02	26.23	<0.01	11.18	11.69	<0.01	26.28	0.02	11.20	11.72	0.02
Longfin smelt	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Northern anchovy	0.86	0.38	0.42	0.43	0.37	826.63	<0.01	352.26	368.50	<0.01	827.49	0.38	352.68	368.93	0.37
Pacific herring	<0.01	<0.01	<0.01	<0.01	<0.01	36.16	<0.01	15.41	16.12	<0.01	36.17	<0.01	15.41	16.12	<0.01
Rockfishes	0.03	0.01	0.01	0.01	0.01	63.96	<0.01	27.26	28.51	<0.01	63.99	0.01	27.27	28.53	0.01
Sacramento splittail	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sculpins	0.02	<0.01	<0.01	<0.01	<0.01	47.94	<0.01	20.43	21.37	<0.01	47.96	<0.01	20.44	21.38	<0.01
Sea Basses	<0.01	<0.01	<0.01	<0.01	<0.01	13.24	<0.01	5.64	5.90	<0.01	13.24	<0.01	5.64	5.90	<0.01
Shrimp (other)	0.03	0.01	0.02	0.02	0.01	429.24	<0.01	182.92	191.35	<0.01	429.27	0.01	182.93	191.36	0.01
Silversides	0.11	0.05	0.05	0.06	0.05	121.84	<0.01	51.92	54.31	<0.01	121.95	0.05	51.97	54.37	0.05
Smallmouth bass	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Smelts	<0.01	<0.01	<0.01	<0.01	<0.01	3.63	<0.01	1.55	1.62	<0.01	3.63	<0.01	1.55	1.62	<0.01
Striped bass	<0.01	<0.01	<0.01	<0.01	<0.01	11.31	<0.01	4.82	5.04	<0.01	11.31	<0.01	4.82	5.04	<0.01
Sunfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Surfperches	0.13	0.06	0.06	0.06	0.06	<0.01	<0.01	<0.01	<0.01	<0.01	0.13	0.06	0.06	0.06	0.06
Total (all species)	**1.82**	**0.80**	**0.90**	**0.90**	**0.77**	**13,861.76**	**<0.01**	**5,907.09**	**6,179.38**	**<0.01**	**13,863.58**	**0.80**	**5,907.98**	**6,180.28**	**0.77**

Scenarios: B = Baseline I&E Mortality losses. 1 = Option 1 (I Everywhere), 2 = Option 2 (I Everywhere and E for Facilities > 125 MGD), 3 = Option 3 (I&E Mortality Everywhere), 4 = Option 4 (I for Facilities > 50 MGD). Values for all options reflect reductions in losses.

C.2 North Atlantic

Table C-3: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the North Atlantic (million A1Es per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality

	Impingement					Entrainment					I&E				
Species	**B**	**1**	**2**	**3**	**4**	**B**	**1**	**2**	**3**	**4**	**B**	**1**	**2**	**3**	**4**
All forage species	0.55	0.38	0.54	0.55	0.38	46.46	<0.01	37.88	39.74	<0.01	47.02	0.38	38.42	40.29	0.38
All harvested species	0.08	0.06	0.08	0.08	0.06	12.90	<0.01	10.52	11.03	<0.01	12.98	0.06	10.60	11.11	0.06
American plaice	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
American shad	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Atlantic cod	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01
Atlantic herring	<0.01	<0.01	<0.01	<0.01	<0.01	0.12	<0.01	0.10	0.11	<0.01	0.13	<0.01	0.10	0.11	<0.01
Atlantic mackerel	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.02	0.02	<0.01	0.02	<0.01	0.02	0.02	<0.01
Atlantic menhaden	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	<0.01	0.03	0.03	<0.01	0.04	<0.01	0.03	0.03	<0.01
Bluefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Butterfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Crabs (other)	0.03	0.02	0.03	0.03	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.02	0.03	0.03	0.02
Cunner	<0.01	<0.01	<0.01	<0.01	<0.01	4.26	<0.01	3.47	3.64	<0.01	4.26	<0.01	3.47	3.64	<0.01
Fish (other)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Pollock	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Red hake	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sculpins	<0.01	<0.01	<0.01	<0.01	<0.01	1.94	<0.01	1.58	1.66	<0.01	1.94	<0.01	1.59	1.66	<0.01
Scup	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Searobin	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01
Silver hake	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Skates	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped bass	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tautog	<0.01	<0.01	<0.01	<0.01	<0.01	0.11	<0.01	0.09	0.10	<0.01	0.11	<0.01	0.09	0.10	<0.01
Weakfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
White perch	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Windowpane	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.02	0.02	<0.01	0.02	<0.01	0.02	0.02	<0.01
Winter flounder	0.03	0.02	0.02	0.02	0.02	6.35	<0.01	5.18	5.43	<0.01	6.38	0.02	5.20	5.46	0.02
Total (all species)	**0.63**	**0.43**	**0.62**	**0.63**	**0.43**	**59.37**	**<0.01**	**48.40**	**50.77**	**<0.01**	**60.00**	**0.43**	**49.02**	**51.40**	**0.43**

Scenarios: B = Baseline I&E Mortality losses, 1 = Option 1 (I Everywhere), 2 = Option 2 (I Everywhere and E for Facilities > 125 MGD), 3 = Option 3 (I&E Mortality Everywhere), 4 = Option 4 (I for Facilities > 50 MGD)

Table C-4: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the North Atlantic (million individuals per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement B	Impingement 1	Impingement 2	Impingement 3	Impingement 4	Entrainment B	Entrainment 1	Entrainment 2	Entrainment 3	Entrainment 4	I&E B	I&E 1	I&E 2	I&E 3	I&E 4
Alewife	0.05	0.02	0.03	0.03	0.02	5.76	<0.01	2.35	2.46	<0.01	5.81	0.02	2.37	2.49	0.02
American plaice	<0.01	<0.01	<0.01	<0.01	<0.01	199.21	<0.01	81.20	85.19	<0.01	199.21	<0.01	81.20	85.19	<0.01
American sand lance	0.16	0.06	0.08	0.08	0.06	1,469.03	<0.01	598.82	628.20	<0.01	1,469.20	0.06	598.90	628.28	0.06
American shad	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Atlantic cod	<0.01	<0.01	<0.01	<0.01	<0.01	117.38	<0.01	47.85	50.19	<0.01	117.38	<0.01	47.85	50.19	<0.01
Atlantic herring	0.03	0.01	0.01	0.01	0.01	87.31	<0.01	35.59	37.33	<0.01	87.34	0.01	35.60	37.35	0.01
Atlantic mackerel	<0.01	<0.01	<0.01	<0.01	<0.01	7,067.69	<0.01	2,880.99	3,022.33	<0.01	7,067.69	<0.01	2,880.99	3,022.33	<0.01
Atlantic menhaden	0.02	<0.01	<0.01	<0.01	<0.01	4,206.13	<0.01	1,714.54	1,798.65	<0.01	4,206.15	<0.01	1,714.55	1,798.66	<0.01
Atlantic silverside	0.14	0.05	0.07	0.07	0.05	96.58	<0.01	39.37	41.30	<0.01	96.71	0.05	39.43	41.37	0.05
Atlantic tomcod	<0.01	<0.01	<0.01	<0.01	<0.01	6.28	<0.01	2.56	2.68	<0.01	6.28	<0.01	2.56	2.69	<0.01
Bay anchovy	0.03	0.01	0.02	0.02	0.01	55,820.08	<0.01	22,753.85	23,870.13	<0.01	55,820.11	0.01	22,753.86	23,870.15	0.01
Blueback herring	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bluefish	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	<0.01	0.02	0.02	<0.01	0.06	<0.01	0.02	0.02	<0.01
Butterfish	<0.01	<0.01	<0.01	<0.01	<0.01	12.15	<0.01	4.95	5.20	<0.01	12.16	<0.01	4.96	5.20	<0.01
Crabs (other)	0.04	0.01	0.02	0.02	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.01	0.02	0.02	0.01
Cunner	<0.01	<0.01	<0.01	<0.01	<0.01	29,170.94	<0.01	11,890.91	12,474.26	<0.01	29,170.95	<0.01	11,890.91	12,474.27	<0.01
Fish (other)	0.06	0.02	0.03	0.03	0.02	521.45	<0.01	212.56	222.99	<0.01	521.51	0.02	212.59	223.02	0.02
Fourbeard rockling	<0.01	<0.01	<0.01	<0.01	<0.01	464.23	<0.01	189.23	198.52	<0.01	464.23	<0.01	189.23	198.52	<0.01
Grubby	0.02	<0.01	0.01	0.01	<0.01	431.08	<0.01	175.72	184.34	<0.01	431.10	<0.01	175.73	184.35	<0.01
Hogchoker	0.04	0.01	0.02	0.02	0.01	549.17	<0.01	223.86	234.84	<0.01	549.22	0.01	223.88	234.86	0.01
Lumpfish	<0.01	<0.01	<0.01	<0.01	<0.01	44.89	<0.01	18.30	19.20	<0.01	44.89	<0.01	18.30	19.20	<0.01
Northern pipefish	<0.01	<0.01	<0.01	<0.01	<0.01	1.15	<0.01	0.47	0.49	<0.01	1.16	<0.01	0.47	0.49	<0.01
Pollock	<0.01	<0.01	<0.01	<0.01	<0.01	3.46	<0.01	1.41	1.48	<0.01	3.47	<0.01	1.41	1.48	<0.01
Radiated shanny	<0.01	<0.01	<0.01	<0.01	<0.01	110.36	<0.01	44.99	47.19	<0.01	110.36	<0.01	44.99	47.19	<0.01
Rainbow smelt	0.05	0.02	0.03	0.03	0.02	17.65	<0.01	7.19	7.55	<0.01	17.70	0.02	7.22	7.57	0.02
Red hake	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Rock gunnel	<0.01	<0.01	<0.01	<0.01	<0.01	395.87	<0.01	161.37	169.29	<0.01	395.88	<0.01	161.37	169.29	<0.01
Sculpins	<0.01	<0.01	<0.01	<0.01	<0.01	218.67	<0.01	89.13	93.51	<0.01	218.67	<0.01	89.14	93.51	<0.01
Scup	<0.01	<0.01	<0.01	<0.01	<0.01	16.64	<0.01	6.78	7.12	<0.01	16.65	<0.01	6.79	7.12	<0.01

Table C-4: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the North Atlantic (million A1Es per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality, continued

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
Seaboard goby	<0.01	<0.01	<0.01	<0.01	<0.01	2,379.58	<0.01	969.99	1,017.57	<0.01	2,379.58	<0.01	969.99	1,017.57	<0.01
Searobin	<0.01	<0.01	<0.01	<0.01	<0.01	11.48	<0.01	4.68	4.91	<0.01	11.48	<0.01	4.68	4.91	<0.01
Silver hake	0.03	0.01	0.02	0.02	0.01	568.71	<0.01	231.82	243.20	<0.01	568.75	0.01	231.84	243.21	0.01
Skates	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped bass	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped killifish	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	<0.01	0.03	0.03	<0.01	0.07	<0.01	0.03	0.03	<0.01
Tautog	<0.01	<0.01	<0.01	<0.01	<0.01	29,299.93	<0.01	11,943.48	12,529.42	<0.01	29,299.94	<0.01	11,943.49	12,529.42	<0.01
Threespine stickleback	0.03	<0.01	0.01	0.01	<0.01	0.09	<0.01	0.04	0.04	<0.01	0.11	<0.01	0.05	0.05	<0.01
Weakfish	<0.01	<0.01	<0.01	<0.01	<0.01	342.21	<0.01	139.49	146.34	<0.01	342.21	<0.01	139.50	146.34	<0.01
White perch	0.01	<0.01	<0.01	<0.01	<0.01	0.28	<0.01	0.12	0.12	<0.01	0.30	<0.01	0.12	0.13	<0.01
Windowpane	0.01	<0.01	<0.01	<0.01	<0.01	2,066.54	<0.01	842.38	883.71	<0.01	2,066.55	<0.01	842.39	883.71	<0.01
Winter flounder	0.09	0.03	0.05	0.05	0.03	6,688.08	<0.01	2,726.25	2,860.00	<0.01	6,688.17	0.03	2,726.30	2,860.04	0.03
Total (all species)	**0.90**	**0.31**	**0.44**	**0.45**	**0.31**	**142,390.18**	**<0.01**	**58,042.28**	**60,889.79**	**<0.01**	**142,391.08**	**0.31**	**58,042.72**	**60,890.23**	**0.31**

Scenarios: B = Baseline I&E Mortality losses. 1 = Option 1 (I Everywhere), 2 = Option 2 (I Everywhere and E for Facilities > 125 MGD), 3 = Option 3 (I&E Mortality Everywhere), 4 = Option 4 (I for Facilities > 50 MGD). Values for all options reflect reductions in losses.

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Table C-5: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the Mid-Atlantic (million A1Es per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality

	Impingement					Entrainment					I&E				
Species	**B**	**1**	**2**	**3**	**4**	**B**	**1**	**2**	**3**	**4**	**B**	**1**	**2**	**3**	**4**
All forage species	18.71	14.27	18.25	18.31	14.26	732.37	<0.01	670.71	679.28	<0.01	751.07	14.27	688.96	697.59	14.26
All harvested species	32.00	24.42	31.22	31.33	24.39	206.98	<0.01	189.56	191.98	<0.01	238.98	24.42	220.78	223.31	24.39
Alewife	0.04	0.03	0.04	0.04	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.03	0.04	0.05	0.03
American shad	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Atlantic croaker	0.31	0.24	0.30	0.31	0.24	21.59	<0.01	19.77	20.03	<0.01	21.90	0.24	20.08	20.33	0.24
Atlantic herring	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Atlantic menhaden	21.72	16.57	21.19	21.26	16.55	3.16	<0.01	2.89	2.93	<0.01	24.88	16.57	24.08	24.19	16.55
Black crappie	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Black drum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Blue crab	1.44	1.10	1.40	1.41	1.10	108.17	<0.01	99.07	100.33	<0.01	109.61	1.10	100.47	101.74	1.10
Bluefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bluegill	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Brown bullhead	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01	0.02	<0.01	0.02	0.02	<0.01
Bullheads	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Butterfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Channel catfish	0.02	0.01	0.02	0.02	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.01	0.02	0.02	0.01
Crabs (other)	0.03	0.02	0.03	0.03	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.02	0.03	0.03	0.02
Crappie	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cunner	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Freshwater drum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Menhadens	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Muskellunge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fish (other)	1.30	0.99	1.27	1.27	0.99	10.81	<0.01	9.90	10.02	<0.01	12.10	0.99	11.16	11.29	0.99
Red drum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Red hake	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Scup	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Searobin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver hake	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver perch	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Smallmouth bass	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table C-5: I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the Mid-Atlantic Region (million A1Es) Estimated Under Baseline and Option Scenarios for All Sources of Mortality, continued

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
Spot	2.95	2.25	2.88	2.89	2.25	35.15	<0.01	32.19	32.60	<0.01	38.10	2.25	35.07	35.49	2.25
Spotted seatrout	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped bass	<0.01	<0.01	<0.01	<0.01	<0.01	1.39	<0.01	1.27	1.29	<0.01	1.40	<0.01	1.28	1.30	<0.01
Striped mullet	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Summer flounder	0.02	0.02	0.02	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.02	0.02	0.02
Sunfish	0.02	0.01	0.02	0.02	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.01	0.02	0.02	0.01
Tautog	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Weakfish	1.43	1.09	1.40	1.40	1.09	2.71	<0.01	2.48	2.51	<0.01	4.14	1.09	3.88	3.91	1.09
White perch	2.66	2.03	2.59	2.60	2.03	23.88	<0.01	21.87	22.15	<0.01	26.53	2.03	24.46	24.75	2.03
Whitefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Windowpane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Winter flounder	0.02	0.01	0.02	0.02	0.01	0.11	<0.01	0.10	0.10	<0.01	0.12	0.01	0.11	0.11	0.01
Total (all species)	**50.71**	**38.69**	**49.47**	**49.64**	**38.65**	**939.35**	**<0.01**	**860.27**	**871.26**	**<0.01**	**990.06**	**38.69**	**909.74**	**920.90**	**38.65**

Scenarios: B = Baseline I&E Mortality losses, 1 = Option 1 (I Everywhere), 2 = Option 2 (I Everywhere and E for Facilities > 125 MGD), 3 = Option 3 (I&E Mortality Everywhere), 4 = Option 4 (I for Facilities > 50 MGD)

Table C-6: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the Mid-Atlantic (million individuals per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality

	Impingement					Entrainment					I&E				
Species	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
Alewife	0.33	0.13	0.16	0.16	0.13	6.10	<0.01	2.80	2.83	<0.01	6.44	0.13	2.96	2.99	0.13
American shad	0.06	0.02	0.03	0.03	0.02	67.07	<0.01	30.71	31.11	<0.01	67.13	0.02	30.74	31.13	0.02
Atlantic croaker	2.28	0.87	1.11	1.12	0.87	689.03	<0.01	315.51	319.54	<0.01	691.31	0.87	316.62	320.66	0.87
Atlantic herring	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Atlantic menhaden	70.44	26.87	34.36	34.48	26.85	122.59	<0.01	56.13	56.85	<0.01	193.03	26.87	90.50	91.33	26.85
Atlantic silverside	1.40	0.53	0.68	0.69	0.53	110.15	<0.01	50.44	51.08	<0.01	111.55	0.53	51.12	51.77	0.53
Atlantic tomcod	0.13	0.05	0.06	0.07	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	0.13	0.05	0.06	0.07	0.05
Bay anchovy	13.78	5.25	6.72	6.74	5.25	98,332.37	<0.01	45,026.92	45,602.31	<0.01	98,346.15	5.25	45,033.64	45,609.05	5.25
Black crappie	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Black drum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Blue crab	2.87	1.09	1.40	1.40	1.09	3,396.61	<0.01	1,555.33	1,575.20	<0.01	3,399.48	1.09	1,556.72	1,576.60	1.09
Blueback herring	1.27	0.48	0.62	0.62	0.48	24.27	<0.01	11.11	11.26	<0.01	25.54	0.48	11.73	11.88	0.48
Bluefish	0.03	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.01	0.01	0.01	0.01
Bluegill	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bluntnose minnow	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Brown bullhead	<0.01	<0.01	<0.01	<0.01	<0.01	0.11	<0.01	0.05	0.05	<0.01	0.12	<0.01	0.05	0.05	<0.01
Bullheads	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Butterfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Carp	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chain pipefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Channel catfish	0.02	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.01	0.01	<0.01
Crabs (other)	0.04	0.01	0.02	0.02	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.01	0.02	0.02	0.01
Crappie	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cunner	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Darters	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fish (other)	5.34	2.04	2.60	2.61	2.03	3,804.94	<0.01	1,742.30	1,764.57	<0.01	3,810.28	2.04	1,744.91	1,767.18	2.03
Freshwater drum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Gizzard shad	0.34	0.13	0.17	0.17	0.13	<0.01	<0.01	<0.01	<0.01	<0.01	0.34	0.13	0.17	0.17	0.13
Gobies	<0.01	<0.01	<0.01	<0.01	<0.01	143.88	<0.01	65.88	66.72	<0.01	143.88	<0.01	65.88	66.72	<0.01
Grubby	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01
Herrings	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hogchoker	0.53	0.20	0.26	0.26	0.20	25,970.61	<0.01	11,892.08	12,044.05	<0.01	25,971.14	0.20	11,892.34	12,044.31	0.20

Table C-6: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the Mid-Atlantic (million individuals per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality, continued

	Impingement					Entrainment					I&E				
Species	**B**	**1**	**2**	**3**	**4**	**B**	**1**	**2**	**3**	**4**	**B**	**1**	**2**	**3**	**4**
Menhadens	<0.01	<0.01	<0.01	<0.01	<0.01	0.11	<0.01	0.05	0.05	<0.01	0.11	<0.01	0.05	0.05	<0.01
Muskellunge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Northern pipefish	0.03	0.01	0.02	0.02	0.01	10.64	<0.01	4.87	4.93	<0.01	10.67	0.01	4.89	4.95	0.01
Rainbow smelt	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Red drum	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01
Red hake	0.07	0.03	0.04	0.04	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	0.07	0.03	0.04	0.04	0.03
Scup	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Seaboard goby	0.02	<0.01	<0.01	<0.01	<0.01	13,691.58	<0.01	6,269.45	6,349.56	<0.01	13,691.59	<0.01	6,269.46	6,349.57	<0.01
Searobin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Shiners	<0.01	<0.01	<0.01	<0.01	<0.01	1.00	<0.01	0.46	0.46	<0.01	1.00	<0.01	0.46	0.46	<0.01
Silver hake	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01
Silver perch	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silversides	<0.01	<0.01	<0.01	<0.01	<0.01	2.84	<0.01	1.30	1.32	<0.01	2.85	<0.01	1.30	1.32	<0.01
Smallmouth bass	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Spot	9.17	3.50	4.47	4.49	3.49	232.64	<0.01	106.53	107.89	<0.01	241.80	3.50	111.00	112.37	3.49
Spotted seatrout	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped bass	0.04	0.01	0.02	0.02	0.01	1,060.00	<0.01	485.38	491.58	<0.01	1,060.04	0.01	485.40	491.60	0.01
Striped killifish	0.32	0.12	0.16	0.16	0.12	<0.01	<0.01	<0.01	<0.01	<0.01	0.32	0.12	0.16	0.16	0.12
Striped mullet	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Suckers	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Summer flounder	0.08	0.03	0.04	0.04	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	0.08	0.03	0.04	0.04	0.03
Sunfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tautog	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Threespine stickleback	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Weakfish	3.31	1.26	1.61	1.62	1.26	486.50	<0.01	222.77	225.62	<0.01	489.81	1.26	224.39	227.24	1.26
White perch	2.81	1.07	1.37	1.37	1.07	2,335.12	<0.01	1,069.26	1,082.93	<0.01	2,337.92	1.07	1,070.63	1,084.30	1.07
Whitefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Windowpane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Winter flounder	0.06	0.02	0.03	0.03	0.02	92.01	<0.01	42.13	42.67	<0.01	92.07	0.02	42.16	42.70	0.02
Total (all species)	**114.86**	**43.81**	**56.03**	**56.22**	**43.77**	**150,580.20**	**<0.01**	**68,951.48**	**69,832.59**	**<0.01**	**150,695.05**	**43.81**	**69,007.51**	**69,888.82**	**43.77**

Scenarios: B = Baseline I&E Mortality losses. 1 = Option 1 (I Everywhere), 2 = Option 2 (I Everywhere and E for Facilities > 125 MGD), 3 = Option 3 (I&E Mortality Everywhere), 4 = Option 4 (I for Facilities > 50 MGD). Values for all options reflect reductions in losses.

C.4 South Atlantic

Table C-7: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the South Atlantic (million A1Es per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
All forage species	21.27	13.43	18.13	18.14	13.43	9.94	<0.01	8.29	8.31	<0.01	31.22	13.43	26.43	26.45	13.43
All harvested species	1.22	0.77	1.04	1.04	0.77	0.96	<0.01	0.80	0.81	<0.01	2.19	0.77	1.85	1.85	0.77
Atlantic menhaden	0.25	0.16	0.21	0.21	0.16	0.03	<0.01	0.02	0.03	<0.01	0.28	0.16	0.24	0.24	0.16
Blue crab	0.45	0.29	0.39	0.39	0.29	<0.01	<0.01	<0.01	<0.01	<0.01	0.45	0.29	0.39	0.39	0.29
Crabs (other)	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.02	0.02	<0.01	0.02	<0.01	0.02	0.02	<0.01
Drums and croakers	0.02	0.01	0.02	0.02	0.01	0.80	<0.01	0.67	0.67	<0.01	0.82	0.01	0.69	0.69	0.01
Flounders	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fish (other)	0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01
Pinfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver perch	0.28	0.18	0.24	0.24	0.18	<0.01	<0.01	<0.01	<0.01	<0.01	0.28	0.18	0.24	0.24	0.18
Spot	0.20	0.12	0.17	0.17	0.12	0.10	<0.01	0.08	0.08	<0.01	0.29	0.12	0.25	0.25	0.12
Spotted seatrout	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Stone crab	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Weakfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total (all species)	**22.50**	**14.20**	**19.18**	**19.19**	**14.20**	**10.91**	**<0.01**	**9.10**	**9.11**	**<0.01**	**33.40**	**14.20**	**28.28**	**28.30**	**14.20**

Scenarios: B = Baseline I&E Mortality losses, 1 = Option 1 (I Everywhere), 2 = Option 2 (I Everywhere and E for Facilities > 125 MGD), 3 = Option 3 (I&E Mortality Everywhere), 4 = Option 4 (I for Facilities > 50 MGD)

Table C-8: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the South Atlantic (million individuals per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement					Entrainment					I&E				
	B	**1**	**2**	**3**	**4**	**B**	**1**	**2**	**3**	**4**	**B**	**1**	**2**	**3**	**4**
Atlantic menhaden	0.82	0.26	0.35	0.35	0.26	157.54	<0.01	65.70	65.81	<0.01	158.36	0.26	66.05	66.15	0.26
Atlantic silverside	0.13	0.04	0.05	0.05	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	0.13	0.04	0.05	0.05	0.04
Bay anchovy	25.54	8.06	10.89	10.89	8.06	2,402.75	<0.01	1,002.00	1,003.65	<0.01	2,428.30	8.06	1,012.88	1,014.54	8.06
Blue crab	0.90	0.28	0.38	0.38	0.28	<0.01	<0.01	<0.01	<0.01	<0.01	0.90	0.28	0.38	0.38	0.28
Crabs (other)	<0.01	<0.01	<0.01	<0.01	<0.01	667.97	<0.01	278.56	279.02	<0.01	667.97	<0.01	278.56	279.02	<0.01
Drums and croakers	0.22	0.07	0.09	0.09	0.07	2,376.84	<0.01	991.19	992.83	<0.01	2,377.05	0.07	991.28	992.92	0.07
Fish (other)	1.67	0.53	0.71	0.71	0.53	272.99	<0.01	113.84	114.03	<0.01	274.66	0.53	114.55	114.74	0.53
Flounders	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Gobies	<0.01	<0.01	<0.01	<0.01	<0.01	3,576.38	<0.01	1,491.43	1,493.89	<0.01	3,576.38	<0.01	1,491.43	1,493.89	<0.01
Herrings	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Pinfish	<0.01	<0.01	<0.01	<0.01	<0.01	71.34	<0.01	29.75	29.80	<0.01	71.34	<0.01	29.75	29.80	<0.01
Scaled sardine	0.03	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	0.01	0.01	<0.01
Shrimp (other)	8.90	2.81	3.79	3.79	2.81	1,040.49	<0.01	433.91	434.62	<0.01	1,049.39	2.81	437.70	438.42	2.81
Silver perch	0.45	0.14	0.19	0.19	0.14	<0.01	<0.01	<0.01	<0.01	<0.01	0.45	0.14	0.19	0.19	0.14
Spot	0.72	0.23	0.31	0.31	0.23	2,152.83	<0.01	897.77	899.25	<0.01	2,153.54	0.23	898.08	899.56	0.23
Spotted seatrout	<0.01	<0.01	<0.01	<0.01	<0.01	35.30	<0.01	14.72	14.75	<0.01	35.30	<0.01	14.72	14.75	<0.01
Stone crab	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Weakfish	0.04	0.01	0.02	0.02	0.01	100.99	<0.01	42.12	42.19	<0.01	101.04	0.01	42.14	42.20	0.01
Total (all species)	**39.42**	**12.44**	**16.80**	**16.81**	**12.44**	**12,855.43**	**<0.01**	**5,360.98**	**5,369.82**	**<0.01**	**12,894.86**	**12.44**	**5,377.79**	**5,386.64**	**12.44**

Scenarios: B = Baseline I&E Mortality losses. 1 = Option 1 (I Everywhere), 2 = Option 2 (I Everywhere and E for Facilities > 125 MGD), 3 = Option 3 (I&E Mortality Everywhere), 4 = Option 4 (I for Facilities > 50 MGD). Values for all options reflect reductions in losses.

C.5 Gulf of Mexico

Table C-9: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the Gulf of Mexico (million A1Es per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
All forage species	5.63	4.31	5.59	5.60	4.28	42.12	<0.01	28.49	28.56	<0.01	47.75	4.31	34.09	34.16	4.28
All harvested species	39.42	30.19	39.15	39.18	29.96	48.47	<0.01	32.79	32.87	<0.01	87.89	30.19	71.94	72.05	29.96
Atlantic croaker	1.65	1.27	1.64	1.64	1.26	<0.01	<0.01	<0.01	<0.01	<0.01	1.65	1.27	1.64	1.64	1.26
Black drum	0.01	<0.01	0.01	0.01	<0.01	5.93	<0.01	4.01	4.02	<0.01	5.94	<0.01	4.02	4.03	<0.01
Blue crab	5.66	4.33	5.62	5.62	4.30	19.03	<0.01	12.87	12.90	<0.01	24.68	4.33	18.49	18.53	4.30
Leatherjacket	0.69	0.53	0.68	0.69	0.52	0.03	<0.01	0.02	0.02	<0.01	0.72	0.53	0.71	0.71	0.52
Mackerels	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Menhadens	4.95	3.79	4.92	4.92	3.76	0.05	<0.01	0.03	0.03	<0.01	5.00	3.79	4.95	4.96	3.76
Fish (other)	1.48	1.14	1.47	1.47	1.13	0.16	<0.01	0.11	0.11	<0.01	1.64	1.14	1.58	1.58	1.13
Pinfish	0.03	0.02	0.03	0.03	0.02	1.07	<0.01	0.72	0.73	<0.01	1.10	0.02	0.75	0.76	0.02
Pink shrimp	21.44	16.42	21.29	21.31	16.30	13.40	<0.01	9.07	9.09	<0.01	34.84	16.42	30.36	30.40	16.30
Red drum	0.08	0.06	0.08	0.08	0.06	0.01	<0.01	<0.01	<0.01	<0.01	0.10	0.06	0.09	0.09	0.06
Sea basses	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Searobin	0.94	0.72	0.93	0.93	0.71	0.36	<0.01	0.25	0.25	<0.01	1.30	0.72	1.18	1.18	0.71
Sheepshead	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	0.02	0.02	<0.01	0.04	<0.01	0.02	0.02	<0.01
Silver perch	0.28	0.22	0.28	0.28	0.21	5.11	<0.01	3.46	3.47	<0.01	5.40	0.22	3.74	3.75	0.21
Spot	0.38	0.29	0.38	0.38	0.29	0.09	<0.01	0.06	0.06	<0.01	0.47	0.29	0.44	0.44	0.29
Spotted seatrout	1.26	0.96	1.25	1.25	0.96	0.15	<0.01	0.10	0.10	<0.01	1.41	0.96	1.35	1.35	0.96
Stone crab	0.19	0.14	0.18	0.19	0.14	0.41	<0.01	0.28	0.28	<0.01	0.60	0.14	0.47	0.47	0.14
Striped mullet	0.37	0.28	0.37	0.37	0.28	2.62	<0.01	1.77	1.78	<0.01	2.99	0.28	2.14	2.14	0.28
Total (all species)	**45.05**	**34.50**	**44.74**	**44.78**	**34.24**	**90.59**	**<0.01**	**61.28**	**61.43**	**<0.01**	**135.64**	**34.50**	**106.02**	**106.21**	**34.24**

Scenarios: B = Baseline I&E Mortality losses, 1 = Option 1 (I Everywhere), 2 = Option 2 (I Everywhere and E for Facilities > 125 MGD), 3 = Option 3 (I&E Mortality Everywhere), 4 = Option 4 (I for Facilities > 50 MGD)

Table C-10: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the Gulf of Mexico (million individuals per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
Atlantic croaker	15.45	5.92	7.67	7.68	5.87	162.35	<0.01	54.91	55.05	<0.01	177.81	5.92	62.59	62.73	5.87
Bay anchovy	4.33	1.66	2.15	2.15	1.65	301,092.72	<0.01	101,837.44	102,087.75	<0.01	301,097.05	1.66	101,839.59	102,089.90	1.65
Black drum	0.02	<0.01	0.01	0.01	<0.01	96,328.24	<0.01	32,580.73	32,660.81	<0.01	96,328.26	<0.01	32,580.74	32,660.83	<0.01
Blue crab	11.26	4.31	5.59	5.60	4.28	280.96	<0.01	95.03	95.26	<0.01	292.22	4.31	100.62	100.86	4.28
Chain pipefish	0.07	0.03	0.03	0.03	0.03	2.13	<0.01	0.72	0.72	<0.01	2.19	0.03	0.75	0.75	0.03
Fish (other)	7.43	2.85	3.69	3.69	2.82	9,784.29	<0.01	3,309.30	3,317.44	<0.01	9,791.72	2.85	3,312.99	3,321.13	2.82
Gobies	0.14	0.05	0.07	0.07	0.05	3,407.68	<0.01	1,152.57	1,155.40	<0.01	3,407.82	0.05	1,152.64	1,155.47	0.05
Gulf killifish	0.04	0.01	0.02	0.02	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.01	0.02	0.02	0.01
Hogchoker	0.15	0.06	0.07	0.07	0.06	198.72	<0.01	67.21	67.38	<0.01	198.87	0.06	67.28	67.45	0.06
Leatherjacket	0.95	0.36	0.47	0.47	0.36	794.02	<0.01	268.56	269.22	<0.01	794.97	0.36	269.03	269.69	0.36
Mackerels	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Menhadens	16.06	6.15	7.98	7.98	6.10	269.13	<0.01	91.03	91.25	<0.01	285.19	6.15	99.00	99.23	6.10
Pinfish	0.12	0.05	0.06	0.06	0.04	107.79	<0.01	36.46	36.55	<0.01	107.91	0.05	36.52	36.61	0.04
Pink shrimp	43.73	16.74	21.71	21.73	16.62	126.32	<0.01	42.73	42.83	<0.01	170.05	16.74	64.44	64.56	16.62
Red drum	0.16	0.06	0.08	0.08	0.06	1.10	<0.01	0.37	0.37	<0.01	1.26	0.06	0.45	0.45	0.06
Scaled sardine	0.32	0.12	0.16	0.16	0.12	2,962.36	<0.01	1,001.95	1,004.41	<0.01	2,962.69	0.12	1,002.11	1,004.57	0.12
Sea basses	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Searobin	1.18	0.45	0.58	0.58	0.45	68.82	<0.01	23.28	23.33	<0.01	70.00	0.45	23.86	23.92	0.45
Sheepshead	<0.01	<0.01	<0.01	<0.01	<0.01	382.88	<0.01	129.50	129.82	<0.01	382.88	<0.01	129.50	129.82	<0.01
Silver perch	0.45	0.17	0.23	0.23	0.17	88,985.72	<0.01	30,097.30	30,171.28	<0.01	88,986.17	0.17	30,097.53	30,171.50	0.17
Spot	1.39	0.53	0.69	0.69	0.53	34.75	<0.01	11.75	11.78	<0.01	36.14	0.53	12.44	12.47	0.53
Spotted seatrout	1.20	0.46	0.60	0.60	0.46	5,338.00	<0.01	1,805.45	1,809.89	<0.01	5,339.20	0.46	1,806.05	1,810.49	0.46
Stone crab	0.27	0.10	0.14	0.14	0.10	28,711.01	<0.01	9,710.82	9,734.68	<0.01	28,711.29	0.10	9,710.95	9,734.82	0.10
Striped mullet	0.45	0.17	0.22	0.23	0.17	15.17	<0.01	5.13	5.14	<0.01	15.62	0.17	5.36	5.37	0.17
Tidewater silverside	0.30	0.11	0.15	0.15	0.11	34.36	<0.01	11.62	11.65	<0.01	34.66	0.11	11.77	11.80	0.11
Total (all species)	**105.48**	**40.39**	**52.38**	**52.42**	**40.09**	**539,088.54**	**<0.01**	**182,333.86**	**182,782.02**	**<0.01**	**539,194.01**	**40.39**	**182,386.23**	**182,834.44**	**40.09**

Scenarios: B = Baseline I&E Mortality losses. 1 = Option 1 (I Everywhere), 2 = Option 2 (I Everywhere and E for Facilities > 125 MGD), 3 = Option 3 (I&E Mortality Everywhere), 4 = Option 4 (I for Facilities > 50 MGD). Values for all options reflect reductions in losses.

C.6 Great Lakes

Table C-11: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the Great Lakes (million A1Es per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
All forage species	38.62	33.46	38.20	38.29	33.17	7.84	<0.01	6.26	6.36	<0.01	46.46	33.46	44.46	44.64	33.17
All harvested species	5.51	4.77	5.45	5.46	4.73	1.53	<0.01	1.22	1.24	<0.01	7.04	4.77	6.67	6.70	4.73
Black bullhead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Black crappie	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bluegill	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Brown bullhead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bullheads	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Channel catfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Crappie	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.01	0.01	<0.01	0.02	<0.01	0.02	0.02	<0.01
Freshwater drum	0.02	0.02	0.02	0.02	0.02	0.05	<0.01	0.04	0.04	<0.01	0.07	0.02	0.06	0.06	0.02
Muskellunge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fish (other)	0.06	0.05	0.06	0.06	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	0.05	0.06	0.06	0.05
Rainbow smelt	0.37	0.32	0.36	0.36	0.32	0.07	<0.01	0.05	0.05	<0.01	0.44	0.32	0.42	0.42	0.32
Salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sculpins	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.02	0.02	<0.01	0.03	<0.01	0.02	0.02	<0.01
Smallmouth bass	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Smelts	4.49	3.89	4.45	4.46	3.86	0.02	<0.01	0.02	0.02	<0.01	4.52	3.89	4.46	4.47	3.86
Sunfish	0.02	0.02	0.02	0.02	0.02	1.18	<0.01	0.95	0.96	<0.01	1.20	0.02	0.96	0.98	0.02
Walleye	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
White bass	0.05	0.04	0.05	0.05	0.04	0.09	<0.01	0.08	0.08	<0.01	0.14	0.04	0.12	0.13	0.04
Whitefish	0.23	0.20	0.22	0.23	0.20	<0.01	<0.01	<0.01	<0.01	<0.01	0.23	0.20	0.22	0.23	0.20
Yellow perch	0.26	0.23	0.26	0.26	0.22	0.07	<0.01	0.05	0.05	<0.01	0.33	0.23	0.31	0.31	0.22
Total (all species)	**44.13**	**38.23**	**43.65**	**43.75**	**37.91**	**9.37**	**<0.01**	**7.48**	**7.60**	**<0.01**	**53.50**	**38.23**	**51.13**	**51.35**	**37.91**

Scenarios: B = Baseline I&E Mortality losses, 1 = Option 1 (I Everywhere), 2 = Option 2 (I Everywhere and E for Facilities > 125 MGD), 3 = Option 3 (I&E Mortality Everywhere), 4 = Option 4 (I for Facilities > 50 MGD)

Table C-12: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the Great Lakes (million individuals per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
Alewife	28.95	12.54	14.32	14.35	12.44	38,098.88	<0.01	15,213.50	15,443.27	<0.01	38,127.84	12.54	15,227.82	15,457.62	12.44
Black bullhead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Black crappie	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Blueback herring	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bluegill	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bluntnose minnow	0.01	<0.01	<0.01	<0.01	<0.01	13.01	<0.01	5.20	5.27	<0.01	13.02	<0.01	5.20	5.28	<0.01
Brown bullhead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bullheads	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Burbot	<0.01	<0.01	<0.01	<0.01	<0.01	0.53	<0.01	0.21	0.21	<0.01	0.53	<0.01	0.21	0.22	<0.01
Carp	0.04	0.02	0.02	0.02	0.02	3,239.89	<0.01	1,293.74	1,313.28	<0.01	3,239.94	0.02	1,293.76	1,313.30	0.02
Channel catfish	<0.01	<0.01	<0.01	<0.01	<0.01	0.20	<0.01	0.08	0.08	<0.01	0.20	<0.01	0.08	0.08	<0.01
Chinook salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Crappie	<0.01	<0.01	<0.01	<0.01	<0.01	0.90	<0.01	0.36	0.36	<0.01	0.90	<0.01	0.36	0.37	<0.01
Darters	0.01	<0.01	<0.01	<0.01	<0.01	2.87	<0.01	1.15	1.16	<0.01	2.88	<0.01	1.15	1.17	<0.01
Emerald shiner	0.40	0.17	0.20	0.20	0.17	47.50	<0.01	18.97	19.25	<0.01	47.90	0.17	19.17	19.45	0.17
Fish (other)	0.19	0.08	0.09	0.10	0.08	40,037.77	<0.01	15,987.73	16,229.19	<0.01	40,037.96	0.08	15,987.82	16,229.28	0.08
Freshwater drum	0.07	0.03	0.03	0.03	0.03	221.20	<0.01	88.33	89.66	<0.01	221.27	0.03	88.36	89.70	0.03
Gizzard shad	14.94	6.47	7.39	7.40	6.42	3,846.52	<0.01	1,535.98	1,559.17	<0.01	3,861.45	6.47	1,543.36	1,566.58	6.42
Golden redhorse	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Herrings	<0.01	<0.01	<0.01	<0.01	<0.01	11.15	<0.01	4.45	4.52	<0.01	11.15	<0.01	4.45	4.52	<0.01
Logperch	0.22	0.10	0.11	0.11	0.09	10.26	<0.01	4.10	4.16	<0.01	10.48	0.10	4.20	4.27	0.09
Muskellunge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Rainbow smelt	0.51	0.22	0.25	0.25	0.22	74.33	<0.01	29.68	30.13	<0.01	74.84	0.22	29.93	30.38	0.22
Salmon	<0.01	<0.01	<0.01	<0.01	<0.01	6.16	<0.01	2.46	2.50	<0.01	6.16	<0.01	2.46	2.50	<0.01
Sculpins	<0.01	<0.01	<0.01	<0.01	<0.01	3.50	<0.01	1.40	1.42	<0.01	3.50	<0.01	1.40	1.42	<0.01
Shiners	0.57	0.25	0.28	0.28	0.24	132.24	<0.01	52.80	53.60	<0.01	132.81	0.25	53.09	53.88	0.24
Smallmouth bass	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Smelts	4.07	1.76	2.01	2.02	1.75	150.69	<0.01	60.17	61.08	<0.01	154.75	1.76	62.18	63.10	1.75
Spotted sucker	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table C-12: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the Great Lakes (million individuals per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality, continued

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
Suckers	<0.01	<0.01	<0.01	<0.01	<0.01	2.31	<0.01	0.92	0.94	<0.01	2.32	<0.01	0.93	0.94	<0.01
Sunfish	<0.01	<0.01	<0.01	<0.01	<0.01	7.03	<0.01	2.81	2.85	<0.01	7.03	<0.01	2.81	2.85	<0.01
Threespine stickleback	0.07	0.03	0.04	0.04	0.03	0.69	<0.01	0.28	0.28	<0.01	0.76	0.03	0.31	0.32	0.03
Walleye	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
White bass	0.05	0.02	0.03	0.03	0.02	38.35	<0.01	15.31	15.54	<0.01	38.40	0.02	15.34	15.57	0.02
White perch	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Whitefish	0.10	0.04	0.05	0.05	0.04	0.17	<0.01	0.07	0.07	<0.01	0.27	0.04	0.12	0.12	0.04
Yellow perch	0.71	0.31	0.35	0.35	0.31	30.26	<0.01	12.08	12.27	<0.01	30.98	0.31	12.44	12.62	0.31
Total (all species)	**50.99**	**22.09**	**25.22**	**25.28**	**21.90**	**85,976.38**	**<0.01**	**34,331.75**	**34,850.27**	**<0.01**	**86,027.37**	**22.09**	**34,356.97**	**34,875.54**	**21.90**

Scenarios: B = Baseline I&E Mortality losses. 1 = Option 1 (I Everywhere), 2 = Option 2 (I Everywhere and E for Facilities > 125 MGD), 3 = Option 3 (I&E Mortality Everywhere), 4 = Option 4 (I for Facilities > 50 MGD). Values for all options reflect reductions in losses.

C.7 Inland

Table C-13: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the Inland Region (million A1Es per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
All forage species	549.42	459.64	531.05	536.22	448.42	164.29	<0.01	134.24	140.41	<0.01	713.71	459.64	665.29	676.63	448.42
All harvested species	34.17	28.59	33.03	33.35	27.89	131.61	<0.01	107.54	112.48	<0.01	165.78	28.59	140.57	145.83	27.89
American shad	0.05	0.04	0.05	0.05	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.04	0.05	0.05	0.04
Black bullhead	0.18	0.15	0.18	0.18	0.15	<0.01	<0.01	<0.01	<0.01	<0.01	0.19	0.15	0.18	0.18	0.15
Black crappie	0.07	0.06	0.06	0.06	0.05	0.50	<0.01	0.41	0.43	<0.01	0.57	0.06	0.47	0.49	0.05
Bluegill	2.11	1.76	2.04	2.06	1.72	0.18	<0.01	0.15	0.15	<0.01	2.29	1.76	2.19	2.21	1.72
Brown bullhead	0.03	0.02	0.03	0.03	0.02	0.04	<0.01	0.04	0.04	<0.01	0.07	0.02	0.06	0.06	0.02
Bullheads	0.02	0.02	0.02	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.02	0.03	0.03	0.02
Channel catfish	1.63	1.36	1.58	1.59	1.33	1.01	<0.01	0.82	0.86	<0.01	2.64	1.36	2.40	2.45	1.33
Crappie	0.11	0.09	0.11	0.11	0.09	1.40	<0.01	1.14	1.20	<0.01	1.51	0.09	1.25	1.31	0.09
Freshwater drum	1.19	1.00	1.15	1.16	0.97	6.31	<0.01	5.16	5.40	<0.01	7.51	1.00	6.31	6.56	0.97
Menhadens	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Muskellunge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fish (other)	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	<0.01	0.05	0.05	<0.01	0.07	<0.01	0.06	0.06	<0.01
Rainbow smelt	0.14	0.12	0.13	0.14	0.11	0.21	<0.01	0.17	0.18	<0.01	0.35	0.12	0.30	0.31	0.11
Salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sauger	0.10	0.08	0.09	0.09	0.08	1.75	<0.01	1.43	1.49	<0.01	1.84	0.08	1.52	1.59	0.08
Smallmouth bass	0.24	0.20	0.23	0.23	0.19	3.70	<0.01	3.03	3.16	<0.01	3.94	0.20	3.25	3.39	0.19
Smelts	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped bass	0.16	0.13	0.15	0.15	0.13	<0.01	<0.01	<0.01	<0.01	<0.01	0.16	0.13	0.15	0.15	0.13
Sturgeons	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.02	0.02	<0.01	0.03	<0.01	0.02	0.02	<0.01
Sunfish	19.92	16.66	19.25	19.44	16.25	110.06	<0.01	89.93	94.07	<0.01	129.98	16.66	109.18	113.51	16.25
Walleye	0.06	0.05	0.05	0.05	0.05	0.68	<0.01	0.56	0.58	<0.01	0.74	0.05	0.61	0.64	0.05
White bass	2.35	1.97	2.27	2.29	1.92	2.66	<0.01	2.18	2.28	<0.01	5.01	1.97	4.45	4.57	1.92
White perch	2.58	2.16	2.49	2.52	2.10	0.55	<0.01	0.45	0.47	<0.01	3.13	2.16	2.94	2.99	2.10
Whitefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Yellow perch	3.24	2.71	3.13	3.16	2.64	2.44	<0.01	1.99	2.08	<0.01	5.67	2.71	5.12	5.24	2.64
Total (all species)	**583.59**	**488.22**	**564.08**	**569.57**	**476.31**	**295.89**	**<0.01**	**241.78**	**252.90**	**<0.01**	**879.49**	**488.22**	**805.86**	**822.46**	**476.31**

Scenarios: B = Baseline I&E Mortality losses, 1 = Option 1 (I Everywhere), 2 = Option 2 (I Everywhere and E for Facilities > 125 MGD), 3 = Option 3 (I&E Mortality Everywhere), 4 = Option 4 (I for Facilities > 50 MGD)

Table C-14: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the Inland Region (million individuals per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
Alewife	42.79	17.90	20.68	20.88	17.46	1.29	<0.01	0.53	0.55	<0.01	44.07	17.90	21.20	21.43	17.46
American shad	19.04	7.96	9.20	9.29	7.77	<0.01	<0.01	<0.01	<0.01	<0.01	19.04	7.96	9.20	9.29	7.77
Bay anchovy	0.03	0.01	0.01	0.02	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.01	0.01	0.02	0.01
Bigmouth buffalo	0.04	0.02	0.02	0.02	0.02	5.38	<0.01	2.20	2.30	<0.01	5.42	0.02	2.22	2.32	0.02
Black bullhead	0.34	0.14	0.16	0.16	0.14	0.04	<0.01	0.02	0.02	<0.01	0.38	0.14	0.18	0.18	0.14
Black crappie	0.35	0.14	0.17	0.17	0.14	24.81	<0.01	10.14	10.60	<0.01	25.16	0.14	10.30	10.77	0.14
Blue crab	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Blueback herring	185.69	77.67	89.74	90.62	75.78	1,750.15	<0.01	715.03	747.92	<0.01	1,935.85	77.67	804.77	838.53	75.78
Bluegill	35.57	14.88	17.19	17.36	14.51	48.04	<0.01	19.63	20.53	<0.01	83.61	14.88	36.82	37.89	14.51
Bluntnose minnow	0.15	0.06	0.07	0.07	0.06	4,918.57	<0.01	2,009.49	2,101.92	<0.01	4,918.72	0.06	2,009.57	2,101.99	0.06
Brown bullhead	0.05	0.02	0.02	0.02	0.02	0.35	<0.01	0.14	0.15	<0.01	0.40	0.02	0.17	0.17	0.02
Bullheads	0.04	0.02	0.02	0.02	0.02	3.68	<0.01	1.50	1.57	<0.01	3.72	0.02	1.52	1.59	0.02
Burbot	<0.01	<0.01	<0.01	<0.01	<0.01	16.04	<0.01	6.55	6.85	<0.01	16.04	<0.01	6.55	6.86	<0.01
Carp	0.37	0.15	0.18	0.18	0.15	4,209.21	<0.01	1,719.68	1,798.78	<0.01	4,209.58	0.15	1,719.86	1,798.96	0.15
Channel catfish	2.03	0.85	0.98	0.99	0.83	209.76	<0.01	85.70	89.64	<0.01	211.80	0.85	86.68	90.63	0.83
Crappie	0.59	0.25	0.29	0.29	0.24	67.69	<0.01	27.66	28.93	<0.01	68.28	0.25	27.94	29.22	0.24
Darters	0.99	0.42	0.48	0.49	0.41	161.74	<0.01	66.08	69.12	<0.01	162.74	0.42	66.56	69.60	0.41
Emerald shiner	3.99	1.67	1.93	1.95	1.63	724.99	<0.01	296.20	309.82	<0.01	728.98	1.67	298.12	311.77	1.63
Fish (other)	83.22	34.81	40.22	40.61	33.96	68,076.66	<0.01	27,812.84	29,092.11	<0.01	68,159.89	34.81	27,853.06	29,132.72	33.96
Freshwater drum	4.58	1.91	2.21	2.23	1.87	3,010.39	<0.01	1,229.90	1,286.47	<0.01	3,014.97	1.91	1,232.11	1,288.70	1.87
Gizzard shad	311.11	130.14	150.36	151.82	126.96	19,070.18	<0.01	7,791.16	8,149.52	<0.01	19,381.30	130.14	7,941.52	8,301.34	126.96
Gobies	<0.01	<0.01	<0.01	<0.01	<0.01	81.15	<0.01	33.15	34.68	<0.01	81.15	<0.01	33.15	34.68	<0.01
Golden redhorse	0.07	0.03	0.03	0.03	0.03	2.86	<0.01	1.17	1.22	<0.01	2.92	0.03	1.20	1.25	0.03
Hogchoker	0.03	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.01	0.01	0.01	0.01
Logperch	1.00	0.42	0.48	0.49	0.41	32.30	<0.01	13.20	13.80	<0.01	33.30	0.42	13.68	14.29	0.41
Menhadens	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Muskellunge	0.02	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	0.01	0.01	<0.01
Rainbow smelt	0.19	0.08	0.09	0.09	0.08	59.23	<0.01	24.20	25.31	<0.01	59.43	0.08	24.29	25.41	0.08
River carpsucker	0.03	0.01	0.02	0.02	0.01	5.15	<0.01	2.10	2.20	<0.01	5.18	0.01	2.12	2.22	0.01
Salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sauger	0.23	0.09	0.11	0.11	0.09	314.24	<0.01	128.39	134.29	<0.01	314.47	0.09	128.49	134.40	0.09

Table C-14: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) in the Inland Region (million individuals per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality, continued

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
Shiners	3.41	1.43	1.65	1.66	1.39	296.49	<0.01	121.13	126.70	<0.01	299.90	1.43	122.78	128.37	1.39
Silversides	0.04	0.02	0.02	0.02	0.02	46.52	<0.01	19.00	19.88	<0.01	46.56	0.02	19.02	19.90	0.02
Skipjack herring	1.52	0.64	0.74	0.74	0.62	0.54	<0.01	0.22	0.23	<0.01	2.06	0.64	0.96	0.97	0.62
Smallmouth bass	0.14	0.06	0.07	0.07	0.06	54.51	<0.01	22.27	23.30	<0.01	54.65	0.06	22.34	23.36	0.06
Smelts	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Spotted sucker	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped bass	1.64	0.69	0.79	0.80	0.67	<0.01	<0.01	<0.01	<0.01	<0.01	1.64	0.69	0.79	0.80	0.67
Striped killifish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sturgeons	<0.01	<0.01	<0.01	<0.01	<0.01	1.46	<0.01	0.59	0.62	<0.01	1.46	<0.01	0.60	0.62	<0.01
Suckers	0.16	0.07	0.08	0.08	0.07	4,342.48	<0.01	1,774.13	1,855.73	<0.01	4,342.64	0.07	1,774.21	1,855.81	0.07
Sunfish	6.38	2.67	3.08	3.11	2.60	648.07	<0.01	264.77	276.95	<0.01	654.45	2.67	267.85	280.06	2.60
Threespine stickleback	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Walleye	0.15	0.06	0.07	0.07	0.06	169.80	<0.01	69.37	72.56	<0.01	169.95	0.06	69.45	72.64	0.06
White bass	2.63	1.10	1.27	1.28	1.07	1,067.79	<0.01	436.25	456.31	<0.01	1,070.42	1.10	437.52	457.60	1.07
White perch	3.87	1.62	1.87	1.89	1.58	660.65	<0.01	269.91	282.33	<0.01	664.53	1.62	271.78	284.22	1.58
Whitefish	<0.01	<0.01	<0.01	<0.01	<0.01	0.75	<0.01	0.31	0.32	<0.01	0.75	<0.01	0.31	0.32	<0.01
Yellow Perch	8.88	3.71	4.29	4.33	3.62	1,100.04	<0.01	449.42	470.10	<0.01	1,108.92	3.71	453.71	474.43	3.62
Total (all species)	**721.46**	**301.78**	**348.67**	**352.06**	**294.41**	**111,183.92**	**<0.01**	**45,424.39**	**47,513.71**	**<0.01**	**111,905.38**	**301.78**	**45,773.07**	**47,865.77**	**294.41**

Scenarios: B = Baseline I&E Mortality losses. 1 = Option 1 (I Everywhere), 2 = Option 2 (I Everywhere and E for Facilities > 125 MGD), 3 = Option 3 (I&E Mortality Everywhere), 4 = Option 4 (I for Facilities > 50 MGD). Values for all options reflect reductions in losses.

C.8 National Estimates

Table C-15: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) Nationally (million A1Es per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
All forage species	634.40	525.66	611.97	617.31	514.11	1020.37	<0.01	900.67	918.13	<0.01	1654.78	525.66	1512.64	1535.44	514.11
All harvested species	113.00	89.31	110.56	111.04	88.31	421.14	<0.01	358.35	367.07	<0.01	534.15	89.31	468.91	478.11	88.31
Alewife	0.04	0.03	0.04	0.04	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.03	0.04	0.05	0.03
American plaice	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
American shad	0.05	0.04	0.05	0.05	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	0.04	0.06	0.06	0.04
Atlantic cod	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01
Atlantic croaker	1.97	1.50	1.95	1.95	1.49	21.59	<0.01	19.77	20.03	<0.01	23.56	1.50	21.72	21.98	1.49
Atlantic herring	<0.01	<0.01	<0.01	<0.01	<0.01	0.12	<0.01	0.10	0.11	<0.01	0.13	<0.01	0.11	0.11	<0.01
Atlantic mackerel	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.02	0.02	<0.01	0.02	<0.01	0.02	0.02	<0.01
Atlantic menhaden	21.97	16.73	21.40	21.48	16.71	3.23	<0.01	2.95	2.99	<0.01	25.20	16.73	24.35	24.47	16.71
Black bullhead	0.18	0.15	0.18	0.18	0.15	<0.01	<0.01	<0.01	<0.01	<0.01	0.19	0.15	0.18	0.18	0.15
Black crappie	0.07	0.06	0.06	0.06	0.05	0.50	<0.01	0.41	0.43	<0.01	0.57	0.06	0.47	0.49	0.05
Black drum	0.01	0.01	0.01	0.01	0.01	5.93	<0.01	4.01	4.02	<0.01	5.94	0.01	4.02	4.03	0.01
Blue crab	7.55	5.72	7.41	7.42	5.68	127.20	<0.01	111.94	113.23	<0.01	134.75	5.72	119.34	120.65	5.68
Bluefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bluegill	2.11	1.76	2.04	2.06	1.72	0.18	<0.01	0.15	0.15	<0.01	2.29	1.76	2.19	2.21	1.72
Brown bullhead	0.03	0.03	0.03	0.03	0.03	0.06	<0.01	0.05	0.05	<0.01	0.09	0.03	0.08	0.08	0.03
Bullheads	0.02	0.02	0.02	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.02	0.03	0.03	0.02
Butterfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cabezon	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	<0.01	0.05	0.05	<0.01	0.06	<0.01	0.05	0.05	<0.01
California halibut	<0.01	<0.01	<0.01	<0.01	<0.01	0.23	<0.01	0.20	0.21	<0.01	0.23	<0.01	0.20	0.21	<0.01
California scorpionfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Channel catfish	1.65	1.38	1.60	1.61	1.35	1.01	<0.01	0.82	0.86	<0.01	2.66	1.38	2.42	2.48	1.35
Crabs (other)	0.09	0.07	0.09	0.09	0.07	7.82	<0.01	6.66	6.97	<0.01	7.91	0.07	6.75	7.06	0.07
Sea Basses	<0.01	<0.01	<0.01	<0.01	<0.01	2.83	<0.01	2.41	2.52	<0.01	2.83	<0.01	2.41	2.53	<0.01
Shrimp (other)	<0.01	<0.01	<0.01	<0.01	<0.01	0.63	<0.01	0.53	0.56	<0.01	0.63	<0.01	0.54	0.57	<0.01
Crappie	0.11	0.09	0.11	0.11	0.09	1.42	<0.01	1.16	1.21	<0.01	1.53	0.09	1.27	1.32	0.09
Cunner	<0.01	<0.01	<0.01	<0.01	<0.01	4.26	<0.01	3.47	3.64	<0.01	4.26	<0.01	3.47	3.64	<0.01

Table C-15: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) Nationally (million A1Es per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality, continued

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
Drums and croakers	0.07	0.05	0.07	0.07	0.05	1.03	<0.01	0.86	0.87	<0.01	1.10	0.05	0.93	0.94	0.05
Dungeness crab	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Flounders	0.01	0.01	0.01	0.01	0.01	0.10	<0.01	0.08	0.09	<0.01	0.11	0.01	0.10	0.10	0.01
Freshwater drum	1.21	1.01	1.17	1.18	0.99	6.36	<0.01	5.20	5.44	<0.01	7.57	1.01	6.37	6.62	0.99
Leatherjacket	0.69	0.53	0.68	0.69	0.52	0.03	<0.01	0.02	0.02	<0.01	0.72	0.53	0.71	0.71	0.52
Mackerels	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Menhadens	4.95	3.79	4.92	4.92	3.76	0.05	<0.01	0.04	0.04	<0.01	5.01	3.79	4.96	4.96	3.76
Muskellunge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fish (other)	2.87	2.20	2.82	2.83	2.19	11.04	<0.01	10.06	10.19	<0.01	13.90	2.20	12.88	13.02	2.19
Northern anchovy	0.34	0.30	0.34	0.34	0.29	0.03	<0.01	0.03	0.03	<0.01	0.38	0.30	0.37	0.37	0.29
Pinfish	0.03	0.02	0.03	0.03	0.02	1.08	<0.01	0.73	0.73	<0.01	1.11	0.02	0.76	0.76	0.02
Pink shrimp	21.44	16.42	21.29	21.31	16.30	13.40	<0.01	9.07	9.09	<0.01	34.84	16.42	30.36	30.40	16.30
Pollock	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Rainbow smelt	0.51	0.44	0.50	0.50	0.43	0.28	<0.01	0.22	0.23	<0.01	0.78	0.44	0.72	0.73	0.43
Red drum	0.09	0.07	0.09	0.09	0.07	0.01	<0.01	<0.01	<0.01	<0.01	0.11	0.07	0.10	0.10	0.07
Red hake	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Rockfishes	0.02	0.01	0.02	0.02	0.01	6.33	<0.01	5.39	5.64	<0.01	6.34	0.01	5.41	5.66	0.01
Salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sauger	0.10	0.08	0.09	0.09	0.08	1.75	<0.01	1.43	1.49	<0.01	1.84	0.08	1.52	1.59	0.08
Sculpins	0.02	0.02	0.02	0.02	0.02	2.39	<0.01	1.96	2.06	<0.01	2.41	0.02	1.98	2.08	0.02
Scup	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sea basses	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Searobin	0.94	0.72	0.93	0.93	0.71	0.38	<0.01	0.26	0.26	<0.01	1.31	0.72	1.19	1.19	0.71
Sheepshead	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	0.02	0.02	<0.01	0.04	<0.01	0.02	0.02	<0.01
Silver hake	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver perch	0.56	0.39	0.52	0.52	0.39	5.11	<0.01	3.46	3.47	<0.01	5.68	0.39	3.98	3.99	0.39
Skates	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table C-15: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) Nationally (million A1Es per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality, continued

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
Smallmouth bass	0.24	0.20	0.23	0.23	0.19	3.70	<0.01	3.03	3.16	<0.01	3.94	0.20	3.26	3.40	0.19
Smelts	4.50	3.90	4.45	4.46	3.87	0.02	<0.01	0.02	0.02	<0.01	4.52	3.90	4.47	4.48	3.87
Spot	3.52	2.66	3.42	3.43	2.66	35.34	<0.01	32.33	32.75	<0.01	38.86	2.66	35.75	36.18	2.66
Spotted seatrout	1.26	0.97	1.26	1.26	0.96	0.15	<0.01	0.10	0.10	<0.01	1.42	0.97	1.36	1.36	0.96
Stone crab	0.19	0.14	0.19	0.19	0.14	0.41	<0.01	0.28	0.28	<0.01	0.60	0.14	0.47	0.47	0.14
Striped bass	0.17	0.14	0.16	0.16	0.14	1.40	<0.01	1.28	1.30	<0.01	1.57	0.14	1.44	1.46	0.14
Striped mullet	0.37	0.28	0.37	0.37	0.28	2.62	<0.01	1.77	1.78	<0.01	2.99	0.28	2.14	2.14	0.28
Sturgeons	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.02	0.02	<0.01	0.03	<0.01	0.02	0.02	<0.01
Summer flounder	0.02	0.02	0.02	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.02	0.02	0.02
Sunfish	19.95	16.69	19.29	19.47	16.29	111.25	<0.01	90.88	95.03	<0.01	131.20	16.69	110.17	114.50	16.29
Surfperches	0.11	0.10	0.11	0.11	0.10	<0.01	<0.01	<0.01	<0.01	<0.01	0.11	0.10	0.11	0.11	0.10
Tautog	<0.01	<0.01	<0.01	<0.01	<0.01	0.11	<0.01	0.09	0.10	<0.01	0.11	<0.01	0.09	0.10	<0.01
Walleye	0.06	0.05	0.05	0.05	0.05	0.68	<0.01	0.56	0.58	<0.01	0.74	0.05	0.61	0.64	0.05
Weakfish	1.44	1.10	1.40	1.41	1.10	2.71	<0.01	2.48	2.51	<0.01	4.14	1.10	3.88	3.92	1.10
White bass	2.40	2.01	2.32	2.34	1.96	2.76	<0.01	2.25	2.35	<0.01	5.16	2.01	4.57	4.70	1.96
White perch	5.24	4.18	5.08	5.12	4.13	24.43	<0.01	22.32	22.62	<0.01	29.67	4.18	27.40	27.74	4.13
Whitefish	0.23	0.20	0.23	0.23	0.20	<0.01	<0.01	<0.01	<0.01	<0.01	0.23	0.20	0.23	0.23	0.20
Windowpane	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.02	0.02	<0.01	0.03	<0.01	0.02	0.02	<0.01
Winter flounder	0.04	0.03	0.04	0.04	0.03	6.46	<0.01	5.28	5.53	<0.01	6.50	0.03	5.32	5.57	0.03
Yellow perch	3.50	2.93	3.39	3.42	2.86	2.50	<0.01	2.05	2.14	<0.01	6.00	2.93	5.43	5.55	2.86
Total (all species)	**747.40**	**614.97**	**722.53**	**728.35**	**602.42**	**1441.52**	**<0.01**	**1259.02**	**1285.20**	**<0.01**	**2188.92**	**614.97**	**1981.55**	**2013.55**	**602.42**

Scenarios: B = Baseline I&E Mortality losses, 1 = Option 1 (I Everywhere), 2 = Option 2 (I Everywhere and E for Facilities > 125 MGD), 3 = Option 3 (I&E Mortality Everywhere), 4 = Option 4 (I for Facilities > 50 MGD)

Table C-16: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) Nationally (million individuals per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
Alewife	72.13	30.59	35.19	35.42	30.04	38,112.03	<0.01	15,219.17	15,449.11	<0.01	38,184.16	30.59	15,254.35	15,484.53	30.04
American plaice	<0.01	<0.01	<0.01	<0.01	<0.01	199.21	<0.01	81.20	85.19	<0.01	199.21	<0.01	81.20	85.19	<0.01
American sand lance	0.16	0.06	0.08	0.08	0.06	1,469.03	<0.01	598.82	628.20	<0.01	1,469.20	0.06	598.90	628.28	0.06
American shad	19.09	7.98	9.23	9.32	7.79	67.08	<0.01	30.72	31.11	<0.01	86.17	7.98	39.94	40.43	7.79
Atlantic cod	<0.01	<0.01	<0.01	<0.01	<0.01	117.38	<0.01	47.85	50.19	<0.01	117.38	<0.01	47.85	50.19	<0.01
Atlantic croaker	17.73	6.79	8.79	8.80	6.74	851.39	<0.01	370.43	374.59	<0.01	869.12	6.79	379.21	383.39	6.74
Atlantic herring	0.04	0.01	0.02	0.02	0.01	87.31	<0.01	35.59	37.34	<0.01	87.34	0.01	35.61	37.35	0.01
Atlantic mackerel	<0.01	<0.01	<0.01	<0.01	<0.01	7,067.69	<0.01	2,880.99	3,022.33	<0.01	7,067.69	<0.01	2,880.99	3,022.33	<0.01
Atlantic menhaden	71.28	27.14	34.72	34.84	27.11	4,486.26	<0.01	1,836.37	1,921.31	<0.01	4,557.54	27.14	1,871.09	1,956.15	27.11
Atlantic silverside	1.66	0.62	0.80	0.81	0.62	206.73	<0.01	89.81	92.38	<0.01	208.39	0.62	90.61	93.19	0.62
Atlantic tomcod	0.14	0.05	0.07	0.07	0.05	6.28	<0.01	2.56	2.68	<0.01	6.42	0.05	2.63	2.75	0.05
Bay anchovy	43.71	15.00	19.79	19.82	14.98	457,647.92	<0.01	170,620.21	172,563.84	<0.01	457,691.63	15.00	170,640.00	172,583.66	14.98
Bigmouth buffalo	0.04	0.02	0.02	0.02	0.02	5.38	<0.01	2.20	2.30	<0.01	5.42	0.02	2.22	2.32	0.02
Black bullhead	0.34	0.14	0.16	0.17	0.14	0.04	<0.01	0.02	0.02	<0.01	0.38	0.14	0.18	0.18	0.14
Black crappie	0.35	0.15	0.17	0.17	0.14	24.81	<0.01	10.14	10.60	<0.01	25.16	0.15	10.30	10.77	0.14
Black drum	0.03	0.01	0.01	0.01	0.01	96,328.24	<0.01	32,580.73	32,660.81	<0.01	96,328.27	0.01	32,580.75	32,660.83	0.01
Blennies	<0.01	<0.01	<0.01	<0.01	<0.01	914.88	<0.01	389.87	407.84	<0.01	914.88	<0.01	389.87	407.84	<0.01
Blue crab	15.03	5.69	7.37	7.38	5.66	3,677.57	<0.01	1,650.35	1,670.46	<0.01	3,692.60	5.69	1,657.73	1,677.85	5.66
Blueback herring	186.97	78.16	90.37	91.24	76.26	1,774.42	<0.01	726.14	759.17	<0.01	1,961.39	78.16	816.51	850.41	76.26
Bluefish	0.03	0.01	0.01	0.01	0.01	0.06	<0.01	0.02	0.02	<0.01	0.09	0.01	0.04	0.04	0.01
Bluegill	35.57	14.88	17.19	17.36	14.52	48.04	<0.01	19.63	20.53	<0.01	83.61	14.88	36.82	37.89	14.52
Bluntnose minnow	0.16	0.07	0.08	0.08	0.07	4,931.58	<0.01	2,014.69	2,107.19	<0.01	4,931.75	0.07	2,014.77	2,107.27	0.07
Brown bullhead	0.06	0.02	0.03	0.03	0.02	0.46	<0.01	0.19	0.20	<0.01	0.52	0.02	0.22	0.23	0.02
Bullheads	0.04	0.02	0.02	0.02	0.02	3.68	<0.01	1.50	1.57	<0.01	3.72	0.02	1.52	1.59	0.02
Burbot	<0.01	<0.01	<0.01	<0.01	<0.01	16.57	<0.01	6.76	7.07	<0.01	16.58	<0.01	6.77	7.07	<0.01
Butterfish	<0.01	<0.01	<0.01	<0.01	<0.01	12.15	<0.01	4.95	5.20	<0.01	12.16	<0.01	4.96	5.20	<0.01
Cabezon	<0.01	<0.01	<0.01	<0.01	<0.01	6.65	<0.01	2.83	2.96	<0.01	6.65	<0.01	2.83	2.96	<0.01
California halibut	<0.01	<0.01	<0.01	<0.01	<0.01	7.71	<0.01	3.29	3.44	<0.01	7.72	<0.01	3.29	3.44	<0.01

Table C-16: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) Nationally (million individuals per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality, continued

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
California scorpionfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Carp	0.41	0.17	0.20	0.20	0.17	7,449.10	<0.01	3,013.42	3,112.06	<0.01	7,449.51	0.17	3,013.62	3,112.26	0.17
Chain pipefish	0.07	0.03	0.04	0.04	0.03	2.13	<0.01	0.72	0.72	<0.01	2.20	0.03	0.75	0.76	0.03
Channel catfish	2.06	0.86	1.00	1.01	0.84	209.96	<0.01	85.78	89.72	<0.01	212.02	0.86	86.77	90.73	0.84
Chinook salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Crabs (other)	0.12	0.05	0.06	0.06	0.05	7,906.88	<0.01	3,363.37	3,506.02	<0.01	7,907.01	0.05	3,363.43	3,506.08	0.05
Crappie	0.60	0.25	0.29	0.29	0.24	68.59	<0.01	28.01	29.29	<0.01	69.19	0.25	28.30	29.58	0.24
Cunner	<0.01	<0.01	<0.01	<0.01	<0.01	29,170.94	<0.01	11,890.91	12,474.26	<0.01	29,170.95	<0.01	11,890.91	12,474.27	<0.01
Darters	1.01	0.42	0.49	0.49	0.41	164.61	<0.01	67.23	70.28	<0.01	165.62	0.42	67.71	70.77	0.41
Delta smelt	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Drums and croakers	0.63	0.25	0.30	0.30	0.24	3,292.06	<0.01	1,381.20	1,400.82	<0.01	3,292.68	0.25	1,381.50	1,401.11	0.24
Dungeness crab	<0.01	<0.01	<0.01	<0.01	<0.01	0.09	<0.01	0.04	0.04	<0.01	0.09	<0.01	0.04	0.04	<0.01
Emerald shiner	4.39	1.84	2.13	2.14	1.80	772.49	<0.01	315.16	329.07	<0.01	776.88	1.84	317.29	331.22	1.80
Fish (other)	98.00	40.36	47.39	47.80	39.49	123,797.72	<0.01	49,732.40	51,319.67	<0.01	123,895.72	40.36	49,779.79	51,367.47	39.49
Flounders	0.01	<0.01	<0.01	<0.01	<0.01	319.23	<0.01	136.04	142.31	<0.01	319.24	<0.01	136.04	142.31	<0.01
Fourbeard rockling	<0.01	<0.01	<0.01	<0.01	<0.01	464.23	<0.01	189.23	198.52	<0.01	464.23	<0.01	189.23	198.52	<0.01
Freshwater drum	4.65	1.94	2.25	2.27	1.90	3,231.60	<0.01	1,318.23	1,376.14	<0.01	3,236.24	1.94	1,320.48	1,378.40	1.90
Gizzard shad	326.39	136.74	157.91	159.39	133.51	22,916.70	<0.01	9,327.13	9,708.69	<0.01	23,243.09	136.74	9,485.04	9,868.08	133.51
Gobies	0.14	0.05	0.07	0.07	0.05	8,788.33	<0.01	3,416.01	3,454.69	<0.01	8,788.47	0.05	3,416.08	3,454.76	0.05
Golden redhorse	0.07	0.03	0.03	0.03	0.03	2.86	<0.01	1.17	1.22	<0.01	2.92	0.03	1.20	1.25	0.03
Grubby	0.02	<0.01	0.01	0.01	<0.01	431.10	<0.01	175.73	184.35	<0.01	431.12	<0.01	175.74	184.36	<0.01
Gulf killifish	0.04	0.01	0.02	0.02	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.01	0.02	0.02	0.01
Herrings	0.07	0.03	0.03	0.03	0.03	37.37	<0.01	15.63	16.21	<0.01	37.44	0.03	15.66	16.24	0.03
Hogchoker	0.74	0.28	0.36	0.36	0.28	26,718.51	<0.01	12,183.16	12,346.27	<0.01	26,719.25	0.28	12,183.52	12,346.63	0.28
Leatherjacket	0.95	0.36	0.47	0.47	0.36	794.02	<0.01	268.56	269.22	<0.01	794.97	0.36	269.03	269.69	0.36
Logperch	1.22	0.51	0.59	0.60	0.50	42.56	<0.01	17.29	17.96	<0.01	43.77	0.51	17.88	18.56	0.50
Longfin smelt	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lumpfish	<0.01	<0.01	<0.01	<0.01	<0.01	44.89	<0.01	18.30	19.20	<0.01	44.89	<0.01	18.30	19.20	<0.01
Mackerels	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Menhadens	16.06	6.15	7.98	7.98	6.10	269.24	<0.01	91.08	91.30	<0.01	285.30	6.15	99.05	99.28	6.10
Muskellunge	0.02	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	0.01	0.01	<0.01
Northern anchovy	0.86	0.38	0.42	0.43	0.37	826.63	<0.01	352.26	368.50	<0.01	827.49	0.38	352.68	368.93	0.37

Table C-16: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) Nationally (million individuals per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality, continued

	Impingement					Entrainment					I&E				
Species	**B**	**1**	**2**	**3**	**4**	**B**	**1**	**2**	**3**	**4**	**B**	**1**	**2**	**3**	**4**
Northern pipefish	0.04	0.01	0.02	0.02	0.01	11.79	<0.01	5.34	5.43	<0.01	11.83	0.01	5.36	5.45	0.01
Pacific herring	<0.01	<0.01	<0.01	<0.01	<0.01	36.16	<0.01	15.41	16.12	<0.01	36.17	<0.01	15.41	16.12	<0.01
Pinfish	0.12	0.05	0.06	0.06	0.04	179.13	<0.01	66.21	66.35	<0.01	179.25	0.05	66.27	66.40	0.04
Pink shrimp	43.73	16.74	21.71	21.73	16.62	126.32	<0.01	42.73	42.83	<0.01	170.05	16.74	64.44	64.56	16.62
Pollock	<0.01	<0.01	<0.01	<0.01	<0.01	3.46	<0.01	1.41	1.48	<0.01	3.47	<0.01	1.41	1.48	<0.01
Radiated shanny	<0.01	<0.01	<0.01	<0.01	<0.01	110.36	<0.01	44.99	47.19	<0.01	110.36	<0.01	44.99	47.19	<0.01
Rainbow smelt	0.76	0.32	0.37	0.37	0.32	151.21	<0.01	61.07	62.99	<0.01	151.97	0.32	61.45	63.36	0.32
Red drum	0.18	0.07	0.09	0.09	0.07	1.10	<0.01	0.37	0.37	<0.01	1.27	0.07	0.46	0.46	0.07
Red hake	0.08	0.03	0.04	0.04	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	0.08	0.03	0.04	0.04	0.03
River carpsucker	0.03	0.01	0.02	0.02	0.01	5.15	<0.01	2.10	2.20	<0.01	5.18	0.01	2.12	2.22	0.01
Rock gunnel	<0.01	<0.01	<0.01	<0.01	<0.01	395.87	<0.01	161.37	169.29	<0.01	395.88	<0.01	161.37	169.29	<0.01
Rockfishes	0.03	0.01	0.01	0.01	0.01	63.96	<0.01	27.26	28.51	<0.01	63.99	0.01	27.27	28.53	0.01
Sacramento splittail	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Salmon	<0.01	<0.01	<0.01	<0.01	<0.01	6.16	<0.01	2.46	2.50	<0.01	6.16	<0.01	2.46	2.50	<0.01
Sauger	0.23	0.09	0.11	0.11	0.09	314.24	<0.01	128.39	134.29	<0.01	314.47	0.09	128.49	134.40	0.09
Scaled sardine	0.35	0.13	0.17	0.17	0.13	2,962.36	<0.01	1,001.95	1,004.41	<0.01	2,962.72	0.13	1,002.12	1,004.59	0.13
Sculpins	0.02	0.01	0.01	0.01	<0.01	270.10	<0.01	110.96	116.30	<0.01	270.13	0.01	110.97	116.31	<0.01
Scup	<0.01	<0.01	<0.01	<0.01	<0.01	16.64	<0.01	6.78	7.12	<0.01	16.65	<0.01	6.79	7.12	<0.01
Sea Basses	<0.01	<0.01	<0.01	<0.01	<0.01	13.24	<0.01	5.64	5.90	<0.01	13.24	<0.01	5.64	5.90	<0.01
Seaboard goby	0.02	<0.01	<0.01	<0.01	<0.01	16,071.16	<0.01	7,239.43	7,367.13	<0.01	16,071.18	<0.01	7,239.44	7,367.14	<0.01
Searobin	1.18	0.45	0.58	0.59	0.45	80.30	<0.01	27.96	28.24	<0.01	81.48	0.45	28.54	28.83	0.45
Sheepshead	<0.01	<0.01	<0.01	<0.01	<0.01	382.88	<0.01	129.50	129.82	<0.01	382.88	<0.01	129.50	129.82	<0.01
Shiners	3.98	1.67	1.93	1.95	1.64	429.73	<0.01	174.39	180.77	<0.01	433.71	1.67	176.32	182.71	1.64
Shrimp (other)	8.93	2.82	3.81	3.81	2.82	1,469.73	<0.01	616.82	625.97	<0.01	1,478.66	2.82	620.63	629.78	2.82
Silver hake	0.05	0.02	0.03	0.03	0.02	568.71	<0.01	231.82	243.20	<0.01	568.76	0.02	231.85	243.22	0.02
Silver perch	0.91	0.32	0.42	0.42	0.32	88,985.72	<0.01	30,097.30	30,171.28	<0.01	88,986.63	0.32	30,097.72	30,171.70	0.32
Silversides	0.16	0.07	0.08	0.08	0.07	171.19	<0.01	72.23	75.51	<0.01	171.35	0.07	72.30	75.59	0.07
Skates	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Skipjack herring	1.52	0.64	0.74	0.74	0.62	0.54	<0.01	0.22	0.23	<0.01	2.06	0.64	0.96	0.97	0.62
Smallmouth bass	0.14	0.06	0.07	0.07	0.06	54.51	<0.01	22.27	23.30	<0.01	54.66	0.06	22.34	23.37	0.06

Table C-16: Baseline I&E Mortality Losses at All In-scope Facilities (Manufacturing and Generating) Nationally (million individuals per year), and I&E Mortality Reductions for Option Scenarios Estimated for All Sources of Mortality, continued

Species	Impingement					Entrainment					I&E				
	B	1	2	3	4	B	1	2	3	4	B	1	2	3	4
Smelts	4.07	1.76	2.01	2.02	1.75	154.31	<0.01	61.72	62.70	<0.01	158.39	1.76	63.73	64.72	1.75
Spot	11.27	4.25	5.47	5.48	4.25	2,420.22	<0.01	1,016.05	1,018.92	<0.01	2,431.49	4.25	1,021.52	1,024.41	4.25
Spotted seatrout	1.21	0.46	0.60	0.60	0.46	5,373.31	<0.01	1,820.18	1,824.64	<0.01	5,374.51	0.46	1,820.77	1,825.24	0.46
Spotted sucker	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Stone crab	0.27	0.11	0.14	0.14	0.10	28,711.01	<0.01	9,710.82	9,734.68	<0.01	28,711.29	0.11	9,710.95	9,734.82	0.10
Striped bass	1.68	0.70	0.81	0.82	0.68	1,071.31	<0.01	490.20	496.62	<0.01	1,072.98	0.70	491.01	497.44	0.68
Striped killifish	0.32	0.12	0.16	0.16	0.12	0.06	<0.01	0.03	0.03	<0.01	0.38	0.12	0.18	0.18	0.12
Striped mullet	0.45	0.17	0.23	0.23	0.17	15.17	<0.01	5.13	5.14	<0.01	15.62	0.17	5.36	5.37	0.17
Sturgeons	<0.01	<0.01	<0.01	<0.01	<0.01	1.46	<0.01	0.59	0.62	<0.01	1.46	<0.01	0.60	0.62	<0.01
Suckers	0.17	0.07	0.08	0.08	0.07	4,344.79	<0.01	1,775.05	1,856.67	<0.01	4,344.96	0.07	1,775.13	1,856.75	0.07
Summer flounder	0.08	0.03	0.04	0.04	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	0.08	0.03	0.04	0.04	0.03
Sunfish	6.40	2.67	3.09	3.12	2.61	655.10	<0.01	267.58	279.80	<0.01	661.50	2.67	270.67	282.92	2.61
Surfperches	0.13	0.06	0.06	0.06	0.06	<0.01	<0.01	<0.01	<0.01	<0.01	0.13	0.06	0.06	0.06	0.06
Tautog	<0.01	<0.01	<0.01	<0.01	<0.01	29,299.93	<0.01	11,943.48	12,529.42	<0.01	29,299.94	<0.01	11,943.49	12,529.42	<0.01
Threespine stickleback	0.11	0.05	0.06	0.06	0.05	0.78	<0.01	0.31	0.32	<0.01	0.89	0.05	0.37	0.37	0.05
Tidewater silverside	0.30	0.11	0.15	0.15	0.11	34.36	<0.01	11.62	11.65	<0.01	34.66	0.11	11.77	11.80	0.11
Walleye	0.15	0.06	0.07	0.08	0.06	169.80	<0.01	69.37	72.56	<0.01	169.96	0.06	69.45	72.64	0.06
Weakfish	3.35	1.28	1.63	1.64	1.28	929.71	<0.01	404.38	414.14	<0.01	933.06	1.28	406.02	415.78	1.28
White bass	2.68	1.12	1.30	1.31	1.10	1,106.14	<0.01	451.56	471.86	<0.01	1,108.82	1.12	452.86	473.17	1.10
White perch	6.70	2.70	3.25	3.27	2.66	2,996.05	<0.01	1,339.29	1,365.37	<0.01	3,002.75	2.70	1,342.54	1,368.65	2.66
Whitefish	0.10	0.04	0.05	0.05	0.04	0.92	<0.01	0.37	0.39	<0.01	1.02	0.04	0.42	0.44	0.04
Windowpane	0.02	<0.01	0.01	0.01	<0.01	2,066.54	<0.01	842.38	883.71	<0.01	2,066.57	<0.01	842.39	883.72	<0.01
Winter flounder	0.15	0.06	0.08	0.08	0.06	6,780.09	<0.01	2,768.38	2,902.67	<0.01	6,780.24	0.06	2,768.46	2,902.75	0.06
Yellow perch	9.59	4.02	4.64	4.68	3.93	1,130.30	<0.01	461.51	482.36	<0.01	1,139.89	4.02	466.15	487.05	3.93
Total (all species)	**1,034.92**	**421.62**	**500.44**	**504.14**	**413.70**	**1,055,936.41**	**<0.01**	**400,351.83**	**407,417.58**	**<0.01**	**1,056,971.34**	**421.62**	**400,852.27**	**407,921.72**	**413.70**

Scenarios: B = Baseline I&E Mortality losses. 1 = Option 1 (I Everywhere), 2 = Option 2 (I Everywhere and E for Facilities > 125 MGD), 3 = Option 3 (I&E Mortality Everywhere), 4 = Option 4 (I for Facilities > 50 MGD). Values for all options reflect reductions in losses.

Appendix D: Discounting Benefits

D.1 Introduction

Discounting refers to the economic conversion of future benefits and costs to their present values, accounting for the fact that individuals tend to value future outcomes less than comparable near-term outcomes. Annualization refers to the conversion of a series of annual costs or benefits of differing amounts to an equivalent annual series of constant costs or benefits. Discounting and annualization are important because these techniques allow for the comparison of benefits and/or costs that occur in different time periods.

For the benefits analysis of the regulatory options for the proposed Section 316(b) Rule, EPA's discounting and annualization methodology included three steps. First, EPA developed a time profile of benefits to show when benefits occur. Second, the Agency calculated the total discounted value of the benefits as of the year 2012. Finally, EPA annualized the benefits of the regulatory options over a 50-year time span. The following sections explain these steps in detail.

D.2 Timing of Benefits

In order to calculate the annualized value of the welfare gain from the regulatory analysis options considered for the proposed Section 316(b) Rule, EPA developed a time profile of total benefits from all facilities that reflects when benefits from each facility will be realized. EPA first calculated the undiscounted welfare gain from the expected annual regional reductions in impingement and entrainment mortality (I&E mortality) under each option, based on the assumptions that all facilities in each region would achieved compliance and that benefits are realized immediately following compliance. Then, since there are regulatory and biological time lags between the potential promulgation of each respective regulatory option and the realization of benefits, EPA created a time profile of benefits that takes into account the fact that benefits do not begin immediately.

Regulatory-related time lags occur because facilities will not always achieve compliance in the same year that costs are incurred. Facilities will face regulatory requirements once the rule takes effect, but it will take time to make the required changes. For this analysis, EPA assumed that facilities, in the aggregate, would achieve compliance on a uniform schedule over the 5-year periods 2013-2017, 2018-2022, or 2023-2027 with all activities associated with the achievement of compliance estimated to occur uniformly over this period. Facilities required to comply with impingement mortality limits are assumed to achieve compliance on a uniform schedule over the 5-year period 2013-2017. Non-nuclear electric generating facilities required to reduce intake flow commensurate with closed cycle cooling are assumed to achieve compliance on a uniform schedule over the 5-year period 2018-2022. Nuclear electric generating facilities and manufacturing facilities required to reduce intake flow commensurate with closed cycle cooling are assumed to achieve compliance on a uniform schedule over the 5-year period 2023-2027. Following the achievement of compliance, all operational effects of compliance (i.e., reduction in I&E mortality losses) are also assumed to occur as though they originated from a compliance schedule that is uniformly spread over the 5-year window. Compliance is assumed to continue until the year 2056 for all facilities. See Chapter11 of the EA report for more detail.

The biological time lags that affect the timing of commercial and recreational fishing benefits (including recreational use of threatened and endangered species) occur because most fish that would be spared from I&E mortality would be in larval or juvenile stages. Since these fish may require several years to grow and mature before commercial and recreational anglers can harvest them, there would be a lag between installation of technologies to reduce I&E mortality and realization of commercial and recreational angling benefits. For example, a larval fish spared from entrainment (in effect, at age zero) may be caught by a recreational angler at age three, meaning that a three-year time lag arises between the installation of technologies to reduce I&E mortality and the realization of the estimated recreational benefit. Likewise, if a one-year-old fish is spared from impingement and is then harvested by a commercial fisherman at age two, there is a one-year lag between the installation of technologies to reduce I&E mortality and the subsequent commercial fishery benefit. In general, fish that tend to be harvested at young ages will have relatively short time lags between implementation of technologies to reduce I&E mortality and the subsequent timing of changes in catch. In contrast, long-lived fish that tend to be caught at relatively older ages would tend to have longer time lags (and, hence, the effects of discounting would be larger, resulting in lower present values).

In order to model the biological lags between installation of technologies to reduce I&E mortality and realization of commercial and recreational benefits, EPA collected species-specific information on ages of fish at harvest to estimate the average time required for a fish spared from I&E mortality to reach a harvestable age. The estimated time lags vary, depending on the life history of each fish species affected. EPA used this information, along with information about the estimated age and species composition of I&E mortality losses in each study region, to develop a benefits recognition schedule for facilities in each region.[58]

Following achievement of compliance, commercial and recreational fishing benefits from facilities in most regions (the California, North Atlantic, Mid-Atlantic, and South Atlantic regions) are assumed to increase over a seven-year period to a long-term, steady-state average, equal to the approximated per-facility benefit value discussed above, according to a numerical profile of <0.0, 0.1, 0.2, 0.8, 0.9, 0.95, 1.0>. This profile indicates the fraction of the steady-state benefit value (i.e., the percentage of commercial and recreational fish spared from I&E mortality that reach a harvestable age) that is realized in each of the first seven years following the achievement of compliance at a facility.

For regions with a relatively high contribution of impingement to total I&E mortality (the Inland, Great Lakes, and Gulf of Mexico regions), EPA used an adjusted profile of <0.1, 0.2, 0.8, 0.9, 0.95, 1.0> for commercial and recreational fishing benefits. This adjusted profile reflects the fact that impinged fish are usually larger and older than entrained fish and thus benefits will be realized sooner in these regions. These profile values are approximations based on a review of the age-specific fishing mortality rates that were used in the I&E mortality analysis and best professional judgment.

In all regions, this fraction remains 1.0 until the final year of compliance, 2056. The commercial and recreational fishing benefits profile declines at the end of the compliance period in the same fashion that it increases at the beginning of compliance. . Specifically, at the end of the compliance period, benefit values follow a profile of <1.0, 0.9, 0.8, 0.2, 0.1, 0.05, 0.0> with the last benefits occurring in 2061. Therefore, the analysis of benefits encompasses a 50-year period from rule promulgation and first

58 The benefits profile aggregated across all facilities in a region or nationwide was calculated using facility-level sample weights. These facility-level sample weights were designed so that the weighted actual regional intake flow for the sample facilities is the same as the estimated actual regional intake flow for the entire universe of facilities. These sample weights and their derivation are described in more detail in Appendix A.

occurrence of compliance-related costs in 2012 until the final benefits in 2061. The number of years when benefits do not equal zero varies among the in-scope facilities depending on the year that it initially achieves compliance.

For nonuse benefits and the HEA analysis, EPA assumes that there is no initial biological lag at the start of the compliance period because benefits are not based on the harvest of fish spared from I&E mortality. Benefits are assumed to begin accruing immediately when a facility comes into compliance and to continue in full (i.e., fraction of 1.0) until the year 2056.

The nonuse and HEA analysis include a linear decline in benefits starting at the end of the compliance period following a profile of <1.0, 0.83, 0.67, 0.50, 0.33, 0.17, 0.0> with the last benefits occurring in 2061. This profile reflects the fact that increases in fish abundance and biological production resulting from reductions in I&E mortality will return to baseline over time. The duration of the profile is consistent with analyses for commercial and recreational fishing benefits and its trajectory is based on best professional judgment.

D.3 Discounting and Annualization

Using the time profile of benefits discussed above, EPA discounted the total benefits generated in each year of the analysis to 2012 using the following formula:

$$\text{Present Value} = \sum_t \frac{\text{Benefits}_t}{(1+r)^{t-2012}} \qquad \text{Equation D-1}$$

where:

Benefits_t	=	benefits in year t
r	=	discount rate (3 percent and 7 percent)
t	=	year in which benefits are incurred

After calculating the present value (PV) of these benefit streams, EPA calculated their constant annual equivalent value (annualized value) using the annualization formula presented below, again using two discount rates, 3 percent and 7 percent.[59] Although the analysis period extends further, EPA annualized benefits over the assumed period of compliance for in-scope facilities. This same annualization concept and period of annualization were also followed in the analysis of costs, although for costs the time horizon of analysis for calculating the present value is shorter than for benefits. Using the same annualization period for both benefits and social costs allows comparison of constant annual equivalent values of benefits and costs that have been calculated on a mathematically consistent basis. The annualization formula is as follows:

$$\text{Annualized Benefit} = \text{PV of Benefit} * \left(\frac{r*(1+r)^n}{(1+r)^n - 1}\right) \qquad \text{Equation D-2}$$

where:

r	=	discount rate (3 percent and 7 percent)
n	=	annualization period, 50 years for the benefits analysis

59 The three percent rate represents an estimate of the social rate of time preference.

Table D-1 presents a summary of the time profile of benefits discounted at the 3 percent and 7 percent rates for each of the regulatory options on the national scale. The table also presents the total value and annualized value that are equivalent to this stream of benefits.

Table D-1: Time Profile of National Mean Total Benefits at In-scope Facilities by Regulatory Option (2009$, thousands)

Year	Option 1: I Everywhere		Option 2: I Everywhere and E for Facilities with DIF > 125 MGD		Option 3: I&E Mortality Everywhere		Option 4: I for Facilities with DIF > 50 MGD	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
2010	0	0	0	0	0	0	$0	$0
2011	0	0	0	0	0	0	$0	$0
2012	$0	$0	$0	$0	$0	$0	$0	$0
2013	$470	$448	$32	$30	$7	$7	$463	$441
2014	$1,309	$1,205	$85	$78	$20	$19	$1,288	$1,186
2015	$4,165	$3,705	$264	$235	$72	$64	$4,091	$3,638
2016	$7,461	$6,393	$458	$392	$126	$109	$7,329	$6,280
2017	$10,765	$8,882	$652	$538	$181	$150	$10,576	$8,726
2018	$13,640	$10,838	$14,443	$11,102	$14,415	$11,064	$13,400	$10,647
2019	$16,019	$12,255	$28,190	$20,863	$28,616	$21,160	$15,737	$12,040
2020	$16,464	$12,126	$44,411	$31,724	$45,435	$32,437	$16,179	$11,915
2021	$16,347	$11,590	$61,484	$42,366	$63,150	$43,496	$16,064	$11,389
2022	$16,047	$10,952	$77,979	$51,791	$80,270	$53,294	$15,769	$10,762
2023	$15,598	$10,248	$86,028	$55,095	$88,729	$56,808	$15,329	$10,070
2024	$15,144	$9,577	$93,426	$57,672	$96,529	$59,571	$14,882	$9,412
2025	$14,703	$8,951	$98,547	$58,596	$102,101	$60,695	$14,449	$8,796
2026	$14,274	$8,365	$103,581	$59,322	$107,577	$61,599	$14,028	$8,220
2027	$13,859	$7,818	$108,187	$59,674	$112,604	$62,100	$13,619	$7,683
2028	$13,455	$7,306	$108,905	$57,873	$113,471	$60,292	$13,223	$7,180
2029	$13,063	$6,828	$109,142	$55,871	$113,816	$58,257	$12,837	$6,710
2030	$12,683	$6,382	$108,273	$53,379	$112,912	$55,661	$12,464	$6,271
2031	$12,313	$5,964	$105,740	$50,188	$110,279	$52,337	$12,101	$5,861
2032	$11,955	$5,574	$102,961	$47,045	$107,385	$49,062	$11,748	$5,478
2033	$11,606	$5,209	$100,080	$44,021	$104,379	$45,906	$11,406	$5,119
2034	$11,268	$4,869	$97,165	$41,141	$101,339	$42,903	$11,074	$4,784
2035	$10,940	$4,550	$94,335	$38,449	$98,387	$40,096	$10,751	$4,471
2036	$10,622	$4,252	$91,588	$35,934	$95,522	$37,473	$10,438	$4,179
2037	$10,312	$3,974	$88,920	$33,583	$92,739	$35,022	$10,134	$3,905
2038	$10,012	$3,714	$86,330	$31,386	$90,038	$32,731	$9,839	$3,650
2039	$9,720	$3,471	$83,816	$29,333	$87,416	$30,589	$9,552	$3,411
2040	$9,437	$3,244	$81,374	$27,414	$84,870	$28,588	$9,274	$3,188
2041	$9,162	$3,032	$79,004	$25,620	$82,398	$26,718	$9,004	$2,979
2042	$8,895	$2,834	$76,703	$23,944	$79,998	$24,970	$8,742	$2,785
2043	$8,636	$2,648	$74,469	$22,378	$77,668	$23,337	$8,487	$2,602
2044	$8,385	$2,475	$72,300	$20,914	$75,406	$21,810	$8,240	$2,432
2045	$8,141	$2,313	$70,194	$19,546	$73,209	$20,383	$8,000	$2,273
2046	$7,903	$2,162	$68,150	$18,267	$71,077	$19,050	$7,767	$2,124
2047	$7,673	$2,020	$66,165	$17,072	$69,007	$17,803	$7,541	$1,985
2048	$7,450	$1,888	$64,238	$15,955	$66,997	$16,639	$7,321	$1,855
2049	$7,233	$1,765	$62,367	$14,911	$65,046	$15,550	$7,108	$1,734
2050	$7,022	$1,649	$60,550	$13,936	$63,151	$14,533	$6,901	$1,621

Table D-1: Time Profile of National Mean Total Benefits at In-scope Facilities by Regulatory Option (2009$, thousands)

Year	Option 1: I Everywhere		Option 2: I Everywhere and E for Facilities with DIF > 125 MGD		Option 3: I&E Mortality Everywhere		Option 4: I for Facilities with DIF > 50 MGD	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
2051	$6,818	$1,541	$58,787	$13,024	$61,312	$13,582	$6,700	$1,515
2052	$6,619	$1,440	$57,074	$12,172	$59,526	$12,694	$6,505	$1,416
2053	$6,426	$1,346	$55,412	$11,376	$57,792	$11,863	$6,315	$1,323
2054	$6,239	$1,258	$53,798	$10,632	$56,109	$11,087	$6,131	$1,236
2055	$6,057	$1,176	$52,231	$9,936	$54,475	$10,362	$5,953	$1,155
2056	$5,881	$1,099	$50,710	$9,286	$52,888	$9,684	$5,779	$1,080
2057	$5,128	$922	$42,374	$7,475	$44,184	$7,794	$5,039	$906
2058	$4,415	$765	$34,749	$5,906	$36,224	$6,156	$4,339	$751
2059	$1,120	$186	$17,101	$2,772	$17,875	$2,897	$1,101	$183
2060	$555	$89	$10,326	$1,608	$10,799	$1,682	$546	$87
2061	$270	$42	$5,135	$770	$5,371	$805	$266	$41
2062	$0	$0	$0	$0	$0	$0	$0	$0
2063	0	0	0	0	0	0	$0	$0
2064	0	0	0	0	0	0	$0	$0
2065	0	0	0	0	0	0	$0	$0
Total Present Value[a]	$453,679	$221,341	$3,108,232	$1,272,593	$3,232,893	$1,320,887	$445,825	$217,499
Annualized Value[b]	$17,632	$16,038	$120,794	$92,200	$125,649	$95,711	$17,327	$15,760

a The total present value is equal to the sum of the values of the benefits realized in all years of the analysis, discounted to 2012.
b The annualized value represents the total present value of the benefits of the regulation, distributed over a 50-year period.
Source: U.S. EPA analysis for this report.

Appendix E: List of T&E Species Overlapping CWIS

Table E-1: List of T&E Species Overlapping One or More In-Scope 316(b) Cooling Water Intake Structure

Latin Name	Common Name
Acipenser brevirostrum	Shortnose Sturgeon
Acipenser medirostris	Green Sturgeon
Acipenser oxyrinchus desotoi	Gulf Sturgeon
Acipenser oxyrinchus oxyrinchus	Atlantic Sturgeon
Acropora cervicornis	Staghorn Coral
Acropora palmata	Elkhorn Coral
Alasmidonta heterodon	Dwarf Wedgemussel
Amblyopsis rosae	Ozark Cavefish
Arkansia wheeleri	Ouachita Rock Pocketbook
Caretta caretta	Loggerhead Sea Turtle
Chelonia mydas	Green Sea Turtle
Conradilla caelata	Birdwing Pearlymussel
Cottus paulus (=pygmaeus)	Pygmy Sculpin
Cyprinella caerulea	Blue Shiner
Cyprogenia stegaria	Fanshell
Dermochelys coriacea	Leatherback Sea Turtle
Dromus dromas	Dromedary Pearlymussel
Elliptio steinstansana	Tar River Spinymussel
Epioblasma brevidens	Cumberlandian Combshell
Epioblasma florentina florentina	Yellow (Pearlymussel) Blossom
Epioblasma florentina walkeri (=E. walkeri)	Tan Riffleshell
Epioblasma obliquata obliquata	Catspaw (Purple Cat's Paw Pearlymussel)
Epioblasma obliquata perobliqua	White (Pearlymussel) Catspaw
Epioblasma penita	Southern Combshell
Epioblasma torulosa gubernaculum	Green (Pearlymussel) Blossom
Epioblasma torulosa rangiana	Northern Riffleshell
Epioblasma torulosa torulosa	Tubercled (Pearlymussel) Blossom
Epioblasma turgidula	Turgid (Pearlymussel) Blossom
Eretmochelys imbricata	Hawksbill Sea Turtle
Etheostoma etowahae	Etowah Darter
Etheostoma percnurum	Duskytail Darter
Etheostoma scotti	Cherokee Darter
Etheostoma wapiti	Boulder Darter
Fusconaia cor	Shiny Pigtoe
Fusconaia cuneolus	Finerayed Pigtoe
Gasterosteus aculeatus williamsoni	Unarmored Threespine Stickleback
Gila bicolor mohavensis	Mohave Tui Chub
Hemistena lata	Cracking Pearlymussel
Hypomesus transpacificus	Delta Smelt
Lampsilis abrupta	Pink (Pearlymussel) Mucket
Lampsilis higginsii	Higgins Eye (Pearlymussel)
Lampsilis powellii	Arkansas Fatmucket
Lampsilis virescens	Alabama Lampmussel
Lepidochelys kempii	Kemp's Ridley Sea Turtle

Table E-1: List of T&E Species Overlapping One or More In-Scope 316(b) Cooling Water Intake Structure

Latin Name	Common Name
Lepidochelys olivacea	Olive Ridley Sea Turtle
Leptodea leptodon	Scaleshell Mussel
Margaritifera hembeli	Louisiana Pearlshell
Microphis brachyurus lineatus	Opossum Pipefish
Notropis albizonatus	Palezone Shiner
Notropis Topeka	Topeka Shiner
Noturus placidus	Neosho Madtom
Noturus stanauli	Pygmy Madtom
Noturus trautmani	Scioto Madtom
Obovaria retusa	Ring Pink (Mussel)
Oncorhynchus clarkii stomias	Greenback Cutthroat
Oncorhynchus keta	Chum Salmon
Oncorhynchus kisutch	Coho Salmon
Oncorhynchus mykiss	Steelhead Trout
Oncorhynchus tshawytscha	Chinook Salmon
Oregonichthys crameri	Oregon Chub
Pegias fabula	Littlewing Pearlymussel
Percina rex	Roanoke Logperch
Percina tanasi	Snail Darter
Phoxinus cumberlandensis	Blackside Dace
Plethobasus cicatricosus	White (Pearlymussel) Wartyback
Plethobasus cooperianus	Orangefoot (Pearlymussel) Pimpleback
Pleurobema clava	Clubshell
Pleurobema collina	James Spinymussel
Pleurobema marshalli	Flat Pigtoe
Pleurobema plenum	Rough Pigtoe
Pleurobema taitianum	Heavy Pigtoe
Potamilus capax	Fat Pocketbook
Potamilus inflatus	Alabama (=Inflated) Heelsplitter
Pristis pectinata	Smalltooth Sawfish
Ptychocheilus lucius	Colorado Pikeminnow (=Squawfish)
Quadrula fragosa	Winged Mapleleaf
Quadrula intermedia	Cumberland (Pearlymussel) Monkeyface
Quadrula sparsa	Appalachian (Pearlymussel) Monkeyface
Quadrula stapes	Stirrupshell
Rivulus marmoratus	Mangrove Rivulus
Salmo salar	Atlantic Salmon
Salvelinus confluentus	Bull Trout
Scaphirhynchus albus	Pallid Sturgeon
Scaphirhynchus suttkusi	Alabama Sturgeon
Speoplatyrhinus poulsoni	Alabama Cavefish
Toxolasma cylindrellus	Pale (Pearlymussel) Lilliput
Villosa perpurpurea	Purple Bean
Villosa trabalis	Cumberland (Pearlymussel) Bean
Xyrauchen texanus	Razorback Sucker

Appendix F: Detailed Methodologies of CWIS, and Estimated Benefits of Regulation on, Threatened and Endangered Species

F.1 I&E Mortality of Sea Turtles

Six species of sea turtles are found in U.S. waters: Green, Hawksbill, Kemp's Ridley, Leatherback, Loggerhead, and Olive Ridley sea turtles. All have extensive ranges, migrate long distances during their lifetime, and are listed as either threatened or endangered (T&E) under the Endangered Species Act (ESA). Because of these large ranges, there is substantial overlap between sea turtle habitat and cooling water intake structures (CWIS) for in-phase power generating and manufacturing facilities. Moreover, because individuals of all ages and sizes are susceptible to impingement and entrainment (Norem 2005), there are more than 730 locations of potential species x CWIS interactions that may result in the injury or death of these T&E species.

Power plants are known to entrain and impinge all species of sea turtles, with individual incidences of mortality reported from California, Texas, Florida, South Carolina, North Carolina and New Jersey (Plotkin 1995). Although the cumulative impact of this mortality is unclear, it is believed to be relatively small considered to fishing mortality. Although quantitative reports are available from a few power stations (Table F-1), high-quality data is available from only one source, the St. Lucie Nuclear Power Plant, at Hutchinson Island, FL, where annual capture rates range from 350-1000 turtles. Although estimated mortality rates due to entrainment are < 3%, approximately 85% of entrained organisms show evidence of injury as a result of entrainment (Norem 2005). As such, true mortality rates from CWIS may be higher than reported, particularly for individuals who are recaptured repeatedly (37% of Green and 13% of Loggerhead sea turtles entrained between May and December 2000 were recaptured individuals) (Norem 2005).

In addition to research sponsored by the National Science Foundation, federal and state governmental spending on sea turtles under the ESA totaled $33.8 million in FY2008 (USFWS 2009). Moreover, the number of volunteer organizations dedicated to sea turtle recovery (Table F-2) provides further evidence of the high non-use values placed upon the survival of these animals by the public.

Table F-1: Reported Values of Sea Turtle Entrainment

Facility	Species	Takes		Dates	Takes / yr		Source
		Non-lethal	Lethal		Non-lethal	Lethal	
Crystal River, FL	Kemp's Ridley, Loggerhead	40	5	1998	40	5	TEWG (2000)
Brunswick, NC	Loggerhead, Kemp's Ridley, Green	50	11	2000	50	11	NMFS (2001)
Oyster Creek, NJ, Salem, NJ, Hope NJ	Loggerhead	40	8	1999	40	8	NMFS (2001)
	Kemp's Ridley	7	3	1999	7	3	
	Green	8	2	1999	8	2	
Salem, NJ	Loggerhead, Kemp's Ridley, Green	23	2	1991	23	2	Eggers (2001)
Salem, NJ	Loggerhead	18	8	1980-1988	2.25	1	Eggers (1989)
Salem, NJ	Kemp's Ridley	6	6	1980-1988	0.75	0.75	
St. Lucie, FL	Loggerhead	6313	169	1976-2005	225.5	6	NMFS (2009)
San Diego, Edison	Olive Ridley	Qualitative Reports Only					(NMFS and USFWS 1998b)
San Diego, Encina, Edison	Green						(NMFS and USFWS 1998a)
St. Lucie, FL	Leatherback	20		1976-1998	0.95		Bresette et al (1998)
St. Lucie, FL	Hawksbill	19		1976-1998	0.90		Bresette et al (1998)
St. Lucie, FL	Green	2297		1976-1998	109.38		Ernest et al (1988)
St. Lucie, FL	Kemp's Ridley	34		1976-1998	1.62		Bresette et al (1998)
All US Waters	Loggerhead		5-50	Annual Estimate		5-50	Plotkin (1995)

Table F-2: A subset of US-based nongovernmental organizations dedicated to sea turtle research and conservation

Name	Group Type	Web Address
Amelia Island Sea Turtle Watch, Inc.	Volunteer	www.ameliaislandseaturtlewatch.com/
Archie Carr Center for Sea Turtle Research	Academic	accstr.ufl.edu/
Bald Head Island Conservancy	Volunteer	www.bhic.org/STPP.shtml
California Turtle & Tortoise Club	Volunteer	www.tortoise.org/
Caribbean Conservation Corporation	Nonprofit	www.helpingseaturtles.org/
Chelonian Research Foundation	Academic	www.chelonian.org/
Clearwater Marine Aquarium	Nonprofit/Volunteer	www.seewinter.com/what-we-do/nesting
Coastal Research and Education Society of Long Island, Inc., New York State Sea Turtle Program	Nonprofit/Volunteer	www.cresli.org/cresli/turtles/turtpage.html
Conservation International Sea Turtle Flagship Program	Nonprofit	www.conservation.org/discover/centers_programs/sea_turtles/Pages/seaturtles.aspx
Earthwatch	Nonprofit/Ecotourism	www.earthwatch.org
Gulf Coast Turtle and Tortoise Society	Volunteer	www.gctts.org/
Hawksbill Sea Turtle Recovery Project	Government/Volunteer	www.fpir.noaa.gov/PRD/prd_volunteer_ops.html
Malama na Honu	Nonprofit/Volunteer	malamanahonu.org/
Marine Turtle Specialist Group	Academic	www.iucn-mtsg.org/
Maryland Marine Mammal and Sea Turtle Stranding Network	Government/Volunteer	www.dnr.state.md.us/fisheries/oxford/research/fwh/strandingprogram.html
National Aquarium in Baltimore, Marine Animal Rescue Program	Nonprofit/Volunteer	www.aqua.org/oceanhealth_marp.html
National Save the Sea Turtle Foundation	Nonprofit	savetheseaturtle.org/
Network for Endangered Seaturtles	Volunteer	www.nestonline.org/
Ocean Conservancy	Nonprofit	www.oceanconservancy.org/
Riverhead Foundation for Marine Research and Preservation	Nonprofit/Volunteer	www.riverheadfoundation.org/index.asp
Sanibel-Captiva Conservation Foundation	Nonprofit/Volunteer	www.sccf.org/
Sea Turtle Restoration Project	Nonprofit	www.seaturtles.org
Share the Beach, Sea Turtle Volunteering Program	Volunteer	www.alabamaseaturtles.com/
The Leatherback Trust	Nonprofit	leatherback.org/
The Turtle Foundation	Nonprofit	www.turtle-foundation.org

F.2 Application of Whitehead (1993)'s Benefit Transfer Approach for Estimating WTP for T&E Sea Turtle Species

EPA identified a study that used a stated preference valuation approach to estimate the total economic value (i.e. use and non-use values) of a management program designed to reduce the risk of extinction for loggerhead sea turtles (Whitehead 1993). The mail survey asked North Carolina households whether they were willing to pay a bid amount for a management program which reduces the probability that loggerhead sea turtles would be extinct in 25 years. Within the model framework, the baseline extinction risk and change from the management program are expressed in terms of a supply probability. Supply probability reflects the probability that “the wildlife resource will continue to exist so it can be enjoyed by recreational users and non users (p.121)” (Whitehead 1993). The household value is expressed as option price, or willingness to pay under conditions of future supply and demand uncertainty. The option price is estimated by solving for the dollar amount which would make respondent indifferent to utility with and without the management program. The function used to estimate option price (Model B from Whitehead (1993)) is:

$$OP\ (1991\$) = 1.272\ [p_2(r_2 - q_2)]\ /\ 0.029 \quad \text{Equation F-3}$$

Variable definitions for the parameters in the function are described in Table F-3.

EPA used Whitehead (1993) to assess the range of benefits potentially resulting from 316(b) regulatory options. Available data sources and biological models were reviewed to assess the potential impact of baseline losses and reductions on sea turtle supply probability (r_2-q_2). While analyses of sea turtle extinction risk have been conducted (e.g., Conant et al. 2009), EPA was unable to identify an existing model or analysis which could be readily used in conjunction with available mortality data to estimate the marginal impacts of CWIS on sea turtle extinction risk. Estimates from the literature suggest that impingement and entrainment mortality is of relatively low importance compared to other human-induced mortality such as shrimp trawling and other fisheries (Plotkin 1995). However, Crouse et al. (1987) found that mortality at juvenile and subadult life stages can have a substantial effect on population growth, suggesting that small changes in survivorship at these age classes could have a measurable impact on extinction risk. As such, EPA believes that marginal change in supply probability of loggerhead sea turtles due to 316(b) regulatory options is unlikely to be lower than 0.01 (i.e., a 1% increase in 25 year survival probability).

EPA specified a marginal improvement of 0.01 within Whitehead’s (1993) modeling framework to bound household values for changes in extinction risk for loggerhead sea turtles as a consequence of 316(b) regulation. Although this assessment is not based on formal quantitative analysis of extinction risk, it is intended to illustrate the range of potential benefits associated with reductions in sea turtle losses. Using the author’s mean values for demand probability (p_2) and supply probability without the management program (q_2) (Table F-3), EPA calculated an annual household value of \$0.35 (2009\$). Estimates were converted to 2009 dollars using the consumer price index (USBLS 2010).

Table F-3: Variable Descriptions and Values used for EPA's Benefits Transfer Application

Variable Name	Description	Value Used in EPA's Applications
OP	Option Price - The amount a household would be willing to pay under conditions of supply and demand uncertainty	Estimated by the model
p_2	Demand Probability - for wildlife users, demand uncertainty occurs when it is indeterminate whether recreational use of the wildlife resource will be pursued because of uncertain travel costs, income, and tastes. For nonusers, demand uncertainty depends on uncertain tastes.	0.51
q_2 [a]	Supply Probability without the Management Program - probability that the resource will continue to exist in 25 years without implementation of the management program.	0.43
r_2	Supply Probability with the Management Program - probability that the resource will continue to exist in 25 years with implementation of the management program.	0.44
(r_2-q_2) [b]	Marginal increase in supply probability resulting from the management program	0.01

[a] The model results are linear for marginal improvements in supply probability.

[b] EPA notes that a marginal change in supply probability of 0.01 is substantially less than changes used by Whitehead (1993) for model estimation. Whitehead (1993) estimated an annual household willingness to payvalue of $10.98 (1991$) for a mean increase in supply probability of 0.47 in 25 years.

F.3 Application of Richardson & Loomis' (2008) WTP Model

To illustrate the potential magnitude of nonuse values for T&E species affected by I&E mortality in the California and Inland regions, EPA applied a WTP meta-analytical model (Richardson and Loomis 2009) to hypothetical scenarios. Because EPA does not currently have region-wide I&E mortality losses for all T&E species, nor population models to estimate the effect of I&E mortality on population size, estimates are presented only to assess the range of benefits potentially resulting from 316(b) regulatory options. The modeled scenarios estimate the WTP for 0.25% and 0.5% increases for all T&E fish populations in the California and Inland regions.

The model used by EPA to estimate nonuse values using benefit transfer is a double log specification (Model 4 from Richardson and Loomis (2009)), where:

$$\ln \text{WTP (2006\$)} = -153.231 + 0.870 \ln \text{CHANGESIZE} + 1.256\ \text{VISITOR} + 1.020\ \text{FISH} + 0.772\ \text{MARINE} + 0.826\ \text{BIRD} - 0.603 \ln \text{RESPONSERATE} + 2.767\ \text{CONJOINT} + 1.024\ \text{CHARISMATIC} - 0.903\ \text{MAIL} + 0.078\ \text{STUDYYEAR} \qquad \text{Equation F-4}$$

Model variables are described in Table F-4. Excepting all policy-relevant variables, EPA used the mean values for all model parameters, and converted estimates to 2009$ using the consumer price index (USBLS 2010).

Table F-4: Variables in the Meta-Analysis Model and Values Used in EPA's Application		
Variable Name	**Description**	**Value Used in EPA's Application**
ln WTP	Natural log of willingness to pay	Estimated by model
ln CHANGESIZE	Natural log of the percentage change in the population of the species of interest	Log of percentage change in fish population: ln(.25) and ln(.5)
VISITOR	= 1 if survey respondents are visitors rather than full-time residents	0.0
FISH	= 1 for fish species	1.0
MARINE	= 1 for marine mammals	0.0
BIRD	= 1 for bird species	0.0
ln RESPONSERATE	Natural log of the survey response rate	4.0
CONJOINT	= 1 for conjoint method surveys	0.0
CHARISMATIC	= 1 for charismatic species	0.0
MAIL	Indicates mail surveys	0.9
STUDY YEAR	Year of study	2007

Appendix G: Estimation of Price Changes for Consumer Surplus

G.1 Introduction

EPA considered estimating consumer surplus values associated with reductions in impingement and entrainment mortality (I&E mortality), but found that dockside prices would not change enough to produce measurable shifts in consumer surplus. This appendix presents the details of this analysis and the estimated price changes by region and species.

G.2 Methodology and Results

To properly estimate price changes, it is necessary to consider the contribution of the species to the overall market. Because individual demand functions incorporating substitutes are not available for most species, EPA estimated price changes in the following way. First, the Agency estimated the total baseline harvest for relevant species (commercial species of similar types to those affected by I&E mortality), in three categories: finfish, shrimp, and crabs.[60,] The totals for finfish were summed for the East Coast and Gulf, and for the West Coast; while totals for shrimp and crabs were summed across all coastal regions.[61] Next, EPA calculated the percentage change in harvest if baseline I&E mortality losses were to be eliminated, by dividing the total increase in harvest from elimination of baseline I&E mortality by the total harvest. The percentage change in price for each region and species was then estimated by dividing the percentage change in harvest by the elasticity for the species group (finfish, shrimp, or crabs).

This last step requires estimates of elasticities. The price elasticity of demand for fish measures the percentage change in demand in response to a percentage change in fish price. Thus, the inverse elasticity, or price flexibility, measures the percentage change in price for a given percentage change in quantity. EPA's review of the economics literature identified several potentially relevant studies, including Asche, Bjorndal, and Gordon (2005); Capps and Lambrgets (1991); Cheng and Capps (1988); Tsoa, Schrank, and Roy (1982); Davis, Yen, and Hwan-Lin (2007); and Lin, Richards, and Terry (1988).

Table G-1 presents the own-price elasticities identified in the literature review for those commercial species where I&E mortality losses were estimated. Since elasticities can vary by species, the Agency grouped the own-price elasticities found in the literature review into three categories: (1) saltwater fish, (2) shrimp, and (3) crabs. The median elasticities within each of these groups, presented in the fourth column of Table G-1, are the elasticities used in this analysis. Table G-1 shows that there is a substantial amount of variation in the elasticity estimates, so by selecting the median elasticity rather than taking an average, the influence of the more extreme estimates is reduced.[62]

60 For example, offshore species such as tuna and swordfish, baitfish species, and shellfish were not included.

61 Harvests for Alaska and Hawaii were not included in the totals.

62 Only two studies were available for crabs, so EPA used the mean elasticity for crabs. The Agency did not distinguish between finfish elasticities for the East and West Coast, because some sources provide elasticities based on models that include both regions.

Table G-1: Own-Price Elasticity Estimates from Literature Review					
Species Group	**Species**	**Study Elasticity**	**Median Species Group Elasticity**	**Study**	**Notes**
Saltwater	Cod	-0.54	-1.89	Cheng and Capps (1988)	
Saltwater	Cod	-3.15	-1.89	Bell (1986) as cited in Asche, Bjorndal and Gordon (2005)	
Saltwater	Cod(Blocks)	-3.16	-1.89	Mazany, Roy and Schrank (1996) as cited in Asche, Bjorndal and Gordon (2005)	
Saltwater	Cod(Fillets)	-0.46	-1.89	Tsoa, Schrank and Roy (1982)	Long run estimate.
Saltwater	Cod(Fillets)	-1.89	-1.89	Asche, Bjorndal and Gordon (2005)	
Saltwater	Flounder	-1.63	-1.89	Mazany, Roy and Schrank (1996) as cited in Asche, Bjorndal and Gordon (2005)	
Saltwater	Flounder/Sole	-0.45	-1.89	Cheng and Capps (1988)	
Saltwater	Flounder/Sole	-1.04	-1.89	Tsoa, Schrank and Roy (1982)	Long run estimate.
Saltwater	Halibut	-5.56	-1.89	Lin, Richards and Terry (1988) as cited in Asche, Bjorndal and Gordon (2005)	
Saltwater	Perch	-0.70	-1.89	Cheng and Capps (1988)	
Saltwater	Perch	-3.09	-1.89	Capps and Lambrgets (1991)	
Saltwater	Perch	-0.60	-1.89	Tsoa, Schrank and Roy (1982)	Long run estimate.
Saltwater	Perch	-215.00	-1.89	Bell (1986) as cited in Asche, Bjorndal and Gordon (2005)	
Saltwater	Rockfish	-3.55	-1.89	Capps and Lambrgets (1991)	
Saltwater	Whitefish	-5.24	-1.89	Capps and Lambrgets (1991)	
Shrimp	Shrimp	-0.70	-0.63	Cheng and Capps (1988)	
Shrimp	Shrimp	-1.08	-0.63	Davis, Yen and Hwan-Lin (2007)	Low income estimate.
Shrimp	Shrimp	-0.30	-0.63	Davis, Yen and Hwan-Lin (2007)	High income estimate.
Shrimp	Shrimp	-2.84	-0.63	Capps and Lambrgets (1991)	
Shrimp	Shrimp	-0.63	-0.63	Doll (1972) as cited in Cheng and Capps (1988)	
Shrimp	Shrimp	0.28	-0.63	Cleary (1969) as cited in Cheng and Capps (1988)	
Shrimp	Shrimp	-0.57	-0.63	Sun (1995) as cited in Asche, Bjorndal and Gordon (2005)	
Crabs	Crabs	-0.77	-1.31	Cheng and Capps (1988)	
Crabs	Crabs	-1.84	-1.31	Capps and Lambrgets (1991)	

Table G-2 shows the results of the calculations of percentage changes in price. These percentage changes were applied to the baseline prices to develop estimates of prices for the increased harvests that would result from eliminating baseline I&E mortality losses. Table G-3 to Table G-7 show the projected prices after eliminating baseline I&E mortality losses.[63] For a 0.27 percent change in total harvest in California,

[63] Values of 0.0 for increased harvest from elimination of baseline I&E mortality losses may include increases less than 0.1 thousand lbs.

finfish prices are predicted to change by 0.14 percent; for a 5.52 percent change in harvest for the East Coast and Gulf, finfish prices are predicted to change by 2.92 percent; for a 0.11 percent change in harvest of shrimp, prices are predicted to change by 0.17 percent; and for a 0.26 percent change in harvest for crabs, prices are predicted to change by 0.20 percent. This translates into very small changes (generally one to two cents) in ex-vessel prices per pound for the species affected by I&E mortality. Because of the negligible effects on prices, EPA did not include measures of changes in consumer surplus in the commercial fishing benefits estimates.

Table G-2: Estimated Percentage Change in Ex-Vessel Price by Region and Species Group

Region	Species Group	Baseline Increase in Harvest[a] (lbs)	Total Average Annual Harvest[b] (lbs)	Percentage Change in Harvest	Elasticity	Percentage Change in Price
California	Finfish	1,373,100	546,791,850	0.25%	-1.89	-0.13%
East Coast and Gulf	Finfish	15,758,900	397,297,400	3.97%	-1.89	-2.10%
All Regions	Crabs	678,900	315,657,146	0.22%	-1.31	-0.16%
All Regions	Shrimp	327,700	289,878,937	0.11%	-0.63	-0.18%

a. Estimated increase in harvest due to elimination of baseline I&E mortality.
b. Sum of total landings for all relevant species; source – NMFS landings data.

Table G-3: Estimated Price Changes for the California Region

Species	Average Annual Harvest 2005-2009 (thousand lbs)	Price Per Pound (2009$)[a]	Increase in Harvest from Elimination of Baseline I&E Losses (thousand lbs)	New Price Per Pound (2009$)[a]
American Shad	75.1	$0.98	0.0	$0.98
Anchovies	22,607.2	$0.05	0.6	$0.05
Cabezon	55.6	$5.83	54.4	$5.82
California Halibut	629.9	$4.06	126.4	$4.05
California Scorpionfish	7.9	$3.40	0.0	$3.40
Commercial Crabs	1,290.8	$1.33	1.6	$1.33
Commercial Shrimp	2,552.2	$1.93	0.0	$1.93
Drums and Croakers	77.0	$0.63	4.9	$0.63
Dungeness Crabs	14,370.0	$2.07	4.3	$2.07
Flounders	474.8	$0.45	10.1	$0.45
Other	57,125.4	$0.89	4.7	$0.89
Rockfishes	2,668.4	$1.25	1,168.7	$1.25
Sculpins	3.5	$3.43	2.6	$3.43
Sea Basses	6.5	$2.39	0.0	$2.39
Smelts	319.5	$0.38	0.2	$0.38
Surfperches	30.9	$1.92	0.5	$1.92
Total	**102,294.7**	**.**	**1,379.0**	**.**

Table G-4: Estimated Price Changes for the North Atlantic Region

Species	Average Annual Harvest 2005-2009 (thousand lbs)	Price Per Pound (2009$)[a]	Increase in Harvest from Elimination of Baseline I&E Losses (thousand lbs)	New Price Per Pound (2009$)[a]
American Shad	38.1	$0.69	0.0	$0.68
Atlantic Cod	15,427.3	$1.55	2.4	$1.52
Atlantic Herring	106,047.1	$0.12	18.0	$0.12
Atlantic Menhaden	5,548.6	$0.10	5.0	$0.10
Bluefish	1,077.2	$0.47	0.0	$0.46
Butterfish	550.9	$0.66	0.2	$0.65
Commercial Crabs	15,107.8	$0.58	0.4	$0.58
Flounders	17,675.4	$1.87	386.9	$1.83
Mackerels	38,896.8	$0.14	2.3	$0.14
Other	270,552.6	$0.44	3.9	$0.43
Pollock	14,567.6	$0.55	0.0	$0.54
Red Hake	576.9	$0.45	0.0	$0.44
Sculpins	<0.1	$0.25	4.0	$0.24
Scup	4531	$0.86	0.1	$0.84
Searobin	23.9	$0.12	0.1	$0.12
Silver Hake	9,613.2	$0.53	0.6	$0.52
Skate Species	31,638.4	$0.20	0.5	$0.20
Tautog	147.1	$2.03	4.9	$1.99
Weakfish	28.2	$1.48	0.2	$1.45
White Perch	6.6	$1.45	0.0	$1.42
Total	**53,2054.6**	**.**	**429.6**	**.**

Table G-5: Estimated Price Changes for the Mid-Atlantic Region

Species	Average Annual Harvest 2005-2009 (thousand lbs)	Price Per Pound (2009$)[a]	Increase in Harvest from Elimination of Baseline I&E Losses (thousand lbs)	New Price Per Pound (2009$)[a]
Alewife	173.3	$0.21	0.4	$0.21
American Shad	111.4	$0.92	1.5	$0.90
Atlantic Herring	1,284.2	$0.11	0.1	$0.11
Atlantic Menhaden	338,097.3	$0.07	4,915.4	$0.07
Black Drum	93.8	$1.26	0.3	$1.23
Blue Crab	62,874.0	$1.17	1,014.2	$1.15
Bluefish	2,906.3	$0.43	0.1	$0.42
Butterfish	501.3	$0.85	0.0	$0.83
Commercial Crabs	2,240.2	$0.60	0.4	$0.60
Drums and Croakers	11,430.1	$0.49	1,519.2	$0.48
Flounders	6,468.0	$2.01	8.7	$1.97
Other	462,429.6	$0.32	1,264.4	$0.31
Red Hake	150.7	$0.52	0.8	$0.51
Scup	3,225.6	$0.98	0.0	$0.96
Searobin	12.0	$0.22	0.0	$0.22
Silver Hake	3,867.0	$0.67	0.1	$0.66
Spot	3,286.9	$0.74	1,111.4	$0.72
Striped Bass	5,413.8	$2.02	88.6	$1.98
Striped Mullet	20.3	$0.53	0.3	$0.52
Tautog	135.9	$2.64	0.0	$2.58
Weakfish	497.0	$1.10	741.9	$1.08
White Perch	1,190.0	$0.76	4.0	$0.74
Total	**906,408.6**	**.**	**10,671.9**	**.**

Table G-6: Estimated Price Changes for the South Atlantic Region

Species	Average Annual Harvest 2005-2009 (thousand lbs)	Price Per Pound (2009$)[a]	Increase in Harvest from Elimination of Baseline I&E Losses (thousand lbs)	New Price Per Pound (2009$)[a]
Atlantic Menhaden	3,726.8	$0.11	55.7	$0.11
Blue Crab	36,414.4	$0.91	4.2	$0.91
Commercial Crabs	518	$1.51	0.0	$1.51
Drums and Croakers	8,333.3	$0.40	14.9	$0.39
Other	93,761.3	$1.17	3.0	$1.15
Spot	1,167.6	$0.65	20.4	$0.64
Stone Crab	101.1	$4.56	0.5	$4.55
Weakfish	266.5	$0.93	0.7	$0.91
Total	**144,289.1**	**.**	**99.4**	

Table G-7: Estimated Price Changes for the Gulf of Mexico Region				
Species	**Average Annual Harvest 2005-2009 (thousand lbs)**	**Price Per Pound (2009$)[a]**	**Increase in Harvest from Elimination of Baseline I&E Losses (thousand lbs)**	**New Price Per Pound (2009$)[a]**
Atlantic Menhaden	930,460.2	$0.06	988.4	$0.06
Black Drum	4,397.3	$0.83	1,885.2	$0.81
Blue Crab	56,804.0	$0.77	228.5	$0.77
Drums and Croakers	81.0	$6.47	40.3	$6.33
Leatherjacket	65.6	$1.40	90.7	$1.37
Mackerels	3,967.4	$1.04	0.3	$1.02
Other	1,250,334.1	$0.41	240.5	$0.40
Pink Shrimp	8,696.5	$2.06	327.7	$2.06
Sea Basses	66.6	$0.97	0	$0.95
Sheepshead	1,366.3	$0.41	0	$0.40
Spot	18.1	$0.43	40.0	$0.42
Stone Crab	5,313.9	$4.23	439.0	$4.22
Striped Mullet	10,347.7	$0.67	1,278.3	$0.66
Total	**2,271,918.70**	**.**	**5,558.9**	**.**

Appendix H: Details of Regional Commercial Fishing Benefits

Table H-1: Commercial Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the California Region, by Species and Regulatory Option (2009$)

Species Name	Average Annual Harvest 2006-2009 (thousand lbs)	Price per Pound	Annual Increase in Commercial Harvest (thousand lbs)					Annual Benefits from Increase in Commercial Harvest (2009$, thousands)				
			Baseline	Option 1	Option 2	Option 3	Option 4	Baseline	Option 1	Option 2	Option 3	Option 4
American Shad	75.1	$0.98	0.0	0.0	0.0	0.0	0.0	.	.	.	.	.
Anchovies	22,607.2	$0.05	0.6	0.5	0.6	0.6	0.5	0.0	0.0	0.0	0.0	0.0
Cabezon	55.6	$5.83	54.4	0.1	46.4	48.5	0.1	166.5	0.2	142.0	148.5	0.2
California Halibut	629.9	$4.06	126.4	0.2	107.8	112.8	0.2	298.8	0.6	254.8	266.5	0.5
California Scorpionfish	7.9	$3.40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Commercial Crabs	1,290.8	$1.33	1.6	0.0	1.3	1.4	0.0	1.5	0.0	1.3	1.4	0.0
Commercial Shrimp	2,552.2	$1.93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drums and Croakers	77.0	$0.63	4.9	0.7	4.3	4.5	0.7	1.3	0.2	1.1	1.2	0.2
Dungeness Crabs	14,370.0	$2.07	4.3	0.4	3.8	3.9	0.4	6.6	0.6	5.7	6.0	0.6
Flounders	474.8	$0.45	10.1	0.9	8.8	9.1	0.9	2.9	0.3	2.5	2.6	0.2
Other	57,125.4	$0.89	4.7	0.6	4.1	4.2	0.6	2.2	0.3	1.9	2.0	0.3
Rockfishes	2,668.4	$1.25	1,168.7	2.6	996.4	1,042.2	2.5	907.7	2.0	774.0	809.6	2.0
Sculpins	3.5	$3.43	2.6	0.1	2.2	2.3	0.1	5.7	0.2	4.9	5.1	0.2
Sea Basses	6.5	$2.39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Smelts	319.5	$0.38	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Surfperches	30.9	$1.92	0.5	0.5	0.5	0.5	0.4	0.4	0.3	0.4	0.4	0.3
Total (undiscounted)	**102,294.7**	**.**	**1,379.0**	**6.7**	**1,176.4**	**1,230.3**	**6.5**	**1,393.9**	**4.7**	**1,188.7**	**1,243.3**	**4.6**
Total (3% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**1,236.0**	**3.7**	**750.8**	**776.0**	**3.6**
Total (7% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**1,195.0**	**3.3**	**573.3**	**589.0**	**3.2**

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere; Option 4 = I for Facilities > 50 MGD

Table H-2: Commercial Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the North Atlantic Region, by Species and Regulatory Option (2009$)

Species Name	Average Annual Harvest 2006-2009 (thousand lbs)	Price per Pound	Annual Increase in Commercial Harvest (thousand lbs)					Annual Benefits from Increase in Commercial Harvest (2009$, thousands)				
			Baseline	Option 1	Option 2	Option 3	Option 4	Baseline	Option 1	Option 2	Option 3	Option 4
American Shad	38.1	$0.69	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Atlantic Cod	15,427.3	$1.55	2.4	0.1	2.0	2.1	0.1	2.5	0.1	2.0	2.1	0.1
Atlantic Herring	106,047.1	$0.12	18.0	0.4	14.8	15.5	0.4	1.7	0.0	1.4	1.4	0.0
Atlantic Menhaden	5,548.6	$0.10	5.0	0.0	4.1	4.3	0.0	0.4	0.0	0.3	0.3	0.0
Bluefish	1,077.2	$0.47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Butterfish	550.9	$0.66	0.2	0.1	0.2	0.2	0.1	0.1	0.0	0.1	0.1	0.0
Commercial Crabs	15,107.8	$0.58	0.4	0.2	0.4	0.4	0.2	0.1	0.1	0.1	0.1	0.1
Flounders	17,675.4	$1.87	386.9	1.3	315.8	331.2	1.3	460.2	1.5	375.5	393.9	1.5
Mackerels	38,896.8	$0.14	2.3	0.0	1.8	1.9	0.0	0.3	0.0	0.2	0.2	0.0
Other	270,552.6	$0.44	3.9	0.2	3.2	3.4	0.2	1.0	0.0	0.8	0.8	0.0
Pollock	14,567.6	$0.55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Red Hake	576.9	$0.45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sculpins	0.0	$0.25	4.0	0.0	4.0	4.0	0.0	.	.	.	.	.
Scup	4,531.0	$0.86	0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.0
Searobin	23.9	$0.12	0.1	0.0	0.1	0.1	0.0	.	.	.	.	.
Silver Hake	9,613.2	$0.53	0.6	0.1	0.5	0.6	0.1	0.2	0.0	0.2	0.2	0.0
Skate Species	31,638.4	$0.20	0.5	0.4	0.5	0.5	0.4	0.1	0.0	0.1	0.1	0.0
Tautog	147.1	$2.03	4.9	0.0	4.0	4.2	0.0	4.5	0.0	3.7	3.8	0.0
Weakfish	28.2	$1.48	0.2	0.0	0.2	0.2	0.0	0.3	0.0	0.2	0.2	0.0
White Perch	6.6	$1.45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total (undiscounted)	**532,054.6**	**.**	**429.6**	**2.9**	**351.7**	**368.6**	**2.9**	**471.2**	**1.9**	**384.6**	**403.4**	**1.9**
Total (3% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**417.9**	**1.5**	**230.6**	**241.5**	**1.5**
Total (7% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**404.0**	**1.3**	**171.3**	**179.3**	**1.3**

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere; Option 4 = I for Facilities > 50 MGD

Table H-3: Commercial Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the Mid-Atlantic Region, by Species and Regulatory Option (2009$)

Species Name	Average Annual Harvest 2006-2009 (thousand lbs)	Price per Pound	Annual Increase in Commercial Harvest (thousand lbs)					Annual Benefits from Increase in Commercial Harvest (2009$, thousands)				
			Baseline	Option 1	Option 2	Option 3	Option 4	Baseline	Option 1	Option 2	Option 3	Option 4
Alewife	173.3	$0.21	0.4	0.3	0.4	0.4	0.3	0.1	0.1	0.1	0.1	0.1
American Shad	111.4	$0.92	1.5	0.0	1.3	1.4	0.0	1.1	0.0	1.0	1.0	0.0
Atlantic Herring	1,284.2	$0.11	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Atlantic Menhaden	338,097.3	$0.07	4,915.4	3,273.9	4,758.3	4,780.2	3,270.8	223.3	148.7	216.1	217.1	148.6
Black Drum	93.8	$1.26	0.3	0.2	0.3	0.3	0.2	0.3	0.2	0.3	0.3	0.2
Blue Crab	62,874.0	$1.17	1,014.2	10.2	929.6	941.4	10.2	678.0	6.8	621.5	629.3	6.8
Bluefish	2,906.3	$0.43	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Butterfish	501.3	$0.85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Commercial Crabs	2,240.2	$0.60	0.4	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1
Drums and Croakers	11,430.1	$0.49	1,519.2	16.5	1,392.6	1,410.2	16.5	549.3	6.0	503.5	509.9	6.0
Flounders	6,468.0	$2.01	8.7	3.4	8.3	8.3	3.4	11.9	4.5	11.2	11.3	4.5
Other	462,429.6	$0.32	1,264.4	126.9	1,167.9	1,181.3	126.8	293.0	29.4	270.6	273.7	29.4
Red Hake	150.7	$0.52	0.8	0.6	0.8	0.8	0.6	0.3	0.2	0.3	0.3	0.2
Scup	3,225.6	$0.98	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Searobin	12.0	$0.22	0.0	0.0	0.0	0.0	0.0	.	.	.	.	.
Silver Hake	3,867.0	$0.67	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Spot	3,286.9	$0.74	1,111.4	120.0	1,111.4	1,111.4	119.9	693.6	74.9	693.6	693.6	74.8
Striped Bass	5,413.8	$2.02	88.6	0.4	81.2	82.2	0.4	119.2	0.6	109.2	110.6	0.6
Striped Mullet	20.3	$0.53	0.3	0.2	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0.1
Tautog	135.9	$2.64	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weakfish	497.0	$1.10	741.9	196.1	694.9	701.4	196.0	619.3	163.7	580.0	585.5	163.6
White Perch	1,190.0	$0.76	4.0	0.3	3.7	3.7	0.3	2.5	0.2	2.3	2.3	0.2
Total (undiscounted)	**906,408.6**	**.**	**10,671.9**	**3,749.8**	**10,151.6**	**10,224.0**	**3,746.3**	**3,192.2**	**435.5**	**3,010.1**	**3,035.4**	**435.1**
Total (3% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**2,831.2**	**342.0**	**1,614.8**	**1,629.0**	**341.6**
Total (7% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**2,736.8**	**302.7**	**1,124.0**	**1,133.9**	**302.4**

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere; Option 4 = I for Facilities > 50 MGD

Table H-4: Commercial Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the South Atlantic Region, by Species and Regulatory Option (2009$)

Species Name	Average Annual Harvest 2006-2009 (thousand lbs)	Price per Pound	Annual Increase in Commercial Harvest (thousand lbs)					Annual Benefits from Increase in Commercial Harvest (2009$, thousands)				
			Baseline	Option 1	Option 2	Option 3	Option 4	Baseline	Option 1	Option 2	Option 3	Option 4
Atlantic Menhaden	3,726.8	$0.11	55.7	31.4	47.4	47.4	31.4	4.7	2.7	4.0	4.0	2.7
Blue Crab	36,414.4	$0.91	4.2	2.6	3.6	3.6	2.6	2.2	1.4	1.9	1.9	1.4
Commercial Crabs	518.0	$1.51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drums and Croakers	8,333.3	$0.40	14.9	0.3	12.4	12.4	0.3	3.2	0.1	2.7	2.7	0.1
Other	93,761.3	$1.17	3.0	1.5	2.5	2.5	1.5	2.1	1.1	1.8	1.8	1.1
Spot	1,167.6	$0.65	20.4	8.6	17.3	17.3	8.6	9.3	3.9	7.9	7.9	3.9
Stone Crab	101.1	$4.56	0.5	0.3	0.5	0.5	0.3	1.4	0.9	1.2	1.2	0.9
Weakfish	266.5	$0.93	0.7	0.4	0.6	0.6	0.4	0.4	0.2	0.4	0.4	0.2
Total (undiscounted)	**144,289.1**	**.**	**99.4**	**45.1**	**84.2**	**84.3**	**45.1**	**23.3**	**10.2**	**19.8**	**19.8**	**10.2**
Total (3% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**20.7**	**8.0**	**11.5**	**11.5**	**8.0**
Total (7% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**20.0**	**7.1**	**8.4**	**8.4**	**7.1**

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere; Option 4 = I for Facilities > 50 MGD

Table H-5: Commercial Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the Gulf of Mexico Region, by Species and Regulatory Option (2009$)

Species Name	Average Annual Harvest 2006-2009 (thousand lbs)	Price per Pound	Annual Increase in Commercial Harvest (thousand lbs)					Annual Benefits from Increase in Commercial Harvest (2009$, thousands)				
			Baseline	Option 1	Option 2	Option 3	Option 4	Baseline	Option 1	Option 2	Option 3	Option 4
Atlantic Menhaden	930,460.2	$0.06	988.4	749.3	978.5	979.2	743.6	44.1	33.5	43.7	43.7	33.2
Black Drum	4,397.3	$0.83	1,885.2	3.1	1,276.5	1,279.7	3.1	1,087.6	1.8	736.5	738.3	1.8
Blue Crab	56,804.0	$0.77	228.5	40.2	171.2	171.5	39.9	126.3	22.2	94.6	94.8	22.0
Drums and Croakers	81.0	$6.47	40.3	30.8	40.0	40.0	30.6	140.7	107.7	139.7	139.8	106.8
Leatherjacket	65.6	$1.40	90.7	66.2	88.7	88.8	65.7	.	.	.	.	.
Mackerels	3,967.4	$1.04	0.3	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Other	1,250,334.1	$0.41	240.5	164.8	230.8	231.0	163.6	45.7	31.3	43.8	43.9	31.1
Pink Shrimp	8,696.5	$2.06	327.7	154.4	285.5	285.9	153.3	293.4	138.3	255.7	256.0	137.2
Sea Basses	66.6	$0.97	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sheepshead	1,366.3	$0.41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spot	18.1	$0.43	40.0	24.8	37.3	37.3	24.6	9.3	5.8	8.7	8.7	5.7
Stone Crab	5,313.9	$4.23	439.0	104.1	340.1	340.7	103.3	1,323.1	313.8	1,024.7	1,026.6	311.4
Striped Mullet	10,347.7	$0.67	1,278.3	121.5	914.9	916.9	120.5	676.0	64.2	483.9	484.9	63.7
Total (undiscounted)	**2,271,918.7**	**.**	**5,558.9**	**1,459.4**	**4,363.8**	**4,371.3**	**1,448.4**	**3,746.5**	**718.7**	**2,831.5**	**2,836.9**	**713.3**
Total (3% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**3,462.9**	**588.4**	**1,805.7**	**1,804.3**	**584.0**
Total (7% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**3,449.9**	**536.8**	**1,394.2**	**1,390.4**	**532.7**

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere; Option 4 = I for Facilities > 50 MGD

Table H-6: Commercial Fishing Benefits from Eliminating or Reducing Baseline I&E Mortality Losses at In-Scope Facilities in the Great Lakes Region, by Species and Regulatory Option (2009$)

Species Name	Average Annual Harvest 2006-2009 (thousand lbs)	Price per Pound	Annual Increase in Commercial Harvest (thousand lbs)					Annual Benefits from Increase in Commercial Harvest (2009$, thousands)				
			Baseline	Option 1	Option 2	Option 3	Option 4	Baseline	Option 1	Option 2	Option 3	Option 4
Bullhead	569.7	$0.41	0.8	0.7	0.8	0.8	0.7	0.1	0.1	0.1	0.1	0.1
Freshwater Drum	497.5	$0.16	16.1	3.8	13.7	13.8	3.8	0.8	0.2	0.6	0.6	0.2
Other	13,819.0	$0.94	97.2	35.0	85.3	86.1	34.7	26.6	9.6	23.3	23.6	9.5
Smelts	522.2	$0.91	105.9	91.2	104.6	104.9	90.5	27.8	24.0	27.5	27.6	23.8
White Bass	432.2	$0.68	22.0	6.4	19.0	19.2	6.4	4.3	1.3	3.7	3.8	1.3
Whitefish	9,406.5	$0.87	101.9	88.3	100.8	101.1	87.6	25.9	22.4	25.6	25.6	22.2
Yellow Perch	1,609.7	$2.08	2.3	1.6	2.2	2.2	1.6	1.4	0.9	1.3	1.3	0.9
Total (undiscounted)	**40,675.8**	**.**	**346.2**	**227.0**	**326.4**	**328.0**	**225.1**	**86.8**	**58.4**	**82.2**	**82.6**	**57.9**
Total (3% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**80.3**	**47.8**	**52.9**	**53.0**	**47.4**
Total (7% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**.**	**80.0**	**43.6**	**41.1**	**41.0**	**43.3**

Scenarios: Baseline = Eliminating Baseline I&E Mortality Losses; Option 1 = I Everywhere; Option 2 = I Everywhere and E for Facilities >125 MGD; Option 3 = I&E Mortality Everywhere; Option 4 = I for Facilities > 50 MGD

Appendix I: Details of Regional Recreational Fishing Benefits

I.1 California

Table I-1: Recreational Fishing Benefits from Eliminating Baseline I&E Mortality Losses at In-scope Facilities in the California Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
California halibut	38,418.0	$5.11	$9.76	$18.62	196.7	374.6	715.4
Flounders	246.0	$5.11	$9.76	$18.62	1.3	2.4	4.6
Total (Flatfish)	**38,664.0**	**$5.11**	**$9.76**	**$18.62**	**198.0**	**377.0**	**720.0**
Striped bass	1,209.0	$4.21	$7.26	$12.43	5.0	9.0	15.0
Total (Small Game)	**1,209.0**	**$4.21**	**$7.26**	**$12.43**	**5.0**	**9.0**	**15.0**
Cabezon	7,158.0	$1.79	$2.96	$4.89	12.8	21.2	35.0
California scorpionfish	58.0	$1.79	$2.96	$4.89	0.1	0.2	0.3
Croakers	32,132.0	$1.79	$2.96	$4.89	57.5	95.0	157.1
Rockfish	285,002.0	$1.79	$2.96	$4.89	509.8	842.9	1,393.2
Sculpin	111,780.0	$1.79	$2.96	$4.89	200.0	330.6	546.4
Sea bass	512,501.0	$1.79	$2.96	$4.89	916.8	1,515.8	2,505.3
Smelts	21.0	$1.79	$2.96	$4.89	0.0	0.1	0.1
Sunfish	13.0	$1.79	$2.96	$4.89	0.0	0.0	0.1
Surfperch	30,172.0	$1.79	$2.96	$4.89	54.0	89.2	147.5
Total (Other Saltwater)	**978,837.0**	**$1.79**	**$2.96**	**$4.89**	**1,751.0**	**2,895.0**	**4,785.0**
Total (Unidentified)	**3,629.0**	**$1.86**	**$3.10**	**$5.18**	**7.0**	**11.0**	**19.0**
Total (Undiscounted)	**1,022,339.0**	**.**	**.**	**.**	**1,960.0**	**3,292.0**	**5,539.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**1,740.0**	**2,923.0**	**4,917.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**1,681.0**	**2,823.0**	**4,750.0**

Table I-2: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 1 (I Everywhere) in the California Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
California halibut	71.0	$5.11	$9.76	$18.62	0.0	0.8	1.5
Flounders	22.0	$5.11	$9.76	$18.62	0.0	0.2	0.5
Total (Flatfish)	**92.0**	**$5.11**	**$9.76**	**$18.62**	**0.0**	**1.0**	**2.0**
Striped bass	0.0	$4.21	$7.26	$12.43	0.0	0.0	0.0
Total (Small Game)	**0.0**	**$4.21**	**$7.26**	**$12.43**	**0.0**	**0.0**	**0.0**
Cabezon	10.0	$1.79	$2.96	$4.89	0.0	0.0	0.0
California scorpionfish	50.0	$1.79	$2.96	$4.89	0.1	0.1	0.2
Croakers	4,696.0	$1.79	$2.96	$4.89	8.4	13.9	23.0
Rockfish	636.0	$1.79	$2.96	$4.89	1.1	1.9	3.1
Sculpin	3,284.0	$1.79	$2.96	$4.89	5.8	9.7	16.1
Sea bass	284.0	$1.79	$2.96	$4.89	0.5	0.8	1.4
Smelts	17.0	$1.79	$2.96	$4.89	0.0	0.1	0.1
Sunfish	1.0	$1.79	$2.96	$4.89	0.0	0.0	0.0
Surfperch	26,391.0	$1.79	$2.96	$4.89	47.0	78.3	129.1
Total (Other Saltwater)	**35,369.0**	**$1.79**	**$2.96**	**$4.89**	**63.0**	**105.0**	**173.0**
Total (Unidentified)	**976.0**	**$1.86**	**$3.10**	**$5.18**	**2.0**	**3.0**	**5.0**
Total (Undiscounted)	**36,438.0**	**.**	**.**	**.**	**66.0**	**109.0**	**180.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**51.0**	**85.0**	**141.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**46.0**	**75.0**	**125.0**

Table I-3: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 2 (I Everywhere and E for Facilities > 125 MGD) in the California Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
California halibut	32,753.0	$5.11	$9.76	$18.62	167.9	319.9	610.0
Flounders	213.0	$5.11	$9.76	$18.62	1.1	2.1	4.0
Total (Flatfish)	**32,967.0**	**$5.11**	**$9.76**	**$18.62**	**169.0**	**322.0**	**614.0**
Striped bass	1,031.0	$4.21	$7.26	$12.43	4.0	7.0	13.0
Total (Small Game)	**1,031.0**	**$4.21**	**$7.26**	**$12.43**	**4.0**	**7.0**	**13.0**
Cabezon	6,103.0	$1.79	$2.96	$4.89	10.9	18.0	29.8
California scorpionfish	57.0	$1.79	$2.96	$4.89	0.1	0.2	0.3
Croakers	28,097.0	$1.79	$2.96	$4.89	50.3	83.1	137.3
Rockfish	242,999.0	$1.79	$2.96	$4.89	434.7	718.6	1,187.8
Sculpin	95,765.0	$1.79	$2.96	$4.89	171.3	283.2	468.1
Sea bass	436,840.0	$1.79	$2.96	$4.89	781.5	1,291.9	2,135.3
Smelts	20.0	$1.79	$2.96	$4.89	0.0	0.1	0.1
Sunfish	12.0	$1.79	$2.96	$4.89	0.0	0.0	0.1
Surfperch	29,711.0	$1.79	$2.96	$4.89	53.2	87.9	145.2
Total (Other Saltwater)	**839,604.0**	**$1.79**	**$2.96**	**$4.89**	**1,502.0**	**2,483.0**	**4,104.0**
Total (Unidentified)	**3,240.0**	**$1.86**	**$3.10**	**$5.18**	**6.0**	**10.0**	**17.0**
Total (Undiscounted)	**876,841.0**	**.**	**.**	**.**	**1,681.0**	**2,822.0**	**4,748.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**1,037.0**	**1,741.0**	**2,929.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**792.0**	**1,330.0**	**2,237.0**

Table I-4: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 3 (I&E Mortality Everywhere) in the California Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
California halibut	34,260.0	$5.11	$9.76	$18.62	174.9	333.8	637.9
Flounders	222.0	$5.11	$9.76	$18.62	1.1	2.2	4.1
Total (Flatfish)	**34,482.0**	**$5.11**	**$9.76**	**$18.62**	**176.0**	**336.0**	**642.0**
Striped bass	1,078.0	$4.21	$7.26	$12.43	5.0	8.0	13.0
Total (Small Game)	**1,078.0**	**$4.21**	**$7.26**	**$12.43**	**5.0**	**8.0**	**13.0**
Cabezon	6,383.0	$1.79	$2.96	$4.89	11.4	18.9	31.2
California scorpionfish	57.0	$1.79	$2.96	$4.89	0.1	0.2	0.3
Croakers	29,198.0	$1.79	$2.96	$4.89	52.2	86.3	142.7
Rockfish	254,174.0	$1.79	$2.96	$4.89	454.5	751.6	1,242.4
Sculpin	100,044.0	$1.79	$2.96	$4.89	178.9	295.9	489.0
Sea bass	456,964.0	$1.79	$2.96	$4.89	817.2	1,351.3	2,233.6
Smelts	21.0	$1.79	$2.96	$4.89	0.0	0.1	0.1
Sunfish	12.0	$1.79	$2.96	$4.89	0.0	0.0	0.1
Surfperch	29,987.0	$1.79	$2.96	$4.89	53.6	88.7	146.6
Total (Other Saltwater)	**876,840.0**	**$1.79**	**$2.96**	**$4.89**	**1,568.0**	**2,593.0**	**4,286.0**
Total (Unidentified)	**3,349.0**	**$1.86**	**$3.10**	**$5.18**	**6.0**	**10.0**	**17.0**
Total (Undiscounted)	**915,750.0**	**.**	**.**	**.**	**1,755.0**	**2,948.0**	**4,959.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**1,096.0**	**1,840.0**	**3,095.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**832.0**	**1,396.0**	**2,349.0**

Table I-5: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 4 (I for Facilities > 50 MGD) in the California Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
California halibut	69.0	$5.11	$9.76	$18.62	0.0	0.8	1.5
Flounders	21.0	$5.11	$9.76	$18.62	0.0	0.2	0.5
Total (Flatfish)	**90.0**	**$5.11**	**$9.76**	**$18.62**	**0.0**	**1.0**	**2.0**
Striped bass	0.0	$4.21	$7.26	$12.43	0.0	0.0	0.0
Total (Small Game)	**0.0**	**$4.21**	**$7.26**	**$12.43**	**0.0**	**0.0**	**0.0**
Cabezon	10.0	$1.79	$2.96	$4.89	0.0	0.0	0.0
California scorpionfish	49.0	$1.79	$2.96	$4.89	0.1	0.1	0.2
Croakers	4,565.0	$1.79	$2.96	$4.89	8.1	13.5	22.3
Rockfish	618.0	$1.79	$2.96	$4.89	1.1	1.8	3.0
Sculpin	3,192.0	$1.79	$2.96	$4.89	5.7	9.5	15.6
Sea bass	276.0	$1.79	$2.96	$4.89	0.5	0.8	1.3
Smelts	16.0	$1.79	$2.96	$4.89	0.0	0.0	0.1
Sunfish	1.0	$1.79	$2.96	$4.89	0.0	0.0	0.0
Surfperch	25,654.0	$1.79	$2.96	$4.89	45.5	76.1	125.4
Total (Other Saltwater)	**34,382.0**	**$1.79**	**$2.96**	**$4.89**	**61.0**	**102.0**	**168.0**
Total (Unidentified)	**949.0**	**$1.86**	**$3.10**	**$5.18**	**2.0**	**3.0**	**5.0**
Total (Undiscounted)	**35,421.0**	**.**	**.**	**.**	**64.0**	**106.0**	**175.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**50.0**	**83.0**	**137.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**44.0**	**73.0**	**121.0**

I.2 North Atlantic

Table I-6: Recreational Fishing Benefits from Eliminating Baseline I&E Mortality Losses at In-scope Facilities in the North Atlantic Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Winter flounder	310,442.0	$3.81	$5.96	$9.42	1,182.0	1,850.0	2,925.0
Total (flatfish)	**310,442.0**	**$3.81**	**$5.96**	**$9.42**	**1,182.0**	**1,850.0**	**2,925.0**
Atlantic mackerel	903.0	$2.13	$5.94	$16.76	1.9	5.8	15.4
Bluefish	1.0	$2.13	$5.94	$16.76	0.0	0.0	0.0
Striped bass	0.0	$2.13	$5.94	$16.76	0.0	0.0	0.0
Weakfish	33.0	$2.13	$5.94	$16.76	0.1	0.2	0.6
Total (small game)	**937.0**	**$2.13**	**$5.94**	**$16.76**	**2.0**	**6.0**	**16.0**
Atlantic Cod	1,281.0	$1.79	$2.98	$4.97	2.3	3.8	6.4
Cunner	107,374.0	$1.79	$2.98	$4.97	191.9	320.2	533.7
Pollock	4.0	$1.79	$2.98	$4.97	0.0	0.0	0.0
Sculpin	323,088.0	$1.79	$2.98	$4.97	577.5	963.4	1,606.0
Scup	128.0	$1.79	$2.98	$4.97	0.2	0.4	0.6
Searobin	823.0	$1.79	$2.98	$4.97	1.5	2.5	4.1
Tautog	14,323.0	$1.79	$2.98	$4.97	25.6	42.7	71.2
White Perch	0.0	$1.79	$2.98	$4.97	0.0	0.0	0.0
Total (other saltwater)	**447,021.0**	**$1.79**	**$2.98**	**$4.97**	**799.0**	**1,333.0**	**2,222.0**
Total (unidentified)	**2,783.0**	**$1.80**	**$3.01**	**$5.03**	**5.0**	**8.0**	**14.0**
Total (Undiscounted)	**761,183.0**	**.**	**.**	**.**	**1,988.0**	**3,197.0**	**5,177.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**1,765.0**	**2,838.0**	**4,596.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**1,705.0**	**2,742.0**	**4,440.0**

Table I-7: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 1 (I Everywhere) in the North Atlantic Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Winter flounder	836.0	$3.81	$5.96	$9.42	3.0	5.0	8.0
Total (flatfish)	**836.0**	**$3.81**	**$5.96**	**$9.42**	**3.0**	**5.0**	**8.0**
Atlantic mackerel	0.0	$2.13	$5.94	$16.76	0.0	0.0	0.0
Bluefish	1.0	$2.13	$5.94	$16.76	0.0	0.0	0.0
Striped bass	0.0	$2.13	$5.94	$16.76	0.0	0.0	0.0
Weakfish	0.0	$2.13	$5.94	$16.76	0.0	0.0	0.0
Total (small game)	**1.0**	**$2.13**	**$5.94**	**$16.76**	**0.0**	**0.0**	**0.0**
Atlantic Cod	40.0	$1.79	$2.98	$4.97	0.1	0.1	0.2
Cunner	19.0	$1.79	$2.98	$4.97	0.0	0.0	0.1
Pollock	1.0	$1.79	$2.98	$4.97	0.0	0.0	0.0
Sculpin	345.0	$1.79	$2.98	$4.97	0.7	0.7	1.4
Scup	8.0	$1.79	$2.98	$4.97	0.0	0.0	0.0
Searobin	45.0	$1.79	$2.98	$4.97	0.1	0.1	0.2
Tautog	17.0	$1.79	$2.98	$4.97	0.0	0.0	0.1
White Perch	0.0	$1.79	$2.98	$4.97	0.0	0.0	0.0
Total (other saltwater)	**476.0**	**$1.79**	**$2.98**	**$4.97**	**1.0**	**1.0**	**2.0**
Total (unidentified)	**181.0**	**$1.80**	**$3.01**	**$5.03**	**0.0**	**1.0**	**1.0**
Total (Undiscounted)	**1,495.0**	**.**	**.**	**.**	**4.0**	**7.0**	**11.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**3.0**	**5.0**	**9.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**3.0**	**5.0**	**8.0**

Table I-8: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 2 (I Everywhere and E for Facilities > 125 MGD) in the North Atlantic Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Winter flounder	253,297.0	$3.81	$5.96	$9.42	964.0	1,510.0	2,387.0
Total (flatfish)	**253,297.0**	**$3.81**	**$5.96**	**$9.42**	**964.0**	**1,510.0**	**2,387.0**
Atlantic mackerel	736.0	$2.13	$5.94	$16.76	1.9	4.8	12.5
Bluefish	1.0	$2.13	$5.94	$16.76	0.0	0.0	0.0
Striped bass	0.0	$2.13	$5.94	$16.76	0.0	0.0	0.0
Weakfish	27.0	$2.13	$5.94	$16.76	0.1	0.2	0.5
Total (small game)	**764.0**	**$2.13**	**$5.94**	**$16.76**	**2.0**	**5.0**	**13.0**
Atlantic Cod	1,054.0	$1.79	$2.98	$4.97	1.9	3.1	5.2
Cunner	87,542.0	$1.79	$2.98	$4.97	156.6	261.0	435.1
Pollock	3.0	$1.79	$2.98	$4.97	0.0	0.0	0.0
Sculpin	263,485.0	$1.79	$2.98	$4.97	471.2	785.6	1,309.6
Scup	106.0	$1.79	$2.98	$4.97	0.2	0.3	0.5
Searobin	682.0	$1.79	$2.98	$4.97	1.2	2.0	3.4
Tautog	11,681.0	$1.79	$2.98	$4.97	20.9	34.8	58.1
White Perch	0.0	$1.79	$2.98	$4.97	0.0	0.0	0.0
Total (other saltwater)	**364,555.0**	**$1.79**	**$2.98**	**$4.97**	**652.0**	**1,087.0**	**1,812.0**
Total (unidentified)	**2,313.0**	**$1.80**	**$3.01**	**$5.03**	**4.0**	**7.0**	**12.0**
Total (Undiscounted)	**620,929.0**	**.**	**.**	**.**	**1,622.0**	**2,608.0**	**4,223.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**939.0**	**1,510.0**	**2,446.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**698.0**	**1,122.0**	**1,817.0**

Table I-9: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 3 (I&E Mortality Everywhere) in the North Atlantic Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Winter flounder	265,676.0	$3.81	$5.96	$9.42	1,012.0	1,583.0	2,503.0
Total (flatfish)	**265,676.0**	**$3.81**	**$5.96**	**$9.42**	**1,012.0**	**1,583.0**	**2,503.0**
Atlantic mackerel	772.0	$2.13	$5.94	$16.76	1.9	4.8	12.5
Bluefish	1.0	$2.13	$5.94	$16.76	0.0	0.0	0.0
Striped bass	0.0	$2.13	$5.94	$16.76	0.0	0.0	0.0
Weakfish	29.0	$2.13	$5.94	$16.76	0.1	0.2	0.5
Total (small game)	**801.0**	**$2.13**	**$5.94**	**$16.76**	**2.0**	**5.0**	**13.0**
Atlantic Cod	1,104.0	$1.79	$2.98	$4.97	2.0	3.3	5.5
Cunner	91,836.0	$1.79	$2.98	$4.97	164.3	273.8	456.5
Pollock	3.0	$1.79	$2.98	$4.97	0.0	0.0	0.0
Sculpin	276,392.0	$1.79	$2.98	$4.97	494.4	823.9	1,374.0
Scup	111.0	$1.79	$2.98	$4.97	0.2	0.3	0.6
Searobin	713.0	$1.79	$2.98	$4.97	1.3	2.1	3.5
Tautog	12,253.0	$1.79	$2.98	$4.97	21.9	36.5	60.9
White Perch	0.0	$1.79	$2.98	$4.97	0.0	0.0	0.0
Total (other saltwater)	**382,413.0**	**$1.79**	**$2.98**	**$4.97**	**684.0**	**1,140.0**	**1,901.0**
Total (unidentified)	**2,417.0**	**$1.80**	**$3.01**	**$5.03**	**4.0**	**7.0**	**12.0**
Total (Undiscounted)	**651,307.0**	**.**	**.**	**.**	**1,701.0**	**2,736.0**	**4,430.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**1,018.0**	**1,638.0**	**2,652.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**756.0**	**1,216.0**	**1,969.0**

Table I-10: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 4 (I for Facilities > 50 MGD) in the North Atlantic Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Winter flounder	836.0	$3.81	$5.96	$9.42	3.0	5.0	8.0
Total (flatfish)	**836.0**	**$3.81**	**$5.96**	**$9.42**	**3.0**	**5.0**	**8.0**
Atlantic mackerel	0.0	$2.13	$5.94	$16.76	0.0	0.0	0.0
Bluefish	1.0	$2.13	$5.94	$16.76	0.0	0.0	0.0
Striped bass	0.0	$2.13	$5.94	$16.76	0.0	0.0	0.0
Weakfish	0.0	$2.13	$5.94	$16.76	0.0	0.0	0.0
Total (small game)	**1.0**	**$2.13**	**$5.94**	**$16.76**	**0.0**	**0.0**	**0.0**
Atlantic Cod	40.0	$1.79	$2.98	$4.97	0.1	0.1	0.2
Cunner	19.0	$1.79	$2.98	$4.97	0.0	0.0	0.1
Pollock	1.0	$1.79	$2.98	$4.97	0.0	0.0	0.0
Sculpin	345.0	$1.79	$2.98	$4.97	0.7	0.7	1.4
Scup	8.0	$1.79	$2.98	$4.97	0.0	0.0	0.0
Searobin	45.0	$1.79	$2.98	$4.97	0.1	0.1	0.2
Tautog	17.0	$1.79	$2.98	$4.97	0.0	0.0	0.1
White Perch	0.0	$1.79	$2.98	$4.97	0.0	0.0	0.0
Total (other saltwater)	**476.0**	**$1.79**	**$2.98**	**$4.97**	**1.0**	**1.0**	**2.0**
Total (unidentified)	**181.0**	**$1.80**	**$3.01**	**$5.03**	**0.0**	**1.0**	**1.0**
Total (Undiscounted)	**1,495.0**	**.**	**.**	**.**	**4.0**	**7.0**	**11.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**3.0**	**5.0**	**9.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**3.0**	**5.0**	**8.0**

I.3 Mid-Atlantic

Table I-11: Recreational Fishing Benefits from Eliminating Baseline I&E Mortality Losses at In-scope Facilities in the Mid-Atlantic Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Summer Flounder	5,310.0	$3.74	$5.62	$8.52	19.7	30.0	45.0
Winter Flounder	4,946.0	$3.74	$5.62	$8.52	18.3	28.0	42.0
Total (Flatfish)	**10,256.0**	**$3.74**	**$5.62**	**$8.52**	**38.0**	**58.0**	**87.0**
Black Crappie	3.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Bluegill	16.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Brown bullhead	3,847.0	$0.53	$1.06	$2.10	1.9	3.9	8.2
Bullhead	11.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Channel catfish	2,891.0	$0.53	$1.06	$2.10	1.5	2.9	6.2
Crappie	1.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Menhaden	966.0	$0.53	$1.06	$2.10	0.5	1.0	2.1
Sunfish	221.0	$0.53	$1.06	$2.10	0.1	0.2	0.5
Total (Panfish)	**7,956.0**	**$0.53**	**$1.06**	**$2.10**	**4.0**	**8.0**	**17.0**
Bluefish	126.0	$2.26	$5.90	$15.52	0.3	0.7	2.0
Red drum	2,667.0	$2.26	$5.90	$15.52	6.0	15.7	41.4
Spotted seatrout	1,768.0	$2.26	$5.90	$15.52	4.0	10.4	27.4
Striped bass	166,917.0	$2.26	$5.90	$15.52	377.4	985.1	2,589.8
Weakfish	459,710.0	$2.26	$5.90	$15.52	1,039.3	2,713.0	7,132.5
Total (Small Game)	**631,187.0**	**$2.26**	**$5.90**	**$15.52**	**1,427.0**	**3,725.0**	**9,793.0**
Northern pike	0.0	$0.00	$0.00	$0.00	0.0	0.0	0.0
Total (Walleye/Pike)	**0.0**	**$0.00**	**$0.00**	**$0.00**	**0.0**	**0.0**	**0.0**
Atlantic croaker	1,782,932.0	$1.85	$2.92	$4.60	3,304.3	5,205.0	8,205.4
Atlantic herring	57.0	$1.85	$2.92	$4.60	0.1	0.2	0.3
Black drum	255.0	$1.85	$2.92	$4.60	0.5	0.7	1.2
Cunner	0.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Scup	1.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Searobin	8.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Silver perch	1.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Smallmouth bass	57.0	$1.85	$2.92	$4.60	0.1	0.2	0.3
Spot	5,388,053.0	$1.85	$2.92	$4.60	9,985.6	15,729.6	24,796.9
Striped mullet	12.0	$1.85	$2.92	$4.60	0.0	0.0	0.1
Tautog	0.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
White perch	33,237.0	$1.85	$2.92	$4.60	61.6	97.0	153.0
Whitefish	426.0	$1.85	$2.92	$4.60	0.8	1.2	2.0
Total (Other Saltwater)	**7,205,039.0**	**$1.85**	**$2.92**	**$4.60**	**13,353.0**	**21,034.0**	**33,159.0**
Total (Unidentified)	**1,226,622.0**	**$1.91**	**$3.24**	**$5.74**	**2,344.0**	**3,978.0**	**7,036.0**
Total (Undiscounted)	**9,081,061.0**	**.**	**.**	**.**	**17,166.0**	**28,803.0**	**50,092.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**15,239.0**	**25,569.0**	**44,467.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**14,721.0**	**24,701.0**	**42,958.0**

Table I-12: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 1 (I Everywhere) in the Mid-Atlantic Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Summer Flounder	4,051.0	$3.74	$5.62	$8.52	15.1	23.1	34.7
Winter Flounder	499.0	$3.74	$5.62	$8.52	1.9	2.9	4.3
Total (Flatfish)	**4,550.0**	**$3.74**	**$5.62**	**$8.52**	**17.0**	**26.0**	**39.0**
Black Crappie	3.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Bluegill	12.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Brown bullhead	787.0	$0.53	$1.06	$2.10	0.5	0.7	1.7
Bullhead	8.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Channel catfish	2,205.0	$0.53	$1.06	$2.10	1.4	2.1	4.8
Crappie	1.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Menhaden	0.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Sunfish	169.0	$0.53	$1.06	$2.10	0.1	0.2	0.4
Total (Panfish)	**3,185.0**	**$0.53**	**$1.06**	**$2.10**	**2.0**	**3.0**	**7.0**
Bluefish	96.0	$2.26	$5.90	$15.52	0.2	0.6	1.5
Red drum	2,035.0	$2.26	$5.90	$15.52	4.6	12.0	31.6
Spotted seatrout	1,349.0	$2.26	$5.90	$15.52	3.0	8.0	20.9
Striped bass	796.0	$2.26	$5.90	$15.52	1.8	4.7	12.4
Weakfish	121,529.0	$2.26	$5.90	$15.52	274.3	716.8	1,885.7
Total (Small Game)	**125,805.0**	**$2.26**	**$5.90**	**$15.52**	**284.0**	**742.0**	**1,952.0**
Northern pike	0.0	$0.00	$0.00	$0.00	0.0	0.0	0.0
Total (Walleye/Pike)	**0.0**	**$0.00**	**$0.00**	**$0.00**	**0.0**	**0.0**	**0.0**
Atlantic croaker	19,396.0	$1.85	$2.92	$4.60	35.9	56.6	89.3
Atlantic herring	43.0	$1.85	$2.92	$4.60	0.1	0.1	0.2
Black drum	195.0	$1.85	$2.92	$4.60	0.4	0.6	0.9
Cunner	0.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Scup	1.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Searobin	5.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Silver perch	1.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Smallmouth bass	44.0	$1.85	$2.92	$4.60	0.1	0.1	0.2
Spot	318,070.0	$1.85	$2.92	$4.60	589.2	928.2	1,464.2
Striped mullet	9.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Tautog	0.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
White perch	2,541.0	$1.85	$2.92	$4.60	4.7	7.4	11.7
Whitefish	325.0	$1.85	$2.92	$4.60	0.6	0.9	1.5
Total (Other Saltwater)	**340,629.0**	**$1.85**	**$2.92**	**$4.60**	**631.0**	**994.0**	**1,568.0**
Total (Unidentified)	**74,846.0**	**$1.91**	**$3.24**	**$5.74**	**143.0**	**243.0**	**429.0**
Total (Undiscounted)	**549,015.0**	.	.	.	**1,077.0**	**2,009.0**	**3,994.0**
Total (3% discount rate)	.	.	.	.	**846.0**	**1,577.0**	**3,136.0**
Total (7% discount rate)	.	.	.	.	**749.0**	**1,396.0**	**2,776.0**

Table I-13: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 2 (I Everywhere and E for Facilities > 125 MGD) in the Mid-Atlantic Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Summer Flounder	5,180.0	$3.74	$5.62	$8.52	19.1	29.2	44.1
Winter Flounder	4,569.0	$3.74	$5.62	$8.52	16.9	25.8	38.9
Total (Flatfish)	**9,749.0**	**$3.74**	**$5.62**	**$8.52**	**36.0**	**55.0**	**83.0**
Black Crappie	3.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Bluegill	16.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Brown bullhead	3,585.0	$0.53	$1.06	$2.10	1.9	3.8	7.6
Bullhead	10.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Channel catfish	2,820.0	$0.53	$1.06	$2.10	1.5	3.0	6.0
Crappie	1.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Menhaden	885.0	$0.53	$1.06	$2.10	0.5	0.9	1.9
Sunfish	216.0	$0.53	$1.06	$2.10	0.1	0.2	0.5
Total (Panfish)	**7,536.0**	**$0.53**	**$1.06**	**$2.10**	**4.0**	**8.0**	**16.0**
Bluefish	123.0	$2.26	$5.90	$15.52	0.3	0.7	1.9
Red drum	2,602.0	$2.26	$5.90	$15.52	5.9	15.4	40.4
Spotted seatrout	1,724.0	$2.26	$5.90	$15.52	3.9	10.2	26.7
Striped bass	152,927.0	$2.26	$5.90	$15.52	345.7	902.6	2,372.8
Weakfish	430,538.0	$2.26	$5.90	$15.52	973.2	2,541.1	6,680.2
Total (Small Game)	**587,915.0**	**$2.26**	**$5.90**	**$15.52**	**1,329.0**	**3,470.0**	**9,122.0**
Northern pike	0.0	$0.00	$0.00	$0.00	0.0	0.0	0.0
Total (Walleye/Pike)	**0.0**	**$0.00**	**$0.00**	**$0.00**	**0.0**	**0.0**	**0.0**
Atlantic croaker	1,634,350.0	$1.85	$2.92	$4.60	3,028.8	4,771.2	7,521.5
Atlantic herring	55.0	$1.85	$2.92	$4.60	0.1	0.2	0.3
Black drum	249.0	$1.85	$2.92	$4.60	0.5	0.7	1.1
Cunner	0.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Scup	1.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Searobin	8.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Silver perch	1.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Smallmouth bass	56.0	$1.85	$2.92	$4.60	0.1	0.2	0.3
Spot	4,959,382.0	$1.85	$2.92	$4.60	9,190.9	14,478.0	22,823.8
Striped mullet	12.0	$1.85	$2.92	$4.60	0.0	0.0	0.1
Tautog	0.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
White perch	30,638.0	$1.85	$2.92	$4.60	56.8	89.4	141.0
Whitefish	415.0	$1.85	$2.92	$4.60	0.8	1.2	1.9
Total (Other Saltwater)	**6,625,167.0**	**$1.85**	**$2.92**	**$4.60**	**12,278.0**	**19,341.0**	**30,490.0**
Total (Unidentified)	**1,129,224.0**	**$1.91**	**$3.24**	**$5.74**	**2,158.0**	**3,662.0**	**6,477.0**
Total (Undiscounted)	**8,359,591.0**	**.**	**.**	**.**	**15,805.0**	**26,536.0**	**46,188.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**8,381.0**	**14,073.0**	**24,501.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**5,831.0**	**9,792.0**	**17,049.0**

Table I-14: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 3 (I&E Mortality Everywhere) in the Mid-Atlantic Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Summer Flounder	5,198.0	$3.74	$5.62	$8.52	19.6	29.1	44.5
Winter Flounder	4,622.0	$3.74	$5.62	$8.52	17.4	25.9	39.5
Total (Flatfish)	**9,820.0**	**$3.74**	**$5.62**	**$8.52**	**37.0**	**55.0**	**84.0**
Black Crappie	3.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Bluegill	16.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Brown bullhead	3,622.0	$0.53	$1.06	$2.10	1.9	3.8	7.6
Bullhead	10.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Channel catfish	2,830.0	$0.53	$1.06	$2.10	1.5	3.0	6.0
Crappie	1.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Menhaden	896.0	$0.53	$1.06	$2.10	0.5	0.9	1.9
Sunfish	216.0	$0.53	$1.06	$2.10	0.1	0.2	0.5
Total (Panfish)	**7,595.0**	**$0.53**	**$1.06**	**$2.10**	**4.0**	**8.0**	**16.0**
Bluefish	123.0	$2.26	$5.90	$15.52	0.3	0.7	1.9
Red drum	2,611.0	$2.26	$5.90	$15.52	5.9	15.4	40.5
Spotted seatrout	1,730.0	$2.26	$5.90	$15.52	3.9	10.2	26.8
Striped bass	154,871.0	$2.26	$5.90	$15.52	350.2	914.0	2,402.9
Weakfish	434,593.0	$2.26	$5.90	$15.52	982.7	2,564.7	6,742.8
Total (Small Game)	**593,930.0**	**$2.26**	**$5.90**	**$15.52**	**1,343.0**	**3,505.0**	**9,215.0**
Northern pike	0.0	$0.00	$0.00	$0.00	0.0	0.0	0.0
Total (Walleye/Pike)	**0.0**	**$0.00**	**$0.00**	**$0.00**	**0.0**	**0.0**	**0.0**
Atlantic croaker	1,655,004.0	$1.85	$2.92	$4.60	3,067.0	4,831.4	7,616.6
Atlantic herring	55.0	$1.85	$2.92	$4.60	0.1	0.2	0.3
Black drum	250.0	$1.85	$2.92	$4.60	0.5	0.7	1.2
Cunner	0.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Scup	1.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Searobin	8.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Silver perch	1.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Smallmouth bass	56.0	$1.85	$2.92	$4.60	0.1	0.2	0.3
Spot	5,018,970.0	$1.85	$2.92	$4.60	9,301.1	14,651.8	23,098.1
Striped mullet	12.0	$1.85	$2.92	$4.60	0.0	0.0	0.1
Tautog	0.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
White perch	30,999.0	$1.85	$2.92	$4.60	57.4	90.5	142.7
Whitefish	417.0	$1.85	$2.92	$4.60	0.8	1.2	1.9
Total (Other Saltwater)	**6,705,773.0**	**$1.85**	**$2.92**	**$4.60**	**12,427.0**	**19,576.0**	**30,861.0**
Total (Unidentified)	**1,142,763.0**	**$1.91**	**$3.24**	**$5.74**	**2,183.0**	**3,706.0**	**6,555.0**
Total (Undiscounted)	**8,459,880.0**	**.**	**.**	**.**	**15,995.0**	**26,851.0**	**46,731.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**8,584.0**	**14,410.0**	**25,078.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**5,975.0**	**10,030.0**	**17,456.0**

Table I-15: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 4 (I for Facilities > 50 MGD) in the Mid-Atlantic Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Summer Flounder	4,047.0	$3.74	$5.62	$8.52	15.1	23.1	34.7
Winter Flounder	499.0	$3.74	$5.62	$8.52	1.9	2.9	4.3
Total (Flatfish)	**4,546.0**	**$3.74**	**$5.62**	**$8.52**	**17.0**	**26.0**	**39.0**
Black Crappie	3.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Bluegill	12.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Brown bullhead	786.0	$0.53	$1.06	$2.10	0.5	0.7	1.7
Bullhead	8.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Channel catfish	2,203.0	$0.53	$1.06	$2.10	1.4	2.1	4.8
Crappie	1.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Menhaden	0.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Sunfish	169.0	$0.53	$1.06	$2.10	0.1	0.2	0.4
Total (Panfish)	**3,182.0**	**$0.53**	**$1.06**	**$2.10**	**2.0**	**3.0**	**7.0**
Bluefish	96.0	$2.26	$5.90	$15.52	0.2	0.6	1.5
Red drum	2,033.0	$2.26	$5.90	$15.52	4.6	12.0	31.5
Spotted seatrout	1,347.0	$2.26	$5.90	$15.52	3.0	8.0	20.9
Striped bass	796.0	$2.26	$5.90	$15.52	1.8	4.7	12.3
Weakfish	121,415.0	$2.26	$5.90	$15.52	274.3	716.8	1,883.7
Total (Small Game)	**125,687.0**	**$2.26**	**$5.90**	**$15.52**	**284.0**	**742.0**	**1,950.0**
Northern pike	0.0	$0.00	$0.00	$0.00	0.0	0.0	0.0
Total (Walleye/Pike)	**0.0**	**$0.00**	**$0.00**	**$0.00**	**0.0**	**0.0**	**0.0**
Atlantic croaker	19,377.0	$1.85	$2.92	$4.60	35.9	56.5	89.2
Atlantic herring	43.0	$1.85	$2.92	$4.60	0.1	0.1	0.2
Black drum	195.0	$1.85	$2.92	$4.60	0.4	0.6	0.9
Cunner	0.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Scup	1.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Searobin	5.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Silver perch	1.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Smallmouth bass	44.0	$1.85	$2.92	$4.60	0.1	0.1	0.2
Spot	317,770.0	$1.85	$2.92	$4.60	589.2	927.2	1,462.3
Striped mullet	9.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
Tautog	0.0	$1.85	$2.92	$4.60	0.0	0.0	0.0
White perch	2,538.0	$1.85	$2.92	$4.60	4.7	7.4	11.7
Whitefish	324.0	$1.85	$2.92	$4.60	0.6	0.9	1.5
Total (Other Saltwater)	**340,307.0**	**$1.85**	**$2.92**	**$4.60**	**631.0**	**993.0**	**1,566.0**
Total (Unidentified)	**74,775.0**	**$1.91**	**$3.24**	**$5.74**	**143.0**	**243.0**	**429.0**
Total (Undiscounted)	**548,496.0**	**.**	**.**	**.**	**1,076.0**	**2,007.0**	**3,991.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**845.0**	**1,576.0**	**3,133.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**748.0**	**1,395.0**	**2,773.0**

I.4 South Atlantic

Table I-16: Recreational Fishing Benefits from Eliminating Baseline I&E Mortality Losses at In-scope Facilities in the South Atlantic Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Flounders	778.0	$3.87	$5.61	$8.28	3.0	4.0	6.0
Total (Flatfish)	**778.0**	**$3.87**	**$5.61**	**$8.28**	**3.0**	**4.0**	**6.0**
Spotted seatrout	1,898.0	$2.72	$5.72	$12.04	4.8	10.5	22.6
Weakfish	455.0	$2.72	$5.72	$12.04	1.2	2.5	5.4
Total (Small Game)	**2,353.0**	**$2.72**	**$5.72**	**$12.04**	**6.0**	**13.0**	**28.0**
Croakers	96,913.0	$2.14	$2.85	$3.78	207.6	276.1	365.6
Pinfish	1,518.0	$2.14	$2.85	$3.78	3.3	4.3	5.7
Silver perch	76.0	$2.14	$2.85	$3.78	0.2	0.2	0.3
Spot	30,313.0	$2.14	$2.85	$3.78	64.9	86.4	114.4
Total (Other Saltwater)	**128,820.0**	**$2.14**	**$2.85**	**$3.78**	**276.0**	**367.0**	**486.0**
Total (Unidentified)	**1,945.0**	**$2.15**	**$2.86**	**$3.82**	**4.0**	**6.0**	**7.0**
Total (Undiscounted)	**133,897.0**	**.**	**.**	**.**	**290.0**	**390.0**	**529.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**257.0**	**346.0**	**469.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**249.0**	**335.0**	**453.0**

Table I-17: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 1 (I Everywhere) in the South Atlantic Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Flounders	491.0	$3.87	$5.61	$8.28	2.0	3.0	4.0
Total (Flatfish)	**491.0**	**$3.87**	**$5.61**	**$8.28**	**2.0**	**3.0**	**4.0**
Spotted seatrout	0.0	$2.72	$5.72	$12.04	0.0	0.0	0.0
Weakfish	224.0	$2.72	$5.72	$12.04	1.0	1.0	3.0
Total (Small Game)	**224.0**	**$2.72**	**$5.72**	**$12.04**	**1.0**	**1.0**	**3.0**
Croakers	1,762.0	$2.14	$2.85	$3.78	3.8	5.0	6.7
Pinfish	0.0	$2.14	$2.85	$3.78	0.0	0.0	0.0
Silver perch	48.0	$2.14	$2.85	$3.78	0.1	0.1	0.2
Spot	12,733.0	$2.14	$2.85	$3.78	27.1	35.9	48.2
Total (Other Saltwater)	**14,543.0**	**$2.14**	**$2.85**	**$3.78**	**31.0**	**41.0**	**55.0**
Total (Unidentified)	**624.0**	**$2.15**	**$2.86**	**$3.82**	**1.0**	**2.0**	**2.0**
Total (Undiscounted)	**15,882.0**	**.**	**.**	**.**	**35.0**	**47.0**	**64.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**28.0**	**37.0**	**50.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**24.0**	**33.0**	**45.0**

Table I-18: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 2 (I Everywhere and E for Facilities > 125 MGD) in the South Atlantic Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Flounders	663.0	$3.87	$5.61	$8.28	3.0	4.0	5.0
Total (Flatfish)	**663.0**	**$3.87**	**$5.61**	**$8.28**	**3.0**	**4.0**	**5.0**
Spotted seatrout	1,583.0	$2.72	$5.72	$12.04	4.0	8.8	19.3
Weakfish	386.0	$2.72	$5.72	$12.04	1.0	2.2	4.7
Total (Small Game)	**1,969.0**	**$2.72**	**$5.72**	**$12.04**	**5.0**	**11.0**	**24.0**
Croakers	80,881.0	$2.14	$2.85	$3.78	173.2	230.2	305.2
Pinfish	1,266.0	$2.14	$2.85	$3.78	2.7	3.6	4.8
Silver perch	65.0	$2.14	$2.85	$3.78	0.1	0.2	0.2
Spot	25,654.0	$2.14	$2.85	$3.78	54.9	73.0	96.8
Total (Other Saltwater)	**107,866.0**	**$2.14**	**$2.85**	**$3.78**	**231.0**	**307.0**	**407.0**
Total (Unidentified)	**1,641.0**	**$2.15**	**$2.86**	**$3.82**	**4.0**	**5.0**	**6.0**
Total (Undiscounted)	**112,139.0**	**.**	**.**	**.**	**243.0**	**327.0**	**443.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**141.0**	**190.0**	**257.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**103.0**	**139.0**	**188.0**

Table I-19: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 3 (I&E Mortality Everywhere) in the South Atlantic Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Flounders	663.0	$3.87	$5.61	$8.28	3.0	4.0	5.0
Total (Flatfish)	**663.0**	**$3.87**	**$5.61**	**$8.28**	**3.0**	**4.0**	**5.0**
Spotted seatrout	1,586.0	$2.72	$5.72	$12.04	4.0	8.8	19.3
Weakfish	387.0	$2.72	$5.72	$12.04	1.0	2.2	4.7
Total (Small Game)	**1,972.0**	**$2.72**	**$5.72**	**$12.04**	**5.0**	**11.0**	**24.0**
Croakers	81,012.0	$2.14	$2.85	$3.78	174.0	231.0	306.0
Pinfish	1,268.0	$2.14	$2.85	$3.78	2.7	3.6	4.8
Silver perch	65.0	$2.14	$2.85	$3.78	0.1	0.2	0.2
Spot	25,677.0	$2.14	$2.85	$3.78	55.1	73.2	97.0
Total (Other Saltwater)	**108,023.0**	**$2.14**	**$2.85**	**$3.78**	**232.0**	**308.0**	**408.0**
Total (Unidentified)	**1,642.0**	**$2.15**	**$2.86**	**$3.82**	**4.0**	**5.0**	**6.0**
Total (Undiscounted)	**112,301.0**	**.**	**.**	**.**	**243.0**	**327.0**	**443.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**141.0**	**190.0**	**257.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**103.0**	**139.0**	**188.0**

Table I-20: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 4 (I for Facilities > 50 MGD) in the South Atlantic Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Flounders	491.0	$3.87	$5.61	$8.28	2.0	3.0	4.0
Total (Flatfish)	**491.0**	**$3.87**	**$5.61**	**$8.28**	**2.0**	**3.0**	**4.0**
Spotted seatrout	0.0	$2.72	$5.72	$12.04	0.0	0.0	0.0
Weakfish	224.0	$2.72	$5.72	$12.04	1.0	1.0	3.0
Total (Small Game)	**224.0**	**$2.72**	**$5.72**	**$12.04**	**1.0**	**1.0**	**3.0**
Croakers	1,762.0	$2.14	$2.85	$3.78	3.8	5.0	6.7
Pinfish	0.0	$2.14	$2.85	$3.78	0.0	0.0	0.0
Silver perch	48.0	$2.14	$2.85	$3.78	0.1	0.1	0.2
Spot	12,733.0	$2.14	$2.85	$3.78	27.1	35.9	48.2
Total (Other Saltwater)	**14,543.0**	**$2.14**	**$2.85**	**$3.78**	**31.0**	**41.0**	**55.0**
Total (Unidentified)	**624.0**	**$2.15**	**$2.86**	**$3.82**	**1.0**	**2.0**	**2.0**
Total (Undiscounted)	**15,882.0**	**.**	**.**	**.**	**35.0**	**47.0**	**64.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**28.0**	**37.0**	**50.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**24.0**	**33.0**	**45.0**

Gulf of Mexico

Table I-21: Recreational Fishing Benefits from Eliminating Baseline I&E Mortality Losses at In-scope Facilities in the Gulf of Mexico Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Mackerels	1,156.0	$2.87	$5.63	$11.04	3.3	6.5	12.8
Red drum	26,719.0	$2.87	$5.63	$11.04	76.6	150.4	294.9
Spotted seatrout	512,503.0	$2.87	$5.63	$11.04	1,470.0	2,885.1	5,656.4
Total (Small Game)	**540,378.0**	**$2.87**	**$5.63**	**$11.04**	**1,550.0**	**3,042.0**	**5,964.0**
Atlantic croaker	179,036.0	$2.14	$2.78	$3.61	382.3	497.3	646.6
Black drum	1,542,661.0	$2.14	$2.78	$3.61	3,294.3	4,284.6	5,571.5
Pinfish	257,750.0	$2.14	$2.78	$3.61	550.4	715.9	930.9
Sea bass	119.0	$2.14	$2.78	$3.61	0.3	0.3	0.4
Searobin	118,160.0	$2.14	$2.78	$3.61	252.3	328.2	426.7
Sheepshead	46.0	$2.14	$2.78	$3.61	0.1	0.1	0.2
Silver perch	1,474.0	$2.14	$2.78	$3.61	3.1	4.1	5.3
Spot	30,308.0	$2.14	$2.78	$3.61	64.7	84.2	109.5
Striped mullet	49,804.0	$2.14	$2.78	$3.61	106.4	138.3	179.9
Total (Other Saltwater)	**2,179,358.0**	**$2.14**	**$2.78**	**$3.61**	**4,654.0**	**6,053.0**	**7,871.0**
Total (Unidentified)	**131,612.0**	**$2.36**	**$3.66**	**$5.91**	**311.0**	**482.0**	**778.0**
Total (Undiscounted)	**2,851,347.0**	**.**	**.**	**.**	**6,515.0**	**9,576.0**	**14,612.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**6,022.0**	**8,852.0**	**13,506.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**5,999.0**	**8,818.0**	**13,456.0**

Table I-22: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 1 (I Everywhere) in the Gulf of Mexico Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Mackerels	885.0	$2.87	$5.63	$11.04	2.5	5.0	9.8
Red drum	17,368.0	$2.87	$5.63	$11.04	49.8	97.8	191.7
Spotted seatrout	351,547.0	$2.87	$5.63	$11.04	1,008.6	1,979.2	3,879.6
Total (Small Game)	**369,800.0**	**$2.87**	**$5.63**	**$11.04**	**1,061.0**	**2,082.0**	**4,081.0**
Atlantic croaker	136,979.0	$2.14	$2.78	$3.61	292.8	380.2	494.6
Black drum	2,576.0	$2.14	$2.78	$3.61	5.5	7.1	9.3
Pinfish	5,161.0	$2.14	$2.78	$3.61	11.0	14.3	18.6
Sea bass	91.0	$2.14	$2.78	$3.61	0.2	0.3	0.3
Searobin	65,096.0	$2.14	$2.78	$3.61	139.1	180.7	235.0
Sheepshead	0.0	$2.14	$2.78	$3.61	0.0	0.0	0.0
Silver perch	59.0	$2.14	$2.78	$3.61	0.1	0.2	0.2
Spot	18,785.0	$2.14	$2.78	$3.61	40.1	52.1	67.8
Striped mullet	4,732.0	$2.14	$2.78	$3.61	10.1	13.1	17.1
Total (Other Saltwater)	**233,480.0**	**$2.14**	**$2.78**	**$3.61**	**499.0**	**648.0**	**843.0**
Total (Unidentified)	**62,417.0**	**$2.36**	**$3.66**	**$5.91**	**147.0**	**228.0**	**369.0**
Total (Undiscounted)	**665,697.0**	**.**	**.**	**.**	**1,707.0**	**2,959.0**	**5,293.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**1,398.0**	**2,422.0**	**4,334.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**1,275.0**	**2,210.0**	**3,953.0**

Table I-23: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 2 (I Everywhere and E for Facilities > 125 MGD) in the Gulf of Mexico Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Mackerels	1,148.0	$2.87	$5.63	$11.04	3.3	6.5	12.7
Red drum	25,256.0	$2.87	$5.63	$11.04	72.5	142.2	278.7
Spotted seatrout	492,047.0	$2.87	$5.63	$11.04	1,412.2	2,770.3	5,430.6
Total (Small Game)	**518,450.0**	**$2.87**	**$5.63**	**$11.04**	**1,488.0**	**2,919.0**	**5,722.0**
Atlantic croaker	177,750.0	$2.14	$2.78	$3.61	379.5	493.6	642.0
Black drum	1,044,602.0	$2.14	$2.78	$3.61	2,230.5	2,900.8	3,772.7
Pinfish	176,490.0	$2.14	$2.78	$3.61	376.9	490.1	637.4
Sea bass	119.0	$2.14	$2.78	$3.61	0.3	0.3	0.4
Searobin	106,846.0	$2.14	$2.78	$3.61	228.1	296.7	385.9
Sheepshead	31.0	$2.14	$2.78	$3.61	0.1	0.1	0.1
Silver perch	1,021.0	$2.14	$2.78	$3.61	2.2	2.8	3.7
Spot	28,270.0	$2.14	$2.78	$3.61	60.4	78.5	102.1
Striped mullet	35,647.0	$2.14	$2.78	$3.61	76.1	99.0	128.7
Total (Other Saltwater)	**1,570,775.0**	**$2.14**	**$2.78**	**$3.61**	**3,354.0**	**4,362.0**	**5,673.0**
Total (Unidentified)	**114,838.0**	**$2.36**	**$3.66**	**$5.91**	**271.0**	**420.0**	**679.0**
Total (Undiscounted)	**2,204,063.0**	**.**	**.**	**.**	**5,113.0**	**7,701.0**	**12,073.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**3,225.0**	**4,866.0**	**7,642.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**2,491.0**	**3,760.0**	**5,908.0**

Table I-24: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 3 (I&E Mortality Everywhere) in the Gulf of Mexico Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Mackerels	1,149.0	$2.87	$5.63	$11.04	3.3	6.5	12.7
Red drum	25,279.0	$2.87	$5.63	$11.04	72.5	142.3	279.0
Spotted seatrout	492,479.0	$2.87	$5.63	$11.04	1,413.2	2,772.2	5,435.3
Total (Small Game)	**518,907.0**	**$2.87**	**$5.63**	**$11.04**	**1,489.0**	**2,921.0**	**5,727.0**
Atlantic croaker	177,884.0	$2.14	$2.78	$3.61	379.8	494.1	642.4
Black drum	1,047,164.0	$2.14	$2.78	$3.61	2,235.9	2,908.4	3,781.9
Pinfish	176,912.0	$2.14	$2.78	$3.61	377.7	491.4	638.9
Sea bass	119.0	$2.14	$2.78	$3.61	0.3	0.3	0.4
Searobin	106,965.0	$2.14	$2.78	$3.61	228.4	297.1	386.3
Sheepshead	31.0	$2.14	$2.78	$3.61	0.1	0.1	0.1
Silver perch	1,024.0	$2.14	$2.78	$3.61	2.2	2.8	3.7
Spot	28,298.0	$2.14	$2.78	$3.61	60.4	78.6	102.2
Striped mullet	35,724.0	$2.14	$2.78	$3.61	76.3	99.2	129.0
Total (Other Saltwater)	**1,574,119.0**	**$2.14**	**$2.78**	**$3.61**	**3,361.0**	**4,372.0**	**5,685.0**
Total (Unidentified)	**114,982.0**	**$2.36**	**$3.66**	**$5.91**	**272.0**	**421.0**	**680.0**
Total (Undiscounted)	**2,208,009.0**	**.**	**.**	**.**	**5,122.0**	**7,714.0**	**12,091.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**3,258.0**	**4,906.0**	**7,690.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**2,510.0**	**3,781.0**	**5,926.0**

Table I-25: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 4 (I for Facilities > 50 MGD) in the Gulf of Mexico Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Mackerels	878.0	$2.87	$5.63	$11.04	2.5	4.9	9.7
Red drum	17,237.0	$2.87	$5.63	$11.04	49.5	97.0	190.2
Spotted seatrout	348,894.0	$2.87	$5.63	$11.04	1,001.0	1,964.0	3,850.1
Total (Small Game)	**367,009.0**	**$2.87**	**$5.63**	**$11.04**	**1,053.0**	**2,066.0**	**4,050.0**
Atlantic croaker	135,945.0	$2.14	$2.78	$3.61	290.4	377.8	491.1
Black drum	2,556.0	$2.14	$2.78	$3.61	5.5	7.1	9.2
Pinfish	5,122.0	$2.14	$2.78	$3.61	10.9	14.2	18.5
Sea bass	91.0	$2.14	$2.78	$3.61	0.2	0.3	0.3
Searobin	64,604.0	$2.14	$2.78	$3.61	138.0	179.6	233.4
Sheepshead	0.0	$2.14	$2.78	$3.61	0.0	0.0	0.0
Silver perch	58.0	$2.14	$2.78	$3.61	0.1	0.2	0.2
Spot	18,644.0	$2.14	$2.78	$3.61	39.8	51.8	67.3
Striped mullet	4,696.0	$2.14	$2.78	$3.61	10.0	13.1	17.0
Total (Other Saltwater)	**231,717.0**	**$2.14**	**$2.78**	**$3.61**	**495.0**	**644.0**	**837.0**
Total (Unidentified)	**61,946.0**	**$2.36**	**$3.66**	**$5.91**	**146.0**	**227.0**	**366.0**
Total (Undiscounted)	**660,672.0**	**.**	**.**	**.**	**1,694.0**	**2,936.0**	**5,253.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**1,387.0**	**2,404.0**	**4,301.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**1,265.0**	**2,193.0**	**3,923.0**

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Table I-26: Recreational Fishing Benefits from Eliminating Baseline I&E Mortality Losses at In-scope Facilities in the Great Lakes Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	23.0	$4.42	$8.56	$16.61	0.1	203.0	394.0
White bass	23,688.0	$4.42	$8.56	$16.61	104.9	203.0	394.0
Total (Bass)	**23,710.0**	**$4.42**	**$8.56**	**$16.61**	**105.0**	**203.0**	**394.0**
Whitefish	69,428.0	$6.10	$9.43	$14.66	424.0	655.0	1,018.0
Total (Other Trout)	**69,428.0**	**$6.10**	**$9.43**	**$14.66**	**424.0**	**655.0**	**1,018.0**
Black crappie	11.0	$0.70	$1.33	$2.50	0.0	0.0	0.0
Bluegill	27.0	$0.70	$1.33	$2.50	0.0	0.0	0.1
Channel catfish	571.0	$0.70	$1.33	$2.50	0.4	0.8	1.4
Crappie	4,785.0	$0.70	$1.33	$2.50	3.3	6.3	12.0
Rainbow smelt	5,802.0	$0.70	$1.33	$2.50	4.1	7.7	14.5
Sculpin	6,516.0	$0.70	$1.33	$2.50	4.6	8.6	16.3
Smelts	14,657.0	$0.70	$1.33	$2.50	10.2	19.3	36.6
Sunfish	13,996.0	$0.70	$1.33	$2.50	9.8	18.5	35.0
Yellow perch	18,055.0	$0.70	$1.33	$2.50	12.6	23.8	45.1
Total (Panfish)	**64,420.0**	**$0.70**	**$1.33**	**$2.50**	**45.0**	**85.0**	**161.0**
Salmon	1,253.0	$8.16	$13.27	$21.61	10.0	17.0	27.0
Total (Salmon)	**1,253.0**	**$8.16**	**$13.27**	**$21.61**	**10.0**	**17.0**	**27.0**
Northern Pike	0.0	$2.18	$4.11	$7.80	0.0	0.0	0.0
Walleye	250.0	$2.18	$4.11	$7.80	1.0	1.0	2.0
Total (Walleye/Pike)	**250.0**	**$2.18**	**$4.11**	**$7.80**	**1.0**	**1.0**	**2.0**
Total (Unidentified)	**190,587.0**	**$3.33**	**$6.22**	**$11.71**	**635.0**	**1,185.0**	**2,232.0**
Total (Undiscounted)	**349,648.0**	**.**	**.**	**.**	**1,219.0**	**2,146.0**	**3,834.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**1,127.0**	**1,984.0**	**3,544.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**1,123.0**	**1,977.0**	**3,530.0**

Table I-27: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 1 (I Everywhere) in the Great Lakes Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	19.0	$4.42	$8.56	$16.61	0.1	60.0	116.0
White bass	6,939.0	$4.42	$8.56	$16.61	30.9	60.0	116.0
Total (Bass)	**6,958.0**	**$4.42**	**$8.56**	**$16.61**	**31.0**	**60.0**	**116.0**
Whitefish	60,141.0	$6.10	$9.43	$14.66	367.0	567.0	882.0
Total (Other Trout)	**60,141.0**	**$6.10**	**$9.43**	**$14.66**	**367.0**	**567.0**	**882.0**
Black crappie	9.0	$0.70	$1.33	$2.50	0.0	0.0	0.0
Bluegill	23.0	$0.70	$1.33	$2.50	0.0	0.0	0.1
Channel catfish	460.0	$0.70	$1.33	$2.50	0.3	0.6	1.1
Crappie	112.0	$0.70	$1.33	$2.50	0.1	0.1	0.3
Rainbow smelt	4,248.0	$0.70	$1.33	$2.50	2.9	5.6	10.6
Sculpin	290.0	$0.70	$1.33	$2.50	0.2	0.4	0.7
Smelts	12,641.0	$0.70	$1.33	$2.50	8.7	16.6	31.6
Sunfish	192.0	$0.70	$1.33	$2.50	0.1	0.3	0.5
Yellow perch	12,437.0	$0.70	$1.33	$2.50	8.6	16.4	31.1
Total (Panfish)	**30,413.0**	**$0.70**	**$1.33**	**$2.50**	**21.0**	**40.0**	**76.0**
Salmon	845.0	$8.16	$13.27	$21.61	7.0	11.0	18.0
Total (Salmon)	**845.0**	**$8.16**	**$13.27**	**$21.61**	**7.0**	**11.0**	**18.0**
Northern Pike	0.0	$2.18	$4.11	$7.80	0.0	0.0	0.0
Walleye	217.0	$2.18	$4.11	$7.80	0.0	1.0	2.0
Total (Walleye/Pike)	**217.0**	**$2.18**	**$4.11**	**$7.80**	**0.0**	**1.0**	**2.0**
Total (Unidentified)	**77,515.0**	**$3.33**	**$6.22**	**$11.71**	**258.0**	**482.0**	**908.0**
Total (Undiscounted)	**176,089.0**	**.**	**.**	**.**	**685.0**	**1,162.0**	**2,001.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**561.0**	**951.0**	**1,638.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**511.0**	**867.0**	**1,495.0**

Table I-28: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 2 (I Everywhere and E for Facilities > 125 MGD) in the Great Lakes Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	22.0	$4.42	$8.56	$16.61	0.1	175.0	340.0
White bass	20,444.0	$4.42	$8.56	$16.61	90.9	175.0	340.0
Total (Bass)	**20,466.0**	**$4.42**	**$8.56**	**$16.61**	**91.0**	**175.0**	**340.0**
Whitefish	68,676.0	$6.10	$9.43	$14.66	419.0	648.0	1,007.0
Total (Other Trout)	**68,676.0**	**$6.10**	**$9.43**	**$14.66**	**419.0**	**648.0**	**1,007.0**
Black crappie	10.0	$0.70	$1.33	$2.50	0.0	0.0	0.0
Bluegill	27.0	$0.70	$1.33	$2.50	0.0	0.0	0.1
Channel catfish	557.0	$0.70	$1.33	$2.50	0.4	0.7	1.4
Crappie	3,846.0	$0.70	$1.33	$2.50	2.7	5.1	9.6
Rainbow smelt	5,568.0	$0.70	$1.33	$2.50	3.9	7.4	13.9
Sculpin	5,267.0	$0.70	$1.33	$2.50	3.7	7.0	13.1
Smelts	14,487.0	$0.70	$1.33	$2.50	10.2	19.2	36.1
Sunfish	11,220.0	$0.70	$1.33	$2.50	7.9	14.9	28.0
Yellow perch	17,155.0	$0.70	$1.33	$2.50	12.1	22.7	42.8
Total (Panfish)	**58,137.0**	**$0.70**	**$1.33**	**$2.50**	**41.0**	**77.0**	**145.0**
Salmon	1,187.0	$8.16	$13.27	$21.61	10.0	16.0	26.0
Total (Salmon)	**1,187.0**	**$8.16**	**$13.27**	**$21.61**	**10.0**	**16.0**	**26.0**
Northern Pike	0.0	$2.18	$4.11	$7.80	0.0	0.0	0.0
Walleye	247.0	$2.18	$4.11	$7.80	1.0	1.0	2.0
Total (Walleye/Pike)	**248.0**	**$2.18**	**$4.11**	**$7.80**	**1.0**	**1.0**	**2.0**
Total (Unidentified)	**169,259.0**	**$3.33**	**$6.22**	**$11.71**	**564.0**	**1,053.0**	**1,982.0**
Total (Undiscounted)	**317,974.0**	**.**	**.**	**.**	**1,124.0**	**1,970.0**	**3,502.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**720.0**	**1,261.0**	**2,241.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**559.0**	**979.0**	**1,739.0**

Table I-29: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 3 (I&E Mortality Everywhere) in the Great Lakes Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	23.0	$4.42	$8.56	$16.61	0.1	177.0	343.0
White bass	20,651.0	$4.42	$8.56	$16.61	90.9	177.0	343.0
Total (Bass)	**20,674.0**	**$4.42**	**$8.56**	**$16.61**	**91.0**	**177.0**	**343.0**
Whitefish	68,832.0	$6.10	$9.43	$14.66	420.0	649.0	1,009.0
Total (Other Trout)	**68,832.0**	**$6.10**	**$9.43**	**$14.66**	**420.0**	**649.0**	**1,009.0**
Black crappie	10.0	$0.70	$1.33	$2.50	0.0	0.0	0.0
Bluegill	27.0	$0.70	$1.33	$2.50	0.0	0.0	0.1
Channel catfish	559.0	$0.70	$1.33	$2.50	0.4	0.7	1.4
Crappie	3,902.0	$0.70	$1.33	$2.50	2.7	5.2	9.7
Rainbow smelt	5,590.0	$0.70	$1.33	$2.50	3.9	7.4	13.9
Sculpin	5,343.0	$0.70	$1.33	$2.50	3.7	7.1	13.3
Smelts	14,520.0	$0.70	$1.33	$2.50	10.2	19.3	36.2
Sunfish	11,386.0	$0.70	$1.33	$2.50	8.0	15.2	28.4
Yellow perch	17,232.0	$0.70	$1.33	$2.50	12.1	22.9	43.0
Total (Panfish)	**58,570.0**	**$0.70**	**$1.33**	**$2.50**	**41.0**	**78.0**	**146.0**
Salmon	1,192.0	$8.16	$13.27	$21.61	10.0	16.0	26.0
Total (Salmon)	**1,192.0**	**$8.16**	**$13.27**	**$21.61**	**10.0**	**16.0**	**26.0**
Northern Pike	0.0	$2.18	$4.11	$7.80	0.0	0.0	0.0
Walleye	248.0	$2.18	$4.11	$7.80	1.0	1.0	2.0
Total (Walleye/Pike)	**248.0**	**$2.18**	**$4.11**	**$7.80**	**1.0**	**1.0**	**2.0**
Total (Unidentified)	**170,680.0**	**$3.33**	**$6.22**	**$11.71**	**569.0**	**1,062.0**	**1,999.0**
Total (Undiscounted)	**320,196.0**	**.**	**.**	**.**	**1,131.0**	**1,982.0**	**3,526.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**725.0**	**1,271.0**	**2,261.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**561.0**	**984.0**	**1,750.0**

Table I-30: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 4 (I for Facilities > 50 <MGD) in the Great Lakes Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	19.0	$4.42	$8.56	$16.61	0.1	59.0	115.0
White bass	6,880.0	$4.42	$8.56	$16.61	30.9	59.0	115.0
Total (Bass)	**6,900.0**	**$4.42**	**$8.56**	**$16.61**	**31.0**	**59.0**	**115.0**
Whitefish	59,632.0	$6.10	$9.43	$14.66	364.0	563.0	874.0
Total (Other Trout)	**59,632.0**	**$6.10**	**$9.43**	**$14.66**	**364.0**	**563.0**	**874.0**
Black crappie	9.0	$0.70	$1.33	$2.50	0.0	0.0	0.0
Bluegill	23.0	$0.70	$1.33	$2.50	0.0	0.0	0.1
Channel catfish	456.0	$0.70	$1.33	$2.50	0.3	0.6	1.1
Crappie	111.0	$0.70	$1.33	$2.50	0.1	0.1	0.3
Rainbow smelt	4,212.0	$0.70	$1.33	$2.50	2.9	5.6	10.5
Sculpin	287.0	$0.70	$1.33	$2.50	0.2	0.4	0.7
Smelts	12,534.0	$0.70	$1.33	$2.50	8.7	16.6	31.2
Sunfish	190.0	$0.70	$1.33	$2.50	0.1	0.3	0.5
Yellow perch	12,332.0	$0.70	$1.33	$2.50	8.6	16.4	30.7
Total (Panfish)	**30,156.0**	**$0.70**	**$1.33**	**$2.50**	**21.0**	**40.0**	**75.0**
Salmon	838.0	$8.16	$13.27	$21.61	7.0	11.0	18.0
Total (Salmon)	**838.0**	**$8.16**	**$13.27**	**$21.61**	**7.0**	**11.0**	**18.0**
Northern Pike	0.0	$2.18	$4.11	$7.80	0.0	0.0	0.0
Walleye	215.0	$2.18	$4.11	$7.80	0.0	1.0	2.0
Total (Walleye/Pike)	**215.0**	**$2.18**	**$4.11**	**$7.80**	**0.0**	**1.0**	**2.0**
Total (Unidentified)	**76,860.0**	**$3.33**	**$6.22**	**$11.71**	**256.0**	**478.0**	**900.0**
Total (Undiscounted)	**174,601.0**	**.**	**.**	**.**	**679.0**	**1,152.0**	**1,984.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**556.0**	**943.0**	**1,624.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**507.0**	**860.0**	**1,482.0**

I.6 Inland

Table I-31: Recreational Fishing Benefits from Eliminating Baseline I&E Mortality Losses at In-scope Facilities in the Inland Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	190,994.0	$4.28	$9.01	$19.08	818.3	1,721.3	3,643.5
White bass	1,656,537.0	$4.28	$9.01	$19.08	7,097.7	14,929.7	31,600.6
Total (Bass)	**1,847,530.0**	**$4.28**	**$9.01**	**$19.08**	**7,916.0**	**16,651.0**	**35,244.0**
Whitefish	2,061.0	$1.52	$2.83	$5.29	3.0	6.0	11.0
Total (Other Trout)	**2,061.0**	**$1.52**	**$2.83**	**$5.29**	**3.0**	**6.0**	**11.0**
Black bullhead	31,025.0	$0.53	$1.06	$2.10	16.4	32.8	65.3
Black crappie	145,478.0	$0.53	$1.06	$2.10	76.9	153.7	306.0
Bluegill	433,471.0	$0.53	$1.06	$2.10	229.0	458.0	911.7
Brown bullhead	14,807.0	$0.53	$1.06	$2.10	7.8	15.6	31.1
Bullhead	5,390.0	$0.53	$1.06	$2.10	2.8	5.7	11.3
Channel catfish	441,689.0	$0.53	$1.06	$2.10	233.4	466.7	929.0
Crappie	386,810.0	$0.53	$1.06	$2.10	204.4	408.7	813.6
Menhaden	308.0	$0.53	$1.06	$2.10	0.2	0.3	0.6
Rainbow smelt	9,240.0	$0.53	$1.06	$2.10	4.9	9.8	19.4
Smelts	1.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Sunfish	1,511,686.0	$0.53	$1.06	$2.10	798.7	1,597.3	3,179.6
White Perch	5,479.0	$0.53	$1.06	$2.10	2.9	5.8	11.5
Yellow perch	625,983.0	$0.53	$1.06	$2.10	330.7	661.5	1,316.7
Total (Panfish)	**3,611,368.0**	**$0.53**	**$1.06**	**$2.10**	**1,908.0**	**3,816.0**	**7,596.0**
Salmon	5.0	$8.16	$13.27	$21.61	0.0	0.0	0.0
Total (Salmon)	**5.0**	**$8.16**	**$13.27**	**$21.61**	**0.0**	**0.0**	**0.0**
American shad	3,070.0	$1.61	$5.36	$18.07	5.0	16.5	55.4
Striped bass	19,797.0	$1.61	$5.36	$18.07	32.2	106.2	357.3
Sturgeon	1,735.0	$1.61	$5.36	$18.07	2.8	9.3	31.3
Total (Small Game)	**24,603.0**	**$1.61**	**$5.36**	**$18.07**	**40.0**	**132.0**	**444.0**
Northern pike	36.0	$1.98	$4.10	$8.53	0.1	0.1	0.3
Sauger	180,270.0	$1.98	$4.10	$8.53	357.2	739.7	1,537.2
Walleye	209,854.0	$1.98	$4.10	$8.53	415.8	861.1	1,789.5
Total (Walleye/Pike)	**390,160.0**	**$1.98**	**$4.10**	**$8.53**	**773.0**	**1,601.0**	**3,327.0**
Total (Unidentified)	**6,716,737.0**	**$1.08**	**$2.23**	**$4.60**	**7,283.0**	**14,985.0**	**30,898.0**
Total (Undiscounted)	**12,592,464.0**	**.**	**.**	**.**	**17,923.0**	**37,191.0**	**77,520.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**16,566.0**	**34,376.0**	**71,653.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**16,504.0**	**34,247.0**	**71,384.0**

Table I-32: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 1 (I Everywhere) in the Inland Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	9,573.0	$4.28	$9.01	$19.08	41.0	86.3	182.6
White bass	649,610.0	$4.28	$9.01	$19.08	2,783.0	5,854.7	12,392.4
Total (Bass)	**659,182.0**	**$4.28**	**$9.01**	**$19.08**	**2,824.0**	**5,941.0**	**12,575.0**
Whitefish	1,642.0	$1.52	$2.83	$5.29	2.0	5.0	9.0
Total (Other Trout)	**1,642.0**	**$1.52**	**$2.83**	**$5.29**	**2.0**	**5.0**	**9.0**
Black bullhead	25,176.0	$0.53	$1.06	$2.10	13.3	26.6	53.0
Black crappie	14,071.0	$0.53	$1.06	$2.10	7.4	14.9	29.6
Bluegill	334,160.0	$0.53	$1.06	$2.10	176.6	353.1	703.0
Brown bullhead	4,771.0	$0.53	$1.06	$2.10	2.5	5.0	10.0
Bullhead	3,245.0	$0.53	$1.06	$2.10	1.7	3.4	6.8
Channel catfish	228,275.0	$0.53	$1.06	$2.10	120.6	241.2	480.2
Crappie	24,144.0	$0.53	$1.06	$2.10	12.8	25.5	50.8
Menhaden	258.0	$0.53	$1.06	$2.10	0.1	0.3	0.5
Rainbow smelt	3,097.0	$0.53	$1.06	$2.10	1.6	3.3	6.5
Smelts	1.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Sunfish	193,777.0	$0.53	$1.06	$2.10	102.4	204.8	407.6
White Perch	4,067.0	$0.53	$1.06	$2.10	2.1	4.3	8.6
Yellow perch	298,679.0	$0.53	$1.06	$2.10	157.8	315.6	628.3
Total (Panfish)	**1,133,719.0**	**$0.53**	**$1.06**	**$2.10**	**599.0**	**1,198.0**	**2,385.0**
Salmon	4.0	$8.16	$13.27	$21.61	0.0	0.0	0.0
Total (Salmon)	**4.0**	**$8.16**	**$13.27**	**$21.61**	**0.0**	**0.0**	**0.0**
American shad	2,569.0	$1.61	$5.36	$18.07	4.1	13.7	46.4
Striped bass	16,562.0	$1.61	$5.36	$18.07	26.6	88.3	299.3
Sturgeon	184.0	$1.61	$5.36	$18.07	0.3	1.0	3.3
Total (Small Game)	**19,315.0**	**$1.61**	**$5.36**	**$18.07**	**31.0**	**103.0**	**349.0**
Northern pike	30.0	$1.98	$4.10	$8.53	0.1	0.1	0.3
Sauger	7,809.0	$1.98	$4.10	$8.53	15.6	32.0	66.6
Walleye	13,152.0	$1.98	$4.10	$8.53	26.3	53.9	112.2
Total (Walleye/Pike)	**20,991.0**	**$1.98**	**$4.10**	**$8.53**	**42.0**	**86.0**	**179.0**
Total (Unidentified)	**2,486,184.0**	**$1.08**	**$2.23**	**$4.60**	**2,696.0**	**5,547.0**	**11,437.0**
Total (Undiscounted)	**4,321,037.0**	**.**	**.**	**.**	**6,194.0**	**12,880.0**	**26,933.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**5,071.0**	**10,545.0**	**22,049.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**4,626.0**	**9,619.0**	**20,115.0**

Table I-33: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 2 (I Everywhere and E for Facilities > 125 MGD) in the Inland Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	157,772.0	$4.28	$9.01	$19.08	676.0	1,421.9	3,009.7
White bass	1,469,625.0	$4.28	$9.01	$19.08	6,297.0	13,245.1	28,035.3
Total (Bass)	**1,627,397.0**	**$4.28**	**$9.01**	**$19.08**	**6,973.0**	**14,667.0**	**31,045.0**
Whitefish	1,977.0	$1.52	$2.83	$5.29	3.0	6.0	10.0
Total (Other Trout)	**1,977.0**	**$1.52**	**$2.83**	**$5.29**	**3.0**	**6.0**	**10.0**
Black bullhead	29,849.0	$0.53	$1.06	$2.10	15.8	31.5	62.8
Black crappie	121,385.0	$0.53	$1.06	$2.10	64.1	128.3	255.3
Bluegill	413,894.0	$0.53	$1.06	$2.10	218.7	437.3	870.6
Brown bullhead	12,951.0	$0.53	$1.06	$2.10	6.8	13.7	27.2
Bullhead	4,984.0	$0.53	$1.06	$2.10	2.6	5.3	10.5
Channel catfish	401,691.0	$0.53	$1.06	$2.10	212.2	424.4	844.9
Crappie	320,377.0	$0.53	$1.06	$2.10	169.3	338.5	673.9
Menhaden	298.0	$0.53	$1.06	$2.10	0.2	0.3	0.6
Rainbow smelt	8,104.0	$0.53	$1.06	$2.10	4.3	8.6	17.0
Smelts	1.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Sunfish	1,269,826.0	$0.53	$1.06	$2.10	670.9	1,341.7	2,671.0
White Perch	5,204.0	$0.53	$1.06	$2.10	2.7	5.5	10.9
Yellow perch	564,857.0	$0.53	$1.06	$2.10	298.4	596.8	1,188.1
Total (Panfish)	**3,153,418.0**	**$0.53**	**$1.06**	**$2.10**	**1,666.0**	**3,332.0**	**6,633.0**
Salmon	5.0	$8.16	$13.27	$21.61	0.0	0.0	0.0
Total (Salmon)	**5.0**	**$8.16**	**$13.27**	**$21.61**	**0.0**	**0.0**	**0.0**
American shad	2,968.0	$1.61	$5.36	$18.07	4.8	15.9	53.7
Striped bass	19,136.0	$1.61	$5.36	$18.07	30.9	102.4	346.1
Sturgeon	1,450.0	$1.61	$5.36	$18.07	2.3	7.8	26.2
Total (Small Game)	**23,554.0**	**$1.61**	**$5.36**	**$18.07**	**38.0**	**126.0**	**426.0**
Northern pike	35.0	$1.98	$4.10	$8.53	0.1	0.1	0.3
Sauger	148,695.0	$1.98	$4.10	$8.53	294.6	609.9	1,267.7
Walleye	173,822.0	$1.98	$4.10	$8.53	344.4	713.0	1,482.0
Total (Walleye/Pike)	**322,552.0**	**$1.98**	**$4.10**	**$8.53**	**639.0**	**1,323.0**	**2,750.0**
Total (Unidentified)	**5,932,467.0**	**$1.08**	**$2.23**	**$4.60**	**6,433.0**	**13,236.0**	**27,290.0**
Total (Undiscounted)	**11,061,370.0**	**.**	**.**	**.**	**15,751.0**	**32,690.0**	**68,154.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**9,578.0**	**19,879.0**	**41,449.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**7,361.0**	**15,277.0**	**31,856.0**

Table I-34: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 3 (I&E Mortality Everywhere) in the Inland Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	164,627.0	$4.28	$9.01	$19.08	705.4	1,483.6	3,140.5
White bass	1,509,996.0	$4.28	$9.01	$19.08	6,469.6	13,609.0	28,805.5
Total (Bass)	**1,674,624.0**	**$4.28**	**$9.01**	**$19.08**	**7,175.0**	**15,092.0**	**31,946.0**
Whitefish	1,999.0	$1.52	$2.83	$5.29	3.0	6.0	11.0
Total (Other Trout)	**1,999.0**	**$1.52**	**$2.83**	**$5.29**	**3.0**	**6.0**	**11.0**
Black bullhead	30,167.0	$0.53	$1.06	$2.10	15.9	31.9	63.5
Black crappie	126,378.0	$0.53	$1.06	$2.10	66.8	133.6	265.8
Bluegill	418,926.0	$0.53	$1.06	$2.10	221.4	442.8	881.2
Brown bullhead	13,347.0	$0.53	$1.06	$2.10	7.1	14.1	28.1
Bullhead	5,077.0	$0.53	$1.06	$2.10	2.7	5.4	10.7
Channel catfish	410,600.0	$0.53	$1.06	$2.10	217.0	434.0	863.7
Crappie	334,101.0	$0.53	$1.06	$2.10	176.6	353.1	702.7
Menhaden	300.0	$0.53	$1.06	$2.10	0.2	0.3	0.6
Rainbow smelt	8,347.0	$0.53	$1.06	$2.10	4.4	8.8	17.6
Smelts	1.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Sunfish	1,320,111.0	$0.53	$1.06	$2.10	697.6	1,395.3	2,776.7
White Perch	5,273.0	$0.53	$1.06	$2.10	2.8	5.6	11.1
Yellow perch	578,320.0	$0.53	$1.06	$2.10	305.6	611.2	1,216.4
Total (Panfish)	**3,250,948.0**	**$0.53**	**$1.06**	**$2.10**	**1,718.0**	**3,436.0**	**6,838.0**
Salmon	5.0	$8.16	$13.27	$21.61	0.0	0.0	0.0
Total (Salmon)	**5.0**	**$8.16**	**$13.27**	**$21.61**	**0.0**	**0.0**	**0.0**
American shad	2,997.0	$1.61	$5.36	$18.07	4.8	16.1	54.1
Striped bass	19,322.0	$1.61	$5.36	$18.07	30.8	103.8	348.7
Sturgeon	1,509.0	$1.61	$5.36	$18.07	2.4	8.1	27.2
Total (Small Game)	**23,828.0**	**$1.61**	**$5.36**	**$18.07**	**38.0**	**128.0**	**430.0**
Northern pike	35.0	$1.98	$4.10	$8.53	0.1	0.1	0.3
Sauger	155,207.0	$1.98	$4.10	$8.53	307.2	637.0	1,323.3
Walleye	181,266.0	$1.98	$4.10	$8.53	358.8	743.9	1,545.4
Total (Walleye/Pike)	**336,508.0**	**$1.98**	**$4.10**	**$8.53**	**666.0**	**1,381.0**	**2,869.0**
Total (Unidentified)	**6,101,138.0**	**$1.08**	**$2.23**	**$4.60**	**6,616.0**	**13,612.0**	**28,066.0**
Total (Undiscounted)	**11,389,049.0**	**.**	**.**	**.**	**16,216.0**	**33,654.0**	**70,160.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**9,966.0**	**20,684.0**	**43,122.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**7,592.0**	**15,755.0**	**32,847.0**

Table I-35: Recreational Fishing Benefits from Reducing I&E Mortality Losses at In-scope Facilities Under Option 4 (I for Facilities > 50 MGD) in the Inland Region, by Species (2009$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2009$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	9,339.0	$4.28	$9.01	$19.08	40.0	84.2	178.2
White bass	633,751.0	$4.28	$9.01	$19.08	2,715.0	5,711.7	12,089.8
Total (Bass)	**643,090.0**	**$4.28**	**$9.01**	**$19.08**	**2,755.0**	**5,796.0**	**12,268.0**
Whitefish	1,602.0	$1.52	$2.83	$5.29	2.0	5.0	8.0
Total (Other Trout)	**1,602.0**	**$1.52**	**$2.83**	**$5.29**	**2.0**	**5.0**	**8.0**
Black bullhead	24,562.0	$0.53	$1.06	$2.10	13.0	26.0	51.7
Black crappie	13,727.0	$0.53	$1.06	$2.10	7.2	14.5	28.9
Bluegill	326,002.0	$0.53	$1.06	$2.10	172.1	344.6	685.6
Brown bullhead	4,655.0	$0.53	$1.06	$2.10	2.5	4.9	9.8
Bullhead	3,165.0	$0.53	$1.06	$2.10	1.7	3.3	6.7
Channel catfish	222,702.0	$0.53	$1.06	$2.10	117.6	235.4	468.3
Crappie	23,555.0	$0.53	$1.06	$2.10	12.4	24.9	49.5
Menhaden	251.0	$0.53	$1.06	$2.10	0.1	0.3	0.5
Rainbow smelt	3,021.0	$0.53	$1.06	$2.10	1.6	3.2	6.4
Smelts	1.0	$0.53	$1.06	$2.10	0.0	0.0	0.0
Sunfish	189,046.0	$0.53	$1.06	$2.10	99.8	199.8	397.6
White Perch	3,967.0	$0.53	$1.06	$2.10	2.1	4.2	8.3
Yellow perch	291,387.0	$0.53	$1.06	$2.10	153.9	308.0	612.8
Total (Panfish)	**1,106,041.0**	**$0.53**	**$1.06**	**$2.10**	**584.0**	**1,169.0**	**2,326.0**
Salmon	4.0	$8.16	$13.27	$21.61	0.0	0.0	0.0
Total (Salmon)	**4.0**	**$8.16**	**$13.27**	**$21.61**	**0.0**	**0.0**	**0.0**
American shad	2,506.0	$1.61	$5.36	$18.07	4.0	13.4	45.2
Striped bass	16,158.0	$1.61	$5.36	$18.07	25.7	86.6	291.6
Sturgeon	179.0	$1.61	$5.36	$18.07	0.3	1.0	3.2
Total (Small Game)	**18,843.0**	**$1.61**	**$5.36**	**$18.07**	**30.0**	**101.0**	**340.0**
Northern pike	29.0	$1.98	$4.10	$8.53	0.1	0.1	0.2
Sauger	7,619.0	$1.98	$4.10	$8.53	15.3	31.3	65.1
Walleye	12,831.0	$1.98	$4.10	$8.53	25.7	52.6	109.6
Total (Walleye/Pike)	**20,479.0**	**$1.98**	**$4.10**	**$8.53**	**41.0**	**84.0**	**175.0**
Total (Unidentified)	**2,425,487.0**	**$1.08**	**$2.23**	**$4.60**	**2,630.0**	**5,411.0**	**11,157.0**
Total (Undiscounted)	**4,215,546.0**	**.**	**.**	**.**	**6,043.0**	**12,566.0**	**26,275.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**4,947.0**	**10,287.0**	**21,511.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**4,513.0**	**9,384.0**	**19,623.0**

Appendix J: Methods Used in the Habitat Based Methodology for Estimating Nonuse Values

J.1 Equations for estimating nonuse values using a habitat based methodology

Equation J-1: estimating lost production from I&E mortality on an annual basis.

Productivity loss due to I&E mortality is calculated as:

$$SP_{x,tot} = \sum_{i=1}^{n} \sum_{j=1}^{k} L_{i,j,x} \times C_{i,j} \times M_i \times DM_i \qquad \text{Equation J-1}$$

where:

- $SP_{x,tot}$ is the estimated loss in regional production for all I&E mortality species under regulatory option x, measured in kg dry mass per year.
- $L_{i,x}$ is the number of individuals of species i (with n species in the region) at life history stage j (with k life history stages) lost to I&E mortality under regulatory option x. Measured in organisms per year.
- $C_{i,j}$ is the ratio used to convert losses of species i and life history stage j into age-1 equivalents.
- M_i is the mass of an individual of species i at age 1. Measured in kg.
- DM_i is the ratio of dry mass to wet mass for species i.

Equation J-2: Estimating habitat-based fish production

The calculation of secondary productivity per acre (SP_{rest}) is as follows:

$$SP_{rest} = PP \times (1 - E) \times TC_1 \times TC_2 \times TC_3 \qquad \text{Equation J-2}$$

where:

- PP is primary productivity per acre of restoration
- E is the rate of productivity export, the portion of primary productivity excluded from transfer to higher trophic levels
- TC_1 the trophic conversion efficiency from primary productivity to detritus
- TC_2 the trophic conversion efficiency from detritus to first level consumers
- TC_3 the trophic conversion efficiency from first level consumers to second level consumers

Equation J-3: Estimating habitat-based fish production

The number of habitat acres (*A*) estimated to generate annual productivity equivalent to reduction in I&E mortality achieved by regulatory option *x* is calculated for each region as:

$$A_x = \left(\sum_{i=1}^{n} SP_{i,x} \right) \Big/ SP_{rest} \qquad \text{Equation J-3}$$

where:

- A_x is the number needed to achieve ecological equivalence with option *x*
- $SP_{i,x}$ is the total increase in secondary productivity per year for species *i* under option *x*
- SP_{rest} is the total secondary productivity gained per year per acre or restoration

J.2 Estimated Primary Productivity and Carbon Export in Marine and Aquatic Habitats

Table J-1: Summary of Aboveground Primary Productivity (measured in kg dry mass acre^{-1} yr^{-1})

Species	Study Region(s)	Sample Size	Min	Max	Mean	Sources
Eelgrass *Zostera marina*	North Atlantic, Mid-Atlantic, and South Atlantic	6	934	7,561	3,745	Beal et al. (2004), Nixon and Oviatt (1972), Murray and Wetzel (1987), Rizzo and Wetzel (1985), Bach et al. (1986)
Smooth cordgrass *Spartina alterniflora*	North Atlantic and Mid-Atlantic	10	1,416	6,520	3,332	Reimold and Linthurst (1977)*, Valiela, Teal, and Sass (1975)*, Steever (1972)*, Walton (1972)*, Cahoon (1975)*, Mendelssohn and Marcellus (1976)*
Smooth cordgrass *Spartina alterniflora*	South Atlantic and Gulf of Mexico	13	1,331	16,148	6,372	Stroud and Cooper (1968)*, Marshall (1970)*, Odum and Fanning (1972)*, de la Cruz (1974)*, Kirby (1972)*, Kirby and Gooselink (1976)*
Turtle grass *Thalassia testudinum*	Gulf of Mexico	5	1,329	3,570	2,417	Tomasko et al. (1996), Kaldy and Dunton (2000)
Giant Kelp *Macrocystis pyrifera*	California	4	1,472	11,344	7,312	Dayton (1985), Rassweiler (2008)
Broadleaf cattail *Typha latifolia*	Great Lakes and Inland	14	2,024	12,971	6,199	Gustafson (1976)*, Penko and Pratt (1986), Grace and Wetzel (1982), Mitsch et al (2002), Smith and Kadlec (1985), Rocha and Goulden (2009), van der Valk and Davis (1978)*, Keefe (1972)*, Whigham and Simpson (1975)*, Johnson (1970)*

Sample size is the number of estimates included in calculation of the mean value. The sample size differs from the number of sources because several studies provide multiple productivity values from different sites.

Values reported in units of g C m^{-2} day^{-1} were converted using specifes-specific factors.

- Eelgrass – carbon accounts for 38% of dry weight biomass (Thom 1988).
- Smooth cordgrass - carbon accounts for 45% of dry weight biomass (French McCay and Rowe 2003; Gallagher 1975).
- Turtle grass - carbon accounts for 36.4% of dry weight biomass (Fourqurean and Zieman 2002).
- Kelp – carbon accounts for 33% of dry weight biomass (Dayton 1985).
- Broadleaf cattail - carbon accounts for 40.2% of dry weight biomass (Esteves et al. 2008).

* Indicates values were taken from USEPA (1980).

Table J-2: Estimates of Carbon Export from Salt Marshes					
Location	**C Export ($g\ C\ m^{-2}\ yr^{-1}$)**	**ANPP ($g\ C\ m^{-2}\ yr^{-1}$)**	**Export as % of NPP**	**Dominant Species**	**Source**
Cape Cod, MA	3	67.5	4.4%	*Spartina alternaflora*	Howes et al (1985)[1]
Flax Pond, NY	-53	372	-14.2%	*Spartina alterniflora*	Woodwell et al (1977)
Canary Creek, DE	159	252	63.1%	*Spartina alterniflora*	Roman & Daiber (1989)
Ware Creek, VA	115	599	19.2%	*Spartina alterniflora*	Axelrad et al. (1976)
Carter Creek, VA	142	599	23.7%	*Spartina alterniflora*	Axelrad et al. (1976)
Beaufort, NC	40	548	7.3%	*Spartina alterniflora*	Bach et al. (1986)*
Beaufort, NC	124	568	21.9%	*Spartina alterniflora*	Bach et al. (1986)*
Beaufort, NC	32	837	3.9%	*Spartina alterniflora*	Bach et al. (1986)*
Bly Creek, SC	252	1080	23.3%	*Spartina alterniflora*	Williams et al. (1992)*
Bly Creek, SC	493	1080	45.6%	*Spartina alterniflora*	Williams et al. (1992)*
North Inlet, SC	456	1059	43.1%	*Spartina alterniflora*	Dame et al (1986)
Bly Creek, SC	242	1028	23.5%	*Spartina alterniflora*	Dame et al. (1991)
Duplin River, GA	1090	2025	12.8-53.8%	*Spartina alterniflora*	Wang and Cai (2004)
Sapelo Island, GA	393	878	44.8%	*Spartina alterniflora*	Teal (1962)
Sapelo Island, GA	365	992	36.8%	*Spartina alterniflora*	Teal (1962)* [2]
Barataria Basin, LA	224	600	37.3%	*Panicum hemitomo* *Eleocharis sp*	Feijtel et al (1985)
Barataria Basin, LA	296	550	53.8%	*Spartina patens* *Distichlis spicata*	Feijtel et al (1985)
Barataria Basin, LA	183	860	21.3%	*Spartina alterniflora*	Feijtel et al (1985)
LA	226	1147	19.7%		Day et al. (1973)*
LA	47	926	5.1%		Hopkinson et al. (1978)*
LA	55	1267	4.3%		Hopkinson et al. (1978)*
LA	161	599	26.8%		Hopkinson et al. (1978)*
LA	821	2416	34.0%		Hopkinson et al. (1978)*
LA	80	540	14.9%		Hopkinson et al. (1978)*
LA	26	518	5.0%		White et al. (1978)*
Coon Creek, TX	25	559-900	2.7-4.5%	*Spartina patens* *Distichlis spicata*	Borey et al. (1983)
EMS-Dollard Marsh Netherlands	-125	500	-25.00%	*Puccinellietum maritime* *Spartina anglica*	Dankers et al (1984)
Kariega Marsh, South Africa	16	200-300	5.0-8.0%	*Spartina perennis, Chenolea diffusa*	Taylor & Allanson (1995)
Hong Kong	0	880	0.0%	*Phragmites communis*	Lee (1990)*
Unknown	58	105	55.8%		McLusky (1981)*
Unknown	51	181	28.2%		McLusky (1981)*
Unknown	142	1080	13.2%		Schlesinger (1997)*
Unknown	431	1080	39.9%		Schlesinger (1997)*
Unknown	117	1080	10.8%		Schlesinger (1997)*
Unknown	99	1080	9.1%		Schlesinger (1997)*
Unknown	164	1080	15.2%		Schlesinger (1997)*

* Indicates values taken from Cebrian (2002).

[1] Carbon export for Howes et al. (1985) was calculated based on annual sediment budget in mol $m^{-2}\ yr^{-1}$.

[2] These values were calculated directly based on Teal (1962) and differ from values included in the meta-data of Cebrian (2002).

J.3 Regional Determination of Preferred Habitat

In the North Atlantic region, species accounting for the greatest proportion of I&E mortality [rock gunnel (42% of regional I&E mortality), winter founder (11%), radiated shanny (7%), cunner (7%), American sand lance (7%) and seaboard goby (7%)] are generally found in estuarine, sandy or nearshore rocky reef areas, and are not strongly associated with coastal wetlands (Fishbase 2009). Therefore, eelgrass was selected for scaling I&E mortality losses in the North Atlantic.

In the Mid-Atlantic region, species with the greatest I&E mortality by mass [bay anchovy (65% of the regional I&E mortality losses), blue crab (10%), Atlantic menhaden (5%) and spot (4%)] are commonly found in tidal salt marshes (Fishbase 2009). Consequently, the preferred habitat for restoration projects is smooth cordgrass, the dominant foundation species in Atlantic salt marshes.

Similarly, in the South Atlantic, important I&E mortality species [bay anchovy (71%), forage shrimp (13%), gobies (4%) and other forage fish (4%)] are associated with salt marshes dominated by cordgrass. Thus, saltmarsh is the preferred habitat choice for this region.

In the Gulf Coast region, there is less dominance by a single species in I&E mortality results [pink shrimp (30%) blue crab (15%) bay anchovy (14%) and other forage fish (11%)], and there is no strong ecological argument for preferring turtle grass or saltmarsh. Consequently, due to its higher productivity, smooth cordgrass was chosen as the preferred habitat type for regional restoration calculations.

In California, the preferred habitat choice is the highly productive giant kelp (*M. pyrifera*), known to be a nursery habitat for many fish species.

In the Great Lakes and Inland regions, the freshwater macrophyte broadleaf cattail (*T. latifolia*) was selected for restoration calculations.

J.4 Willingness to Pay for Fish Production and Other Aquatic Habitat Goods and Services

Table J-3: Studies Used to Estimate WTP Values for Fish Production Services and Habitat

Study	Survey Year	Location (State)	Habitat	WTP $acre^{-1}$ yr^{-1} (2009$)[1]	Population (Sample Size)	Change Valued	Survey Methods
Peconic Estuary Study (Johnston et al. 2002a; Johnston et al. 2001; Mazzotta 1996; Opaluch et al. 1995; Opaluch et al. 1998)	1995	New York	Eelgrass and Salt marsh	Eelgrass - $0.07608 Saltmarsh- $0.0672	East End Long Island Households (968 completed surveys)	Eelgrass presented at current level of 9,000 acres, "no action" level of 8,000 acres, and with restoration level of 11,000 acres. Wetlands presented at their current level of 16,000 acres, "no action" level of 12,000 acres, and with restoration level of 17,500 acres.	Used an original contingent choice study to estimate relative preferences of residents for preserving key natural and environmental resources.
Bauer, Cyr, and Swallow (2004)	2004	Rhode Island	Salt marsh	$0.0190	Rhode Island Households (320 in-person surveys administered)	Survey level included four levels of wetland preservation or restoration; 33, 64, 101, or 135 acres. One-time payment converted to annual value assuming 3% discount rate.	Stated-preference survey designed to elicit public preferences for salt marsh mitigation projects and to determine public willingness to trade off mitigation-site attributes such as cost, size, public access, and presence of endangered species.
De Zoysa (1995)	1994	Ohio	Freshwater wetlands	$0.0299	Residents of Maumee, Ohio (476 responses)	Wetlands program description indicated that the proposed program would restore and protect 3,000 acres of wetlands from a baseline of 10,000 existing acres that were declining.	The study used the contingent valuation method with seven versions of the survey, each of which described a different resource conservation program involving groundwater, surface water, wetlands, or some combination thereof.
Bishop et al. (2000)	1999	Wisconsin	Freshwater wetlands	$0.00125	Households within a ten county area around Green Bay (470 responses)	Restoration level ranging up to a 11,600 acre increase in wetlands within five miles of Green Bay, WI to support birds, fish, and other wildlife equivalent to a 20% increase from the 58,000 baseline acres. WTP reported here is the mid-point of marginal values for 5% and 20% changes.	Total Value Equivalency (TVE) study conducted to support restoration planning conducted as part of the Lower Fox River/Green Bay NRDA.

Table J-3: Studies Used to Estimate WTP Values for Fish Production Services and Habitat

Study	Survey Year	Location (State)	Habitat	WTP $acre^{-1}$ yr^{-1} (2009$)[1]	Population (Sample Size)	Change Valued	Survey Methods
Mullarky (1997; 1999)	1994	Wisconsin	Freshwater wetlands	$0.0082[2]	Wisconsin residents (239 complete surveys)	Case study of a highway expansion project in Northwest Wisconsin which would require filling of 110 acres of wetlands. One-time payment converted to annual value assuming 3% discount rate.	Contingent valuation study of Wisconsin wetlands. Losses would be mitigated by the creation of 220 acres of isolated basin along the highway; WTP reported here is based on a mean from the "scope group" which was not informed that mitigation was being conducted.
Blomquist and Whitehead (1998)	1990	Kentucky	Freshwater wetlands	$0.0056	Kentucky residents (379 responses)	WTP to purchase and manage 500 acres which if not purchased would be mined and reclaimed after ten years.	Contingent valuation study resulting in WTP values for four separate wetland types. WTP reported here is for the Flat creek persistent emergent wetland, which is most consistent with scaled habitat.
Whitehead and Blomquist (1991)	1989	Kentucky	Freshwater wetlands	$0.0037	Kentucky residents (215 responses)	WTP for purchase and management of the approximately 5,000 acres Clear Creek wetland which would be mined if not purchased.	Contingent valuation study with three groups with each presented different information about related environmental resources. Smaller sample than Blomquist and Whitehead (1998)

[1] WTP values were converted to 2009$ based on the Consumer Price Index (CPI).

[2] Mullarky (1997; 1999) present multiple WTP estimates based on the survey group used for the estimate ("base group" or "scope group") and certainty level treatment of the polychotomous choice format. The reported value is based for the "scope group", which was not informed regarding mitigation, and the highest certainty level for responses.

J.5 Narragansett Bay Wetland Restoration Study

J.5.1 Survey Development and Data Collection

EPA designed a survey instrument, entitled *Rhode Island Salt Marsh Restoration: 2001 Survey of Rhode Island Residents* to assess tradeoffs among attributes of salt marsh restoration plans. Development of this survey required more than 16 months and involved extensive background research, interviews with experts in salt marsh ecology and restoration, and 16 focus groups with more than 100 Rhode Island residents. Numerous pretests, including verbal protocol analysis (Schkade and Payne 1994) ensured that the survey language and format would be easily understood by respondents, and that respondents would have a common understanding of survey scenarios (cf. Johnston et al. 1995).

Johnston et al. (2002b) chose attributes distinguishing restoration plans based on background research, expert interviews, and focus groups. The authors tailored these attributes to reflect primary salt marsh services in the northeast United States that would be influenced by restoration activities, and characterized each wetland by the size of the marsh, together with effects of restoration, on (1) habitat for birds, (2) habitat for fish, (3) habitat for shellfish, (4) potential to control mosquito nuisance, (5) recreational access, and (6) household cost.[64] Based on the results of focus groups and expert interviews, habitat and mosquito control services were presented from a standardized, statewide perspective. For example, improvements to fish habitat were characterized as "ecological improvements to RI fish populations…[resulting from a particular restoration project]…as judged by wetlands experts, compared to all other potential salt marsh restoration projects in Rhode Island."

Following the general approach of Johnston et al. (1999), the conjoint (or multi-attribute choice) survey presented respondents with four sets of discrete choices, each involving two alternative, multi-attribute restoration plans. The authors used fractional factorial design to construct a range of survey questions with an orthogonal array of attribute levels, resulting in 80 contingent choice questions divided among 20 unique booklets. Attributes distinguishing plans were selected based on background research, expert interviews, and focus groups. All attributes were free to vary over their full range for both restoration plans presented in each question, with no imposed ordering of attribute levels between the two plans. Based on these attributes, respondents chose one of the two plans, or chose "Neither Plan."

The survey was conducted from September through December, 2001. Respondents were intercepted in person at Rhode Island Department of Motor Vehicle offices, public libraries, and other survey sites. Interviewers did not tell respondents that the survey concerned salt marsh restoration. Rather, interviewers asked respondents to participate in an important survey regarding "environmental issues in Rhode Island," to reduce the potential for topic-related nonresponse. Following the general approach of Johnston et al. (1999), the survey presented respondents with four sets of discrete choices, each involving two alternative, multi-attribute restoration plans. Attributes included in the survey included the size of salt marsh restoration, and the importance of (1) habitat for birds, (2) habitat for fish, (3) habitat for shellfish,

[64] Additional, non-habitat services that may be provided by salt water wetlands include, among others, nutrient transformation, storm buffering, and coastal erosion control. Interviews with experts on salt water wetland functions in New England (and Rhode Island in particular) indicated, however, that wetland restoration would provide negligible impacts on these non-habitat functions in the majority of cases. They based this assessment on the small size of most New England coastal wetlands, and on the fact that restoration may not always increase substantially the ability of a wetland to provide such functions as storm buffering or erosion control. Based on this advice, the survey focused mainly on wetland habitat functions.

(4) the potential for mosquito control, (5) recreational access, and (6) household cost. Based on variations in the presented attributes of conservation plans, respondents either chose either one of two plans presented, or chose “Neither Plan.” In total, interviewers collected 661 completed surveys, providing complete and usable responses to 2,341 individual contingent choice questions (89% of a potential 2,644).

J.5.2 Results

Table J-4 presents variables incorporated in the analysis of salt marsh restoration choices. These variables include: (1) a dummy variable identifying the “neither” option, (2) quadratic interactions between this dummy and certain demographic characteristics, and (3) variables for the restored salt marsh attributes. Mean values for salt marsh attributes (Table 9-5) indicate the mean values of these attributes over all completed surveys included in the analysis. The final column of the table calculates these mean values with "neither plan" data rows excluded. (As noted above, each wetland restoration choice included the option of choosing neither plan. In the multinomial logit data, these options are presented as a "plan" with zeros for all wetland attributes.)

Table J-5 presents results for a conditional logit model of survey data. The model is significant at $p < 0.0001$ (-2LnL P2=1157.56, df = 13); all individual parameter estimates are significant at $p < 0.05$, with most significant at $p < 0.01$.

The signs of parameter estimates correspond with prior expectations derived from focus groups, where prior expectations exist. Respondents favor plans that restore larger salt marshes; improve bird, fish, and shellfish habitat; control mosquitoes; provide public access; and result in lower costs to the household. Comparing preferences for habitat improvements and mosquito control (all measured on a ten-point scale), respondents placed the greatest weight on mosquito control, followed by habitat improvements for shellfish, fish, and birds, respectively. The likelihood of rejecting restoration outright (i.e., choosing neither plan) was smaller for members of environmental organizations, and larger for members of taxpayers organizations, lower income individuals, and more highly educated individuals (Johnston et al. 2002b). Changes in education and income do not influence the marginal utility of fish and shellfish habitat, or that of other wetland attributes.

Results of the conjoint analysis (i.e., the public survey results) presented by Johnston et al. (2002b) allow policy makers to rank restoration projects based on their estimated influence on residents’ welfare. These results also allow assessment of residents’ willingness to trade off elements of wetland restoration plans, or WTP for particular wetland attributes. Finally, for any specified restoration plan, provided that incremental gains or losses in wetland services are known, it allows the calculation of the proportion of the total gain in social value attributable to a particular service (e.g., fish habitat).

To estimate the proportion of value associated with fish habitat, in a representative, conservative scenario, EPA began with the average wetland restoration scenario considered by the Rhode Island survey sample. The mean values of wetland attributes presented to survey respondents provide the most representative set of results from which value proportions may be estimated, and forecast the value proportions that would result from an average survey respondent confronted with an average wetland restoration scenario, as characterized by the Rhode Island Salt Marsh Restoration Survey data. Excluding all “Neither Plan” scenarios, which offered zero restoration, Table J-4 summarizes the mean values for services considered by the Rhode Island sample.

Table J-4: Definitions and Summary Statistics for Model Variables for Narragansett Bay Wetland Restoration Study

Variable Name	Description	Whole Sample Mean (Std. Dev.)	Mean, Excluding "Neither Plan" Scenarios[a]
Neither	Neither=1 identifies "neither plan" options	0.333 (0.471)	0.000
Environ	Dummy variable identifying respondents with membership in environmental organizations	0.190 (0.392)	0.190
Taxgrp	Dummy variable identifying respondents with membership in taxpayer associations	0.023 (0.151)	0.023
Loincome	Dummy variable identifying respondents with household income less than $35,000/year	0.245) (0.430)	0.245
Hiedu	Dummy variable identifying respondents with greater than a four-year college degree	0.182 (0.386)	0.182
Birds	Ecological improvement to statewide bird populations resulting from specified salt marsh restoration plan, compared to all other potential salt marsh restoration plans in Rhode Island (0-10 scale)	2.761 (2.607)	4.141
Fish	Ecological improvement to statewide fish populations resulting from specified salt marsh restoration plan, compared to all other potential salt marsh restoration plans in Rhode Island (0-10 scale)	2.908 (2.653)	4.361
Shellfish	Ecological improvement to statewide shellfish populations resulting from specified salt marsh restoration plan, compared to all other potential salt marsh restoration plans in Rhode Island (0-10 scale)	2.907 (2.652)	4.362
Mosquito	Increased ability to control statewide mosquito nuisance resulting from specified salt marsh restoration plan, compared to all other potential salt marsh restoration plans in Rhode Island (0-10 scale)	2.908 (2.651)	4.362
Size	Size of restored salt marsh (minimum 3 acres; maximum 12 acres)	4.889 (4.397)	7.334
Pro-access	Dummy variable indicating that respondent feels that access to salt marshes should be "somewhat limited" or "unlimited"	0.837 (0.370)	0.837
Con-access	Dummy variable indicating that respondent feels that access to salt marshes should be "severely limited" or "prohibited"	0.227 (0.419)	0.163
Platform	Dummy variable indicating that restoration provides "viewing platforms" but no "trails"	0.222 (0.415)	0.340
Both	Dummy variable indicating that restoration provides both "viewing platforms" and "trails"	0.222 (0.415)	0.332
Cost	Annual cost of restoration plan in increased taxes (minimum $0; maximum $200)	63.169 (70.782)	94.754

[a] Each wetland restoration choice included the option of choosing neither plan. In the multinomial logit data, this option is presented as a "plan" with zeros for all wetland attributes. The final column of the table calculates means with the "neither plan" zeros excluded.

Although mean values are used for most attributes (i.e., wetland attributes or services considered by survey respondents in choice scenarios), changes in certain attributes are set to zero to correspond more closely with the policy scenario and with the Peconic study (because the purpose of this analysis is to assess the proportion of the Peconic wetland values that may reasonably be attributed to fish habitat services). For example, because the Peconic study survey did not specify or discuss the provision of viewing platforms or trails at preserved wetlands, EPA assumed that survey respondents to the Peconic study did not consider such provisions when making survey choices. Accordingly, in calculating value proportions in this analysis using the Rhode Island data, EPA assumed that viewing platforms and trails are not provided.

EPA also assumed that any wetland created or restored to provide fish habitat will likely not provide a great degree of additional mosquito control, because a large proportion of existing salt marshes have already been modified to minimize mosquito production.[65] For this reason, modern marsh restoration typically does not provide a significant increase in mosquito control. Rather, it often replaces older, more detrimental (to marsh function and habitat) forms of mosquito control with Open Marsh Water Management (OMWM), in which open water and natural fish predation is used to control mosquito nuisance (Kennish 2001). OMWM has not been an "unqualified success" at eliminating the mosquito nuisance (New York Conservationist 1997). Accordingly, for many salt marshes, the positive net effect of restoration on mosquito nuisance, if any, is often minimal. To generate the most conservative estimates, however, and in recognition of the fact that some salt marsh restoration projects may provide significant mosquito control, EPA also estimated value proportions assuming that significant additional mosquito control is provided. For all other wetland attributes included in the Rhode Island survey, EPA used the mean values shown in the final column of Table J-4.

Estimation of value proportions is based on the estimated utility function *v(.)*, which specifies the utility provided by a wetland restoration plan as a function of the attributes or services provided by that plan (Johnston et al. 2002b). That is, following the standard random utility model of Hanemann (1984), the underlying model specifies respondents' choices using the conditional logit specification, in which the probability (P_i) of choosing any wetland restoration plan *i* (plan A, plan B, or neither plan) over the two remaining options (*j* or *k*) is given by:

$$P_i = \frac{\exp[v_i(\cdot)]}{\exp[v_i(\cdot)] + \exp[v_j(\cdot)] + \exp[v_k(\cdot)]} \quad \text{Equation J-4}$$

where v(.) represents the relative benefits or utility resulting from each restoration option, including the "neither plan" option. The function v(.) is typically estimated as a simple function of program attributes (in this case wetland restoration); in practice linear, functional forms are often used (Johnston et al. 2002b).

From the assumptions and model noted above, the attribute definitions given in Table J-4, and the model results of Table J-5, the estimated utility function used to calculate value proportions is specified as

$$\begin{aligned} v(.) = 0.1191(birds) + 0.1465(fish) + 0.1587(shellfish) + \\ 0.1611(mosquito) + 0.0510(size) \end{aligned} \quad \text{Equation J-5}$$

If mosquito control is not provided, then *mosquito*=0. Given this linear specification, the proportion of wetland restoration value provided by the gain in fish habitat services is given by

$$\frac{v_{fish}(\cdot) - v_{fish}(\cdot)_{=0}}{v_{fish}(\cdot)} \quad \text{Equation J-6}$$

where $v(.)_{fish}$ represents the value of *v(.)* with the gain in fish habitat services set to its mean value (as described above), and $v(.)_{fish}$=0 represents the value of the function with the gain in fish habitat services set to zero.

[65]The mosquito control variable was included in the survey in response to the strong concern of Rhode Island residents over the impact of restoration on mosquitoes and related illnesses for which mosquitoes are the primary vector. Wetlands experts indicated, however, that salt marsh restoration had limited impact on mosquito populations in most cases.

Table J-5: Conditional Logit Results for Narragansett Bay Wetland restoration Study

	Parameter Estimate	Std. Error	z	P>|z|
Neither	1.157	0.193	5.98	0.0001
Neither x Environ	-1.182	0.223	-5.30	0.0001
Neither x Tax	0.868	0.365	2.38	0.0170
Neither x Loincome	0.310	0.144	2.16	0.0310
Neither x Hiedu	0.415	0.169	2.46	0.0140
Birds	0.119	0.015	7.78	0.0001
Fish	**0.147**	**0.016**	**9.36**	**0.0001**
Shellfish	**0.159**	**0.016**	**9.78**	**0.0001**
Mosquito	0.161	0.016	9.95	0.0001
Size	0.051	0.010	5.22	0.0001
Pro-access x Platform	0.168	0.083	2.03	0.0420
Pro-access x Both	0.431	0.084	5.11	0.0001
Cost	-0.007	0.001	-14.23	0.0001
-2LnL P^2	1157.56	Prob>P^2	0.0001	

Table J-6 shows the resulting value proportions, in which EPA calculated the proportion of wetland restoration value associated with different wetland services based on mean values of wetland attributes presented to survey respondents, as discussed above. Analogous methods were used to assess value proportions associated with shellfish and other habitat services; Table J-6 shows these results for comparison. The table also illustrates the results of a sensitivity analysis in which EPA calculated analogous value proportions for wetland habitat services, but allow wetland size to vary. Wetland size was allowed to vary from its minimum value in the Rhode Island survey data (3 acres) to its maximum value (12 acres), while holding habitat service changes constant. EPA chose these size values to be representative of unrestored salt water wetlands currently existing in Narragansett Bay, which are typically quite small (i.e., less than five acres). The three estimates of acreage are therefore likely closer to the "average" Rhode Island wetland than estimates based on larger acreages. (In actual wetlands, changes in restored acres are typically correlated with larger gains in habitat services (Johnston et al. 2002b). To illustrate even more conservative estimates, however, Table J-6 contains cases in which restored wetland size increases from the mean, without any resultant increase in habitat services.)

Across scenarios the proportion of value associated with fish habitat ranges from 0.2035 to 0.3231, with a mean value over all scenarios of 0.2564 (Table J-6). Scenario 1a is perhaps the most representative scenario for estimating value proportions for two reasons: (1) restored wetlands are not expected to provide additional mosquito control and (2) other wetland attributes are set to their mean values. Its results are somewhat higher than those of scenario 3a, which represents the mean value over all scenarios presented. To be conservative (i.e. low) in its estimates, EPA used the proportion calculated in scenario 3a (0.2564) as an estimate of the proportion of total wetland restoration value attributable to gains in fish habitat services, given representative, mean values for other wetland services.

Table J-6: Proportions of Restored Wetland Value Associate with Various Service Categories

Restoration Scenario	Percentage of Value Associated with Service:				
	Fish Habitat	Bird Habitat	Shellfish Habitat	Mosquito Control	Other[b]
1a: No additional mosquito control; mean values for all other attributes	**0.291**	0.224	0.315	0.000	0.170
1b: No additional mosquito control; mean values for habitat gains; Size=3 acres	**0.323**	0.249	0.350	0.000	0.077
1c: No additional mosquito control; mean values for habitat gains; size=12 acres	**0.262**	0.202	0.284	0.000	0.251
2a: Mosquito control at mean value; mean values for all other attributes	**0.220**	0.170	0.239	0.242	0.129
2b: Mosquito control at mean value; mean values for habitat gains; size=3 acres	**0.238**	0.184	0.258	0.262	0.057
2c: Mosquito control at mean value; mean values for habitat gains; size=12 acres	**0.204**	0.157	0.220	0.224	0.195
3a: Mean over all scenarios	**0.256**	0.198	0.278	0.121	0.147

[a] Results assume that restoration does not provide viewing platforms or hiking trails.

[b] Other services may include, among others, nutrient transformations, storm buffering, and coastal erosion control.

Although these numbers are not directly comparable to other results found in the literature, they appear to be reasonable and conservative compared to similar proportions generated for freshwater habitats. For example, Schulze et al. (1995) estimate that between 32.98 percent and 33.44 percent of WTP for resource cleanup in the Clark Fork River Basin was associated with "aquatic resources and riparian habitat" (p. 5-13).

EPA also considered directly the parametric results of Table J-5 for further support of the soundness of the proposed value proportions. Estimates presented in Table J-5 indicate that the parametric weights are similar among the dominant wetland services in Narragansett Bay (i.e., bird habitat services, fish habitat services, shellfish habitat services, and mosquito control). In other words, the parameter estimates are very similar among these four variables. This correspondence suggests that restoration providing similar scale improvements for each of these services should produce a roughly equivalent increment to utility. Given the four habitat services considered in the survey (including mosquito control), each service provides roughly 1/4 (or 25 percent) of the total marginal utility associated with the combination of habitat improvements and mosquito control. For wetlands that do not provide substantial access provisions (e.g., boardwalks) and that are of moderate or small size, it would be highly improbable for the proportion of value associated with fish habitat to fall significantly below the 25.64 percent approximation estimated here.

J.6 Determining the Affected Population and Estimating Aggregate Values

Table J-7: Number of Households by State and Percentage of Regional Habitat Acres Assigned to Each State.

State	No. of Households	California	North Atlantic	Mid-Atlantic	South Atlantic	Gulf of Mexico	Great Lakes	Inland
AL	1,836,096	-	-	-	-	-	-	5.90%
AR	1,132,706	-	-	-	-	-	-	1.53%
AZ	2,266,797	-	-	-	-	-	-	0.21%
CA	12,371,970	100.00%	-	-	-	-	-	<0.01%
CO	1,891,368	-	-	-	-	-	-	0.22%
CT	1,365,529	-	29.83%	-	-	-	-	0.14%
DC	268,559	-	-	-	-	-	-	<0.01%
DE	329,246	-	-	5.08%	-	-	-	0.02%
FL	7,252,011	-	-	-	70.27%	53.26%	-	0.54%
GA	3,472,892	-	-	-	2.66%	-	-	2.36%
IA	1,248,977	-	-	-	-	-	-	1.73%
IL	4,821,525	-	-	-	-	-	3.76%	7.30%
IN	2,501,050	-	-	-	-	-	11.63%	4.58%
KS	1,120,251	-	-	-	-	-	-	1.56%
KY	1,695,340	-	-	-	-	-	-	2.53%
LA	1,595,221	-	-	-	-	7.44%	-	5.02%
MA	2,533,224	-	49.80%	-	-	-	-	0.11%
MD	2,138,174	-	-	24.02%	-	-	-	0.34%
ME	561,927	-	3.54%	-	-	-	-	0.08%
MI	3,977,292	-	-	-	-	-	35.46%	1.62%
MN	2,095,360	-	-	-	-	-	1.27%	1.56%
MO	2,373,024	-	-	-	-	-	-	4.51%
MS	1,106,531	-	-	-	-	2.28%	-	0.66%
MT	383,318	-	-	-	-	-	-	0.13%
NC	3,562,025	-	-	-	19.12%	-	-	6.24%
ND	285,857	-	-	-	-	-	-	0.65%
NE	719,904	-	-	-	-	-	-	2.17%
NH	518,506	-	12.92%	-	-	-	-	0.17%
NJ	3,186,057	-	-	22.20%	-	-	-	0.08%
NM	735,720	-	-	-	-	-	-	0.03%
NV	947,691	-	-	-	-	-	-	0.05%
NY	7,303,783	-	-	31.93%	-	-	19.52%	1.85%
OH	4,622,384	-	-	-	-	-	11.95%	4.92%
OK	1,431,014	-	-	-	-	-	-	1.36%
OR	1,476,434	-	-	-	-	-	-	0.04%
PA	5,021,383	-	-	0.17%	-	-	0.20%	4.77%
RI	419,621	-	3.91%	-	-	-	-	-
SC	1,718,297	-	-	-	7.94%	-	-	4.36%
SD	327,165	-	-	-	-	-	-	0.01%
TN	2,449,562	-	-	-	-	-	-	6.81%
TX	8,271,247	-	-	-	-	37.02%	-	17.89%
UT	837,511	-	-	-	-	-	-	0.03%
VA	2,996,176	-	-	16.60%	-	-	-	1.32%
VT	260,831	-	-	-	-	-	-	0.23%
WA	2,519,727	-	-	-	-	-	-	0.18%
WI	2,302,752	-	-	-	-	-	16.21%	1.23%
WV	756,778	-	-	-	-	-	-	2.80%
WY	211,883	-	-	-	-	-	-	0.16%